



| Research Article

Analysis of Urban Growth Patterns and Industrial Area Expansion on Land Use Change in Batam City, Indonesia (2017–2025)

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Abstract: The growth of urban areas and the expansion of industrial estates are the main factors that encourage land use changes in Batam City, as one of the strategic industrial estates in Indonesia. This study aims to analyze the patterns of urban growth, the expansion of industrial estates, and land-use changes in Batam City during the period 2017–2025. The study uses a quantitative descriptive approach, utilizing Sentinel-2 land cover data obtained from the Esri Living Atlas and analyzed in a Geographic Information System (GIS) through spatial overlay techniques. The results of the study show that the area of built-up areas increased from 17,188.50 ha in 2017 to 21,399.70 ha in 2025, an increase of 4,211.20 ha. In contrast, open land, agricultural land, grassland, and flooded vegetation have declined in extent due to land conversion for industrial estates, settlements, trade, and urban infrastructure. The growth of built-up areas is concentrated in the northern, central, and western areas of Batam City, which have high accessibility and are adjacent to industrial areas and major transportation networks. These findings show that urban growth and the expansion of industrial estates were the main drivers of the spatial transformation of Batam City during the study period. This research provides spatial information to support spatial planning, land conversion control, and more sustainable urban development, helping maintain a balance between economic growth and environmental sustainability.

Keywords: Urban Growth; Industrial Area Expansion; Land Use Change; Batam City.

1. INTRODUCTION

Land use refers to all forms of human activities that utilize land resources to meet various needs. The development of social, economic, and regional activities significantly affects land use patterns in a certain region (Fedriansya & Rahman, 2025). One of the most common factors influencing land-use change is population growth, which increases the demand for space for settlement, trade, services, industry, and supporting infrastructure (Ramadhan & Murti, 2024). This ever-increasing demand for land ultimately drives the conversion of land from previous uses to forms that are considered more economically productive (Ado et al., 2023). In addition to population growth, location is another important factor that affects the rate of land use change. Areas near industrial estates, transportation networks, commercial centers, service centers, and fast-growing areas are more likely to experience land-use transformation than other areas (Furqona et al., 2025). This happens because the presence of economic activities and supporting facilities increases land value and attracts new development in the surrounding area (Rahmadan et al., 2024).

Batam City is one of the largest industrial cities in Indonesia and occupies a strategic position along international shipping routes while sharing close proximity with Singapore and Malaysia (Lovina, 2022). This geographical advantage makes Batam an attractive destination for investment and economic development. The industrial sector in Batam has grown rapidly and has become one of the main drivers of regional economic growth. According to Hutasoit et al., (2023), Batam City has at least 26 industrial estates and more than 1,300 companies spread across various parts of the city, employing around 169,000 workers. The rapid industrial development in Batam City also contributes to a sustainable population increase through migration. The availability of job opportunities in industrial estates attracts people from various

regions to settle in Batam. Population growth increases the demand for land for housing, social facilities, public services, and other urban supporting infrastructure. As a result, changes in land use are an inevitable consequence of the development process of Batam City (Hanafi et al., 2024).

The development of the industrial sector also affects the spatial structure of urban areas. Kurniati et al., (2022), Industrial growth encourages the urbanization process and accelerates the expansion of residential areas and infrastructure development. This condition triggered the formation of new growth centers, which further altered the city's spatial development pattern. This phenomenon also occurs in Batam City, which is shown by the increase in the area of industrial estates from 2,623 hectares in 2011 to 4,887 hectares in 2021 (Saragi et al., 2023). The expansion of the industrial estate was followed by an increase in built-up areas to support economic activities and an increase in the need for space due to population growth.

The change in land use in Batam City is not only reflected in the expansion of industrial and residential areas but also in the reduction of vegetation cover. Research by Susilo et al. (2025) shows that some districts serving as urban development centers are experiencing intensive urbanization. As a result, the availability of green open space is becoming increasingly limited due to infrastructure development, housing expansion, and industrial growth (Isra et al., 2025). This condition shows that rapid regional development has put considerable pressure on undeveloped land in Batam City.

