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Economic valuation of agricultural land conversion to oil palm plantations: Assessing economic benefits and environmental impacts

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ABSTRACT
Background: The conversion of agricultural land into oil palm plantations has become a pressing issue due to its significant economic and environmental impacts. While oil palm production offers economic benefits, it also contributes to biodiversity loss and the degradation of ecosystem services. This study aims to assess both the economic valuation and the environmental consequences of land conversion in Muaro Jambi Regency, addressing the gap in current research regarding the dual impact of this transformation. **Methods:** A total economic valuation (TEV) approach was applied, combining direct use value (DUV), indirect use value (IUV), and option value (OV) to quantify the economic impacts. Data collection included secondary data from government reports, industry studies, and previous academic works. Statistical methods were employed to estimate the economic contributions and environmental costs associated with land conversion. **Findings:** The total economic value of converting agricultural land to oil palm plantations was estimated at IDR 1.097 trillion per year, predominantly driven by the direct use value of palm oil production. The conversion, however, resulted in the loss of vital ecosystem services worth IDR 1.55 billion per year, as well as significant biodiversity and cultural heritage loss, valued at IDR 12.37 billion annually. These findings suggest that while oil palm cultivation provides substantial economic benefits, it also presents serious environmental challenges. **Conclusion:** The study underscores the importance of balancing economic benefits with environmental sustainability in land conversion decisions. Effective policy interventions, such as Payment for Ecosystem Services (PES), sustainability certifications, and land rehabilitation programs, are essential to mitigate the environmental impacts of oil palm plantations. **Novelty/Originality of this article:** While previous research has focused on the economic benefits, this study addresses the environmental consequences, such as biodiversity loss and ecosystem service degradation, providing a more comprehensive analysis.

KEYWORDS: economic valuation; land conversion; oil palm plantation.

1. Introduction

Indonesia and Malaysia are the world's largest producers and exporters of palm oil, contributing over 90% of their production, which accounts for approximately 80% of global palm oil supply (Putra et al., 2020; Tan & Lim, 2019). The transformation of agricultural land into oil palm plantations in Indonesia has become a significant economic and social phenomenon. In recent decades, the rising global demand for palm oil has driven the

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expansion of oil palm plantations in various tropical regions, with Indonesia being one of the world's largest palm oil producers. Data shows that the area of oil palm plantations in Indonesia has more than tripled from 4 million hectares in 2000 to over 12 million hectares in 2018, contributing up to 2.5% of the national GDP and employing more than 8 million workers (Rustiadi et al., 2023; Sari, 2024).

The expansion of oil palm plantations and the increase in crude palm oil (CPO) processing mills continue in Indonesia (Chong & Loh, 2023; Hidayat, 2018; Sodri & Septriana, 2022). This expansion often involves the conversion of productive agricultural land, triggering various economic, social, and environmental impacts. In the context of oil palm plantations, environmental economics highlights the importance of assessing external costs such as water pollution and land degradation (Utami et al., 2017). Land conversion to oil palm plantations is often seen as a strategic step to enhance the economic value of the land (Panjaitan et al., 2023). Studies show that land management for oil palm plantations provides economic benefits, such as a 13% increase in farmers' income and income diversification through non-agricultural work (Aulia et al., 2020; Mehraban et al., 2021). Studies reveal that peat fires caused by palm oil plantation in Indonesia have caused economic losses exceeding IDR 4.46 trillion, with over 50% of the losses stemming from the loss of goods and services, followed by carbon emissions (Putra et al., 2020; Tan & Lim, 2019). The decline in ecosystem services, such as carbon storage and water quality, is also a major concern in this transformation process (Chrisendo et al., 2021; Rafli & Buchori, 2022).

Economic valuation becomes a crucial tool in evaluating the benefits and costs of this transformation. Market-based economic valuation is an essential tool for understanding the benefits and costs of land conversion. This method allows for the measurement of total economic value (TEV), including financial, environmental, and social values. Research in Jambi indicates that large-scale oil palm plantation investments can be financially feasible with a positive Net Present Value (NPV), but become unfeasible when environmental and social costs are considered (Asyuzal et al., 2020; Sari, 2024). The economic growth generated by this expansion is accompanied by significant environmental losses, including deforestation, biodiversity loss, and increased greenhouse gas emissions.

