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TIME-SERIES EXPANSION OF OIL PALM PLANTATION IN PULANG PISAU REGENCY

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ABSTRACT

The primadonna of oil palm is unavoidable as the largest commercially cultivated crop in tropical regions, especially Indonesia. The escalation in oil palm demand aligns with Land Use Land Cover (LULC) conversion and the transformation of global agricultural landscape. Expansion in Kalimantan proves that the oil palm areas increased from 90,300 ha to 3,164,000 ha, with 90% of the converted land being forest areas. Complexity of these issues drives need to conduct research on oil palm plantation expansion in Pulang Pisau Regency. This study presents the manifestation of LULC conversion into oil palm plantations through remote sensing. The results show the expansion of oil palm plantations from 2009-2023, non-compliance with applicable spatial regulations, and changes in the agrarian structure of the surrounding communities. This analysis can serve as a decision-making tool for stakeholders in the oil palm sector that is effective and efficient in terms of cost, time, and effort.

A. INTRODUCTION

The primadonna of oil palm is unavoidable as the largest commercially cultivated crop in tropical regions, especially Indonesia (Abubakar et al., 2023). The long history of oil palm business development has made Indonesia a leading producer and exporter in the world, with 14 million hectares of oil palm areas and supplying 60% of global Crude Oil Palm (CPO) production (Lim et al., 2023). The existence of oil palm, which is capable of producing 40% of global vegetable oil needs, has become a superior power for Indonesia (Bausano et al., 2023). In addition to CPO exports, Indonesia has started producing various oil palm derivatives in the biofuel, food ingredients, cosmetics, and biodegradable plastics businesses (H. Purnomo et al., 2020). This achievement is evidenced by an annual production of 256 million tons of Fresh Fruit Bunches (FFB), supplying the country's foreign exchange reaching IDR 359.14 trillion, contributing 14% of the country's non-oil and gas export income, and ensuring energy sovereignty (Qaim et al., 2020). This multi-sector role is felt down to the regional level, where 25 out of 38 provinces experience positive sustainable economic growth, village development, and progressive

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depreciation of poverty levels (Edwards et al., 2019).

The escalation in oil palm demand aligns with LULC conversion and the transformation of the global agricultural landscape (Beyer et al., 2020). The reality of LULC conversion into plantations is dominated by forest regions (Yuliani et al., 2020). Extreme deforestation, especially of peat forests and tropical rainforests has adverse effects on soil organic matter, greenhouse gases, biodiversity, and large-scale ecological transitions (Meijaard et al., 2020).

The fact in Indonesia is that 2.5 million hectares of oil palm plantations are in illegal forest areas, with 68% becoming smallholder plantations, and 60% of forest fires are caused by oil palm business actors (H. Purnomo et al., 2019). From a socio-economic perspective, the LULC transformation for oil palm plantations has increased conflicts between communities and agro-industrial companies (Pasaribu et al., 2020). Institutional and policy factors have resulted in a proactive legal framework for powerful parties-companies (Papilo et al., 2022). Practices of corruption, collusion, and nepotism occur at various levels of government, even decentralization gives great power for discretion over permits, contracts, and oil palm plantation concessions (Aspinall, 2019).

Illegal governance of oil palm in forest areas also occurs in Kalimantan (Schoneveld et al., 2019). Explanations prove that the areas of oil palm plantations increased from 90,300 ha to 3,164,000 ha, with 90% of the converted being forest areas (Carlson et al., 2013). At the provincial level, Central Kalimantan shows that 70% of oil palm plantations do not have permits for forest area release (Astuti et al., 2022). Even at the regency level, Pulang Pisau experienced a similar tragedy, where agricultural and forest area fires due to natural factors (el nino) and human factors (companies and communities) have transformed into oil palm plantations (Purnomo et al., 2019). The damage that has occurred has damaged soil nutrients, made it dry, and tarnished Indonesia's image as a cross-border air pollution in Southeast Asia (Astuti, 2020).

