Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 05 May-2026, Page No.-9982-9991

DOI: 10.47191/etj/v11i05.32, I.F. – 8.595

GIS-Based Assessment of Land Use and Land Cover Change in Bulacan Province, Philippines (2020–2025)

Ellaine S. Nepomuceno[1], Dimple Joy R. Busalfa[2], Amer F. Garcia[3], Chrizalyn C. Yap[4], Hannah Grace E. Corpuz[5], Rosel V. Babalcon[6]

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

ABSTRACT: In the field of civil engineering, understanding land use and land cover (LULC) dynamics is essential for effective planning and sustainable development. This study assessed the LULC changes in Bulacan Province, Philippines, from 2020 to 2025 using Geographic Information System (GIS) techniques. The research aimed to identify major LULC categories, quantify changes in area and percentage, and analyze trends associated with urban development. Secondary spatial datasets obtained from the Philippine Geoportal were utilized and processed through GIS-based change detection analysis, including data standardization, spatial mapping, and comparative evaluation. The results showed that annual crops remained the dominant land cover despite a slight decrease, indicating the continued importance of agriculture in the province. Built-up areas exhibited a notable increase, reflecting ongoing urban expansion, while grassland showed the most significant decline. Closed forest demonstrated a slight increase, although this may be influenced by classification variability. Other land cover types remained relatively stable during the study period. Overall, the findings indicate gradual shifts in land use patterns driven by urbanization and development pressures, providing baseline information for land use planning and environmental management.

KEYWORDS: Land Use and Land Cover (LULC), Geographic Information System (GIS), Change Detection Analysis, Spatial Analysis, Urban Expansion, Remote Sensing

CHAPTER I
THE PROBLEM AND ITS SETTING
INTRODUCTION

Land use and land cover (LULC) change is one of the most important indicators of environmental transformation driven by both natural processes and human activities. It describes how land surfaces such as forests, agricultural areas, wetlands, and open spaces are converted or modified over time due to development and environmental factors. According to Ellis (2011), modern environmental change is now largely influenced by human activity, making LULC studies essential in understanding the interaction between human systems and the natural environment.

Globally, rapid urbanization and land conversion have significantly altered natural landscapes. Agricultural and vegetated areas are continuously being replaced by built-up structures such as roads, buildings, and industrial zones. These transformations affect ecological processes including water infiltration, surface runoff, biodiversity, and soil stability. Prestele et al. (2016) emphasized that land-use transitions create "hotspots of uncertainty," where rapid changes challenge environmental planning and policy development. Furthermore, urban land expansion has been identified as a major driver of habitat loss, carbon reduction, and ecosystem disruption (Seto, Güneralp, & Hutyra, 2012).

In addition, land use changes can also contribute to environmental risks such as flooding and erosion, especially in areas where natural land cover is replaced by impervious surfaces. Prashanth et al. (2023) explained that such changes disrupt natural drainage systems and increase surface runoff, which can intensify environmental hazards in vulnerable regions.

In the Philippines, land use change is strongly influenced by rapid population growth and urban expansion, particularly in provinces near Metro Manila. Bulacan Province, located in Central Luzon, serves as a transition zone between highly urbanized areas and agricultural landscapes. Because of its strategic location and accessibility, it has experienced continuous land conversion from agricultural and natural areas into residential, commercial, and industrial developments. This makes Bulacan highly relevant for studying spatial and temporal land use changes.

To address these changes, Geographic Information Systems (GIS) and Remote Sensing have become essential tools in monitoring and analyzing LULC dynamics. GIS allows the integration of spatial data over time, enabling accurate mapping and analysis of land transformations. Wagh and Auti (2025) emphasized that GIS plays a crucial role in land use planning by providing reliable spatial information for decision-making. In addition, Wulder et al. (2018) highlighted that satellite-based datasets allow systematic monitoring of land cover changes, particularly in detecting urban expansion and vegetation loss.

Despite the availability of LULC studies, there is still a need for updated and consistent provincial-scale assessments using standardized GIS datasets. Many previous studies focus on limited areas or use varying classification methods, leading to inconsistencies in spatial interpretation. This creates a research gap in terms of recent, comparative, and systematic analysis of land use changes in Bulacan Province.

Therefore, this study focuses on the GIS-based assessment of land use and land cover changes in Bulacan Province from 2020 to 2025. It aims to analyze spatial patterns and quantify changes in major land cover categories using secondary GIS datasets. The study provides a clearer understanding of how land use has evolved over time in response to urbanization and development pressures.

Overall, this research highlights the importance of continuous monitoring of land use changes in rapidly developing areas. Understanding these transformations is essential for promoting sustainable land use planning and environmental management, especially in provinces experiencing strong urban expansion such as Bulacan.

Statement of the Problem

Rapid urbanization and infrastructure expansion in Bulacan may have altered existing land use and land cover patterns over time. However, updated spatial assessments of these changes remain limited.

