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GEOSPATIAL ANALYSIS OF LAND USE LAND COVER AND POPULATION DENSITY IN CONGRESSIONAL DISTRICT 2, DAVAO CITY

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ABSTRACT
Urban expansion has become a major issue in many cities today. Despite cities having borders, constant expansion has resulted in urban areas becoming bigger than they were originally designed to be. The effects of fast population growth have an even more profound impact on Davao City, which is considered to be the most rapidly growing urban area in the Philippines with a total population of 1,765,385 people as of 2020. Examining the relationship between land cover land use and population density is important in understanding trends of urban expansion and developing evidence-based policies for sustainable spatial planning. This study analyzed the land use land cover (LULC) changes in Congressional District 2, Davao City between 2020 and 2024 and its relationship with population density through Geographic Information System (GIS) and bivariate correlation analysis. Land cover data was acquired from Environmental Systems Research Institute (ESRI). Meanwhile, population data for 2020 and 2024 were from Philippine Statistics Authority (PSA). Semi-automatic Classification Plugin (SCP) was utilized for land cover analysis while population density was calculated in GIS. Chloropleth maps for population density were created and overlay analysis was utilized to determine relationships. Results showed that higher population densities were concentrated in the built-up areas of second congressional district, whereas forested areas exhibited dispersed population. Both 2020 and 2024 revealed identical coefficient (-0.037) which indicate consistent pattern that forestlands are associated to lower population densities across different timelines. Subsequently, built-up areas had a negative relationship (0.210 and 0.022) for 2020 and 2024, respectively. Expansion of built-up area was attributed to horizontal development. The findings demonstrate that land cover influences population density highlighting the importance of accommodating urban growth while protecting forestlands, agricultural land, and waterways.

Keywords:
Land use Land Cover, Population Density, GIS, Second Congressional District, Davao City

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INTRODUCTION

Urban expansion has become a major issue in many cities today. Despite cities having borders, constant expansion has resulted in urban areas becoming bigger than they were originally designed to be (Masancay et. al, 2025). Deliberately, urbanization has become a major phenomenon with about 56% of the world's population being in urban areas in 2020 and rising to 68% in 2050 (Zegeye et al., 2026). Nonetheless, fast urbanization has led to urban sprawl and improper use of land. (Lu et al., 2020). These changes highlight the importance of understanding land use and land cover dynamics as a foundation for sustainable urban and environmental planning.

Expansion of cities can also play a role in the destruction of habitats, loss of biodiversity, increasing flood hazards, and climatic effects (United Nations Human Settlements Programme [UN-Habitat], 2022; Intergovernmental Panel on Climate Change [IPCC], 2023). It is, therefore, important to monitor and analyze the LULC changes using geospatial methods in order to identify trends of urban expansion and facilitate planning decisions (United Nations, 2023; European Space Agency, 2021). New research has further shown improvements in LULC change modelling for urban planning by using GIS, remote sensing, and machine learning (Gaur & Singh, 2023). The effects of fast population growth have an even more profound impact on Davao City, which is considered to be the most rapidly growing urban area in the Philippines with a total population of 1,765,385 people as of 2020 (Saniel & Salapa, 2024).

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Urbanization in the Philippines has been another cause of land changes, especially in highly urbanized areas where human activities have transformed land use. In Davao City, it has been associated with an increase in built-up areas and vegetation changes, indicating the effect of human activities on LULC changes (Dumdumaya & Cabrera, 2023). The expansion of residential communities, economic activities, and infrastructure development has resulted in the conversion of agricultural, open, and vegetated areas into built-up spaces (Department of Human Settlements and Urban Development [DHSUD], 2020; PSA, 2023). Sustainable spatial planning faces difficulties with growing populations increasing the need for public amenities, housing, and green open spaces (Putri, 2025). In this context, understanding LULC dynamics at the local level is necessary to support appropriate land use policies and development strategies, particularly in rapidly growing urban areas such as Davao City.

A substantial decline in both dense and moderate vegetation, accompanied by a continuous increase in non-vegetated areas, was observed across the three congressional districts of Davao City. These findings indicate extensive urban expansion and land conversion, resulting in the gradual transformation of vegetated landscapes into built-up and developed areas over time (Batican et al., 2025). The Second Congressional District of Davao City, composed of diverse urban and peri-urban communities, has undergone development pressures due to increasing settlement demands, infrastructure expansion, and economic activities (Davao City Planning and Development Office, 2023). These conditions emphasize the need to examine land cover and land use changes within the district to determine how urban expansion has altered the landscape between 2020 and 2024. Therefore, this study aims to investigate the land cover changes between 2020 and 2024. Specifically (a) analyze the land use land cover changes of Second Congressional District, Davao City between 2020 and 2024 (b) Calculate the population density of Second Congressional District, Davao City between 2020 and 2024 (c) Determine the spatiotemporal distribution of the population density in Second Congressional District (d) assess the relationship of LULC to population density.

Geographic Information Systems (GIS) have become an essential tool for spatial analysis, land resource management, and the integration of demographic and environmental data to support evidence-based planning (Longley et al., 2015). High population density can cause issues such as traffic congestion and air pollution, thereby affecting sustainable development and impacting the lives of the people living in urban areas (Lu et. al,2023). Using geospatial analysis, this study examines the spatiotemporal distribution of population density in the Second Congressional District of Davao City between 2020 and 2024 to provide valuable information on demographic trends that influence the land use patterns and urban expansion. Understanding these trends supports evidence-based planning and sustainable management of land resources.

