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Assessment of Land Use and Land Cover Changes in San Leonardo, Nueva Ecija from 2020 to 2025 Using GIS Mapping

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ABSTRACT: This study examines the land use and land cover (LULC) changes in San Leonardo, Nueva Ecija from 2020 to 2025 through the application of Geographic Information System (GIS) techniques and pre-classified geospatial datasets obtained from the Philippine Geoportal. Employing a descriptive-spatial research design, the study utilizes QGIS to analyze, quantify, and compare changes in major land cover categories, including annual crops, built-up areas, perennial crops, inland water, and grassland/shrubland.

Findings indicate that although agricultural land remains the dominant land use, it experienced a decrease of 382.88 hectares, while built-up areas significantly increased by 246.84 hectares over the five-year period. These changes suggest a gradual transition from an agricultural landscape toward increased urban development. The results underscore the value of GIS-based spatial analysis in monitoring land use dynamics and providing essential data to support sustainable land use planning and policy formulation at the municipal level.

KEYWORDS: land use, land cover, GIS mapping, QGIS, San Leonardo, Nueva Ecija, change detection, urban expansion, agricultural land

I. INTRODUCTION

1.1 Background of the Study

Land use and land cover (LULC) change is a key indicator of how human activities and natural processes transform the Earth's surface over time. These changes, particularly the conversion of agricultural land into built-up areas, have important implications for environmental sustainability, resource availability, and land use planning. In the Philippines, rapid urbanization has contributed to significant land use transitions, especially in lowland and agriculturally productive regions. (El-Zeiny, 2018) Land use and land cover change (LULCC) assessment helps to detect the extent of human influence on the natural environment. Central Luzon, known as the "rice granary of the Philippines," plays a major role in national food production. Within Central Luzon, Nueva Ecija remains one of the country's primary agricultural provinces, with rice farming as a dominant land use. However, ongoing infrastructure development, settlement expansion, and economic activities have likely contributed to gradual land use transitions in selected municipalities. These changes raise concerns regarding the long-term sustainability of agricultural land and its role in ensuring regional food security.

The quality of remotely-sensed imagery for LULC classification is often affected by the level of cloud cover in the image, as clouds block a sensor's view of the ground at many electromagnetic wavelength regions (e.g. visible (VIS), near infrared (NIR), shortwave infrared (SWIR), and thermal infrared (TIR) wavelength regions), (Johnson & Iizuka, 2016). (Hussain, 2020) Land use/land cover (LULC) change has serious implications for the environment as LULC is directly related to land degradation over a period of time and results in many changes in the environment. Monitoring the locations and distributions of LULC changes is important for establishing links between regulatory actions, policy decisions, and subsequent LULC activities.

San Leonardo, a municipality in Nueva Ecija, reflects these broader regional trends. Traditionally characterized by flat terrain and fertile agricultural land suitable for rice cultivation, the municipality has experienced gradual development in recent years. Such patterns highlight the need for localized analysis to better understand land use dynamics at the municipal scale.

Advancements in Geographic Information Systems (GIS) and remote sensing have significantly improved the ability to analyze land use changes over time. The Philippine Space Agency (PhilSA, 2024) notes that multi-temporal satellite datasets and geospatial platforms enable efficient monitoring of land cover trends at different scales. (Meshesha, 2016) analysing the trend of land use/land cover change and its cause and consequence on human livelihoods as well as on the environment is a matter of concern for sustainable development and management of natural resource

In the Philippine context, several studies have applied geospatial techniques to examine LULC dynamics. For example, (Iizuka et al., 2017) observed urban expansion and agricultural land conversion in the Laguna de Bay region, while (Almadrones-Reyes and Dagamac, 2022) reported associations between increasing built-up areas and environmental changes such as rising land surface temperatures. These studies demonstrate the value of GIS-based analysis in understanding land use transitions in rapidly developing areas.

Therefore, this study aims to analyze land use and land cover changes in San Leonardo, Nueva Ecija from 2020 to 2025 using GIS-based spatial analysis and pre-classified geospatial datasets obtained from the Philippine Geoportal. By providing municipal-level spatial and quantitative insights into land use trends, the study seeks to contribute to evidence-based land use planning and sustainable development strategies in San Leonardo and similar agricultural municipalities in Central Luzon.

