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| Research Article

Spatial Assessment of Urban Vegetation Density Using Landsat 8 NDVI: A Case Study of Sibolga, Indonesia

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Abstract: The intensive growth of urban areas has increased the conversion of vegetated land into built-up areas, thereby reducing the quality of the environment and green open spaces. Sibolga City as a coastal city with limited land faces urbanization pressures that have the potential to accelerate the decline in vegetation cover. This study aims to analyze and map the level of vegetation density in Sibolga City using the Normalized Difference Vegetation Index (NDVI) approach. The study uses a descriptive quantitative method based on spatial analysis by utilizing Landsat 8 imagery in 2025 as the main data. Data processing was carried out through the pre-image processing stage, calculation of NDVI values using ArcGIS Pro, classification of vegetation density levels into five classes, and descriptive analysis of the spatial distribution of the mapping results. The results showed that the middle greenery class dominated the Sibolga City area with an area of 546.77 ha (47.77%), followed by very low greenery of 221.83 ha (19.38%), unvegetated land of 207.61 ha (18.14%), low greenery of 166.43 ha (14.45%), while high greenery only 2.89 ha (0.25%) remained. The accumulation of unvegetated land, very low greenery, and low greenery reached 51.97% of the total area, indicating the dominance of the built landscape as well as the high pressure on urban vegetation. This study concludes that the condition of vegetation cover in Sibolga City requires strengthening spatial planning policies based on spatial data through the protection of vegetated areas, the development of green open spaces, and the control of land conversion to support the sustainability of the urban environment.

Keywords: NDVI; Vegetation Density; Remote Sensing; Landsat 8; Sibolga City.

1. INTRODUCTION

The growth of the urban population is a global phenomenon that continues to day. Data released by the World Bank in 2025 notes that more than half of the world's population, or about 4.4 billion people, now live in urban areas. This figure is projected to increase to close to 70 percent by 2050. This massive urban expansion is driving the conversion of natural land into large-scale built-up areas (Anestis & Stathakis, 2024; Angel, 2023). Urban vegetation is one of the most affected environmental elements due to the pressure of development (Semeraro et al., 2021; Yang et al., 2021). Indonesia is also experiencing urbanization pressures similar to this global trend (Shinta, 2024).

The growth of cities in various regions can be seen from the increase in urban community activities (Duranton & Puga, 2023; Mahtta et al., 2022). The development of commercial and industrial residential areas continues to meet the needs of the growing population. This condition creates a big challenge in maintaining the balance of the urban environment (Nugroho et al., 2022). Green open space in many major cities in Indonesia has decreased in area due to rapid land conversion (Devi & Santosa, 2022). The phenomenon of

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shrinking urban green space is clearly reflected in several major cities in Indonesia. The city of Surabaya lost around 1,190 hectares of green area in the period 2023 to 2024 due to industrial and residential expansion. The percentage of public green open space in the city decreased from 18.22 percent in 2021-2022 to 14.25 percent in 2023-2024. A similar pattern also occurred in Semarang City, with green space shrinking again to 45.95 percent after improving the previous year.

Pressure is much greater in cities with limited land, such as coastal areas flanked by the sea and hills. The availability of narrow land forced development to encroach on steeply sloped areas and vegetated areas that previously functioned as the city's ecological buffer (Sudarso et al., 2023). This kind of topographic condition is vulnerable to hydrometeorological disasters such as landslides and floods if vegetation cover continues to decrease. The city of Sibolga in North Sumatra Province is one of the real examples of this condition. Geographically, Sibolga City is sandwiched between the coastline of Tapian Nauli Bay and the steep hills of Bukit Barisan. The city serves as a center of economic growth and an important port on the west coast of Sumatra, thus facing significant land limitations (Sinaga et al., 2021).

Population growth drives increased demand for housing and citizens' economic activity, which contributes rapidly to the physical development of the city (Amri & Giyarsih, 2022). Increasing demographic and urbanization pressures have triggered the expansion of built-up areas that penetrate hilly areas and turn vacant land and vegetated land into built-up areas. This condition threatens the existence of green open spaces that are essential for human life and the sustainability of other species around it (Surya et al., 2021). Remote sensing technology is an effective solution for monitoring land cover dynamics spatially amid the complexity of these problems. The Normalized Difference Vegetation Index or NDVI is one of the most widely used indices to assess vegetation canopy density through the evaluation of leaf chlorophyll conditions (Farias et al., 2023; Zhao & Qu, 2024).