Planning for a sustainable and resilient city should be informed by scientific knowledge and spatial data. Land use information, environmental monitoring and climate risk assessment can help governments develop their land use and prepare for disaster response and build climate-resilient cities. In addition, the report emphasizes that evidence-based urban planning can mitigate environmental risks and foster sustainable development objectives (United Nations, 2023).

Despite the importance of monitoring LULC changes and population growth, limited studies have focused on the spatial relationship between land transformation and population density at the district level in Davao City, particularly within the Second Congressional District. Existing studies often examine urban growth or population trends separately, creating a gap in understanding their interconnected impacts. Addressing this gap, the study applies geospatial analysis to examine LULC changes, population density patterns, and their relationship from 2020 to 2024. The study started by gathering land cover, land use, and population data from available sources. These datasets were processed and analyzed using GIS to examine the spatial distribution, changes, and relationships between landscape transformation and population dynamics.

The theoretical basis for this research is based on the Land Change Science (LCS) Framework. According to the LCS framework, LULC change arises from the interactions of demographic, socio-economic, environmental, and institutional factors. Population growth and urbanization play a great role in transforming land due to the increased need for residential land use, transport, commerce, and other infrastructures that convert lands into built-up land use (Turner et al., 2007; Verburg et al., 2004). The framework also highlights the significance of incorporating geospatial technologies, such as Geographic Information Systems (GIS) and remote sensing, to monitor, analyze, and understand the spatial and temporal dynamics of land change.

The conceptual foundation of this study is based on the framework proposed by Liu, B., Song, W., Meng, Z., & Liu, X. (2023), which identifies population growth, urbanization, and socioeconomic development as key drivers of land use and land cover change. Their framework highlights the application of GIS and remote sensing in monitoring spatial dynamics and emphasizes integrating geospatial information into planning and policy-making. Guided by this framework, the present study investigates the relationship between population density and LULC

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changes in the Second Congressional District of Davao. The findings of this study are expected to provide valuable information for local government planning, sustainable land management, disaster risk reduction, and environmental conservation within the district.

MATERIALS AND METHODS

Design and Procedure

This study employed a descriptive-quantitative research design. A descriptive research design was utilized because the study aims to describe and analyze the existing land use and land cover (LULC) changes and the population density distribution in the Second Congressional District of Davao City from 2020 to 2024. Descriptive research systematically presents the characteristics and spatial patterns of variables without manipulating them, making it appropriate for geographic and environmental studies (Creswell & Creswell, 2018).

A quantitative research design was employed because numerical and spatial datasets were analyzed using Geographic Information Systems (GIS) and statistical techniques. The study quantified changes in land cover areas, calculated population density, and measured the relationship between LULC changes and population density using statistical analysis. Quantitative research allows objective measurement and analysis of variables through numerical data.

The combination of descriptive and quantitative approaches is appropriate because the study not only describes the spatial distribution and temporal changes of land cover and population density but also statistically examines the relationship between these variables

This study utilized secondary data. Population data for the years 2020 and 2024 were obtained from the Philippine Statistics Authority (PSA). Land use and land cover (LULC) shapefiles were acquired from the Environmental Systems Research Institute (ESRI). Geographic Information System (GIS) software was used to process and analyze the spatial datasets. The GIS Field Calculator was utilized to compute the population density of each barangay by dividing the total population by its corresponding land area.

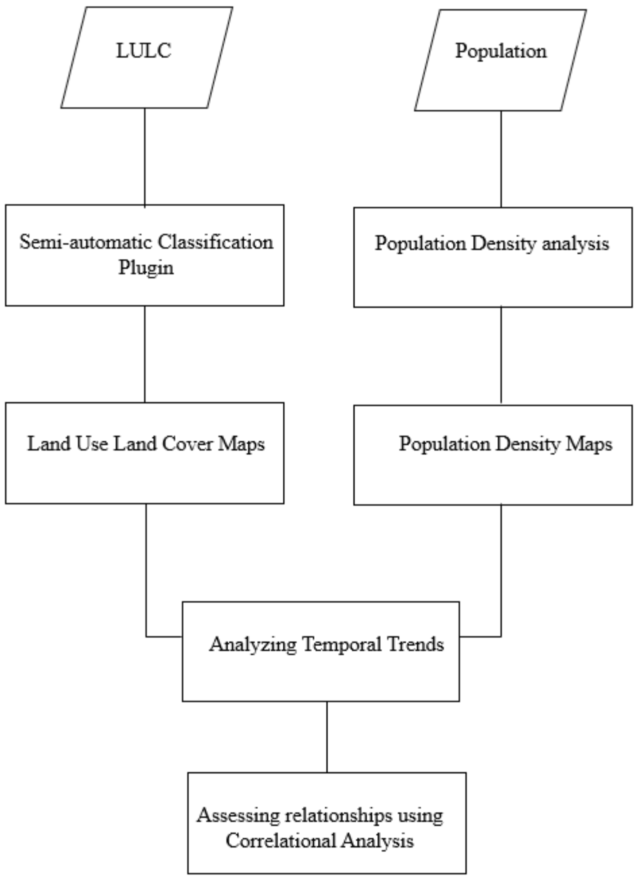

Figure 1. The procedure for conducting the study

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Furthermore, Land Use Land Cover (LULC) between 2018-2023 will be extracted from ESRI and will be categorized in QGIS using Semi-Automatic Classification Plugin (SCP). In QGIS, maps be generated comparing LULC and Population Density between 2020 and 2024 in Davao City. Once data has been acquired, data will be tabulated and be inputted in QGIS software. Chloropleth maps will be created in QGIS based on the population density data.

Bivariate correlation analysis will be used to determine the magnitude of correlation between land use categories and population density. Correlations between land use categories (built-up, forest areas, water bodies, barren areas, and agricultural areas) and population density were measured based on the calculations of the Pearson's correlation coefficient.

