Vol. 15, No. 1 (2026): 10 - 18 http://dx.doi.org/10.23960/jtepl.v15i1.10-18

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Geospatial Mapping of Smallholder Oil Palm Plantation in Tanah Laut Regency Using QGIS

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Article History:

Received : 7 February 2025
Revised : 13 July 2025
Accepted : 16 July 2025

Keywords:

Oil palm,
Production,
QGIS,
Smallholder plantation,
Yield.

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ABSTRACT

Smallholder oil palm plantations play a crucial role in the Indonesian palm oil industry, but research on their spatial characteristics and performance at the district level is limited, as most previous studies tend to generalize plantation trends without utilizing local geospatial analysis. This study addresses this gap by using QGIS 3.32.1 to classify, map, and assess the status of smallholder oil palm plantations in Tanah Laut Regency, South Kalimantan. Plantations are categorized into productive and non-productive based on district-level BPS data, with a total planted area of 14,479 ha, consisting of 12,693 ha of productive land and 1,786 ha of non-productive land. Batu Ampar has the largest productive land (3,527 ha), while Tambang Ulang and Panyipatan have significant non-productive land, 328 ha and 300 ha, respectively, indicating the presence of immature plantations. Total production varied between 396–4,603 tons, with Batu Ampar, Jorong, and Tambang Ulang as the main contributors, while yield per hectare ranged from 435–620 kg, with Bati-Bati recording the highest yield. These findings confirm that plantation management practices determine productivity more than land area alone. This study presents an integrative method that combines spatial and statistical data, facilitates district-level plantation monitoring, and demonstrates that the use of open-source GIS tools such as QGIS offers a cost-effective, replicable approach that supports planning, policy, and sustainable development for smallholder farmers.

1. INTRODUCTION

Oil palm (*Elaeis guineensis*) is a major agricultural commodity in Indonesia, and has contributed to national economic growth, employment and rural development (Agustira *et al*., 2015; Begum *et al*., 2019; Purnomo *et al*., 2020; Alhaji *et al*., 2024). The palm oil sector is characterized by large plantations and smallholders, the latter having an important function in sharing out the economic benefits (Abazue *et al*., 2015; Abdullah *et al*., 2015; Agustira *et al*., 2015; Jaya *et al*., 2022, 2023, 2024; Jelsma *et al*., 2017b; Purnomo *et al*., 2020; Alhaji *et al*., 2024). Many oil palm smallholders are found in several areas such as Tanah Laut Regency and become the main sources of livelihoods for the farmers in that location. But with small-holder plantations being an economic priority, tracking their growth and productivity proves difficult because we do not have detailed or current information.

Clear spatial data on smallholder plantations is essential for sustainable land use planning and effective resource management. Important factors like productive planted area, non-productive planted area, total plantation area, production volume, and yield must be examined to evaluate overall plantation performance. Without proper mapping and monitoring, land use may become inefficient, productivity may decline, and environmental damage may occur. In this situation, Geographic Information System (GIS) technology, particularly QGIS, offers a practical and affordable way to map and visualize smallholder oil palm plantations (Duarte *et al*., 2018; Dzulfansyah *et al*., 2024).

Previous studies have demonstrated the effectiveness of QGIS applications in agricultural monitoring and land-use planning. Research conducted by Kanniah & Yu (2024); Pribadi *et al*. (2023), highlighted the use of QGIS in assessing plantation expansion and productivity trends, providing valuable insights into the spatial distribution of oil palm farms. Another study by Fernando & Premasiri (2010) utilized GIS to identify yield variations and optimize plantation layouts for improved productivity. While these studies provide a helpful framework, there has been little research focused specifically on smallholder oil palm plantations in Tanah Laut Regency. Current spatial data on smallholder plantations are often general, outdated, or not linked to plantation performance metrics. This makes it hard to support local decision-making. This study aims to fix these issues by combining statistical data with geospatial maps to offer insights at the district level. It is important to address the lack of detailed spatial data on smallholder oil palm plantations in Tanah Laut, as this limits effective planning and decision-making locally. To aid policymaking and promote sustainable land use, this study uses a spatial classification framework that combines plantation status (productive and non-productive), total land cover, production volume, and yield performance. This approach allows for district-level assessments of plantation conditions and helps identify priority areas for intervention.