1.2 Objectives of the Study

This study aims to analyze the land use and land cover (LULC) changes in San Leonardo, Nueva Ecija from 2020 to 2025 using Geographic Information System (GIS)-based spatial analysis and pre-classified datasets from the Philippine Geoportal processed in QGIS.

Specifically, it aims to:

1. Describe the LULC classifications of San Leonardo, Nueva Ecija for the years 2020 and 2025 based on Geoportal datasets.
2. Compute the total area (in hectares) of each LULC classification for both years using GIS spatial measurement tools.
3. Analyze and quantify the changes in LULC between 2020 and 2025 through comparative spatial analysis.

1.3 Significance of the Study

This study is deemed significant to the following:

Local Government Units (LGUs). This study provides GIS-based spatial information on land use and land cover (LULC) changes in San Leonardo, Nueva Ecija, which may serve as a reference for land use planning, zoning, and sustainable development policies.

Farmers and Agricultural Stakeholders. The findings may help farmers and agricultural stakeholders understand possible changes in agricultural land areas over time, which may be useful for land resource awareness and farming-related decision-making.

Urban and Land Use Planners. The study provides insights into land conversion trends, particularly the transition between agricultural and built-up areas, which may support the formulation of more efficient and sustainable land use plans.

Researchers and Academic Community. This study contributes to the growing body of GIS-based land use and land cover change research in the Philippines. It also serves as a reference for future studies using pre-classified geospatial datasets from the Philippine Geoportal, particularly at the municipal scale.

1.4 Scope and Limitation

This study focuses on the analysis of land use and land cover (LULC) changes in San Leonardo, Nueva Ecija, covering the period from 2020 to 2025. The analysis utilizes secondary, pre-classified LULC datasets obtained from the Philippine Geoportal, processed and analyzed using Geographic Information System (GIS) software (QGIS).

The study is strictly limited to spatial analysis, specifically the computation of land area changes and the temporal comparison of LULC classes. It does not involve primary data collection, field surveys, or the manual classification of raw satellite imagery. Furthermore, the study does not include an in-depth analysis of socio-economic, political, or policy-driven factors that may influence land use change. It is limited to GIS-based measurement and visual comparison of datasets and does not perform formal accuracy assessment procedures, such as confusion matrix validation.

Crucially, the study relies on the inherent quality of the secondary, pre-classified LULC datasets from the Philippine Geoportal. The timing of data acquisition, classification methods, and source accuracy may not fully represent actual ground conditions during the study period. No independent accuracy validation was conducted. Thus, the study does not assess classification reliability and relies entirely on the source dataset integrity rather than exact ground-validated measurements.

Finally, the results are strictly confined to the administrative boundaries of San Leonardo, Nueva Ecija, and may not be generalized to other areas with different land use dynamics.

1.5 Conceptual Framework

Input	Process	Output
•Qgis software, • LULC data. • Land Classification and area.	• Calculation of area per land classification • GIS mapping and digitizing of land cover types.	• Land Use and Land Cover maps for 2020 and 2025. • Statistical summary of land cover changes.

Figure 1. Conceptual Framework

II. REVIEW OF RELATED LITERATURE

The surface of the Earth is undergoing rapid LULC changes due to various socioeconomic activities and natural phenomena. (Pande et al., 2021) applied land-use and land-cover change detection mapping for effective planning and management of environment, land-use policy, and hydrological systems. Their work illustrates how land-use and land-cover mapping plays an important role in watershed planning and management in semiarid regions. Similarly, emphasized that understanding LULC change dynamics and the factors responsible for such change are vital for modelling future changes to support sustainable and robust policy decisions and strategies.

The technical feasibility of monitoring these changes is supported by the Philippine Space Agency (PhilSA, 2024), which utilized Google Earth Engine and multi-temporal satellite data to map land cover across Luzon.

