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|Research Article

Utilization of Normalized Difference Vegetation Index (NDVI) for Vegetation Density Analysis in Binjai City

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Abstract: Urban development in Binjai City has increased the conversion of vegetated land into built-up areas, so up-to-date information on vegetation density is needed for spatial planning. This study aims to map the density and spatial distribution of vegetation across the entire administrative area of Binjai City in 2025 as a baseline for sustainable spatial planning. A Landsat 9 image was pre-processed through radiometric and atmospheric correction and clipped to the city boundary, and the Normalized Difference Vegetation Index (NDVI) was calculated from the near-infrared and red bands in ArcGIS Pro. NDVI values were classified into five density classes and analysed spatially and descriptively. The high greenness class covered 7,385 ha (78.5% of the analysed area) and was concentrated in the southern, western and northern parts of the city, where agricultural land and plantations still dominate the urban fringe. The moderate greenness class (11.9%) was scattered in the central and eastern parts, while the low and very low greenness classes (9.6%) were concentrated in the city centre and along the main road corridors. Vegetation cover in Binjai City is therefore still dominated by high greenness, although low-vegetation areas have formed in the urban core and along transport corridors. These results provide a city-wide baseline for monitoring future vegetation change and for prioritising green open space in the city centre.

Keywords: Binjai City; Vegetation Density; Landsat 9; NDVI; Remote Sensing

1. INTRODUCTION

Land-use change in urban areas has accelerated over the past few decades, driven by growing demand for space for settlements, infrastructure, and economic activities. This process reduces vegetation cover, which plays an important role in maintaining environmental quality in cities. Population growth increases the need for space, changes land-use patterns, and gradually replaces vegetated land with built-up areas, which can cause ecological imbalance if it is not guided by appropriate spatial planning (Yunianto, 2021). Vegetation loss can increase flood risk, raise surface temperatures, and weaken the ecological functions of urban areas; for this reason, vegetation is widely used as an indicator of a region's environmental quality (Hardianto et al., 2021).

Binjai City is a strategic city in North Sumatra Province, located on the main route connecting Medan with Langkat Regency and northern Sumatra. This position has encouraged Binjai to develop as a centre of trade, services, transportation, and settlement. The growth of these activities influences land-use patterns and requires balanced spatial management so that development continues to consider environmental aspects (Sidabutar & Indera, 2021). With a population of 303,272 people in 2023 (BPS Kota Binjai, 2024), pressure on land in Binjai is likely to increase, making information on vegetation distribution essential for planning.

Remote sensing provides an efficient way to obtain vegetation information over large areas and at regular intervals. One of the most widely used methods is the Normalized Difference Vegetation Index (NDVI), which uses the difference in reflectance between the red and near-infrared (NIR) bands. NDVI

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ranges from −1 to +1; high values indicate dense, healthy vegetation, while low values indicate open land, built-up areas, or water (Lasaiba & Saud, 2022). Classifying NDVI values into density classes provides a systematic overview of vegetation conditions and makes it easier to analyse their spatial distribution and changes over time (Nailufar et al., 2018; Lasaiba & Tetelepta, 2024). Landsat-based NDVI has been used to map vegetation density in several Indonesian cities and regencies, including Bandar Lampung, Ambon, Batu, Magelang and Surabaya (Budiputra, 2021; Hardianto et al., 2021; Lasaiba & Saud, 2022; Nailufar et al., 2018; Safitri et al., 2025), and the results have been used as a basis for environmental management and regional planning (Husni et al., 2024; Putri et al., 2026).

Several studies have examined green open space and vegetation in Binjai City. Afrizal (2025) analysed the relationship between population density and the availability of green open space, while Setiawan (2025) examined green open space in relation to land surface temperature. Other studies covered only part of the city. Zaitunah (2021) focused on West Binjai and Binjai Kota Districts, and Hadi (2021) analysed vegetation density in North Binjai District using 2019 data. These studies highlight the importance of vegetation in Binjai, but none provide an up-to-date vegetation density map for the city's entire administrative area.

This study addresses this gap by mapping vegetation density across Binjai City under 2025 conditions using Landsat 9 imagery and NDVI. The objectives are (1) to classify vegetation density in Binjai City and calculate the area of each class, and (2) to describe the spatial distribution of these classes across the city. The resulting map is intended as a city-wide baseline for monitoring future vegetation change and for supporting green open space planning in Binjai City.