The complexity of these problems drives the need to actualize research on oil palm plantation expansion in Pulang Pisau Regency. The dominance of the Pulang Pisau areas as protected forest and production forest areas, with even 70% of LULC being peat (Djaenudin et al., 2021). The astonishing fact is that 10,000 ha of ex-peat development areas for food estate allocation (Fitriana & Marni, 2021) have turned into oil palm plantations due to forest fires and inconsistent soil for vegetable farming.

This study presents the manifestation of LULC conversion into oil palm plantation through remote

sensing, which has been widely actualized in various regions (Sarzynski et al., 2020), but currently, no one has applied rapid mapping of this activity in Pulang Pisau Regency. The impact of changes in the agrarian structure has realistically caused various losses for local communities. This is reinforced by the issuance of plantation business permits to 18 companies from 2016 to 2015 covering an area of 176,149.80 ha (Meichia et al., 2021). The integration of this analysis becomes a decision-making tool for stakeholders regarding the expansion of the oil palm sector in Pulang Pisau Regency.

B. METHOD

Pulang Pisau Regency is one of the regional areas with the largest forest areas in Central Kalimantan Province. According to the Statistics Center Agency, 18% of the Pulang Pisau community works in the agriculture, plantation, and forestry sectors, making this sector the strongest supporter. This is evidenced by the Gross Regional Domestic Product by business field in 2022, which shows that this sector generated the largest income of IDR 2,380,995,000, accounting for 36.83% of all sectors. In addition, the oil palm planted areas increased from 7,725 ha in 2021 to 8,469 ha in 2022.

The study of applying spatial patterns with existing oil palm plantations can review the commitment of stakeholders (government, business actors, and the community) to actualize the Regional Spatial Plan policy (Wardhana et al., 2023), particularly in controlling the sustainable function of forest areas. This research uses a mixed method, namely quantitative through LULC classification as evidenced by spatial accuracy tests and qualitative methods regarding spatial mechanisms in the implications of the suitability of oil palm plantation expansion to spatial regulations. There are six types of data that are analyzed in depth, as shown in Table 1.

Table 1. Spatial Data Specifications

Nu.	Data Components	Source
1	Landsat 5 imagery in 2009	USGS Earth Explorer
2	Landsat 8 imagery in 2016 and 2023	USGS Earth Explorer
3	Province Spatial Plan of Central Kalimantan in 2015-2035	Regional Office of the National Land Agency of Central Kalimantan Province
4	Regency Spatial Plan of Pulang Pisau in 2019- 2039	Pulang Pisau Regency Land Office
5	Forest Spatial Plan of Pulang Pisau Regency in 2019	Pulang Pisau Regency Land Office
6	Administrative Boundary of Pulang Pisau Regency	Geospatial Information Agency

(Source: analysis result, 2024)

The overall data analysis in this study collaborates with Geographic Information Systems (GIS) and remote sensing in a spatio-temporal manner. This collaboration has many advantages in integrating spectral information of the earth's surface and digital-based spatial statistical analysis (Eko Noviandi et al., 2021; Zulsfi et al., 2021). Landsat satellite image data for 2009, 2016, and 2023 was downloaded through the USGS Earth Explorer website. Landsat imagery has become a staple of free remote sensing technology that provides advantages in terms of wide portrait areas, good accuracy, and precision, as well as a long-year range compared to other competitors (Arrafi et al., 2022; Hardianto et al., 2021; Mirwanda et al., 2021). LULC classification applies supervised classification modeling with the maximum likelihood method. This method is the best compared to other supervised methods by unifying spatial, pixel, and spectral statistics from the assessment of mean, standard deviation, variance, and covariance (Aritonang et al., 2022; Sawitri et al., 2021). In addition to digital interpretation, manual interpretation is carried out through digitization to obtain the best results on oil palm plantation areas, which is the top priority in this study.

