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Yani Kusuma Perkasa Company

P-ISSN: | E-ISSN:

| Research Article

Spatial Analysis of Vegetation Density Using the Normalized Difference Vegetation Index Method Based on Landsat 8 Imagery in Pematangsiantar, North Sumatra, Indonesia

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Received: June 09, 2026 | Revision: June 25, 2026 | Accepted: July 25, 2026

Abstract: Vegetation plays an important role in maintaining environmental balance through carbon dioxide absorption, oxygen production, air temperature regulation, and improving the quality of the urban environment. Regional development and land use changes in Pematangsiantar City can affect vegetation cover, so monitoring is needed to determine the level of density and spatial distribution of vegetation. This study aims to analyze the distribution of vegetation density in Pematangsiantar City using the Normalized Difference Vegetation Index (NDVI) method based on Landsat 8 imagery in 2026. This study uses Landsat 8 Level 1 imagery from the United States Geological Survey (USGS) as well as Indonesian Terrain Map (RBI) data as supporting data. The research procedure includes data collection, radiometric correction, image cutting according to administrative boundaries, NDVI calculation, vegetation density classification, and spatial analysis using ArcGIS Pro software. The greenery class includes 1,078.65 hectares (14.22%), low greenery 851.85 hectares (11.23%), very low greenery 202.32 hectares (2.67%), and unvegetated land 3.60 hectares (0.05%). High vegetation density is commonly found in suburbs dominated by farmland, plantations, and green open spaces. In contrast, low NDVI values are concentrated in city centers with higher levels of development. The vegetation in Pematangsiantar City is still relatively good. The NDVI method has proven to be effective in identifying and mapping vegetation density and can be used as a basis for sustainable development planning and urban environmental management.

Keywords: NDVI; Vegetation Density; Landsat 8; Pematang Siantar

1. INTRODUCTION

Vegetation is a major component of ecosystems and plays an important role in maintaining environmental balance, including by absorbing carbon dioxide, producing oxygen, regulating air temperature, and protecting land from degradation (Purboyo et al., 2021). In addition, vegetation serves as a key indicator for assessing environmental quality, particularly in urban areas facing development pressures and intensive land-use changes (Rahmalia et al., 2022). Adequate vegetation availability contributes to ecological stability, improved air quality, and reduced negative impacts of human activities on the environment.

Population growth and development in urban areas often lead to a decrease in vegetation cover due to the conversion of land into settlements, trade areas, or infrastructure. The impacts of these changes include

http://doi.org/10.63639/ykp.v2i1.146

increased surface temperature, decreased air quality, and reduced carrying capacity of the urban environment (Husni & Sazali, 2025). Findings (Hardianto et al., 2021) also show that rapid development can reduce green land area and reduce environmental quality. The change in land use from natural vegetation to built-up areas is one of the main factors affecting environmental conditions and vegetation density in an area (Khoirunnisa et al., 2024; Surianto et al., 2026). Therefore, regular monitoring of vegetation conditions is needed to determine the level of density and distribution as a basis for decision-making in regional planning.

Advances in remote sensing technology have increased the effectiveness and efficiency of vegetation monitoring compared to conventional field surveys. This technology provides spatial information with wide-area coverage, as well as regularly updated data (Faradila, 2026). The use of satellite imagery in vegetation mapping is considered superior in terms of time, cost, and energy compared to terrestrial methods, so it is widely used in environmental and spatial planning research (Piawai et al., 2022). One commonly used method for vegetation analysis is the Normalized Difference Vegetation Index (NDVI), which utilizes spectral reflectance values in red and near-infrared channels to identify vegetation conditions (Lasaiba & Saud, 2022).

NDVI is used to map land cover, monitor vegetation changes, and assess crop health levels under various environmental conditions (Padatuan et al., 2024). The NDVI value is obtained by comparing the Near Infrared (NIR) channel and the red channel (Red), so it can describe the level of greenery and vegetation density of an area (Sagita et al., 2022). NDVI value ranges from -1 to +1, with high values indicating dense and healthy vegetation, while low values indicate open land, built-up areas, or sparse vegetation (Aryastana et al., 2022). The NDVI method has been widely used to identify vegetation density levels because it can provide fast, accurate, and easily interpretable information on different types of land cover (Yanti et al., 2020).

