Jurnal Inovasi Ekonomi
Vol. 09 No. 01 April 2024 Pages: 33-42
P-ISSN: 2477-4804 E-ISSN: 2686-3804 http://ejournal.umm.ac.id/index.php/jiko

Maximizing economic potential and sustainability: Replanting waste management in West Kalimantan's oil palm plantations

Rosyadi[1]

Economic Study, Faculty of Economics and Business, Universitas Tanjungpura, Indonesia [1]

Received: 19-08-2023 | Revision: 21-12-2023 | Accepted: 21-12-2023 | Published: 19-01-2024
DOI: https://doi.org/10.22219/jiko.v9i01.23410

Abstract
Oil palm plantations are the largest in terms of land area and output in West Kalimantan. The output produced is not limited to palm oil but also includes other by-products, such as production waste, which can harm the environment. For this reason, replanting is carried out to reduce the resulting ecological impact. However, even replanting conducted by independent growers still generates significant waste, such as oil palm trunks and other biomass, which holds high economic potential. Therefore, it is necessary to estimate the potential waste generated during replanting activities, as well as the economic benefits that can be derived from processing this waste. The estimation results show that if replanting waste is processed into wood pellets, it will provide an annual economic value of IDR 125,376,725,586.59 for independent plantations and will be carbon neutral.

Keywords: Palm Oil; Replanting; Green Economy

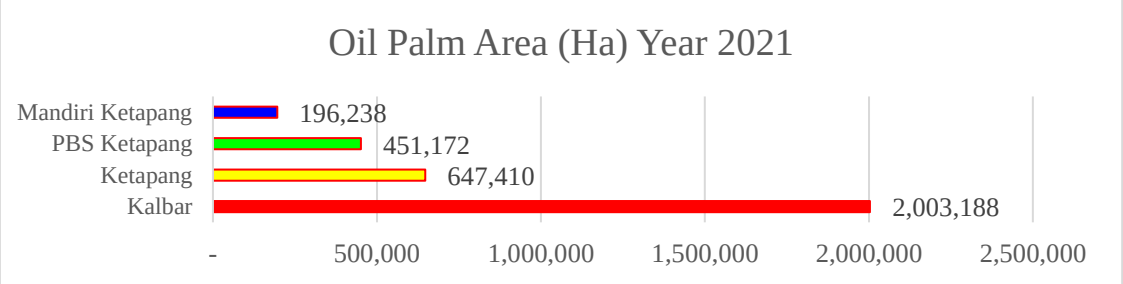
*Corresponding author: rosyadi@ekonomi.untan.ac.id

1. Introduction

In Indonesia, as well as in many other ASEAN countries, the oil palm plantations that are currently being established often fail to meet sustainability standards. These unsustainable plantations have a range of negative ecological consequences, including a loss of biodiversity, deforestation, and the destruction of vital water absorption areas. These environmental issues are critical, as they contribute to long-term ecological degradation and undermine efforts to combat climate change. In order to achieve a sustainable oil palm plantation, it must meet three key criteria: economic viability, social responsibility, and ecological soundness (Hidayat, 2018). These pillars are essential to ensure that oil palm production does not come at the expense of the environment or local communities, but rather contributes to sustainable development.

West Kalimantan is one of the regions in Indonesia with the largest areas dedicated to oil palm plantations, playing a significant role in the national palm oil industry. The expansion of oil palm plantations in the region has been rapid, contributing to both economic growth and environmental challenges. According to data published by the West Kalimantan Plantation and Livestock Service (DISBUNNAK), Ketapang Regency stands out as the region with the largest concentration of oil palm plantations in West Kalimantan. This area has become a key focus for both economic development and sustainability efforts. The composition of oil palm land ownership in Ketapang Regency, as of 2021, reflects the dynamics of plantation management in the region, showing a mix of community-owned and private land. Understanding this ownership structure is essential for evaluating the potential for sustainable plantation practices and the implementation of responsible environmental and social policies.

Efforts to transition toward sustainable palm oil production in Ketapang will require collaboration between government bodies, local communities, and plantation companies. Sustainable practices, such as responsible land use planning, improved waste management, and replanting with environmentally friendly techniques, will be critical to reducing the ecological footprint of the region's palm oil industry. The establishment of certification schemes, such as the Roundtable on Sustainable Palm Oil (RSPO), will also play a key role in promoting sustainability and ensuring that oil palm production in West Kalimantan is both economically and environmentally beneficial in the long term.