2. RESEARCH METHOD

This research was conducted in Binjai City, North Sumatra Province, which consists of five districts: Binjai Kota, Binjai Utara, Binjai Barat, Binjai Timur, and Binjai Selatan **(Figure 1)**. The city borders Langkat Regency and Deli Serdang Regency. Residential areas, commercial zones, and public facilities dominate the city centre, while agricultural land, plantations, and other vegetated areas are still found on the urban fringe. Binjai was selected because it is one of the urban areas in North Sumatra experiencing relatively rapid land-use development. The study covered the city's entire administrative area and used 2025 data.

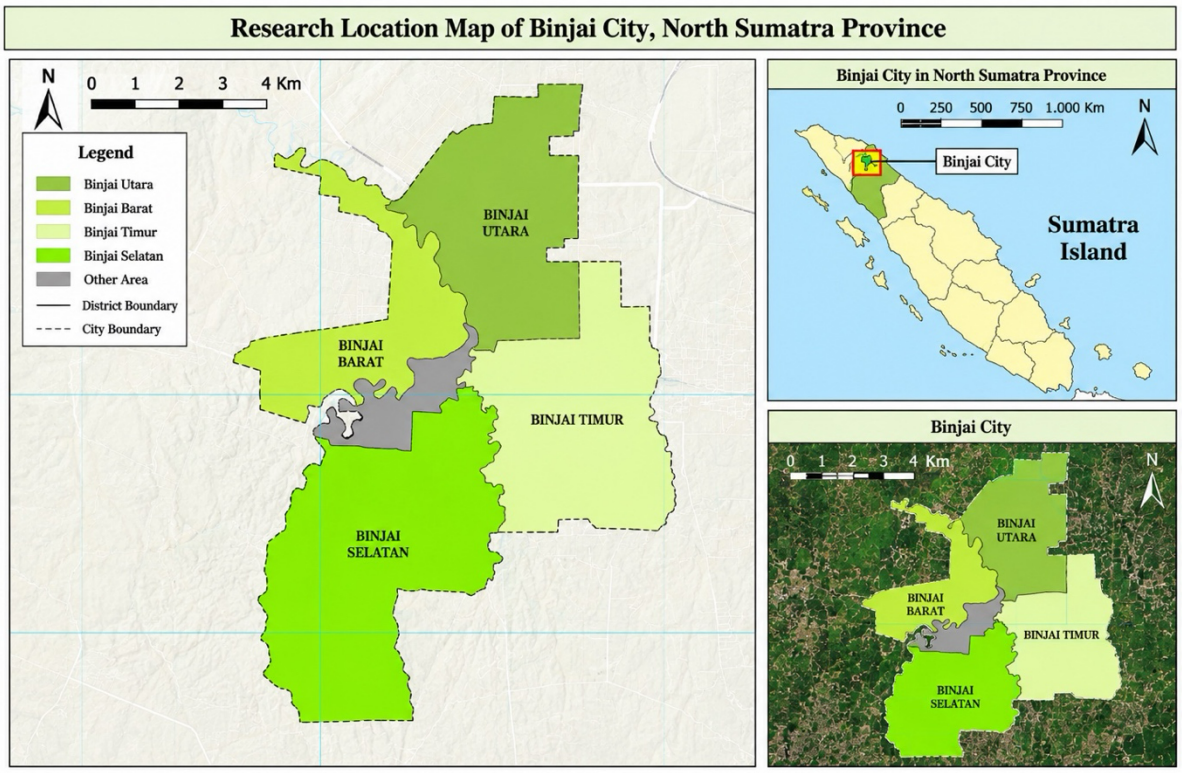


Figure 1. Research location map (Source: Data Processing, 2026)

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This research used two secondary datasets. The main data were Landsat 9 OLI-2 imagery downloaded from the United States Geological Survey (USGS) EarthExplorer. Landsat imagery was chosen because its 30 m spatial resolution and its red and near-infrared bands are adequate for vegetation analysis at the city scale. The analysis area was delimited using the administrative boundary map of Binjai City from the Indonesian Geospatial Information Agency (BIG) at 1:25,000 scale. All data were processed in ArcGIS Pro.