Oil palm plantations in Jambi Province are a primary example of how this sector drives economic and social transformation. Data shows that the agricultural sector, particularly the plantation sub-sector, contributes an average of 30.24% to the Gross Regional Domestic Product (PDRB) of Jambi Province. The contribution of oil palm plantations not only includes increased farmers' income but also creates significant employment, particularly in rural areas (Asyuzal et al., 2020; Mettauer et al., 2021). The expansion of oil palm in Jambi has also led to significant environmental pressures, including deforestation, biodiversity loss, and increased carbon emissions (Aulia et al., 2020; Pahmi et al., 2023). Studies show that the conversion of forests to oil palm plantations in Sumatra and Kalimantan has led to significant biodiversity declines while increasing carbon emissions (Ersoy Mirici & Berberoglu, 2024; Utami et al., 2017).

Although land conversion brings tangible economic benefits, such as a 13% increase in farmers' income and economic stability for small households, there are several conditions that are expected to align with reality, yet often do not. For example, while oil palm is considered an economic solution, its environmental and social impacts are not always beneficial. Some studies show that unsustainable management can reduce environmental services such as water regulation, carbon storage, and soil productivity (Aulia et al., 2020; Chrisendo et al., 2021).

Socially, this conversion brings mixed impacts. While it creates jobs and improves infrastructure access in local communities, it also triggers land conflicts and social inequalities in some regions. A case study in Jambi revealed that the expansion of oil palm plantations has accelerated the structural transformation of rural areas, but with negative consequences on local ecosystem balance and the well-being of indigenous communities (Pahmi et al., 2023; Sharma et al., 2019).

Muaro Jambi Regency, one of the regencies in Jambi Province, covers an area of 5,883.95 km^2 with a population of 441,897 (2023). Geographically, the region is dominated by lowlands, with the Batanghari River flowing through it. Muaro Jambi's economy relies on agriculture, plantations, and fisheries. The regency experienced an economic growth of 4.87% in 2023. The area of productive rice fields in Jambi Province has continued to decrease. From 68,000 hectares in 2019, it is now down to 61,119 hectares. Land conversion to oil palm plantations is the primary cause, although the government continues to support farmers.

Several factors drive land conversion, including inadequate infrastructure, a lack of interest from the younger generation in farming, and the more promising economic benefits of oil palm. The Jambi Provincial Government continues to enhance rice production through various programs, such as seed assistance, agricultural machinery, and farmer assistance. Muaro Jambi Regency has the potential to develop irrigated rice farming, with a harvested area of 5,274 hectares and a production of 21,775 tons in 2021, though its productivity remains low (4.12 tons/ha). This expansion of oil palm plantations brings complex impacts to Muaro Jambi. On one hand, oil palm plantations contribute to the regional economy and provide jobs. On the other hand, the conversion of agricultural land to oil palm plantations could threaten food security, reduce biodiversity, and increase the risk of environmental damage. Monitoring and controlling agricultural land conversion, implementing sustainable farming practices, and developing non-agricultural sectors are some measures that could be considered.

This study aims to analyze the total economic value of land conversion from agriculture to oil palm plantations and provide recommendations based on environmental economic instruments for policymaking to balance economic benefits and environmental sustainability. This research is expected to make a significant contribution to land use policy planning that is more sustainable from both economic and ecological perspectives. Through a comprehensive approach, this study can serve as a reference for formulating evidence-based policies that support sustainable development (Halkos & Managi, 2023). This research is expected to provide a deeper understanding of the differences between the potential economic benefits and the environmental consequences that are often overlooked. With a thorough approach, the findings of this study are expected to offer strategic solutions to maximize the economic value of land conversion while sustainably managing its negative environmental impacts (Aulia et al., 2020; Chrisendo et al., 2021)

2. Methods

This study employs a literature review approach to estimate the economic valuation of agricultural land conversion to oil palm plantations using the TEV (Total Economic Value) = DUV (Direct Use Value) + IUV (Indirect Use Value) + OV (Option Value) framework. DUV is calculated based on direct market values, such as income from agricultural and palm oil yields, derived from productivity data and commodity prices sourced from government reports or agricultural economics journals. IUV is evaluated through indirect ecosystem services, including carbon sequestration and water regulation, measured via benefit transfer methods or replacement cost valuation, referencing ecological-economic literature. OV is analyzed as the potential future value of lost biodiversity, drawing on studies that apply contingent valuation or willingness-to-pay approaches. The research critically compares methodologies, discount rate assumptions, and variables used in existing literature to identify inconsistencies or gaps, such as the imbalance between short-term economic gains (palm oil profits) and long-term environmental costs (land degradation).

