JAPSI (Journal of Agriprecision and Social Impact)
Volume 3 Issue 3 November 2026
e-ISSN: 3032-7849; p-ISSN: 3046-5397, Page 360-371
DOI: https://doi.org/10.62793/japsi.v3i3.119
Available online at: https://journal.kdp.co.id/index.php/japsi

Spatial Conformity of Existing Plantations with the Spatial Pattern Plan in Babulu District, Penajam Paser Utara Regency

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Abstract. *This study evaluates the spatial conformity of existing plantation land use in 2026 with the 2023–2043 Spatial Pattern Plan of Penajam Paser Utara Regency in Babulu District, Indonesia. Existing plantation areas were delineated through on-screen interpretation of Sentinel-2A imagery and high-resolution Google Satellite imagery, then compared with the official spatial-plan layer using the Identity overlay tool in ArcGIS. The mapped plantation area was approximately 15,912.23 ha, of which 13,752.05 ha (86.42%) were spatially conforming and 2,160.18 ha (13.58%) were outside the designated plantation zones. The largest non-conforming areas occurred in Sumber Sari (215.00 ha), Sri Raharja (84.81 ha), and Rawa Mulia (46.87 ha), where the spatial plan allocates no plantation area. Field checking of 12 purposively selected plantation points found 11 matches between image interpretation and field conditions, equivalent to 91.67% agreement for these points. Because the validation involved only 12 purposively selected points, this percentage should be interpreted as a preliminary point-based check rather than a statistically representative estimate of map-wide accuracy. The results identify locations that warrant closer review by spatial-planning authorities; the overlay indicates spatial inconsistency, but does not by itself establish a legally confirmed violation or its cause.*

Keywords: *Babulu, Geographic Information System (GIS), Remote sensing, Spatial conformity, Spatial pattern plan*

Received: July 3, 2026 ; Accepted: October 25, 2026 ; Published: November 15, 2026
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INTRODUCTION

Plantation cultivation is an important component of rural land use and regional economies in Indonesia. However, the location of existing plantations may not always correspond with the spatial allocation established in a Regional Spatial Plan (RTRW). Such differences matter because spatial planning provides a framework for coordinating land use and evaluating the implementation of planned spatial patterns. Indonesia's Government Regulation No. 21 of 2021 includes provisions for spatial planning, utilization control, monitoring, incentives and disincentives, and sanctions (Government of Indonesia, 2021). These provisions make spatial comparison a useful first step for identifying areas that may require further administrative review. Claims about the causes or legal status of a particular land-use mismatch, however, require evidence beyond a map overlay.

Babulu District, Penajam Paser Utara Regency, is the study area for this assessment. The district contains existing plantation areas as well as agricultural areas, making it relevant to examine whether plantation land use corresponds with the 2023–2043 spatial pattern plan. A spatial mismatch may arise from several possible circumstances, including differences between the mapped plan and current land use, changes in land use, or limitations in spatial data. These possibilities cannot be distinguished by overlay analysis alone.

Previous GIS-based studies have used overlay analysis to compare existing land use with spatial plans (Luthfina et al., 2019; Yunita et al., 2022; Kurniawati & Purwantara, 2025). The present study adds a village-level assessment for all 12 villages in Babulu District using plantation mapping for 2026 and the Regency's 2023–2043 spatial pattern plan. Its specific objective is to quantify conforming and non-conforming plantation areas and identify villages where the mapped differences are most pronounced. Unlike a multitemporal change study, this research evaluates the spatial distribution of existing plantations at one assessment period and does not measure the rate or timing of existing plantation distribution.

LITERATURE REVIEW

Spatial planning provides a framework for coordinating land utilization and environmental and development objectives. In Indonesia, Government Regulation No. 21

of 2021 addresses spatial planning and the control and monitoring of spatial utilization (Government of Indonesia, 2021). Spatial planning serves as a critical regulatory framework designed to harmonize economic development with environmental sustainability through the establishment of Spatial Pattern Plans (Wahanisa & Adiyatma, 2021). However, within the constellation of agricultural regions, a significant challenge arises from the massive expansion of plantations, which frequently occurs sporadically and disregards official zoning boundaries (Linda et al., 2022). Previous studies have applied GIS overlay to assess the relationship between land use and spatial plans, demonstrating the usefulness of this approach for locating spatial inconsistencies (Luthfina et al., 2019; Sodikin et al., 2022; Kurniawati & Purwantara, 2025). These studies establish a methodological basis for the present analysis. The contribution of this study is its village-level quantification of existing plantation areas relative to the 2023–2043 spatial pattern plan in Babulu District. The analysis does not independently determine the legality of individual land holdings or the causes of the observed patterns. A study by (Toyibulah & Khairunnisa, 2025) found that soil chemical properties varied according to plantation age, with older plantations exhibiting lower soil pH and base saturation levels. These findings emphasize that spatial planning policies should not only regulate the location of plantation expansion but also consider the long-term environmental implications of plantation development on soil resources

