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Spatiotemporal Analysis of Land Use and Land Cover (LULC) Changes in Bongabon, Nueva Ecija (2015–2025)

Leila Cando[1], Jhon Mark M. Liwag[2], Jeremy Martin[3], Arianne Joy N. Mirador[4], Mark David A. Valeriano[5], Rosel V. Babalcon[6]

[1,2,3,4,5,6] Nueva Ecija University of Science and Technology, Sumacab Este, Cabanatuan, Nueva Ecija

ABSTRACT: This study analyzed the spatiotemporal changes in Land Use and Land Cover (LULC) in Bongabon from 2015 to 2025 using Geographic Information System (GIS) and remote sensing techniques. The study aimed to identify LULC classifications, determine spatial and temporal changes, quantify area variations, and identify dominant land cover changes within the municipality. Secondary datasets from Geoportal Philippines and GADM were processed using QGIS to generate thematic maps and change detection analysis. Nine LULC categories were identified, including annual crops, perennial crops, built-up areas, forest classes, grassland, inland water, and open/barren land. Results revealed that annual crops remained the largest single land cover category, reflecting the municipality's agricultural character. However, notable changes occurred over the ten-year period, including increases in built-up areas, perennial crops, and closed forest, alongside decreases in open forest and annual crop areas. Spatial patterns showed that land transformation was concentrated near settlements, transportation corridors, and accessible lowland areas. The findings may be associated with urbanization, agricultural activities, and infrastructure development are significant drivers of land cover change. The study highlights the importance of sustainable land use planning and environmental management in supporting balanced development within the municipality.

KEYWORDS: Land Use and Land Cover (LULC), GIS, remote sensing, spatiotemporal analysis, land cover change, QGIS, urban expansion, agriculture, Bongabon

I. INTRODUCTION

1.1 Background of the Study

Land use and land cover (LULC) changes constitute one of the most dynamic anthropogenic and natural processes reshaping the Earth's surface, profoundly influencing ecosystem services, climate regulation, and human well-being (Foley et al., 2005; Turner et al., 2008). Land cover refers to the biophysical characteristics of the Earth's surface (e.g., vegetation, water bodies), while land use denotes human activities imposed upon it (e.g., agriculture, urbanization), with the two inextricably coupled such that alterations in one invariably cascade to the other (Lambin & Geist, 2006). The LULC changes are among the most significant because they have a direct impact on biotic diversity, contribute to climate change, affect ecosystem services that support and sustain human needs, and are a primary source of soil degradation (Lambin et al. 2001). In the Philippines, rapid population growth, agricultural development, and urban expansion continue to influence land cover patterns, particularly in rural municipalities (Bayan et al., 2021). Rural municipalities are transitioning from agrarian monocultures to heterogeneous landscapes, often at the expense of prime farmlands (Lillesand et al., 2015). Bongabon, a first-class municipality in Nueva Ecija province, Central Luzon, demonstrates this shift. Covering 22,524.119 hectares with fertile alluvial soils from the Pampanga River basin, Bongabon earns its moniker as the "Onion Capital of the Philippines," producing over 40% of the nation's onions alongside rice, garlic, and sweet corn (Philippine Statistics Authority, 2020). Its economy sustains a population exceeding 50,000 (PSA, 2020), yet intensive agricultural practices—characterized by heavy pesticide (e.g., organophosphates) and fertilizer applications—have raised concerns over soil degradation and water contamination (Molina et al., 2019; David, 2016). Government initiatives such as "Build, Build, Build" have spurred infrastructure expansion, including roads and irrigation networks, accelerating land conversions (Department of Public Works and Highways, 2022).

1.2 Statement of the Problem

Land use and land cover (LULC) changes reflect the interaction between natural processes and human activities, particularly in municipalities undergoing agricultural and urban development. In Bongabon, Nueva Ecija, shifts in land use may occur due to changing land demands; however, there is limited localized, quantified information describing the extent and pattern of these changes over time.

Although LULC datasets are available through national platforms such as Geoportal Philippines, these datasets have not been specifically processed and analyzed to assess temporal changes within the municipal boundary of Bongabon. Without such analysis, there is a lack of clear understanding of how different land cover types have increased, decreased, or transitioned over time.

This study seeks to address the following questions:

1. What are the land use and land cover classifications in Bongabon, Nueva Ecija?
2. How have land use and land cover changed spatially and temporally within the municipality between 2015 and 2025?
3. What are the changes in area and percentage for each land use and land cover category over the 10 years?

4. What are the dominant land cover changes observed between 2015 and 2025?

1.3 Objectives

The primary objective of this study is to assess land use and land cover (LULC) changes in Bongabon, Nueva Ecija, from 2015 to 2025 using GIS-based analysis.

Specifically, the study aims to:

1. Identify the LULC classification based on the Geoportal PH.
2. Develop LULC maps and classify the areas of each LULC of Bongabon for the years 2015 and 2025.
3. Analyze spatial and temporal changes in LULC between 2015 and 2025.
4. Discuss possible drivers of observed LULC changes based on spatial patterns and supporting literature.

1.4 Significance of the Study

This study will greatly benefit various stakeholders in the following ways:

Local Government Units (LGUs). The output of this study will be beneficial to the LGUs in the development of appropriate and well-informed policies with regard to land use planning and management. Through the identification of the trends and patterns of land cover changes in the area, LGUs can formulate appropriate and effective plans and regulations for the development of the area. In addition, the output of this study will be beneficial in the implementation of appropriate and sustainable development plans in the area.