The growing need for frequent and accurate land cover data has led to the use of multisource satellite imagery and cloud-based platforms like Google Earth Engine to map large areas such as Luzon Island (Candido et al., 2024). (Rivera et al., 2024) conducted a comprehensive spatiotemporal analysis of coastal municipalities in La Union, Philippines, utilizing Landsat imagery and GIS to track LULC changes over three decades (1990-2021). Their study observed a significant 15.32% decrease in vegetation cover alongside an increase in urban, agricultural, and barren land classes.

(Iizuka et al.,2017) modeled future urban sprawl in the Laguna de Bay area, highlighting that gains in built-up areas were primarily attributed to a decrease in crop-grass land, consistent with transitional development patterns observed in San Leonardo. Similarly, (Munthali, 2019) emphasized that understanding LULC change dynamics and the factors responsible for such change are vital for modelling future changes to support sustainable and robust policy decisions and strategies. The integrated remote sensing (RS) and geographic information system (GIS) approach was utilized in this study to classify land use and land cover (LULC), detect changes based over time, and identify transition trends in the Marikina sub-watershed, Laguna de Bay watershed, Philippines (Abino, 2015).

(Almadrones-Reyes and Dagamac, 2022) investigated the relationship between LULC changes and land surface temperature in Metro Manila, demonstrating a correlation between declining vegetation indices and rising urban heat island effects. Olfato-Parojinog et al. (2023) tracked landscape transformations in Rizal province, confirming that conversion of agricultural lands into settlements is primarily driven by population growth and regional economic shifts.

(Doyog, 2021) emphasized that integrating GIS-based LULC analysis into land use planning supports more informed and evidence-based decision-making in the Philippines. These collectively established studies validate the use of supervised GIS classification as a robust scientific method for quantifying land-use shifts over an observation period. The land use and land cover study (LULC) play an essential role in regional socio-economic development and natural resource management to develop sustainable development in vegetation changes, water quantity and quality, land resources, and coastal management (Abdulbasit, 2023).

III. METHODOLOGY

3.1 Research Design

This study utilizes a descriptive-spatial research design to assess LULC changes in San Leonardo, Nueva Ecija, from 2020 to 2025. Rather than generating new image classifications from raw satellite data, the research focuses on analyzing pre-classified LULC datasets obtained from the Philippine Geoportal. Geographic Information Systems (GIS), particularly QGIS, are employed for data processing, analysis, and change detection.

The study applies comparative spatial overlay and temporal GIS analysis by comparing LULC datasets from 2020 and 2025 to identify spatial and quantitative changes in land use categories such as built-up areas, agricultural land, vegetation, and water bodies

3.2 Research Locale

The study was conducted in San Leonardo, a municipality in the province of Nueva Ecija, Central Luzon, Philippines, located at approximately 15.36° North latitude and 120.96° East longitude. It has a total land area of 151.90 square kilometers (15,190 hectares) and is bounded by Santa Rosa to the north, Gapan City and San Isidro to the south, Penãaranda to the east, and Jaen to the west (PhilAtlas, 2020). San Leonardo is situated within the Central Luzon plain, characterized by generally flat terrain and low elevation, making it highly suitable for agricultural activities, particularly rice production.

3.3 Research Instrument

The research instruments consist of geospatial software and secondary spatial datasets. Pre-classified LULC datasets obtained from the Philippine Geoportal serve as the primary data source for identifying land use categories for the years 2020 and 2025. QGIS is used as the main analytical tool for data management, coordinate reference system standardization, clipping, and spatial analysis. The OpenStreetMap (OSM) basemap is integrated as a reference layer, and Google Earth Pro is used for visual validation of land cover conditions.

3.4 Sampling Procedure

This study utilized a purposive data selection approach. Pre-classified LULC datasets were directly exported from the Philippine Geoportal platform, ensuring standardized and government-sourced information. The study area was defined using the administrative boundary of San Leonardo, Nueva Ecija, which served as the primary spatial unit of analysis. All LULC datasets were clipped to this boundary to limit the analysis within the municipality. Land was classified into standardized categories including built-up areas, annual crops, perennial crops, inland water, and grassland/shrubland.

