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Land use conversion from oil palm plantations to settlements: Environmental impacts and socio-economic determinants in Warmare District

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Abstract

This study examines the environmental and socio-economic impacts of converting oil palm plantations into residential areas in Warmare District, Manokwari Regency, West Papua. Using a descriptive quantitative approach, data were collected from 50 purposively selected respondents through interviews, structured questionnaires, and field measurements. Results show that land conversion significantly affects the environment, with respondents reporting increased air temperatures (66%), pest infestations (86%), flooding (28%), and overall ecosystem degradation (88%). The conversion of 448 hectares of oil palm plantations resulted in an estimated carbon stock loss of 1,045,632 tons, reinforcing previous findings that land-use change is a major contributor to carbon emissions. Socioeconomic analysis reveals that education, income, land accessibility, and low land prices are significant factors influencing land conversion decisions, while household size and agricultural knowledge had no notable effect. The findings also show that households diversify their income sources, with fisheries contributing the largest share. This study highlights the tension between short-term economic benefits and long-term ecological risks. To address these challenges, policy measures are needed, including stronger spatial governance, community capacity-building, sustainable economic incentives, and multi-stakeholder collaboration to ensure that regional development aligns with environmental sustainability principles.

Keywords: Land conversion; Oil palm plantation; Environmental impacts; Carbon stock; Socio-economic factors; Sustainable land management

1. Introduction

Indonesia, as an agrarian country, relies heavily on the agricultural and plantation sectors to sustain its national economy. However, regional development often triggers the conversion of productive land into residential areas and public facilities. According to Utomo et al. (1992), land conversion refers to the change in land use from its original purpose to other functions, which often generates negative impacts on both the environment and the potential of the land itself. This phenomenon is also occurring in Manokwari Regency, particularly in the Warmare District, where a portion of oil palm plantation areas has been converted into new residential zones (RTRW Manokwari Regency 2013–2023).

Such land conversion brings ecological as well as socio-economic implications. From an environmental perspective, the clearing of oil palm plantations for housing leads to the loss of carbon reserves, rising temperatures, an increased risk of flooding, and disruptions to ecological balance (Pulhin et al., 2014; Panuju, 2017). From a socio-economic perspective,

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farmers' decisions to convert land are influenced by internal factors such as household income levels and land productivity, as well as external factors such as land prices, accessibility, and spatial planning policies (Jamal, 2001; Vandi, 2008).

Community understanding of the impacts of land conversion also plays an important role, since their perceptions and decisions can either accelerate or slow down the conversion process. Many residents in the study area perceive that land conversion provides short-term economic benefits, while at the same time, they also experience adverse environmental changes. In this context, the present study seeks to further examine the environmental impacts of oil palm plantation land conversion in Warmare District, while also analyzing the social, economic, and accessibility factors driving this process. The findings are expected to strengthen policy recommendations for sustainable land management and to help prevent further environmental degradation in the future.

2. Research Method

This study was conducted in Warmare District, Manokwari Regency, West Papua, with the research site selected purposively. The research employed a descriptive quantitative method, involving 50 respondents chosen purposively, namely community members who had lived on converted land for at least three years and purchased land from customary landowners around Nimbai Village, Warmare District.