Farmers and the Agricultural Sector. The output of this study will be beneficial to the farmers and the agricultural sector in the area in the following ways: the study will provide them with appropriate and valuable information with regard to the effects of changes in land use on agricultural productivity and sustainability. In this way, the farmers in the area can be encouraged to practice appropriate and sustainable agricultural practices.

Civil, Geological, and Environmental Engineers. This study should provide valuable analysis and insights for Civil, Geological, and Environmental Engineers to support their respective work. Civil Engineers can apply the study to build more effective and environmentally friendly infrastructure projects while considering both land suitability and areas at risk from natural disasters. Geological Engineers can use the spatial data and GIS-based analysis generated from this study to create maps and conduct land assessments. Environmental Engineers can utilize the analysis in this study to identify potential environmental concerns and develop solutions to address those types of problems, such as flooding, soil erosion, and land degradation. This study will therefore be valuable to the overall engineering profession.

Researchers and Students. The study could be helpful as a reference material in the future for researchers and students who are interested in studying land use studies, environmental science, and GIS applications. This is because the study is localized, which could be helpful in the academic community. It could be used as a basis of comparison in another region.

Community. This study would be helpful to the community because it would create awareness among the people about the significance of proper land management and environmental conservation. This is because the people would be able to understand the impact of land use changes and would be more aware of the need to conserve the environment.

1.5 Scope and Limitations

This study examines the Land Use and Land Cover (LULC) changes in Bongabon by analyzing spatial and temporal variations using satellite imagery, maps, GIS, remote sensing, and local records. It focuses on identifying major land use types, such as agricultural areas, and evaluating the patterns and extent of their changes. The study also considers factors influencing these changes, including population growth, agricultural activities, and infrastructure development within the municipality and the selected timeframe.

However, the study is limited by the availability and quality of data, which may affect accuracy and reliability. The analysis only covers selected periods and may not capture short-term or seasonal variations. Possible classification errors, no field validation, and constraints in time and resources may also affect the results. Additionally, the study does not fully address all socio-economic, political, and environmental factors influencing land use change, and its findings are specific to Bongabon.

1.6 Process Framework

This framework outlines the technical execution required to achieve your objectives, specifically focusing on the 10-year comparison.

Table I. Process Framework

Phase	Technical Stage	Objective Alignment
I. Multi-Temporal Acquisition	Sourcing LULC datasets for both 2015 and 2025 via Geoportal PH and GADM.	Obj 1: Develop LULC maps for both years.
II. Spatial Standardization	Filtering to the Bongabon boundary; geometry repair (Buffer 0m); ensuring both years use the same CRS (Coordinate Reference System).	Obj 1 & 2: Create a consistent baseline for comparison.
III. Comparative Analysis	Performing Clip operations for both years; Attribute table analysis to calculate Area (km2 or Hectares).	Obj 2 & 4: Quantify area and percentage changes.
IV. Change Detection	Identify spatial overlaps and areas of change between classifications (e.g., Forest to Agricultural).	Obj 3 & 4: Identify major transitions and spatial shifts.
V. Visualization	Producing side-by-side layouts in QGIS at 600 DPI for visual evidence of change.	Final Deliverable: Spatio-temporal change report.

1.7 Conceptual Framework

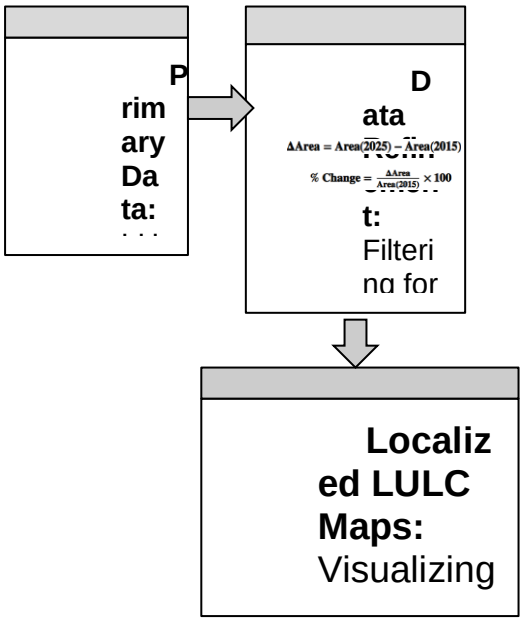

Figure 1. Paradigm of the Study

II. REVIEW OF RELATED LITERATURE

An attempt has been made in this study to evaluate changes in land cover in a few Nueva Ecija towns and cities. Landsat images (Landsat 4 TM, Landsat 7 ETM+, Landsat 5 TM, and Landsat 8 OLI_TIRS) were used in the study's remote sensing and GIS methodology. The findings showed that between 1989 and 2018, the research areas had changes in land cover in agricultural, urban, and forestry areas. Urban areas grew at a significantly faster rate than any other land cover class, although making up a far smaller fraction of the landscape and land cover over both time periods. Deforestation, or the removal of some forest areas and their conversion to agriculture and habitation in towns and cities, is mostly caused by the growth of agricultural and urban regions (Camazo et al., 2019)

According to Tumbaga (2023), the study tracked land cover changes surrounding Minalungao National Park in Nueva Ecija, Philippines. The study used Landsat images (Landsat 7 ETM+ and Landsat 8) from 2001, 2014, and 2021. It is used as part of remote sensing and GIS analysis. The images were processed using the Semi-Automatic Classification Plugin in QGIS. The results showed four types of land cover: inland water, closed forest, open forest, and open/barren land. The findings show that the area had both increases and decreases in land cover due to different community activities. Positive changes were connected to forest restoration and ecotourism, while negative changes were caused by tree-cutting and livestock grazing. The study also shows how GIS and remote sensing are useful in monitoring land cover changes and helping in environmental management.