GIS overlay is commonly used to compare mapped land use with planning allocations. Remote-sensing interpretation can support land-use mapping, but its reliability depends on image characteristics, interpretation rules, reference data, and validation design. (Olofsson et al., 2014). To evaluate the degree of regulatory compliance, the utilization of Geographic Information Systems (GIS) and remote sensing through overlay techniques is highly crucial for mapping conforming (conformity) and non-conforming (inconformity) areas (Luthfina et al., 2019; Yunita et al., 2022) recommend documenting the sampling and reference procedures and reporting accuracy estimates with appropriate caution. In this study, the overlay results are interpreted as spatial conformity classes, while the limited field-check sample is reported as a preliminary validation result.

RESEARCH METHODS

This research was conducted from December 2025 to April 2026 in Babulu District, Penajam Paser Utara Regency, with data processing at the GIS Laboratory, Faculty of Agriculture, Universitas Mulawarman. A quantitative descriptive spatial approach was applied using ArcGIS Desktop. Data consisted of Sentinel-2A imagery from 2025, high-resolution Google Satellite Imagery from 2026, the official 1:50,000 spatial pattern plan map for the Penajam Paser Utara Regency RTRW 2023–2043 obtained from BAPELITBANG, and administrative/topographic data from the Geospatial Information Agency (BIG). The manuscript source materials do not specify the exact image acquisition dates, coordinate reference system, or a formal minimum mapping unit; these details should be added if the original GIS project metadata are available.

Sentinel-2A imagery was visually interpreted using a false-colour RGB 8-4-3 composite, and plantation boundaries were digitized on screen with reference to the 2026 high-resolution Google Satellite imagery. The resulting vector layer represented existing plantation land use in 2026. The plantation polygons were compared with the official spatial-plan layer using the Identity overlay function in ArcGIS. Polygons falling within the mapped plantation allocation were classified as conforming; polygons intersecting other spatial-plan allocations were classified as non-conforming. Sentinel-2 bands used in this composite include 10 m spatial-resolution bands, although the final delineation also depended on visual interpretation and the supporting high-resolution imagery (European Space Agency, 2015).

Field verification was conducted at 12 purposively selected plantation observation points, one in each village, using GPS coordinates to compare image interpretation with observed land cover. Eleven points were recorded as matching plantation land use and one point in Labangka was identified as a residential/administrative area with some remaining trees. The point agreement was calculated as $11/12 \times 100 = 91.67\%$. Because the sample was small and purposively selected, this value is not treated as a statistically representative estimate of overall map accuracy. A more robust accuracy assessment would require a documented probability-based sampling design and a reference error matrix (Olofsson et al., 2014). The study identifies possible economic or institutional explanations only as hypotheses for follow-up research; it did not use household surveys, interviews, or agency-level data to test those explanations.

RESULTS AND DISCUSSION

1. Planned Spatial Allocations vs. Actual Existing Plantations

The spatial plan allocates 26,469.11 ha to plantation areas across Babulu District. These allocations are concentrated in several villages, particularly Labangka and Babulu Darat (Table 1). This figure describes the planned plantation allocation and should not be interpreted as a measured expansion target or evidence that all allocated land is suitable for plantation cultivation.