Study Area

The Second Congressional District of Davao City was selected as the study area because it represents a rapidly developing district characterized by a combination of urban, peri-urban, agricultural, and environmentally significant landscapes. The district encompasses expanding residential communities, commercial establishments, transportation corridors, and remaining agricultural and forested areas that are increasingly subjected to land conversion pressures. This diversity of land uses makes the district an appropriate case for examining the interaction between population growth and LULC changes. Moreover, the district has experienced continuous infrastructure investments and urban expansion, making it suitable for assessing the spatial effects of urbanization on land resources (CPDO, 2023; Department of Human Settlements and Urban Development [DHSUD], 2020).

The period from 2020 to 2024 was selected to capture recent patterns of landscape transformation following the implementation of major infrastructure projects, post-pandemic recovery, and continued urban expansion. This period also provides updated information that supports current local planning initiatives and aligns with the availability of recent satellite imagery and demographic datasets. Examining recent LULC changes enables planners and policymakers to better understand emerging development trends and formulate responsive land use policies.

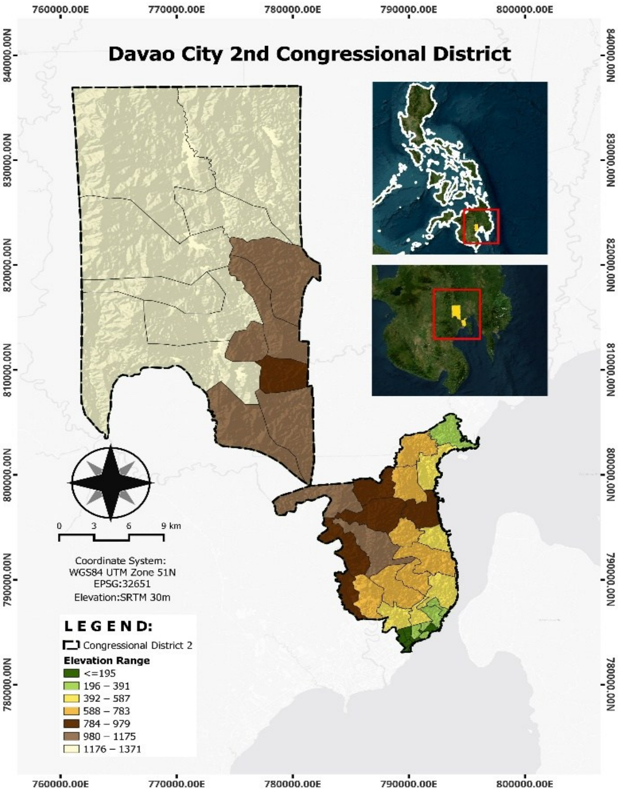

Figure 2. Map Showing the Location of the Study

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RESULTS AND DISCUSSION

Land Use Land Cover Change of Congressional District 2

Forestland remained the dominant land-cover class, increasing from 61,118.97 hectares (78.48%) in 2020 to 62,314.86 hectares (80.02%) in 2024. The apparent gain of 1,195.89 hectares may reflect vegetation regeneration, forest rehabilitation, improved protection, or the reclassification of previously barren or sparsely vegetated areas (Dumdumaya & Cabrera, 2023).

Built-up area expanded by 770.88 hectares, from 10.03% to 11.02% of the district. This is the clearest indication of continuing urban development and may be associated with the growth of settlements, commercial areas, roads, institutions, and other infrastructure (Allan et al., 2022). Because land-use change is influenced by population, accessibility, economic activity, planning decisions, and environmental constraints, the observed expansion should be interpreted as part of a broader urbanization process rather than as the result of a single factor (Allan et al., 2022; Dumdumaya & Cabrera, 2023).

Agricultural land declined by 331.18 hectares, while barren land decreased by 1,697.09 hectares. These changes suggest that some agricultural, exposed, or undeveloped areas may have been converted to built-up land or may have developed denser vegetation (Allan et al., 2022). The reduction in agricultural land is particularly important because continued conversion can fragment farms, reduce productive land, and affect farming livelihoods and local food production (Dela Cruz & Soriano, 2024). Waterbodies increased by only 61.50 hectares, a small change that may reflect seasonal water levels, rainfall, river width, or differences in image classification.

	Year				
LULC Classes	**2020**		**2024**		
	Area (ha)	**%**	**Area (ha)**	**%**	**%(-/+)**
Waterbodies	437.33	0.56	498.83	0.64	0.08
Forestland	61118.97	78.48	62314.86	80.02	**1.54**
Agricultural Area	1360.34	1.75	1029.16	1.32	**-0.43**
Built-up Area	7813.72	10.03	8584.6	11.02	**0.99**
Barren	7144.57	9.17	5447.48	7	**-2.17**
Total	**77874.93**	**99.99**	**77874.93**	**100.00**	**0.01**

Table 1. Land Use and Land Cover Changes in Congressional District 2, 2020 and 2024

	Year (Area %)		
LULC Classes	**2020**	**2024**	**Rate of Change (%)**
Waterbodies	0.56	0.64	**14.06**
Forestland	78.48	80.02	**1.96**
Agricultural Area	1.75	1.32	**-24.35**
Built-up Area	10.03	11.02	**9.87**
Barren	9.17	7	**-23.75**

Table 2. Rate of Change in Land Use and Land Cover in Congressional District 2, 2020 and 2024