In order to offer useful data for land resource management plans, the extent of land use and land cover (LULC) conversion of Mt. Pulag National Park (MPNP), Benguet Province, Philippines, between 1990 and 2020 was evaluated. The park is in danger of additional deterioration due to the growing demand for vegetable farming. Sentinel-2 for 2020 and Landsat 5 for 1990–2010 were used to calculate the extent of changes in MPNP's LULC. Before data processing, the reflectance of the satellite pictures was improved using the FLAASH (Fast Line-of-sight Atmospheric processing of Hypercubes) program. The MPNP was classified into five LULC changes using the maximum likelihood classification (MLC), with an overall accuracy of 90.58% and areal percentage cover of 15.88, 0.26, 1.34, 80.51, and 2.01%, respectively, in 2020 for agricultural lands, barren lands, built-up areas, forest lands, and grasslands. Agricultural areas increased by 8.96%, barren lands declined by 2.14%, built-up areas climbed by 1.02%, forest lands decreased by 8.35%, and grasslands decreased by 2.14%, according to the LULC percentage of change from 1990 to 2020, which grew by 0.51%. The findings demonstrated that the main factor contributing to the loss of forest land is the expansion of human-induced LULC classes, such as built-up and agricultural regions. Nonetheless, the woodland region benefits from the arid areas that are naturally regenerating. Consequently, the LULC conversion pattern indicates that the park will continue to lose a sizable amount of the forest as a result of land conversion if nothing is done (Doyog, 2021)

Land use and Land Cover (LULC) refers to alterations of natural landforms and human activities. Land cover focuses on the physical features present on the earth's surface, such as vegetation, water bodies, and soil. Land use refers to how people use natural resources in things like urbanization, agriculture, and resource extraction. According to Dumdumaya and Cabrera (2023), changes in LULC are caused by natural phenomena and human activities such as agricultural expansion, urban development, and climate change. These changes significantly impact ecological balance, biodiversity, and environmental sustainability.

III. METHODOLOGY

This chapter outlines the study's methodology and research design. With the aim of meeting the goals of the study, it outlines the techniques and methods used in collecting, evaluating, and interpreting the data. In particular, it covers the research instruments, data gathering methods, and research locale for data processing. By using these techniques, the study guarantees that the information gathered is accurate and suitable for addressing the research objectives and accomplishing the study's overall goal.

3.1 Research Design

This study employed a quantitative descriptive-comparative research design using GIS-based spatial analysis to examine Land Use and Land Cover (LULC) changes in Bongabon between 2015 and 2025. The study utilized pre-classified LULC datasets obtained from Geoportal Philippines and processed them in QGIS to examine spatial distribution, area variations, and temporal changes among land cover categories.

The analysis involved municipal boundary clipping, area computation, thematic mapping, and comparative spatial assessment between the two study years. Changes in land cover were evaluated through area and percentage comparisons rather than through independent satellite image classification.

3.2 Research Locale / Study Area

This study was conducted in Bongabon municipality, located in the province of Nueva Ecija, Central Luzon, Philippines. Bongabon is a major agricultural hub renowned for onion production and extensive farming activities, making it highly suitable for LULC analysis. The area features diverse land cover, including agricultural lands, settlements, forested/upland areas, and water bodies, which are ideal for detecting spatiotemporal changes from 2015 to 2025 using QGIS.

3.3 Data Sources

Data Sources

All data used in this study are secondary sources.

a. LULC Data

- The study utilized pre-classified Land Use and Land Cover (LULC) datasets obtained from Geoportal Philippines for the years 2015 and 2025. These datasets were derived from Landsat-based national land cover mapping initiatives and follow standardized land cover classification systems used by Philippine mapping agencies.
- The researchers did not independently perform raw satellite image classification or atmospheric correction. Instead, the existing LULC datasets were processed and analyzed within QGIS for municipal-level spatial assessment.

b. Boundary Data

- **Bongabon municipal boundary**: Administrative Level 2 polygon (22,524.119 hectares), sourced from GADM 4.1 database (Global Administrative Areas, 2023) and validated against NAMRIA 1:50,000 topographic maps.

c. Supporting Data

- **PSA population reports**: 2015 (43,134) and 2020 (46,175) Census data (Philippine Statistics Authority, 2021).
- **Municipal profiles**: Bongabon Agriculture Office reports on onion production (25,000 MT/year) (DA-RFO III, 2022).
- **Bongabon MPDC CLUP vol. 1 and 3:** Bongabon Municipal Planning and Development Coordinator Comprehensive Land Use Plan Vol. 1 and 3.