3.5 Data Gathering Procedure

The primary data consists of pre-classified LULC datasets obtained from the Philippine Geoportal for the years 2020 and 2025. The acquired datasets were imported into QGIS and standardized to a common coordinate reference system (CRS). The LULC datasets were then clipped using the administrative boundary of San Leonardo. An OpenStreetMap standard basemap was integrated as a reference layer. Land use categories were organized into built-up areas, annual crops, perennial crops, inland water, and grassland/shrubland. Data verification was conducted through visual comparison using Google Earth Pro. Change detection analysis was performed by overlaying the LULC maps for 2020 and 2025 in QGIS, with area calculations in hectares using attribute tables and Microsoft Excel.

3.6 Data Analysis Procedure

The data analysis procedure focused on assessing land use and land cover (LULC) changes in San Leonardo, Nueva Ecija, from 2020 to 2025 using pre-classified spatial datasets obtained from the Philippine Geoportal as the sole data source.

The LULC datasets were processed and analyzed using QGIS, where spatial layers for 2020 and 2025 were aligned, clipped to the study area boundary, and organized into standardized land use categories such as built-up areas, agricultural land, vegetation, and water bodies. An initial comparative spatial overlay analysis was conducted to identify spatial differences between the two time periods. The total area of each land use category was computed in hectares and converted into percentage distribution using attribute table calculations and Microsoft Excel.

To provide a more in-depth analysis of land use dynamics, the net change in area for each land use category was calculated by comparing the 2020 and 2025 datasets, allowing the study to identify which categories experienced increases or decreases over the five-year period. In addition, a GIS-based temporal comparison was performed through spatial overlay and area comparison techniques to assess spatial and quantitative differences between land cover classes across the two time periods. This allowed the study to identify not only the magnitude of change but also the general direction of land use shifts.

The results were presented through thematic maps, tables, and graphical representations to clearly illustrate spatial patterns, trends, and transitions in land use over the five-year period.

IV. RESULTS AND DISCUSSION

4.1 Land Use and Land Cover (2020)

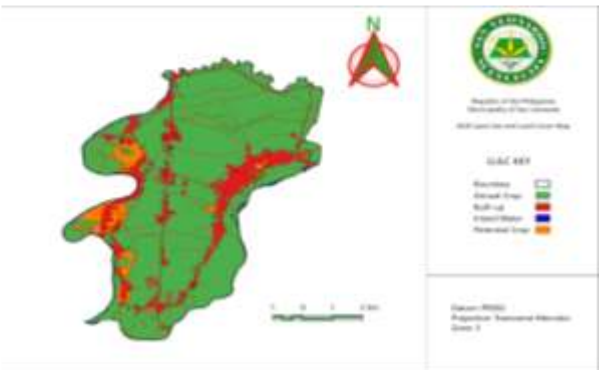
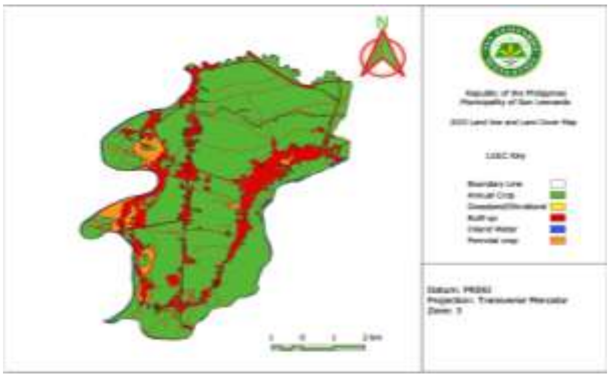


Figure 4.1 Land Use and Land Cover Map of San Leonardo Nueva Ecija (2020)

Figure 4.1 shows the spatial distribution of land use and cover in San Leonardo for 2020. The dominant land cover is Annual Crops, covering 87.18% of the municipality's total land area, indicating that San Leonardo was primarily agricultural in character during this period. Built-up areas account for 5.47% of the total land area and are mostly concentrated along major road networks, suggesting early-stage settlement development following a linear urban growth pattern. Perennial crops occupy 4.25% of the land, while Inland Water covers 3.10%.