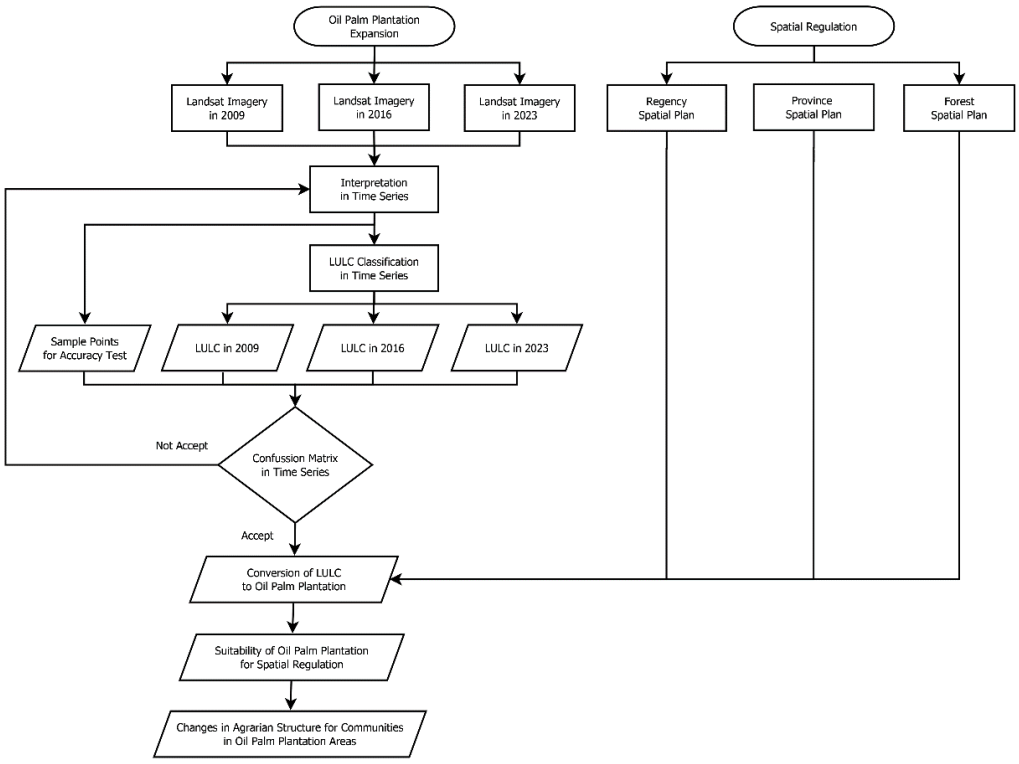

Figure 1. Research Diagram
(Source: analysis result, 2024)

Spatial accuracy testing uses a confusion matrix to represent a summary of LULC class predictions that have been processed against existing fields at that time (Lu et al., 2019). User's accuracy is the ratio comparison of pixels that have been classified correctly from a class to all pixels in that class as well. Producer's accuracy is the ratio comparison of pixels whose truth has been classified between a certain class to the total pixels in all classes. Overall accuracy is the entire ratio of pixels that have been classified compared to the total of all pixels. The Kappa coefficient calculates the ratio of pixels for each class, the total pixels of the same class, and the total pixels of all classes that have an analytical relationship to the user's accuracy, producer's accuracy, and overall accuracy (Amini et al., 2022). The accuracy test results are said to be correct when obtaining a kappa coefficient value above 80% (Rakuasa et al., 2023).

$$\text{PA (\%)} = \frac{Diagonal\ Value\ of\ Column}{Column\ Total} \times 100 \quad (1)$$

$$\text{UA (\%)} = \frac{Diagonal\ Value\ of\ Row}{Row\ Total} \times 100 \quad (2)$$

$$\text{OA (\%)} = \frac{Diagonal\ Value\ of\ Column + Diagonal\ Value\ of\ Row}{Total\ Number\ of\ Frequency} \times 100 \quad (3)$$

$$\text{K} = \frac{\frac{\sum a}{N} - \sum ef}{1 - \sum ef} \quad (4)$$

(Source: Dewo Kusumaningrat et al., 2017)

The LULC information in time series is analyzed spatially to estimate conversion areas, especially oil palm plantations. Furthermore, LULC in 2023 is analyzed against the applicable spatial regulations, namely the Regency Spatial Plan of Pulang Pisau, the Province Spatial Plan of Central Kalimantan, and the Forest Spatial Plan of Pulang Pisau Regency. Changes that occur, especially in oil palm plantation areas are known for the total areas and percentage of land that is suitable and not suitable according to these three spatial regulations. Lastly, to understand the changes in agrarian structure and their impact on communities living in areas around oil palm plantations.