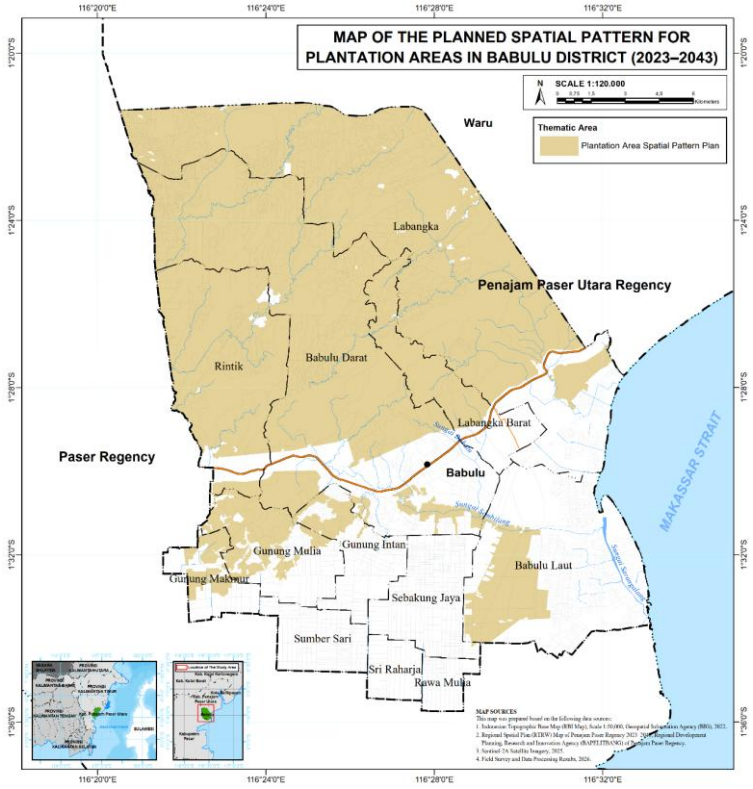


Figure 1. Plantation allocation in the 2023–2043 Spatial Pattern Plan (RTRW). Source: BAPELITBANG, Penajam Paser Utara Regency.

The 2026 mapping delineated approximately 15,912.23 ha of existing plantation land. Comparing this footprint with the spatial plan shows that the total existing area is smaller than the total plantation allocation, but this district-wide comparison alone does not demonstrate conformity. Conformity depends on whether each existing plantation polygon falls within the mapped plantation zone. Table 1 therefore compares planned and existing areas by village, while Table 2 reports the overlay-based conformity classification.

Table 1. Matrix of Planned Plantation Zones vs. Actual Existing Plantation Areas per Village (2026)

No	Village Name	Planned Plantation Area (ha)	Existing Plantation Area (ha)	Variance / Land Reserve (ha)
1	Babulu Darat	8,294.72	5,109.33	3,185.39
2	Babulu Laut	1,149.48	637.63	511.85
3	Gunung Intan	279.37	591.68	-312.31
4	Gunung Makmur	354.87	227.10	127.77
5	Gunung Mulia	927.33	774.51	152.82
6	Labangka	10,291.77	5,564.29	4,727.48
7	Labangka Barat	1,273.86	499.65	774.21
8	Rawa Mulia	0.00	46.87	-46.87
9	Rintik	3,894.08	1,908.54	1,985.54
10	Sebakung Jaya	3.63	252.83	-249.20
11	Sri Raharja	0.00	84.81	-84.81
12	Sumber Sari	0.00	215.00	-215.00
	Total	**26,469.11**	**15,912.24**	**10,556.87**

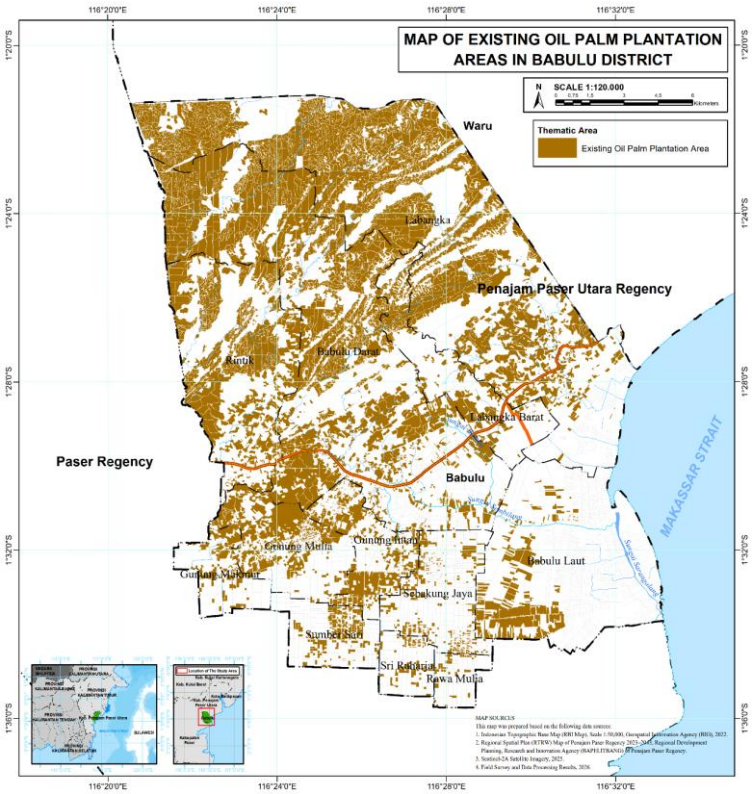


Figure 2. Distribution of existing plantation areas mapped for 2026. Source: analysis of Sentinel-2A and Google Satellite imagery.