4.2 Land Use and Land Cover (2025)

Figure 4.2 Land Use and Land Cover Map of San Leonardo Nueva Ecija (2025)

Figure 4.2 presents the land use and land cover distribution in San Leonardo for the year 2025. Compared to 2020, there is a noticeable increase in built-up areas, which now account for 7.10% of the total land area. This expansion is visible particularly along and beyond the major road corridors, indicating that urban growth has spread further into previously open agricultural spaces.

Annual Crop land remains the dominant category at 84.65%, though its coverage has decreased compared to 2020, which may indicate gradual expansion of developed land uses into previously agricultural areas. Spatially, agricultural land appears to be better retained in the interior portions of the municipality, particularly in areas farther from the main road networks, suggesting that distance from transport corridors may function as a partial buffer against development pressure. Grassland/Shrubland, which was not present as a classified category in the 2020 dataset, appeared in 2025 at 1.55%. This emergence may be attributed to differences in classification schemes or dataset processing between the two reference years, rather than confirmed land cover change.

4.3 LULC Area and Percentage (Table)

TABLE I. LAND COVER CLASSIFICATION AREA DISTRIBUTION (2020)

Land Cover Type	Area (Hectares)	Percentage (%)
Annual Crop	13,241.31	87.18%
Built-Up	831.66	5.47%
Inland Water	470.89	3.10%
Perennial Crop	646.14	4.25%
Total	15,190	100%

Table 1 presents the land cover classification and area distribution of San Leonardo for 2020. The results indicate that Annual Crop is the dominant land cover, followed by Built-Up, Perennial Crop, and Inland Water, in descending order of area.

TABLE II. LAND COVER CLASSIFICATION AREA DISTRIBUTION (2025)

Land Cover Type	Area (Hectares)	Percentage (%)
Annual Crop	12,858.43	84.65%
Built-Up	1,078.50	7.10%
Grassland/Shrubland	235.34	1.55%
Inland Water	455.70	3.00%
Perennial Crop	562.03	3.70%
Total	15,190	100%

Table 2 presents the land cover classification and area distribution for 2025. It should be noted that Grassland/Shrubland was not present as a classified category in the 2020 dataset and appeared only in the 2025 dataset. This difference may be attributed to variations in classification schemes or dataset processing between the two reference years, rather than confirmed land cover transformation. Annual Crop remains the dominant land cover, followed by Built-Up, Inland Water, Perennial Crop, and Grassland/Shrubland.

4.4 Comparison and Changes

TABLE III. COMPARATIVE ANALYSIS OF LULC (2020-2025)

Land Cover Type	2020 Area (ha)	2025 Area (ha)	% Change
Annual Crop	13,241.31	12,858.43	-2.89%
Built-Up	831.66	1,078.50	+29.68%
Grassland/Shrubland	0.00	235.34	+100%
Inland Water	470.89	455.70	-3.23%
Perennial Crop	646.14	562.03	-13.02%

The comparison of land cover data between 2020 and 2025 reveals a shift in the landscape of San Leonardo. While the municipality remains fundamentally agricultural, the data points toward a trend of urbanization and land conversion across major categories.

4.4.1 The Expansion of Built-Up Areas

The most significant change between 2020 and 2025 is the growth of built-up areas, which increased by approximately 246.84 hectares. Spatially, this expansion appears most pronounced along and adjacent to major road corridors, suggesting a corridor-led pattern of urban growth where settlement clusters along transport infrastructure before gradually extending into surrounding agricultural interiors. The general direction of built-up growth appears oriented toward the southern and western portions of the municipality, where proximity to Gapan City and major inter-municipal road connections may be driving settlement expansion.

This pattern is consistent with regional trends in Central Luzon, where infrastructure development often serves as a catalyst for gradual land use change. The observed spatial clustering of built-up expansion along road networks suggests that urban growth in San Leonardo may be concentrating in areas with existing access infrastructure, while interior agricultural zones farther from these corridors appear to retain their crop land character, representing de facto agricultural retention zones. This spatial differentiation may intensify as development pressure increases. This shift may reflect ongoing regional transitions toward more permanent urbanization, as noted by Olfato-Parojinog et al. (2023), potentially linked to economic and demographic pressures reported in similar contexts.