3.4 Software / Tools Used

The analysis was conducted using a suite of specialized software tools designed for spatial and quantitative data processing. QGIS 4.0 served as the primary Geographic Information System (GIS) platform, facilitating essential tasks such as layer clipping, thematic mapping, and detailed area analysis. To complement the spatial data, spreadsheet software was utilized to organize raw datasets into structured tables, calculate percentages, and generate visual graphs for better data interpretation. Together, these tools ensured a seamless workflow between geographic visualization and statistical accuracy.

3.5 Data Preparation

To prepare the datasets for analysis, the raw files were first imported into QGIS, where a critical initial step involved verifying the Coordinate Reference System (CRS) to ensure spatial alignment across all layers. The official municipal boundary of Bongabon was then loaded to serve as the definitive study area. Using this boundary, both the 2015 and 2025 data layers were processed through a clipping tool, effectively removing all geographic information outside the municipality's jurisdiction. Finally, the clipped layers were systematically organized within the layers panel to facilitate a direct and accurate comparison of land cover transitions over the ten-year period, ensuring that the final analysis focused exclusively on the Bongabon area.

3.6 Land Cover Classification

The study adopted **9 LULC classes** from GeoPortal Philippines datasets, harmonized with **NAMRIA Land Cover Mapping Standards (2020),** and validated by regional studies:

1. **Annual Crop** (Rice, corn, onion) - 65% of Bongabon baseline
2. **Perennial Crop** (Coconut, mango) - Dominant in Central Luzon lowlands (DA-RFO III, 2022)
3. **Built-up** - Urban expansion hotspots
4. **Closed Forest** (>70% canopy) - Sierra Madre remnants (0.8% provincial cover; DENR, 2021)
5. **Open Forest** (10-40% canopy) - Degraded uplands
6. **Brush/Shrubs** - Fallow/agroforestry transition
7. **Grassland** - Pasture/rangeland (8.5% provincial; PSA, 2021)
8. **Inland Water** - Irrigation systems/rivers (3.2% baseline; NAMRIA, 2016)
9. **Open/Barren** - Construction sites/quarries (<2%)

3.7 Spatial and Temporal Analysis

To measure the land cover transitions, the total area for each classification was calculated for both the 2015 and 2025 datasets. By comparing these values, the specific increase or decrease in each category was identified, allowing for a detailed analysis of spatial movement and urban or agricultural expansion across the municipality. To quantify these shifts, the Area Change was determined by subtracting the initial year from the final year:

$$\Delta\, ha = Area(2025) - Area(2015)$$

Additionally, the Percentage Change was calculated to assess the relative growth or decline of each class using the following formula:

$$\%\,\Delta = \frac{Area(2025) - Area(2015)}{Area(2015} x100\%$$

These metrics provided a clear statistical foundation for understanding how the landscape of Bongabon evolved over the decade.

3.8 Map Preparation

The cartographic visualization phase involved the systematic generation of thematic maps to illustrate the decadal landscape transformation of Bongabon, Nueva Ecija, from 2015 to 2025. Utilizing QGIS, two primary LULC maps were produced—representing the baseline year (2015) and the terminal year (2025)—alongside a derived Change Map designed to highlight the spatial "extent and pattern" of agricultural-to-urban transitions. To ensure rigorous comparative analysis, a standardized classification scheme was maintained, utilizing identical color palettes for corresponding land cover classes (e.g., annual crops, built-up areas, forests, and grasslands) across both temporal datasets. Each map was rendered at a high resolution of 600 DPI and integrated essential cartographic elements, including a descriptive title, a comprehensive legend, a north arrow, and a scale bar, all framed within the GADM 4.0 administrative boundary lines. Furthermore, the LULC layers were set to 80% opacity to facilitate the overlay of barangay labels and professional grids, ensuring that the final outputs provided the necessary localized context for identifying specific communities impacted by urban growth and environmental vulnerability.

3.9 Data Validation / Reliability

The reliability of the findings in this study is fundamentally contingent upon the accuracy and precision of the secondary datasets retrieved from Geoportal Philippines and GADM. While the Landsat-derived LULC layers utilize established remote sensing standards for thematic mapping, it must be noted that no primary field validation or ground-truthing was conducted by the researchers due to significant time and resource limitations. To mitigate potential discrepancies and ensure internal consistency, the study adhered to the

Multitemporal LULC Change Detection Protocol. Consequently, the quantitative transitions and change matrices generated represent an analysis of official geospatial records, and their validity is employed by the source agencies.

3.10 Limitations of Method

This study analyzed only 2015 and 2025 from GeoPortal Philippines, missing intermediate yearly changes. As secondary data was used exclusively, no field validation was conducted by researchers due to time/resource constraints, with accuracy depending entirely on source dataset standards. Change causes were inferred from matrix patterns and literature only, without primary investigation. The research excluded household surveys or socio-economic modeling, focusing solely on spatiotemporal LULC assessment in Bongabon municipality.

IV. RESULTS AND DISCUSSION

4.1 Overview

This chapter presents the results of the land use and land cover (LULC) analysis for Bongabon, Nueva Ecija, for the years 2015 and 2025 using datasets obtained from Geoportal Philippines and processed in QGIS. The analysis includes the generated LULC maps, computed area statistics, percentage changes, and observed spatial transitions between land cover categories. The discussion focuses on the major land cover changes observed in the municipality based on the available data.