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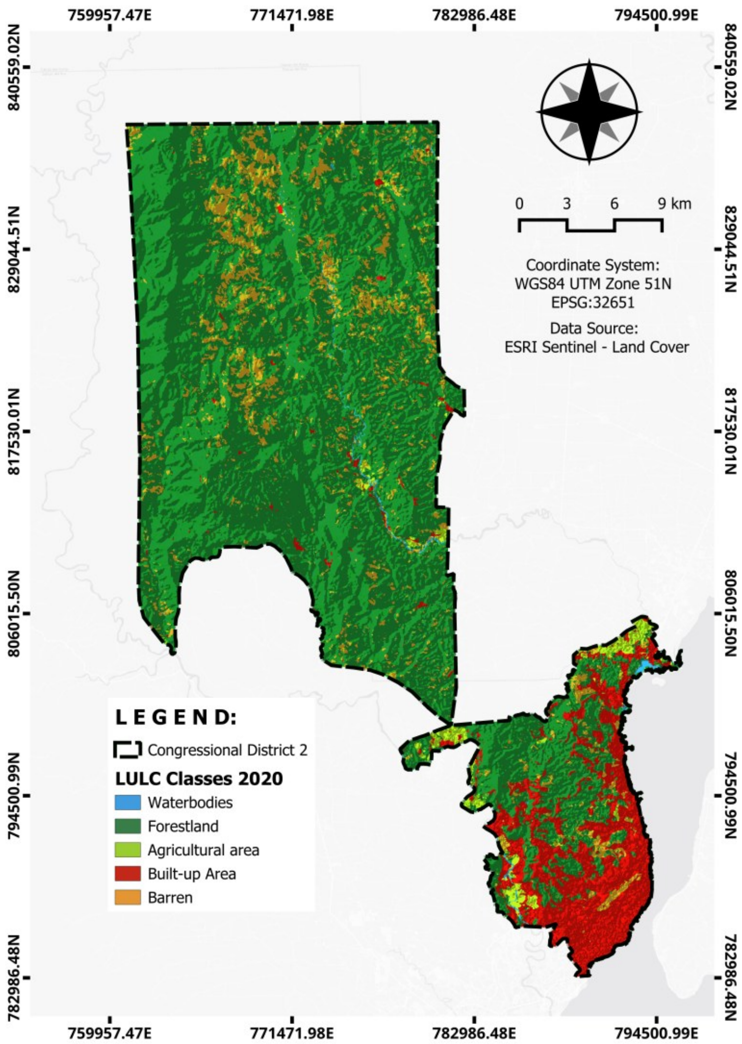

Figure 3. Land use Land cover of Congressional District 2 in 2020

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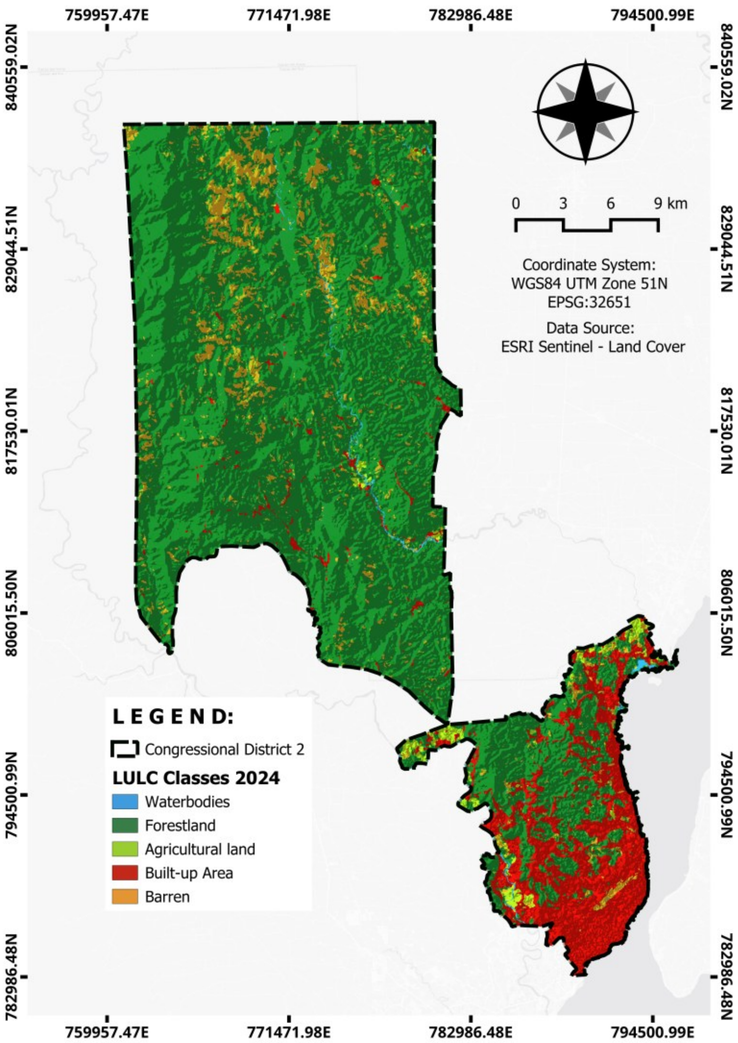

Figure 4. Land use Land cover of Congressional District 2 in 2024

Population Density in Congressional District 2

Table 3 shows that the population-density value increased slightly from 75.32 people per hectare in 2020 to 75.83 people per hectare in 2024, an increase of 0.51 or approximately 0.68%. The change is modest and indicates gradual population intensification rather than a major district-wide shift (World Bank, 2017). Even a small increase can raise demand for housing, roads, public transportation, water, electricity, drainage, waste management, schools, healthcare, and other urban services, particularly where growth is concentrated in already developed communities.

