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Paddy Field Loss and Zoning Non-Conformity in Gorontalo City, Indonesia: Comparing the 2019 and 2024 Standard Paddy Field Maps Against a Fixed Detailed Spatial Plan

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Abstract: This study assessed how the Standard Paddy Field Map (*Lahan Baku Sawah*, LBS) of Gorontalo City, Indonesia, changed between 2019 and 2024 relative to a fixed reference, the 2021 Detailed Spatial Plan (*Rencana Detail Tata Ruang*, RDTR). Both LBS editions were overlaid on RDTR zoning in a geographic information system using intersect and difference operations. Recorded LBS area fell from 1,135.16 ha to 760.65 ha, a net decrease of 374.51 ha (33.0%), or 74.9 ha per year, combining 378.53 ha removed and 4.02 ha added through boundary adjustment. LBS in non-agricultural zones decreased by 41.8%, compared with 1.8% in the zone designated for sustainable food agriculture. The non-conforming share therefore fell from 78.0% to 67.8% while the plan stayed the same. Medium-density residential zones contributed 40.7% of the net decrease. A total of 511.77 ha remained verified paddy in non-agricultural zones in both years, a persistent condition we term a non-conformity trap. The overlay measures spatial association and cannot identify causes of conversion. Recorded paddy loss concentrated in zones without agricultural protection, which supports assessing a partial RDTR revision and LBS screening in permit approval.

Keywords: Agricultural land protection; Detailed spatial plan; Land conversion; Paddy field; Zoning conformity

Introduction

The conversion of productive agricultural land driven by rapid urban expansion represents one of the most structurally consequential land-use challenges of the twenty-first century. Rice (*Oryza sativa* L.) remains the dominant staple food crop for more than half of the world's population, with its cultivation concentrated in the river deltas and lowland plains of Asia and Southeast Asia precisely the regions experiencing the most intense urbanization pressure (Kuenzer & Knauer, 2013). Globally, urbanization transforms approximately 1.2 million hectares of agricultural land annually, generating escalating risks of food scarcity that disproportionately affect developing nations (Ayejugbagbe et al., 2026). Projections by Bren d'Amour et al. (2017) demonstrate that future urban expansion between 2000 and 2030 is expected to encroach upon 1.8–2.4% of global cropland, with 84% of associated production losses concentrated in Africa and Asia regions where land for agricultural extensification is already severely constrained. This structural competition between urbanization and food production is further aggravated by the geographic reality that cities have historically been established in the most fertile lowland zones, meaning that urban growth inherently targets the world's most productive agricultural land (Bren d'Amour et al., 2017; Li et al., 2024). The multidimensional consequences of this process extend beyond food supply reduction to encompass ecosystem degradation, the erosion of agrarian livelihoods, and

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deepening socioeconomic vulnerability for smallholder farming communities (Li et al., 2024).

Indonesia exemplifies this global challenge with particular severity. Paddy fields supply approximately 95% of national rice production, making them the irreplaceable foundation of food sovereignty for a population exceeding 270 million (Gandharum et al., 2025; Firmansyah et al., 2021). Yet the national inventory of registered paddy land formally designated as *Lahan Baku Sawah* (LBS), or the Standard Paddy Field, representing the geospatially verified extent of active paddy cultivation has contracted persistently, declining from 8.4 million hectares in 1990 to 7.18 million hectares in 2022, equivalent to an annual net loss exceeding 38,000 hectares (Suciati & Kunu, 2026). This contraction is most acute in peri-urban transition zones, where the highest concentrations of irrigated paddy land coincide geographically with the highest rates of urban population growth, creating a direct spatial competition between rice agriculture and urban development (Mulya et al., 2026; Rizq & Manessa, 2025). The phenomenon mirrors the broader *desakota* dynamic documented across Java's peri-urban fringe, in which agricultural and urban land uses overlap in a chaotic mosaic of transition as land values rise and farming's social and economic centrality diminishes (Pribadi & Pauleit, 2015). This structural vulnerability has positioned Indonesia among the countries with the highest rates of paddy field conversion globally, compounding the urgency of implementing robust, data-driven protection mechanisms.

The application of remote sensing technology and Geographic Information Systems (GIS) has been firmly established as the most effective methodological approach for the temporally continuous, spatially precise monitoring of paddy field dynamics. Kuenzer et al. (2013) provided comprehensive evidence that satellite-based remote sensing enables accurate, scalable detection of paddy cultivation extent across geographically diverse contexts, significantly outperforming conventional ground-based inventories in terms of temporal resolution and spatial coverage. Integration of high-resolution satellite imagery with GIS-based spatial overlay analysis further allows the precise quantification of conformity between actual paddy field distribution and the zoning designations contained in spatial planning documents producing objective, reproducible evidence that is not achievable through periodic field surveys alone (Wijayanto et al., 2025; Nur et al., 2024). It is this methodological strength that underpins the construction of Indonesia's National LBS Map by the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN) through Presidential Regulation (*Peraturan Presiden*/Perpres) No. 59 of 2019, and that constitutes the analytical foundation of the present study in evaluating LBS spatial conformity against the RDTR of Gorontalo City.

The scientific literature on paddy field spatial conformity with planning documents in Indonesia has expanded considerably over the past decade. Studies applying GIS overlay methods have consistently documented systematic mismatches between the spatial distribution of actual paddy fields and their classification within regional land-use zoning schemes, with conformity gaps ranging from moderate to severe depending on the level of integration between LBS data and planning documents (Harpudiansyah & Apriyanti, 2025; Khairullah et al., 2025; Ekafitrawan et al., 2020). The legal and institutional dimensions of this problem have received increasing scholarly attention following the enactment of Government Regulation (*Peraturan Pemerintah*/PP) No. 21 of 2021, which integrated the Detailed Spatial Plan (*Rencana Detail Tata Ruang*/RDTR) into the Online Single Submission (OSS) licensing mechanism, establishing the RDTR as the automatic reference document for the issuance of Space Utilization Activity Conformity permits (*Kesesuaian Kegiatan Pemanfaatan Ruang*/KKPR). Research has demonstrated that under this framework, productive paddy fields classified under non-agricultural zones in the RDTR can receive legal conversion permits automatically, without additional agricultural land evaluation effectively rendering the LBS–RDTR spatial relationship a direct determinant of paddy field legal vulnerability (Harpudiansyah & Apriyanti, 2025; Irawan & Wibisono, 2025). Evidence for Gorontalo comes from Gorontalo Regency, where Ekafitrawan et al. (2020) documented paddy field conversion and its inconsistency with the spatial plan, and from North Gorontalo Regency, where Djafar et al. (2026) mapped land cover change and urban growth. These studies cover other jurisdictions and use data and definitions of paddy land that differ from the official LBS inventory analysed here, so their figures are not comparable with the city-level LBS change reported in this paper.