4.2 LULC Maps of Bongabon (2015 and 2025)

4.2.1 LULC Map – 2015

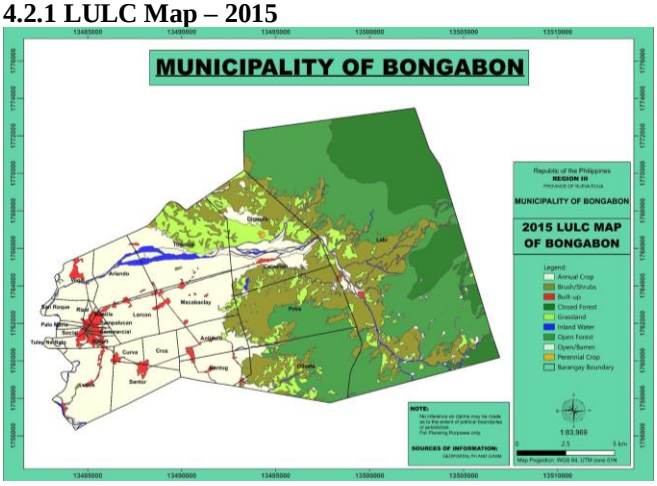

Figure 2. 2015 Bongabon, Nueva Ecija Land Use and Land Cover Classification Map

source link: click here

The 2015 LULC map shows that the municipality is predominantly composed of agricultural land, particularly annual crops, which are concentrated in the central lowland areas where terrain and irrigation conditions are favorable. This spatial distribution is consistent with the role of Nueva Ecija as a major agricultural production area in the Philippines (Philippine Statistics Authority [PSA], 2023; Department of Agriculture, 2022). Forest-related land cover classes, including open forest, closed forest, and brush or shrubland, are largely located in the eastern upland areas, reflecting natural topographic conditions and limitations to intensive land use (Department of Environment and Natural Resources [DENR], 2018; Food and Agriculture Organization [FAO], 2020). Built-up areas are relatively limited and are primarily concentrated near the poblacion and along major transportation routes, reflecting typical rural settlement patterns (Bhatta, 2010). Inland water features correspond with known river systems that traverse agricultural zones and serve as important water sources (DENR, 2017).

4.2.2 LULC Map – 2025

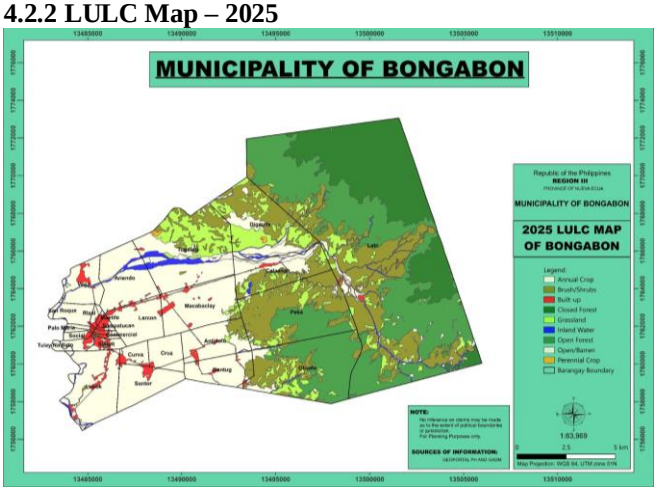

Figure 3. 2025 Bongabon, Nueva Ecija Land Use and Land Cover Classification Map

source link: click here

The 2025 LULC map, based on the mapped extent from the available Geoportal dataset, shows observable changes in the spatial distribution of land cover. Built-up areas extend outward from previously established settlements and along road networks, while some agricultural zones show localized changes at their boundaries. Forest classes exhibit internal shifts, particularly between open and closed forest categories. These spatial patterns are consistent with general land use transitions observed in developing rural municipalities (Bhatta, 2010; UN-Habitat, 2020).

4.2.3 Comparative Map Discussion

A comparison of the 2015 and 2025 maps indicates that land cover change is spatially concentrated rather than uniformly distributed across the municipality. Expansion of built-up areas is primarily observed near existing settlements, while agricultural areas remain largely intact in interior lowland zones. Changes in forest cover are mostly confined to upland areas, consistent with terrain-related land use constraints (FAO, 2020).

4.3 Classification and Quantification of LULC Categories

This section outlines the systematic classification and quantification of land use and land cover (LULC) categories in Bongabon, Nueva Ecija, as shown in the following tables. The classification scheme adheres to NAMRIA technical standards, ensuring consistency with national and regional studies. Quantification is based on satellite-derived data to ensure accuracy and reliability.

Table II. Land Use and Land Cover (LULC) Categories and Their Descriptions Based on NAMRIA Standards

LULC Category	Description (NAMRIA Standard)
Annual Crop	Land cultivated with crops that have a growing cycle of under one year (e.g., rice, onions).
Perennial Crop	Land cultivated with crops that occupy

	the land for many years (e.g., fruit trees, orchards).
Built-up	Areas characterized by residential, commercial, and industrial infrastructure.
Closed Forest	Formations where trees in various storeys and undergrowth cover >50% of the ground.
Open Forest	Formations with a discontinuous tree layer, with a crown cover between 10% and 50%.
Brush/Shrubs	Land with woody vegetation, generally of height less than 5 meters.
Grassland	Lands covered with grass (e.g., Cogon, Talahib) with little to no tree cover.
Inland Water	Rivers (Digmala/Coronel), streams, and other bodies of fresh water.
Open/Barren	Land with less than 10% vegetation cover, including rocky areas and riverbeds.