4.4.2 The Decline of Agricultural Land

Annual crop land experienced a notable decline, representing a net loss of approximately 382.88 hectares over the five-year period. The spatial distribution of this decline suggests that agricultural land loss is concentrated in areas proximate to road corridors and existing settlement boundaries, where built-up expansion is most evident. These areas likely represent the transition zones between urban and agricultural uses, where development pressure may be gradually displacing productive rice fields. The observed spatial relationship between areas of built-up growth and agricultural land reduction may indicate a gradual conversion associated with urban development, though parcel-level verification would be needed to confirm the specific direction of these transitions. This trend aligns with the findings of Cabrera and Dumdumaya (2023), who documented declines in agricultural land in urbanizing Philippine municipalities, and is consistent with the broader pattern of agricultural retention in interior areas farther from road networks.

4.5 Interpretation

The land cover changes observed between 2020 and 2025 reveal that San Leonardo exhibits indicators consistent with gradual urbanization, with built-up areas increasing by 29.7% over five years. Despite this growth, the municipality remains fundamentally agricultural in character. The absolute loss of 382.88 hectares of agricultural land represents a 2.89% decline, indicating a gradual rather than rapid process of land use change. The spatial co-occurrence of built-up expansion and agricultural land reduction, particularly near road corridors, may indicate gradual land use change associated with urban development, though the pre-classified secondary datasets used in this study preclude parcel-level confirmation of conversion direction. The appearance of Grassland/Shrubland (235.34 ha) in 2025, absent from the 2020 dataset, should be interpreted with caution, as this is more likely attributable to differences in classification schemes between the two datasets than to confirmed land cover transformation.

V. SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 Summary of Findings

This study analyzed LULC dynamics using Geographic Information System (GIS) processing of pre-classified datasets from the Philippine Geoportal. The results indicate that Annual Crops remained the dominant land cover throughout the five-year period, although its area decreased from 13,241.31 hectares (87.18%) in 2020 to 12,858.43 hectares (84.65%) in 2025. This net loss of 382.88 hectares may indicate a gradual reduction in agricultural land within the municipality. Conversely, Built-up areas showed a measured increase, rising from 831.66 hectares (5.47%) to 1,078.50 hectares (7.10%), a growth of 246.84 hectares that may reflect an expansion of developed land uses often associated with population growth and infrastructure development.

Other observed shifts included a decrease in Perennial Crops from 4.25% to 3.70% and a marginal decline in Inland Water. A new classification, Grassland/Shrubland, appeared in the 2025 dataset, accounting for 235.34 hectares. However, as this category was absent in the 2020 data, its emergence should be interpreted with caution, as it may be attributed to differences in classification schemes or dataset processing rather than confirmed land cover transformation.

Overall, the data may indicate a gradual pattern of land use change associated with urban development, suggesting that portions of agricultural land may be accommodating development needs while the municipality maintains its predominantly agricultural character.

5.2 Conclusions

The assessment of San Leonardo's LULC changes from 2020 to 2025 using GIS mapping suggests that the municipality is in a potential transitional phase. The observed growth of built-up areas alongside the recorded reduction of annual crop land may indicate that development pressure in San Leonardo is becoming more evident. Because the municipality is situated within Nueva Ecija—a province vital to national rice production—a continued reduction in agricultural area could have long-term implications for local farming communities and regional agricultural sustainability. It is important to note that without parcel-level verification or a formal transition matrix, the specific direction of land conversion cannot be definitively confirmed. The appearance of Grassland/Shrubland in 2025 further highlights the reliance on secondary dataset integrity, as this shift may reflect reclassification rather than actual ground-validated changes.

Consequently, field validation remains necessary to determine the exact nature of these spatial variations. Nevertheless, the study demonstrates that GIS-based spatial analysis using government-sourced datasets provides a practical, municipal-level approach for monitoring potential land use trends and supporting evidence-based planning in Central Luzon.

