

Dynamics of land cover change on population growth based on Geographic Information System (GIS) 2020–2024 in Palembang City

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ABSTRACT

This study aimed to analyze population growth and land cover change in Palembang City from 2020 to 2024 using GIS, the overlay method, and correlation analysis between population data and time-series land cover maps. The results show that population growth significantly contributes to the expansion of open/built-up land, particularly in densely populated districts such as Sukarami, Ilir Barat Satu, and Alang-Alang Lebar. The correlation matrix indicates a strong association between population and open/built-up land ($r=0.84$), and a moderate association with vegetation ($r=0.47$). A strong negative interaction between open/built-up land and vegetation ($r=0.77$) suggests that the growth of built-up regions reduces green space. Population size is almost uncorrelated with water/clouds ($r=0.01$), indicating that natural factors influence this category more than human activity. Overall, the study concludes that population expansion in Palembang drives urbanization and vegetation decline, highlighting the need for sustainable spatial management to balance development and environmental sustainability.

Keywords: Alang-Alang Lebar, Ilir Barat Satu, population, Sukarami, vegetation degradation

INTRODUCTION

Population and economic growth are strongly related to the increase in built-up land and the decline in green space and agricultural land in large cities (Rachman et al., 2024). Palembang City, the capital of South Sumatra Province, is experiencing rapid urbanization that intensifies pressure on land cover. Historical data show that between 2000 and 2013, land conversion in Palembang increased significantly, especially from plantation and agricultural land to residential areas. Residential areas expanded by 4,368 hectares between 2000 and 2013, exceeding the 2,531 ha converted between 1989 and 2000 (Nguyen et al., 2016). Other studies indicate that the expansion of built-up areas has contributed to rising land surface temperatures

(LST), signaling ecological degradation driven by urbanization (Gaol et al., 2020). The reduction of vegetation and green open space, alongside the growth of residential and commercial zones, signifies a shift in land use that prioritizes economic and housing needs over the maintenance of environmental balance (Gaol et al., 2020; Romdhoni, 2020). These conditions lead to several research questions: what is the pattern of land cover change in Palembang from 2020 to 2024, what are the spatial trends of population growth, how strong is the relationship between the two using a Geographic Information System (GIS) approach, and how can the results support sustainable spatial planning.

A literature review shows similar patterns in Jakarta, where population and economic growth strongly correlate with increases in built-up areas

and reductions in green space and agricultural land over the past three decades. The most significant conversion occurred in green spaces and fishponds, especially after 2015, in response to increasing development and infrastructure needs (Rachman et al., 2024). (Maheng et al., 2024). also emphasized that LULC changes in the capital city substantially affect urban temperatures. Time-series satellite analyses reveal consistent vegetation loss in major Indonesian cities due to urbanization (Agustiyara et al., 2025; Rachman et al., 2024). In Medan, researchers documented considerable vegetation decline (Zaitunah et al., 2021) and a pattern of urban heat islands corresponding with population density (Wei et al., 2024). Multi-temporal remote sensing has proven effective for monitoring LULC change (Mashala et al., 2023). Research in Semarang highlights a trade-off between economic growth and environmental sustainability through LULC dynamics affecting SDG achievement (Kelly Fair et al., 2022), while a study in Makassar shows that urban expansion has significantly reduced forest and wetland areas (Nganro et al., 2024). At the global scale, CA-Markov modeling is widely used to predict urban growth and LULC changes (Selmy et al., 2023; Tahir et al., 2025), and review studies emphasize that urbanization-driven LULC change has critical implications for urban sustainability (Alshayeb, 2025). A comprehensive assessment confirmed that LULC transformation associated with urbanization significantly impacts river hydro-morphology (Argaw & Yohannes, 2024), while recent findings from Indonesia's new capital (IKN) reveal extensive land alteration driven by large-scale urban development (Kalalinggi et al., 2023).