This table provides the operational definitions for each land category. Crucially, it distinguishes between **Closed Forest** (>50% crown cover) and **Open Forest** (10–50% crown cover). These definitions are vital for interpreting the shift from open to closed forest, which could be associated with classification shifts or vegetation density changes, an increase in canopy density rather than just an increase in total forested area. The observed increase may reflect classification shifts, canopy density changes, or natural vegetation regeneration within the dataset.

Table III. 2015 Land Use and Land Cover (LULC) Classification

LULC Category	2015 Area (ha)
Annual Crop	6,536.199
Perennial Crop	14.92198
Built-up	480.891
Closed Forest	2,845.407
Open Forest	5,893.544
Brush/Shrubs	4,116.399
Grassland	1,845.490
Inland Water	380.680
Open/Barren	410.587
Total	22,524.119 ha

Table III presents the mapped land use and land cover distribution of Bongabon, Nueva Ecija, for 2015. The results characterize the municipality as predominantly agricultural, with annual crops occupying the largest proportion of the total land area. This pattern is consistent with the broader role of Nueva Ecija as a major agricultural region in the Philippines, particularly in rice and crop production (Philippine Statistics Authority [PSA], 2023; Department of Agriculture, 2022). The concentration of agricultural land in central lowland areas reflects the suitability of these areas for cultivation due to relatively flat terrain and access to water resources.

Forest-related classes, including open forest and closed forest, form the second most extensive group of land cover types and are primarily associated with upland areas. This distribution aligns with established observations that forest cover is commonly retained in higher elevation zones where terrain limits intensive land use (Department of Environment and Natural Resources [DENR], 2018; Food and Agriculture Organization [FAO], 2020). Other land cover categories, such as grassland, brush or shrubs, inland water, and open or barren land, occupy comparatively smaller portions of the landscape. Built-up areas account for the least spatial extent, reflecting relatively limited settlement development, which is typical of rural municipalities (Bhatta, 2010).

Table IV. 2025 Land Use and Land Cover (LULC) Classification

LULC Category	2025 Area (ha)
Annual Crop	6,468.895
Perennial Crop	20.950
Built-up	525.637
Closed Forest	3,303.702
Open Forest	5,457.239
Brush/Shrubs	4,123.120
Grassland	1,857.199
Inland Water	375.393
Open/Barren	391.984
Total	22,524.119 ha

Table IV shows the mapped land use and land cover distribution for 2025 based on the available Geoportal dataset. The overall land use structure remains largely consistent with the 2015 condition, with annual crops continuing to dominate the landscape. This persistence reflects the continued importance of agriculture in the local economy (PSA, 2023).

However, some changes in the relative extent of certain categories are observable. Built-up areas occupy a larger proportion of the total area compared to 2015, which is consistent with general patterns of gradual settlement expansion in developing municipalities (Bhatta, 2010; UN-Habitat, 2020). Forest-related classes continue to represent a significant component of land cover, with closed forest showing a greater extent than open forest in the mapped dataset. This pattern is consistent with observations of vegetation structure changes reported in forest monitoring studies (FAO, 2020).

Other categories, including grassland, brush or shrubs, inland water, and open or barren land, exhibit only minor variations in extent. Overall, the 2025 distribution reflects continuity in dominant land uses, with moderate adjustments across selected land cover categories.

4.3.1 Consistency Assessment of Mapped Outputs

The reliability of the LULC outputs was assessed through visual comparison with known geographic conditions, municipal records, and established land use patterns. The spatial distribution of the mapped land cover classes corresponds well with expected conditions in Bongabon. Agricultural areas are concentrated in the central lowlands, consistent with known farming zones (PSA, 2023). Built-up areas are located near the poblacion and along transportation routes, reflecting typical settlement patterns (Bhatta, 2010). Forest-related land cover classes are found in the eastern upland areas, where elevation and terrain limit agricultural and urban development (DENR, 2018). Water bodies align with mapped river systems within the municipality (DENR, 2017). These correspondences indicate that the mapped outputs provide a reasonable representation of actual land use patterns in the study area.

4.4 Percentage Changes and Observed Land Cover Trends

This section examines the most significant transitions among land-use and land-cover (LULC) categories in Bongabon, Nueva Ecija, from 2015 to 2025. The analysis draws on area changes and percentage trends from previous tables, providing insight into how land cover types have shifted over the decade. Identifying these major transitions is crucial for understanding the drivers of land cover change and their implications for local land management.