Although various studies have examined land-use changes and the development of industrial estates in Batam City, most still focus on identifying land-cover changes or analyzing urban development separately. Studies that integrate analyses of urban growth patterns and the expansion of industrial estates to evaluate the dynamics of spatial and temporal land-use change, especially during the 2017–2025 period, remain relatively limited. In fact, understanding the relationship among industrial estate growth, urban development, and land-use change is needed to support sustainable spatial planning and control of built-up area expansion.

Based on these conditions, this study aims to analyze the pattern of urban growth and expansion of industrial estates and their influence on land use changes in Batam City during the period 2017–2025 using remote sensing approaches and Geographic Information Systems (GIS). The novelty of this research lies in integrating spatial analysis of urban growth with the dynamics of industrial estate development to identify patterns of land-use change in rapidly developing archipelago industrial cities. The results of the research are expected to make a scientific contribution to the study of urban spatial dynamics and serve as a basis for the preparation of more sustainable spatial management policies in Batam City.

2. RESEARCH METHODS

This study employed a quantitative descriptive approach based on Geographic Information Systems (GIS) to analyze urban growth patterns and industrial area expansion in relation to land-use change in Batam City during the period 2017–2025. This approach was selected because it enables the identification and visualization of spatial conditions and land-use changes over time through geospatial data analysis.

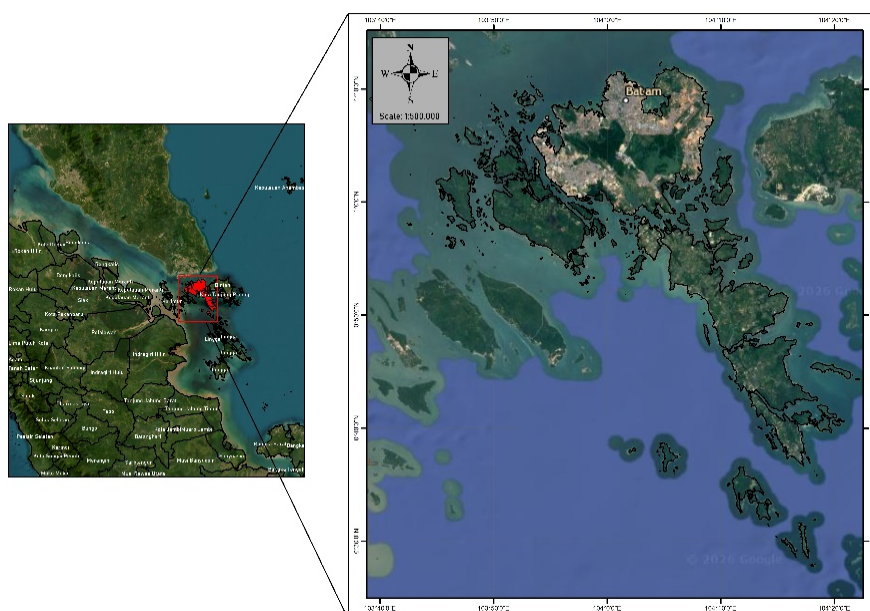


Figure 1. Map of the Batam Research Site (Source: Data Processing, 2026)

Batam City was selected as the study area because it is one of Indonesia's strategic national development regions, characterized by rapid urbanization and industrialization. The growth of economic activities, infrastructure development, and industrial area expansion has significantly contributed to land-use changes in recent years. The primary data used in this study consisted of Sentinel-2 land-cover data obtained from the Esri Living Atlas for 2017 and 2025. The land cover data included seven classification categories: water bodies, trees, flooded vegetation, cropland, built-up areas, bare land, and grassland. In addition, administrative boundary data of Batam City were used as a reference for spatial analysis. Data processing and analysis were conducted using ArcGIS software. The initial stage involved clipping and adjusting land cover data according to the administrative boundaries of Batam City. Subsequently, the area of each land-cover class was identified and calculated to assess land-use conditions in 2017 and 2025.

