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Spatial Evaluation of Existing Agricultural Land-Use Conformity Against Spatial Pattern Planning to Mitigate Land Conversion in Babulu District

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Abstract. *Spatial utilization constitutes a critical dimension of regional development, frequently characterized by discrepancies between planned spatial structures and their empirical realization on the ground. This study aims to evaluate the degree of conformity between the 2023–2043 spatial pattern plan and the existing agricultural land use in Babulu District, Penajam Paser Utara Regency. The methodological framework employs a Geographic Information System (GIS)-based spatial analysis approach through overlay techniques integrating spatial pattern planning maps with agricultural land use data derived from satellite imagery interpretation, particularly Sentinel-2A imagery. The research procedures encompass data processing, on-screen digitization, overlay analysis, and field verification to assess the accuracy level of land use interpretation results. The findings indicate that the total area of existing agricultural land use covers 8,235.54 hectares, of which 7,898.61 hectares are classified as conforming areas, while 336.94 hectares are non-conforming. Sebakung Jaya Village exhibits the largest extent of conforming agricultural land, reaching 1,422.42 hectares (99.96%), whereas the highest degree of agricultural land-use inconsistency occurs in Gunung Makmur Village (197.97 hectares or 34.33% of its existing area). The accuracy assessment based on Groundcheck verification yielded an accuracy value of 83.3% for the agricultural class based on 12 observation points. Several factors contributing to spatial non-conformity include expansion of built-up areas driven by population growth, lack of synchronization with the latest village development, and weak zoning regulation enforcement. The study concludes that while agricultural space protection in Babulu District is relatively strong, local inconsistencies require immediate integration into the upcoming detailed spatial plan (RDTR) to support food security in the new national capital (IKN) buffer zone.*

Keyword: *Babulu, Food security, GIS, Land use, Spatial pattern plan*

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INTRODUCTION

Spatial planning serves as a critical regulatory blueprint to harmonize economic growth, environmental ecosystems, and national food sovereignty through legally codified Spatial Pattern Plans within the Regional Spatial Plan (RTRW). Aligning spatial planning documents with the pace of physical development on the ground is essential for minimizing environmental degradation in agrarian regions (Wiwoho et al., 2024). In alignment with Law Number 26 of 2007, these planning frameworks are legally mandated to safeguard environmental carrying capacity and protect specific zones like Sustainable Food Agricultural Land (LP2B). However, rapid population growth and massive infrastructure acceleration consistently drive complex spatial dynamics, creating intense competition between ideal land-use planning and empirical field utilization.

Following the establishment of the New National Capital, Ibu Kota Nusantara (IKN), East Kalimantan is undergoing a profound geopolitical and spatial transformation. Within this framework, Babulu District in Penajam Paser Utara (PPU) Regency occupies a highly strategic position, officially designated as the primary agricultural food buffer zone (*lumbung pangan*) tasked with securing food logistics for the IKN. Buffer zones surrounding emerging growth centers are generally highly susceptible to land speculation, which often accelerates the fragmentation of productive agricultural land (Mulya et al., 2024). Despite its vital role in supplying regional wetland agriculture, the economic pull of the IKN megaproject has triggered immense land conversion pressures, where population migration and commercial development pose immediate threats to these productive agricultural fields.

In practice, substantial spatial non-conformities frequently emerge between paper-based RTRW documents and actual land-use realities due to weak zoning enforcement, outdated macro-level spatial data, and pragmatic socio-economic drivers. To address this evaluative gap, this study integrates Remote Sensing and Geographic Information System (GIS) technologies to execute precise spatial overlay analysis. The primary objective is to quantitatively assess the spatial conformity of existing functional agricultural land in 2026 across the 12 villages of Babulu District against the PPU Regency Spatial Pattern Plan (2023–2043), ultimately providing empirical policy recommendations for upcoming Detailed Spatial Plans (RDTR) and more stringent land conversion controls.