Landsat 8 and Landsat 9 imagery are widely used in vegetation analysis because they have a spatial resolution of 30 meters, a wide area coverage, and easily accessible data. Integrating Landsat data with Geographic Information Systems software such as ArcGIS Pro allows spatial analysis and visualization of vegetation distribution to be carried out more accurately and systematically (Ruuhulhaq & Setianingrum, 2024). Hardianto et al. (2021) stated that Landsat 8 is particularly suitable for vegetation density analysis because it can record the spectral information required for NDVI calculations. In addition, Landsat 8 is also widely used for mapping the distribution and density of vegetation because it can provide information on vegetation conditions in large areas on a regular basis (Piawai et al., 2022; Surya et al., 2020).

Vegetation density analysis using the Normalized Difference Vegetation Index (NDVI) method has been widely carried out in various regions of Indonesia by utilizing satellite imagery such as Landsat and SPOT (Yanti et al., 2020; Lasaiba & Saud, 2022; Putri et al., 2026). However, most of those studies only highlight the identification of vegetation density levels and changes in land cover in general. Studies that specifically discuss the distribution of the latest vegetation density in Pematangsiantar City are still very limited. In addition, previous research was generally conducted in areas with different physical characteristics and land use, so the results did not represent the condition of urban vegetation in Pematangsiantar City specifically. This condition indicates a research gap in the form of the latest spatial information on the distribution and density level of vegetation in Pematangsiantar City, which can be used as a basis for environmental management and regional planning.

The novelty of this research lies in the use of Landsat 8 imagery in 2026 to produce the latest information on vegetation density levels and the distribution of vegetation in Pematangsiantar City through the NDVI approach integrated with Geographic Information System (GIS) analysis using ArcGIS Pro. Unlike previous research, which generally only measured the level of vegetation density, this study also analyzed the spatial distribution pattern of vegetation density in urban areas. The findings of this study are expected to provide more comprehensive information as the basis for green open space management, environmental quality monitoring, and sustainable development planning in Pematangsiantar City.

The city of Pematangsiantar in North Sumatra Province is one of the cities that has experienced regional development and increased development activities. Land use changes have the potential to affect vegetation cover conditions, so studies on current vegetation density levels are very important. Information on the distribution of vegetation density is needed to support environmental management, the provision of green open spaces, and sustainable development planning.

Based on this description, this study aims to analyze the distribution of vegetation density in Pematangsiantar City using the Normalized Difference Vegetation Index (NDVI) method based on Landsat 8

http://doi.org/10.63639/ykp.v2i1.146

imagery in 2026. The results of the study are expected to provide spatial information about vegetation conditions that can be used as a basis for consideration in environmental management and regional planning in Pematangsiantar City.

2. RESEARCH METHODS

This research was carried out in the administrative area of Pematangsiantar City, North Sumatra Province, geographically located between 2°53'20" and 3°01'00" N latitude and 99°01'00" and 99°06'35" E longitude**.** Pematangsiantar City was chosen as the research location because it is an urban area that experiences land use development and development that has the potential to affect the condition of vegetation cover. The map of the research location is presented in Figure 1.