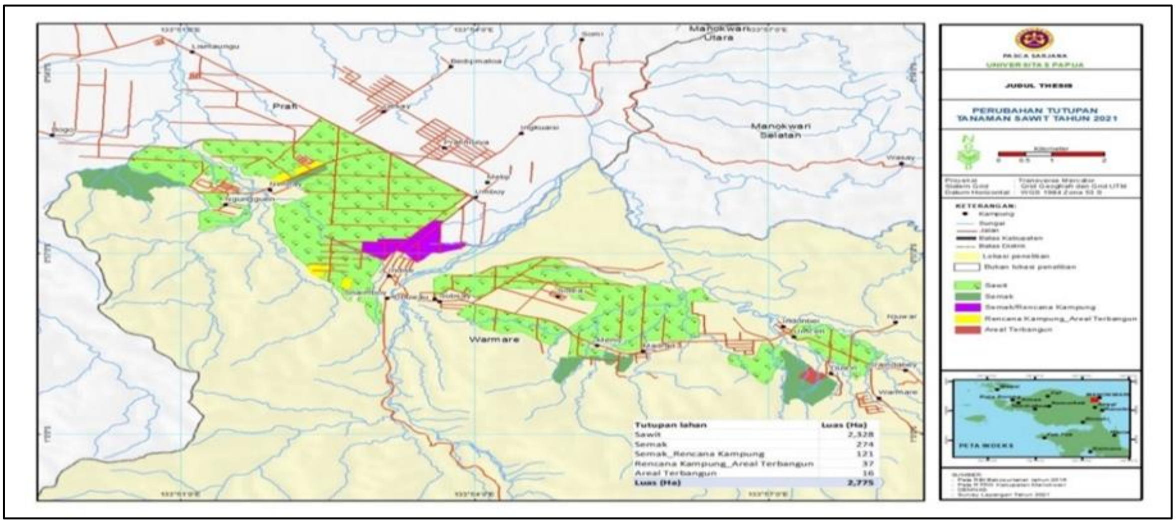

Figure 1 Research site in Warmare, Manokwari, West Papua, Indonesia

The data consisted of primary and secondary sources. Primary data were obtained through interviews with customary landowners and land buyers using structured questionnaires, as well as field measurements of oil palm trees (diameter, total height, and number of trees) to estimate potential carbon loss. Secondary data were collected from related institutions (BPS, Warmare District Office, palm oil companies in Warmare, Prafi, Masni, and Sidey) and from a literature review.

The observed variable is included: (1) environmental impacts of land conversion, (2) carbon stock loss, and (3) determining factors of land-use change. Community perceptions were assessed using a Likert scale (1–5) and analyzed descriptively through tabulation and scoring techniques.

Determinant factors of land conversion were analyzed using a linear regression model as follows:

$$Y = a + b1X1 + b2X2 + b3X3 + b4X4 + b5X5 + b6X6 + b7X7 + e$$

Where:

Y = WTP (willingness to pay)

X1 = age, X2 = education, X3 = income,

X4 = household size, X5 = food security,

X6 = access to information, X7 = agriculture knowledge.

Carbon stock analysis was carried out by estimating oil palm biomass using an allometric equation (Lubis, 2011): Y = 0,002382 x D2,3385 x H0,9411.
Y = Dry biomass (kg/tree)
D = Diameter at breast height (cm)
H = Height to the first frond (m)
Carbon storage was then calculated by multiplying dry biomass by a carbon content factor of 0.5 (SNI, 2011): C_b = B x % C Organik

Cb = Carbon content of the biomass (tons)
B = Total biomass (tons)
%C Organic = Percentage of carbon content, equal to 0.5
and converted into per-hectare units (Hairiah et al., 2011):

$$C = \frac{C_{b1} + C_{b2} + \ldots C_{bn}}{L} \times 10.000$$

C = Carbon stock

Cb = Carbon stock of oil palm trees (tons C/ha)

L = Plot area

10,000 = Conversion factor from m^2 to ha

3. Result and Discussion

3.1. Environmental Impacts of Land Conversion

The findings from Warmare District highlight how the conversion of oil palm plantations into residential areas has caused notable environmental disturbances. Based on community perceptions (Table 1).

Table 1 Community Perceptions of Environmental Impacts of Land Conversion

Environmental Impact	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
Change in air temperature	0	14	20	66	0
Flooding	0	44	28	28	0
Pest infestation	0	0	14	86	0
Environmental degradation	0	0	12	40	48

Source: Primary data 2024

• Change in air temperature: 66% of respondents agreed that air temperature increased following land conversion. This perception aligns with the IPCC Special Report on Climate Change and Land (IPCC, 2019), which indicates that land-use change, especially deforestation, disrupts microclimatic regulation by reducing canopy cover and evapotranspiration. Similar patterns were observed in tropical regions of Southeast Asia, where deforestation and plantation conversion led to increased land surface temperature and altered local rainfall patterns (Lee et al., 2020; Rosa et al., 2021).