5.3 Recommendations

Establish protective zoning for remaining agricultural land. Given the net loss of 382.88 hectares of Annual Crop land over five years, the local government of San Leonardo may consider using the results of this study as supporting evidence in reviewing and strengthening zoning ordinances that protect its remaining 12,858.43 hectares of agricultural land—particularly areas classified as Strategic Production Areas—to help manage potential expansion of residential or commercial development.

Address the emergence of Grassland/Shrubland. The appearance of Grassland/Shrubland areas in 2025, covering 235.34 hectares, warrants attention from environmental and land use authorities. As these areas were absent in 2020, they may reflect differences in classification schemes or dataset processing rather than confirmed land transformation, and should therefore be further validated before any land management decisions are made. These areas may be considered for further assessment to determine their current condition and future land use potential, and appropriate measures such as reforestation or soil stabilization may be explored to prevent soil degradation and runoff in affected zones.

Regulate development along road corridors. Since the spatial analysis shows that built-up expansion began along major road networks, the municipal government may consider developing or strengthening corridor development guidelines that help manage the pace and direction of settlement growth, preventing unplanned sprawl into productive agricultural interiors.

Conduct a formal accuracy assessment in future LULC studies. This study relied solely on visual validation through Google Earth Pro, without a formal accuracy assessment such as a confusion matrix. Future research on LULC change in San Leonardo may incorporate ground truthing and quantitative accuracy measures to strengthen the reliability of spatial classifications.

Utilize higher-resolution and more frequent datasets. Future studies may consider using higher-resolution geospatial data and shorter time intervals—such as five-year comparisons—to capture more detailed and timely land use transitions, enabling more responsive planning and earlier detection of potential conversion trends.

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APPENDICES

APPENDIX A

Raw Land Use and Land Cover (LULC) Data — San Leonardo, Nueva Ecija (2020 & 2025)

Table A1. LULC Area Measurements — 2020 Dataset

Land Cover Category	Area (ha)	Percentage (%)
Annual Crop	13,241.31	87.18%
Built-Up	831.66	5.47%
Perennial Crop	646.14	4.25%
Inland Water	470.89	3.10%
Grassland/Shrubland	0.00	0.00%
TOTAL	15,190.00	100.00%

Table A2. LULC Area Measurements — 2025 Dataset

Land Cover Category	Area (ha)	Percentage (%)
Annual Crop	12,858.43	84.65%
Built-Up	1,078.50	7.10%
Perennial Crop	562.03	3.70%
Inland Water	455.70	3.00%
Grassland/Shrubland	235.34	1.55%
TOTAL	15,190.00	100.00%

Table A3. Net Area Change by Land Cover Category (2020–2025)

Land Cover Category	2020 (ha)	2025 (ha)	Net Change (ha)	% Change
Annual Crop	13,241.31	12,858.43	– 382.88	– 2.89%
Built-Up	831.66	1,078.50	+246.84	+29.68%
Grassland/Shrubland	0.00	235.34	+235.34	+100%*
Inland Water	470.89	455.70	– 15.19	– 3.23%
Perennial Crop	646.14	562.03	– 84.11	– 13.02%

***Grassland/Shrubland was unclassified in 2020; the +100% reflects a new classification in 2025 and may indicate reclassification rather than confirmed land conversion.**

APPENDIX B

QGIS Data Processing Workflow — Summary

Detailed below are the key phases of the GIS processing pipeline used to analyze LULC change. Full reproducibility requires QGIS 3.x (LTR) with the QuickMapServices plugin.

Phase	Procedure
Software & Data	QGIS 3.x (LTR); pre-classified LULC shapefiles (2020 & 2025) and San Leonardo municipal boundary from Philippine Geoportal (NAMRIA); CRS: PRS92 / EPSG:4683.
CRS Standardization	All layers reprojected to PRS92 (EPSG:4683) via Vector > Data Management > Reproject Layer.
Clipping	LULC datasets clipped to municipal boundary: Vector > Geoprocessing Tools > Clip (applied separately to 2020 and 2025 layers).
Area Calculation	New field Area_ha (decimal) added to attribute table; populated using Field Calculator expression: $area / 10000. Totals summarized via Statistics Panel.