Data Analysis Techniques

Vegetation density analysis was performed using the Normalised Difference Vegetation Index (NDVI) method, one of the most widely used vegetation indices in remote sensing studies for identifying vegetation condition and greenness. NDVI utilises the differences in the spectral response of vegetation in the red (Red) and near-infrared (Near Infrared/NIR) channels, where healthy vegetation tends to absorb energy in the red channel for photosynthesis and reflect higher energy in the near-infrared channel, thereby producing high NDVI values (Hardianto et al., 2021; Doni et al., 2021).

NDVI was selected because it provides quick, consistent information on vegetation conditions over large areas, and its values can be classified into density classes suitable for analysing urban vegetation cover (Purwanto, 2015). Reclassifying vegetation index values into density classes has been shown to produce reliable information on green-cover distribution for evaluating environmental conditions (Ulfami et al., 2026).

Image processing was carried out in three stages. The first stage was image selection: Landsat 9 scenes covering Binjai City in 2025 were screened, and the scene with the lowest cloud cover over the study area was used. The second stage was pre-processing, which included radiometric correction to top-of-atmosphere reflectance, atmospheric correction using a method such as Dark Object Subtraction, and clipping the image to the administrative boundary of Binjai City. The third stage was the NDVI calculation, using the near-infrared (NIR, band 5) and red (band 4) bands of Landsat 9 in the following formula:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}}$$

The NDVI values were then classified into five vegetation density classes. Higher NDVI values indicate greater greenness and vegetation density. The classified map was analysed spatially to describe vegetation distribution in Binjai City in 2025, and the area of each class was calculated from the number of pixels (900 m² per pixel). The results are presented as maps, tables, and a descriptive explanation of vegetation density in the study area.

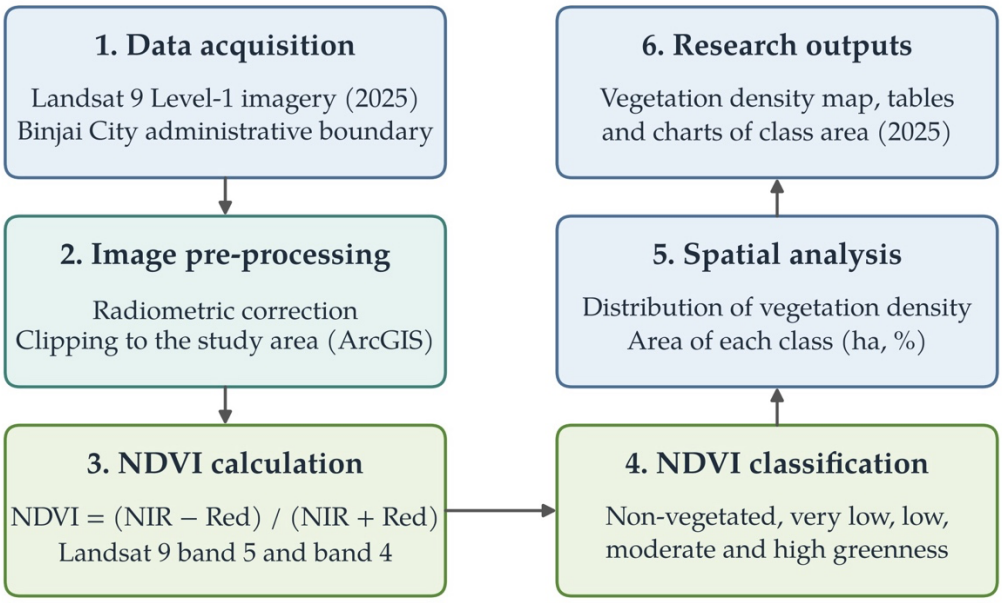


Figure 2. Research Framework (Source: Data Processing, 2026)

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3. RESULTS AND DISCUSSION

Based on the NDVI calculation, vegetation density in Binjai City in 2025 was classified into five classes: non-vegetated land (NDVI < 0.0), very low greenness (0.0–0.2), low greenness (0.2–0.4), moderate greenness (0.4–0.6), and high greenness (> 0.6) (Figure 3). High greenness dominates, covering 78.5% of the city area, especially in the southern part. Low and very low greenness are concentrated in the north-central built-up area along the main road corridor **(Figure 2).**