Despite these extensive studies, research in Palembang remains limited. (Nguyen et al., 2016) examined land cover change primarily in relation to carbon stocks, whereas (Gaol et al., 2020) analyzed the relationship between urbanization and land surface temperature. Neither study directly links LULC changes with population growth data. Consequently, a research gap remains: no comprehensive assessment has integrated multi-temporal LULC data from 2020–2024 with population growth in Palembang using GIS. The present study addresses this gap

by combining multi-temporal satellite imagery with annual population data and analyzing them through GIS-based techniques such as overlay, zoning, and spatial correlation. Spatial correlation is particularly beneficial because it enables models to incorporate information from nearby areas, improving predictive accuracy in applications such as soil mapping, weather forecasting, and spatial genomic analysis (Behrens et al., 2018). The purpose of This study was to approach provides a more detailed and spatially explicit understanding of the relationship between population growth and land cover change.

MATERIALS AND METHODS

Research Location

The research site (Figure 1) was in Palembang City, one of Sumatra Island's largest metropolitan areas and the capital of South Sumatra Province, with a significant role in the economy, education, and culture. Palembang experiences major changes in spatial planning and land cover due to its relatively large area and annual population growth. This makes Palembang City a strategic research location for exploring the relationship between population growth and land-use change, especially in the context of sustainable urban development (BPS Palembang City, 2025).

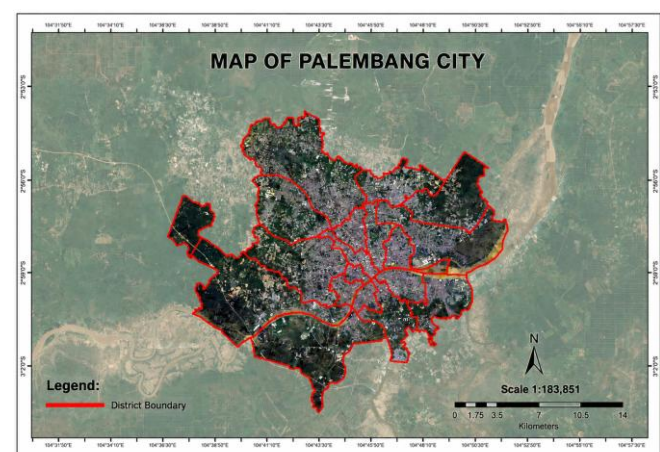


Figure 1. Map of Palembang city area

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) was one of the most important and extensively used remote sensing indices for

assessing the health, density, and distribution of vegetation on Earth's surface. NDVI uses differences in red and near-infrared reflectance from plants to create a quantitative picture of vegetation health. The NDVI was calculated using the formula.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

NIR is the near-infrared reflectance, whereas Red is the red light reflectance. NDVI values vary from -1 to +1, with positive values indicating healthy and dense vegetation and negative values indicating areas lacking vegetation or non-green surfaces like water or bare land (Jiang et al., 2021; Rachman et al., 2024). The Normalized Difference Vegetation Index (NDVI) was an index that ranges from -1 to +1 and was used to describe the health and density of vegetation. Healthy vegetation has high NDVI values as it absorbs red radiation for photosynthesis and reflects NIR radiation, while open or disturbed land has lower values. Due to its simplicity, versatility, and sensitivity to vegetation dynamics, NDVI was commonly employed in land cover change research and environmental degradation monitoring (Ajun, 2022; Lufilah et al., 2017). The following is the NDVI classification table (Table 1).

Table 1. NDVI classification table

Class	Score NDVI
Rare	0.2343 – 0.2813
Moderate	0.2814 – 0.3143
Dense	0.3144 – 0.6294

Note: (Lufilah et al., 2017)

Correlation Method

The correlation method was a statistical approach that measures and describes the closeness of a link between two variables. This methodology assists researchers in determining if alterations in one variable were succeeded by modifications in other variables, either in a congruent (positive) or divergent (negative) manner. Correlation does not imply causation; it only indicates the strength and direction of the relationship between variables. As a result, this method was widely used in social, economic, and environmental research as a preliminary step before more in-depth studies. The Pearson

correlation was a statistical technique employed to assess the strength and direction of the linear association between two normally distributed continuous variables. The correlation coefficient (r) ranges between -1 and +1, with -1 indicating a perfect negative link, +1 indicating a perfect positive association, and 0 indicating no linear relationship. Although simple and extensively used, this technique primarily captures linear relationships, making it less ideal for non-linear relationship patterns between variables (Janse et al., 2021; Schober & Schwarte, 2018).