This study aims to map and examine the growth of smallholder oil palm plantations in Tanah Laut Regency using QGIS 3.32.1. It will classify plantation land into productive and non-productive areas, assess total plantation coverage, and evaluate production levels and yield performance. By using spatial analysis, this study seeks to provide clear data that can help policymakers, plantation managers, and smallholder farmers make informed decisions. These findings are expected to lead to better land management practices, increased productivity, and sustainable agricultural development in Tanah Laut.

2. MATERIALS AND METHODS

2.1. Data Collection and Processing

This study uses secondary data from the Tanah Laut in Figures 2024 publication issued by the Central Statistics Agency of the Republic of Indonesia (BPS Tanah Laut, 2023), which provides detailed information on “Farmers’ Planted Area,” “Production,” and “Average Palm Oil Yield per District” in Tanah Laut Regency in 2023. These data provide a comprehensive overview of the distribution of smallholder oil palm plantations, including productive and non-productive land, as well as overall production and production performance across the regency.

Data from the Indonesian Statistics Agency (BPS) will be processed and organized to ensure that oil palm plantation data in each district is clearly defined. Planted areas are categorized into productive and non-productive based on BPS definitions, which distinguish productive (yielding) plantations from immature or temporarily unproductive plantations. This classification supports analysis of plantation maturity and production potential across districts. This data will form the basis for spatial analysis and mapping in QGIS 3.32.1.

2.2. Spatial Analysis and Visualization

Analysis and visualization will be conducted using QGIS (Quantum Geographic Information System) 3.32.1 series, a widely used software for geospatial data processing and mapping. The basemap for this study will be derived from the Indonesian geospatial shapefile available on the Geospatial Indonesia website (https://www.indonesia-geospasial.com), which includes boundary data for South Kalimantan Province and Tanah Laut Regency. QGIS will be used to create a spatial map showing the distribution of smallholder oil palm plantations, by combining data on planted areas, production, and yield. Tabular data from the Tanah Laut Statistics Agency (BPS), including planted area (productive and non-productive), production, and yield per regency, were transformed into spatial layers by linking each data point to its administrative boundary using regency-level shapefiles. This process involved editing attribute tables and spatial merging in QGIS 3.32.1 to produce georeferenced thematic layers for analysis.

2.3. Validation, Data Integration, and Mapping

Validation was performed by cross-referencing spatial attributes with original BPS data and manually checking spatial alignment and attribute consistency in QGIS. The maps in this study were created by integrating multiple spatial layers in QGIS, specifically combining district boundaries with data on productive and non-productive plantation areas, total planted areas, production metrics, and district yields. Although these layers are visualized separately in Figures 1 to 4 for clarity, each figure is generated from the same integrated dataset to represent different aspects of plantation performance in Tanah Laut Regency.

3. RESULTS AND DISCUSSION

This study offers a spatial overview of smallholder oil palm plantations in Tanah Laut Regency. It combines data on area, production, and yield with geospatial images. The analysis highlights the differences in plantation growth, maturity levels, and productivity throughout the regency. By looking at these mapped patterns, the study reveals which areas are the top contributors to production, which are falling behind in development, and where focused efforts may be necessary. The next sections examine each spatial layer in connection with plantation classification, total coverage, and changes in yield.