$$TEV = DUV + IUV + OV \quad \text{(Eq. 1)}$$

The synthesized findings underpin policy recommendations that integrate TEV-based frameworks to balance ecological sustainability with holistic economic considerations. Here is the economic valuation calculation used in this study (Sari, 2024). Total Economic

Value (TEV) includes Direct Use Value (DUV) for direct benefits, Indirect Use Value (IUV) for ecosystem services, and Non-Use Value (NUV) for existence value (Eq. 1).

3. Results and Discussion

3.1 Land area converted

To calculate the Total Economic Value (TEV) of converting agricultural land into oil palm plantations in Muaro Jambi Regency, several assumptions were made to estimate the economic value and its environmental impact. A key assumption is that a portion of the expansion in oil palm plantation area comes from the conversion of land previously used for agriculture. Based on available data, the area of oil palm plantations in Muaro Jambi Regency was recorded at 136,405 hectares in 2022, increasing to 139,497 hectares in 2023. This represents an expansion of 3,092 hectares within one year.

A key assumption is that a portion of the expansion in oil palm plantation area comes from the conversion of land previously used for agriculture. This assumption reflects the empirical realities of land-use dynamics in the regency, where farmers and landowners are increasingly influenced by market incentives favoring oil palm cultivation. The superior profitability of oil palm—due to its global demand, stable pricing, and industrial processing linkages—often drives smallholders and commercial actors to transition away from food crops, despite the potential risks to food security and landscape heterogeneity.

Based on available data, the area of oil palm plantations in Muaro Jambi Regency was recorded at 136,405 hectares in 2022, increasing to 139,497 hectares in 2023. This represents an expansion of 3,092 hectares within one year. This significant annual increase underscores the intensity of land conversion pressure in the region and signals the need to evaluate not only the immediate economic returns from oil palm but also the long-term ecological trade-offs. Such rapid expansion, if left unmanaged, may lead to cumulative environmental degradation, including the loss of arable land, decreased agrobiodiversity, and altered hydrological regimes.

Of this total increase, it is assumed that approximately 50%, or 1,546 hectares, resulted from the conversion of agricultural land into oil palm plantations. This assumption is based on land-use change trends in the region, where much of the oil palm expansion often occurs at the expense of agricultural land, such as rice fields and farms, due to the higher economic potential of oil palm compared to food crops. This is further supported by the fact that oil palm is a leading commodity in Muaro Jambi Regency, incentivizing farmers to shift from traditional agriculture to oil palm cultivation.

This is further supported by the fact that oil palm is a leading commodity in Muaro Jambi Regency, incentivizing farmers to shift from traditional agriculture to oil palm cultivation. Government support programs, market access, and the promise of higher and more stable income streams contribute to the appeal of oil palm. However, this economic logic must be weighed against the socio-ecological consequences and the diminished multifunctionality of rural landscapes. Therefore, integrating TEV analysis into spatial and development planning can help decision-makers account for both visible profits and hidden costs, ensuring that land-use policies are economically sound, environmentally sustainable, and socially equitable.

3.2 Direct use value

Within the TEV framework, the direct use value encompasses the economic benefits derived from the conversion of agricultural land into oil palm plantations. Oil palm production generates higher average income compared to food crops such as rice or corn. Based on data from the Central Statistics Agency of Jambi Province, oil palm production in 2022 was 232,725 thousand tons, increasing to 253,175 thousand tons in 2023, resulting in an average production of 242,950 thousand tons. With a market price of approximately IDR 3,000 per kilogram, the gross income per hectare from oil palm reaches around IDR

728,850,000, or IDR 730 million per year. In contrast, agricultural land producing rice yielded an average harvest of 21,775 tons in 2021, with an assumed 5% annual increase due to agricultural development efforts. Thus, the average harvest for 2022 and 2023 is estimated at 5,676 tons per hectare. The price of unhusked rice in Muaro Jambi varies depending on quality and type. According to data from the Central Statistics Agency (BPS) of Muaro Jambi Regency, the price of unhusked rice at the farmer level in 2020 ranged from IDR 4,200 to IDR 4,500 per kilogram, while the price at the milling level reached IDR 5,000 to IDR 5,200 per kilogram. Assuming a market price of IDR 5,000 per kilogram, the gross income from rice cultivation is approximately IDR 28,380,713, or IDR 28 million per hectare per year. The significant difference of IDR 700 million highlights the greater economic potential of oil palm, which is a primary driver of land-use conversion.