Thus, this study aims to assess:

1. What major LULC categories were present in Bulacan in 2020?
2. What major LULC categories are present in Bulacan in 2025?
3. What changes in area and percentage occurred between 2020 and 2025?
4. Which categories showed the greatest increase or decrease?
5. What possible factors, based on secondary literature, may help explain the observed LULC changes?

Objectives of the Study

The main objective of this study is to assess land use and land cover changes in Bulacan Province between 2020 and 2025 using GIS mapping.

Specifically, it aims to:

1. Identify LULC categories in 2020.
2. Identify LULC categories in 2025.
3. Quantify area and percentage changes.
4. Determine categories with greatest increase/decrease.
5. Discuss possible factors that may help explain the observed LULC changes based on related literature.

Significance of the Study

This study is significant as it offers a more comprehensive understanding of the changes in land use and land cover within the Province of Bulacan from 2020 to 2025. Through the application of GIS mapping techniques, the research provides reliable data and visual representations that illustrate the location, extent, and progression of these changes over time.

For the Provincial Government of Bulacan. The findings of this study may serve as a reference for provincial planning and policy formulation. The generated spatial data and maps can support decisions related to land allocation, infrastructure development, and environmental management. The results may also help in identifying areas that require more careful monitoring, especially in rapidly developing zones.

Municipal Planners. The study may assist municipal planners in evaluating land use distribution within their jurisdictions. The identified changes in land cover may support zoning decisions, urban expansion control, and local development planning. The spatial outputs can be used as a guide in aligning municipal plans with actual land conditions.

Environmental Agencies. The results may help environmental agencies in monitoring changes in vegetation, forest cover, and other natural land types. These findings may support the development of strategies for environmental protection, resource management, and risk reduction, particularly in areas that may be vulnerable to flooding or land degradation.

Engineers. The study may provide useful baseline information for civil engineers in planning infrastructure projects such as drainage systems, roads, and flood control structures. Understanding land use patterns may help in assessing potential impacts of development and in designing more sustainable engineering solutions.

Students and Researchers. This study demonstrates the application of GIS in analyzing land use and land cover changes at a provincial scale. It may serve as a reference for future studies, particularly in improving methodology, ensuring data consistency, and applying more advanced spatial analysis techniques.

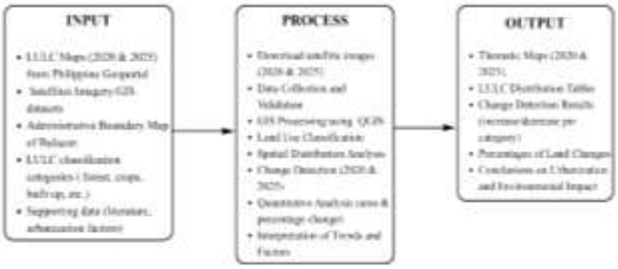
Overall, the study offers spatial insights that may support planning and decision-making. However, as emphasized in the study limitations, the findings depend on the accuracy and consistency of the available GIS data and should be used with appropriate caution.

Scope and Limitations

This study focuses on assessing land use and land cover (LULC) changes in the Province of Bulacan using Geographic Information System (GIS) techniques. The analysis covers the entire province and compares LULC conditions for the years 2020 and 2025 only. The study utilizes secondary spatial datasets obtained from the Philippine Geoportal and other available GIS sources. These datasets were treated as pre-classified LULC layers and were processed and analyzed to determine the distribution and changes in major land cover categories across the province. The study aims to identify spatial patterns and trends in land use and land cover over the specified period.

However, the study has several limitations. It relies solely on secondary GIS data, and no field validation was conducted to verify the actual ground conditions. The accuracy of the results depends on the quality and classification accuracy of the source datasets. In addition, the study compares only two time periods (2020 and 2025), which may not fully capture intermediate or long-term trends. The analysis is limited to identifying spatial patterns and changes in land use and land cover and does not directly determine the causes of these changes. Therefore, the study does not claim exact land conversion from one category to another; it only reports observed differences in mapped LULC area and percentage between the two datasets. Any discussion of possible factors influencing LULC change is based only on related literature and not on direct measurement or primary data.

CONCEPTUAL FRAMEWORK



The Input–Process–Output (IPO) model is widely used in research to organize the flow of data from collection to results. Grounded in systems theory, it provides a structured way to analyze complex processes through interconnected components (Skyttner, 2005). In land use and land cover (LULC) studies, IPO is applied by treating satellite imagery and GIS data as inputs, spatial analysis and classification as the process, and thematic maps and quantified land changes as outputs.

GIS and remote sensing have become essential tools in LULC analysis. High-resolution satellite imagery enables researchers to monitor land cover changes, detect urban expansion, and measure vegetation loss effectively (Wulder et al., 2018). The IPO framework supports this by clearly organizing the workflow from raw data to meaningful results.

Additionally, urbanization and population growth drive LULC changes. A structured analytical approach is necessary to understand these transformations, making IPO a suitable framework for processing spatial data and presenting results for planning and decision-making (Güneralp et al., 2017).