Research Ally & Daniswara (2023) in the city of Surakarta proves that population growth contributes significantly to the decline in NDVI values spatially from year to year. The findings reinforce evidence that demographic pressure and vegetation index are closely related in many cities in Indonesia. Other research by Hardianto et al. (2021) in Bandar Lampung City also used Landsat 8 imagery to identify the value of the vegetation density index in the 2013 and 2019 range. They found a consistent pattern of decreasing vegetation density as the built-up area in the study area expanded. The two studies show that the NDVI method can accurately and consistently capture the dynamics of urban vegetation in various cities. Similar spatial information regarding vegetation density in Sibolga City is still very limited, even though this city has unique topographic characteristics in the form of a combination of coastal and hilly areas with narrow land.

This data gap is an urgent problem, considering that development pressure in Sibolga City continues amid extreme land limitations. Vegetation density mapping based on Landsat 8 imagery recorded in 2025 is a strategic step to describe the current condition of urban vegetation. This research is novel in presenting data and a map of the distribution of vegetation density in Sibolga City that has never been documented before, using the latest 2025 imagery. Based on the problems and gaps in the research, this study aims to analyze, measure, and map the level of vegetation density in Sibolga City using the NDVI approach to obtain spatial information that can support environmental management and sustainable regional development.

2. RESEARCH METHODS

This study uses a descriptive quantitative approach with spatial analysis based on remote sensing. This approach was chosen because the research is non-field, so the entire process of data collection and processing is carried out through the interpretation of satellite images and geographic information system devices. The research design aims to measure and map the level of vegetation density in Sibolga City using the Normalized Difference Vegetation Index method based on Landsat 8 imagery in 2025.

The population in this study is the entire administrative area of Sibolga City, which covers a coastal and hilly area of 1,144.53 hectares based on the results of image mapping. Because this study is spatial and does not involve human respondents, the sample used is Landsat 8 imagery data in 2025, which covers the entire area of Sibolga City without a random sample extraction technique. All image pixels within the city administration boundaries become a unit of research analysis so that the NDVI results obtained represent the overall vegetation conditions.

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This research is located in Sibolga City, North Sumatra Province (Figure 1). Geographically, Sibolga City is located on the west coast of Sumatra Island at coordinates 1°42'–1°46' North Latitude and 98°44'–98°48' East Longitude. The administrative area of this city is bordered by Central Tapanuli Regency to the north, south, and east, and Tapian Nauli Bay to the west.