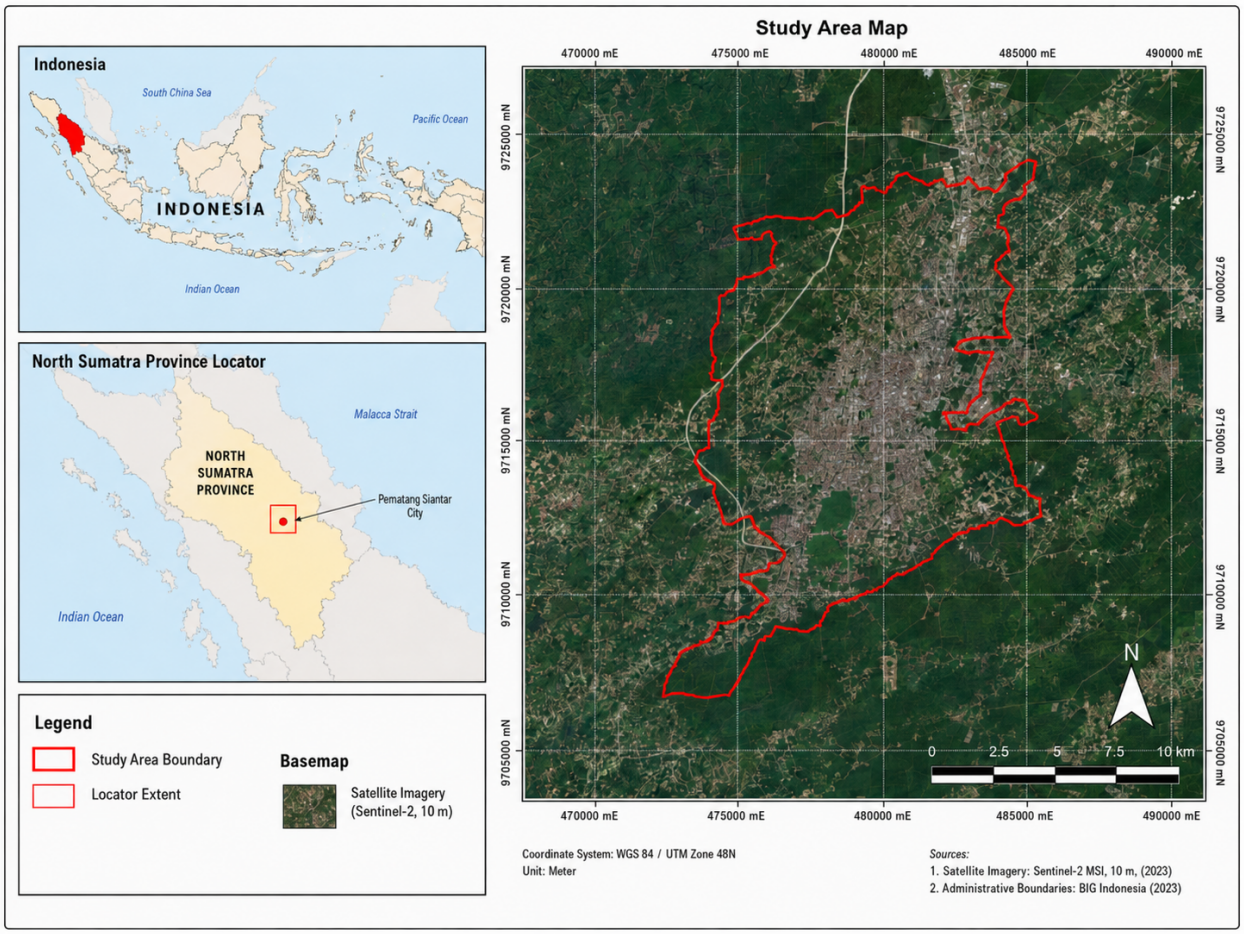

Figure 1. Research Location Map (Source: Data Processing, 2026)

The primary datasets used in this study comprised Landsat 8 Level-1 satellite imagery acquired in 2026 and obtained from the United States Geological Survey (USGS), 2026, as well as the Indonesian Topographic Map (Rupa Bumi Indonesia/RBI) dataset accessed through the Ina-Geoportal of the Geospatial Information Agency (Ina Geoportal (BIG), 2026. The RBI dataset was used as supporting spatial data to delineate the administrative boundaries of Pematangsiantar City and to clip the Landsat imagery to the defined study area.