C. RESULT AND DISCUSSION

C.1. RESULT

a. Accuracy Test

The LULC accuracy test in 2009 shows user's accuracy values: (i) water at 97.15%; (ii) vegetation at 96.50%; (iii) agriculture at 98.25%; (iv) oil palm plantation at 97.00%; (v) built-up area at 95.60%; (vii) and fallow land at 92.50%. The producer's accuracy results show: (i) water at 96.40%; (ii) vegetation at 97.80%; (iii) agriculture at 96.00%; (iv) oil palm plantation at 95.15%; (v) built-up area at 96.50%; (vii) and fallow land at 93.25%. The calculation results for overall accuracy is 98.25% and kappa accuracy is 97.80%. The LULC classification in 2016 shows user's accuracy values: (i) water at 98.00%; (ii) vegetation at 95.60%; (iii) agriculture at 97.65%; (iv) oil palm plantation at 97.90%; (v) built-up area at 96.20%; (vii)

and fallow land at 92.50%. The producer's accuracy results show: (i) water at 97.10%; (ii) vegetation at 96.25%; (iii) agriculture at 96.50% (iv) oil palm plantation at 96.80%; (v) built-up area at 97.00%; (vii) and fallow land at 93.10%. The calculation results for overall accuracy is 97.90% and kappa accuracy is 98.15%.

The LULC in 2023 shows user's accuracy results show: (i) water at 95.70%; (ii) vegetation at 98.50%; (iii) agriculture at 96.45%; (iv) oil palm plantation at 98.50%; (v) built-up area at 95.25%; (vii) and fallow land at 93.00%. The producer's accuracy results show: (i) water at 94.90%; (ii) vegetation at 97.80%; (iii) agriculture at 97.00% (iv) oil palm plantation at 98.35%; (v) built-up area at 96.15%; (vii) and fallow land at 93.80%. The calculation results for overall accuracy is 97.50% and kappa accuracy is 98.35%. All classifications in 2009, 2016, and 2023 are declared valid and the data can be used for time series LULC analysis.

b. Land Use and Land Cover (LULC) Changes in Time Series

Extreme LULC changes that have occurred need to be known in terms of area size in time series to understand human exploitation in using natural resources (Alawamy et al., 2020). The LULC classification in 2009 shows: (i) water covering 15,739.29 ha; (ii) vegetation covering 492,486.57 ha; (iii) agriculture covering 372,052.54 ha; (iv) oil palm plantation covering 72,808.64 ha; (v) built-up area covering 5,718.83 ha; (vii) and fallow land covering 8,099.15 ha. The LULC in 2016 shows: (i) water covering 9,983.39 ha; (ii) vegetation covering 398,505.54 ha; (iii) agriculture covering 283,401.08 ha; (iv) oil palm plantation covering 113,665.73 ha; (v) built-up area covering 6,455.75 ha; (vii) and fallow land covering 53,933.29 ha.

