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GIS-Based Analysis of Land Use and Land Cover Changes in Peñaranda, Nueva Ecija Between 2020 and 2025

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ABSTRACT: This study focuses on the updating of the Land Use and Land Cover (LULC) map of Peñaranda, Nueva Ecija from 2020 to 2025, emphasizing its significance in supporting sustainable land management, urban planning, and environmental monitoring. Understanding spatial and temporal land cover changes is essential for informed decision-making, particularly in the preservation of agricultural areas and other critical land resources.

The study utilizes Geographic Information Systems (GIS) as the primary analytical tool to examine LULC changes within the municipality. It is limited to the geographic scope of Peñaranda and relies on secondary data derived from remotely sensed imagery. The accuracy of the results is dependent on the quality and resolution of the satellite data used. Field validation was not conducted, and the analysis primarily focuses on spatial land cover changes.

Spatial datasets obtained from Geoportal for the years 2020 and 2025 were processed and analyzed using GIS techniques to evaluate LULC dynamics in the study area. The findings indicate that urban expansion is a major driver of land use change in Peñaranda, likely influenced by population growth, infrastructure development, and increasing land demand.

Overall, the study suggests that Peñaranda, Nueva Ecija is undergoing a gradual transition from a predominantly agricultural landscape toward a more urbanized environment. The observed increase in built-up areas alongside the decline in agricultural land highlights ongoing land conversion processes driven by socio-economic development pressures.

KEYWORDS: GIS Mapping, Land Use and Land Cover, LULC Change, Peñaranda, Nueva Ecija, Urban Expansion, Agricultural Land Conversion

I. INTRODUCTION

1.1 Background of the Study

As the global population is projected to reach 9.7 billion by 2050, the competition for land resources between food production, infrastructure, and renewable energy development is becoming increasingly critical (Blaydes et al., 2025). Due to rapid urbanization, population growth, and environmental degradation, shortages of suitable land for agriculture and crop development are intensifying globally. Agriculture is undeniably essential for human survival, economic development, and societal stability, often considered the fundamental pillar of human civilization (Unity Environmental University, 2025). Consequently, acres of agricultural land are dedicated to farming and crop cultivation. However, with the population growing at an exponential rate, the demand for residential and commercial development is higher than ever, resulting in increased competition with agricultural use.

Land covers only 30% of the Earth's surface, and 44%, almost half of the habitable land area, is used for agriculture, totaling a range of 48 million square kilometers (Ritchie and Roser, 2019). Even though the Earth is not running out of physical space, land resources are becoming scarce across different regions due to various driving factors.

Peñaranda was historically recognized for producing high-quality crops, particularly betel leaf, locally known as *ikmo*, which was traditionally used as a chewing substance among older generations. However, the cultivation of betel leaf has steadily declined over the years, with only a limited number of farmers continuing its production. However, rice remains a flourishing crop, allocating hectares of land for its production (Municipality of Peñaranda, 2020). With a growing population of 29,882 in 2015, increasing to 32,269 in 2020, the municipality experienced a 7.99% population growth. This increase has intensified the demand for expanded residential and commercial areas (Municipality of Peñaranda, 2023).

A reverse relationship exists between population growth rate and the availability of infrastructure facilities in cities (Tripathi, 2017). As population increases, municipalities such as Peñaranda are compelled to expand residential, commercial, and infrastructural developments to meet growing demands. In response, several facilities have been established, including the RHU Peñaranda X-Ray Facility, NEUST–Peñaranda Academic Extension Campus, and the Peñaranda Public Market (Municipality of Peñaranda, 2025). In addition, agricultural land in Peñaranda is expected to host the largest solar photovoltaic (PV) installation in the Philippines, known as the MTerra Solar Project, which involves converting previously utilized ranch and agricultural lands into construction areas for renewable energy development (Skujins, 2024). Furthermore, the Department of Public Works and Highways has contributed to land cover changes through a 2.09-kilometer road rehabilitation project, which includes the removal of damaged pavement and the construction of new concrete roads (DPWH, 2025). Collectively, these developments contribute to the conversion of agricultural land into built-up areas, significantly driving land use and land cover changes.

Updated land use and land cover maps are necessary to understand the extent and distribution of land conversion. Lamien and Farzaneh (2025) determined that land use and land cover serve as critical factors in the site selection process in ensuring safety, economic viability, and environmental sustainability. Without accurate and updated spatial data, planners, policymakers, and engineers may face challenges in assessing the environmental and socio-economic impacts of built-up area developments. Unregulated transformation of annual and perennial crop lands in Peñaranda can trigger a cascade of negative environmental impacts. Analyzing land use and land cover spatial data from 2020 and 2025 can provide valuable insights into how built-up expansion and natural processes have transformed agricultural landscapes in the municipality.

Therefore, this study aims to analyze and compare the land use and land cover spatial maps of Peñaranda between 2020 and 2025 to determine the extent of agricultural land conversion associated with residential and commercial development and natural processes.

1.2 Statement of the Problem

This study aims to determine and analyze the updated Land Use and Land Cover (LULC) of Peñaranda, Nueva Ecija, Philippines by comparing spatial data between the years 2020 and 2025. Specifically, this research seeks to address the following questions:

1. What are the existing land use and land cover maps in Penaranda, Nueva Ecija?
2. What spatial changes in land use and land cover occurred between 2020 and 2025?
3. What factors are associated with the observed changes in land use and land cover in Peñaranda, Nueva Ecija between 2020 and 2025?
4. What updated information can be generated using Geographic Information System (GIS) regarding the land use and land cover of Peñaranda, Nueva Ecija?

1.3 Significance of the Study

This study examines the Land Use and Land Cover (LULC) of the Municipality of Peñaranda, focusing on the changes in agricultural land between 2020 and 2025. The findings of this research are expected to benefit several key groups:

Civil Engineering Students. The study can help students understand how land use changes over time and how these changes influence land planning and infrastructure development. It may also help them apply concepts related to land analysis, site evaluation, and environmental considerations in real-world engineering situations.