Source: West Kalimantan Plantation and Animal Husbandry Service

Figure 1. West Kalimantan and Ketapang Oil Palm Plantations in 2021

Based on Figure 1, the largest oil palm plantation area in West Kalimantan is located in Ketapang Regency, which spans a total of 647,410 hectares. Of this area,

196,238 hectares are managed by local communities, while large private plantations account for the remaining 451,172 hectares. This substantial plantation area represents a significant economic asset, but it also comes with considerable environmental challenges, particularly in terms of waste management.

One promising solution to these challenges is the integration of oil palm waste into replanting efforts. Replanting in Ketapang, where a significant portion of the land is community-owned, generates substantial waste, including oil palm trunks, fronds, and other biomass materials. Traditional replanting methods typically result in unsustainable plantation practices, which contribute to environmental degradation. However, if replanting is coupled with the integrated use of palm oil waste, it could become a critical driver of both ecological and economic sustainability.

A key component of this integrated approach is the management of oil palm replanting residue, particularly the oil palm trunks (OPT). These trunks, which are considered waste when they reach the end of their productive life (usually after 25 years), can be transformed into valuable products. When processed, these trunks can be used to create wood pellets, which serve as a renewable energy source. The production of wood pellets involves compacting the trunks using a compactor machine, or alternatively, they can be converted into torrefied pellets. Torrefied pellets, which are produced by heating the trunks at varying temperatures and pressures, have a higher density and energy content compared to regular pellets (Chotikhun et al., 2022). This method not only reduces waste but also provides a sustainable alternative fuel source.

In Ketapang, the replanting process still generates large quantities of palm oil waste. If replanting continues using conventional methods, the plantations may face challenges related to sustainability, and efforts to transition towards a green economy could be hindered. Therefore, it is crucial to explore the economic and ecological potential of integrated waste management in the replanting process. By harnessing the value of oil palm waste, particularly oil palm trunks, Ketapang can move towards more sustainable practices that benefit both the local economy and the environment.

Several studies have already explored the potential of incorporating green practices into oil palm plantations. Research by Abdulrazik et al. (2017) analyzed the optimal potential of oil palm biomass and estimated that processing this biomass could generate an annual profit of up to $713,642,269, assuming all production facilities were owned by a single entity. Similarly, Adawiyah and Dirgantoro (2018) examined the economic potential of utilizing palm oil waste for zero-waste production and found that this approach could significantly reduce costs associated with electricity generation, charcoal briquette production, raw material sourcing for pulp, and animal feed. Additionally, utilizing palm oil waste could lead to substantial savings on fertilizer costs. Hambali and Rivai (2017) also studied the potential of palm oil biomass in Indonesia, finding that by 2020 and 2030, palm oil biomass would be an abundant resource spread across 22 provinces. This biomass can be utilized in a variety of ways, including as alternative fuels, fertilizers, and chemicals, further demonstrating its significant economic and ecological potential.

These studies highlight the promising opportunities for integrating waste management into oil palm replanting efforts, providing a pathway for Ketapang

Regency and other regions to achieve both economic growth and environmental sustainability.

2. Method

Quantitative analysis is research that uses data in the form of numbers to obtain scientific information (Martono, 2017). This analysis was conducted to explore and gather detailed information about the conventional replanting system implemented by independent oil palm smallholders in Ketapang Regency.

Oil Palm Trunk Biomass Volume

To analyze the potential for replanting, a mathematical model will be used so that the amount of biomass produced each year can be written as follows:

$$\textbf{Volume} = \pi r^2.T$$

r = Radius
T = Height
π = 3.14

Mass of Oil Palm Trunk Biomass

After knowing the volume of each oil palm trunk biomass produced, the mass of each oil palm trunk biomass produced will be calculated with the following calculation:

$$\mathbf{m} = \varrho.\mathbf{v}$$

m = mass
ϱ =density
v = Volumes

The density of oil palm trunks has different values, ranging from 222 kg/m^3 to 404 kg/m^3, where the outermost has the highest density value and the innermost has the lowest density value (Srivaro, et al 2018). Therefore, the average density will be used, which is 313 kg/m^3, or 0.313 ton/m^3.

3. Empirical Result

Oil palm trees in Ketapang have an average height of 12 m, an average diameter of 0.35 m (or a radius of 0.175 m), and a density at the outermost part of 404 kg/m^3, which decreases to 222 kg/m^3 at the innermost part of the oil palm trunk (Srivaro et al., 2018). Therefore, it is necessary to calculate the volume of each tree using the following calculations:

$$\mathbf{V = (3.14159\ (0.175)(0.175)(12)}$$

$$\mathbf{V = 1.15453530\ m^3}$$

Then it is assumed that replanting will be carried out in stages, the first stage is 30% of the total land area which is old trees which is carried out within 5 years, then the second stage is 40% of the total land area which is trees that are starting to grow old after replanting the first stage, and the third stage of 30% of the total land area which are young trees that have aged since the first replanting stage.