Land-use change analysis was performed by comparing land cover data from both observation years using a spatial overlay technique. This process aimed to identify changes in the area and distribution patterns of each land-use class and to determine land-conversion trends during the study period. The identified changes were then analyzed to examine their relationship with urban growth and industrial development in Batam City. Urban growth patterns were analyzed based on the increase and spatial distribution of built-up areas during the observation period. Meanwhile, industrial expansion was evident in the development of built-up areas concentrated within industrial zones and their surrounding areas. The results were presented as maps, tables, graphs, and descriptive explanations to provide a comprehensive understanding of urban growth patterns, industrial expansion directions, and their influence on land-use change in Batam City from 2017 to 2025.

3. RESULTS AND DISCUSSION

Land Use Conditions in Batam City in 2017

Based on the interpretation of the 2017 land use map, Batam City is still dominated by natural land cover, including tree vegetation, agricultural land, grassland, and open land. The distribution of built areas during this period remains relatively concentrated in urban centers, major industrial areas, and areas with high accessibility, particularly along main road corridors and coastal areas that are emerging as centers of economic activity. This pattern shows that the development of urban areas in 2017 is still centralized (compact development), so the expansion of built areas to suburban areas has not taken place massively.

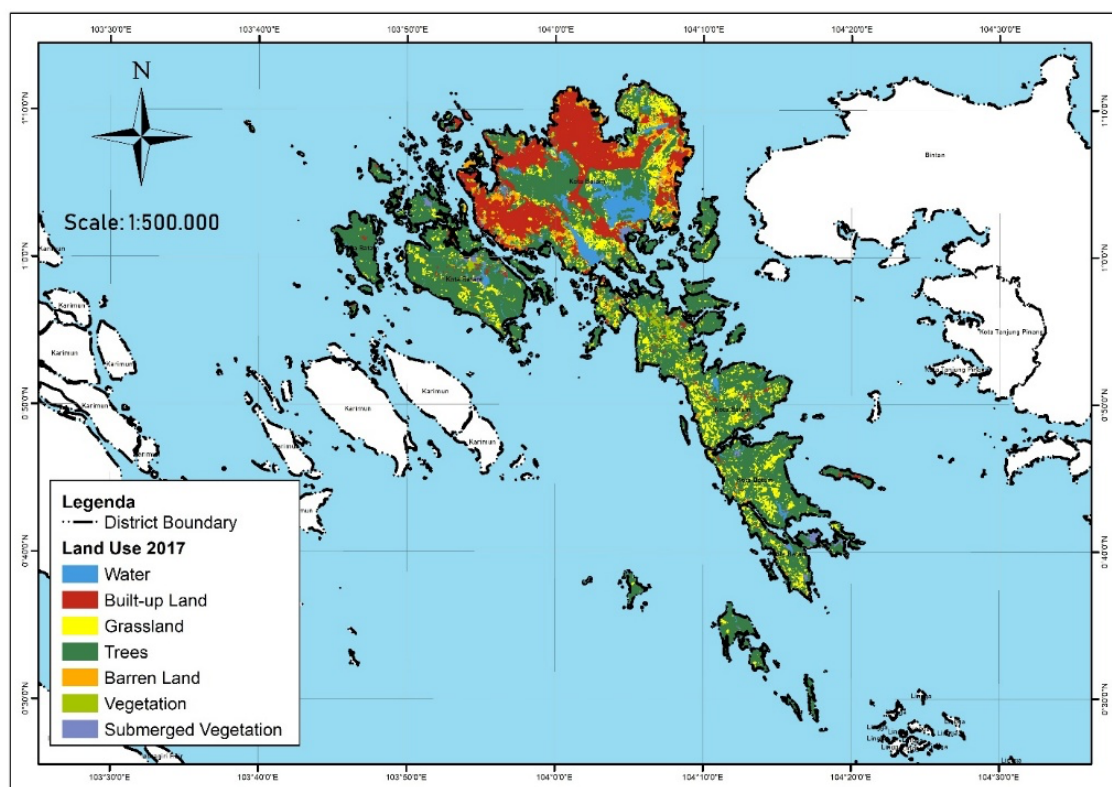


Figure 2. Urban Growth Pattern and Land Use Change in Batam City, 2017

(Source: Primary Data Processing, 2026)