Engineers and Practicing Professionals. The findings may assist engineers in evaluating land conditions when planning or designing projects in areas where land conversion is occurring. By understanding land use and land cover changes, engineers can better consider site suitability, environmental impacts, and sustainable development practices.

Urban and Regional Planners. The results of the study may support planners in monitoring land use changes and managing the balance between agricultural land, infrastructure development, and renewable energy projects. This information can help guide future land-use planning and promote sustainable community development.

Government Agencies. The study may provide useful information for agencies involved in land management, agriculture, and energy development. Understanding land use changes associated with solar farm development can support informed decision-making in policy development, land management, and sustainable energy planning.

Future Researchers. This research may serve as a reference for future studies related to land use change, renewable energy development, and environmental management. It can provide baseline information that other researchers can use in examining the long-term impacts of solar farm expansion on land resources.

1.4 Scope and Limitations

This study analyzes Land Use and Land Cover (LULC) conditions in Peñaranda, Nueva Ecija through a comparison of datasets from 2020 and 2025. Existing LULC data from Geoportal Philippines were processed using QGIS to assess spatial changes in land use and land cover.

The study is limited to secondary data within the municipality and does not involve the generation of new LULC maps or field validation. Results depend on the accuracy and resolution of the existing datasets and exclude detailed socio-economic and environmental impact analysis.

1.5 Conceptual Framework

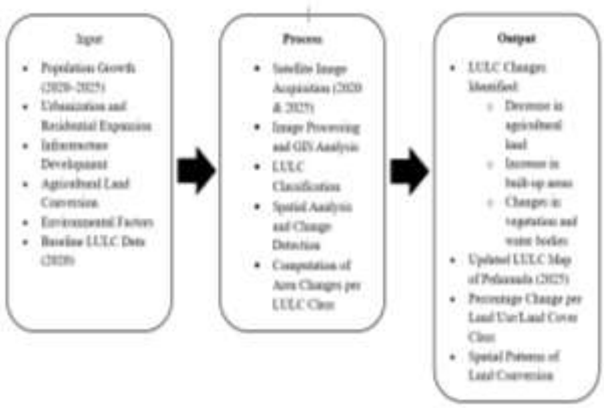

Figure 1. GIS-Based Analysis of LULC Changes

II. REVIEW OF RELATED LITERATURE

Review of Related Literature

2.1 GIS and Remote Sensing for Land Use and Land Cover (LULC) Mapping

Land Use and Land Cover (LULC) mapping has become increasingly advanced through the integration of Geographic Information Systems (GIS) and remote sensing technologies, which provide reliable spatial and temporal data for environmental monitoring and land management.

Fu and Weng (2016) explored the application of remote sensing and GIS in detecting urban expansion and land use changes. Their study demonstrated that integrating satellite imagery with spatial analysis techniques enables accurate identification of land cover transitions, particularly the conversion of vegetated and agricultural lands into urban areas. They further emphasized that LULC mapping plays a crucial role in sustainable urban planning by providing reliable data for decision-making and environmental management. These findings support the relevance of GIS-based LULC analysis in assessing spatial changes and guiding future land use strategies.

Similarly, Kumar et al. (2023) highlighted the importance of satellite imagery and Geographic Information Systems (GIS) in analyzing LULC changes over time. Through the integration of spatial and temporal datasets, these tools allow researchers to visualize complex land conversion patterns and monitor environmental changes with high accuracy. In particular, GIS and remote sensing facilitate the detection of agricultural land loss, urban expansion, and vegetation changes over long periods, providing essential input for informed planning and sustainable land management.

Wagh (2025) further emphasized that Geographic Information System (GIS) has become a vital tool in land use and land cover (LULC) analysis, offering a clear and accessible way to visualize complex spatial data and support informed decision-making. By integrating spatial and temporal information, GIS enables researchers and stakeholders to monitor changes in land use, assess environmental impacts, and plan for sustainable resource management. Numerous studies have emphasized the role of GIS in enhancing the accuracy of LULC mapping, guiding land management strategies, and supporting policy formulation. In the context of converting agricultural land into solar farms, GIS facilitates the identification and quantification of transformed areas, helping planners balance energy development with food security concerns. By providing data-driven insights, GIS strengthens land use planning, optimizes land allocation, and promotes resilient, sustainable development practices

Advancements in methodological approaches further strengthen LULC analysis.,Fargas Jr., Narciso, and Blanco (2021) investigated the spatiotemporal dynamics of agricultural land conversion in Cavite, a major rice-producing province in the Philippines. The study highlighted that continuous conversion of agricultural lands poses significant threats to food security, yet monitoring has been limited due to ineffective policies. To address this, the researchers developed an operational methodology for generating Land Use and Land Cover (LULC) change maps using a multi-sensor remote sensing approach, integrating Landsat 8 and Sentinel-1 imagery. By combining optical and radar datasets, and employing Random Forest classification along with feature selection algorithms, the study produced high-accuracy LULC maps that could detect agricultural-to-built-up conversions even at small spatial scales. The results demonstrated that multi-sensor approaches provided superior classification accuracy compared to single-sensor methods, emphasizing the importance of integrating different types of satellite data for precise monitoring.

Over the last few decades, Geographic Information Systems (GIS) have significantly advanced in terms of processing capabilities and analytical applications. In a study conducted in the Hulan River Basin in northeastern China, Cheng et al. (2024) quantitatively assessed soil loss, identified erosion hotspots, and generated a soil erosion risk map using a GIS-based Universal Soil Loss Equation (USLE) model. The results indicated that increased human activities contributed to a slight rise in high-erosion-risk areas, particularly in regions with intensive land use. Despite some limitations due to reliance on empirical equations and limited field validation, the model proved useful in understanding the spatial distribution of soil erosion and supporting land management decisions. These findings highlight the critical role of GIS in LULC change analysis, particularly in areas with high human activity, such as agricultural lands and croplands, where monitoring and sustainable management are essential.