The village-level comparison identifies several locations where the mapped existing plantation area exceeds the plantation allocation. The plan allocates 0 ha to Rawa Mulia, Sri Raharja, and Sumber Sari, while existing plantation areas were mapped at 46.87 ha, 84.81 ha, and 215.00 ha, respectively. Sebakung Jaya has a planned plantation allocation of 3.63 ha and an existing mapped area of approximately 252.83 ha. These comparisons indicate spatial inconsistencies that merit verification against authoritative planning and land-use records; they do not, on their own, establish the legal status of each parcel.

2. Quantitative Spatial Analysis of Plantation Conformity

The Identity overlay classified existing plantation polygons according to whether they intersected the plantation allocation in the spatial pattern plan. The resulting areas and percentages are summarized in Table 2. In this manuscript, "non-conforming" refers to mapped plantation areas located outside the designated plantation zone; it is a spatial classification, not a determination of a legal offence.

Table 2. Analysis of Spatial Conformity and Non-Conformity Rates of Existing Plantations Against Spatial Pattern Plans

No	Village Name	Existing Plantation (ha)	Conforming Area (ha)	Non-Conforming Area (ha)	Conformity Rate (%)	Non-Conformity Rate (%)
1	Babulu Darat	5,109.33	4,655.62	453.71	91.12	8.88
2	Babulu Laut	637.63	444.99	192.63	69.79	30.21
3	Gunung Intan	591.68	208.98	382.69	35.32	64.68
4	Gunung Makmur	227.10	186.79	40.31	82.25	17.75
5	Gunung Mulia	774.51	648.31	126.21	83.70	16.30
6	Labangka	5,564.29	5,339.74	224.55	95.96	4.04
7	Labangka Barat	499.65	421.83	77.82	84.43	15.57
8	Rawa Mulia	46.87	0.00	46.87	0.00	100.00
9	Rintik	1,908.54	1,844.84	63.70	96.66	3.34
10	Sebakung Jaya	252.83	0.95	251.88	0.37	99.63
11	Sri Raharja	84.81	0.00	84.81	0.00	100.00
12	Sumber Sari	215.00	0.00	215.00	0.00	100.00
	Total	**15,912.24**	**13,752.05**	**2,160.18**	**86.42**	**13.58**

The overlay indicates that 13,752.05 ha (86.42%) of the mapped plantation area falls within the designated plantation zone. Rintik has the highest village-level conformity rate (96.66%), followed by Labangka (95.96%). These results are consistent with the purpose of GIS-based conformity assessments reported in previous studies, which use overlay to identify where existing land use differs from planned allocations (Luthfina et al., 2019; Sodikin et al., 2022; Kurniawati & Purwantara, 2025).

The mapped non-conforming area is 2,160.18 ha, equivalent to 13.58% of the total. The largest non-conforming proportions occur in Rawa Mulia, Sri Raharja, and Sumber Sari (100% of their mapped plantation areas), followed by Sebakung Jaya (99.63%) and Gunung Intan (64.68%). These results identify priority locations for ground verification and coordination between land-use mapping and spatial-planning authorities. Whether these differences reflect unauthorized use, changes after the plan was prepared, or discrepancies between datasets requires additional documentary and field investigation.