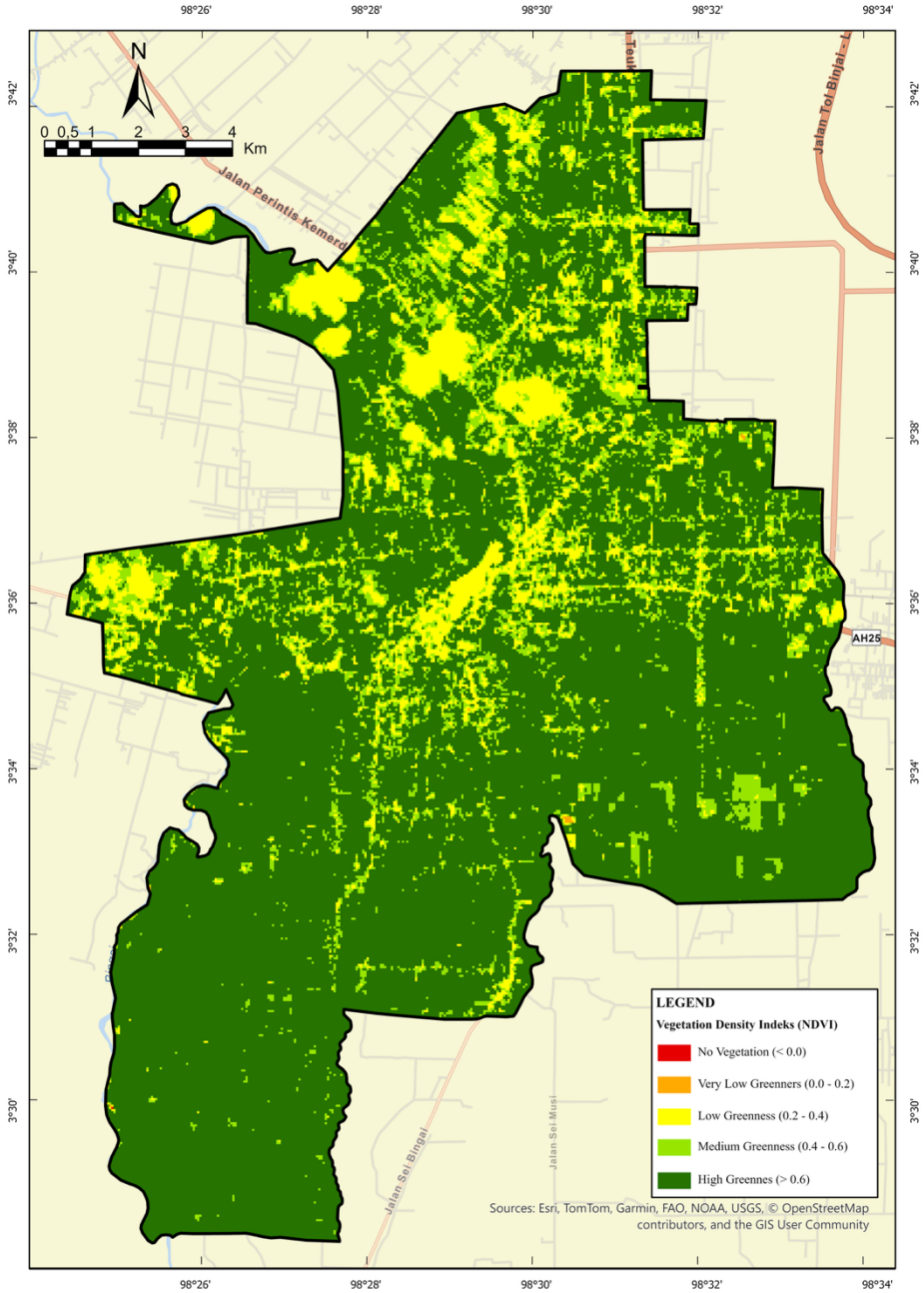


Figure 2. NDVI-based vegetation density map of Binjai City, 2025 (Source: Data Processing, 2026)

The high greenness class is the most widespread and covers most of the southern, western, and northern parts of the city. These areas lie on the urban fringe, where agricultural land, plantations, and mixed gardens are still common. The moderate greenness class is scattered across the city's central and eastern parts. The low and very low greenness classes are concentrated in the city centre and along the main road corridors, where built-up land is dense. The non-vegetated land class has the smallest area and appears only as small, scattered patches.