The integration of crowdsourced geospatial data has also emerged as an important development in LULC mapping. A study integrating OpenStreetMap (OSM) data with Landsat time-series imagery demonstrated that volunteered geographic information can enhance supervised classification of LULC. In this research, polygon datasets tagged for "landuse" and "natural" from OSM were automatically extracted and used alongside NDVI-derived satellite image data to classify LULC categories over the Laguna de Bay region of the Philippines. Although the OSM data contained class noise due to mismatches in tag definitions, it enhanced rapid LULC map production when combined with remote sensing and machine learning algorithms, achieving high overall classification accuracy. This approach shows how freely available, crowdsourced geographic data such as OSM can be incorporated into GIS-based LULC mapping workflows, which is relevant to studies that use OSM standards and plugins in QGIS for updating and analyzing land cover changes (Johnson & Iisuka, 2016).

From a Comprehensive Review on Land Use/Land Cover (LULC) Change Modeling for Urban Development: Current Status and Future Prospects by Srishti Gaur (2022), land use and land cover (LULC) modeling is recognized as one of the most effective approaches for analyzing and predicting the dynamics of land transformation and future development trends. The study highlights the application of various LULC modeling techniques, including traditional statistical methods, machine learning algorithms, and hybrid approaches that combine both, to achieve more accurate and spatially detailed analyses. These models are particularly valuable for land management and urban planning, as they allow the integration of policy frameworks, environmental data, and socio-economic factors to support informed decision-making and sustainable land use strategies.

2.2 Agricultural Land Conversion and Environmental Impacts

Agricultural land conversion has become one of the most critical consequences of rapid land use change, particularly in developing regions, where it significantly affects food security and ecosystem stability.

De Luna et al. (2021) emphasized the significance of remote sensing and GIS in identifying and measuring temporal land cover changes. Their research demonstrated that converting agricultural land for alternative uses can lead to significant shifts in surface cover, which may affect soil conditions and reduce the area available for cultivation. By mapping these changes, remote sensing enables the evaluation of trade-offs between land allocated for infrastructure or renewable energy facilities and agricultural production. Such analysis provides critical insights into how the expansion of solar-powered farms may influence local crop productivity and the sustainability of agricultural landscapes in transitioning areas.

Similarly, a study conducted by Araza et al. (2025) in the Philippines identified Central Luzon as a primary hotspot for the conversion of agricultural land into built-up areas. A national-scale spatial analysis (2000–2020) led by researchers from the University of the Philippines revealed a strong correlation ($r = 0.89$) between the loss of croplands and the expansion of infrastructure and industrial projects in the region. The study emphasized that rapid urban expansion has intensified pressure on agricultural lands, raising critical concerns regarding food security and environmental sustainability. The findings highlight the necessity of institutionalizing spatial planning through high-resolution Earth Observation mapping and GIS to protect and manage agricultural areas effectively.

Environmental implications of land conversion extend beyond land loss. Ven et al. (2021) found that land use and land cover changes can lead to variations in carbon storage depending on regional conditions and land management practices. The study highlights that the conversion of vegetation-rich areas, such as forests and agricultural lands, results in measurable changes in land cover characteristics. These findings emphasize the importance of monitoring and analyzing LULC changes to better understand the extent and nature of land transformation over time

In rapidly urbanizing environments, these impacts become more pronounced. Gabisa et al. (2025) reported significant LULC changes in Burayu Sub City, Shager City, Ethiopia from 1993 to 2023 have been attributed to urbanization and population pressure. The study revealed a substantial decrease in croplands, forest lands, and grasslands over the 30-year period, while settlement areas expanded dramatically, leading to the large-scale conversion of agricultural land into built-up areas. The researchers credited expansion of agricultural land, deforestation for fuelwood and charcoal production, infrastructure construction, overgrazing, and the extension of both rural and urban settlements as the direct drivers of the ecosystem services decline, resulting in a 38.4% decrease in agricultural practices and food security. These findings emphasize the significant influence of human activities on landscape characteristics and ecosystem services, highlighting the need to integrate environmental considerations into local development planning, particularly in agricultural areas such as Peñaranda, Nueva Ecija.

Similarly, Caiyong et al. (2020) examined LUCC and climate change impacts on the Ecosystem Vulnerability (ESV) using remote sensing and some statistical models around the Yellow River, Ningxia, China. Eleven classes of LUCC were identified during 1995 and 2019: village land, bare land, grassland, industrial land, irrigated land, swamp land, tidal flat, transportation land, urban land, water bodies, and water channels. Grassland may be decreased annually with a percentage − 5.873% due to some human activities and environmental changes in climate from one season to another.

From a hydrological perspective, Anastacio and Trespalacio (2023) stated the impact of land use and land cover (LULC) on hydrology is gaining increased attention due to global concerns about water sustainability.

topic, there were only a few publications that specifically focused on the effects of LULC on soil water infiltration. This study gathered and synthesized relevant research publications and performed co-occurrence and co-citation analyses to identify the existing themes and the research development trend on LULC-soil infiltration relation. Analysis of 103 Scopus-indexed articles from as early as 2000 revealed four major themes: soil characteristics, hydrology and watershed, hydrology and management, and groundwater and LULC. These findings highlight key areas of focus and can assist in identifying research gaps and topics requiring further exploration. The paper offers a concise overview of the current research trajectory in the realm of LULC and soil water infiltration.

The increasing population in urban areas has increased the conversion of agricultural land to urban use. Bravo (2017) examined the level and speed of urbanization in the Philippines and its influence on agriculture. Over the last 20 years, the level of urbanization in the Philippines has stabilized, but the tempo has decreased, which implies a higher growth rate in the rural population than in the urban population. The influence of urbanization is seen in terms of the declining share of agriculture in the national economy and a minimal reduction in employment in the agricultural sector. Urbanization has resulted in decreases in the area and fragmentation of farm parcels as well as in the conversion of agricultural lands to urban use. The process of urbanization resulted in substantial land conversion, which, in turn, led to a drastic decrease in crop production areas and changed the agricultural landscape of the Metropolitan Manila area. It also placed pressure on urban fringes, making land use conversion inevitable in cities. Findings point to the need for concomitant policies to preserve agricultural lands and sustain domestic food production, and promote urban agriculture to create and preserve the green and open spaces in the cities.