CHAPTER II
REVIEW OF RELATED LITERATURE

Land Use and Land Cover (LULC) Change Concepts

Rattanarat et al. (2024) describe land use and land-cover (LULC) classification as a dynamic process influenced by both natural factors and human activities. Changes in land cover and land use are continuously shaped by environmental conditions and human decisions.

Similarly, Seto, Güneralp, and Hutyra (2012) highlight that urban land-cover change threatens biodiversity and reduces ecosystem productivity due to habitat loss, decreased biomass, and reduced carbon storage.

GIS and Remote Sensing in LULC Monitoring

Attri, Chaudhry, and Sharma (2015) emphasized that Remote Sensing and GIS are essential tools for analyzing land use and land cover (LULC) changes, enabling efficient collection and interpretation of spatial data. Similarly, Prakasam (2010) noted that these technologies support effective analysis, planning, and modeling of land use issues. Yildirim et al. (2002) further highlighted that multitemporal GIS and remote sensing data are highly useful for detecting LULC changes at the regional level, improving the reliability of monitoring.

Urbanization and Agricultural Land Conversion

Urbanization is a major driver of land use and land cover (LULC) change, as population growth increases demand for housing and infrastructure, leading to the conversion of agricultural and natural lands into built-up areas.

Ceccarelli et al. (2014) noted that high-quality lands are increasingly threatened by mismanagement and inappropriate land-use changes, particularly urban expansion and unsustainable agriculture. Meanwhile, Araza et al. (2026) highlighted that policies such as Republic Act 9700 aim to protect prime agricultural lands, but there is still limited comprehensive analysis on the extent of land conversion and its policy implications.

Philippine and Local Context of LULC Studies

Janiola and Puno (2018) demonstrated the application of remote sensing and GIS in monitoring and mapping land cover changes in the Allah Valley landscape, producing baseline maps that support local government and stakeholder decision-making. Similarly, Mapili (1996) established that GIS is an effective tool not only for mapping land use changes but also for analyzing their relationships with environmental conditions.

Several studies further emphasize the impacts of urban expansion on land use. Soriano et al. (2019) reported a 117% increase in built-up areas within the buffer zone of the Mount Makiling Forest Reserve from 1992 to 2015, despite existing land management policies, indicating growing pressure on ecologically sensitive areas. In addition, Estoque and Murayama (2017) identified a significant increase in impervious surfaces and a corresponding decline in green spaces in Baguio City between 1987 and 2015. Supporting these findings, Macaspac, Valenzuela, and Ramos (2024) observed that residential areas now occupy a substantial portion of the city's land area, contributing to urban congestion and the encroachment of development into open and forested lands.

CHAPTER III
METHODOLOGY

Research Design

This study employed a descriptive quantitative research design using GIS-based change detection to assess land use and land cover (LULC) changes in Bulacan Province from 2020 to 2025. Change detection refers to the process of identifying differences in land conditions over time (Singh, 1989).

The analysis focuses on identifying, quantifying, and comparing LULC patterns between the two periods. GIS was utilized to support spatial visualization and quantitative assessment of land transformations, providing a reliable approach for analyzing temporal changes (Moisa et al., 2023). By integrating multi-temporal datasets, the study also examines the extent and rate of LULC conversion across categories (Panuju et al., 2020).

Methodological Limitations

This study relies on secondary LULC datasets; thus, the accuracy of the results depends on the quality and classification accuracy of the source data. No field validation or ground-truthing was conducted to verify actual land conditions.

Minor differences in total computed area between the 2020 and 2025 datasets may be attributed to variations in source resolution, boundary delineation, digitization, and classification methods. Although consistent GIS processing procedures were applied, such discrepancies are inherent in secondary spatial data.

To ensure comparability, the analysis prioritizes percentage-based distribution rather than absolute area values. Hence, results should be interpreted as indicative of general LULC trends rather than exact, ground-validated land conversions.

Additionally, the study is limited to two time periods (2020 and 2025), which may not fully capture intermediate land use changes.

Locale of the Study

The study focuses on Bulacan Province, located in Region III (Central Luzon), Philippines. It serves as a transition zone between the highly urbanized National Capital Region and the agricultural areas of Central Luzon, with a diverse landscape that includes coastal areas, industrial zones, and agricultural lands.

Bulacan was selected due to its proximity to the National Capital Region and its ongoing urban and infrastructure development, which significantly influence land use patterns. The province has experienced rapid conversion of agricultural lands into residential and industrial areas, making it a suitable site for examining spatial and temporal land use changes using GIS techniques.