Existing conformity studies in Indonesia share a common design: they overlay one paddy field dataset on one spatial plan and report the share of paddy land inside and outside agricultural zones. Ekafitrawan et al. (2020) combined land-use change with a plan suitability assessment in Gorontalo Regency; Harpudiansyah et al. (2025) evaluated LP2B against land use and the regional spatial plan of Boyolali Regency; Khairullah et al. (2025) quantified the inconsistency of protected rice fields with the spatial plan of Purworejo Regency; and Amri et al. (2025) examined rice field distribution against spatial planning in Aceh Province. These studies show how much paddy land is exposed to non-agricultural zoning at one moment, but a single snapshot cannot show whether that exposure is followed by loss. Holding the

planning reference fixed and observing two LBS editions makes a different question answerable: does LBS in non-agricultural zones disappear faster than LBS in agricultural zones? If it does, the non-conforming share also marks the locations where recorded paddy land is being lost. We refer to land that remains verified paddy yet stays in non-agricultural zones in both editions as being in a "non-conformity trap". The term describes a persistent zoning condition; this study does not test it as a causal mechanism. GIS overlay is a standard method, and the contribution of this study is empirical: it tracks the conformity status of LBS against a fixed plan and quantifies differential loss by conformity class in Gorontalo City. The objectives are: (1) to quantify gross and net LBS change between 2019 and 2024 and its spatial distribution; (2) to assess the conformity of LBS 2019 and LBS 2024 with the spatial zoning pattern (*pola ruang*) of the Gorontalo City RDTR (Mayor Regulation No. 44 of 2021); (3) to compare LBS loss between conforming and non-conforming zones and among RDTR zone types; and (4) to identify policy options for LP2B protection that follow from the spatial evidence.

The urgency of this research is amplified by a set of structural conditions that render formal regulatory alignment uniquely critical in the Gorontalo City context. Under the KKPR-OSS framework established by PP No. 21 of 2021, the RDTR functions as the automatic reference for conversion permit issuance; paddy fields located outside RDTR agricultural zones may therefore obtain conformity approval without the agricultural land screening intended under Law No. 41 of 2009 on the Protection of Sustainable Agricultural Food Land (LP2B) and Perpres No. 59 of 2019. Most recently, Presidential Regulation No. 4 of 2026 on the Control of Paddy Field Land Conversion designating approximately 6.39 million hectares of LBS as Protected Paddy Fields (*Lahan Sawah Dilindungi*/LSD) and LP2B has reinforced the national commitment to regulatory-based agricultural land protection, making the synchronization of LBS data with RDTR zoning a prerequisite for effective implementation of this policy. Generating spatially precise, temporally comparative evidence on the LBS–RDTR relationship in Gorontalo City is therefore not merely an academic exercise but an immediate empirical foundation for evidence-based spatial governance reform.

Method

Research Design

This study uses a quantitative spatial design that compares two editions of the official Standard Paddy Field Map (*Lahan Baku Sawah*/LBS), 2019 and 2024, against one fixed planning reference: the spatial zoning pattern of the Gorontalo City Detailed Spatial Plan (*Rencana Detail Tata Ruang*/RDTR; Mayor Regulation No. 44 of 2021). With the plan held constant, any difference in conformity between the two years reflects change in the LBS layer alone. The design yields a conformity assessment for each year and a transition matrix that links each unit of 2019 LBS to its 2024 status, so that loss can be compared between agricultural and non-agricultural zones (Khairullah et al., 2025; Irawan & Wibisono, 2025).

Because the RDTR was enacted in 2021, the assessment of LBS 2019 is a retrospective evaluation against the plan now in force. It does not establish that LBS 2019 was non-compliant with the planning rules applicable in 2019, which were set by the Gorontalo City Spatial Plan (RTRW) 2019–2039 (Regional Regulation No. 9 of 2019; Gorontalo City Government, 2019), a city-wide plan prepared at a coarser scale than the RDTR. The 2021 RDTR is used for both years because it is the document that now governs space utilization conformity decisions (KKPR) for the land that remains. The 2019 result therefore shows how the paddy land that existed in 2019 sits under the current plan. It cannot show whether earlier decisions breached earlier rules.

Study Area

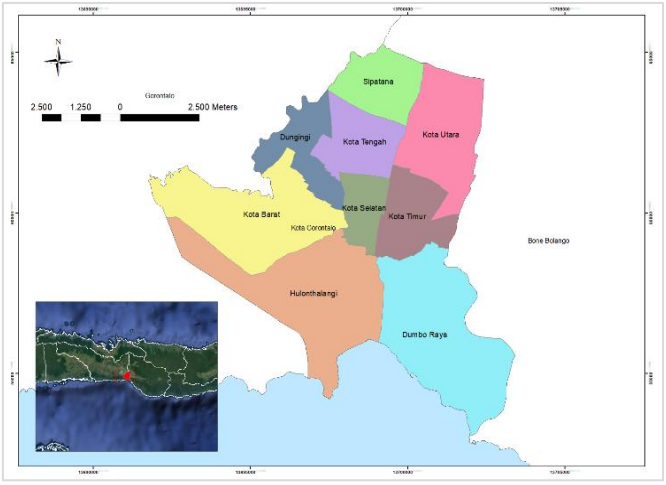


Figure 1. Research location map of Gorontalo City

The study was conducted in Gorontalo City, the provincial capital of Gorontalo Province, located at coordinates 0°28'17"–0°35'56" N; 122°59'44"–123°05'59" E, covering a total administrative area of 79.03 km² across 9 sub-districts and 50 urban villages. The city occupies a strategic position as the administrative, commercial, and service center of Gorontalo Province and has experienced rapid urban growth during the past two decades, driven by expansion of residential, commercial, and infrastructural land uses into formerly agricultural areas (Djafar et al., 2026). The selection of Gorontalo City as the study area was based on two criteria: (1) the

availability of two officially verified LBS datasets for different periods (2019 and 2024) from the ATR/BPN Gorontalo City Office; (2) the existence of a legally operative RDTR document (Mayor Regulation No. 44 of 2021) providing the reference spatial zoning plan.