According to Chakraborty et al. (2019), planning of land use and infrastructure in advance for a population that is projected to grow rapidly is highly important for its sustainable development. A correlative approach of land use shifts and infrastructure design is perhaps the best sustainable urban development option that can be made at present. This paper is aimed at suggesting policy foresight, in terms of infrastructure and land use management of Mega Manila. Using Land Change Modeller, this study assessed landscape pattern, change process and future scenario of land changes in the study area. The land use/landscape change pattern, with vulnerability analysis and predicting 2030 land use maps, enabled us to understand impacts of urban expansion on different land use sectors. Overall analysis of gains and losses in different land use categories across different sectors between 1989 and 2010 indicated that built-up area experienced the highest net gain of 90.96%.

2.3 Urban Expansion and Built-Up Area Growth

Urban expansion is one of the dominant drivers of land use change, leading to the continuous conversion of agricultural and natural landscapes into built-up areas.

Yourfee Kennedy (2024) from Eberswalde University for Sustainable Development examined land use and land cover changes in the Philippines from 2017 to 2023 using multi-temporal spatial analysis and climate data. The study revealed a significant increase in built-up areas due to rapid urban expansion, accompanied by the gradual conversion of agricultural and natural landscapes. It also highlighted that rising temperatures and irregular precipitation patterns influence environmental conditions and land surface dynamics. These changes are important from a geological perspective because land cover transformation can affect soil stability, drainage patterns, and surface processes, particularly in areas dominated by alluvial plains such as those found in Nueva Ecija. The findings are relevant to the present study because similar land conversions may occur with the development which require large land areas and may modify existing soil and land surface conditions.

Lamien and Farzaneh (2025) further emphasized the importance of integrating GIS into urban planning. Their study developed an integrated Land Use and Land Cover (LULC) modeling framework to guide land allocation in rapidly developing areas. The findings demonstrate that accurate LULC data are essential for identifying suitable land uses and supporting sustainable planning. Furthermore, the study emphasizes the role of Geographic Information Systems (GIS) in monitoring land transformation and aiding decision-making processes.

The increasing population and tourism in the "Summer Capital of the Philippines" have led to its rapid urbanization, elevating the demand for residential and commercial areas. According to Macaspac et al. (2023), residential areas account for 59.1% of Baguio's land area. However, with the increasing demand for housing, the expansion of new built-up areas is expected to continue occupying land. In this study, Land Use and Land Cover change assessment and modelling were done using the Modules for Land Use Change Evaluation (MOLUSCE) plugin in QGIS. Analyzing the LULC change between 2011 and 2019, the model predicted the expansion of new built-up areas away from the Central Business District, in line with the city's efforts to alleviate congestion, minimal built-up expansion in forest reservations, and avoiding development near hazardous sinkholes, aligning with the city's urban planning expectations as outlined in their Comprehensive Land Use Plan (CLUP). It can be concluded that QGIS is a viable tool for predicting future land use and land cover change, yielding an overall accuracy of 72.80%, serving as a guide for creating land use development plans.

Butuan City Land use and land cover (LULC) changes have been influenced by rapid urban development, prompting researchers to analyze the city using a landscape ecology approach and GIS. Multi-temporal satellite images from 1995, 2014, and 2024 were classified into five land cover types: tree cover, fields/crops, bare land, water, and built-up areas. Results showed a 41% decrease in tree cover and a 36% increase in built-up areas between 2015 and 2024, with tree cover largely replaced by bare land and fields/crops. Landscape metrics also revealed patterns of fragmentation and built-up expansion, especially in urbanizing zones (Beltran, 2025)

Research conducted on land cover change in Nueva Ecija demonstrates the effectiveness of Geographic Information Systems (GIS) and remote sensing technologies in analyzing land use and land cover (LULC) dynamics over time (Bulaong et al., 2018). Through the use of multi-temporal satellite imagery and classification techniques, the researchers were able to identify significant transformations in agricultural, forest, and urban areas in Nueva Ecija. Notably, their findings showed that built-up areas consistently increased at a faster rate compared to other land cover types, largely influenced by urbanization and population growth, while natural and agricultural lands were gradually reduced due to land conversion. These findings support the present study by establishing consistent patterns of land transformation and confirming the reliability of GIS-based methods in monitoring LULC changes for informed planning and sustainable land management.

The Department of Public Works and Highways (2025) reported the completion of a road rehabilitation project in Barangay Sinasajan, Peñaranda, Nueva Ecija, aimed at improving transportation, connectivity, and trade between nearby municipalities. Infrastructure developments such as road expansion and improvement play a significant role in accelerating urban growth, as they increase accessibility and encourage the conversion of nearby lands into residential, commercial, and service areas. Such improvements in connectivity are often associated with gradual shifts in land use patterns, particularly in areas experiencing increasing economic and development activities.

2.4 Philippine Municipal LULC Studies

Local-scale studies in the Philippines provide important insights into land use dynamics and their environmental implications, particularly in agricultural and protected areas.

Doyog et al. (2021) on Mt. Pulag National Park in the Philippines demonstrates how GIS and satellite-based LULC monitoring can reveal the environmental impacts of human activities on natural landscapes. The study used multi-temporal satellite imagery to track shifts from forested areas to agricultural land, emphasizing the contribution of spatial analysis to land management and planning. These findings underscore the role of GIS and remote sensing in mapping changes and assessing ecological consequences, offering a framework for evaluating land use transformations in both natural and semi-developed regions.