LITERATURE REVIEW

Spatial planning functions as a fundamental legal instrument designed to balance regional economic acceleration, environmental sustainability, and regional food security through the institutionalization of Spatial Pattern Plans within the Regional Spatial Plan (RTRW) (Wahanisa

& Adiyatma, 2021). Under the mandate of Law Number 26 of 2007 concerning Spatial Planning, these spatial frameworks are legally bound to safeguard environmental carrying capacities and strictly preserve productive zones, particularly Sustainable Food Agricultural Land (LP2B) (Anita et al., 2022). The protection of Sustainable Food Agricultural Land (LP2B) zoning requires strong political commitment and robust legal instruments to prevent it from being undermined by short-term commercial interests (Emha et al., 2024). However, in agrarian regions undergoing intense development pressures, a recurring conflict arises between macro-level planning ideals and community-driven land utilization. In these dynamic landscapes, agricultural zones face severe encroachment, primarily fueled by rapid urban expansion, population influxes, and pragmatic local economic drivers that catalyze unauthorized land-use conversions. (Toyibulah & Fahrunsyah, 2024) emphasized that land-use decisions should be aligned with land capability characteristics and spatial planning objectives to support sustainable agricultural land management and minimize land-use conflicts.

To systematically detect and monitor these spatial deviations, the integration of Geographic Information Systems (GIS) and remote sensing technologies offers an empirical, precise, and highly efficient evaluation methodology (Simatupang et al., 2020). Studies on spatial conformity have shown that GIS-based evaluation provides valuable information for monitoring the consistency of existing land use with spatial planning objectives and for improving land-use governance (Kurniawati & Purwantara, 2025). Utilizing multi-temporal satellite imagery, such as Sentinel-2A and high-resolution Google Satellite data, allows researchers to accurately delineate functional, real-time land-use polygons via on-screen digitization. The availability of dedicated vegetation-sensitive spectral bands in Sentinel-2A imagery provides a significant advantage for accurately distinguishing the growth stages of food crops (Maolan et al., 2024). By deploying identity overlay techniques within a spatial modeling framework, the actual land-use layers can be directly cross-examined with official zoning maps (Luthfina et al., 2019). This process mathematically categorizes spatial configurations into binary conditions: conforming (*conformity*), where physical land-use aligns with local zoning policies, and non-conforming (*inconformity*), which signifies critical spatial friction and a breach of regulatory boundaries.

In the context of Babulu District—a region strategically designated as the vital food-security buffer zone (*lumbung pangan*) for the New National Capital, Ibu Kota Nusantara (IKN)—evaluating this spatial conformity is highly imperative (Wicaksono et al., 2024). This study successfully mapped a total of 8,235.54 hectares of existing functional agricultural land, establishing that while 7,898.61 hectares adhere to the designated agricultural zones, approximately 336.94 hectares exhibit spatial non-conformity against the 2023–2043 Spatial Pattern Plan of Penajam Paser Utara Regency. While agricultural protection remains exceptionally stable in areas like Sebakung Jaya Village with a 99.96% conformity rate, critical deviances peak in Gunung Makmur Village, where 34.33% of productive agricultural land has shifted toward residential and alternative developmental zones (Desrihastuti et al., 2024). These micro-level inconsistencies highlight an urgent need for local authorities to accelerate the enforcement of Detailed Spatial Plans (RDTR) to effectively mitigate further land conversion.

RESEARCH METHODS

This study was conducted from December 2025 to April 2026 across the 12 administrative villages of Babulu District, Penajam Paser Utara (PPU) Regency, with data processing executed at the GIS Laboratory, Faculty of Agriculture, Universitas Mulawarman. The technical equipment comprised high-specification laptops running ArcGIS Desktop with the Spatial Analyst extension and Google Earth Pro. The integrated geodatabase contained primary and secondary spatial datasets: cloud-free 2025 Sentinel-2A imagery, high-resolution 2026 Google Satellite imagery, the official vector shapefile of the PPU Regency Spatial Pattern Plan Map 2023–2043 (1:50.000 scale) from BAPELITBANG, and the Topographic Map of Indonesia (Peta RBI) from the Geospatial Information Agency (BIG).

The data processing workflow proceeded through image pre-processing (radiometric correction and subset clipping) followed by detailed on-screen digitization. Active food crops, including irrigated/rainfed paddy fields and seasonal horticulture, were delineated based on spectral signatures and high-resolution textures to generate the *Existing Agricultural Land 2026* layer. A spatial intersection was subsequently executed using the *Identity* method in ArcGIS, overlaying the 2026 existing land-use layer onto the official PPU Regency RTRW 2023–2043 identity layer. This segmented each existing agricultural polygon by its corresponding planning zone attribute.