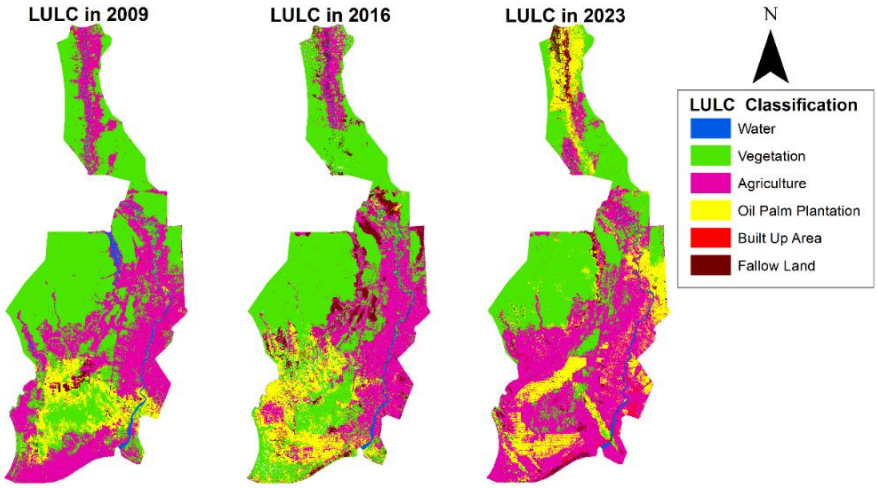

Figure 2. Land Use Land Cover (LULC) Changes in Time Series
(Source: analysis result, 2024)

The LULC in 2023 shows: (i) water covering 9,466.17 ha; (ii) vegetation covering 328,550.87 ha; (iii) agriculture covering 410,683.10 ha; (iv) oil palm plantation covering 162,153.24 ha; (v) built-up area covering 14,942.04 ha; (vii) and fallow land covering 28,436.22 ha. In time series, oil palm plantations from 2009-2016 experienced an increase of 40,857.09 ha (56.12%), followed by another increase of 48,487.51 ha (42.66%) from 2016-2023.

c. Analysis of LULC Suitability for Spatial Regulation

The main objective is to understand the LULC in 2023 in accordance with existing spatial regulations. The focus is on 2023 data due to the issuance of these spatial regulations and to understand the latest compliance. First, the Regency Spatial Plan of Pulang Pisau which has been in effect from 2019 until now needs to be examined. Conformity analysis is carried out by comparing actual LULC with the planned type of area allocation in the Regency Spatial Plan. The spatial pattern in the Regency Spatial Plan consists of designations for protected forests, cultivation areas, lakes, ponds, and rivers. The results show that the areas of oil palm plantations that comply are 121,415.71 ha and the non-compliant areas are 40,725.92 ha. The compliant areas are in cultivation areas, while non-compliant areas are in protected forests, lakes, ponds, and rivers.

The second analysis is LULC with the Province Spatial Plan of Central Kalimantan. The spatial pattern in the Province Spatial Plan consists of designations for protected forests, production forests, cultivation areas, nature reserves, nature conservation, waters, plantations, settlements, and agriculture. The results show that the area of oil palm plantations that comply is 27,071.15 ha and the non-compliant area is 135,138.36 ha. The compliant areas are in cultivation and plantation, while non-compliant areas are in production forests, waters, settlements, protected forests, nature reserves, nature conservation, and agriculture.

The third analysis is LULC with the Forest Spatial Plan of Pulang Pisau Regency issued by the Ministry of Environment and Forestry in 2019. The forest areas in Pulang Pisau Regency consist of other use areas that can be used for non-forestry sectors such as agriculture, plantations, and settlements. This area can be owned and controlled by the community under the provisions of applicable laws and regulations. Protected forests, production forests, waters, nature reserves, and nature conservation cannot be disturbed for human activities because have a role in ecological sustainability. The analysis results show that the compliant areas are 57,306.73 ha and the non-compliant areas are 75,080.00 ha.

It is important to note that the analysis of LULC compliance with spatial

regulations must consider the changes that occurred at that time. Up-to-date data and information must be obtained so that the analysis is carried out to gain an accurate understanding. This analysis also involves the use of GIS and remote sensing to obtain comprehensive spatial data (Kaya et al., 2019). The results of the conformity analysis can also identify potential problems or conflicts that may arise. Risk mitigation can be proposed to the government to make changes or improvements to spatial regulations and LULC by the community (Froese & Schilling, 2019). Mitigation can involve consultation with various stakeholders, such as farmers, entrepreneurs, local communities, and environmental organizations. With this analysis, it is hoped that Pulang Pisau Regency will be more in line with the needs and potential of the region. Positive benefits can be optimally felt by the community and the environment in the future.