Data Sources and Materials

This study relies exclusively on official secondary spatial datasets obtained through formal requests submitted to the relevant government agencies. All spatial data were received in shapefile format (.shp), the standard vector data format for GIS analysis (QGIS Development Team, 2024). Four primary datasets were used, as summarized in Table 1.

The LBS 2019 dataset was compiled by the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN) under ATR/BPN Ministerial Decree No. 686/SK-PG.03.03/XII/2019, establishing the National LBS Map as the mandatory geospatial reference for paddy field governance under Presidential Regulation No. 59 of 2019. The LBS 2024 dataset represents the most recent field verification update conducted by the ATR/BPN Gorontalo City Office using the multi-source verification methodology mandated by ATR/BPN Ministerial Regulation No. 2 of 2024, which integrates high-resolution satellite imagery, ground-truth field surveys, and participatory mapping. The two editions were produced under different procedures, and the 2024 verification rules were issued after the 2019 map was compiled. Their comparability therefore cannot be assumed (Gandharum et al., 2025): Table 2 summarizes the characteristics of each edition, and the treatment of geometric differences between them is described under Step 3 below. The RDTR spatial zoning map (pola ruang) was obtained from the Gorontalo City Public Works and Spatial Planning Office (Dinas PUPR), representing the legally operative detailed spatial plan for Gorontalo City covering the period 2021–2041, as established under Mayor Regulation No. 44 of 2021. The administrative boundary dataset was obtained from ATR/BPN and the Geospatial Information Agency (BIG) through the Ina-Geoportal national geospatial data platform.

Table 1. Primary Spatial Datasets Used in the Study

Dataset	Year	Source / Legal Basis	Format
LBS Map	2019	ATR/BPN Ministerial Decree No. 686/SK-PG.03.03/XII/2019	Shapefile (.shp)
LBS Map	2024	ATR/BPN Ministerial Decree No. 446.1/SK-PG.03.03/V/2024	Shapefile (.shp)
RDTR Spatial Zoning Map	2021–2041	Gorontalo City PUPR Office — Mayor Regulation No. 44/2021	Shapefile (.shp)
Administrative	Current	ATR/BPN + BIG via Ina-Geoportal	Shapefile (.shp)

Table 2. Characteristics of the LBS 2019 and LBS 2024 Datasets

Attribute	LBS 2019	LBS 2024
Legal basis	ATR/BPN Ministerial Decree No. 686/SK-PG.03.03/XII/2019	ATR/BPN Ministerial Decree No. 446.1/SK-PG.03.03/V/2024
Base imagery and resolution	High-resolution satellite imagery (CSRT), SPOT-6/7, 1.5 m; acquired 2018–2019	CSRT Pléiades/WorldView, 0.5 m, and UAV orthophoto; acquired 2023–2024
Mapping scale	1:5,000	1:5,000
Delineation method	Visual interpretation and manual digitizing of satellite imagery	Update by spatial overlay and high-resolution imagery, field ground-truthing and ATR/BPN verification
Field validation	Field sample verification by ATR/BPN and the local agricultural office	Field ground-truthing and spatial verification by the Gorontalo City Land Office under ATR/BPN Ministerial Regulation No. 2 of 2024
Positional accuracy	Horizontal ≤ 2.5 m (Class 2, 1:5,000 scale)	Horizontal ≤ 2.5 m (Class 2, 1:5,000 scale)
Polygons in Gorontalo City (n)	405	208
Area in Gorontalo City (ha)	1,135.16	760.65

Software and Tools

All spatial processing and analysis were performed using QGIS Desktop version 3.44.14, a free and open-source GIS platform widely adopted in academic spatial research across earth and environmental sciences (Brovelli et al., 2017; QGIS Development Team, 2024). QGIS provides a comprehensive suite of vector geoprocessing tools including clip, intersect, dissolve, and calculate geometry functions that are functionally equivalent to those available in proprietary GIS platforms, while ensuring reproducibility and accessibility of the analytical workflow (Brovelli et al., 2017). Tabular data aggregation, statistical calculations, and result formatting were conducted using Microsoft Office Excel, which is widely used in GIS-based land-use research as a complement to spatial processing software for the generation of area summary tables and percentage calculations.

Data Processing and Analysis Procedures

The analytical workflow followed eight structured, sequential geoprocessing steps designed to produce comparable spatial conformity outputs for each study period. The complete workflow is summarized in Table 3 and described in detail below.

Table 3. Analytical Workflow: Geoprocessing Steps

Step	Process	Tool / Operation	Output
1	Coordinate standardization	Reproject all layers → WGS 1984 UTM Zone 51N	Unified CRS across all datasets
2	Administrative clipping	Fix geometries; clip LBS 2019 & LBS 2024 to city boundary	City-specific LBS layers per period
3	LBS change detection	Intersect (2019 ∩ 2024); Difference (2019 − 2024 and 2024 − 2019)	Retained, removed and added LBS polygons; sliver sensitivity test
4	RDTR layer preparation	Clip pola ruang to LBS spatial extent	Analysis-ready RDTR zoning layer
5	Conformity overlay — 2019	Intersect LBS 2019 ∩ RDTR pola ruang	LBS 2019 × RDTR conformity layer
6	Conformity overlay — 2024	Intersect LBS 2024 ∩ RDTR pola ruang	LBS 2024 × RDTR conformity layer
7	Conformity classification	Attribute query: S = agricultural zone; TS = non-agricultural zone	Binary conformity field added to both layers
8	Area calculation & aggregation	Calculate Geometry (Ha); disaggregate by sub-district and RDTR zone	Statistical tables per period & comparative matrix

Coordinate System Standardization

All spatial datasets were reprojected to a common Projected Coordinate Reference System (CRS): WGS 1984 UTM Zone 51N (EPSG: 32651). Standardization to a single projected CRS is a fundamental prerequisite for multi-layer spatial analysis, as it eliminates geometric distortions arising from differences in map projection and ensures that area calculations are performed in metric units (metres/hectares) rather than angular units (degrees), which would introduce systematic measurement errors (Tiede, 2014). UTM Zone 51N was selected as the appropriate zone for Gorontalo's geographic position (approximately 123° E longitude), providing meter-scale coordinate accuracy essential for precise polygon area calculations.