	Year				
	2020		**2024**		Area
Congressional District 2	People/Hectare	%(-,+)	People/Hectare	%(-,+)	(ha)
	75.32	**-**	**75.83**	**0.51**	**77,791.72**

Table 3. Population-Density Values in Congressional District 2, 2020 and 2024

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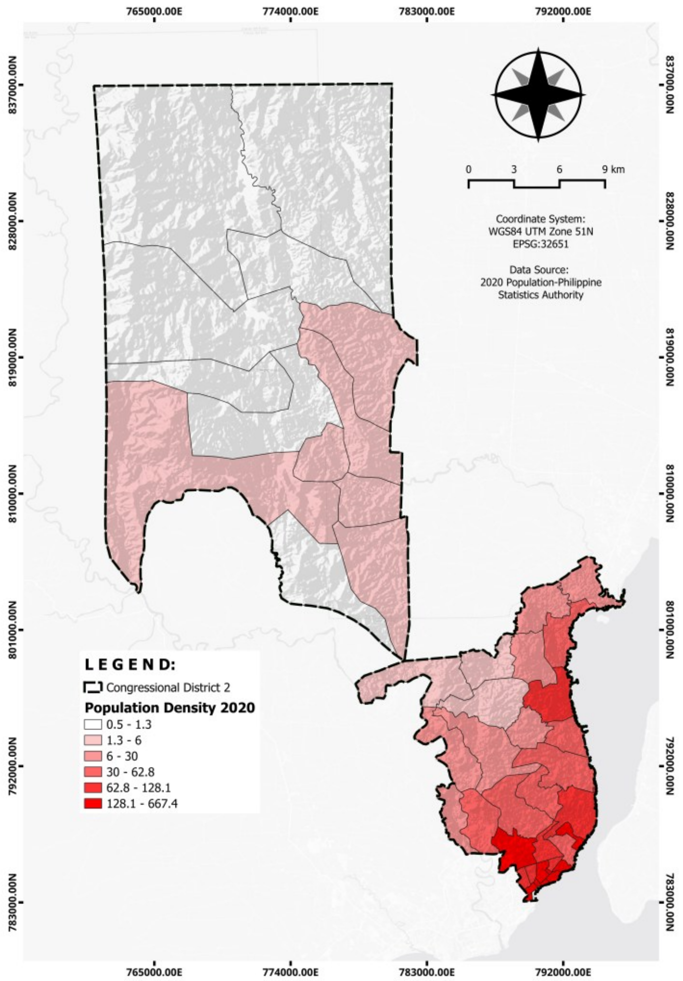

Figure 5. Population Density of Congressional District 2 in 2020

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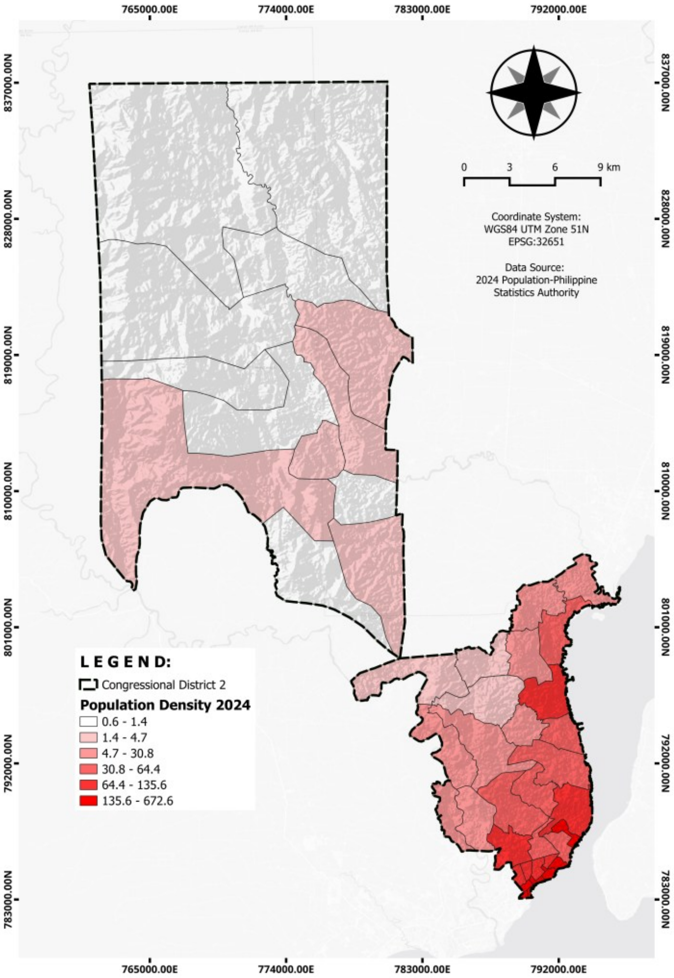

Figure 6. Population Density of Congressional District 2 in 2024

Population density remained spatially uneven in both years. Higher-density barangays were concentrated mainly in the southern, more urbanized portion of the district, while most northern barangays remained in lower-density categories. The broad spatial structure changed little between 2020 and 2024, suggesting gradual intensification within established population centers rather than extensive redistribution toward the forest-dominated north.

The concentration of population in developed areas has both planning advantages and risks. Compact settlement can improve the efficiency of public transport and service delivery, but unmanaged growth can increase congestion, housing pressure, informal development, and unequal access to services. Additional buildings and paved surfaces can also reduce infiltration and increase surface runoff, especially where drainage and flood-control systems are insufficient (Feng et al., 2021; Intergovernmental Panel on Climate Change, 2022; Johnson et al., 2021).