• Flooding: 44% of respondents disagreed, while 28% agreed that flooding had increased. Although community responses are mixed, scientific literature confirms that the removal of perennial vegetation reduces soil infiltration and increases runoff, elevating flood risks (Tan et al., 2022). Conversion of palm plantations to non-vegetated land reduces the soil's hydraulic conductivity, leading to more rapid peak flows during heavy rainfall events.

• Pest infestation: A striking 86% of respondents agreed that pest infestations, particularly millipedes, migrated from abandoned plantations into nearby settlements. This finding corresponds with Shaver et al. (2022), who highlight that land conversion alters ecological niches and disrupts predator-prey balances, often driving pests into human-dominated landscapes. Oil palm monocultures, when disturbed, may release pest populations that previously depended on plantation ecosystems.

• Environmental degradation: 88% of respondents (agree + strongly agree) believed land conversion degraded the environment. This aligns with earlier insights from Utomo et al. (1992) and is reinforced by newer studies that show land-use change reduces biodiversity, soil fertility, and overall ecological resilience (Curtis et al., 2018; Austin et al., 2019). In particular, clearing oil palm without ecological safeguards exacerbates soil erosion, nutrient leaching, and carbon stock loss, accelerating environmental decline.

The community's perceptions correspond closely with global scientific findings. Land conversion reduces microclimate regulation, destabilizes hydrological balance, fosters pest migration, and accelerates ecological degradation. These consequences underscore the urgent need for sustainable land-use planning, ecological restoration, and participatory approaches to mitigate risks in Papua Barat.

3.2. Loss of Carbon Stock

The conversion of 448 hectares of oil palm plantation land also resulted in substantial carbon loss. Using the allometric equation proposed by Lubis (2011), the estimated carbon stock loss is presented in Table 2.

Table 2 Potential Carbon Stock Loss from Land Conversion

Land Area (ha)	Average Carbon Stock (ton/ha)	Total Carbon Lost (ton)
448	2,334	1,045,632

Source: Primary data 2024

This finding underscores the severity of land-use change in terms of greenhouse gas (GHG) emissions. The magnitude of carbon loss aligns with earlier studies (Pulhin et al., 2014; FAO, 2017), which emphasize that deforestation and agricultural land conversion are among the leading sources of anthropogenic carbon emissions in developing nations.

Recent research highlights that oil palm ecosystems can hold significant aboveground and belowground carbon, particularly in mature stands (Murdiyarso et al., 2020). When these plantations are cleared, not only is the biomass carbon released, but soil organic carbon also declines rapidly due to disturbance and exposure (Carlson et al., 2018). Furthermore, carbon loss is compounded by the absence of compensatory vegetation capable of sequestering equivalent levels of carbon, resulting in a net increase in atmospheric CO_2 (Fargione et al., 2018).

In the Indonesian context, large-scale oil palm expansion and subsequent conversion have been documented as a major contributor to national GHG emissions (Wijedasa et al., 2020). The Warmare case contributes to this trend, illustrating how localized land-use changes can disproportionately impact carbon budgets. The Intergovernmental Panel on Climate Change (IPCC, 2022) also warns that such emissions from tropical deforestation and land degradation jeopardize global climate mitigation targets, especially the Paris Agreement goal of limiting warming to 1.5°C.

Therefore, the loss of over one million tons of carbon in this single district highlights the urgency of implementing sustainable land-use planning, carbon offset programs, and reforestation initiatives. Strengthening monitoring frameworks through remote sensing, carbon accounting, and community-based management is essential to minimize further carbon stock depletion in Papua Barat and similar regions.

3.3. Socioeconomic Factors Driving Land Conversion

Multiple regression analysis was employed to identify socioeconomic factors influencing land conversion decisions. The results are presented in Table 3.