3.3 Indirect use value

The indirect use value of converting agricultural land into oil palm plantations in Muaro Jambi Regency includes the benefits and losses related to ecosystem services. Agricultural land previously served as water catchment areas, flood mitigation zones, and soil stabilizers, functions that are diminished in oil palm plantations due to monoculture systems prone to soil erosion and reduced water absorption capacity (Rafli & Buchori, 2022). Additionally, this land conversion results in a loss of carbon storage of 5-10 tons per hectare per year compared to agricultural land or forests, although oil palm still absorbs approximately 10 tons of carbon per hectare annually (Rafli & Buchori, 2022; Sari, 2024). Assuming ecosystem services such as flood control and water absorption are valued at IDR 1 million per hectare per year and carbon sequestration by oil palm at IDR 1 million per hectare per year, the total indirect use value for the conversion of 1,546 hectares is estimated at IDR 3,092 billion per year. This figure underscores the importance of sustainable environmental management in oil palm plantation development in Muaro Jambi Regency.

Beyond the monetary estimation, the reduction in ecosystem services due to land conversion has broader implications for environmental resilience and community well-being. Water catchment and flood mitigation functions, which were more effectively performed by diversified agricultural landscapes, are significantly reduced under monoculture oil palm systems. As a result, surrounding communities may face increased vulnerability to seasonal flooding, water shortages during dry periods, and declining soil fertility. These ecological shifts can lead to rising costs in infrastructure maintenance, disaster response, and public health—costs often borne by local governments and residents rather than the plantation sector. Thus, undervaluing indirect ecosystem services in land-use decisions can lead to externalized environmental and social burdens. In this context, it becomes crucial to integrate ecological compensation mechanisms, such as reforestation zones within plantation areas or the implementation of agroecological practices that mimic natural functions. The development of oil palm plantations should be guided by spatial planning that designates protection areas for high-ecological-value land, particularly those that contribute to hydrological balance and carbon regulation. By incorporating the valuation of indirect use values into environmental impact assessments (EIA), local governments and investors can better balance economic growth with ecological sustainability (Zhang et al., 2024). The case of Muaro Jambi highlights how indirect values—often overlooked in traditional economic calculations—play a vital role in maintaining environmental services that support both agricultural productivity and human livelihoods over the long term.

3.4 Non-use value

The non-use value of land conversion in Muaro Jambi Regency includes the loss of biodiversity, cultural heritage, and global ecological impacts. The conversion of agricultural land to oil palm plantations reduces wildlife habitats by up to 60% and threatens the

cultural sustainability of traditional communities such as the Suku Anak Dalam, who depend on forests (Rafli & Buchori, 2022; Utami et al., 2017). Assuming the existence value of ecosystems at IDR 5 million, cultural heritage at IDR 2 million, and carbon storage loss at IDR 1 million per hectare per year, the total non-use value lost from the conversion of 1,546 hectares is estimated at IDR 12.37 billion per year. This value highlights the importance of land management that considers ecosystem sustainability and local cultural preservation.

The conversion of agricultural land to oil palm plantations reduces wildlife habitats by up to 60% and threatens the cultural sustainability of traditional communities such as the Suku Anak Dalam, who depend on forests. Habitat fragmentation not only isolates species populations, increasing their vulnerability to extinction, but also disrupts ecological corridors critical for migratory species. Moreover, forest clearance alters the microclimate, water cycles, and soil conditions, causing cascading ecological effects that may not be immediately visible but have long-term consequences. For indigenous groups, whose survival is intertwined with forest ecosystems, land conversion represents both environmental degradation and cultural dispossession.