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Relationships of Land Use Land Cover to Population Density

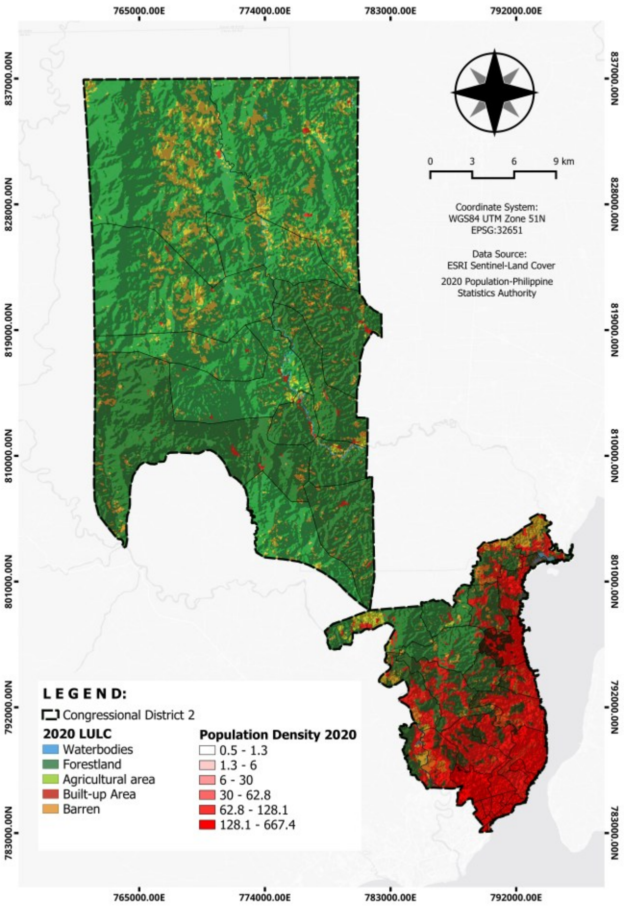

Figure 7. Overlay of land use and land cover with population density in 2020

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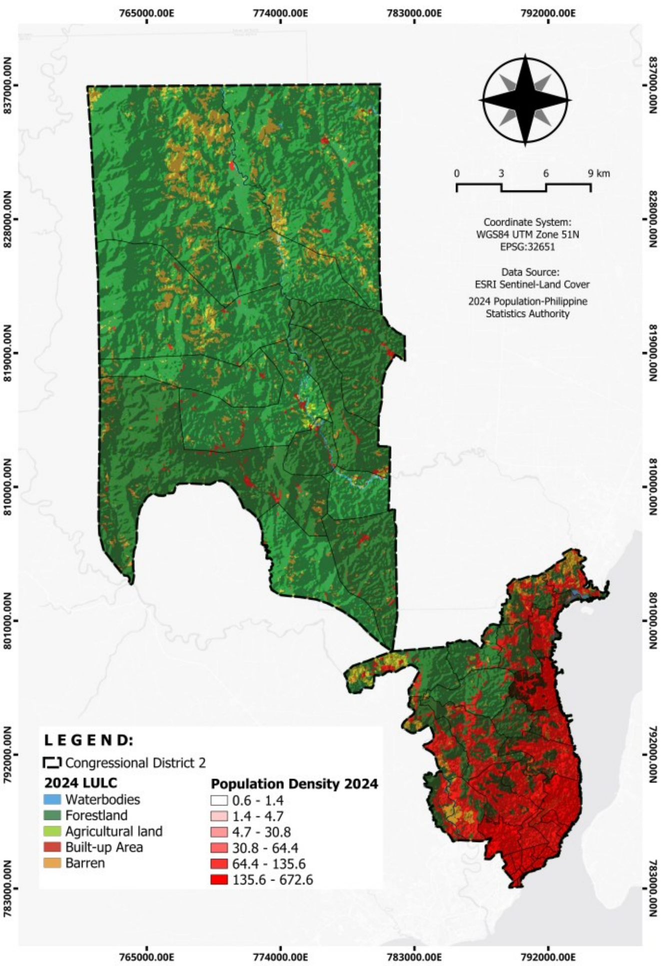

Figure 8. Overlay of land use and land cover with population density in 2024

The overlay maps indicate that higher population densities generally coincide with the built-up southern portion of the district, whereas the extensive forest areas in the north are associated with lower population. This descriptive pattern is consistent with the expectation that settlement and infrastructure cluster in accessible, developed locations (Allan et al., 2022). However, the district-wide increase in both built-up area and forestland also shows that population and land-cover change do not occur uniformly across space. Urban growth may be concentrated in selected barangays while vegetation recovery or reclassification occurs elsewhere.

Table 2 shows that agricultural land recorded the largest proportional decline (-24.35%), closely followed by barren land (-23.75%). Barren land had the greatest absolute decrease, while built-up area increased by 9.87%, reinforcing the evidence of continued urban expansion. Water bodies showed the highest positive relative change (14.06%), but this result is driven by their very small initial area; the actual increase was only 61.50 hectares.

Multiple Regression Analysis

The 2020 regression model was statistically significant ($F = 3.281$, $p = 0.014$), with Multiple $R = 0.539$ and $R^2 = 0.291$. Thus, the selected LULC variables collectively explained approximately 29.1% of the variation in population density. Water bodies ($B = -2.475$, $p = 0.033$), forestland ($B = -0.037$, $p = 0.028$), and built-up area ($B = -0.206$, $p = 0.031$) were significant negative predictors after the other LULC variables were held constant. Agricultural area and barren land were not significant predictors. This results, further consistent with Lambin and Geist (2006), explained that forested landscape generally supports lower population densities because environmental constraints and conservation policies limit intensive and urban development.