Change Detection	Category names standardized across datasets; net change and percentage change computed in Microsoft Excel. Categories with >±5% change flagged for spatial review.
Map Production	Categorized symbology applied per LULC class; thematic maps composed in Print Layout with legend, north arrow, scale bar, and title. Exported as PNG/PDF at ≥ 300 DPI.

APPENDIX C

Glossary of Key Terms

Definitions reflect usage specific to this study. Common GIS and remote sensing terms are defined only where study-specific nuance applies.

Term	Definition
Annual Crop	Vegetation completes its life cycle within one growing season; primarily lowland rice fields in this study.
Built-Up Area	Land covered by impervious surfaces including structures, roads, and man-made infrastructure.
Change Detection	GIS/remote sensing technique quantifying spatial differences in land cover between two observation dates.
CRS (Coordinate Reference System)	Framework defining how geographic data is spatially referenced. This study uses PRS92 (EPSG:4683).
Grassland/Shrubland	Low-growing grasses, herbs, and scattered shrubs; includes idle or transitional agricultural land.
Inland Water	Permanent or semi-permanent water bodies such as rivers, ponds, and irrigation canals.
LULC (Land Use and Land Cover)	Integrated term describing physical land surface characteristics and associated human activities.
Net Change	Arithmetic difference in area (ha) of a land cover class between two periods (positive = gain; negative = loss).
Perennial Crop	Multi-season vegetation (e.g., fruit trees, coconut palms) not replanted annually.
Philippine Geoportal	Official spatial data repository of the Philippine government (NAMRIA), providing pre-classified LULC shapefiles.
Pre-Classified Dataset	Geospatial data with land cover categories assigned by the provider via remote sensing algorithms, precluding manual classification.
PRS92	Philippine Reference System 1992; official national geodetic reference, equivalent to WGS 84 under EPSG:4683.
QGIS	Open-source GIS application used for spatial data management, analysis, and cartographic output in this study.
Visual Validation	Qualitative accuracy check comparing GIS outputs against Google Earth Pro imagery without formal statistical assessment.

APPENDIX D

Data Source Documentation

Dataset	Source	Format	Year	Notes
LULC 2020	Philippine Geoportal (NAMRIA)	Shapefile	2020	Pre-classified; 4 LULC categories
LULC 2025	Philippine Geoportal (NAMRIA)	Shapefile	2025	Pre-classified; 5 LULC categories
Admin Boundary	Philippine Geoportal / PhilAtlas	Shapefile	2020	San Leonardo, Nueva Ecija boundary
Basemap	OpenStreetMap	Web tile	Current	Reference layer only; not analyzed
Validation	Google Earth Pro	Visual/raster	2020–2025	Visual cross-checking only

Data Limitations

- LULC datasets are pre-classified by NAMRIA; classification accuracy has not been independently validated and is assumed based on source integrity.

- Grassland/Shrubland appeared only in the 2025 dataset; this may reflect inter-dataset classification scheme differences rather than confirmed land conversion.
- Area computations are planar (QGIS) and may deviate marginally from geodetic values for large polygons.
- No formal accuracy assessment (e.g., confusion matrix) was conducted given the use of pre-classified secondary datasets.

APPENDIX E

Statistical Summary of LULC Change Analysis (2020–2025)

The consolidated change table is presented in Appendix A (Table A3). The derived rate-of-change metrics below supplement that analysis.

Table E1. Derived Rate-of-Change Metrics

Metric	Category	Value
Largest absolute gain	Built-Up	+246.84 ha
Largest absolute loss	Annual Crop	− 382.88 ha
Highest relative growth rate	Built-Up	+29.68% over 5 years
Annualized Built-Up growth	Built-Up	≈ +49.37 ha/year
Annualized agricultural loss	Annual Crop	≈ − 76.58 ha/year
Study period	All categories	5 years (2020–2025)

Note: Annualized rates are linear approximations (net change ÷ 5 years) and do not account for non-uniform rates of change within sub-periods.