Assuming the existence value of ecosystems at IDR 5 million, cultural heritage at IDR 2 million, and carbon storage loss at IDR 1 million per hectare per year, the total non-use value lost from the conversion of 1,546 hectares is estimated at IDR 12.37 billion per year. This estimation provides a compelling economic argument to integrate ecological valuation into land-use planning and environmental policy. The recognition of non-use values in environmental accounting reflects a paradigm shift toward more holistic and inclusive frameworks that value nature not just for its extractive benefits, but also for its intrinsic, cultural, and regulatory services (Markanday et al., 2014). Quantifying these losses in monetary terms enables policymakers and stakeholders to better understand the hidden costs of land conversion and to advocate for conservation-based alternatives.

This value highlights the importance of land management that considers ecosystem sustainability and local cultural preservation. Integrating non-use value assessments into environmental impact analyses, spatial planning, and licensing processes can prevent short-term economic gains from undermining long-term environmental and social welfare. Furthermore, it supports the development of compensation mechanisms, such as environmental taxes, PES (Payment for Ecosystem Services), or biodiversity offsets, to mitigate the irreversible costs of ecosystem loss. In this context, sustainable land management must go beyond productivity metrics and include ethical considerations of intergenerational equity, cultural continuity, and ecological stewardship.

3.5 Total economic valuation

Based on the Total Economic Valuation (TEV) calculation, the conversion of 1,546 hectares of agricultural land into oil palm plantations in Muaro Jambi Regency generates significant economic value. From the direct use value perspective, income from oil palm cultivation reaches IDR 730 million per hectare per year, while rice cultivation only yields IDR 28 million per hectare per year. This results in an income difference of IDR 700 million per hectare annually, which, when applied to the entire 1,546 hectares, amounts to a total direct use value of IDR 1,083 trillion per year. In terms of indirect use value, the land provides essential ecosystem services, such as flood control and water absorption, estimated at IDR 1 million per hectare per year, and carbon sequestration at another IDR 1 million per hectare per year. This yields a combined indirect use value of IDR 3,092 billion per year. Furthermore, the non-use value, which encompasses the existence value of ecosystems (IDR 5 million per hectare), cultural heritage (IDR 2 million per hectare), and the loss of carbon storage (IDR 1 million per hectare), contributes an additional IDR 12,37 billion per year. Together, these components reflect the substantial total economic value of the land, encompassing both its market and non-market benefits.

Therefore, the total economic value of converting agricultural land into oil palm plantations in Muaro Jambi Regency reaches IDR 1,098 trillion per year. However, this value is dominated by direct economic benefits, while the negative impacts on ecosystem services

and non-use values emphasize the importance of sustainable management. Balanced policy strategies are needed to ensure that economic benefits do not come at the expense of environmental sustainability and local community well-being.

The research findings indicate that the conversion of agricultural land into oil palm plantations in Muaro Jambi Regency has contributed significantly to the economy, with a total economic valuation of IDR 1.097 trillion per year. This value is predominantly driven by the direct economic benefits from oil palm production, which provides much higher income compared to rice farming. With a revenue difference of IDR 700 million per hectare per year, oil palm plantations present an attractive economic option for farmers transitioning from traditional agriculture. However, despite the substantial direct economic benefits, the environmental impact presents serious challenges, particularly regarding ecosystem sustainability.

From the perspective of direct use value, the revenue from oil palm production is the main driver of land conversion. The average production of 242,950 tons of palm oil per year at a market price of IDR 3,000 per kilogram generates significantly higher income compared to rice farming, which yields only IDR 28 million per hectare per year. This indicates the substantial economic potential of oil palm plantations. However, this land conversion also results in a decline in indirect use value, such as the loss of water absorption functions, flood control, and soil stabilization. These ecosystem services are valued at around IDR 1.55 billion per year for the 1,546 hectares of converted land. These challenges require careful management to minimize negative impacts.

Moreover, land conversion also affects non-use values, such as biodiversity and cultural heritage. The loss of up to 60% of wildlife habitats and the disruption of traditional communities, such as the Anak Dalam Tribe, demonstrate that land use change has far-reaching effects beyond economic aspects. With an estimated loss of IDR 12.37 billion per year for ecosystem existence value, cultural heritage value, and lost carbon reserves, it is crucial to implement policies that consider the long-term impacts on ecosystems and communities.