Table V. Percentage Change and Trends in Land Use and Land Cover (LULC) Categories in Bongabon, Nueva Ecija (2015–2025)

LULC Category	% Change	Remarks
Perennial Crop	+40.40%	Significant Increase
Closed Forest	+16.11%	Major Increase
Built-up	+9.30%	Steady Increase
Grassland	+0.63%	Minor Increase
Brush/Shrubs	+0.16%	Stable/Minor Increase
Annual Crop	-1.03%	Minor Decrease
Inland Water	-1.39%	Minor Decrease
Open/Barren	-4.53%	Moderate Decrease
Open Forest	-7.40%	Major Decrease

Table V summarizes the changes in land use and land cover between 2015 and 2025. The results indicate that this pattern may indicate gradual peri-urban expansion associated with population growth and transportation accessibility. Although they continue to represent a smaller proportion of the total land area compared to agricultural land. This pattern is consistent with incremental urban expansion observed in rural and peri-urban areas (Bhatta, 2010; UN-Habitat, 2020). Annual crops show a slight reduction in extent but remain the largest single land cover category, reinforcing the continued importance of agriculture in the municipality (PSA, 2023). Within forest-related categories, closed forest shows an increase while open forest shows a decrease, suggesting a shift in vegetation characteristics within forested areas rather than a clear overall gain or loss in total forest cover (FAO, 2020; DENR, 2018).

Other land cover types exhibit relatively minimal changes in area, indicating relative stability in these categories over time. The overall pattern of change suggests that land cover dynamics in Bongabon during the study period are characterized by gradual and localized adjustments rather than large-scale transformation. The consistency in total mapped area between 2015 and 2025 supports the comparability of the datasets and allows for the identification of general land use trends within the municipality.

4.5 Spatial Patterns of Change

The spatial distribution of changes indicates that land transformation occurred in specific zones within the municipality. Built-up expansion is concentrated near existing settlements and along road networks, while agricultural land remains widespread in central lowland areas. Forest-related changes are primarily observed in upland areas. This pattern suggests that land cover change is influenced by spatial factors such as accessibility and terrain, resulting in localized rather than uniform changes across the landscape (Bhatta, 2010; Verburg et al., 2004).

4.5.1 Urban Expansion Zones

Urban expansion was primarily observed near existing settlement centers and transportation corridors. The spatial distribution of built-up areas in the 2025 map shows outward growth from previously established residential and commercial zones, particularly near the poblacion and barangays connected by major roads.

This pattern is supported by the measured increase in built-up land area from 480.891 hectares in 2015 to 525.637 hectares

in 2025, representing a 9.30 percent increase over the ten-year period (Bongabon Municipal Planning and Development Coordinator Comprehensive Land Use Plan Vol. 1 and 3).

The concentration of development near transportation networks suggests that accessibility may influence the shaping of settlement expansion. Areas with existing infrastructure are generally more suitable for residential and commercial development, leading to gradual outward growth from established urban centers rather than dispersed development across rural areas.

4.5.2 Agricultural Retention Zones

Agricultural land remained widely distributed across the central plains and lowland areas of Bongabon throughout the study period. These areas continued to support crop production due to favorable terrain, soil conditions, and irrigation availability.

The relative stability of agricultural zones is supported by the small decrease in annual crop land from 6,536.199 hectares in 2015 to 6,468.895 hectares in 2025, representing a reduction of approximately 1.03 percent (Bongabon Municipal Planning and Development Coordinator Comprehensive Land Use Plan Vol. 1 and 3).

The persistence of agricultural land suggests that farming remains the dominant land use in the municipality. Although some localized land conversion occurred, the majority of productive agricultural areas remained intact, suggesting that land conversion pressures were concentrated near settlement zones rather than across the entire agricultural landscape.

4.5.3 Forest / Upland Changes

Changes in forest cover were primarily observed in upland and slope areas located in the eastern portion of the municipality. The comparative analysis shows contrasting trends between open and closed forest categories.

Closed forest area increased from 2,845.407 hectares in 2015 to 3,303.702 hectares in 2025, representing an increase of approximately 16.11 percent, while open forest decreased from 5,893.544 hectares to 5,457.239 hectares, representing a decline of about 7.40 percent during the same period (Bongabon Municipal Planning and Development Coordinator Comprehensive Land Use Plan Vol. 1 and 3).

These changes may suggest a shift in vegetation structure within upland zones, may indicate natural regeneration, vegetation densification, or land management practices. The concentration of forest transitions in elevated terrain highlights the influence of slope and accessibility on land cover dynamics.

4.6 Discussion of Possible Drivers

The observed land use and land cover changes in Bongabon between 2015 and 2025 may be associated with several interacting socio-economic and environmental factors. While the study did not directly measure population, economic, or infrastructure variables, the spatial and quantitative patterns provide reasonable indications of possible influences on land transformation.

Population growth may be associated with the expansion of built-up land observed during the study period. The increase of approximately 44.746 hectares in built-up area suggests growing demand for residential and commercial space within the municipality (Bongabon Municipal Planning and Development Coordinator, Comprehensive Land Use Plan Vol. 1 and 3).

Road accessibility may influence settlement development patterns. The concentration of built-up expansion near transportation routes indicates that improved connectivity may encourage land development by facilitating the movement of goods, services, and people.

Agricultural intensification may be another possible driver of land cover change. The increase in perennial crop land from 14.922 hectares in 2015 to 20.950 hectares in 2025, representing a 40.40 percent increase, although perennial crops exhibited the highest percentage increase, the absolute area increase was relatively small, which may reflect adjustments in cropping strategies in response to market demand or agricultural productivity goals (Bongabon Municipal Planning and Development Coordinator Comprehensive Land Use Plan Vol. 1 and 3).