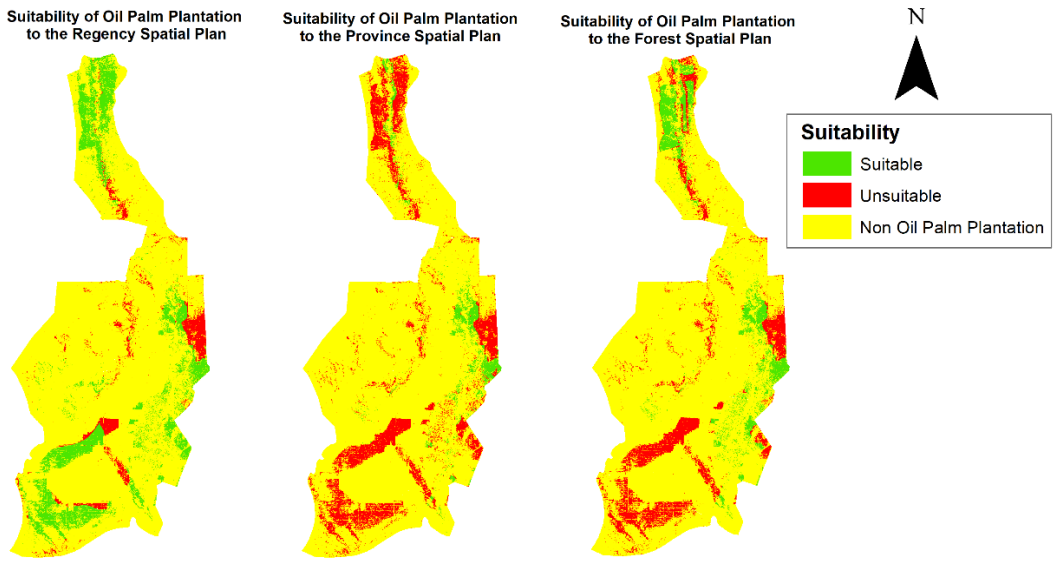

Figure 3. Analysis of Oil Palm Plantation Suitability for Spatial Regulation
(Source: analysis result, 2024)

C.2. DISCUSSION

a. Changes in Community Agrarian Structure in Oil Palm Plantation Areas

The past life of the community was closely tied to fields and hunting activities as the main source of food. The meaning of fields at that time became a form of natural economy where harvest results were used for household consumption and not exchanged in the market ecosystem. These various practices reflect the community's dependence on natural resources and local customary-based management in maintaining an ecocentric existence. The arrival of Dutch colonials in the 20th century brought changes to agricultural activities with the introduction of rubber plants. Rubber plants thrived in their soil

and provided new economic opportunities. The community became increasingly interested in learning modern agriculture to manage rubber, making rubber plantations their main source of income. Income from rubber gardens was used to meet living needs that had to be purchased through the market system, while farming yields were used for daily basic needs. This collaboration demonstrated the community's ability to maintain a balance between local wisdom and global market demands while creating a sustainable economic system in facing economic globalization dynamics.

The expansion of oil palm plantations in Pulang Pisau Regency revealed unique facts. Typically, oil palm plantation expansion uses the state property regime with cultivation rights permits. However, this expansion used community-owned land that was previously planted with rubber, rattan, and rice. In 2005, people rarely planted rice due to frequent attacks by rice ear bugs that caused crop failure, and regulations prohibiting forest burning added to the reasons why people did not cultivate their land. The culture of rice planting began to be abandoned and former rice fields became dormant land. Oil palm plantation expansion began in early 2008. The expansion of oil palm plantations began with the process of searching for community-owned land for land consolidation. The company continued to match locations and find community-owned land to be purchased with the help of village governments and community leaders. The selling value of land has different prices, depending on whether there are already plants and the type of plants. The expansion of oil palm plantations began with the process of searching for community-owned land consolidation. The company continued to match locations and find community-owned land to be purchased with the help of village governments and community leaders. The selling value of land has different prices, depending on whether there are already plants and the type of plants.