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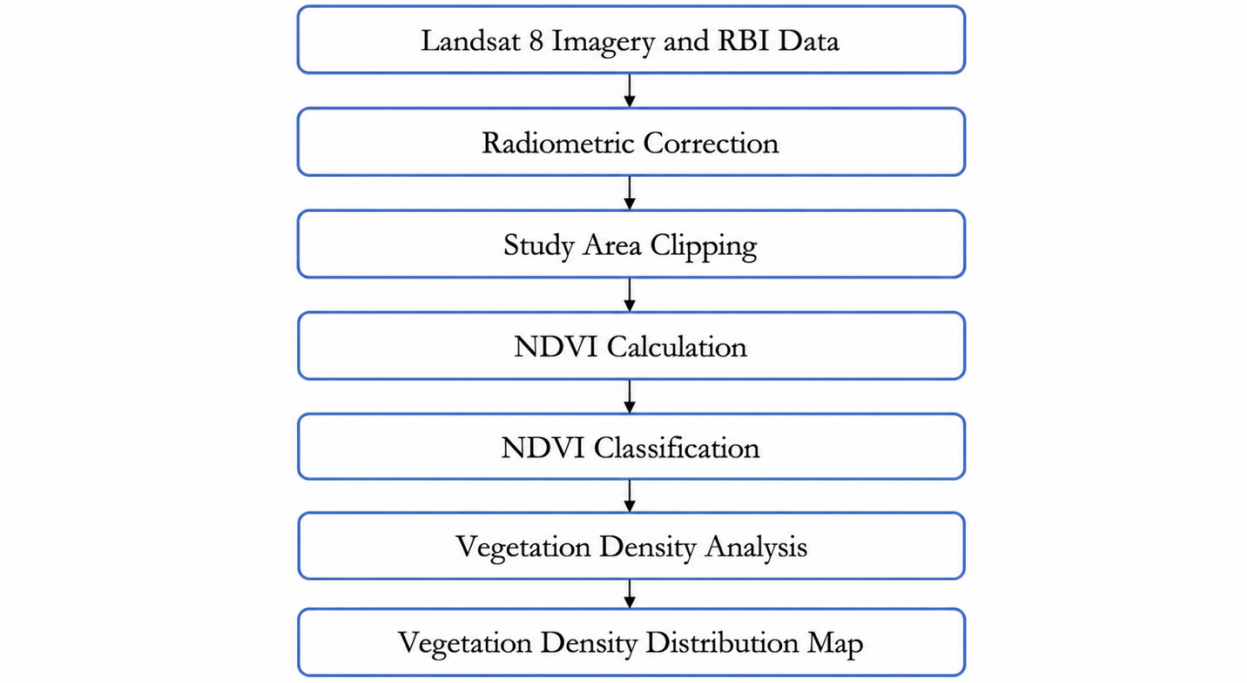

Figure 2. Research Framework (Source: Data Processing, 2026)

This research was carried out through several stages arranged within the research framework, as shown in Figure 2. These stages include data collection, image pre-processing, vegetation index calculation, vegetation density classification, and analysis and presentation of results in the form of thematic maps. The image preprocessing stage includes radiometric correction and calibration to improve the quality of the image reflectance values so that they better represent the condition of the object on the earth's surface. Furthermore, the images were cut based on the administrative boundaries of Pematangsiantar City so that the analysis was focused on the research area.

Vegetation density analysis was carried out using the Normalized Difference Vegetation Index (NDVI) method. NDVI, according to Rouse et al. (1974), is a vegetation index that utilizes differences in reflectance values in red (Red) and near-infrared (NIR) channels to identify the level of greenery and vegetation density. This method is widely used in vegetation mapping because it can describe vegetation conditions effectively and is easy to interpret (Lasaiba & Saud, 2022; Putri et al., 2026). Vegetation density analysis was carried out using the Normalized Difference Vegetation Index (NDVI) method. The NDVI calculation is done based on the following equation (J. W. Rouse et al., 1974).

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

The NDVI values obtained were then classified into five classes of vegetation density, namely non-vegetated land, very low greenness, low greenness, medium greenness, and high greenness. This classification refers to the range of NDVI values used by Putu Aryastana et al., 2022. The entire data processing and analysis were carried out using ArcGIS Pro software to produce a map of vegetation density distribution and calculate the area of each vegetation class.

3. RESULTS AND DISCUSSION

The analysis of vegetation density in Pematangsiantar City was carried out using the Normalized Difference Vegetation Index (NDVI) method based on Landsat 8 imagery that has undergone radiometric

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calibration. The NDVI processing results produced a vegetation density classification map consisting of five classes: unvegetated land, very low greenery, low greenery, medium greenery, and high greenery.