Land conversion pressure may also be associated with economic development and infrastructure expansion. As communities grow and land demand increases, portions of agricultural or open land may be converted into residential or commercial uses. These processes are consistent with gradual development patterns commonly observed in rural municipalities undergoing demographic and economic change.

4.7 Environmental and Planning Implications

The identified land cover changes have implications for environmental management and land use planning. The reduction in open vegetation may increase susceptibility to soil erosion and surface runoff, particularly in upland areas (FAO, 2020). The expansion of built-up areas may place pressure on nearby agricultural land, especially in zones adjacent to settlements. The continued dominance of agricultural land highlights the importance of protecting productive farmland (PSA, 2023). These findings suggest the need for effective land use planning strategies that guide development while maintaining agricultural productivity and environmental stability (UN-Habitat, 2020).

4.8 Summary of Key Findings

The results indicate that built-up areas increased moderately over the study period, while agricultural land remained the dominant land use despite a slight decrease. Forest cover showed changes between open and closed forest categories, with closed forest increasing and open forest decreasing. Land cover change was spatially concentrated in accessible areas rather than occurring uniformly across the municipality.

V. SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 Summary of the Study

This study analyzed the spatiotemporal changes in **Land Use and Land Cover (LULC) in Bongabon, Nueva Ecija, from 2015 to 2025** using GIS-based spatial analysis. The study aimed to identify existing LULC classifications, develop LULC maps for 2015 and 2025, examine spatial and temporal changes in land cover, and identify possible drivers associated with the observed land transformations within the municipality.

Secondary LULC datasets from Geoportal Philippines and administrative boundary data from GADM were processed and analyzed in QGIS using a consistent municipal boundary covering 22,524.119 hectares for all spatial computations and percentage calculations. The datasets were clipped and organized into thematic layers to analyze area and percentage changes among nine land cover categories between 2015 and 2025. Spatial and temporal analyses were conducted through area calculations, percentage change analysis, and comparative analysis of mapped land cover categories. Since the study relied exclusively on secondary datasets, the outputs were visually compared with known geographic patterns,

municipal records, and reference maps to assess consistency in land cover representation.

Nine land cover categories were identified in the municipality: annual crops, perennial crops, built-up areas, closed forest, open forest, brush/shrubs, grassland, inland water, and open/barren land. The results showed that annual crops remained the largest single land cover category throughout the study period. Built-up areas, perennial crops, and closed forest exhibited increases in mapped area between 2015 and 2025, while open forest and annual crops showed decreases in extent. Spatial patterns indicated that changes in built-up areas were concentrated near settlements and transportation corridors, while forest-related changes were primarily observed in upland portions of the municipality.

5.2 Summary of Findings

The study identified nine major land use and land cover (LULC) classifications in Bongabon for both 2015 and 2025, namely annual crops, perennial crops, built-up areas, closed forest, open forest, brush/shrubs, grassland, inland water, and open/barren land. Among these, annual crops remained the largest land cover category throughout the study period, reflecting the municipality's continuing agricultural character. Spatial distribution patterns showed that agricultural areas were mainly concentrated in the central lowland portions of Bongabon, while forest-related land cover classes were primarily located in the eastern upland areas. Built-up areas, meanwhile, were concentrated near the poblacion and along transportation corridors.

In terms of land cover changes from 2015 to 2025, built-up areas increased by approximately 9.30%, perennial crops increased by about 40.40%, and closed forest increased by around 16.11%. In contrast, open forest decreased by approximately 7.40%, while annual crop areas slightly declined by about 1.03%. The expansion of built-up areas was mainly observed near existing settlements and accessible road networks, indicating ongoing development and infrastructure growth. Despite these changes, agricultural land remained widely distributed across the municipality. Forest-related land cover changes were primarily observed in upland areas, and overall spatial changes were concentrated in accessible and developed portions of Bongabon rather than being evenly distributed across the landscape.

5.3 Conclusions

Measurable land use and land cover (LULC) changes were observed in Bongabon between 2015 and 2025. Annual crops remained the largest single land cover category throughout the study period despite minor reductions in mapped area. Built-up areas showed an increase in extent over time, particularly near existing settlements and transportation corridors, indicating continued development and expansion of accessible zones. Closed forest areas increased in mapped extent, while open forest areas decreased during the same period. Despite these changes, agricultural land remained widely distributed within the municipality throughout the ten-year span.

Overall, the spatial analysis showed that land cover changes were not uniformly distributed across Bongabon but were instead concentrated in lowland settlements, accessible road networks, and upland areas. The generated LULC maps provided a clear representation of observed land cover patterns and changes using available secondary datasets and GIS-based analysis. These results highlight the combined influence of agricultural persistence, urban expansion, and forest cover transitions in shaping the municipality's landscape over time.

5.4 Recommendations

Based on the findings of this study, the generated LULC maps and GIS-based spatial analysis may be used by local government units (LGUs) to support land use planning, zoning updates, and environmental monitoring within the municipality. Since changes in built-up, agricultural, and forest-related land cover categories were observed over time, continuous monitoring and sustainable land management practices are recommended to help assess spatial changes and maintain environmental and agricultural sustainability. The study also highlights the importance of strengthening conservation and monitoring activities, particularly in upland and watershed areas. For future studies, the use of higher-resolution satellite imagery, additional temporal intervals, socio-economic data, and field validation methods is recommended to further improve the accuracy and reliability of LULC analysis.

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