Table 1. Palm Oil TrunkBiomass Potential in 2022 to 2026

No	First Stage (30%)	Area (Ha)	Volume (m^3)	Mass (Ton)
1	Private Palm Oil Plantation	135.351,60	21.252.475,22	6.652.024,74
2	Independent	58.871,40	9.243.798,89	2.893.309,05
3	Lahan	194.223,00	30.496.274,11	9.545.333,80
No	**Yearly First Stage (30%)**	**Yearly Area (Ha)**	**Yearly Volume (m^3)**	**Yearly Mass (Ton)**
1	Private Palm Oil Plantation	27.070,32	4.250.495,04	1.330.404,95
2	Independent	11.774,28	1.848.759,78	578.661,81
3	Total Lahan	38.844,60	6.099.254,82	1.909.066,76

Source. Researcher Calculation.

Table 2. Palm Oil Trunk Biomass Potential in 2027 to 2036

No	Second Stage (40%)	Area (Ha)	Volume (m^3)	Mass (Ton)
1	Private Palm Oil Plantation	180.468,80	28.336.633,62	8.869.366,32
2	Independent	78.495,20	12.325.065,18	3.857.745,40
3	Total	258.964,00	40.661.698,81	12.727.111,73
No	**Yearly Second Stage (40%)**	**Yearly Area (Ha)**	**Yearly Volume (m^3)**	**Yearly Mass (Ton)**
1	Private Palm Oil Plantation	18.046,88	2.833.663,36	886.936,63
2	Independent	7.849,52	1.232.506,52	385.774,54
3	Total	25.896,40	4.066.169,88	1.272.711,17

Source. Researcher Calculation.

Table 3. Palm Oil Trunk Biomass Potential in 2037 to 2046

No	Third Stage(30%)	Area (Ha)	Volume (m^3)	Mass (Ton)
1	Private Palm Oil Plantation	135.351,60	21.252.475,22	6.652.024,74
2	Independent	58.871,40	9.243.798,89	2.893.309,05
3	Total	194.223,00	30.496.274,11	9.545.333,80
No	**Yearly Third Stage (30%)**	**Yearly Area (Ha)**	**Yearly Volume (m^3)**	**Yearly Mass (Ton)**
1	Private Palm Oil Plantation	13.535,16	2.125.247,52	665.202,47
2	Independent	5.887,14	924.379,89	289.330,91
3	Lahan	19.422,30	3.049.627,41	954.533,38

Source. Researcher Calculation.

In the next 10 years, the total biomass generated from oil palm trunks in Ketapang Regency is projected to reach 12,727,111.73 tons, with an annual production of 1,272,711.17 tons. This biomass will come from both private oil palm lands and independent oil palm lands. The private oil palm plantations will contribute 886,936.63 tons of biomass, primarily in the form of oil palm trunks, while the independent oil palm lands are expected to generate a larger share, producing 1,272,711.17 tons annually. This highlights the significant potential for biomass production in Ketapang, particularly from community-managed lands.

In terms of long-term projections, over the course of 10 years, the biomass produced from oil palm trunks will accumulate to 9,545,333.80 tons, with an annual output of 954,533.38 tons. Private oil palm plantations will contribute 665,202.47 tons of this biomass, while independent oil palm plantations will produce 289,330.91 tons annually. This further underscores the considerable contribution of the community-managed lands in terms of biomass production, which can be a key resource for

developing sustainable practices in the region.

When considering the replanting process in Ketapang Regency over a 25-year period, the average annual biomass produced from oil palm trunks will be 1,378,770.44 tons. Of this, independent oil palm lands will contribute an average of 417,922.42 tons annually, while private lands will generate 960,848.02 tons annually. This shows a clear division between the contributions from privately managed plantations and those owned by local communities, with private lands playing a dominant role in biomass production.

The biomass produced from oil palm trunks has significant potential for conversion into valuable products, one of which is wood pellets. It is assumed that approximately 20% of the biomass generated will be processed into wood pellets. Based on this assumption, the total quantity of wood pellets produced will be 275,754.09 tons. The economic potential of this biomass conversion can be further evaluated by considering the price per ton of wood pellets, which is estimated at IDR 1,500,000.00, according to Simangunsong et al. (2016).