Figure 2: Satellite View from QGIS of Bulacan, Region 3, Philippines

Data Analysis Procedures

The analysis was executed using QGIS to process, interpret, and visualize spatial data. To address the complexities of land transformation, the procedure followed a structured, multi-stage workflow:

1. **Data Preparation**
   The 2020 and 2025 LULC datasets were reprojected to a common coordinate reference system and clipped using the same Bulacan provincial boundary shapefile to ensure spatial comparability.
2. **Clipping and Standardization**
   Both datasets were clipped using a consistent provincial boundary shapefile to maintain uniform spatial extent. LULC classifications were standardized across both datasets to ensure comparability.
3. **Spatial Analysis and Mapping**
   The spatial distribution of land cover types was mapped for both years to visualize patterns and identify dominant land use categories.
4. **Change Detection Analysis**
   A comparative analysis was conducted to determine changes in area and percentage of each LULC category between 2020 and 2025. The analysis focused on identifying increases, decreases, and stable land cover types.
5. **Quantitative Assessment**
   Area measurements were computed in hectares and converted into percentage values to determine the relative distribution of each category.

To quantify the distribution of land use and land cover (LULC), the percentage of each category was computed using the formula:

For percentage area:

Percentage Area = (Area of LULC Category / Total LULC Area) × 100

For percentage change:

Percentage Change = [(2025 Value − 2020 Value) / 2020 Value] × 100

These computations were used to identify increases and decreases in each LULC category and to support the comparative analysis of land use trends.

Data Sources

The study utilized secondary spatial datasets obtained from the Philippine Geoportal and other relevant GIS repositories. The primary datasets include LULC maps for the years 2020 and 2025, which were treated as pre-classified land use and land cover layers. GIS-based change detection methods are widely utilized to monitor these dynamics, providing a cost-effective and repeatable means of territorial data collection (Ngondo et al., 2021).

The LULC categories analyzed include closed forest, open forest, annual crop, perennial crop, brush/shrub, built-up area, grassland, inland water, open/barren land, mangrove forest, marshland/swamp, and fishpond.

A provincial boundary shapefile of Bulacan was also used to ensure spatial consistency during analysis.

Table 1.GIS Datasets Used

Dataset	Source	Type	Year
LULC Map	Philippine Geoportal	Polygon/ Raster	2020
LULC Map	Philippine Geoportal	Polygon/ Raster	2025
Provincial Boundary	Geoportal/ PSA	Shapefile	Latest
Supporting Literature	Journals/ Reports	Text	Various

CHAPTER IV
RESULT AND DISCUSSION

The Results and Discussion section presents the findings of the land use and land cover assessment of the Province of Bulacan for the years 2020 and 2025 using GIS mapping techniques. This section also interprets and discusses the data analyzed.

Thematic Map

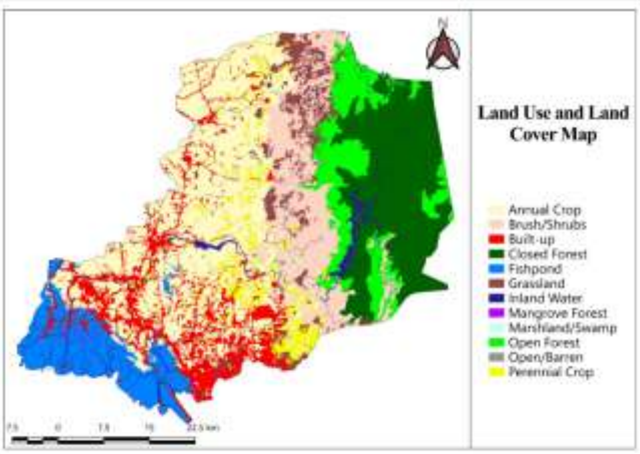


Figure 3: Land Use and Land Cover Map of Bulacan Province, 2020

Figure 3 presents the land use and land cover (LULC) map of Bulacan Province for 2020, showing the spatial distribution of different land cover categories. The map indicates that annual crops occupy the largest portion of the province, while built-up areas are concentrated in developed zones. This spatial pattern reflects the dominance of agricultural land use alongside emerging urban areas, particularly in locations influenced by proximity to metropolitan regions (Güneralp et al., 2017).

Based on the 2020 LULC data, annual crops dominate the landscape, covering approximately 67,520.37 hectares, indicating that a large portion of Bulacan remains primarily agricultural. This is consistent with studies showing that agricultural land continues to be a major land use in developing regions due to food production demands and land suitability (Ceccarelli et al., 2014). The dominance of agricultural land also suggests the continued reliance of the province on farming activities for economic and food security purposes.

Closed forest areas, covering about 47,306.81 hectares, are mainly located in the eastern portion of the province. These forested areas contribute to ecological stability, biodiversity conservation, carbon storage, and watershed protection (Seto et al., 2012). In addition, forest cover plays a crucial role in regulating hydrological processes such as reducing surface runoff and preventing soil erosion.

Brush/shrubs and built-up areas also occupy significant portions of land. The presence of built-up areas reflects ongoing urban development processes, which are commonly observed in provinces near metropolitan regions (Güneralp et al., 2017). This spatial distribution suggests that Bulacan is undergoing gradual urban transition, particularly in areas closer to transport networks and economic centers.