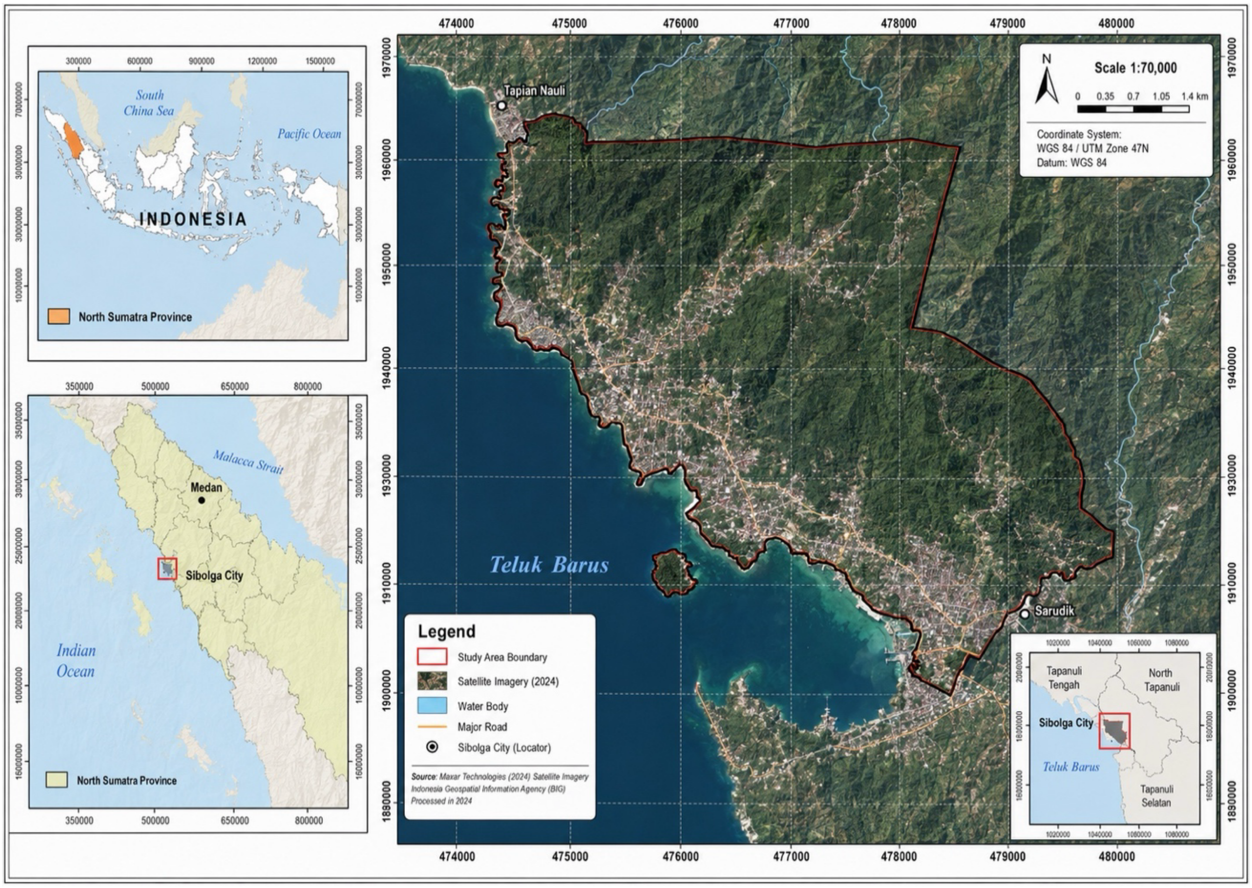

Figure 1. Research Location Map (Source: Data Processing, 2026)

Data Collection Techniques

Data were collected through documentation methods and secondary data tracing without field surveys. The main data, in the form of Landsat 8 imagery in 2025, were obtained from the United States Geological Survey (USGS), with a low percentage of cloud cover to maintain interpretation accuracy. Supporting data in the form of the Sibolga City Administration Map is used as a boundary so that the data processing process is focused on the scope of Sibolga City. Validation of the accuracy of the object distribution was carried out through visual cross-testing using high-resolution imagery from Google Earth Pro, considering that this study did not involve direct field checking.

Data Analysis Techniques

Data analysis is carried out through digital processing using ArcGIS Pro software with the following stages.

1. Pre-processing of images in *the* form of image cutting according to the administrative boundaries of Sibolga City and checking for cloud disturbances.
2. Extraction of vegetation index values using the Raster Calculator function on a combination of Band 5 (Near-Infrared) and Band 4 (Red) Landsat 8 imagery with the formula:

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$$\text{NDVI} = \frac{\text{BAND 5} - \text{BAND 4}}{\text{BAND 5} + \text{BAND 4}}$$

Description:
NDVI = Normalized Difference Vegetation Index (nilai indeks kerapatan vegetasi)
Band 5 = Near-Infrared (NIR) channel on Landsat 8 imagery
Band 4 = Red channel on Landsat 8 imagery

The classification of vegetation density is carried out by grouping the NDVI values of the image transformation into five classes based on their greenness level, as presented in Table 1 below.

Table 1. Classification of Vegetation Density Class Based on NDVI Value

Density Class	Range NDVI	Indicators / Characteristics
Land is not vegetated	-1 s/d -0,03	Open ground surfaces, water bodies, and built-up areas such as asphalt, concrete, and building roofs
Very low greenery	-0,03 s/d 0,15	Sparsely vegetated transition areas around settlements and infrastructure
Low greenery	0,15 s/d 0,25	Vegetation of shrubs or young plants with a canopy cover not yet tight
Medium greenery	0,26 s/d 0,35	Tree and shrub vegetation with a fairly good canopy density
High greenery	0,36 s/d 1,00	Very dense canopy density vegetation or primary forest characteristics

(Source: VITO (Vision on Technology, 2017)

The entire stages of data analysis are briefly described in the research framework chart in Figure 2 below.