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Table 2. Area of each vegetation density class in Binjai City, 2025

Class	Area (ha %)
Non-vegetated land	3 (0.03)
Very low greenness	196 (2.1)
Low greenness	706 (7.5)
Moderate greenness	1,117 (11.9)
High greenness	7,385 (78.5)

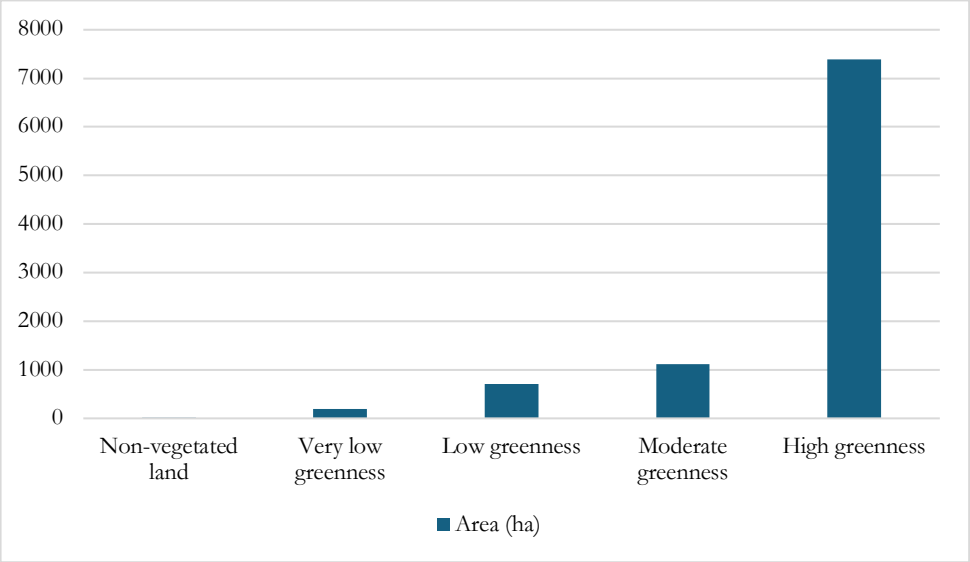


Figure 3. Area of each vegetation density class in Binjai City, 2025

High greenness is the largest class, covering 7,385 ha (78.5%) of the analysed area, followed by moderate greenness (1,117 ha; 11.9%), low greenness (706 ha; 7.5%), and very low greenness (196 ha; 2.1%). Non-vegetated land covers only 3 ha (0.03%) **(Table 2 and Figure 3)**. The total analysed area is 9,407 ha. The dominance of the high greenness class shows that much of Binjai City is still covered by vegetation. However, this class should not be read as urban green space alone. Because it lies in the southern, western, and northern parts of the city, much of it consists of agricultural land, plantations, and mixed gardens on the urban fringe, which may be converted as the city grows. Table 3 compares this study's results with two previous NDVI studies in Indonesian cities.

Table 3. Comparison of the results with previous studies

Comparison Component	This study (2025)	Hardianto, et al. (2021)	Safitri, et al. (2025)
Study location	Binjai City	Bandar Lampung City	Surabaya City
Data Utilized	Landsat 9 image (2025)	Landsat 8 images (2013 and 2019)	Landsat 8 images (2015 and 2025)
Method	NDVI	NDVI	NDVI
NDVI Classification	Non-vegetated land, very low greenness, low greenness, moderate greenness, and high greenness.	Cloud and water, non-vegetation, sparse vegetation, moderately dense vegetation, and dense vegetation.	Non-vegetation, low vegetation, moderate vegetation and high vegetation.
Research Findings	High greenness dominates (7,385 ha; 78.5%), followed by moderate (1,117 ha), low (706 ha) and very	Dense vegetation experienced a decrease, whereas sparse vegetation and non-vegetation areas	Most of the Surabaya region is dominated by low vegetation due to the development of