Fishpond areas are concentrated in coastal and low-lying zones, highlighting the role of aquaculture in local livelihoods. This distribution aligns with typical land use patterns in the Philippines, where coastal areas are often utilized for fish production (Briones, 2017).

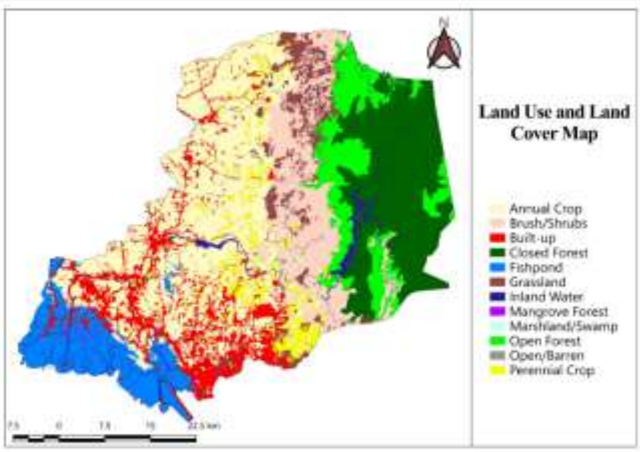


Figure 4: Land Use and Land Cover Map of Bulacan Province, 2025

Figure 4 presents the land use and land cover (LULC) map of Bulacan Province for 2025, showing the spatial distribution of different land cover categories. The map indicates that annual crops remain the dominant land cover, although built-up areas have expanded compared to 2020. This reflects ongoing urban expansion, particularly in areas influenced by transportation networks and proximity to metropolitan regions (Güneralp et al., 2017).

For 2025, annual crops remain the dominant land cover, although a slight decrease in area is observed. This trend may suggest gradual land conversion or shifts in land utilization, which is consistent with patterns of agricultural land transformation reported in previous studies (Araza et al., 2026). The reduction, although minimal, may reflect increasing pressure from urban development and infrastructure expansion.

Closed forest shows a slight increase in area; however, this result should be interpreted cautiously, as variations may be influenced by classification differences in GIS datasets rather than actual forest expansion (Wulder et al., 2018). Nonetheless, if the increase reflects real conditions, it may indicate localized conservation efforts or natural vegetation recovery.

Built-up areas increased to 36,581.18 hectares, which may be consistent with urban expansion trends observed in rapidly developing regions (Güneralp et al., 2017; Hegazy & Kaloop, 2015). This increase may have significant implications for land surface characteristics, particularly increased impervious surfaces that reduce infiltration, increase runoff, and contribute to flooding risks, especially in low-lying areas of the province.

Fishpond areas remain relatively stable, suggesting continued aquaculture activity and established land use patterns in coastal zones.

Table 2. Land use and land cover Area Distribution of Bulacan Province for 2020

2020	Area Per Hectare
Annual crop	67,520.37
Brush/shrubs	37,603.91
Built up	31,915.14
Closed forest	47,306.81
Fishpond	22,683.20
Grassland	11,943.31
Inland water	5,994.35
Mangrove forest	806.10
Marshland/Swamp	168.94
Open forest	16,336.72
Open/barren	969.05
Perennial crop	14,361.79
Total	**257,609.70**

Table 2 presents the land use and land cover (LULC) distribution of Bulacan Province for the year 2020, showing the area of each category measured in hectares. The table provides an overview of the spatial composition of the province at the beginning of the study period and serves as a baseline for comparison with subsequent years.

The dominance of annual crops in 2020 highlights the importance of agriculture in Bulacan's land use system. This finding is consistent with studies indicating that agricultural land remains a primary land use in regions with favorable farming conditions (Ceccarelli et al., 2014). Such dominance supports both local food production and rural economic activity.

The presence of forested and semi-natural areas such as closed forest and brush/shrubs supports ecological functions including biodiversity conservation, carbon sequestration, and climate regulation (Seto et al., 2012). These areas also contribute to maintaining environmental balance within the province.

Meanwhile, built-up areas reflect existing settlements and infrastructure, which are typically associated with population growth and economic development (Güneralp et al., 2017). The spatial distribution of these areas may indicate zones of higher economic activity and accessibility.

Table 3. Land Use and Land Cover Area Distribution of Bulacan Province for 2025

2025	Area Per Hectare
Annual crop	65,795.71
Brush/shrubs	36,161.32
Built up	36,581.18
Closed forest	48,444.65
Fishpond	22,798.46
Grassland	9,343.37
Inland water	6,085.16
Mangrove forest	768.40
Marshland/Swamp	305.82
Open forest	16,821.99
Open/barren	925.48
Perennial crop	13,577.34
Total	**257,608.87**

Table 3 presents the land use and land cover (LULC) distribution of Bulacan Province for the year 2025. The table illustrates the spatial extent of each category in hectares and allows for comparison with the baseline data from 2020.