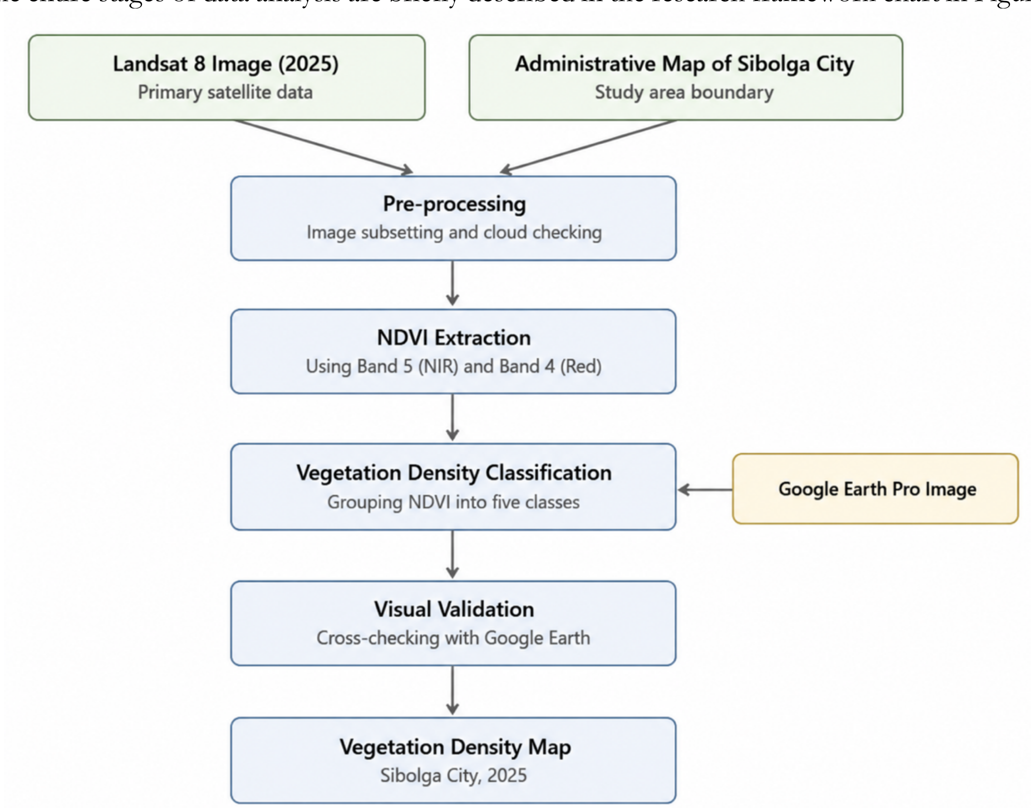

Figure 2. Research Framework (Source: Data Processing, 2026)

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3. RESULTS AND DISCUSSION

Spatial Distribution and Density of Vegetation in Sibolga City

Based on the results of processing Landsat 8 satellite images recorded in 2025 using the Normalized Difference Vegetation Index (NDVI) method in ArcGIS Pro, a map of the spatial distribution of vegetation density in Sibolga City was obtained. The density class is divided into five classes, namely Non-Vegetated Land, Very Low Greenness, Low Greenness, Medium Greenness, and High Greenness.