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Comparison Component	This study (2025)	Hardianto, et al. (2021)	Safitri, et al. (2025)
	low greenness (196 ha); non-vegetated land covers 3 ha.	experienced an increase during the 2013–2019 period.	built-up areas and urbanization.
Influencing Factors	Low vegetation is concentrated in the city centre and along main roads; the urban fringe is still largely agricultural.	Population growth and urban development caused the conversion of vegetated land into built-up areas.	Urbanization and metropolitan city development led to a reduction in green open spaces and an increase in built-up areas.
Implications	Baseline for monitoring vegetation change and for planning green open space in the city centre.	The decline in vegetation increases pressure on urban environmental quality.	The decline in vegetation impacts increasing environmental pressure, including higher land surface temperatures and reduced green open spaces.

Binjai City retains a much higher proportion of vegetated land than larger cities such as Surabaya, where urban expansion has led to the dominance of low vegetation and built-up surfaces (Safitri et al., 2025). The concentration of low and very low greenness classes in the commercial core and along main road corridors reflects Binjai's stage of urban development. As Yang et al. (2021) showed for Chinese cities, the effect of urban expansion on NDVI differs by a city's growth stage, spatial organisation, and greening efforts. In medium-sized cities such as Binjai, vegetation loss tends to occur first in the urban core, while the periphery still retains substantial agricultural and tree cover. This peripheral vegetation is therefore the area most exposed to future conversion.

Moderate and high greenness together account for more than 90% of the analysed area. This indicates that, in 2025, built-up development in Binjai was still concentrated in a relatively small part of the city. Because this study uses one image date, it cannot show whether vegetation has decreased over time; a multi-temporal comparison, as carried out in Bandar Lampung and Surabaya, is needed to assess the rate of vegetation loss (Hardianto et al., 2021; Safitri et al., 2025).

The low and very low greenness classes correspond to built-up areas, high-density residential zones, road networks, and land under conversion, which have low NIR reflectance relative to the red band (Hidayati et al., 2018). This pattern is common in urban areas undergoing intensive physical development, where growing demand for space reduces vegetation cover if it is not balanced by adequate green open space.

With a population of 303,272 people in 2023 and a density of 3,352 people/km² (BPS Kota Binjai, 2024), land pressure in Binjai is likely to continue. Areas with low vegetation density, especially in the city centre and along the main corridors, therefore need particular attention in spatial planning, for example, through providing new green open space and street trees. Vegetated areas also contribute to urban environmental quality. Evenly distributed vegetation helps maintain environmental quality and support sustainable development in cities (Sista et al., 2025), and higher NDVI values are generally associated with denser, healthier vegetation (Arnanto, 2013).

Dense vegetation may also help moderate the urban microclimate. Studies in other cities have found that NDVI is negatively related to land surface temperature, with densely vegetated areas tending to be cooler (Weng et al., 2004; Purwanto & Rahma, 2026). Setiawan (2025) also examined green open space and surface temperature in Binjai. The vegetated fringe of Binjai is therefore likely to play a cooling role, although this was not measured in the present study.

This study has several limitations. First, the analysis is based on a single image date, so it describes vegetation at one point in time and cannot measure change. Second, NDVI values for agricultural land, especially rice fields, vary with the crop stage at the time of image acquisition. Third, Landsat's 30 m resolution produces mixed pixels in dense urban areas, so small green spaces may not be detected (Jiménez et al., 2022). Fourth, the classification was not validated with field observations. Future studies should

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compare several years, combine NDVI with land-use data to separate agricultural land from urban green space, and validate the results using high-resolution imagery or field checks.

4. CONCLUSION

Vegetation density in Binjai City in 2025 is dominated by the high greenness class, which covers 78.5% of the analysed area and is concentrated in the southern, western, and northern parts of the city. Low and very low greenness classes are concentrated in the city centre and along the main road corridors, reflecting the distribution of built-up land. These results provide a city-wide baseline for future monitoring. Because much of the high greenness area lies on the agricultural fringe, it is the area most vulnerable to future conversion. The city government should protect these vegetated areas in spatial planning and increase green open space in the low-vegetation city centre.

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