Table 3 Regression Analysis of Factors Driving Land Conversion

Variable	Regression Coefficient	Significance (p-value)	Interpretation
Age (X1)	0.021	0.214	Not significant
Education (X2)	0.188	0.078	Significant at α = 10%
Agricultural income (X3)	0.274	0.034	Significant at α = 5%
Fisheries income (X4)	0.315	0.009	Significant at α = 1%
Household size (X5)	0.043	0.322	Not significant
Low land price (X6)	0.427	0.000	Significant at α = 1%
Land accessibility (X7)	0.196	0.041	Significant at α = 5%
Agricultural knowledge (X8)	0.144	0.126	Not significant

Adjusted $R^2 = 0.83$

Education ($p < 0.10$) significantly influences land conversion. Higher education levels increase awareness of land value and opportunities, making households more likely to diversify land use (Abdulai & CroleRees, 2019). Educated farmers tend to evaluate land not only for subsistence but also for market-oriented purposes, reinforcing Jamal (2001).

Both agricultural and fisheries incomes were significant ($p < 0.05$ and $p < 0.01$, respectively). This suggests that households with stable income sources are more capable of investing in land or shifting land use to more profitable ventures. Recent studies confirm that livelihood diversification, particularly through fisheries and non-farm activities, often accelerates agricultural land conversion in rural Southeast Asia (Seto & Ramankutty, 2016; Susanti et al., 2022).

Low land price ($p < 0.01$) emerged as the most influential driver (coefficient 0.427). Affordable land prices act as a strong incentive for external buyers and local households to purchase and repurpose agricultural land (Villamor et al., 2015). This dynamic often leads to speculative practices, further fueling rapid land conversion in peri-urban and rural areas (Pribadi & Pauleit, 2015).

Land accessibility ($p < 0.05$) also strongly predicts conversion. Improved infrastructure—roads, transport networks, and proximity to markets—lowers transaction costs and increases land attractiveness for residential or commercial purposes (Meyfroidt et al., 2022). In Papua Barat, new road development under regional planning has accelerated settlement expansion into former plantation zones.

Age, household size, and agricultural knowledge were not statistically significant. While these variables may influence decision-making indirectly, they were overshadowed by stronger economic and structural drivers. This finding is consistent with Mertens et al. (2000), who found that demographic factors alone are insufficient to explain land conversion without considering market and institutional contexts.

The dominance of education, income, land price, and accessibility reflects a transition from subsistence-oriented land use toward market-driven land decisions. These findings emphasize the importance of integrated land governance policies that account for both socioeconomic drivers and environmental consequences. Failure to regulate these factors may lead to accelerated conversion, undermining sustainable development goals in Papua Barat.

3.4. Sources of Household Income

The study also found that households in Warmare have diversified income sources after engaging in land-use change. Average household income is presented in Table 4.

Table 4 Average Household Income per Year

Income Source	Average (Rp)
Agriculture	2,560,000
Fisheries	4,940,000

Livestock	1,480,000
Trade	1,120,000
Others	860,000
Total	10,960,000

Source: Primary data 2024

The predominance of fisheries income demonstrates a shift from traditional agricultural dependence toward diversified livelihood portfolios. This supports Chambers & Conway's (1992) sustainable livelihoods framework, which argues that rural households diversify to reduce vulnerability to shocks and secure long-term well-being. Fisheries, in particular, provide both subsistence and cash income, making them an attractive and resilient livelihood option in coastal and riverine communities of Papua Barat.

The dominance of fisheries aligns with broader evidence across Indonesia and Southeast Asia, where coastal and inland fisheries are increasingly critical for rural income (Béné et al., 2016; HLPE, 2014). Access to fishery resources often allows households to generate regular cash flow, which complements seasonal agricultural income. Recent studies also emphasize the role of small-scale fisheries in improving food security and poverty reduction (FAO, 2022).

Agriculture still contributes significantly (Rp 2.56 million/year), reflecting its role as a subsistence and fallback livelihood. Livestock (Rp 1.48 million/year) adds further income stability, consistent with findings that mixed farming systems enhance resilience by spreading risks across sectors (Thornton et al., 2019). Meanwhile, trade and other informal activities (Rp 1.98 million combined) illustrate the emergence of non-farm income opportunities as households adapt to changing land-use patterns.