Based on the identity overlay attribute table, the land was mathematically classified into two spatial conformity states: Conforming (*Conformity*), if the existing agricultural land fell within the officially designated agricultural zones, and Non-Conforming (*Inconformity*), if it intersected planned alternative zones such as settlement, industrial, plantation, or forest reserves. To validate the interpretation model, groundchecking was executed via purposive sampling across 12 representative observation stations (one per village) using a handheld GPS and the GPS Map Camera application. The empirical field data was ultimately structured into a confusion matrix to evaluate overall mapping accuracy using the following equation:

$$Accuracy = \left(\frac{\sum \text{Correctly Verified Points}}{\text{Total Sample Observation Points}}\right) \times 100\%$$

The confusion matrix is widely used to quantify classification errors, including omission and commission errors, thereby ensuring the reliability of the resulting thematic maps (Cardille et al., 2023).

RESULTS AND DISCUSSION

1. Overview of Babulu's Agricultural Spatial Planning

According to the official Regional Regulation on the Spatial Plan (RTRW) of Penajam Paser Utara Regency 2023–2043, Babulu District holds the largest spatial allocation for food crop commodities at the regency level. The total area reserved and designated as an agricultural zone in Babulu District reaches 16,671.81 hectares. This expansive zoning underscores the local government's spatial policy commitment to anchoring Babulu as a regional grain lumbung.

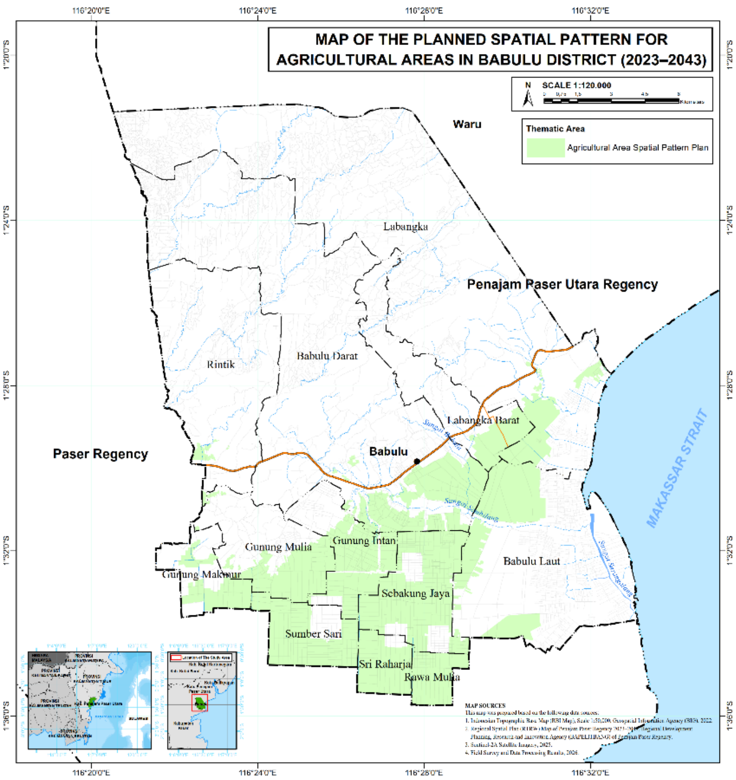

Figure 1. Official Agricultural Spatial Pattern Allocation under the 2023–2043 Regional Spatial Plan (RTRW)

However, this plan on paper frequently diverges from physical growth patterns on the ground. Based on the 2026 satellite imagery analysis, the total area of functional and actively cultivated agricultural land is logged at 8,235.55 hectares. This variance of over 8,000 hectares reveals that a significant portion of the planned agricultural zones still consists of alternative land covers, such as shrublands, secondary forests, open clearings, or smallholder plantation estates. The village-level breakdown comparing planned zones against existing realities is detailed in Table 1.

Table 1. Distribution of Planned Spatial Zones and Existing Agricultural Land per Village in Babulu District (2026)

No	Village Name	Planned Agricultural Area (ha)	Existing Agricultural Area (ha)	Variance (ha)
1	Babulu Darat	1,139.75	1,119.29	20.46
2	Babulu Laut	1,130.73	931.77	198.96
3	Gunung Intan	8,828.40	826.60	8,001.80
4	Gunung Makmur	405.13	576.67	-171.54
5	Gunung Mulia	755.68	716.91	38.77
6	Labangka	496.73	405.30	91.43
7	Labangka Barat	363.50	352.63	10.87
8	Rawa Mulia	478.35	452.45	25.90
9	Rintik	61.30	55.70	5.60
10	Sebakung Jaya	1,498.52	1,422.96	75.56
11	Sri Raharja	585.22	509.60	75.62
12	Sumber Sari	927.50	865.67	61.83
	Total	16,671.81	8,235.55	8,436.26