Administrative Boundary Clipping

The LBS 2019 and LBS 2024 layers were individually clipped to the administrative boundary of Gorontalo City using the vector clip function in QGIS. This step confines the analysis to the city's jurisdictional extent, eliminating any paddy field polygons that may cross the administrative boundary and ensuring that all area measurements reflect only land within Gorontalo City. The resulting city-specific LBS layers for each period serve as the two primary input layers for subsequent temporal and conformity analyses.

LBS Change Detection via Intersect and Difference Overlays

Temporal change in LBS extent was quantified with three overlay operations. Intersect (LBS 2019 ∩ LBS 2024) returns the area present in both editions, classified as retained. Because intersect returns only overlapping area, removed and added areas were derived with the Difference operation: LBS 2019 minus LBS 2024 gives the area recorded in 2019 but absent in 2024 (removed), and LBS 2024 minus LBS 2019 gives the area recorded in 2024 but absent in 2019 (added). The three layers partition both editions, so that retained plus removed equals the 2019 total and retained plus added equals the 2024 total (Tiede, 2014; Gandharum et al., 2025).

Before overlay, invalid geometries in both layers were repaired with Fix Geometries. Because the two editions were delineated from imagery of different resolution, their boundaries do not coincide, and the overlay produces small or narrow sliver polygons along shared edges. Overlay outputs were flagged as candidate slivers when their area was below a threshold or their approximate width (2 × area/ perimeter) was below 2.5 m, the horizontal accuracy of 1:5,000 mapping (Table 2); this width measure is an approximation. The figures reported in this paper are unfiltered; the influence of slivers was assessed as a sensitivity test by excluding candidate slivers, without merging them into neighbouring polygons, from both the removed and the added layers at area thresholds of 0.001, 0.01 and 0.05 ha and recalculating gross and net change.

Removal from the LBS layer may reflect physical conversion, reclassification during verification, or boundary correction. Removed polygons were not validated against independent multitemporal imagery or field observation in this study. Change is therefore reported as a change in the official inventory: the terms "removed" and "decrease in recorded LBS" are used throughout, and no removed area is described as converted.

RDTR Layer Preparation

The RDTR spatial zoning layer (*pola ruang*) was clipped to the combined spatial extent of both LBS layers using the vector clip function, reducing the dataset to the area relevant for conformity analysis. This step reduces

computational processing load while maintaining the full attribute content particularly the land zone type (zona) attribute required for the conformity classification in subsequent steps.

Spatial Conformity Overlay — 2019 and 2024

The central analytical operations of this study were the vector intersect overlays between LBS 2019 and the RDTR *pola ruang* layer (Step 5), and between LBS 2024 and the same RDTR layer (Step 6). The intersect overlay is the methodological standard for assessing the spatial alignment between two polygon datasets in land-use planning research (Harpudiansyah & Apriyanti, 2025; Khairullah et al., 2025). Each intersect operation generates a new polygon layer in which every output polygon carries the combined attribute fields of both input layers specifically the LBS polygon identifier and the RDTR zone type enabling a direct attribute-based determination of whether each unit of paddy land falls within an agriculturally designated zone or a non-agricultural zone in the RDTR. The deliberate use of the same RDTR document as the reference against which both LBS 2019 and LBS 2024 are compared ensures strict methodological consistency: any differences in conformity outcomes between the two periods reflect changes in LBS extent, not changes in the planning reference document.

Binary Conformity Classification

Following the intersect overlay, each output polygon was classified into one of two conformity categories based on the RDTR zone type attribute: (S — *Sesuai*, Conforming) where the RDTR zone is designated as an agricultural or LP2B zone; or (TS — *Tidak Sesuai*, Non-Conforming) where the RDTR zone is designated for non-agricultural purposes, including residential (*permukiman*), commercial and service (*perdagangan dan jasa*), office (*perkantoran*), or public facilities (*fasilitas umum*). The assignment of each of the 20 zones present in the study area is listed in Table 5. It follows the zoning regulation of the RDTR (Mayor Regulation No. 44 of 2021): Article 65(1), which sets the activity and land-use provisions for the food crop sub-zone (P-1); Article 65(5), which governs LP2B designation within specified blocks; and the activity and land-use provisions table (ITBX matrix) in Annex XVI. A zone is classed S only where it is the food crop sub-zone (P-1) designated as LP2B, and all zones in which paddy cultivation is not the designated principal use are classed TS. Agricultural activities that the ITBX matrix may allow on a limited or conditional basis in other zones were not treated as conforming, because such permission does not give paddy land the protected status of the P-1 sub-zone. The binary scheme follows the legal categories relevant to paddy field protection under Government Regulation No. 21 of 2021 (Harpudiansyah & Apriyanti, 2025), but it treats zones of different development intensity alike, so Table 7 compares the non-agricultural zones.

Area Calculation and Spatial Aggregation

Area (in hectares) was calculated for all polygons in both the LBS 2019 conformity layer and the LBS 2024 conformity layer using the Calculate Geometry function in QGIS, operating on the projected UTM coordinate system to ensure metric accuracy. Results were then spatially disaggregated by sub-district and by RDTR zone type for both study periods, enabling spatial pattern identification at the sub-district level. The conformity percentage for each period was computed using the following formulae:

A transition matrix was then constructed by cross-tabulating the conformity class of each unit of LBS 2019 with its status in 2024. Because the RDTR reference is the same for both years, a unit retained in both editions keeps its class, and transitions between S and TS cannot occur. The matrix therefore has six non-empty cells:

a) S → S (retained in an agricultural zone);
b) S → removed (in LBS 2019, absent from LBS 2024, agricultural zone);
c) TS → TS (retained in a non-agricultural zone);
d) TS → removed (in LBS 2019, absent from LBS 2024, non-agricultural zone);
e) added → S (absent from LBS 2019, in LBS 2024, agricultural zone); and
f) added → TS (absent from LBS 2019, in LBS 2024, non-agricultural zone).