In Nueva Ecija, Abella et al. (2023) from Central Luzon State University focused on optimizing land use allocation to achieve sustainable development. The study assessed various land classifications, including agricultural, institutional, and residential areas, as part of the university's Land Use Development and Infrastructure Plan for 2021–2031. It utilized multiple goal linear programming as a decision-support tool to balance development needs with environmental considerations. The findings highlight the importance of accurate land use classification and mapping in supporting effective planning, resource allocation, and sustainable land management.

Similarly, Tumbaga (2023) analyzed land cover changes in Minalungao National Park using remote sensing and GIS based on NAMRIA classification. The study identified four land cover types and found acceptable classification accuracy across multiple years. Results showed improved forest cover within the park due to restoration and monitoring efforts, while surrounding areas experienced forest decline due to land conversion. The study emphasized the importance of continuous LULC monitoring using GIS to support land use planning and environmental management.

2.5 Population Growth and Urban Expansion

Population growth is widely recognized in international literature as a major driver of residential land expansion, particularly in rapidly urbanizing areas where increasing population levels intensify housing demand and accelerate the outward spread of built-up environments. This process is often characterized by the conversion of agricultural and peri-urban lands into residential and commercial zones as cities continuously adjust their spatial structure to accommodate demographic pressures. Shih et al. (2022) emphasize that residential land expansion is strongly associated with demographic growth and urban migration, highlighting how expanding populations reshape urban form and land use patterns over time.

Population increase is considered one of the primary factors influencing urban expansion and land use change, as increasing population creates higher demand for housing, infrastructure, and services, leading to the conversion of agricultural and natural lands into built-up areas. In the Philippines, studies have shown that rapid urbanization is closely linked to population increases, resulting in the expansion of urban areas and transformation of land cover over time (Santillan & Heipke, 2024). Moreover, recent studies highlight that urban growth is increasingly occurring in provincial and municipal areas, emphasizing the role of population pressure in shaping spatial development patterns and the need for effective land use planning (Dela Cruz & Valdez, 2026)). These changes can be effectively analyzed using Geographic Information Systems (GIS), utilizing spatial data from platforms such as OpenStreetMap and Philippine Geoportal to monitor land use and land cover changes over time.

According to the Philippine Statistics Authority (2016), the mid-year population of Peñaranda, Nueva Ecija was 32,269 in 2020 and is projected to reach 35,225 by 2025, signaling a steady increase in population pressure within the municipality. Several studies support the relationship between population growth and land transformation. Research has shown that rapid population increase and urban expansion are closely linked to the rise of built-up areas and the decline of agricultural land. For instance, studies on LULC change indicate that urban expansion, often driven by population growth and migration, results in significant conversion of cropland and open space into residential and commercial areas (Sen, 2025). Similarly, findings from LULC analyses reveal that population growth exerts pressure on limited land resources, contributing to the expansion of urban areas and the reduction of vegetation and agricultural land (Hassan et al., 2016).

In the Philippine context, similar patterns can be observed at the local level, where empirical studies further illustrate the direct relationship between population increase and urban land transformation. A GIS-based study conducted in Calamba City revealed that rapid population growth significantly influences urban expansion, particularly through the transformation of agricultural lands and open spaces into residential and commercial developments. The study found that increasing population size drives higher demand for housing, infrastructure, and economic services, thereby contributing to the continuous growth of built-up areas. It further notes that, without effective land-use planning and management, such expansion can result in environmental degradation and inefficient spatial development. These findings underscore the importance of GIS-based spatial analysis in understanding land-use dynamics and in supporting more sustainable urban planning and policy formulation in rapidly growing urban areas (Bagarinao, 2015).

2.6 Agriculture and Food Security

Agriculture remains the backbone of the global food system. As noted by Islam (2025), it provides employment to over one billion people worldwide, making it the largest employment sector. Despite this, agriculture is increasingly challenged in meeting the rising demand for food. With the global population expected to approach 10 billion by 2050, food production must expand by about 50% to sustain future needs. This surge in demand is compounded by pressing environmental and socio-economic issues, including climate change, soil degradation, water scarcity, and unequal resource distribution. In this regard, the interconnected roles of agriculture, food security, and sustainability are vital in addressing these challenges. Ensuring sustainable agricultural practices is key to maintaining productivity while protecting natural resources. A comparable scenario is evident in Peñaranda, where rapid population growth and the conversion of agricultural land into built-up areas pose increasing threats to food security and the resilience of the local economy.

2.7 Spatiotemporal Analysis of Land Use and Land Cover (LULC) Change

Spatiotemporal analysis of Land Use and Land Cover (LULC) change is a key approach in GIS and remote sensing that examines how land use patterns change across both space and time. It is widely applied in detecting land conversion trends, particularly in rapidly developing areas, as it allows researchers to quantify changes and understand their spatial distribution and driving factors.

Withanage et al. (2024) demonstrated the effectiveness of Landsat time-series data in capturing long-term LULC changes, particularly in identifying gradual land conversion processes. Their findings show that spatiotemporal analysis is essential in revealing continuous transitions such as vegetation loss and built-up expansion, which may not be visible in single-date analysis. This highlights the importance of multi-temporal datasets in producing more reliable land change assessments.

Similarly, Muhammad et al. (2022) emphasized that spatiotemporal LULC analysis is not only descriptive but also predictive. Using GIS-based modeling (MOLUSCE), the study showed that land cover changes are influenced by both physical and socio-economic drivers, resulting in increasing impervious surfaces and declining green spaces. This indicates that spatiotemporal analysis can support future land use planning by simulating possible development scenarios.

In the Philippines, Masancay et al. (2025) found that urban sprawl in Davao City can be effectively mapped through LULC time-series analysis, revealing a steady expansion of built-up areas at the expense of agricultural and open lands. This reinforces the role of spatiotemporal methods in identifying urban growth patterns and land conversion trends in local contexts.