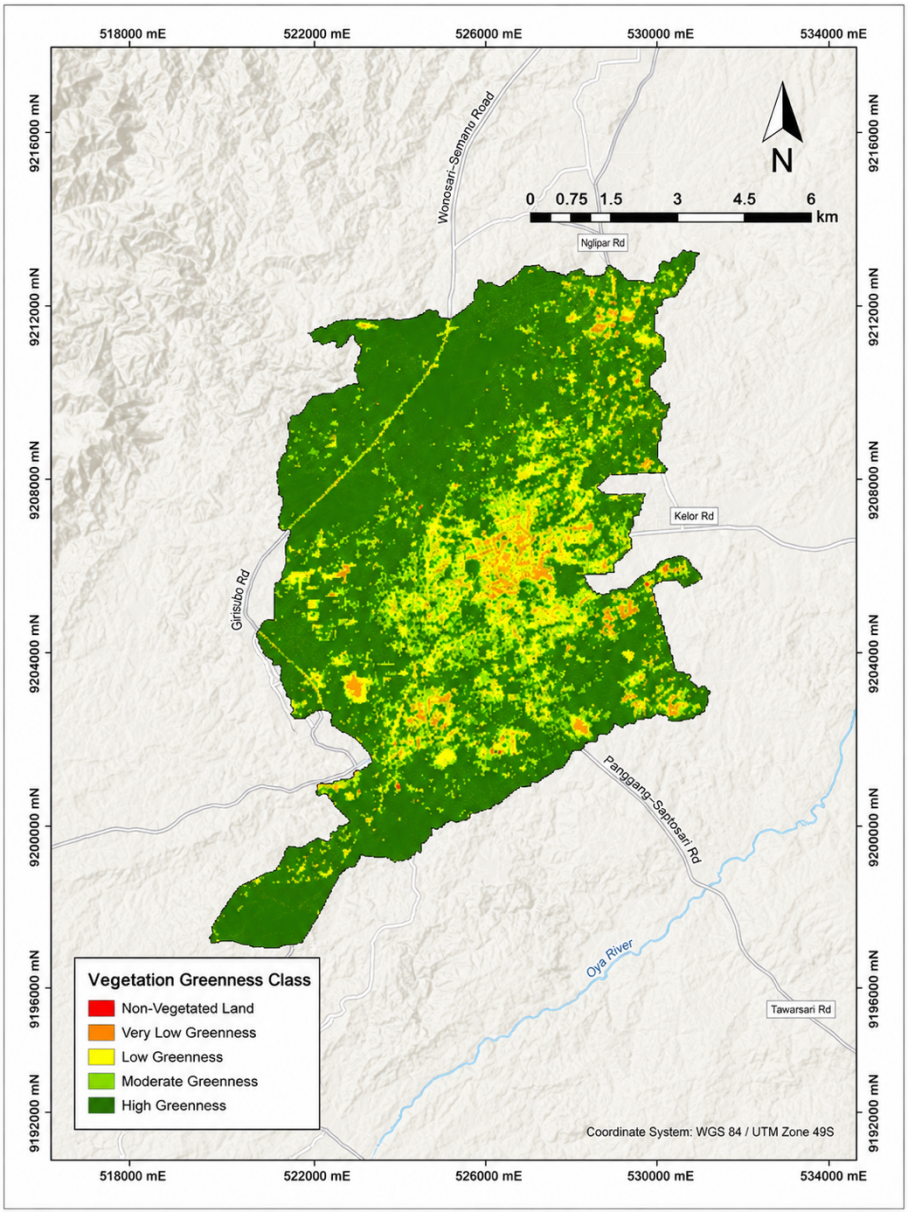

Figure 3. Vegetation density classification map of Pematangsiantar City in 2026 (Source: Data Processing, 2026)

Figure 3 shows that the distribution of vegetation in Pematangsiantar City is dominated by high-greenery classes, spread almost throughout the area, especially in suburban areas, which still consist of agricultural land, plantations, and green open spaces. In contrast, low to very low greenery grades are generally concentrated in urban centers that have high building density and human activity levels. This difference reflects the different characteristics of land use between urban areas and areas that are still dominated by natural vegetation or cultivated land. Padatuan et al. (2024) state that increased development and land conversion can lead to a decrease in vegetation cover and a decrease in environmental quality if not balanced with adequate management of green open space.

http://doi.org/10.63639/ykp.v2i1.146

Lasaiba & Saud (2022) stated that a high NDVI value indicates dense and healthy vegetation conditions because the near infrared reflectance (Near Infrared/NIR) is greater than the reflectance in the red channel (Red). In contrast, low NDVI values are generally found in built-up areas, open land, or areas with limited vegetation cover. This statement is supported by Husni et al. (2025), who explain that NDVI vegetation observations are based on a comparison of red and near-infrared channel reflectance, where higher NDVI values indicate better vegetation condition and plant chlorophyll content. In addition, Aldzahabi et al. (2024) state that NDVI is a vegetation greenery index that represents photosynthetic activity and can be used to describe the level of vegetation density in an area.