Tabel 1. Planted area of smallholders, production and average yield of palm oil by district in Tanah Laut Regency, 2023 (BPS Tanah Laut, 2024)

District	Planted Area (Ha)			Production (Ton)	Yield Kg/Ha
	Not Productive	Productive	Total Planted Area		
Pelaihari	85	940	1025	1269	450
Bati-bati	223	1214	1437	2258	620
Panyipatan	300	700	1000	1134	540
Kintap	260	942	1202	1524	540
Takisung	63	920	983	1656	600
Bajuin	140	376	516	654	540
Bumi makmur	0	0	0	0	0
Jorong	40	2725	2765	4414	540
Batu ampar	347	3527	3874	4603	435
Kurau	0	245	245	396	540
Tambang ulang	328	1104	1432	1788	540
Tanah Laut Regency	**1786**	**12693**	**14479**	**19696**	**485.9**

The distribution of productive oil palm plantation areas across districts in Tanah Laut Regency is shown in Figure 1. The map shows significant spatial variation. Districts in the western and central regions, such as Batu Ampar, Jorong, and Tambang Ulang, have significantly larger productive areas. Conversely, districts in the eastern and coastal regions, such as Kurau and Bumi Makmur, exhibit relatively low levels of activity. This spatial contrast suggests a relationship between land availability, infrastructure support, and plantation sector development. This interpretation is reinforced by Table 1, which presents quantitative data on productive and unproductive land area, total production, and average yield per hectare. Districts with extensive productive areas generally correspond to higher production outputs, although some such as Batu Ampar, show lower yield values, indicating possible inefficiencies in land management. The concentration of productive plantations in certain areas shows inter-regional differences in the level of smallholder participation, intensity of land use, and agronomic achievements.

Referring to the data in Table 1, Batu Ampar District has the largest productive planted area (3,527 ha), followed by Jorong (2,725 ha) and Bati-Bati (1,214 ha). Conversely, Bumi Makmur District did not record any productive oil palm plantations, possibly reflecting minimal cultivation activity or the lack of official documentation of smallholder plantations in the area.

Spatial variations in the distribution of productive land indicate that Batu Ampar, Jorong, and Bati-Bati are the main centers of smallholder oil palm plantation activity in Tanah Laut Regency. This difference is likely influenced by local biophysical factors, ease of access to agricultural infrastructure, and the implementation of better management practices. This pattern of concentration of productive plantations in certain areas aligns with previous research findings, which revealed that oil palm expansion is generally concentrated in areas with more favorable institutional support and market access (Jelsma *et al*., 2017a; Mulyasari *et al*., 2023). Productivity data shows striking differences between districts, from 435 kg/ha in Batu Ampar to 620 kg/ha in Bati-Bati, with Takisung reaching 600 kg/ha. This