The 2025 data indicate that agriculture remains the dominant land use, although with slight reductions. This may suggest gradual land conversion, which has been observed in other parts of the Philippines where agricultural land is increasingly being transformed into built-up areas (Araza et al., 2026). This trend reflects the growing demand for residential and commercial space in developing provinces.

The increase in built-up areas is consistent with urban expansion trends reported in both local and global studies (Güneralp et al., 2017; Hegazy & Kaloop, 2015). This expansion may have implications for land management, including increased demand for infrastructure, transportation, and drainage systems.

Fishpond areas remain substantial, which may suggest continued aquaculture activities. However, without detailed transition analysis, this study does not confirm whether these areas have expanded or remained unchanged due to stable land use practices.

Table 4. Percentage Distribution and Percentage Change of LULC Categories in Bulacan Province from 2020 to 2025

Percentage Changes per LULC	2020 (%)	2025 (%)	Percentage changes (%)	Trend
Annual Crop	26.21	25.54	-2.56	Decrease (−)
Brush/Shrubs	14.60	14.04	-3.84	Decrease (−)
Built-up	12.39	14.20	14.61	Increase (+)
Closed Forest	18.36	18.81	2.45	Increase (+)
Fishpond	8.81	8.85	0.45	Increase (+)
Grassland	4.64	3.63	-21.77	Decrease (−)
Inland Water	2.33	2.36	1.28	Increase (+)
Mangrove Forest	0.31	0.30	-3.23	Decrease (−)
Marshland/ Swamp	0.07	0.12	71.43	Increase (+)
Open Forest	6.34	6.53	3.00	Increase (+)
Open/Barren	0.38	0.36	-5.26	Decrease (−)
Perennial Crop	5.58	5.27	-5.56	Decrease (−)

The table presents the percentage distribution of land use and land cover (LULC) for the years 2020 and 2025, showing varying degrees of change across categories over the five-year period.

The large percentage increase in marshland/swamp should be interpreted with caution, as its base area in 2020 was very small, which can exaggerate percentage change values.

Grassland showed a notable decrease from 4.64% in 2020 to 3.63% in 2025. This decline may suggest possible land conversion to other uses or classification differences, which are common limitations in GIS-based studies (Wulder et al., 2018). If the change reflects actual land transformation, it may indicate increasing development or agricultural expansion.

Built-up areas increased from 12.39% to 14.20%. This increase is consistent with urbanization trends, where expanding populations and economic activities drive land development (Güneralp et al., 2017; Seto et al., 2012). The expansion of built-up areas may contribute to environmental challenges such as increased runoff, reduced infiltration, and higher flood susceptibility, particularly in urbanizing regions.

Closed forest showed a slight increase (+2.43%), but this should be interpreted cautiously, as such changes may reflect classification variability rather than actual forest growth (Wulder et al., 2018). Nevertheless, maintaining forest cover remains important for ecological sustainability.

Annual crops slightly decreased but remained dominant, suggesting that agriculture continues to play a major role despite increasing development pressures. This balance between agricultural retention and urban expansion reflects the transitional nature of land use in Bulacan Province.

Overall, the observed changes are consistent with broader land use trends where urban expansion, agricultural adjustment, and environmental variability interact to shape land cover patterns over time (Seto et al., 2012; Güneralp et al., 2017). These findings highlight the importance of integrated land use planning to balance development and environmental sustainability.

CHAPTER V
SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

This study utilized Geographic Information System (GIS) techniques to systematically assess and map land use and land cover (LULC) changes in the Province of Bulacan over a five-year period from 2020 to 2025. Secondary spatial datasets from the Philippine Geoportal were used to establish baseline conditions for 2020 and compare them with 2025 data to identify spatial patterns and changes over time.

The results indicate that Bulacan maintains a diverse land use composition, with annual crops consistently serving as the dominant land cover category despite a slight decrease in area. The most notable relative increase was observed in marshland/swamp areas, although they remain minimal in total extent. Built-up areas also showed a significant increase, indicating continued urban expansion, particularly in zones influenced by proximity to Metro Manila. In contrast, grassland exhibited the most notable decline among land cover types, suggesting possible conversion to other land uses or classification shifts in the dataset.

Closed forest also showed a slight increase, indicating that forested areas remain an important component of the provincial landscape. Overall, annual crop areas remained dominant across both years despite gradual reduction.

Overall, the observed changes reflect gradual but clear shifts in land use patterns driven by urban development, agricultural transitions, and environmental dynamics. GIS-based mapping effectively illustrated these trends by providing spatial representations of their distribution and extent.

CONCLUSION

The analysis of land use and land cover in Bulacan Province from 2020 to 2025 reveals a landscape undergoing gradual transformation that may be associated with environmental and socio-economic factors discussed in related literature. The province remains predominantly agricultural, with annual crops occupying the largest share of land use despite a slight decline in area.