The area distribution of each vegetation class was obtained through the calculation of the NDVI classification result area, as shown in Table 1. Information about the area of each vegetation class is important for determining land cover condition and vegetation density, and can be used as a basis for environmental management planning and monitoring vegetation changes over time.

Table 1. Total Area of Each Vegetation Class

No	Vegetation Class	Wide (ha)
1	Unvegetated Land	3,60
2	Very Low Greenness	202,32
3	Low Greenness	851,85
4	Medium Greenery	1.078,65
5	Medium Greenery	5.450,22
6	Total	7.586,64

Table 1 shows that the high greenery class has the largest area, at 5,450.22 hectares, or about 71.84% of the total research area. These findings show that most of the Pematangsiantar City area still has good vegetation cover. The medium greenery class covers 1,078.65 hectares, or about 14.22%, while the low greenery class reaches 851.85 hectares, or about 11.23%, of the total research area. The very low greenery class has an area of 202.32 hectares or about 2.67%, while the non-vegetated land only reaches 3.60 hectares or about 0.05% of the total area. A very small percentage of unvegetated land class confirms that Pematangsiantar City is still dominated by vegetation.

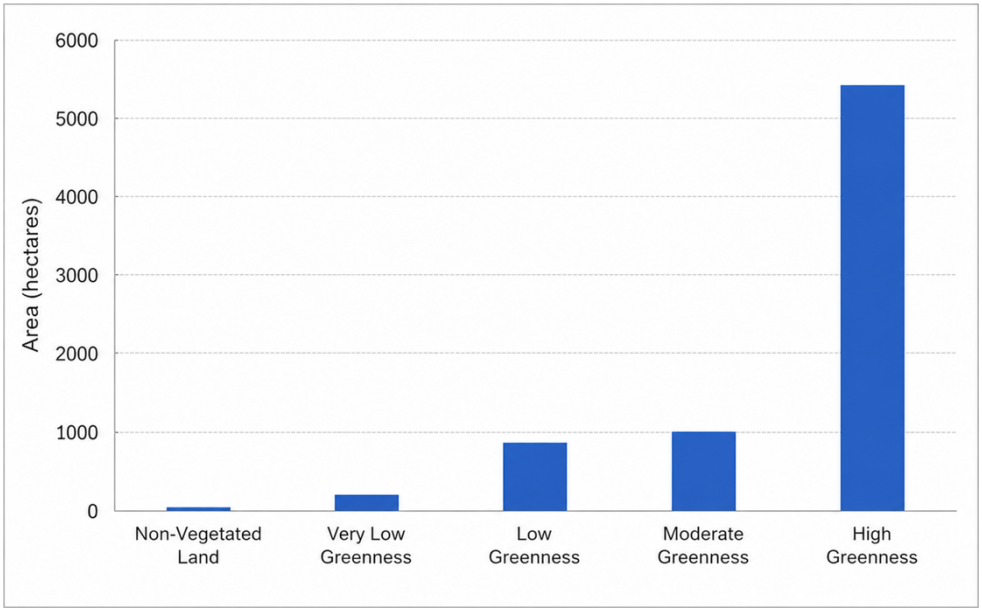

Figure 4. Graph of the Distribution of Vegetation Density Class Based on NDVI Value in Pematangsiantar City in 2026 (Source: Data Processing, 2026)

http://doi.org/10.63639/ykp.v2i1.146

Figure 4 shows that the high greenery class has a much larger area than the other classes. This significant difference shows that the condition of vegetation cover in Pematangsiantar City is still maintained. These findings indicate that the research area still has a good ecological function in supporting the balance of the urban environment. NDVI analysis shows that Pematangsiantar City is dominated by high greenery, with an area of 5,450.22 hectares or around 71.84% of the total research area. These findings confirm that most areas still have dense and healthy vegetation cover. Aryastana et al. (2022) state that high NDVI values reflect vegetation conditions with optimal photosynthetic activity and high vegetation density levels. Zeng et al. (2022) also emphasized that remote sensing-based vegetation indices are an effective approach to monitor ecosystem conditions and vegetation dynamics at various spatial and temporal scales.