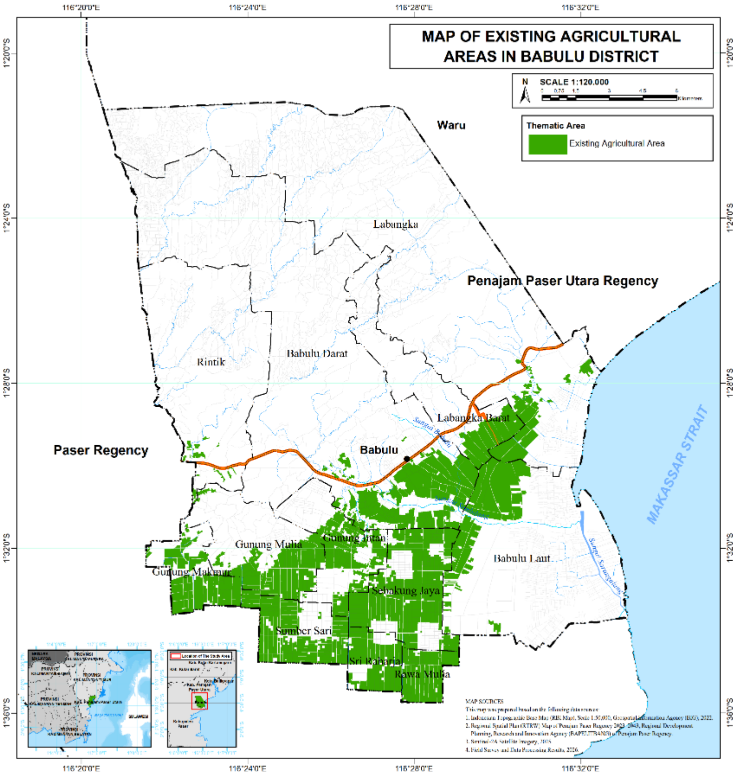

Figure 2. Spatial Distribution of Existing Agricultural Land-Use in 2026

Deep analysis of Table 1 and Figure 2 confirms a sharp spatial anomaly in Gunung Intan Village. The village is designated to have 8,828.40 hectares of agricultural space (nearly 53% of the district's total plan), yet functional agricultural land identified on the ground stands at only 826.60 hectares. This indicates that macro-level planning (*top-down planning*) under-evaluated the physical readiness of the land or local community preferences, which empirically lean toward perennial plantation commodities. The mismatch between planned spatial allocation and actual land use at the site level is often attributable to the limited incorporation of local community aspirations during the formulation of spatial plans (RTRW) (Runiawan et al., 2024). Conversely, Gunung Makmur Village exhibits a "spatial deficit," where the existing agricultural footprint (576.67 ha) surpasses its allocated plan (405.13 ha), indicating that food crop cultivation has encroached into zones slated for non-agricultural development.

2. Quantitative Analysis of Agricultural Spatial Conformity

Through the identity overlay operation intersecting existing agricultural land-use maps with the spatial pattern plans, an objective depiction of spatial compliance was derived. Aggregating these datasets partitions existing land uses into two main states:

conforming (*conformity*) and non-conforming (*inconformity*). The comprehensive calculations are presented in Table 2.

Table 2. Spatial Conformity Analysis Matrix of Existing Agricultural Land Against Spatial Pattern Plans per Village

No	Village Name	Existing Agri Area (ha)	Conforming Area (ha)	Non-Conforming Area (ha)	Conformity Rate (%)	Non-Conformity Rate (%)
1	Babulu Darat	1,119.29	1,068.20	51.09	95.44	4.56
2	Babulu Laut	931.77	929.35	2.42	99.74	0.26
3	Gunung Intan	826.60	789.39	37.21	95.50	4.50
4	Gunung Makmur	576.67	378.70	197.97	65.67	34.33
5	Gunung Mulia	716.91	713.12	3.79	99.47	0.53
6	Labangka	405.30	391.47	13.83	96.59	3.41
7	Labangka Barat	352.63	351.60	1.03	99.71	0.29
8	Rawa Mulia	452.45	450.92	1.52	99.66	0.34
9	Rintik	55.70	37.74	17.96	67.76	32.24
10	Sebakung Jaya	1,422.96	1,422.42	0.54	99.96	0.04
11	Sri Raharja	509.60	507.33	2.27	99.56	0.44
12	Sumber Sari	865.67	858.36	7.31	99.16	0.84
	Total	8,235.55	7,898.61	336.94	95.91	4.09