Supporting this, Leonylyn et al. (2024) highlighted that accurate land cover classification is crucial for spatiotemporal analysis, as reliable outputs depend on high classification performance. Their use of the Random Forest algorithm in Nueva Ecija achieved strong accuracy in distinguishing land cover classes, confirming that machine learning improves the reliability of temporal land change assessments.

Overall, these studies show that spatiotemporal LULC analysis is an effective tool for understanding land transformation, as it integrates spatial patterns, temporal changes, and classification accuracy. In relation to Peñaranda, Nueva Ecija, this approach is essential for identifying and quantifying land use changes between 2020 and 2025, particularly the conversion of agricultural areas into built-up land.

III. METHODOLOGY

3.1 Research Design

This study adopts a geospatial change detection design using remote sensing and Geographic Information Systems (GIS) techniques, providing a comprehensive framework for analyzing Land Use and Land Cover (LULC) patterns. This approach enables the systematic identification, classification, and quantification of spatial changes over time, allowing for a data-driven assessment of LULC distribution and transformations in Peñaranda. It is particularly suitable for analyzing spatial datasets such as maps and satellite imagery, as it facilitates accurate representation of land cover categories including built-up areas, agricultural lands, vegetation, water bodies, and other classifications. This design aligns with the objectives of the study, which focus on evaluating both the extent and temporal changes in land use and land cover within the study area.

Data is obtained from GeoPortal maps and other spatial datasets, which are processed and analyzed using QGIS software. Satellite imagery and existing land cover data are classified to generate LULC maps for selected time periods, and these maps are subsequently compared to detect spatial changes. The analysis includes calculating area and percentage changes for each land use class to determine patterns of gain and loss. Through this approach, the study provides a clear, consistent, and quantitative evaluation of land dynamics and their relationship with environmental risks in the study area.

3.2 Research Locale

The study was conducted in the Municipality of Peñaranda, a predominantly agricultural area in the province of Nueva

Ecija. The municipality is composed of several barangays with varying land uses. This setting provides an appropriate context for analyzing changes in land use and land cover (LULC) over time, particularly regarding agricultural land conversion and urban expansion.

This research focused on identifying and comparing the LULC of Peñaranda for the years 2020 and 2025. The analysis aimed to determine changes across different land cover types. By examining these changes, the study provides insight into how land use patterns in the municipality have evolved over the past decade.

The study was limited to the geographical boundaries of Peñaranda and did not include neighboring municipalities or other regions. Data were obtained from available online sources and processed using geospatial tools such as QGIS and the Philippine Geoportal. These tools were used to generate, visualize, and compare LULC maps for the selected years. The study relied solely on secondary data and mapping techniques, with no field validation or primary data collection conducted

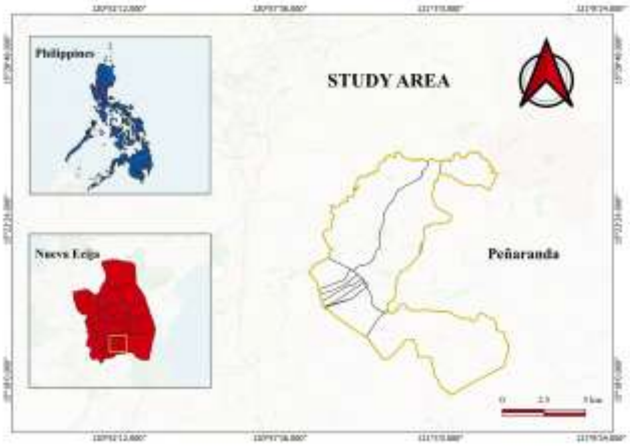

Figure 2. Study Area

3.3. Data Collection

This case study utilized secondary data to analyze the land use and land cover (LULC) of Peñaranda, Nueva Ecija. The study used existing LULC datasets obtained from Geoportal Philippines, which were processed and analyzed in QGIS software for comparison between the years 2020 and 2025. QGIS served as the primary tool for data visualization, spatial analysis, and map generation. The QuickMapServices plugin, particularly the OpenStreetMap (OSM) Standard basemap, was used as a visual reference to support map interpretation and validation.

The LULC data were then examined and compared across the selected years to identify spatial changes in categories such as agricultural land, built-up areas, vegetation, and water bodies.

Overall, the use of GIS-based secondary data provided an efficient, cost-effective, and reliable approach to assessing and updating the LULC of Peñaranda, Nueva Ecija

3.4 Research Instrument

This study utilizes Geographic Information Systems (GIS) as the primary research tool to analyze Land Use and Land Cover (LULC) changes in Peñaranda, Nueva Ecija. LULC data for the years 2020 and 2025 were obtained from Geoportal Philippines and served as the main data source.

Spatial analysis and mapping were conducted using QGIS. The datasets were imported and processed within the software, while the QuickMapServices plugin (using OSM Standard basemap) was utilized for visual reference and map validation. These tools were used to analyze and visualize LULC data and assess spatial changes over time.

3.5 Data Analysis

The spatial data obtained from Geoportal Philippines for the years 2020 and 2025 were processed and analyzed using QGIS to examine Land Use and Land Cover (LULC) changes in Peñaranda, Nueva Ecija. Existing LULC datasets were clipped to the municipal boundary of Peñaranda and processed within the software for spatial analysis. The researchers did not perform independent satellite image classification. Instead, the study utilized pre-classified LULC categories from the existing datasets, including annual crops, built-up areas, inland water, perennial crops, shrubs, grassland, barren land, and fishponds. The areal extent and percentage distribution of each LULC class were calculated, and comparative analysis was conducted to assess spatial changes between 2020 and 2025.