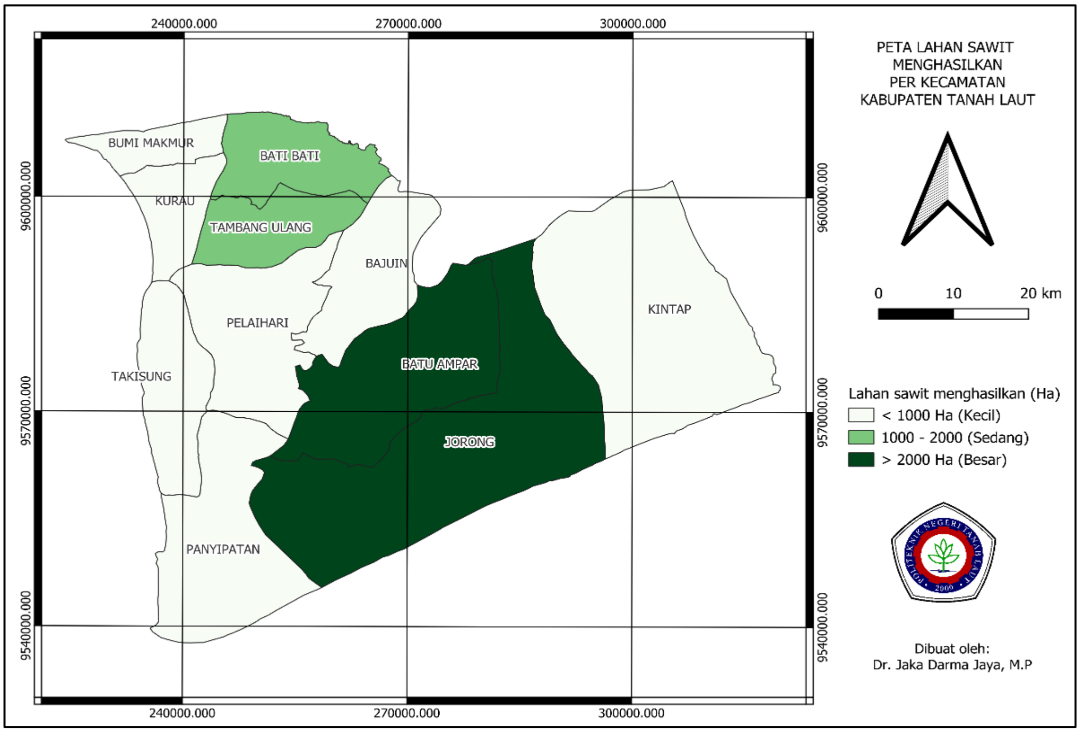

Figure 1. Visualization of producing palm oil plantation area per district in Tanah Laut Regency

variation confirms that agronomic practices and plantation management play a significant role in determining yields, not just land potential. These findings emphasize the need for strengthened technical extension and the implementation of GAP to increase smallholder productivity.

The spatial analysis shown in Figure 1 and Table 1 has important implications for regional planning and policy. Districts with large productive land areas and high yields, such as Batu Ampar and Jorong, are priority locations for productivity improvement programs. Suggested efforts include more focused training, improved input supply systems, and incentives that support sustainable practices (Lee *et al*., 2014). In contrast, districts like Pelaihari and Kurauwith medium-sized productive land areas and relatively stable yields are more appropriately directed towards land optimization strategies through efficient resource utilization. Previous research also confirms that implementing GAP has the potential to increase smallholder farmer productivity across a variety of agro-ecological conditions (Abazue *et al*., 2015; Abdullah *et al*., 2015; Purnomo *et al*., 2020).

Figure 2 presents the visualization of the planted area of oil palm that has not yet produced yields across the districts in Tanah Laut Regency. The map illustrates the spatial distribution of non-productive plantations and reveals varying degrees of land allocation for plantations that are still in immature phases. Table 1 complements this map by providing numerical data that differentiate between productive and non-productive areas, as well as total planted area and production output. The largest areas of non-productive land are in Batu Ampar (347 ha), Tambang Ulang (328 ha), Panyipatan (300 ha), Bati-Bati (223 ha), and Kintap (260 ha). These areas represent a significant portion of the land that has not yet contributed to current production. Rather than projecting future productivity, this study uses non-productive land as a proxy for spatial growth potential. While not using a formal spatial prediction model, combining non-productive land mapping data with district-level yields provides a clear spatial basis for identifying areas with potential for increased productivity as the plants mature. This interpretation provides a starting framework for further studies or local monitoring systems focused on yield forecasting and plantation performance dynamics.

The large area of non-productive land may reflect the ongoing expansion of smallholder plantations, driven by increased investment, land availability, or new planting activities. The stage of land development indicates the potential for future production when the crops enter the productive phase. A comparison between Figure 2 and Table 1