The dominance of vegetation cover during that period indicates that most of the Batam City area still has a fairly good ecological function as an environmental buffer. The presence of vegetation and open land not only helps maintain ecosystem balance but also provides land reserves that could be converted as the need for space increases with population growth and economic activity. Meanwhile, industrial and residential estates that have developed serve as growth centers, triggering the development of new areas around them through increased economic activity, investment, and infrastructure development.

This condition is in line with the concept of urban development, [Tian et al., \(2024\)](#), which states that industrial growth plays a major catalyst for urbanization through the expansion of residential areas, infrastructure development, and the formation of new growth centers. The findings of this study are also consistent with the results of [Anurogo et al. \(2022\)](#), which show that Batam City's early development is still concentrated in industrial areas and service centers, while areas outside the city center are dominated by vegetation and undeveloped land. In addition, [\(Ronaldy Lovina, 2022\)](#) explained that the strategic position of Batam City as a Free Trade Zone and industrial area has made urban development develop following investment locations and transportation networks that connect industrial areas with ports and distribution centers.

Overall, the land-use conditions in 2017 indicate that Batam City is still in the early phase of urban expansion, with a relatively larger proportion of undeveloped land than of built areas. This land use pattern is an important baseline for evaluating land-use dynamics in the next period, especially for identifying the direction of urban growth, industrial area expansion, and the rate of conversion of vegetated land to built-up areas during the 2017–2025 period.

Land Use Conditions in Batam City in 2025

The interpretation of the 2025 land use map shows a significant increase in the extent of built areas compared to 2017. The development of urban areas is no longer concentrated only in urban centers but has extended to suburban areas through spatial expansion that follows the paths of infrastructure development and economic activity. Areas around industrial centers, major transportation corridors, and locations with high levels of accessibility experienced the fastest growth. This pattern indicates that the development of Batam City is shifting from centralized (compact) growth to more widespread urban expansion, alongside an increasing need for space to support industrial activities and urban development.