IV. RESULTS AND DISCUSSION

4.1 Results

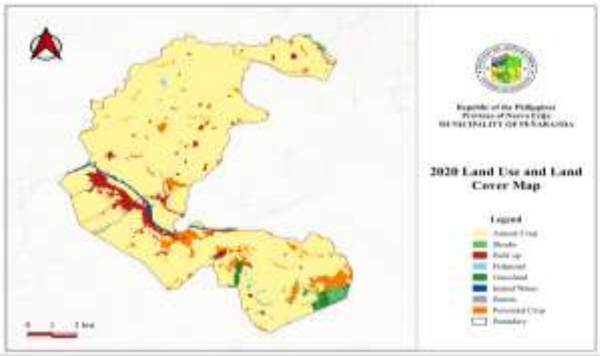

Figure 3. 2020 Land Use and Land Cover Map of Peñaranda, Nueva Ecija

Figure 3 presents the 2020 Land Use and Land Cover (LULC) map of Peñaranda. The map shows that annual crops were the dominant land use class across the municipality, followed by built-up areas, while the fishpond class occupied the smallest proportion. Among the barangays, Sto. Tomas recorded the largest extent of built-up areas because of its large land mass compared to the four Poblacions. In contrast, Las Piñas, Sinasajan, and Callos were primarily composed of annual and perennial crops, indicating their strong agricultural land use during this period. The presence of roads is noticeable; however, the network appears to terminate before reaching Las Piñas, suggesting limited connectivity or incomplete infrastructure development.

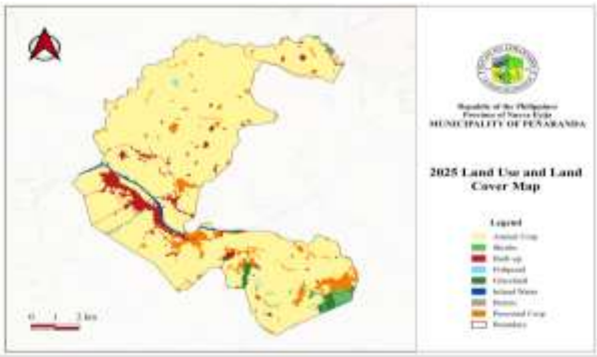

Figure 4. 2025 Land Use and Land Cover Map of Peñaranda, Nueva Ecija

Figure 4 shows the updated 2025 LULC map which reveals that annual crops remain the dominant land use class despite a noticeable decline over the 5-year period. Significant changes in land cover distribution are observed in several barangays. Las Piñas, which was previously dominated by agricultural land with sparse built-up areas, now exhibit an increase in built-up areas, indicating ongoing land conversion.

While the built-up areas in the town center, particularly in Poblacion I, II, III, and IV, remain relatively concentrated with minimal expansion, a portion of agricultural land in Las Piñas has been converted into built-up areas. Additionally, the previously unconnected road in Sinasajan is now linked to San Leonardo through Las Piñas, indicating improved road connectivity within the municipality.

Table 1. LULC Classifications and it's Percent Changes Between 2020 and 2025

LULC Classifications	Percentage in 2020	Percentage in 2025	Change in Percentage
Annual Crop	68.9153	63.7327	-5.1826
Shrubs	9.5031	9.3900	-0.1131
Built-up	18.4248	23.8455	+5.4207
Grassland	1.1872	1.1688	-0.0184
Inland water	0.0077	0.0076	-0.0001
Barren	0.0144	0.0141	-0.0002
Perennial	1.9033	1.7978	-0.1055
Fishpond	0.0442	0.0435	-0.0007
Total	100	100	

Table 1 presents the areal distribution and percentage share of each land use and land cover (LULC) class in 2020 and 2025. In 2020, annual crops occupied the largest portion of the study area, accounting for 68.9153% of the total land area. Over the 5-year period, this class experienced a decline of 5.1826%, decreasing to 63.7327% in 2025. Despite this reduction, annual crops remained the dominant land use class, consistent with the spatial patterns observed in the LULC maps.

The most significant and only increase was observed in built-up areas, which expanded by 5.4207%. From only 18.42483% in 2020, built-up areas rose sharply to 23.8455% in 2025, indicating rapid urban development within the municipality.

Hydrological land cover classes, such as inland water and fishponds, exhibited minimal declines. Inland water, which occupied only 0.0077% in 2020, slightly decreased to 0.0076% in 2025. Similarly, fishponds declined marginally from 0.0442% to 0.0435%.

Other land cover types also showed slight reductions in extent. Grassland decreased from 1.1872% to 1.1688%, while barren land declined from 0.0144% to 0.0141%. Shrubland, which covered a relatively larger area compared to other minor classes, decreased from 9.5031% to 9.3900%. Perennial crops also declined from 1.9033% to 1.7978%. These changes are relatively minor and are not visually distinguishable in the LULC maps, but are detectable through quantitative classification and area-based analysis.

Overall, the observed changes in LULC classes indicate a gradual shift from predominantly agricultural land use toward increased urbanization, with built-up areas expanding at the expense of agricultural and vegetated land covers. All classes collectively account for 100% of the total land area in both years.

4.2 Discussion

The most notable change between 2020 and 2025 in the Municipality of Peñaranda was the conversion of annual crop areas to built-up land, where annual crops experienced a decrease of 5.1826%, while built-up areas increased by 5.4207%. This significant shift reflects the ongoing transformation of Peñaranda, Nueva Ecija from a predominantly agricultural landscape into a more urbanized environment.

This phenomenon can possibly be attributed to multiple drivers in the area, particularly population growth and infrastructure development. According to the Municipality of Peñaranda (2023), the population increased from 29,882 in 2015 to 32,269 in 2020. In a relatively small agricultural municipality, this increase is linked to higher demand for housing, road expansion, and public services (Santillan & Heipke, 2024). This is evident in the expansion of built-up areas in barangays such as Poblacion I, II, III, and IV, as well as in Las Piñas, which were previously dominated by agricultural land. Developments such as the San Isidro–General Tinio Road Rehabilitation, MTerra Solar Project, NEUST–Peñaranda Academic Extension Campus, Peñaranda Public Market, and other infrastructure projects have contributed to these land cover changes. These local observations support the findings of Araza et al. (2025), which identified a strong correlation between the loss of croplands and the expansion of built-up areas. Sen (2025) associated rapid population increase and urban expansion with the rise of built-up areas and the decline of agricultural land. Kennedy (2024) further supported this idea, revealing that rapid urban expansion likely leads to the gradual conversion of agricultural and natural landscapes into developed areas. A similar trend was observed in Butuan City, where rapid urban development influenced the decrease of tree cover (Beltran, 2025). These studies support the theory that the decline of annual crop areas in Peñaranda might be primarily driven by infrastructure development and urban expansion brought about by population growth.