Row sums equal the 2019 class totals and column sums equal the 2024 class totals, so the matrix reconciles both editions. Dividing cells (b) and (d) by their 2019 class totals gives the loss rate in each class, which a single-period assessment cannot provide (Harpudiansyah & Apriyanti, 2025; Khairullah et al., 2025).

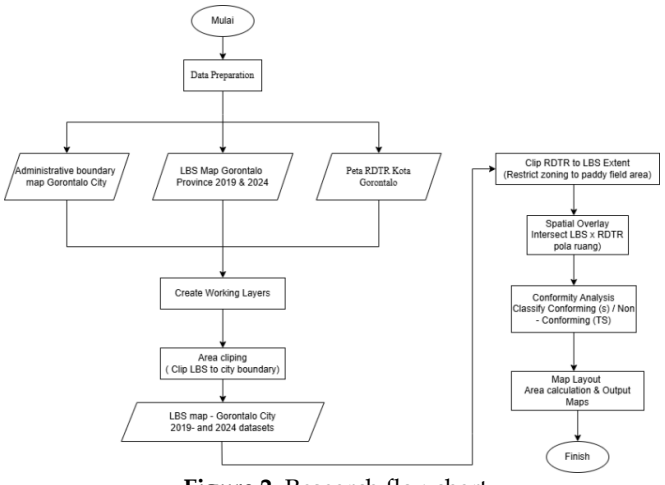


Figure 2. Research flowchart

Result and Discussion

Between 2019 and 2024 the recorded LBS area decreased from 1,135.16 ha to 760.65 ha (Table 4). The net decrease of 374.51 ha (33.0%) corresponds to 74.9 ha per year over the five-year interval. It combines a gross removal of 378.53 ha and 4.02 ha of LBS 2024 that lies outside the 2019 footprint (Table 6). Most of this added area does not consist of candidate slivers, since 3.98 ha remains after removing candidate slivers at the 0.05 ha threshold. It reflects boundary adjustments made during the 2024 verification; no new paddy fields were established. The net decrease is a change in the official inventory; it was not validated against imagery or field observation and may include reclassification and boundary correction as well as physical conversion. Removing candidate slivers reduced the net decrease from 374.51 ha to 374.37 ha, 374.34 ha and 372.57 ha at the 0.001, 0.01 and 0.05 ha thresholds, a change of at most 1.94 ha (0.5%). Most candidates were narrow edge strips with little area (732 polygons totalling 0.13 ha at the 0.001 ha threshold), so candidate slivers, whether or not all of them are boundary artefacts, have little effect on the estimated change. Kota Utara recorded the largest absolute decrease (136.70 ha). The highest proportional decreases occurred in Kota Selatan (90.3%, from a small base of 6.31 ha), Dungingi (76.7%) and Kota Barat (67.4%). This uneven distribution is consistent with the peri-urban transition pattern in which conversion pressure concentrates near established commercial and residential corridors (Nuissl & Siedentop, 2021; Rizq & Manessa, 2025).

Table 4. LBS Change by Sub-District and Conformity Class, Gorontalo City (2019–2024)

District	LBS 2019 (Ha)	Conforming 2019 (Ha)	Non-Conforming 2019 (Ha)	LBS 2024 (Ha)	Conforming 2024 (Ha)	Non-Conforming 2024 (Ha)	Net Decrease (Ha)
Kota Barat	84.81	0.00	84.81	27.69	0.00	27.69	57.12
Kota Timur	126.63	40.73	85.91	107.05	40.50	66.54	19.59
Kota Utara	572.23	149.67	422.56	435.53	148.13	287.40	136.70
Kota Selatan	6.31	0.00	6.31	0.61	0.00	0.61	5.70
Kota Tengah	110.56	0.00	110.56	64.49	0.00	64.49	46.07
Hulonthalangi	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dungingi	67.21	0.00	67.21	15.63	0.00	15.63	51.58
Dumbo Raya	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sipatana	167.41	59.05	108.36	109.65	56.29	53.36	57.76
Total	1135.16	249.44	885.72	760.65	244.92	515.73	374.51

