Assessing the Impact of Sustainable Independent Oil Palm Cultivation on Rural Development: A Case Study of Angkola Sangkunur Sub-District, South Tapanuli Regency

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

This study evaluates the impact of sustainable independent oil palm cultivation on rural development in the Angkola Sangkunur sub-district, South Tapanuli Regency, Indonesia. The research focuses on five key aspects: legal, technical cultivation, environmental management, labor, and institutional factors. Data was collected through a combination of primary and secondary sources, with primary data obtained via questionnaires distributed to a probability-based sample of 165 respondents. The analysis employed multiple linear regression to assess the influence of each aspect on regional development, with hypotheses tested using both F-tests and t-tests. The results reveal that the technical cultivation and institutional aspects exert a significant positive influence on rural

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development, underscoring the critical role of advanced agricultural practices and strong governance structures. While legal and environmental management aspects also have positive effects, their impact was not statistically significant, indicating that these factors may require further development or longer timeframes to manifest significant outcomes. Conversely, the labor aspect showed a negative but statistically insignificant effect, suggesting that the costs associated with implementing sustainable labor practices may pose challenges for smallholder farmers. This study concludes that enhancing technical capabilities and institutional frameworks offers the most immediate and substantial benefits for rural development in the region. However, a holistic approach that also addresses legal, environmental, and labor issues is essential for achieving long-term sustainability. The findings provide valuable insights for policymakers, stakeholders, and researchers focused on sustainable agriculture and rural development.

1. Introduction

The Indonesian government identifies the palm oil industry as a crucial economic sector with significant potential for growth, largely due to its efficient use of land (Adwiyah, et al 2023). Palm oil plantations, though they occupy only 6% of the country's agricultural land, are responsible for producing over 40% of the world's vegetable oil. This efficiency makes palm oil far more productive per hectare compared to other crops, positioning it as a vital contributor to both the national and global economy.

Despite this impressive contribution, smallholder palm oil plantations, particularly those managed independently, often struggle with lower productivity. Independent smallholders in regions like Sumatra and Kalimantan have productivity rates up to 40% lower than plantations that adhere to Good Agricultural Practices (GAP) (Alamsyah, 2024). Several factors contribute to this shortfall, including suboptimal plantation management, the use of low-quality planting materials, insufficient input production, and mistakes in implementing Best Management Practices (BMP), such as incorrect water management and poor pest control.

The challenges faced by smallholder palm oil plantations have broader implications for the industry, especially in the context of global sustainability concerns. The Indonesian palm oil industry, while economically beneficial, has come under scrutiny for its environmental and social impacts (Euler, 2016). This has led to increased global attention and criticism, particularly from anti-palm oil NGOs that have launched negative campaigns highlighting the industry's sustainability issues. These campaigns have influenced public perception and altered the competitive landscape for vegetable oils globally.

In response to these challenges, various stakeholders, including international organizations and the Indonesian government, have introduced sustainability standards to guide palm oil production. The Roundtable on Sustainable Palm Oil (RSPO), established in 2004, represents a voluntary standard aimed at promoting sustainable practices within the industry (Parish, 2021). Additionally, the Indonesian government has implemented mandatory regulations, such as Presidential Regulation No. 44 of 2020 and the Minister of Agriculture Regulation No. 38 of 2020, which enforce the Indonesian Sustainable Palm Oil (ISPO) certification for both palm oil companies and smallholder farmers.

Sustainability certification, whether through RSPO or ISPO, encompasses a comprehensive approach to palm oil management (Cattau, 2016). This includes ensuring compliance with legal requirements, which are critical for securing business certainty. Legal compliance involves obtaining proper documentation, such as Land Ownership Certificates (LOC) and Plantation Registration Certificates (PRC), which not only prevent land disputes but also facilitate access to financing. These legal frameworks are foundational to the sustainability and stability of the palm oil industry.

Beyond legal compliance, the technical aspects of palm oil cultivation are also crucial. Sustainable management practices emphasize the importance of best farming techniques to improve the quality and productivity of palm oil (Abas, 2022). By adopting these practices, smallholder farmers can enhance their yields of fresh fruit bunches, thereby contributing to rural development and increasing their overall welfare. These

improvements are essential for aligning smallholder practices with broader sustainability goals.