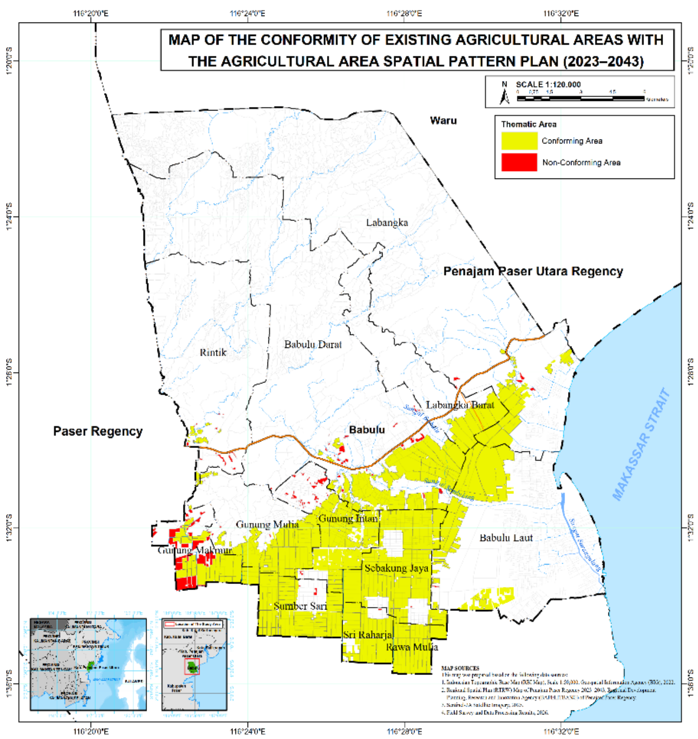

Figure 3. Spatial Conformity and Inconformity Evaluation of Existing Agricultural Land

The results in Table 2 demonstrate that the vast majority of existing agricultural land-use practices in Babulu District align closely with regional spatial policy guidelines. Out of 8,235.55 total hectares of existing agricultural land, areas positioned within appropriate planning zones (*conformity*) reach 7,898.61 hectares, or 95.91%. This proves that the core agricultural corridors in Babulu possess a robust spatial foundation and have not suffered massive conversion. The total non-conformity (*inconformity*) was successfully constrained to a relatively low level of 336.94 hectares (4.09%).

Evaluations at the village level position Sebakung Jaya Village as the region with the most successful agricultural spatial management. The conformity rate of existing agricultural land here approaches near-perfection at 99.96% (1,422.42 ha conforming, with only 0.54 ha non-conforming). Historically and sociologically, this high compliance rate is driven by Sebakung Jaya’s status as a legacy transmigrant zone, whose foundational layout was rigidly engineered for wetland agricultural activities. The presence of mature secondary and tertiary irrigation infrastructure, coupled with strong institutional awareness among local farmers' associations, acts as a decisive mechanism "locking in" land function against conversion pressures. Similar conformity rates exceeding 99% are mirrored in other key buffer villages such as Babulu Laut (99.74%), Labangka Barat (99.71%), Rawa Mulia (99.66%), Sri Raharja (99.56%), and Sumber Sari (99.16%).

Conversely, spatial warning signs are apparent in two villages exhibiting significant deviations: Gunung Makmur and Rintik. In Gunung Makmur Village, the non-conformity rate of existing agricultural land reaches 34.33% (197.97 ha of its 576.67 ha footprint is non-conforming). Cartographically, these agricultural polygons intersect with planned *Residential Zones* and *Commercial/Service Areas* within the PPU Regency RTRW. This situation is stimulated by Gunung Makmur's proximity to the district's economic center and main transit roads. Consequently, spatial plans project this area as a future hub for urban expansion, creating a structural conflict with functional agricultural lands currently managed by local farmers. Meanwhile, in Rintik Village, spatial non-conformity is recorded at 32,24% (17,96 ha), where active smallholder farming overlaps with areas legally designated as minimal production forests or large-scale commercial plantation zones. The results suggest that spatial planning conformity is a critical indicator of sustainable regional development.

3. Field Verification (Groundcheck) Results

To validate the reliability of the spatial models derived from satellite imagery interpretation, field tracking was conducted across 12 representative coordinate stations distributed across the villages. The field verifications yielded a satisfactory accuracy rate while identifying valuable deviations for review.