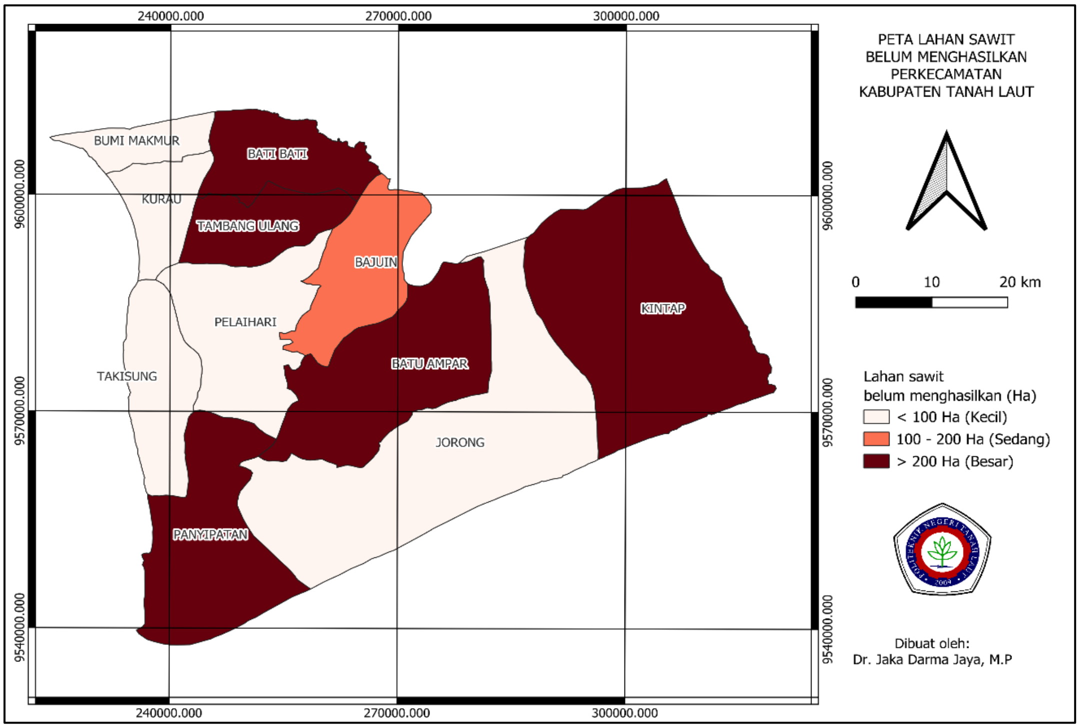

Figure 2. Visualization of immature (non-productive) palm oil plantation area per district in Tanah Laut Regency

also shows that Pelaihari, despite having a large total planted area (1,025 ha), only has 85 ha of non-productive land remaining. This reflects the high level of plantation maturity and efficiency in converting land into productive areas, consistent with its status as one of the highest-producing districts. In contrast, Batu Ampar has a significant non-productive area (347 ha) alongside a predominance of productive land (3,527 ha), indicating both current production capacity and potential future yields. Similarly, Tambang Ulang and Panyipatan exhibit significant non-productive areas, reflecting ongoing plantation development and the potential for significant contributions to regional production in the coming years.

The transition period from initial planting to productivity in oil palm typically ranges from three to four years (Corley & Tinker, 2015; Khatun *et al*., 2017). Therefore, districts with a relatively high proportion of non-productive land, such as Batu Ampar, Tambang Ulang, and Kintap, are expected to experience a rise in output as these plantations mature. Strategic monitoring and support in these districts will be critical to ensure efficient transition and sustainable production growth.

The large proportion of non-productive land is a critical concern for regional land-use policies. Without proper management, plantation expansion risks land degradation and inefficient resource use. Challenges such as low-quality seeds, suboptimal land preparation, and delayed maintenance can hinder the transition to productivity. Addressing these issues through policies such as technical assistance, distribution of certified seedlings, and integrated land management can accelerate the conversion of non-productive land to productive land, increasing smallholder profits and overall crop yields.

Figure 3 presents a comprehensive visualization of the total planted area of smallholder oil palm plantations in Tanah Laut Regency, encompassing both productive and non-productive land. This spatial distribution is reinforced by Table 1, which shows the planted area for each regency and demonstrates the disparity in plantation development across regions. Based on Table 1, the districts with the largest planted areas are Batu Ampar (3,874 ha), Jorong (2,765 ha), and Tambang Ulang (1,432 ha), which mark the main areas of smallholder oil palm cultivation with high levels of adoption and land allocation. In contrast, Bumi Makmur does not report planted area, likely indicating the absence of smallholder plantations or incomplete documentation.