Environmental management is another critical component of sustainable palm oil cultivation. This aspect focuses on conserving vulnerable areas, such as swamps and rivers, which are prone to erosion, and avoiding the deforestation of forested lands for new development (Nasution, 2021). By prioritizing environmental conservation, the palm oil industry can mitigate some of the negative impacts associated with its expansion and contribute to broader environmental sustainability efforts.

Lastly, labor and institutional aspects play a significant role in the sustainability framework. Proper labor management, including the provision of personal protective equipment (PPE) and adherence to fair labor practices, is expected to reduce workplace accidents and ensure workers' rights (Sorribes, 2021). Strong institutional management, supported by internal control systems, enhances the effectiveness of organizations involved in palm oil production, improving access to markets and production resources. These combined efforts are essential for the successful implementation of sustainable palm oil practices, particularly among smallholder farmers who face numerous challenges in adopting these standards.

However, despite these initiatives, the adoption of sustainable palm oil management practices among smallholder farmers remains limited compared to large plantation companies. Smallholders often pursue these practices to increase their productivity and income, but they continue to face significant barriers, particularly in accessing markets and obtaining the necessary certifications. This research aims to explore the impact of sustainable independent oil palm cultivation on regional development in the Angkola Sangkunur sub-district, South Tapanuli Regency, to better understand the challenges and opportunities faced by smallholder farmers in this context.

2. Method

This research adopts a descriptive quantitative approach, focusing on the Angkola Sangkunur District in South Tapanuli Regency. The study was conducted in 2022 and aims to assess the impact of sustainable independent oil palm cultivation on regional development. The research design was chosen to quantify the relationships between various factors, such as legal, technical, environmental, labor, and institutional aspects, and their influence on rural development in the district.

To gather the necessary data, the study utilized both primary and secondary sources. Primary data was collected through a structured questionnaire administered to a probability-based sample of respondents. This method ensured that each member of the population had an equal chance of being selected, thereby increasing the reliability and generalizability of the findings. The questionnaire was designed to capture respondents' perceptions and experiences related to the different aspects of sustainable palm oil cultivation.

Secondary data was sourced from relevant institutions and literature, providing additional context and supporting the analysis of primary data. These secondary sources included previous research studies, official reports, and other documents pertinent to palm oil cultivation and rural development in the region. The combination of primary and secondary data allowed for a comprehensive analysis of the factors influencing regional development in Angkola Sangkunur.

The sample size was determined using the Slovin formula, which is commonly used in research to calculate the necessary sample size for a given population while considering the margin of error. This calculation resulted in a sample size of 165 respondents, which was deemed sufficient to represent the population of the district and to provide statistically significant results.

To ensure the accuracy and reliability of the data collected, the study conducted validity and reliability tests on the research instruments. Validity tests were performed to confirm that the questionnaire items accurately measured the intended variables, while reliability tests, such as Cronbach's Alpha, were used to assess the consistency of the responses. The results indicated that all items in the questionnaire were both valid and reliable, thus supporting the credibility of the findings.

Data analysis was carried out using multiple linear regression, a statistical method that examines the relationship between one dependent variable and several independent variables. This approach was chosen because it allows for the quantification of the impact of each independent variable on the dependent variable, in this case, rural area development. The analysis aimed to identify which aspects of sustainable palm oil cultivation have the most significant influence on development in the district.

In addition to the regression analysis, the study employed partial (t-test) and simultaneous (F-test) hypothesis tests. The t-test was used to determine the significance of individual independent variables, while the F-test assessed the overall significance of the regression model. These tests were essential for validating the results and ensuring that the conclusions drawn from the data were statistically sound.

Finally, the data analysis also involved checking for the satisfaction of classical assumptions, which are necessary for ensuring the validity of regression results. These assumptions include tests for multicollinearity, normality, and heteroscedasticity. The study confirmed that all these assumptions were met, indicating that the regression model used in the analysis was appropriate and that the results could be interpreted with confidence.

3.   Results

3.1 Validity Test

The validity of the research instrument was assessed to ensure that the questionnaire accurately measured the variables of interest. The sample size for this test was set at 30 respondents, with a degree of freedom calculated as $df=n-2=28$ df = n-2 = 28df=n−2=28. At a significance level (α) of 0.05, the critical r-table value was determined to be 0.361. The results of the validity test revealed that all the calculated r-values for the 37 items in the questionnaire were higher than the r-table value of 0.361. This outcome confirms that each item in the questionnaire is valid, meaning they effectively capture the intended constructs. The high validity of these items suggests that the data collected will accurately reflect the underlying theoretical concepts, providing a solid foundation for subsequent analyses.