Overlay

Overlay is a spatial analysis approach that stacks two or more maps or images using the same spatial reference system. This approach enables a more detailed understanding of the spatial relationships between characteristics on each layer. In environmental mapping, overlays are commonly used to identify and compare changes in land cover, vegetation, and other elements across time. This strategy can aid decision-making in regional management, spatial planning, and continuous monitoring of environmental dynamics (Elisabete, 2017). The overlay approach has the advantage of performing extensive spatial analysis, which allows for the accurate identification of overlapping areas, modifications, and positional errors. This technique can also integrate data from other sources, resulting in a more in-depth understanding of an area's conditions. However, the accuracy of the outputs was heavily influenced by the quality of the input data and the consistency of the geographical references. Small errors in data registration or alignment can result in incorrect interpretations, therefore proper data preparation was critical (Lee et al., 2016; Elisabete, 2017).

Landsat-8

Landsat-8, a remote sensing satellite launched in 2013, resulted from a collaboration between NASA and the USGS. This satellite was intended to collect medium-resolution image data of the earth's surface, from land to the poles, using the visible, near infrared, shortwave infrared, and thermal infrared channels. Landsat-8, in contrast to its predecessor, features new bands including a

blue band for shallow water analysis, a specialized band for cirrus cloud detection, and two additional sensitive thermal bands, thereby markedly enhancing detection capabilities, land cover classification, and the assessment of environmental changes over time. The main instruments on Landsat-8 are the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). OLI had a spatial resolution of 30 meters for the multispectral band and 15 meters for the panchromatic band, but TIRS had a native resolution of 100 meters that was later reduced to 30 meters to align with the other bands. This instrument's improved quality is complemented by a higher signal-to-noise ratio and radiometric resolution of up to 12 bits, resulting in image data that was more precise, detailed, and sensitive to alterations on the Earth's surface. Landsat-8 can acquire almost 60% more images daily than its predecessor, resulting in enhanced geographical and temporal coverage, hence facilitating more frequent and continuous environmental monitoring (Barsi et al., 2014; Roy et al., 2014).

Time-Series Data on Population of Palembang City

Population growth per sub-district in Palembang City from 2020 to 2024 indicates a general annual upward trend. Sukarami District had the fastest and most steady increase, with over 212 thousand inhabitants in 2024 (Figure 2), making it the district with the biggest population. Significant growth was also observed in the Kalidoni and Alang-Alang Lebar sub-districts, which continue to expand annually.

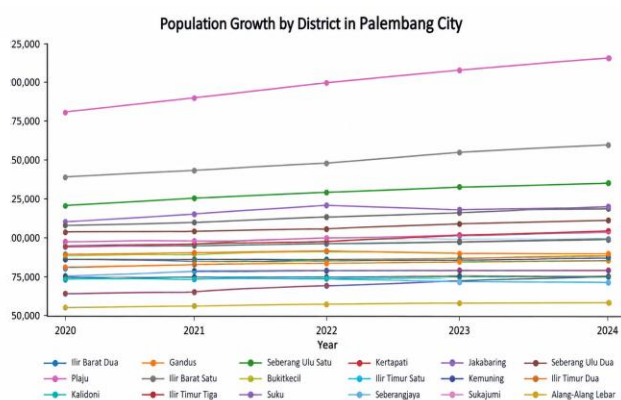


Figure 2. Population growth by District in Palembang City (2020-2024)

Meanwhile, some sub-districts in the city core, including Bukitkecil and Ilir Timur Satu, remained stagnant or even declined marginally. Most other sub-districts saw a minor increase. This shows that suburban areas are growing faster than the city center, likely due to the construction of new residential areas and urbanization (BPS Palembang City, 2025).