The 2024 model was also statistically significant ($F = 3.805$, $p = 0.006$), with Multiple $R = 0.568$ and $R^2 = 0.322$.

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The model therefore explained 32.2% of the variation in population density, a modest increase from 2020. Forestland (B = -0.037, p = 0.012) and built-up area (B = -0.210, p = 0.022) remained significant negative predictors, while water bodies, agricultural area, and barren land were not significant. The negative coefficient for forestland for 2020 and 2024 indicates that barangays with higher forestland cover has lower population density, which can be observed on the pattern that the northern part of Congressional District 2 has dispersed population while the southern part is built up. This finding is consistent with studies showing that areas with extensive forest cover generally support lower population densities because environmental constraints and conservation policies limit intensive settlement and urban expansion (Shih, 2022; Tong, et al, 2020).

LULC	2020 Coefficient (B)	2020 p-value	Relationship	2024 Coefficient	2024 p-value	Relationship
Waterbodies	-2.475	0.033	Significant Negative	-1.702	0.178	Not Significant
Forestland	-0.037	0.028	Significant Negative	-0.037	0.012	Significant Negative
Agricultural Area	0.143	0.265	Not Significant	-0.230	0.557	Not Significant
Built-Up	-0.206	0.031	Significant Negative	-0.210	0.022	Significant Negative
Barren	0.088	0.357	Not Significant	0.150	0.151	Not Significant

Table 4. Multiple Regression Coefficients for LULC Predictors of Population Density

CONCLUSION

LULC analysis showed that Congressional District 2 remained predominantly forested from 2020 to 2024. Forestland increased by 1,195.89 hectares and built-up area increased by 770.88 hectares, while agricultural land and barren land declined by 331.18 hectares and 1,697.09 hectares, respectively. Water bodies increased only slightly. These findings indicate continuing urban expansion alongside an apparent increase in mapped forest cover; however, a transition matrix and field validation are required to determine the exact land conversions and to confirm whether the forest increase represents genuine ecological improvement.

Population-density value increased slightly from 75.32% in 2020 to 75.83% in 2024. This modest change suggests gradual population intensification rather than rapid district-wide growth. The stated density unit and aggregation method should nevertheless be verified against the barangay population totals before the results are finalized. In addition, population density was spatially concentrated in the southern, more urbanized barangays, while the northern portion remained less densely populated and predominantly forested. The basic spatial pattern remained stable across the two years, indicating that recent growth was concentrated mainly within established settlements and development corridors.

Furthermore, the multiple regression models were statistically significant in both 2020 and 2024 and explained 29.1% and 32.2% of the variation in population density, respectively. Forestland and built-up area were significant predictors in both years, while water bodies were significant only in 2020. These relationships should be interpreted cautiously because the LULC classes are interdependent and may introduce multicollinearity. Population density is also shaped by many social, economic, infrastructural, and physical factors not included in the model.

Integrated land-use, infrastructure, population, and environmental planning is therefore necessary to accommodate urban growth while protecting agricultural land, forest resources, waterways, and hazard-sensitive areas.

The researchers recommend the local government unit (LGU) of Davao and related agencies should improve how they share geospatial data between planning, environment, disaster risk reduction, and statistics offices. Keeping

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a regularly updated spatial database will help make better decisions and track urban growth, land changes, and environmental shifts.

Environmental and urban planners are encouraged to use GIS-based monitoring systems in their regular land-use planning, especially when updating Comprehensive Land Use Plans (CLUPs), zoning rules, and development strategies. By combining LULC maps, population density, hazard data, and infrastructure networks, planners can better identify areas suitable for urban growth and reduce environmental risks.

Future planning should focus on compact, well-serviced development, protecting farmland, conserving forests, preserving waterways, and creating ecological buffers. Planners should look at both current land conditions and expected population growth and infrastructure needs when making decisions.

The findings also show how important it is to balance development with conservation. Fast-growing areas need the right infrastructure, while sensitive environments should be protected with stronger zoning, conservation efforts, and sustainable land management.

REFERENCES

1) Allan, A., Soltani, A., Abdi, M. H., & Zarei, M. (2022). Driving forces behind land use and land cover change: A systematic and bibliometric review. *Land, 11*(8), 1222. https://doi.org/10.3390/land11081222
2) Almeida, B., Cabral, P., Fonseca, C., Gil, A., & Scemama, P. (2024). Top 10+1 indicators for assessing forest ecosystem conditions: A five-decade fragmentation analysis. *Science of the Total Environment, 957*, 177527. https://doi.org/10.1016/j.scitotenv.2024.177527
3) Ascano, E. Z., Ayob, D. E., Corro, M. A., Diesca, K. M. F., & Pardillo, J. S. (2021). Participatory planning process of the local government unit of Davao City, Mindanao, Philippines. *European Journal of Research and Reflection in Educational Sciences, 9*(6), 15–24.
4) Batican, M. D., Dumdum, R. C., Lemente, R. F., Jr., & Paragamac, J. B. (2025). Dynamics of urban green spaces in Davao City: A spatiotemporal analysis. *Acta Biologica Universitatis Daugavpiliensis, 25*(1), 1–32. https://doi.org/10.59893/abud.25(1).001
5) Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.
6) Davao City Planning and Development Office. (2023). *Davao City Comprehensive Land Use Plan 2019–2028*. City Government of Davao.
7) Department of Human Settlements and Urban Development. (2020). *National human settlements framework*. DHSUD.
8) Dela Cruz, J., & Soriano, M. C. (2024). The extent of agricultural land cover change: The case of Bautista, Pangasinan. *CLSU International Journal of Science and Technology, 8*(1), 1–17.
9) Duan, X., Haseeb, M., Tahir, Z., Mahmood, S. A., & Tariq, A. (2025). Analyzing and predicting land use and land cover dynamics using multispectral high-resolution imagery and hybrid CA-Markov modeling. *Land Use Policy, 157*, 107655. https://doi.org/10.1016/j.landusepol.2025.107655
10) Dumdumaya, C. E., & Cabrera, J. S. (2023). Determination of future land use changes using remote sensing imagery and artificial neural network algorithm: A case study of Davao City, Philippines. *Artificial Intelligence in Geosciences, 4*, 111–118. https://doi.org/10.1016/j.aiig.2023.08.002
11) Environmental Systems Research Institute. (2023). *ArcGIS Living Atlas of the World: Land cover data*. ESRI.
12) European Space Agency. (2021). *Earth observation for land monitoring and sustainable development*. European Space Agency.
13) Feng, B., Zhang, Y., & Bourke, R. (2021). Urbanization impacts on flood risks based on urban growth data and coupled flood models. *Natural Hazards, 106*, 613–634. https://doi.org/10.1007/s11069-020-04480-0
14) Gaur, S., & Singh, R. (2023). A comprehensive review on land use/land cover (LULC) change modeling for urban development: Current status and future prospects. *Sustainability, 15*(2), 903. https://doi.org/10.3390/su15020903.
15) Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed.). Pearson.
16) Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press.
17) Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report*. IPCC.