3.2 Reliability Test

In addition to validity, the reliability of the questionnaire was rigorously evaluated using Cronbach's Alpha, a widely accepted measure of internal consistency. The results showed that the Cronbach's Alpha values for all variables exceeded the standard threshold of 0.6, indicating good reliability. High reliability means that the questionnaire items are consistently interpreted by respondents, leading to dependable and reproducible results. This consistency is critical for ensuring that any observed relationships between variables are due to the constructs being measured rather than random variation or measurement error.

3.3 Classical Assumption Tests

3.3.1 Multicollinearity Test

The classical assumptions underlying multiple regression analysis were thoroughly examined, beginning with the assessment of multicollinearity among the independent variables. Multicollinearity occurs when two or more independent variables in a regression model are highly correlated, potentially distorting the results. To detect multicollinearity, the Tolerance and Variance Inflation Factor (VIF) values were calculated for each independent variable. The results, displayed in Table 1, indicate that all Tolerance values were greater than 0.10 and all VIF values were below the threshold of 10. These findings suggest that multicollinearity is not a concern in this model, meaning that each independent variable provides unique information and contributes meaningfully to the regression equation.

3.3.2 Normality Test

The normality of the residuals, a key assumption of linear regression, was tested using the Kolmogorov-Smirnov test. The Asymptotic Significance (2-tailed) value obtained was 0.065, which is greater than the significance level of 0.05. This result implies that the

residuals are normally distributed, satisfying the normality assumption. Normality was further confirmed by examining the normal probability plot, where the data points aligned closely with the diagonal line, indicating that deviations from normality are minimal. Ensuring normality is crucial because it validates the use of parametric tests and supports the reliability of the regression coefficients.

3.3.3 Heteroscedasticity Test

Heteroscedasticity, which refers to the presence of non-constant variance in the residuals, was assessed using a scatter plot of the residuals against the predicted values. The plot revealed that the residuals were randomly dispersed and symmetrically distributed around the zero line, suggesting that heteroscedasticity is not present in the data. Additionally, the histogram of residuals showed a bell-shaped curve, further indicating that the variance of the residuals is constant across all levels of the independent variables. The absence of heteroscedasticity supports the validity of the regression model, ensuring that the estimates are both unbiased and efficient.

3.4 Multiple Regression Analysis

The multiple regression analysis was conducted to examine the impact of the independent variables—Legal Aspect (X1), Technical Cultivation Aspect (X2), Environmental Management Aspect (X3), Labor Aspect (X4), and Institutional Aspect (X5)—on the dependent variable, Rural Area Development (Y). The resulting regression equation is:

$$Y = 0.767 + 0.253X_1 + 0.572X_2 + 0.266X_3 - 0.116X_4 + 0.437X_5 + e$$

This equation provides insight into how each independent variable influences rural development when all other factors are held constant. The constant ($\beta0$) of 0.767 indicates that, in the absence of all independent variables, the baseline value of Rural Area Development is 0.767. The coefficient for the Legal Aspect ($\beta1$) of 0.253 suggests that for every one-unit increase in legal compliance, Rural Area Development improves by 0.253 units, assuming other variables remain unchanged. Similarly, the Technical Cultivation Aspect ($\beta2$) has a coefficient of 0.572, highlighting its strong positive effect on rural development.

3.5 Testing of Partial Significance (t-test)

The significance of each independent variable was further tested using the t-test to determine whether their respective coefficients differ significantly from zero. The Legal Aspect (X1) yielded a t-value of 1.798 with a p-value of 0.074, indicating a positive but statistically non-significant effect on Rural Area Development. This result suggests that while legal compliance is beneficial, its direct impact on development may not be as strong or consistent. In contrast, the Technical Cultivation Aspect (X2) had a highly significant t-value of 4.641 with a p-value of 0.000, demonstrating a robust positive influence on rural development. This underscores the critical role of advanced cultivation practices in enhancing agricultural productivity and, consequently, regional development.