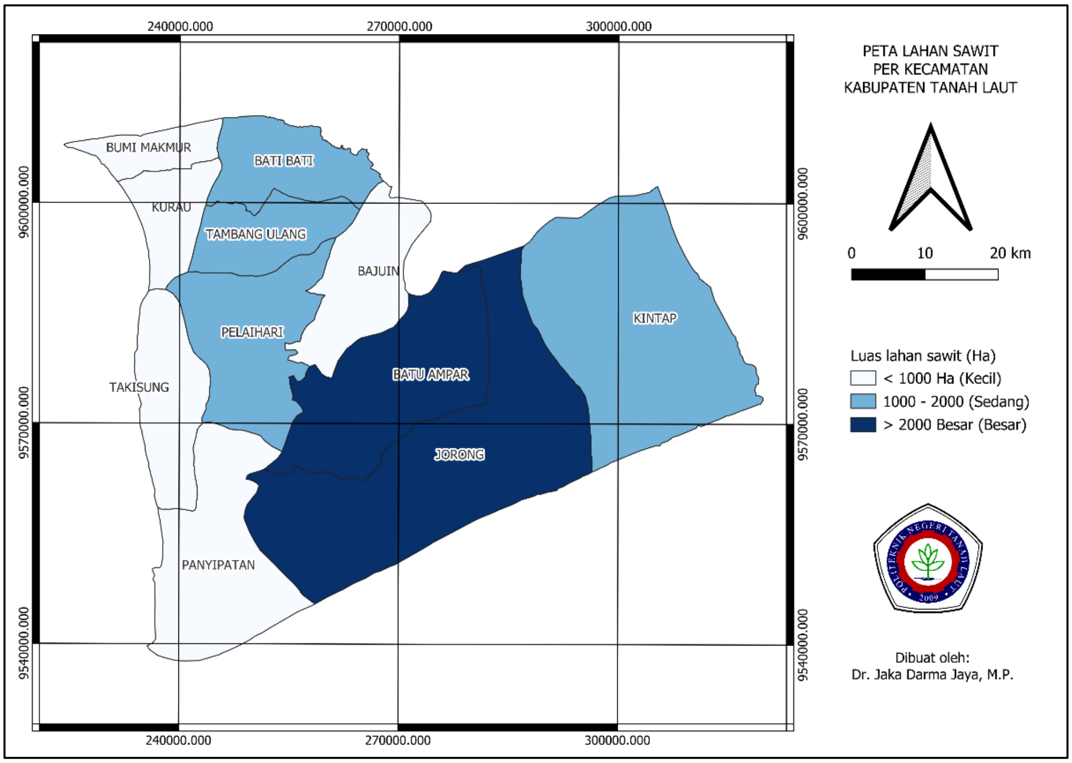

Figure 3. Visualization of total planted area of smallholder oil palm plantations per district in Tanah Laut Regency

The dominance of Batu Ampar and Jorong in total planted area reflects mature cultivation systems, likely supported by favorable agro-ecological conditions, adequate infrastructure, and intense farmer participation. The presence of both productive and non-productive land in these two districts indicates active expansion, with the potential for increased production as non-productive land reaches maturity. Tambang Ulang also has a significant total planted area (1,432 ha), with a balanced proportion of productive (1,104 ha) and non-productive (328 ha) land, indicating sustainable plantation development. Meanwhile, Pelaihari, with a total planted area of 1,025 ha, has a high proportion of productive land (940 ha), indicating plantation maturity and operational efficiency. Smaller planted areas are observed in districts such as Kurau (245 ha), Bajuin (516 ha), and Panyipatan (1,000 ha). These areas may face constraints such as limited land availability, lower investment capacity, or slower adoption of oil palm as a primary livelihood crop. In such contexts, targeted interventions, including land suitability assessments and access to financial or technical support, may be essential to stimulate expansion.