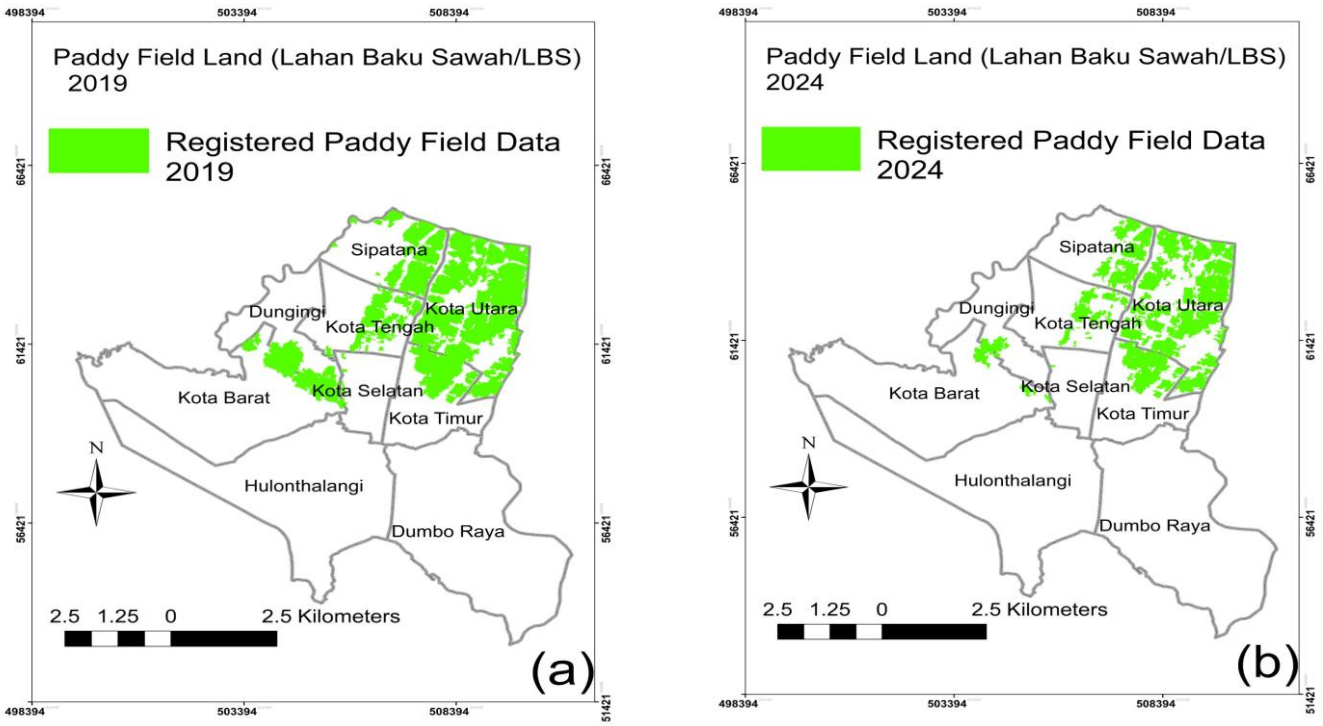


Figure 3. Map of LBS Gorontalo City 2019 (a) – Map of LBS Gorontalo City 2024 (b)

LBS–RDTR Spatial Conformity

Measured against the 2021 RDTR, 78.0% of LBS 2019 (885.72 ha) and 67.8% of LBS 2024 (515.73 ha) lay in non-agricultural zones (Table 5). The RDTR did not change, so the rise in the conforming share from 22.0% to 32.2% results from unequal losses: LBS in non-agricultural zones decreased by 369.99 ha (41.8%), whereas LBS in the agricultural zone decreased by 4.52 ha (1.8%) (Table 7). In terms of remaining area, high-density residential zones held the largest share of total LBS in both years (29.5% and 31.8%). In terms of change, however, medium-density residential zones contributed most of the decrease (152.60 ha, 40.7% of the net decrease), followed by high-density residential zones (93.33 ha, 24.9%) and the two trade and services zones (74.02 ha combined, 19.8%).

Table 5. LBS 2019 and LBS 2024 by RDTR Zone Type and Conformity Class (RDTR of Gorontalo City, Mayor Regulation No. 44 of 2021)

RDTR Zone	Raw Paddy Field (LBS) 2019 (Ha)	2019 (%)	Raw Paddy Field (LBS) 2024 (Ha)	2024 (%)	Remarks
Water Body	0.490	0.043%	0.040	0.005%	Non-Conforming
Road Body	11.428	1.007%	0.660	0.087%	Non-Conforming
Medium Intensity Mixed Use	13.039	1.149%	9.770	1.284%	Non-Conforming
Wastewater Treatment Plant (WWTP)	0.477	0.042%	0.180	0.024%	Non-Conforming
Drinking Water Treatment Plant (DWTP)	0.009	0.001%	0.000	0.000%	Non-Conforming
City-Scale Trade and Services	5.247	0.462%	0.610	0.080%	Non-Conforming
SWP-Scale Trade and Services	85.465	7.529%	49.050	6.448%	Non-Conforming
WP-Scale Trade and Services	69.297	6.105%	31.700	4.167%	Non-Conforming
Warehousing	1.163	0.102%	0.230	0.030%	Non-Conforming
Office	19.622	1.729%	7.190	0.945%	Non-Conforming
Local Protection Zone	0.311	0.027%	0.050	0.007%	Non-Conforming
Defense and Security	0.043	0.004%	0.010	0.001%	Non-Conforming
Medium-Density Residential	280.625	24.721%	128.030	16.832%	Non-Conforming
High-Density Residential	334.937	29.506%	241.610	31.764%	Non-Conforming
Urban Forest	0.231	0.020%	0.000	0.000%	Non-Conforming
District-Scale Public Facility (SPU)	0.109	0.010%	0.000	0.000%	Non-Conforming
Kelurahan-Scale Public Facility (SPU)	0.855	0.075%	0.011	0.001%	Non-Conforming
City-Scale Public Facility (SPU)	61.913	5.454%	46.430	6.104%	Non-Conforming
RW-Level Park	0.461	0.041%	0.158	0.021%	Non-Conforming
Food Crops / Agricultural Land (LP2B)	249.441	21.974%	244.920	32.199%	Conforming – Protected LP2B
Total Area	1.135.163	100%	760.649	100%	

Notes: RDTR = Detailed Spatial Plan | SWP = Sub-Planning Area | WP = Planning Area | SPU = Public Utility Facilities | LP2B = Protected Agricultural Land for Food Sustainability | WWTP = Wastewater Treatment Plant | DWTP = Drinking Water Treatment Plant

Cross-tabulation of the two editions produced the transition matrix in Table 6, whose rows reconcile to the 2019 totals and whose columns reconcile to the 2024 totals. The largest cell is LBS retained in non-agricultural zones (TS → TS, 511.77 ha). This land remains in the verified paddy inventory, yet its RDTR zoning designates a non-agricultural principal use. Under the KKPR–OSS framework of Government Regulation No. 21 of 2021, in which the RDTR is the reference for space utilization conformity, it therefore lacks RDTR-level protection as paddy land (Harpudiansyah & Apriyanti, 2025; Irawan & Wibisono, 2025). Overlaying this cell with the LP2B spatial layer available to the authors found no meaningful overlap (0.00 ha, 0.00%). The official Protected Paddy Field (LSD) map, governed by ATR/BPN Ministerial Regulation No. 2 of 2024, was not available, so protection under that instrument could not be assessed; the result therefore does not establish that this land is unprotected by other legal instruments. The 244.86 ha retained in the agricultural zone (S → S) is the area on which the RDTR and the LBS agree.