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18) Johnson, B. A., Estoque, R. C., Li, X., Kumar, P., Dasgupta, R., Avtar, R., & Magcale-Macandog, D. B. (2021). High-resolution urban change modeling and flood exposure estimation at a national scale using open geospatial data: A case study of the Philippines. *Computers, Environment and Urban Systems, 90*, 101704. https://doi.org/10.1016/j.compenvurbsys.2021.101704
19) Lambin, E. F., & Geist, H. J. (2006). *Land-use and land-cover change: Local processes and global impacts*. Springer.
20) Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information science and systems* (4th ed.). Wiley.
21) Lu, H., Shang, Z., Ruan, Y., & Jiang, L. (2023). Study on urban expansion and population density changes based on the inverse S-shaped function. *Sustainability, 15*(13), 10464. https://doi.org/10.3390/su151310464
22) Masancay, F. D., Arizobal, A. E., Pascua, V. T., & Petalcorin, I. G. D. (2025). Urban sprawl mapping based on land use and land cover (LULC) time-series in District II of Davao City, Philippines. *Davao Research Journal, 16*(1), 72–88. https://doi.org/10.59120/drj.v16i1.305
23) Philippine Statistics Authority. (2023). *Age and sex distribution in Davao City: 2020 Census of Population and Housing*. PSA.
24) Philippine Statistics Authority. (2025). *2024 Census of Population official population counts: City of Davao*. PSA.
25) Putri, T. (2025). Balancing urban growth and environmental sustainability through spatial planning: A policy and land use analysis. *Journal of Placemaking and Streetscape Design, 3*, 55–67. https://doi.org/10.61511/jpstd.v3i1.2025.2290
26) Saniel, J. R., & Salapa, A. C. (2024). Assessing the urbanization-driven challenges of transportation scarcity and commuter accessibility in Davao City: A systematic review. *Cognizance Journal of Multidisciplinary Studies, 4*(12), 491–501.
27) Shih, H. C. (2022). The relative timing of population growth and land-use change. *Land, 11*(12), 2204. https://doi.org/10.3390/land11122204
28) Talukdar, S., Singha, P., Mahato, S., Shahfahad, Pal, S., Liou, Y. A., & Rahman, A. (2020). Land-use land-cover classification by machine learning classifiers for satellite observations: A review. *Remote Sensing, 12*(7), 1135. https://doi.org/10.3390/rs12071135
29) Tong, Q., & Qiu, F. (2020). Population growth and land development: Investigating the directional interactions. *Ecological Economics, 169*, 106505. https://doi.org/10.1016/j.ecolecon.2019.106505
30) Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences, 104*(52), 20666–20671. https://doi.org/10.1073/pnas.0704119104
31) United Nations. (2023). *United Nations Sustainable Development Cooperation Framework for the Philippines 2024–2028*. United Nations Philippines.
32) United Nations Human Settlements Programme. (2022). *World cities report 2022: Envisaging the future of cities*. UN-Habitat.
33) Verburg, P. H., Schot, P. P., Dijst, M. J., & Veldkamp, A. (2004). Land use change modelling: Current practice and research priorities. *GeoJournal, 61*, 309–324. https://doi.org/10.1023/B:GEJO.0000045940.30154.f6
34) Wang, D., Wang, M., Zheng, W., Song, Y., & Huang, X. (2025). A multi-level spatial assessment framework for identifying land use conflict zones. *Land Use Policy, 157*, 107382. https://doi.org/10.1016/j.landusepol.2024.107382
35) World Bank. (2017). *Philippines urbanization review: Fostering competitive, sustainable, and inclusive cities*. World Bank.
36) Ybañez, A. G., Polistico, A. A., Descalsota, C. R., & EnP, M. A. (2025). Assessing urban resilience and land use planning: A SWOT analysis of the Davao City Comprehensive Land Use Plan (2019–2028). *International Journal of Engineering Technology Research & Management, 9*(5), 290–295. https://doi.org/10.5281/zenodo.15465050
37) Zegeye, M. K., Azagew, S., & Nuriye, G. (2026). A hybrid model of predicting land use scenarios for sustainable urban land use planning in Debre Birhan City, Ethiopia. *Discover Sustainability*. https://doi.org/10.1007/s44274-026-00827-9