Understanding the spatial distribution of total planted area is crucial for designing location-specific plantation development strategies. Districts with large plantation areas require measures to support productivity and sustainability, such as optimal fertilization, pest control, and yield monitoring. Conversely, smaller regions can benefit from policies that encourage responsible expansion and increase farmer engagement. Furthermore, integrating plantation development with sustainable land use is essential to mitigate environmental impacts through agroforestry practices, erosion control, and adherence to conservation guidelines, thus achieving a balance between productivity and environmental sustainability.

Figure 4 displays a visualization of smallholder oil palm production across various districts in Tanah Laut Regency, showing total production in tons and highlighting the main producing areas. Table 1 complements this visualization with numerical data per district, allowing for more detailed comparative analysis. Batu Ampar recorded the highest production at 4,603 tons, followed by Jorong (4,414 tons) and Tambang Ulang (1,788 tons). The high production volumes in these districts align with their productive land area, indicating a close relationship between land use and yield. In contrast, Bumi Makmur has no production reports, possibly indicating the absence of smallholder

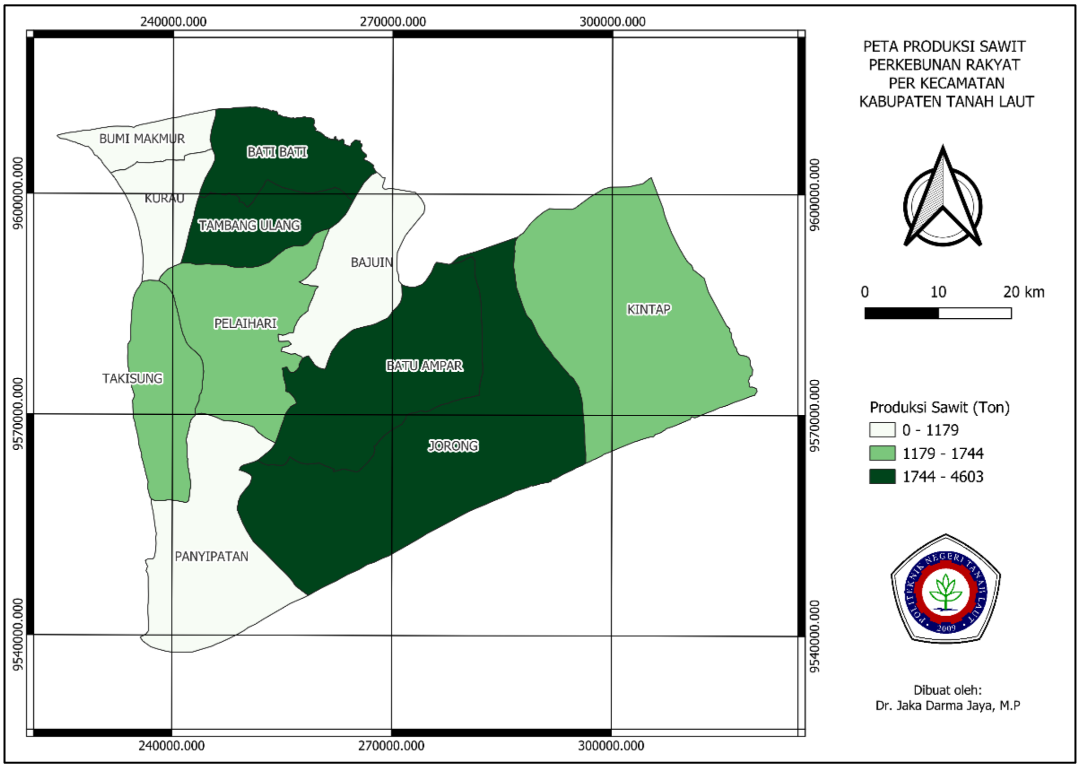

Figure 4. Visualization of smallholder oil palm plantation production per district in Tanah Laut Regency