The non-conforming share in Gorontalo City (78.0% in 2019) is much higher than the shares reported elsewhere: 23.6% for Aceh Province (Amri et al., 2025), 13.8% for Gorontalo Regency (paddy fields against the regency RTRW, using 2007–2017 land-use data) (Ekafitrawan et al., 2020), 19.0% for Boyolali Regency (LP2B against the regency RTRW, using SPOT-6 imagery) Harpudiansyah & Apriyanti, 2025) and about 8.8% for Purworejo Regency (2,582 ha of 29,224 ha of protected rice fields against the 2021–2041 RTRW) (Khairullah et al., 2025). These studies differ in scale, data and zone classification, so their figures cannot be compared one to one. The Aceh study evaluated rice fields against a provincial plan with coarser zoning; the regency studies used regency spatial plans and paddy,

LP2B or protected rice field layers rather than the LBS; and each study defines conforming zones in its own way. A city-level RDTR allocates most land to urban functions, so a high non-conforming share is expected wherever paddy fields remain inside city limits. The studies agree on direction, though not on magnitude: zones designated for settlement expansion overlap paddy land in each setting, as Ekafitrawan et al. (2020) also found for Gorontalo Regency.

Table 6. Transition Matrix of LBS Conformity Status, 2019–2024

Change Category	Area (ha)	Description
Retained, conforming (S → S)	244.86	Agricultural (LP2B) zone; present in both LBS editions
Retained, non-conforming (TS → TS)	511.77	Verified paddy in both editions; non-agricultural zone
Removed, conforming (S → removed)	4.58	In LBS 2019, absent from LBS 2024; agricultural zone
Removed, non-conforming (TS → removed)	373.95	In LBS 2019, absent from LBS 2024; non-agricultural zone
Added, conforming (added → S)	0.06	Boundary adjustment in the 2024 verification; agricultural zone
Added, non-conforming (added → TS)	3.96	Boundary adjustment in the 2024 verification; non-agricultural zone
Total LBS 2019 (rows 1–4)	1,135.16	Gross removal (rows 3–4): 378.53 ha
Total LBS 2024 (rows 1, 2, 5, 6)	760.65	Net decrease: 374.51 ha (33.0%)

Note: Rows 3–6 are derived from the class totals in Tables 4 and 5 and agree within 0.01 ha with the unfiltered difference overlays (378.54 ha removed; 4.03 ha added). Values are unfiltered; see the text for the sliver sensitivity test.

Table 7. Net LBS Decrease by Conformity Class and RDTR Zone, 2019–2024

Conformity class / RDTR zone	2019 (ha)	2024 (ha)	Net decrease (ha)	Loss rate (%)	Share of net decrease (%)
Conforming: agricultural (LP2B) zone	249.44	244.92	4.52	1.8	1.2
Non-conforming: all zones	885.72	515.73	369.99	41.8	98.8
Medium-density residential	280.63	128.03	152.6	54.4	40.7
High-density residential	334.94	241.61	93.33	27.9	24.9
Trade and services, WP scale	69.3	31.7	37.6	54.3	10
Trade and services, SWP scale	85.47	49.05	36.42	42.6	9.7
City-scale public facility	61.91	46.43	15.48	25	4.1
Office	19.62	7.19	12.43	63.4	3.3
Road body	11.43	0.66	10.77	94.2	2.9
Other non-conforming zones (12)	22.44	11.06	11.38	50.7	3
All LBS	1,135.16	760.65	374.51	33	100

Note: Net decrease per zone equals the 2019 area minus the 2024 area and includes the 4.02 ha added in 2024. Loss rate = net decrease / 2019 area. Zones contributing less than 2% of the net decrease are grouped.

Three conditions in the planning system may help explain why non-conformity persists, although the overlay does not test them. First, the agricultural zone boundaries of the RDTR were derived from local land inventories compiled while the plan was drafted, rather than from the nationally verified LBS (Gandharum et al., 2025). Second, before Presidential Regulation No. 59 of 2019, spatial planning regulations did not require LBS to be used as an input to RDTR preparation (Harpudiansyah & Apriyanti, 2025; Irawan & Wibisono, 2025). Third, the LBS is updated periodically, whereas the RDTR has a 20-year horizon with five-yearly review, so field conditions and zoning drift apart between reviews. To keep interpretation separate from evidence, we distinguish three levels. Administrative non-conformity is LBS located in a non-agricultural zone (885.72 ha in 2019). Persistent non-conformity, which we call the non-conformity trap, is LBS that remains verified paddy and remains in a non-agricultural zone in both editions (511.77 ha). Recorded loss is LBS removed between editions (378.53 ha gross), which has not been validated as physical conversion. The first two levels describe zoning status; only the third describes change, and the overlay does not show that zoning caused it.

The study contributes in two ways. First, comparing two LBS editions against a fixed plan shows that loss was concentrated where zoning did not protect paddy land: 98.8% of the net decrease occurred in non-agricultural zones, where the loss rate was about 23 times that in the agricultural zone. Single-period conformity studies cannot observe this differential (Amri et al., 2025; Khairullah et al., 2025). Second, the distinction among administrative non-conformity, persistent non-conformity and recorded loss offers a simple framework for reporting conformity results without implying causation.

The high non-conforming share may also reflect a physical overlap between paddy cultivation and urban growth. Paddy fields need flat, low-lying land with reliable water, and the same characteristics make peri-urban land attractive for residential and commercial development (Bren d'Amour et al., 2017; Pribadi & Pauleit, 2015). RDTR zone designations tend to follow anticipated urban growth rather than existing

agricultural use, so in a city of 79.03 km² with little land outside the urban core, much of the remaining paddy land falls within zones planned for urban uses.