The Environmental Management Aspect (X3), with a t-value of 1.708 and a p-value of 0.090, showed a positive but not statistically significant effect on rural development. This finding suggests that while environmental management practices contribute positively to development, their impact may be less immediate or direct compared to technical or institutional factors. The Labor Aspect (X4), however, had a negative coefficient of -0.116 with a t-value of -1.007 and a p-value of 0.315, indicating no significant impact on rural development. This negative relationship, though not statistically significant, suggests potential challenges or costs associated with labor practices in the context of sustainable palm oil cultivation.

3.6 Simultaneous Testing (F-test)

To assess the collective impact of all independent variables on Rural Area Development, an F-test was conducted. The F-test yielded a significance value of 0.000, which is well below the 0.05 threshold, indicating that the model as a whole is statistically

significant. This means that the combination of Legal Aspect, Technical Cultivation Aspect, Environmental Management Aspect, Labor Aspect, and Institutional Aspect has a meaningful and significant impact on rural development in the Angkola Sangkunur sub-district. The significance of the F-test confirms the overall reliability of the regression model and the importance of considering all these factors together when analyzing rural development outcomes.

3.7 Determination Coefficient Test (R-Square)

The R-Square value, which represents the proportion of variance in the dependent variable explained by the independent variables, was found to be 0.357 (35.70%). This indicates that 35.70% of the variability in Rural Area Development can be explained by the five independent variables included in the model. The remaining 64.30% of the variance is attributed to other factors not captured in this study. While the R-Square value suggests a moderate explanatory power, it also highlights the complexity of rural development, which is likely influenced by a range of additional variables beyond those examined in this research.

3.8 Interpretation of Key Findings

The analysis reveals that the Legal Aspect, while positively correlated with rural development, does not have a statistically significant effect. This may be due to the complexity of legal frameworks and their indirect influence on development outcomes. In contrast, the Technical Cultivation Aspect emerges as a critical driver of rural development, reflecting the importance of adopting modern agricultural practices to boost productivity and economic growth. The Environmental Management Aspect, though positively associated with development, may require more time or additional supportive policies to demonstrate a significant impact. The Labor Aspect's negative coefficient, albeit non-significant, suggests that sustainable labor practices, while essential, may impose short-term costs that challenge smallholder farmers.

The Institutional Aspect, with its significant positive impact, underscores the importance of strong organizational structures and governance in fostering rural development. Effective institutions can enhance access to resources, improve market linkages, and support the implementation of best practices, ultimately contributing to sustainable development. These findings suggest that policies aimed at strengthening technical capabilities and institutional frameworks are likely to have the most immediate and significant impact on rural development in the region.

4. Conclusion and Recommendations

4.1 Conclusion

This study aimed to analyze the impact of sustainable independent oil palm cultivation on regional development in the Angkola Sangkunur sub-district, South Tapanuli Regency, by examining the influence of various factors including legal, technical cultivation, environmental management, labor, and institutional aspects. The findings provide valuable insights into the dynamics of rural development in areas heavily dependent on agricultural activities, particularly oil palm cultivation.

The analysis revealed that the **Technical Cultivation Aspect** and **Institutional Aspect** are the most significant drivers of rural development in the region. The strong positive impact of the Technical Cultivation Aspect underscores the importance of adopting advanced agricultural practices, such as the use of high-quality seeds, effective pest management, and proper fertilization techniques. These practices not only enhance productivity but also contribute to the economic well-being of smallholder farmers, thereby fostering broader regional development.

Similarly, the significant positive influence of the Institutional Aspect highlights the crucial role of robust organizational structures and governance mechanisms in supporting sustainable agricultural practices. Institutions that provide effective management, market access, and resource distribution are pivotal in enabling smallholder farmers to overcome challenges associated with sustainable palm oil cultivation. The development of strong

institutions is therefore essential for ensuring the long-term success of sustainable agriculture in the region.

In contrast, the **Legal Aspect** and **Environmental Management Aspect** were found to have positive but statistically insignificant effects on rural development. While legal compliance and environmental stewardship are important for sustainable development, their direct impact on immediate economic outcomes may be less pronounced or may require a longer timeframe to become evident. The results suggest that while these aspects are foundational, they might not independently drive rapid development without the support of other more directly impactful factors like technical and institutional support.