plantations or undocumented data. Despite its relatively small land area, Pelaihari district managed to achieve significant production, at 1,269 tons, demonstrating high efficiency in converting land into crops. Takisung and Kintap contributed 1,656 and 1,524 tons, respectively, reflecting efficient productivity despite their medium-sized plantations. Meanwhile, Bati-Bati recorded a production of 2,258 tons, with the highest yield in all districts, reaching 620 kg/ha, confirming the superior quality of plantation management.

Table 1 shows the variation in yields between districts, ranging from 435 kg/ha in Batu Ampar to 620 kg/ha in Bati-Bati. These differences highlight the influence of management practices, input quality, and agronomic conditions on productivity. In Batu Ampar, despite high production, yields per hectare are relatively low, suggesting that production volume is driven more by land area than by land efficiency.

The disparity between planted area and output is particularly evident in districts like Bajuin and Panyipatan. Bajuin, with a total area of 516 ha, produces only 654 tons, while Panyipatan, with 1,000 ha, produces 1,134 tons. This relatively low productivity is likely due to a high proportion of immature plantations or suboptimal cultivation practices. Districts with high production but low yields per hectare present opportunities for intervention through agronomic training, input optimization, and improved land use planning. Conversely, areas like Bati-Bati, with high production and yields, could serve as models for replication in other districts. Monitoring plant age and replanting or rehabilitation programs on aging land are essential for maintaining long-term productivity. The production patterns shown in Figure 4 and Table 1 emphasize the need to align plantation expansion with yield increases through targeted program support, infrastructure investment, and access to certified seeds, so that the productivity gap can be narrowed and plantation development is equitable across Tanah Laut Regency.

The results show that districts with established plantations and supported infrastructure tend to have higher production. Many of these areas are close to main roads and administrative centers, emphasizing the importance of accessibility for input distribution, market access, and extension services. Several high-performing areas are also within official agricultural development zones, indicating alignment with land-use policies. Although these spatial factors are not formally modeled, their influence on productivity distribution is clearly visible. Investments in training, input subsidies, and replanting of aging plantations could further increase productivity, particularly in less accessible or marginalized area (Jelsma *et al*., 2017a; Khatun *et al*., 2017; Mulyasari *et al*., 2023).

4. CONCLUSION

Using QGIS 3.32.1, this study successfully classified smallholder oil palm plantations in Tanah Laut Regency into productive and non-productive areas, assessed total plantation area, and evaluated production performance and yields. Batu Ampar recorded the highest area and production (3,874 ha and 4,603 tons), followed by Jorong and Tambang Ulang. The largest non-productive areas were found in Batu Ampar, Tambang Ulang, and Panyipatan, indicating potential for future growth. Yield productivity varied between 435–620 kg/ha, with Bati-Bati achieving the highest values, indicating that plantation management determines yield more than land size alone. Spatial mapping using QGIS proved effective for assessing plantation conditions and designing targeted interventions to improve smallholder performance and sustainability. While providing important insights, this study relied on secondary data that may not fully reflect the dynamic field conditions. The analysis focused on key plantation indicators, while additional spatial variables such as infrastructure access and ecological characteristics were not included. Future research is recommended to integrate field validation and a wider range of spatial data to strengthen interpretations and support more comprehensive planning.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
JDJ	✓	✓	✓			✓		✓	✓		✓			
RM				✓	✓		✓			✓				

C: Conceptualization	Fo: Formal Analysis	O: Writing - Original Draft	Fu: Funding Acquisition
M: Methodology	I: Investigation	E: Writing - Review & Editing	P: Project Administration
So: Software	D: Data Curation	Vi: Visualization	
Va: Validation	R: Resources	Su: Supervision	

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