Out of the 12 coordinates interpreted from satellite imagery as belonging to the "Food Crop Agriculture" class, groundchecking confirmed that 10 points were consistently configured as active, functional paddy fields across various stages (vegetative, generative, or temporarily fallow). However, 2 observation stations exhibited a classification mismatch against empirical ground reality.

The first interpretation error was encountered at an observation station in Gunung Intan Village (coordinates -1.503503° S, 116.428437° E). Initial Sentinel-2A image processing flagged this polygon with spectral reflectance signatures typical of exposed, pre-planting agricultural soils (*barren land*). Upon field inspection, however, the area had undergone permanent land clearing for a newly platted, self-funded residential subdivision. The second mismatch was recorded in Sumber Sari Village (coordinates -1.560758° S, 116.433392° E). This polygon, originally classified as dryland food crop agriculture, was verified as an association of dense wild shrubs and cogon grass (*abandoned land*). Interviews with local farmers' union representatives revealed that the plot had been abandoned for more than four consecutive planting cycles due to irrigation shortages and escalating production overheads. The abandonment of fields due to insufficient irrigation water supply often serves as a primary pathway leading to the permanent conversion of agricultural land to non-agricultural uses (Hidayat et al., 2023). Incorporating these empirical findings into the calculation, the spatial interpretation accuracy for the food crop agriculture class is derived as follows:

$$Accuracy = \left(\frac{10}{12}\right) \times 100\% = 83.3\%$$

This accuracy rating of 83.3% is scientifically acceptable and complies with cartographic standards, exceeding the minimum 80% accuracy threshold required for digital mapping applications.

4. Driving Factors of Spatial Non-Conformity

Although a non-conformity rate of 4.09% (336.94 ha) appears minor percentage-wise, it carries serious implications for the spatial trajectory of Babulu. Integrating spatial analyses, field observations, and policy reviews highlights three primary driving factors stimulating agricultural spatial non-conformity in Babulu District:

IKN Peripheral Urbanization Pressure: The designation of Penajam Paser Utara as the legal jurisdiction for the IKN buffer zone has driven up land rent values exponentially. Village corridors intersected by the Trans-Kalimantan highway, such as Gunung Makmur and Babulu Darat, are experiencing rapid spatial transformations. Real estate speculators and private investors are purchasing productive agricultural plots along transportation vectors to convert them into shop-houses, logistics warehouses, or residential compounds ahead of detailed local zoning ordinances. Major interprovincial road corridors frequently become focal areas for intensive physical agglomeration, leading to the encroachment upon agricultural greenbelt areas (Robinson et al., 2026).

Temporal Spatial Data Lag: The Spatial Pattern Plan Map within the PPU Regency RTRW was compiled at a macro-scale (1:50.000) with a five-year evaluative review cycle. This macro approach is limited in capturing micro-spatial dynamics at the village level. Consequently, a time lag occurs where land traditionally cultivated by the community as paddy fields is mapped into alternative zones due to spatial resolution constraints during regulation drafting.

Weak Spatial Control and Zoning Enforcement: Administrative oversight of spatial utilization at the sub-district level remains largely reactive. The operational rollout of incentive frameworks (such as property tax subsidies, seed distribution assistance, or price guarantees for farmers maintaining active fields) remains incomplete. Concurrently, a lack of disincentives or legal enforcement against unauthorized agricultural land conversion compromises the effectiveness of Sustainable Food Agricultural Land (LP2B) protections. The accelerated preparation of Detailed Spatial Plans (RDTR) integrated with an electronic permitting system has become a critical instrument for automatically screening land-use conversion applications (A. Wicaksono et al., 2026).

CONCLUSION

This spatial evaluation study indicates that the preservation of agricultural corridors in Babulu District, Penajam Paser Utara Regency, is well-regulated at a macro-scale. This is demonstrated by an overall spatial conformity rate of 95.91% (covering 7,898.61 hectares) between existing agricultural land use and the 2023–2043 Spatial Pattern Plan. Primary agricultural zones, led by Sebakung Jaya Village, achieved the highest spatial compliance rates (99.96%). Functional spatial non-conformities account for only 4.09% (336.94 ha), though conversion vulnerabilities are concentrated within the urbanizing corridors of Gunung Makmur Village (34.33%) and Rintik Village (32.24%). Field verification of the spatial model yielded a map reliability of 83.3%, confirming that the GIS and remote sensing framework deployed is both valid and representative.

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