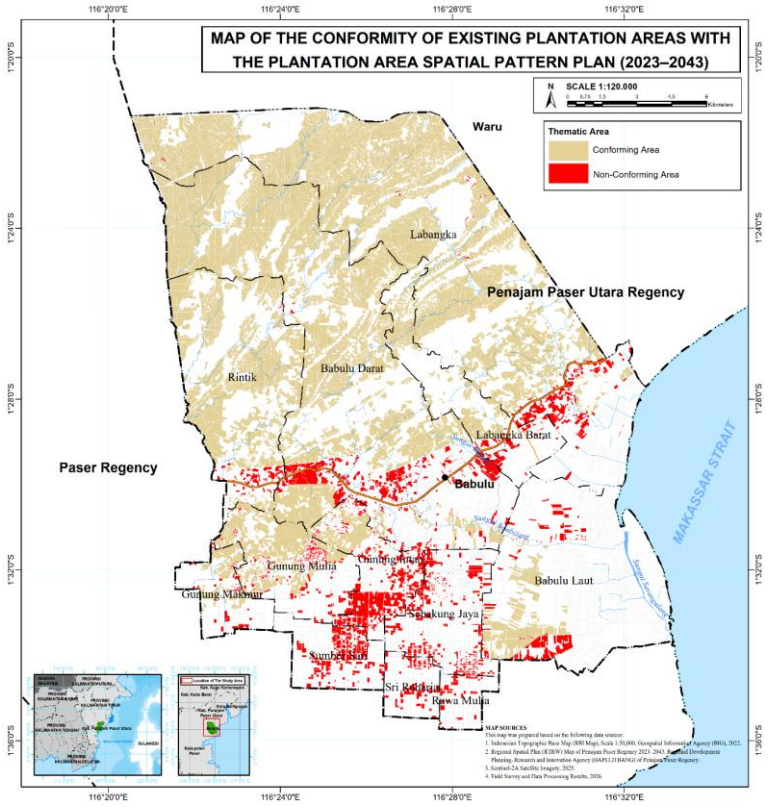


Figure 3. Spatial conformity of existing plantations with the plantation allocation.

Source: overlay analysis in ArcGIS.

The spatial overlay shows that plantation areas in Rawa Mulia (46.87 ha), Sri Raharja (84.81 ha), and Sumber Sari (215.00 ha) fall entirely outside the designated

plantation zones because no plantation allocation is mapped for these villages. In Sebakung Jaya, 251.88 ha of the 252.83 ha mapped plantation area is classified as non-conforming, while Gunung Intan has 382.69 ha of non-conforming plantation area. These findings describe spatial relationships between the mapped land use and plan; they should not be interpreted as proof of illegal activity or as evidence that plantation development has caused specific environmental impacts. Further checks against current official maps and land-use records are needed before administrative action is considered.

3. Field Verification and Map Accuracy Assessment

Field verification was undertaken at 12 purposively selected points, distributed across the 12 villages. Eleven points were confirmed as plantation land use, while one point in Labangka, initially interpreted as plantation from the imagery, was observed as a residential and administrative cluster with some remaining trees. This mismatch illustrates a limitation of visual interpretation: tree cover near buildings can resemble plantation cover in satellite imagery.

The observed point agreement was 11 of 12 points, or 91.67%. This result is reported only for the selected validation points. Because the sample comprised 12 purposively selected locations and was not designed as a probability sample, the percentage should not be generalized as the accuracy of every mapped plantation polygon. Recommended practice for remote-sensing accuracy assessment includes a clear sampling design, reference classification protocol, and error-matrix reporting (Olofsson et al., 2014).

$$\text{Accuracy} = \left(\frac{11}{12}\right) \times 100\% = 91.67\%$$

The point-based check supports the broad plausibility of the interpretation at the sampled locations, but it is insufficient to establish map-wide accuracy. Future validation should use a larger, spatially distributed reference sample and report an error matrix, including class-specific accuracy measures where data permit.

4. Economic Dynamics and Cross-Sectoral Drivers of Spatial Conflict

The mapped non-conformity should be interpreted as a spatial pattern requiring further investigation, not as a demonstrated causal outcome. The present study did not

collect household economic data or conduct interviews with government agencies. Accordingly, economic incentives, inter-agency coordination, and enforcement practices are possible explanations raised for future investigation rather than empirically established causes in this study.

- Economic considerations may influence land-use decisions, but this study did not compare plantation and food-crop income or survey landholders. The relative profitability of commodities should therefore be tested using farm-level data before it is identified as a cause of the spatial patterns observed.
- Coordination among agencies responsible for spatial planning, agriculture, and land administration may be relevant when addressing mapped inconsistencies. However, inter-agency coordination was not measured in this study. A follow-up assessment could compare the spatial-plan layer with licensing records and conduct interviews with the relevant agencies.
- Government Regulation No. 21 of 2021 provides for the control and monitoring of spatial utilization, including incentives, disincentives, and sanctions (Government of Indonesia, 2021). The present overlay analysis does not establish whether sanctions have been applied or whether a particular plantation is in violation of applicable requirements. Any enforcement decision should be based on verification against authoritative spatial plans, land/permit records, and the relevant administrative process.

CONCLUSION

This study provides a village-level spatial assessment of existing plantation land use in Babulu District against the 2023–2043 spatial pattern plan. The overlay classified 13,752.05 ha (86.42%) of mapped plantations as conforming and 2,160.18 ha (13.58%) as non-conforming. The largest non-conforming areas were found in Sumber Sari (215.00 ha), Sri Raharja (84.81 ha), and Rawa Mulia (46.87 ha), where no plantation allocation is mapped. These results provide a basis for prioritizing field and document verification, but spatial inconsistency should not be equated automatically with a legally confirmed violation. The main limitations are the single-period assessment, the small purposive validation sample of 12 points, and the absence of direct evidence on economic or institutional causes. Future work should use a larger probability-based validation sample,

document image and coordinate metadata, and verify the overlay results against current official planning and land-use records.

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