To address the imbalance between economic benefits and environmental impacts, evidence-based and collaborative policy approaches are necessary. One strategic solution is the implementation of Payment for Ecosystem Services (PES), which provides incentives for farmers to preserve ecosystem functions such as water absorption and biodiversity. This scheme has been proven successful in various tropical regions in supporting ecosystem sustainability and improving local community welfare. Furthermore, the application of sustainability certifications such as RSPO (Roundtable on Sustainable Palm Oil) and ISPO (Indonesian Sustainable Palm Oil) can ensure that palm oil production is carried out with minimal negative environmental impact. Land rehabilitation programs are also a priority to restore the ecological functions of degraded land. Approaches like agroforestry, which integrates protective and productive plants, not only improve biodiversity but also provide additional economic benefits for communities. Environmental taxes can also be implemented to internalize the environmental damage costs of land conversion, with the funds allocated to conservation and sustainable land management programs.

However, the main challenge in implementing these policies is effective coordination between the government, businesses, and local communities. Technology-based monitoring, such as GIS, is also crucial to ensure compliance with environmental regulations and detect land changes in real-time. Additionally, education and awareness campaigns about the importance of sustainability must be consistently conducted to enhance public participation in ecosystem preservation. Therefore, the success of land conversion management in Muaro Jambi Regency depends on the ability to balance economic benefits with environmental conservation. A holistic approach that integrates evidence-based policies, environmental economic instruments, and multi-stakeholder participation can ensure that economic development through oil palm plantations does not sacrifice ecosystem sustainability and local community welfare. With these steps, Muaro Jambi Regency is expected to become a model for sustainable land management.

Based on the research results and the calculation of Total Economic Valuation (TEV), environmental instruments are necessary to support sustainability in managing the conversion of agricultural land into oil palm plantations in Muaro Jambi Regency. These instruments aim to maintain the balance between economic benefits and environmental preservation. Here are recommendations for implementation:

3.6 Payment for ecosystem services (PES)

The PES scheme is an approach that provides incentives to farmers or local communities to maintain ecosystem functions, such as biodiversity conservation, water resource protection, and the preservation of remaining small forests. By compensating for ecosystem services managed, local communities will be more motivated to maintain ecosystem balance, which is essential for long-term sustainability. For instance, water absorption areas around oil palm plantations can be protected through this incentive. Previous studies have proven that the PES approach has been effective in various tropical regions as an ecosystem-based management solution (Strange et al., 2024; Utami et al., 2017).

In addition to providing financial incentives, the successful implementation of PES schemes requires strong institutional support, clear land tenure systems, and active participation from multiple stakeholders, including local governments, NGOs, and the private sector. Legal certainty regarding land ownership is particularly crucial, as it ensures that payments are directed to the rightful stewards of the land and prevents potential conflicts over resource control. Furthermore, integrating PES programs with community development initiatives—such as capacity building, sustainable agriculture training, and participatory monitoring—can enhance the long-term effectiveness and social acceptance of the scheme. When communities feel a sense of ownership over both the process and outcomes, they are more likely to commit to conservation efforts. Therefore, PES should not be viewed merely as a financial transaction but as part of a broader strategy to strengthen socio-ecological resilience and foster inclusive environmental governance (Gómez-Baggethun & Ruiz-Pérez, 2011; Strange et al., 2024).

To ensure the sustainability of PES schemes in the long term, it is essential to establish robust monitoring and evaluation (M&E) mechanisms that are transparent, participatory, and adaptive. Monitoring is not only needed to verify the actual delivery of ecosystem services but also to maintain accountability among all parties involved. A well-designed M&E framework should include both biophysical indicators—such as changes in forest cover, water quality, and biodiversity—and socio-economic indicators, including household income improvements and changes in community engagement. Participatory monitoring, involving local communities as data collectors and evaluators, can increase the legitimacy of PES schemes and strengthen community capacity for environmental stewardship.

Furthermore, long-term funding mechanisms must be considered to prevent program discontinuation due to financial constraints. While initial PES schemes are often supported by donor funding or corporate social responsibility (CSR) initiatives, sustainable financing can be secured through the establishment of environmental trust funds, green taxes, or integration into national budget allocations. Incorporating PES into regional or national environmental policy frameworks—such as climate change mitigation programs or sustainable land use strategies—can also help institutionalize the practice and scale it beyond pilot initiatives (Shang et al., 2024).