In this study, high-greenery vegetation is generally found in the suburbs of Pematangsiantar City, which are dominated by agricultural land, plantations, and green open spaces. These findings are consistent with the results of the study by M. F. Husni et al. (2025) and Winarti & Rahmad (2019), which state that areas with low development intensity tend to have higher NDVI values than dense urban areas. The dominance of vegetation in the suburban area shows that the ecological function of the area is still maintained.

The results of this study are in line with the findings Putri et al. (2026), which analyzed the vegetation index using the NDVI method based on SPOT 7 imagery in Simeulue Regency. The study shows the dominance of vegetation classes with a high level of greenery, reflecting vegetation cover that is still maintained. The similarity of results between the two studies confirms that the NDVI method can produce consistent information for identifying vegetation density levels, even when using different data sources. However, there are differences in regional characteristics. Simeulue Regency is dominated by natural vegetation and plantations, while Pematangsiantar City is an urban area with higher development pressure and land use change. In addition, Putri et al. (2026) used SPOT 7 imagery with higher spatial resolution than the Landsat 8 imagery used in this study. Nevertheless, both studies showed the dominance of high vegetation classes, which indicated relatively good vegetation conditions.

The dominance of vegetation with a high level of greenery in Pematangsiantar City confirms the important role of vegetation in maintaining the quality of the urban environment. Zeng et al. (2022) state that vegetation plays a role in the carbon cycle, energy balance, and hydrological systems that support ecosystem sustainability. Lee et al. (2023) also emphasize that vegetation information is a key component in sustainable urban planning because it is directly related to environmental quality and urban comfort.

In contrast, low and very low greenery grades are more prevalent in the center of Pematangsiantar City, which is dominated by residential, commercial, and urban infrastructure areas. These findings show the influence of development activities on the decline in vegetation cover. Rahmalia et al. (2022) stated that the increase in the area of built land and the development of residential areas caused a decrease in the value of NDVI due to the reduction of vegetation area that functions as green open space. This statement is reinforced by Purboyo et al. (2021), who explain that the development of urban areas without adequate green open space can reduce environmental quality. The results of this study are also consistent with Munyati (2024), who suggests that reduced urban vegetation is closely related to increased surface temperature and decreased environmental quality.

The findings of this study are consistent with the results of Wirawan & Chernovita (2023), which show that population growth and the development of residential areas encourage land use change from vegetated areas to built-up areas. These changes have an impact on decreased NDVI values and vegetation density. Similar results were also reported by Furusawa et al. (2023), yang menyatakan bahwa perubahan penggunaan lahan merupakan faktor utama yang memengaruhi perubahan tutupan vegetasi yang terdeteksi melalui citra satelit. In addition, the rate of vegetation degradation in Pematangsiantar City is still low. These results are consistent with research by Rafsanjani & Papilaya (2024), which states that the dominance of high NDVI values reflects environmental conditions that still support optimal vegetation growth. Yankovich et al. (2023) also explained that areas dominated by high NDVI classes generally have stable vegetation conditions and contribute to the sustainability of the region's ecological function. Overall, the results of this study reinforce the findings (Putri et al. (2026; Lasaiba & Saud, 2022; Rafsanjani & Papilaya, 2024; Rakuasa & Sihasale, 2023) shows that the dominance of high NDVI values is an indicator of good vegetation conditions and plays an important role in maintaining environmental quality. The information on the distribution of vegetation density produced in this

http://doi.org/10.63639/ykp.v2i1.146

study can be used as a basis for decision-making for green open space management, environmental quality monitoring, and sustainable development planning in Pematangsiantar City.

4. CONCLUSION

NDVI analysis using Landsat 8–9 imagery and ArcGIS Pro software shows that the density of vegetation in Pematangsiantar City in 2026 is generally relatively good. The high greenery class dominated the research area with an area of 5,450.22 hectares, followed by moderate greenery with an area of 1,078.65 hectares, low greenery with an area of 851.85 hectares, very low greenery with an area of 202.32 hectares, and non-vegetated land with an area of 3.6 hectares. The distribution of vegetation with high density is generally found in suburban areas dominated by agricultural land, plantations, and green open spaces. In contrast, low NDVI values are concentrated in urban centers that have higher levels of development. These findings indicate that the NDVI method is effective for analyzing and mapping vegetation conditions and can be used as a basis for sustainable development planning and urban environmental management in Pematangsiantar City.

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