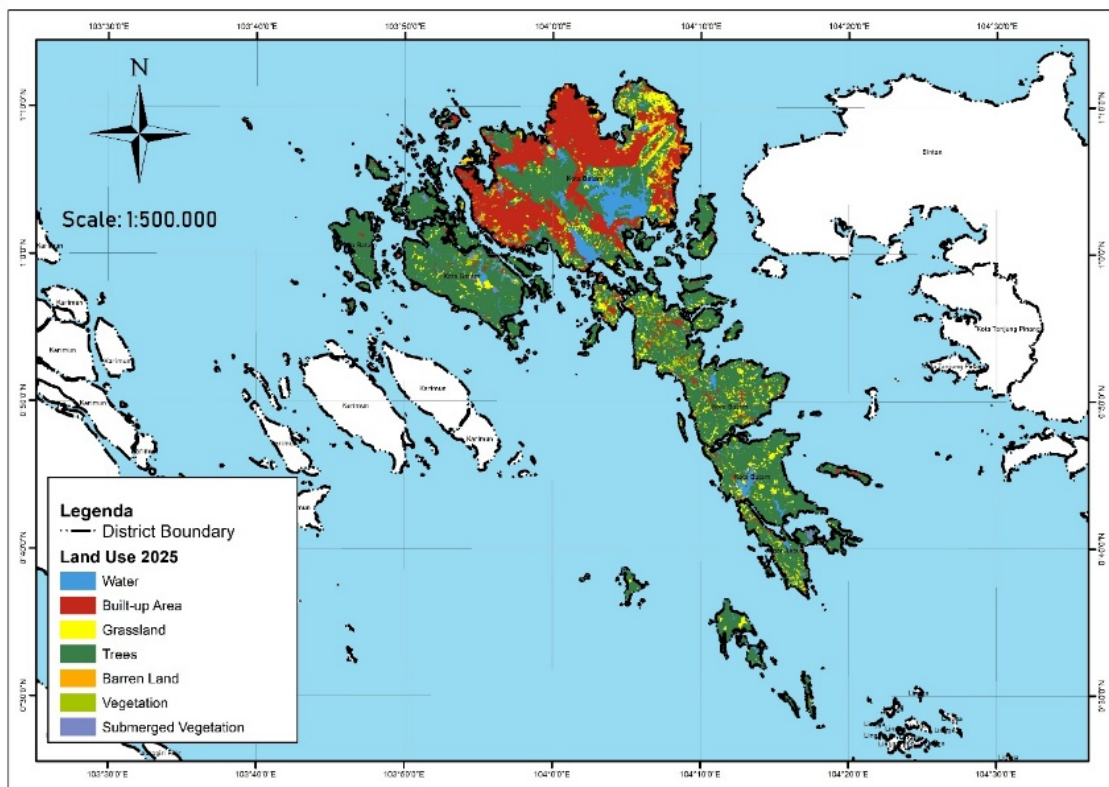


Figure 3. Urban Growth Pattern and Land Use Change in Batam City, 2025
(Source: Primary Data Processing, 2026)

The expansion of the built-up area is shown by the increasing area of industry, settlements, trade areas, and supporting infrastructure that develops around the centers of economic growth. The results of the spatial analysis show that some areas that in 2017 were still in the form of vegetation, open land, and agricultural land have been converted into built-up areas. This change reflects the high pressure on land resulting from increasing investment, population growth, and the development of economic activities in Batam City. This phenomenon shows that land-use conversion not only occurs in the city's core area but also extends to suburban areas that were previously dominated by natural land cover.

The results of this study are in line with the findings of [Fakhira & Cahyono, \(2022\)](#) who stated that the acceleration of industrial estate development in Batam City has been the main factor that encourages land conversion to built-up areas. Similarly, [\(Ado et al., 2023\)](#) explain that the growth of the industrial sector plays a role in accelerating urbanization through the expansion of settlements, infrastructure development, and the emergence of new growth centers that change the spatial structure of cities. Research [\(Sari & Fathimatuzzahrooui's, 2023\)](#) also shows that areas that develop as centers of economic activity in Batam City have experienced an increase in urbanization followed by a decrease in the area of green open space due to the expansion of industrial and residential areas.

Overall, the land-use conditions in 2025 indicate that Batam City has entered a more intensive phase of urban development, with a dominance of increasingly large built-up areas. The expansion of industrial estates is one of the main factors driving land-use changes and shaping urban growth patterns during the 2017–2025 period. These findings show that industrial development not only contributes to regional economic growth but also significantly influences the transformation of urban spatial structures by converting vegetation and open land into built-up areas. Therefore, controlling land-use change through sustainable spatial planning is an important means of maintaining a balance between economic development and environmental sustainability in Batam City.

Land Use Area in Batam City in 2017 and 2025

To provide an overview of the initial land-use conditions in Batam City, the results of the 2017 image classification are presented in Table 1. The information shows the broad distribution of each land use class, which is then used as a reference in the analysis of land use changes during the 2017–2025 period.

Table 1. Land Use Area in Batam City in 2017

No	Land Use Classification	Area (Ha)
1.	Water	7.963,61
2.	Trees	5.9547,4
3.	Flooded Vegetation	1.284,46
4.	Cropland	2.020,97
5.	Built-up Area	17.188,5
6.	Bare Land	3.809,25
7.	Grassland	11.419,2

(Source: [Primary Data Processing, 2026](#))

The results of the 2017 land use classification are presented in Table 1, which shows that the Batam City area comprises seven land-use types: water bodies, trees, flooded vegetation, agricultural land (cropland), built-up areas, bare land, and grasslands. Based on the classification results, tree-dominated vegetation cover is the most prevalent land-use class, covering 59,547.40 ha. This dominance shows that in 2017, most of the Batam City area still had natural characteristics, with forested areas and vegetation. These results reinforce the interpretation of land-use maps, which show that urban development during that period remained concentrated in the centers of economic activity, while the area outside the city's core was still dominated by vegetation.