Landsat-8 Land Cover Time-Series Data Analysis of Palembang City

Land use statistics for Palembang City from 2020 to 2024 (Figures 3, 4, and 5) reveal variation among sub-districts. Downtown neighborhoods like Ilir Timur, Bukit Kecil, and Kemuning were dominated by developed terrain with sparse and stagnant vegetation cover. Outlying areas, such as Sukarami, Gandus, and Kertapati, continue to retain considerable vegetation cover despite seasonal variations. Open or built-up land was expanding in various sub-districts, indicating a strong urbanization development, particularly near the city center (Data processing using GEE Landsat-8 imagery, 2025).

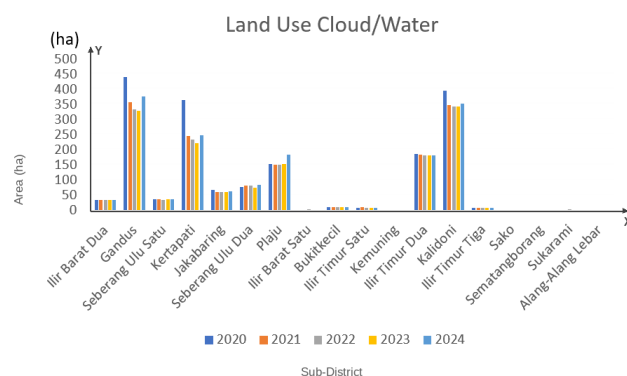


Figure 3. Land use cloud/water

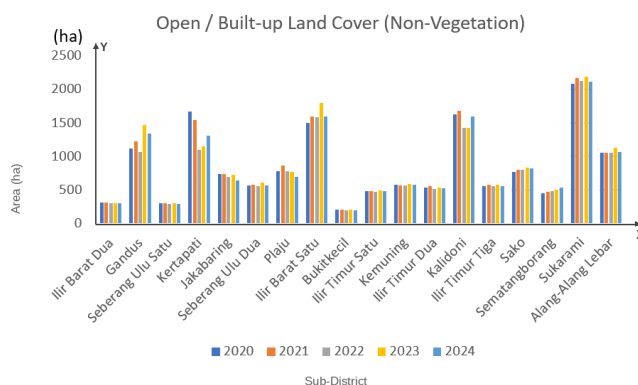


Figure 4. Open/built-up land cover (non-vegetation)

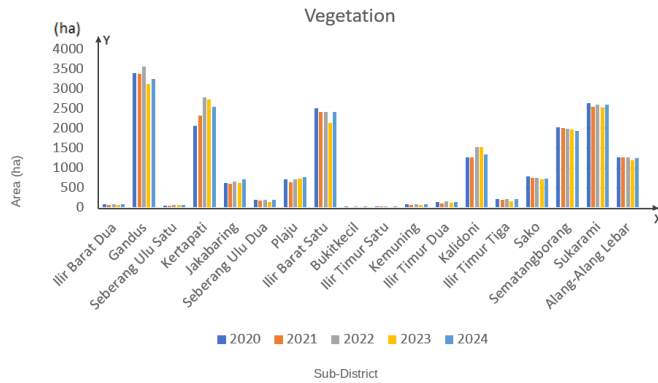


Figure 5. Vegetation

RESULTS

The time-series land-cover map of Palembang City for 2020-2024 (Figure 6), created using the NDVI approach, depicts land-cover change dynamics. Blue symbolizes water/cloud areas, yellow represents open or developed areas, and green represents vegetation. A correlation coefficient of ($r=0.84$) suggests a high link between population and land area. Because the value was close to +1, it was reasonable to deduce that as land area increases, population also increases. This link is very strong, allowing us to accurately anticipate population number based on land area (Figure 7).