Ultimately, the success of PES lies in its ability to align ecological goals with social and economic incentives, creating a win-win scenario for conservation and development. In regions such as Muaro Jambi, where land-use pressure from oil palm expansion is intense, PES provides a valuable alternative that rewards communities for protecting ecological assets rather than converting them. When designed inclusively and supported by strong institutions, PES schemes can catalyze a broader transformation in landscape governance—one that promotes environmental justice, supports rural livelihoods, and contributes to the

resilience of socio-ecological systems (Gómez-Baggethun & Ruiz-Pérez, 2011; Strange et al., 2024).

3.7 Sustainability certifications (RSPO and ISPO)

Implementing sustainability certifications such as RSPO (Roundtable on Sustainable Palm Oil) and ISPO (Indonesian Sustainable Palm Oil) is crucial to ensuring that palm oil production is carried out with minimal negative impacts on the environment and society. These certifications promote better management practices, such as non-burning practices, conservation of important habitats, and environmentally friendly waste management. Additionally, these certifications can enhance the competitiveness of palm oil products in international markets, which increasingly demand sustainability standards. The implementation of RSPO and ISPO can also encourage transparency and accountability in land management (Mettauer et al., 2021; Strange et al., 2024).

These certifications promote better management practices, such as non-burning practices, conservation of important habitats, and environmentally friendly waste management. Certified producers are required to adhere to strict criteria, including zero-burning policies for land clearing, protection of High Conservation Value (HCV) and High Carbon Stock (HCS) areas, and proper management of effluents and solid waste. These practices not only reduce greenhouse gas emissions and air pollution but also mitigate biodiversity loss and water contamination—two of the most pressing issues in plantation landscapes. Moreover, certification encourages the use of integrated pest management, reduced chemical inputs, and improved soil conservation techniques, thereby contributing to long-term environmental resilience.

Additionally, these certifications can enhance the competitiveness of palm oil products in international markets, which increasingly demand sustainability standards (Abdul Hamid & Lim, 2019; Garcia-Nunez et al., 2016). Global buyers, especially in the European Union and North America, are progressively implementing due diligence and deforestation-free sourcing policies. Certified palm oil products, therefore, gain preferential access to these markets and can command price premiums, attracting environmentally conscious investors and partners. Certification also reduces reputational risks for companies operating within complex global supply chains and reinforces their commitment to corporate social responsibility (CSR). For exporting countries like Indonesia, widespread certification uptake strengthens national branding and trade positioning in the global agribusiness arena.

The implementation of RSPO and ISPO can also encourage transparency and accountability in land management. Through third-party audits, public reporting requirements, and grievance mechanisms, these certification schemes foster greater visibility into land acquisition processes, labor conditions, and environmental compliance. This transparency can deter illegal practices such as land grabbing, unregulated deforestation, or labor exploitation, while promoting dialogue among stakeholders—ranging from plantation companies to indigenous communities and civil society organizations. Ultimately, RSPO and ISPO contribute to building institutional trust and governance capacity, making them vital instruments in transitioning toward a more ethical and sustainable palm oil industry (Mettauer et al., 2021; Strange et al., 2024).

3.8 Land rehabilitation and agroforestry

Degraded land resulting from conversion to oil palm plantations must undergo rehabilitation through reforestation programs or the introduction of agroforestry systems. Agroforestry is an approach that combines protective plants, trees, and productive crops that not only help restore ecosystem functions but also increase biodiversity. This approach can provide additional economic benefits to local communities through extra harvests from productive crops. Land rehabilitation can also reduce the risk of soil erosion and improve

water absorption capacity, which is crucial for maintaining local ecosystems (Ersoy Mirici & Berberoglu, 2024).

Agroforestry is an approach that combines protective plants, trees, and productive crops that not only help restore ecosystem functions but also increase biodiversity. Unlike monoculture systems, agroforestry mimics the structure and function of natural forests by integrating diverse species that serve different ecological roles. For instance, deep-rooted trees can stabilize soil and draw nutrients from deeper layers, while nitrogen-fixing plants can enhance soil fertility. This functional diversity helps re-establish ecosystem services such as nutrient cycling, microclimate regulation, and natural pest control. Importantly, agroforestry can also function as a buffer zone around core conservation areas, enhancing landscape connectivity and resilience.