The built-up area ranks second at 17,188.50 ha, followed by grasslands at 11,419.20 ha, water bodies at 7,963.61 ha, open land at 3,809.25 ha, agricultural land at 2,020.97 ha, and inundated vegetation at 1,284.46 ha. The composition of land use shows that although Batam has developed as one of the national industrial centers, the proportion of built areas in 2017 remains smaller than the total area of vegetation. This condition indicates that the urbanization process in that period is still in the early stages of development, so that the pressure on natural land has not occurred comprehensively.

This finding is in line with the results of a study [\(Gustin et al., 2023\)](#), which states that the development of Batam City in the previous decade was still dominated by vegetation areas, while

industrial and residential areas developed in concentrated strategic locations with high accessibility. Kang & Ma, (2021) Also explained that the expansion of built areas in industrial cities generally begins with the development of industrial estates as growth centers, followed by the development of settlements, trade facilities, and supporting infrastructure in the surrounding area. Therefore, the land-use conditions in 2017 can be considered a baseline for describing the spatial structure of Batam City before the accelerated expansion of the built area in the subsequent period.

The dominance of vegetation cover in 2017 plays an important role in maintaining environmental balance, including hydrological functions, biodiversity, and urban microclimate quality. However, the existence of open land and large vegetation areas also shows the high potential for land use conversion in line with the increasing need for space due to industrial growth, urbanization, and infrastructure development (Jatav et al., 2025). Therefore, land use data in 2017 is an important reference to evaluate the direction of land use changes and urban growth patterns that occurred in Batam City during the 2017–2025 period.

To find out the current condition of land use in Batam City, the results of the 2025 land use classification are presented in Table 2. The table shows the broad distribution of each land use class after experiencing the dynamics of urban development and industrial estate expansion during the 2017–2025 period.

Table 2. Land Use Area in Batam City in 2025

No	Land Use Classification	Area (Ha)
1.	Water	8.887,79
2.	Trees	61.673,30
3.	Flooded Vegetation	692,49
4.	Cropland	1.688,64
5.	Built-Up Area	21.399,70
6.	Bare Land	1.803,63
7.	Grassland	7.155,63

(Source: Primary Data Processing, 2026)

In 2017, bare land covered 3,809.25 ha, agricultural land (cropland) 2,020.97 ha, and flooded vegetation, the smallest land use class, at 1,284.46 ha. Overall, the land-use composition during that period was still dominated by vegetation cover, even though the built-up area had developed into a center of urban activity. This condition shows that before the acceleration of development, Batam City still had a relatively large proportion of natural land, which served as a reserve for the development of urban and industrial areas in the next period.

For comparison, the results of the 2025 land use classification are presented in Table 2. The classification results show that tree cover remains the dominant land-use class, covering 61,673.30 ha. However, the built-up area has increased significantly to 21,399.70 ha, making it the second-largest land-use class after vegetation. Furthermore, the water body covers 8,887.79 ha, followed by grasslands at 7,155.63 ha, open land at 1,803.63 ha, agricultural land at 1,688.64 ha, and the remaining flooded vegetation at 692.49 ha. The change in composition indicates that the development of built-up areas occurred intensively during the period 2017–2025 and was followed by a reduction in several classes of natural land use.