The increase in built-up areas may be associated with urban expansion and infrastructure development pressures, particularly because of Bulacan’s proximity to Metro Manila. Meanwhile, closed forest showed a slight increase in the mapped dataset, suggesting relative stability in the Geoportal-derived classification.

The observed decrease in grassland and annual crop areas suggests potential shifts in land utilization, possibly influenced by development pressures or changes in land management practices. Additionally, the increase in marshland/swamp areas may indicate localized environmental changes in low-lying regions.

Overall, the study demonstrates that GIS and remote sensing are effective tools for identifying general land use trends and spatial patterns. However, due to the use of secondary data, the findings should be interpreted as indicative trends rather than exact land conversions. These results can support planning and decision-making related to sustainable land use and environmental management in Bulacan Province.

RECOMMENDATIONS

Based on the results and conclusion of the study, the following recommendations are suggested:

- Regular GIS-based monitoring of land use and land cover in Bulacan Province should be conducted to continuously track changes in urban expansion, agricultural areas, and other land cover categories over time.
- Local planners and government agencies should consider the observed increase in built-up areas when preparing land use, zoning, and infrastructure development plans to support sustainable urban growth.
- Agricultural lands and environmentally sensitive areas should be continuously monitored and protected to promote sustainable land management and minimize potential environmental impacts associated with land cover change.
- Future studies should incorporate ground validation and additional time periods to improve the accuracy, consistency, and reliability of land use and land cover (LULC) analysis.
- Further research may also include analyses related to flood risk, population growth, and urban development to better understand the possible factors influencing land cover changes in Bulacan Province.

REFERENCES

1. Araza, A. B., Gagarin, W., Corales, M. C., Osorio, C. P., Mendoza, M. D., & Ancog, R. (2026). Land-use conversion from agricultural production areas to built-up areas in the Philippines (2000–2020): Spatial analysis and policy implications. *Land Use Policy, 162*, 107874. https://doi.org/10.1016/j.landusepol.2025.107874
2. Attri, P., Chaudhry, S., & Sharma, S. (2015). Remote sensing & GIS-based approaches for

LULC change detection: A review. *International Journal of Current Engineering and Technology*, *5*(5), 3126–3137.

3. Briones, R. M. (2017). *Characterization of agricultural land conversion in the Philippines*. Philippine Institute for Development Studies. https://pidswebs.pids.gov.ph/CDN/PUBLICATIONS/pidsdps1702.pdf
4. Briones, R. M., & Castro, N. (1986). Effective management of a tropical watershed: The case of the Angat River Watershed in the Philippines. *Water International*, *11*(4), 157–161. https://doi.org/10.1080/02508068608686432
5. Ceccarelli, T., Bajocco, S., Perini, L., & Salvati, L. (2014). Urbanisation and land take of high-quality agricultural soils: Exploring long-term land use changes. *International Journal of Environmental Research*, *8*(1), 181–192. https://doi.org/10.22059/IJER.2014.707
6. Ellis, E. C. (2011). Anthropogenic transformation of the terrestrial biosphere. *Philosophical Transactions of the Royal Society A*, *369*(1938), 1010–1035. https://doi.org/10.1098/rsta.2010.0331
7. Estoque, R. C., & Murayama, Y. (2017). Monitoring surface urban heat island formation in a tropical mountain city using Landsat data (1987–2015). *ISPRS Journal of Photogrammetry and Remote Sensing*, *133*, 18–29. https://doi.org/10.1016/j.isprsjprs.2017.09.008
8. Güneralp, B., Reba, M., Hales, B. U., Wentz, E. A., & Seto, K. C. (2017). Trends in urban land expansion, density, and land transitions (1970–2010). *Global Environmental Change*, *44*, 1–9. https://doi.org/10.1016/j.gloenvcha.2017.02.005
9. Hegazy, I. R., & Kaloop, M. R. (2015). *Monitoring urban growth and land use change detection using GIS and remote sensing. International Journal of Sustainable Built Environment*, *4*(1), 117–124. https://doi.org/10.1016/j.ijsbe.2015.02.005
10. Iizuka, K., Johnson, B. A., Onishi, A., Magcale-Macandog, D. B., Endo, I., & Bragais, M. (2017). Modeling future urban sprawl and landscape change in Laguna de Bay, Philippines. *Land*, *6*(2), 26. https://doi.org/10.3390/land6020026
11. Janiola, M. D. C., & Puno, G. R. (2018). Land use and land cover change detection using Landsat imagery: Allah Valley, Philippines. *Journal of Biodiversity and Environmental Sciences*, *12*(2), 98–108.
12. Macaspac, K. L., Valenzuela, M. L., & Ramos, R. V. (2024). Land use land cover (LULC) change analysis in Baguio City using GIS-based transition potential modeling. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-4/W8-2023, 357–363. https://doi.org/10.5194/isprs-archives-XLVIII-4-W8-2023-357-2024
13. Mapili, M. C., Jr. (1996). Land-use and water quality: A GIS evaluation of Pampanga River Basin. University of British Columbia. https://dx.doi.org/10.14288/1.0087872
14. Moisa, M. B., Busha Hinkosa, L., Negasa, G. F., Olika, G., Ijigu, T. E., Wedajo, Y. N., Gurmessa, M. M., Deribew, K. T., & Gemeda, D. O. (2023). GIS and remote sensing based analysis of Land use and Land cover Change in the Upper Anger watershed, Western Ethiopia. *Geology, Ecology, and Landscapes*, 1–10. https://doi.org/10.1080/24749508.2023.2237323
15. Ngondo, J., Mango, J., Liu, R., Nobert, J., Dubi, A., & Cheng, H. (2021). Land-Use and Land-Cover (LULC) Change Detection and the Implications for Coastal Water Resource Management in the Wami–Ruvu Basin, Tanzania. *Sustainability*, *13*(8), 4092. https://doi.org/10.3390/su13084092
16. Panuju, D. R., Paull, D. J., & Griffin, A. L. (2020). Change Detection Techniques Based on Multispectral Images for Investigating Land Cover Dynamics. *Remote Sensing*, *12*(11), 1781. https://doi.org/10.3390/rs12111781
17. Prakasam, C. (2010) LU and LC Change Detection through Remote Sensing Approach: A Case Study of Kodaikanal Taluk, Tamil Nadu. https://www.researchgate.net/publication/284879730_Land_use_and_land_cover_change_detection_through_remote_sensing_approach_Acass_study_of_Kodaikanal_taluk_Tamil_nadu
18. Prashanth, M., Kumar, A., Dhar, S., Verma, O., Rai, S. K., & Kouser, B. (2023). LULC change and soil erosion in Himalayan watershed. *Frontiers in Forests and Global Change*, *6*. https://doi.org/10.3389/ffgc.2023.1124677
19. Prestele, R., Alexander, P., Rounsevell, M. D. A., Arneth, A., Calvin, K., Doelman, J., Eitelberg, D., Engström, K., Fujimori, S., Hasegawa, T., Havlík, P., Herrero, M., Krisztin, T., Kyle, P., Meiyappan, P., Popp, A., Sands, R., Schaldach, R., Schüngel, J., … Verburg, P. H. (2016). Hotspots of uncertainty in land-use projections. *Global Change Biology*, *22*, 3967–3983. https://doi.org/10.1111/gcb.13337
20. Rattanarat, C., Jaroensutasinee, K., Jaroensutasinee, M., & Sparrow, E. B. (2024). Land use/land cover and environmental impacts. *Emerging Science Journal*, *8*(5), 1783–1797. https://doi.org/10.28991/ESJ-2024-08-05-06

21. Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion. *PNAS*, *109*(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109
22. Seto, K. C., Sanchez-Rodriguez, R., & Fragkias, M. (2010). The new geography of urbanisation. *Annual Review of Environment and Resources*, *35*, 167–194. http://www.igbp.net/download/18.5831d9ad13275d51c098000263/1376382967979/Seto.ARER.2010.pdf
23. Shalaby, A., & Tateishi, R. (2007). Remote sensing and GIS for land cover change. *Applied Geography*, *27*(1), 28–41. https://doi.org/10.1016/j.apgeog.2006.09.004
24. Singh, A. (1989). Review article: Digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing*, *10*(6), 989–1003. https://doi.org/10.1080/01431168908903939
25. Skyttner, L. (2005). *General Systems Theory: Problems, Perspectives, Practice*. World Scientific Publishing.
26. Soriano, M., Nolasco, J. B., Geronimo, R. C., & Hernandez, A. J. (2019). Land use/land cover change and urban sprawl in the Philippines. *Environments*, *6*(2), 9. https://doi.org/10.3390/environments6020009
27. Wagh, R. V., & Auti, S. K. (2025). Role of GIS in land use planning. *International Journal of Innovations in Science Engineering and Management*, *4*(1), 366–370. https://doi.org/10.69968/ijisem.2025v4i1366-370
28. Wulder, M. A., Loveland, T. R., Roy, D. P., Crawford, C. J., Masek, J. G., Woodcock, C. E., Allen, R. G., Anderson, M. C., Helder, D., Irons, J. R., Johnson, D. M., Kennedy, R., Scambos, T. A., Schaaf, C., Schott, J. R., Sheng, Y., Vermote, E. F., Belward, A. S., Bindschadler, R., Cohen, W. B., … Zhu, Z. (2018). Status of Landsat program and future prospects. *Remote Sensing of Environment*, *225*, 127–147. https://doi.org/10.1016/j.rse.2018.04.015
29. Yildirim, H., Özel, M. E., Radberger, R., & Akça, A. (2002). Monitoring von
30. Landnutzungsänderungen über einen langen Zeitraum mit Hilfe von Satellitenfernerkundung und GIS. *Allgemeine Forst- und Jagdzeitung*, 173, 15–20.