When calculating the total economic value of the biomass converted into wood pellets, the result is substantial. By multiplying the quantity of wood pellets produced (275,754.09 tons) by the price per ton (IDR 1,500,000.00), the total economic potential from the biomass in the form of wood pellets can be determined. This economic potential can be seen as a key opportunity for local communities, plantation owners, and other stakeholders involved in the oil palm industry. Not only does this conversion process offer a way to reduce waste and create renewable energy sources, but it also generates significant economic value for the region.

By utilizing this biomass more efficiently, Ketapang Regency could foster sustainable practices within the oil palm industry while also contributing to the local economy. The integration of biomass management into replanting activities is an essential step toward achieving a circular economy, where waste materials are repurposed into valuable products that support both environmental and economic goals. As such, this approach has the potential to transform the oil palm sector into a more sustainable and profitable industry for both private and community stakeholders in Ket

Table 4. Economic Potential of Oil Palm Biomass

No	Biomass Source	Yearly Bioass Average (Ton)	Wood Pellet 20% (Ton)	Potensi (Rp)
1	Private Palm Oil Plantation	960.848,02	192.169,60	288.254.405.550,16
2	Independent	417.922,42	83.584,48	125.376.725.586,59
3	Total	1.378.770,44	275.754,09	413.631.131.136,74

Source. Researcher Calculation.

Based on table 4. It can be seen that if the biomass produced from the replanting process is processed into wood pellets, it is estimated that it will provide an economic potential of Rp 413.631.131.136,74-. Private oil palm lands will have a potential of Rp. 288.254.405.550,16-, and independent oil palm lands will have a potential of Rp. 125.376.725.586,59- annually.

Potential for Oil Palm Replanting

Replanting oil palm in Ketapang Regency is expected to generate a significant amount of biomass, primarily in the form of oil palm trunks and palm fronds. This study estimates that the biomass produced from oil palm stalks will reach approximately 1,378,770.44 tons annually. Such a large volume of biomass presents a valuable opportunity for further processing, and one promising application is the conversion of this biomass into wood pellets. These pellets can serve as an alternative fuel for power plants, industrial boilers, and furnaces, potentially supplying both local and export markets.

Processing this biomass into wood pellets offers several benefits, both from an economic and environmental perspective. By transforming palm oil waste into a valuable energy source, the palm oil industry can increase its value-added products, enhancing its economic contribution. Additionally, using this biomass for energy production contributes to sustainability by reducing waste and offering an alternative to more traditional, often more polluting, fuels. According to projections from European countries, wood pellets provide a stable and cost-effective option for heating and energy generation. They are increasingly seen as a competitive alternative to fossil fuels due to their lower environmental impact and reliable performance (Nunes et al., 2019).

Wood pellets, when sourced from plant biomass such as oil palm waste, can be considered a green fuel. While the combustion of wood pellets does release carbon dioxide (CO2) into the atmosphere, this process is part of a broader carbon cycle. The plants from which the biomass was originally derived are capable of reabsorbing the CO2 released during combustion as they grow, making the overall process carbon neutral. This cyclical reabsorption helps mitigate the environmental impact of burning wood pellets, unlike fossil fuels, which release carbon that has been stored underground for millions of years. Thus, the use of wood pellets made from oil palm biomass could contribute to achieving a lower carbon footprint in energy production, aligning with global efforts to reduce greenhouse gas emissions and combat climate change (Schlesinger, 2018).

If the biomass from replanting oil palm trees in Ketapang is processed into wood pellets, it will offer a sustainable solution that has minimal negative environmental impact. The resulting wood pellets will be carbon neutral, helping to reduce the carbon emissions associated with traditional fossil fuels and contributing to a greener energy future. Moreover, by utilizing this biomass for energy production, Ketapang Regency could become a model for other regions seeking to balance economic development with environmental responsibility, particularly in the palm oil industry, which is often criticized for its environmental impact.

Conclusions

Replanting oil palm in Ketapang Regency will produce a significant amount of biomass in the form of oil palm trunks and palm fronds. The biomass from oil palm trunks is estimated to be approximately 1,378,770.44 tons annually. If this ecological potential is not properly maximized by stakeholders, including independent farmers and the

government, it could negatively impact the environment. Generally, the waste products from replanting oil palm plantations—such as tree trunks, leaves, and fronds—are chopped and left on the plantation land. This practice can attract pests and lead to suboptimal absorption of soil nutrients, resulting in negative ecological consequences.

The economic potential from the utilization of biomass from replanting is significant. This biomass can be processed into pellets that are both useful and valuable, providing an alternative energy source. The resulting pellets can be sold locally or exported, generating a potential revenue of Rp 125,376,725,586.59 annually from independent plantations in Ketapang Regency.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study

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