Although vegetation cover will still dominate land use in Batam City by 2025, the increase in built-up area reflects the growing influence of urbanization and industrial area expansion on urban spatial dynamics. The increase in the area of built-up areas, accompanied by a decrease in open land, agricultural land, grasslands, and flooded vegetation, indicates the process of land conversion to meet the need for space for industrial activities, settlements, trade, and urban infrastructure

Spatial Analysis of Urban Growth and Industrial Expansion in Batam City (2017–2025)

The interpretation of land-use maps for 2017 and 2025 reveals that urban growth and industrial expansion were concentrated primarily in the northern, western, and central parts of Batam City.

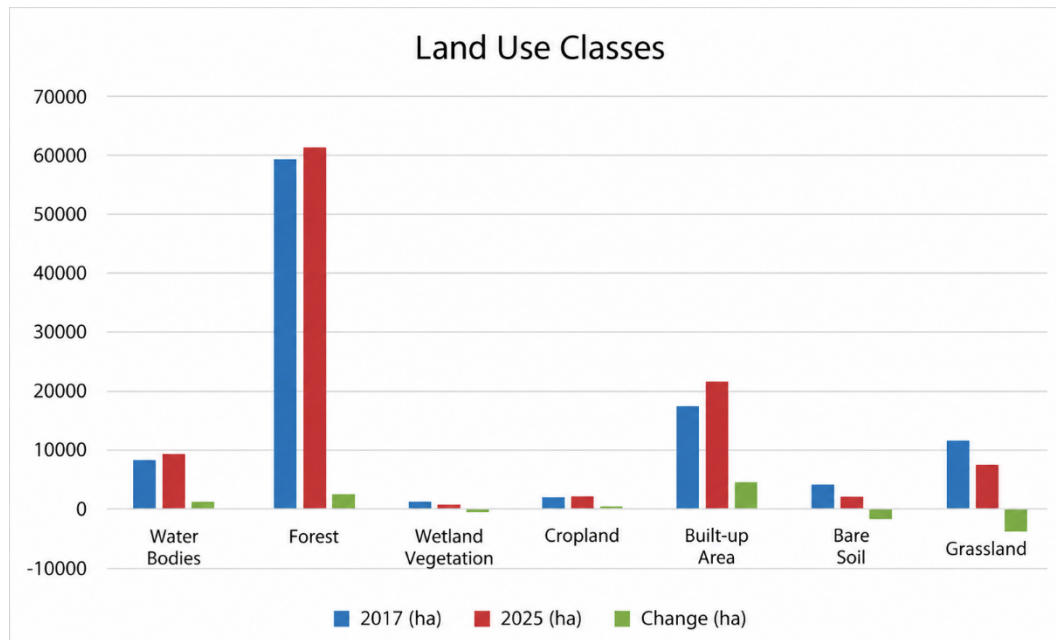


Figure 4. Land Use Classification Diagram (Source: Primary Data Processing, 2026)

The interpretation of the land use maps for 2017 and 2025 shows that growth in urban areas and the expansion of industrial estates in Batam City are concentrated in the northern, western, and central parts of the city. This development pattern indicates that urbanization in Batam City is taking place unevenly, following economic growth centers with high accessibility and supported by transportation infrastructure and industrial activities. This condition indicates that the direction of urban development is influenced by the area's function, the transportation network, and proximity to the center of economic activity.

Based on Figure 4, the North Batam area, especially Batam Kota, Lubuk Baja, and Nongsa Districts, is experiencing very rapid development of built-up areas. The three regions are developing as centers of government, trade, services, tourism, and settlements, thus encouraging the increase in the development of buildings, residential areas, commercial centers, and urban infrastructure. Meanwhile, the western and southwestern regions, such as Sekupang, Batu Aji, and Sagulung Districts, show more dominant industrial area development. The area's proximity to ports, trade areas, and logistics distribution lines makes it a center of industrial activity that continues to grow, with the increasing development of industrial estates, warehouses, factories, and worker settlements. On the other hand, the central area of Batam City also experienced an increase in built-up areas due to growing economic activity and the need for urban land. These development patterns tend to follow the corridors of major roads and coastal areas, suggesting that accessibility is one of the main factors controlling the direction of urban growth.