The **Labor Aspect**, however, exhibited a negative and statistically insignificant impact on rural development. This finding suggests that the costs associated with implementing sustainable labor practices, such as providing personal protective equipment (PPE) and adhering to fair wage standards, may pose challenges for smallholder farmers, particularly in the short term. While these practices are critical for ensuring worker safety and rights, they may also increase operational costs, potentially hindering economic growth in the absence of sufficient support mechanisms.

Overall, the findings of this study emphasize the complexity of rural development, where multiple factors interact to influence outcomes. While technical and institutional improvements offer the most direct pathways to enhancing development, a holistic approach that also considers legal, environmental, and labor aspects is necessary for achieving truly sustainable growth.

4.2 Recommendations

Based on the findings of this research, several recommendations can be made to further enhance rural development through sustainable oil palm cultivation in the Angkola Sangkunur sub-district:

1. **Strengthening Technical Support and Training**: Given the significant impact of the Technical Cultivation Aspect, it is crucial to invest in ongoing education and training programs for smallholder farmers. These programs should focus on best practices in cultivation, including the adoption of advanced technologies, efficient water management, and sustainable pest control methods. Providing farmers with access to high-quality seeds and fertilizers will also be essential for improving productivity and ensuring the sustainability of oil palm cultivation.

2. **Enhancing Institutional Capacity**: To capitalize on the positive effects of strong institutional frameworks, efforts should be made to strengthen local agricultural institutions. This can be achieved by improving the governance structures, enhancing the capacity of farmer cooperatives, and fostering partnerships between smallholders and larger market players. Institutions should also focus on improving market access for smallholder farmers, ensuring that they can sell their products at fair prices and access necessary inputs at reasonable costs.

3. **Promoting Legal Compliance and Certification**: Although the Legal Aspect did not show a significant impact in this study, ensuring legal compliance remains critical for long-term sustainability. Efforts should be made to simplify the certification process and provide farmers with the necessary support to obtain legal ownership certificates, which can enhance their access to credit and other financial resources. Additionally, raising awareness about the benefits of legal compliance, including reduced risk of land disputes and improved business security, can encourage more farmers to pursue certification.

4. **Balancing Environmental Management with Economic Viability**: While environmental management is vital for sustainability, it is important to balance these practices with the economic needs of smallholder farmers. Policies should be developed to provide incentives for environmentally friendly practices, such as subsidies for conservation efforts or payments for ecosystem services. Encouraging the adoption of agroforestry and other sustainable land-use practices

can help preserve the environment while maintaining or even enhancing agricultural productivity.

5. **Addressing Labor Challenges**: The negative impact of the Labor Aspect suggests a need to revisit the implementation of labor standards in the context of smallholder farming. It is essential to ensure that labor standards do not disproportionately burden smallholders. Providing financial support or subsidies to offset the costs associated with meeting labor requirements, such as the provision of PPE and fair wages, can help alleviate the financial pressures on smallholders. Additionally, training programs on labor rights and safety practices should be made widely accessible to ensure compliance without compromising economic viability.

6. **Holistic Policy Development**: Policymakers should take a holistic approach when designing interventions for rural development. This includes integrating legal, technical, environmental, labor, and institutional aspects into a cohesive policy framework that addresses the unique challenges faced by smallholder farmers. Collaboration between government agencies, non-governmental organizations, and the private sector will be crucial in implementing these policies effectively.

7. **Monitoring and Evaluation**: Continuous monitoring and evaluation of the impacts of these interventions are necessary to ensure that they are achieving the desired outcomes. Establishing a system for regular data collection and analysis will help track progress, identify emerging challenges, and adjust strategies as needed. This adaptive management approach will allow for the refinement of policies and programs over time, ensuring that they remain relevant and effective.

8. **Promoting Research and Innovation**: Finally, further research is needed to explore the long-term impacts of sustainable oil palm cultivation on rural development. Investing in research and innovation will provide new insights and help develop more effective strategies for promoting sustainability in the agricultural sector. Encouraging collaboration between academic institutions, industry stakeholders, and farmers will be essential for driving innovation and ensuring that research findings are translated into practical applications.

In conclusion, while significant progress has been made in promoting sustainable oil palm cultivation in the Angkola Sangkunur sub-district, there is still much work to be done. By focusing on the key drivers of rural development identified in this study, and by addressing the challenges associated with legal, environmental, and labor aspects, it is possible to create a more sustainable and prosperous future for smallholder farmers in the region.

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