This approach can provide additional economic benefits to local communities through extra harvests from productive crops. In many cases, agroforestry systems are designed to include marketable species such as fruit trees, medicinal plants, or timber species with sustainable harvesting practices. This provides local communities with diversified income streams, reduces dependency on a single commodity, and enhances food security. By aligning ecological restoration with community livelihoods, agroforestry offers a practical model for inclusive and sustainable land management, thereby gaining broader social acceptance and long-term viability.

Land rehabilitation can also reduce the risk of soil erosion and improve water absorption capacity, which is crucial for maintaining local ecosystems. Degraded soils often become compacted and lose their ability to retain water, leading to increased runoff, flooding, and downstream sedimentation. Rehabilitation efforts—particularly those that increase vegetation cover and organic matter—can reverse this trend by enhancing soil structure, increasing infiltration rates, and recharging groundwater systems. These improvements are essential not only for ecological stability but also for agricultural productivity and the provision of clean water resources to surrounding communities (Ersoy Mirici & Berberoglu, 2024).

3.9 Environmental tax

Implementing environmental taxes based on the area of land converted or the level of ecological impact is a strategic step to internalize environmental costs. The funds collected from this tax can be allocated to support land rehabilitation, conservation programs, or research on sustainable ecosystem management. Additionally, environmental taxes can serve as a tool to encourage plantation companies to adopt more environmentally friendly practices (Ersoy Mirici & Berberoglu, 2024; Rustiadi et al., 2023).

The funds collected from this tax can be allocated to support land rehabilitation, conservation programs, or research on sustainable ecosystem management. Revenue from environmental taxes can be earmarked for critical environmental initiatives such as reforestation, restoration of degraded wetlands, soil quality improvement, and the establishment of ecological corridors. Moreover, financing academic and applied research into sustainable land management practices ensures that future development is informed by evidence-based strategies, while also promoting innovation in areas such as agroforestry, regenerative agriculture, and biodiversity conservation. These reinvestments not only repair ecological damage but also contribute to long-term resilience and sustainability of the affected ecosystems.

Additionally, environmental taxes can serve as a tool to encourage plantation companies to adopt more environmentally friendly practices. By creating economic disincentives for environmentally harmful practices, such as extensive land clearing or inadequate waste management, environmental taxation fosters behavioral change among private sector actors (Al Bulushi et al., 2018; Wibowo et al., 2024). Plantation companies may be driven to invest in cleaner technologies, implement certification standards such as RSPO (Roundtable on Sustainable Palm Oil), or explore less impactful cultivation techniques to reduce their tax burden. Over time, this policy tool can stimulate a shift toward more

responsible corporate behavior, aligning private sector activities with national environmental goals and international commitments such as the Sustainable Development Goals (SDGs) and the Paris Agreement.

4. Conclusions

The conversion of agricultural land into oil palm plantations in Muaro Jambi Regency contributes significantly to the economy with a total economic valuation of IDR 1.097 trillion per year. This benefit is dominated by the direct use value of palm oil production, with a revenue of IDR 700 million higher per hectare per year compared to rice farming. However, the negative environmental impacts cannot be ignored. The loss of ecosystem services such as water absorption and soil stabilization amount to IDR 1.55 billion per year, while the loss of biodiversity and cultural heritage value totals IDR 12.37 billion per year. This highlights the importance of sustainable management to maintain the balance between economic benefits and environmental sustainability. Therefore, the implementation of environmental instruments such as Payment for Ecosystem Services (PES), which provides incentives for local communities to preserve ecosystem functions, sustainability certifications such as RSPO and ISPO to ensure environmentally friendly palm oil practices, and environmental taxes to internalize the costs of ecosystem damage, is necessary. Furthermore, land rehabilitation programs through reforestation and agroforestry should be implemented to restore ecological functions. Technology such as GIS should also be utilized to monitor land use changes in real-time. Education for local communities and collaboration between the government, businesses, and communities are essential to creating inclusive and sustainable land management. These measures are expected to ensure that economic development in Muaro Jambi Regency proceeds in harmony with ecosystem preservation and community welfare.

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