The findings of this study are in line with research (Wan et al., 2024), which states that urban growth in industrial cities generally follows the network of main roads and centers of economic activity, as these areas have higher accessibility. In addition, (Oyalowo, 2022), it was explained that the expansion of industrial estates is a key driver of the formation of new built areas through increased investment, infrastructure development, and settlement growth in the surrounding area. Thus, the growth pattern of Batam City during the 2017–2025 period shows that the development of industrial estates and increased accessibility are the dominant factors driving land-use changes and transformations in the urban spatial structure.

Influence of Urban Growth and Industrial Area Expansion on Land Use Change in Batam City (2017–2025)

Based on the interpretation of land-use maps from 2017 and 2025, urban growth and industrial area expansion have significantly affected land-use change in Batam City. These changes are reflected in the increase in built-up areas, the reduction in vegetated and bare land, the expansion of industrial and residential areas, and the continued development of urban infrastructure. Land conversion has occurred as a result of increasing demand for space driven by population growth and economic development. Areas previously

covered by vegetation, cropland, and bare land have been transformed into industrial zones, residential areas, commercial centers, and other urban facilities.



Figure 5. Research Documentation in Batam City, 2026

The observed land-use changes also indicate a spatial transformation of Batam City from a predominantly vegetated landscape to an urban and industrial region. Areas with high accessibility and close proximity to industrial centers have experienced more rapid development than other parts of the city. The increase in built-up areas from 17,188.50 ha in 2017 to 21,399.70 ha in 2025 represents an expansion of 4,211.20 ha during the study period. This trend indicates the continuous growth of urban areas, industrial zones, residential developments, and supporting infrastructure in line with the economic growth of Batam City.

This development is particularly evident in strategic economic centers such as the Nagoya area in Lubuk Baja District, which has evolved into a major center for trade, services, hospitality, and business activities. Furthermore, the expansion of industrial estates and residential areas into surrounding regions has strengthened Batam's role as a major economic growth center in the Riau Islands Province. Overall, the urban growth pattern in Batam City during the period 2017–2025 demonstrates a tendency toward the expansion of built-up areas into previously non-built-up land, particularly grasslands and bare land. In contrast, areas dominated by tree cover have experienced relatively minor changes and continue to function as stable components of Batam City's land-use structure.

4. CONCLUSION

This study shows that during 2017–2025, Batam City experienced significant land-use changes due to urban growth and industrial expansion. The results of the spatial analysis show that the built-up area has increased considerably, especially in the northern, central, and western areas of Batam City, which are developing as centers for government, trade, settlements, and industry. In contrast, some land use classes, such as open land, agricultural land, grassland, and flooded vegetation, have experienced a decline in area due to land conversion. Although tree cover remains the dominant land use, the expansion of built-up areas indicates intensified urbanization, thereby changing the spatial structure of Batam City.

The results of the study also confirm that the growth of urban areas tends to follow major transportation corridors, industrial estates, and areas with high accessibility. This shows that industrial development is a key driver of land-use change by increasing the need for space for economic activities,

settlements, and supporting infrastructure. The application of remote sensing technology and Geographic Information Systems (GIS) has been shown to identify urban growth patterns and the spatial and temporal expansion of industrial estates. The findings of this study contribute to understanding the dynamics of land use change in Batam City and can be the basis for the formulation of more sustainable spatial policies through land conversion control, protection of vegetated areas, and more targeted development of urban areas so that the balance between economic growth and environmental sustainability can be maintained.

This research still has some limitations. The analysis of land use change was carried out using two observation periods, namely 2017 and 2025, and therefore could not capture the annual dynamics of land use change. In addition, the identification of urban growth and industrial area expansion still relies on the spatial interpretation of land cover data and does not integrate other driving factors, such as population growth, industrial investment, transportation networks, and spatial planning policies. Therefore, further research is recommended that uses multitemporal data with tighter time intervals and combines remote sensing analysis with spatial modeling, statistical analysis, and socio-economic factors to better understand the processes of land-use change and the direction of urban growth.

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