The pink region surrounding the regression line denotes the confidence interval. This was the interval in which the actual trendline was most likely situated. Although the data points do not consistently align with the red line, this region indicates the reliability of the model used to characterize the trend. A narrower interval indicates a more consistent and reliable observable link in the data.

The correlation matrix illustrates (Figure 8) the relationship between land cover variables and population in Palembang City. Population shows a strong association with open/built-up land ($r=0.84$). The relationship between population and vegetation was somewhat correlated ($r=0.47$). Conversely, population exhibits negligible connection with water/clouds ($r=0.01$). Simultaneously, open or developed terrain exhibits a strong association with vegetation ($r=0.77$).

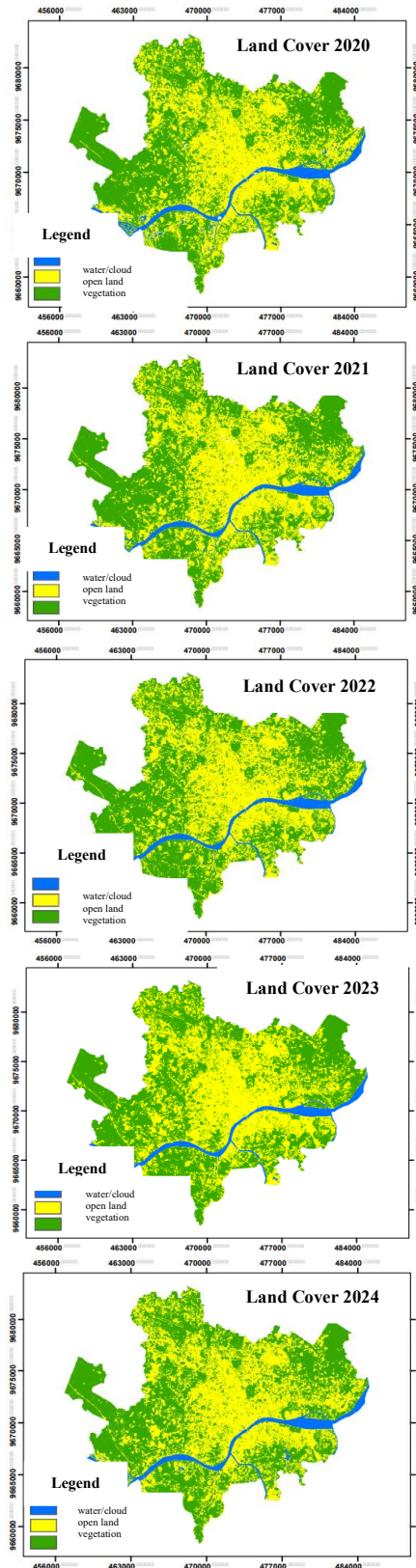


Figure 6. Time series map of land cover changes in Palembang City 2020-2024

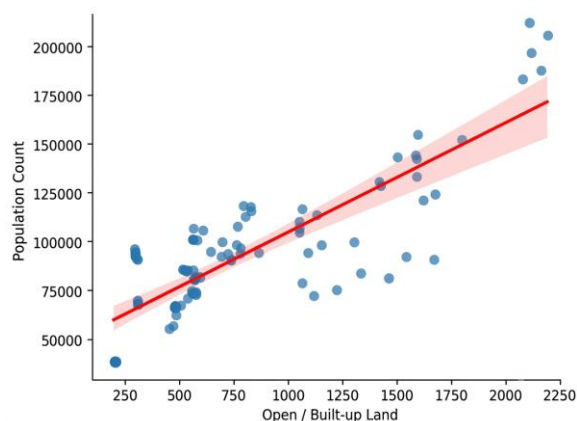


Figure 7. Correlation of population number to open/built-up land

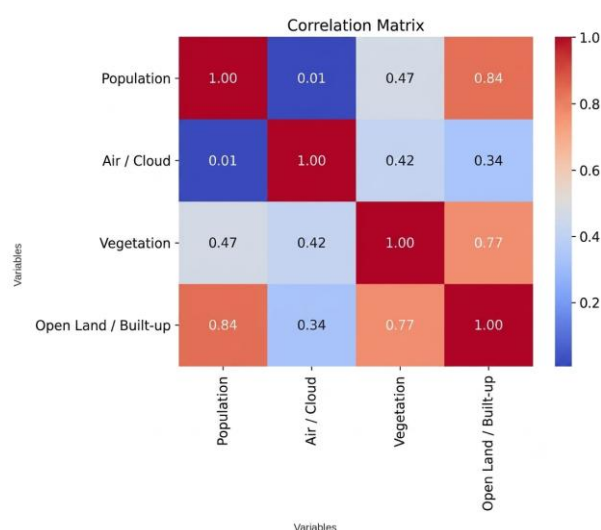


Figure 8. Matriks correlation

DISCUSSION

Time Series Map of Land Cover in Palembang City 2020–2024

The data demonstrates that vegetation continues to dominate most locations, particularly in the suburbs. However, open/built-up land tends to rise year after year, particularly in the city core, indicating fast urbanization. On the other hand, the water area is largely stable, although some vegetative areas are shrinking owing to land conversion. This data shows that Palembang's rapid expansion has reduced green space, even though some vegetated areas remain. According to studies (Puplampu & Boafu, 2021), expanding built-up regions diminishes green space by transforming it into impervious surfaces like concrete and asphalt.

Correlation of Land Cover Changes with Population Growth

The correlation analysis between population and open/built land area in Palembang City (Figure 7) yields a value of 0.84, indicating a strong positive link. A larger population correlates with a greater extent of open and built-up land used. This shows how population growth increases the need for housing, infrastructure, and city facilities, resulting in the expansion of built-up areas. This pattern is plainly obvious in the regression line that follows the data trend, albeit with a few deviations. These findings suggest that urbanization and population growth in Palembang contribute significantly to converting vegetated land into built-up areas, potentially resulting in less green space, lower environmental quality, and an increased risk of urban problems such as flooding and urban density. Research by (Duan et al., 2025) corroborates this assertion, indicating that elevated population density intensifies the strain on green spaces and amplifies disparities in access to a healthy environment.