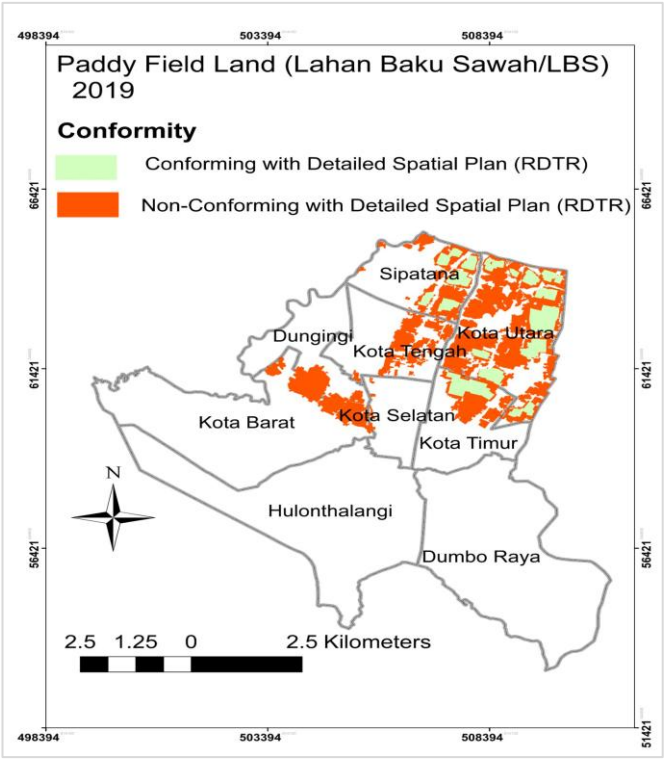


Figure 4. Spatial conformity map of LBS 2019 against the Detailed Spatial Plan (RDTR) of Gorontalo City

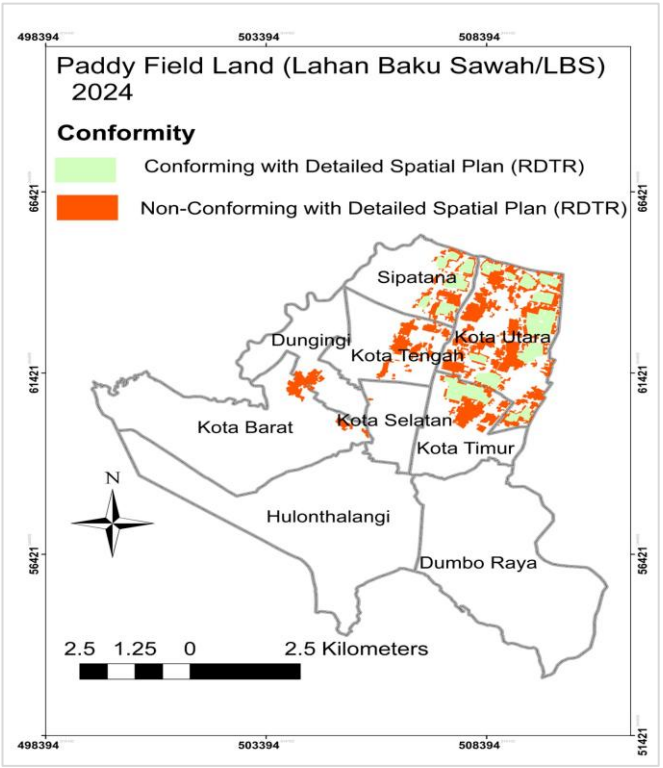


Figure 5. Spatial conformity map of LBS 2024 against the Detailed Spatial Plan (RDTR) of Gorontalo City

The findings identify policy options that need assessment beyond an overlay. Under Government Regulation No. 21 of 2021 the RDTR is reviewed once every five years, and ATR/BPN Ministerial Regulation No. 11 of 2021 allows an earlier partial revision where strategic conditions have changed; the 2021 RDTR of Gorontalo City reaches its first scheduled review in 2026. Three options merit assessment in that process: (1) examining the 511.77 ha of LBS that stayed non-conforming, beginning with Kota Utara (287.40 ha of non-conforming LBS in 2024), for possible LP2B designation after field verification and consultation with landowners; (2) giving the 244.86 ha of LBS that stayed conforming an explicit LP2B layer in the zoning regulation; and (3) screening KKPR applications in the OSS system against the LBS, in line with Presidential Regulation No. 4 of 2026. The legal and social feasibility of rezoning, given existing permits and land ownership, requires further study.

This study has five limitations. First, LBS 2019 is evaluated against a plan enacted in 2021, so the results describe its position under the current plan, not compliance with the rules in force in 2019. Second, the two LBS editions were produced under different procedures; although the sliver sensitivity test changed net change by at most 0.5%, differences in imagery and delineation may account for part of the measured change. Third, removed LBS was not validated against multitemporal imagery or field observation, so the decrease reported here cannot be equated with physical conversion; such validation is a priority for further research. Fourth, the analysis does not include parcel-level permits or land transactions, so it cannot attribute loss to legal or informal conversion pathways or test whether zoning caused it. Fifth, the binary classification treats all non-agricultural zones alike, and the single-city scope limits generalization; replication in other Indonesian cities with multi-period LBS data is needed.

Conclusion

Between 2019 and 2024 the recorded LBS area of Gorontalo City decreased by 374.51 ha (33.0%), from 1,135.16 ha to 760.65 ha, or 74.9 ha per year. Gross removal was 378.53 ha; this is a change in the official inventory and was not validated as physical conversion. Measured against the 2021 RDTR, the non-conforming share fell from 78.0% to 67.8% with the plan unchanged, because LBS in non-agricultural zones decreased by 41.8% while LBS in the agricultural zone decreased by 1.8%. Medium-density and high-density residential zones together accounted for 65.7% of the net decrease, and Kota Utara for the largest absolute loss. A total of 511.77 ha remained verified paddy in non-agricultural

zones in both editions. We describe this persistent condition as a non-conformity trap; the term names a zoning status associated with higher recorded loss, and this study does not show that it causes conversion. The main contribution of the study is to show, by holding the plan constant across two LBS editions, that loss was concentrated where zoning offered no RDTR-level protection. The results are limited by the retrospective use of a 2021 plan for 2019 data, by differences between LBS editions and by the absence of parcel-level permit data. Partial RDTR revision, explicit LP2B layers and LBS screening in OSS are options that warrant further regulatory and field assessment, and replication in other cities would test whether the pattern holds elsewhere.

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The authors declare no conflict of interest.

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