Changes in the agrarian structure due to the entry of oil palm plantations occur in the context of ownership, control, use, and utilization of land (Chrisendo et al., 2021; E. P. Purnomo et al., 2019b). The status of land ownership is in the form of state land that has been owned by the community through a statement letter from the local village. Proof of ownership persisted when the company entered, then land registration was carried out and it has been certified as freehold. Land control, which was previously largely controlled in the name of the community, then decreased after the entry of the company. LULC has changed, which was previously dominated by rubber and rice fields, then rice fields have largely disappeared, dominated by oil palm and rubber. Land utilization has also

changed, which was previously for trading and agricultural activities, changed to trading and plantation activities.

Oil palm plantations have significant socio-economic impacts on communities, both positive and negative. The presence of oil palm companies opens up opportunities for local communities and job opportunities become abundant. Before the establishment of oil palm plantations, the majority of people worked as farmers with uncertain income. After the presence of the company, people got permanent jobs as laborers. The absorption of labor by the company is very helpful, especially for people who previously had to leave the village to find work and leave their families. In addition, working on an oil palm plantation provides more stable income for the community.

The expansion of oil palm plantations brings changes to the lifestyle of local communities. Many who previously lived in agriculture and hunting now depend on work from companies. Changes in consumption patterns of basic needs have occurred, which previously relied on local agricultural products, and now rely more on food ingredients from outside the region. Oil palm plantations also created economic vulnerability for communities who no longer owned land. The company initially provided 30 working days slots, but several internal conditions led to a reduction to 15 working days. This reduction caused anxiety as it resulted in a drastic decrease in income for the community. Additionally, social problems emerged when the land began to be considered as having economic value. Before the company entered and purchased community-owned lands, land was not considered particularly valuable by the community. Land purchases by the company encouraged residents to mark their land boundaries, and conflicts arose when community members sold land that didn't belong to them to the company without the landowners' knowledge.

This expansion also causes negative ecological impacts. The expansion of plantation areas often causes deforestation and clearing of peatlands with massive environmental degradation consequences. These adverse impacts include loss of biodiversity, increased greenhouse gas emissions, and degradation of ecosystem services (Ayompe et al., 2021; Mohd Hanafiah et al., 2021). The ecological changes that occur can worsen the vulnerability of communities in plantation areas, namely natural disasters, disrupt local water cycles, and reduce the availability of forest resources that are very important for the local wisdom lifestyle of the community. The location of the area that is now oil palm was formerly an area rich in natural resources. Many small river flows that flowed through the area functioned as habitats for various fish species and now these rivers have been damaged. In fact, the function of these

rivers for the community is not only as a source of water but also as a main source of protein that is vital for basic needs.

D. CONCLUSION

In time series, the areas of oil palm plantation from 2009-2016 increased by 40,857.09 ha (56.12%), followed by another increase of 48,487.51 ha (42.66%) from 2016-2023. Compliance with spatial regulations shows that oil palm plantations conforming to the Regency Spatial Plan, covering 121,415.71 ha are suitable, while not suitable areas cover 40,725.92 ha. Oil palm plantations conforming to the Province Spatial Plan, cover 27,071.15 ha are suitable, while not-suitable areas cover 135,138.36 ha. Oil palm plantations conforming to the Forest Spatial Plan, cover 57,306.73 ha are suitable, while not-suitable areas cover 75,080.00 ha.

The expansion of oil palm plantations has brought profound changes to the agrarian structure that directly affect community life. Land control, which was previously largely controlled by the community, has been sold to companies. Land utilization has changed, which is now in the plantation sector. LULC has changed from rice fields to rubber and oil palm. Negative impacts occur when the community's dependence on the company for income sources and ecological damage, especially to water resources.

This study suggests that stakeholders conduct empowerment programs to educate the community about food security and preserving nature. Community empowerment is focused on farming technique programs and harvest distribution. This program can be supported by providing seeds, fertilizers, and agricultural tools from the government and companies as part of social responsibility. The community's food needs that can be met from their own harvest can reduce dependence on market prices and reduce expenses. These efforts have a positive impact on improving family nutrition quality as well as improving the economy and community self-reliance in the future. In addition, analysis modeling needs to be explored in depth to strengthen the assessment of land change mitigation and sustainable land management and control strategies.

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