Correlation Matrix of Land Cover Changes Against Population Increase

The correlation matrix illustrates the relationship between land cover variables and population in Palembang City. Population has a robust association with open/built-up land ($r = 0.84$), suggesting that population growth is driving the expansion of built-up areas. The association between population and vegetation is moderate ($r = 0.47$), suggesting that population increase affects the decrease of green space. In contrast, population density shows negligible correlation with water/clouds ($r = 0.01$), as this variable is mostly determined by natural conditions rather than anthropogenic factors. Simultaneously, open/built-up land exhibits a strong association with vegetation ($r = 0.77$), signifying an inverse relationship in which a rise in built-up land typically corresponds to a reduction in vegetation. Overall, this matrix shows that population expansion and urbanization in Palembang significantly change land cover, particularly by converting vegetation into built-up areas. Research by (Abbas et al., 2025) indicates a robust positive association

between population growth and urbanization and the expansion of built-up regions, with a negative correlation with the extent of vegetation and vacant land.

CONCLUSION

The land cover dynamics of Palembang City from 2020 to 2024 indicate that greenery predominates in the suburbs; nevertheless, its extent is diminishing due to conversion into built-up areas in the city core. Open and built-up land expand each year due to urbanization, showing a strong association with population growth ($r=0.84$). Vegetation has a moderate correlation with population growth ($r=0.47$), indicating that the loss of green space is linked to population expansion, but water areas are largely steady, with a very low correlation ($r=0.01$). Furthermore, the strong association between built-up land and vegetation ($r=0.77$) shows an inverted pattern: increases in built-up land are followed by decreases in vegetation. Overall, these dynamics show that population growth and urbanization in Palembang have significantly accelerated the conversion of vegetation into built-up areas, resulting in less green space, declining environmental quality, and increased risks of urban problems like flooding and population density.

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