Considering that Peñaranda is located in Nueva Ecija, a province widely recognized for its agricultural productivity, the reduction in annual crop areas raises concerns about the sustainability of its land use practices. If these unregulated LULC changes continue, they may lead to environmental and socio-economic consequences. Ven et al. (2021) revealed that land use changes may result in variations in carbon storage depending on regional conditions and land management practices. In Peñaranda, where many residents depend on agriculture for their livelihood, the rapid conversion of farmland threatens to intensify pressure on remaining agricultural areas. This raises critical concerns regarding local food security and may strain the municipality's local economy. Islam (2025) associated the threat to food security and local economy to demand of the growing population. Farmers and farm laborers form the backbone of agriculture. However, without sufficient agricultural land, food production cannot be sustained, placing significant strain on local food security and the economy. Gabisa et al. (2025) also emphasized that the degradation and conversion of annual and perennial croplands might lead to a decline in agricultural practices and threaten food security.

The use of satellite imagery and Geographic Information Systems (GIS), particularly Geoportal PH and QGIS (QuickMapServices - OSM Standards), plays a crucial role in analyzing land use and land cover changes over time in municipalities like Peñaranda. GIS enables the visualization and quantification of spatial transformations, clearly demonstrating how annual crop areas decreased from 68.9153% in 2020 to 63.7327% in 2025. This approach is particularly useful in areas where field validation is limited but land use changes are occurring rapidly. These identified drivers are largely derived from previous studies and should be considered as general interpretations, as they may not fully represent the actual conditions in Peñaranda. The analysis relies mainly on GIS-based observations, supplemented by findings from related literature.

However, despite its effectiveness, GIS-based analysis has several limitations. The accuracy of results is highly dependent on the quality of input data. Inaccurate, outdated, or low-resolution satellite imagery can lead to errors in mapping and misclassification of land use and land cover. In a municipality like Peñaranda, where land parcels are relatively small and diverse, low spatial or temporal resolution may fail to capture detailed features, making it difficult to distinguish between similar land cover types such as built-up areas and bare land. Furthermore, automated classification methods may produce errors due to spectral similarities among crops, grassland, and shrubs. These limitations should be considered when interpreting the results of the study.

V. SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 Summary

The focus of the study is to examine the updated Land Use and Land Cover in Peñaranda, Nueva Ecija from the selected years 2020 and 2025. To achieve this, gathering of data will require the use of a software that can generate the spatial analysis and mapping of the area. The tool used in this study is the QGIS (Quantum Geographic Information System), it is a free open-source GIS software used to generate, analyze, and visualize spatial or geographic data.

Secondary data, including satellite imagery, were processed using QGIS to produce an updated LULC map of Peñaranda, Nueva Ecija. The gathered data shows that built-up areas around the location undergo rapid increment. It increased by 5.420654985% after 5 years. The data simply demonstrate an increasing urbanization. The portion that implies the largest occupancies between the years 2020 and 2025 is the annual crops, consisting of 68.9153% of the total land area. Five years later, there occurs a reduction of 5.182564284% leading to the value of 63.73273% in 2025. When it comes to the inland water and fishponds, it shows almost the same value in percentage for both years, though it has a small decrease of -0.000119379 for inland water and -0.000686415 for fishponds.

The remaining classifications such as shrubs, grassland, barren, and perennial depict a slight reduction after five years. From 9.503093, shrubs became 9.389992, while grassland decreased -0.018427985. Barren land declined from 0.0144% to 0.0141% and perennial decreased -0.105533123.

5.2 Conclusions

The analysis of Land Use and Land Cover (LULC) in Peñaranda, Nueva Ecija from 2020 to 2025 shows that the municipality remains predominantly agricultural, but noticeable changes in land distribution have occurred. The most evident change is the decline in annual crop areas alongside the increase in built-up land, indicating a gradual transformation in land use patterns. Despite these shifts, agricultural land continues to occupy the largest share, highlighting its continued importance in the municipality while also reflecting emerging changes in how land is being utilized.

These trends imply that land conversion is occurring at a steady pace, placing increasing pressure on available land resources. The observed changes suggest that factors such as population growth, infrastructure development, and rising land demand are influencing land use, which may affect agricultural productivity and environmental conditions if not properly managed. The findings of this study are valuable for planners and decision-makers as they provide a clearer understanding of current land use trends and support the use of GIS-based analysis in planning. This highlights the need for balanced and sustainable land-use strategies that accommodate development while preserving agricultural land and environmental resources in Peñaranda.

5.3 Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. **For Future Researchers**

Future studies may expand the temporal scope by including additional years to better capture long-term Land Use and Land Cover (LULC) trends in Peñaranda. The use of higher-resolution satellite imagery and additional spectral indices is also recommended to improve classification accuracy. Moreover, integrating ground validation and considering factors such as population growth and infrastructure development can provide a more comprehensive analysis of land use changes.

2. **For Practitioners**

Local government units and planners may utilize the generated LULC maps as a basis for land use planning and policy formulation. The application of GIS can support informed decision-making in managing lands and regulating urban expansion. Continuous monitoring of land cover changes is recommended to promote sustainable land management.

3. **For Improving the Study**

The study may be enhanced by incorporating field validation to verify accuracy of land cover classifications. The inclusion of additional datasets, such as socio-economic and environmental data, can provide deeper insights into the drivers of land use change. Furthermore, the use of advanced classification techniques and machine learning approaches may improve the overall reliability and precision of the results.

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