The diversification observed in Warmare reflects a structural shift in rural livelihoods, where households increasingly combine farm, fishery, and non-farm activities. This mirrors global trends in rural economies, where non-agricultural income sources are gaining importance (Barrett et al., 2019). Such diversification enhances household resilience but may also accelerate land conversion if higher incomes stimulate demand for land-intensive activities. Policymakers thus need to balance livelihood diversification with sustainable land management practices.

4. Implications

The findings highlight the tension between short-term economic needs and long-term environmental sustainability. On the one hand, land conversion provides immediate income opportunities driven by low land prices and accessibility. On the other hand, it results in carbon loss, ecosystem degradation, and pest migration into settlements.

Based on these findings, four key policy implications are proposed:

- Strengthening spatial governance through stricter enforcement of spatial planning regulations (RTRW) and Law No. 41/2009 on Sustainable Agricultural Land Protection.
- Enhancing community capacity through extension services on land conversion impacts, carbon management, and environmental sustainability (FAO, 2017).
- Introducing sustainable economic incentives, such as Payment for Environmental Services (PES) schemes, to provide households with alternative livelihoods that support conservation (Angelsen & Kaimowitz, 1999).
- Promoting multi-stakeholder collaboration among local government, communities, and plantation companies. Palm oil companies in Warmare and surrounding districts could be required to adopt sustainable practices and contribute to land rehabilitation under corporate social responsibility (CSR) principles.

With the integration of quantitative evidence (tables) and theoretical perspectives, the discussion underscores that land conversion in Warmare District affects not only the environment but also the socioeconomic sustainability of local communities. Balanced policy solutions are therefore required to ensure that development aligns with sustainability principles.

5. Conclusion

This study demonstrates that the conversion of oil palm plantations into residential areas in Warmare District has significant environmental and socioeconomic consequences. Environmentally, land conversion has led to increased air temperatures, pest infestations, flooding, and ecosystem degradation. The estimated carbon stock loss of 1,045,632 tons from 448 hectares highlights the magnitude of environmental damage and its contribution to carbon emissions.

From a socioeconomic perspective, factors such as education, agricultural and fisheries income, land accessibility, and low land prices strongly influence community decisions to purchase and manage converted land. While land conversion provides short-term income opportunities and alternative livelihoods, it simultaneously poses long-term risks to environmental sustainability and food security.

Overall, the findings underscore the inherent tension between immediate economic needs and the preservation of ecological systems. Addressing this challenge requires integrated strategies that balance environmental, social, and economic dimensions.

5.1. Recommendations

- Strengthen Land Use Governance

The Manokwari Regency Government should enforce spatial planning regulations and implement Law No. 41/2009 on the Protection of Sustainable Agricultural Land to control unregulated land conversion.

- Enhance Community Capacity

Targeted extension programs are needed to raise awareness of the ecological impacts of land conversion and to build community knowledge on sustainable land and resource management.

- Introduce Sustainable Economic Incentives

Payment for Environmental Services (PES) schemes or community-based forest management initiatives could provide alternative income sources while promoting conservation and reducing pressure on land conversion.

- Promote Multi-Stakeholder Collaboration

Stronger partnerships among local governments, plantation companies, and local communities are essential. Palm oil companies operating in Warmare and surrounding areas should adopt sustainable practices and contribute to land rehabilitation through corporate social responsibility (CSR).

- Future Research

Further studies should incorporate long-term monitoring of land-use change impacts, including biodiversity loss, soil fertility, and socio-cultural dynamics, to provide a more holistic basis for sustainable land management policies.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the conduct of this study, the collection and interpretation of data, or the preparation of this manuscript. All institutional and community contributions—including those of oil palm farmers in Manokwari, the enumerator team, colleagues, and families—were purely in the form of technical assistance, facilitation, and moral support. None of these contributions influenced the research outcomes or the conclusions presented in this paper.

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