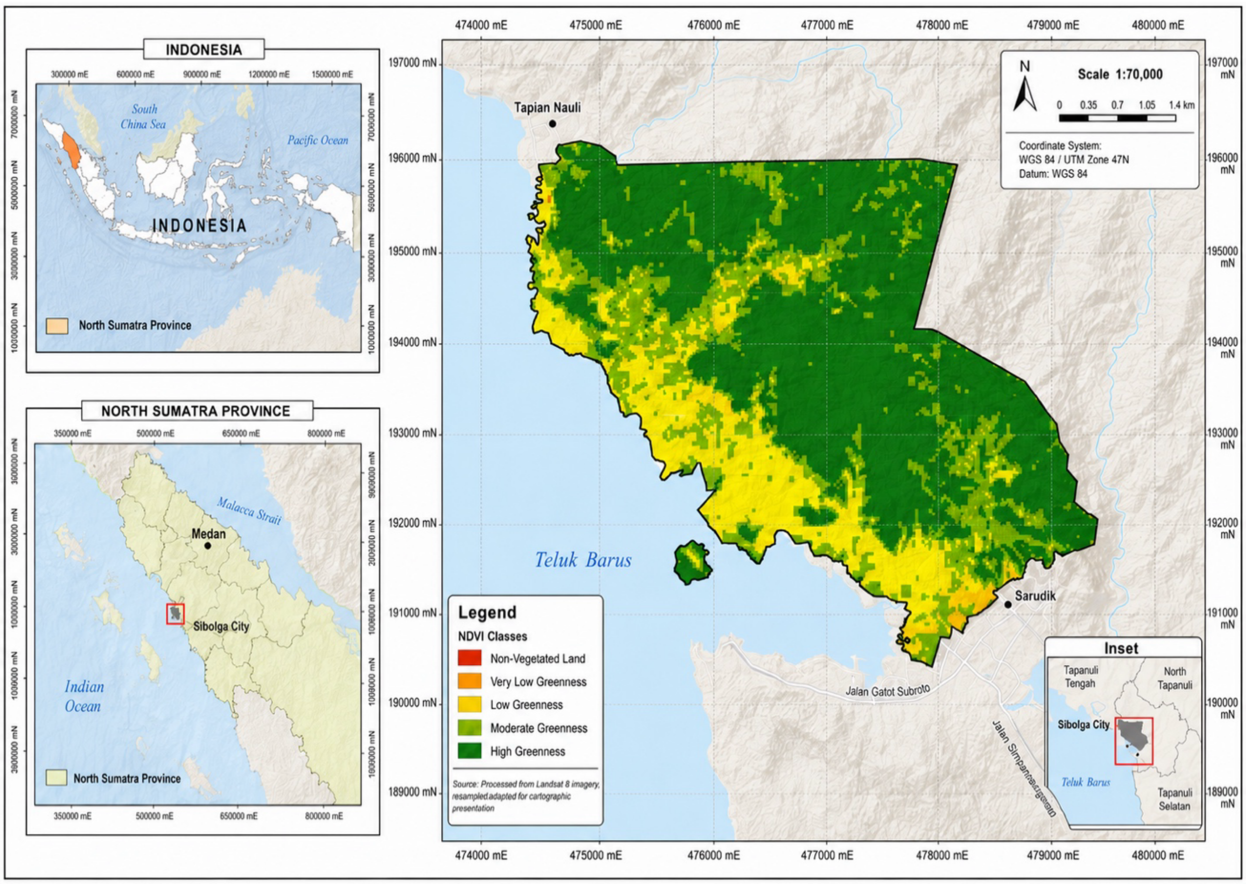

Figure 2. Spatial Distribution Map of Vegetation Density NDVI Sibolga City in 2025
(Source: Processed from Landsat 8 USGS imagery, 2026).

Based on the spatial visualization in Figure 2, the distribution of vegetation density in Sibolga City shows contrasting zoning characteristics between hilly interior areas and coastal areas. The Medium Greenery class (light green) dominates the sloped areas on the north and east sides because the steep topography makes it difficult to clear large-scale land, while the High Greens (dark green) class only remains as small pixels on isolated hilltops. In contrast, the Low Greenery and Very Low Greens classes converge along the west coast lowlands that follow residential centers, roads, and harbors, with boxes of Unvegetated Land at downtown points covered with cement, asphalt, or building roofs. In the small island parts in the south (Poncan Island and its surroundings), the cover is dominated by Medium Greenery in the middle of the island surrounded by a Low Greening ring on its coastline.

Table 1. Area and Percentage of Vegetation Density of Sibolga City in 2025

Density Class	Wide (ha)	Percentage (%)
Medium Greenery	546,77	47,77
Very Low Greenness	221,83	19,38
Unvegetated Land	207,61	18,14

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Low Greenness	166,43	14,45
High Greenery	2,89	0,25
Total	1.144,53	100

(Source: Data Processing, 2026)

Based on Table 1, the total land area of Sibolga City that has been mapped is 1,144.53 hectares, dominantly controlled by the Medium Greenery class (47.77%), which covers hills and steep slopes in the north-east of the city. Crucial facts were found in the High Greenery class, which covers only 2.89 hectares (0.25%), indicating extreme shrinkage of the primary forest area. If the Unvegetated, Very Low Green, and Low Greenness classes are combined, about 51.97% of Sibolga City's land is dominated by non-natural landscapes, concentrated and elongated along the west coast of Tapian Nauli Bay.

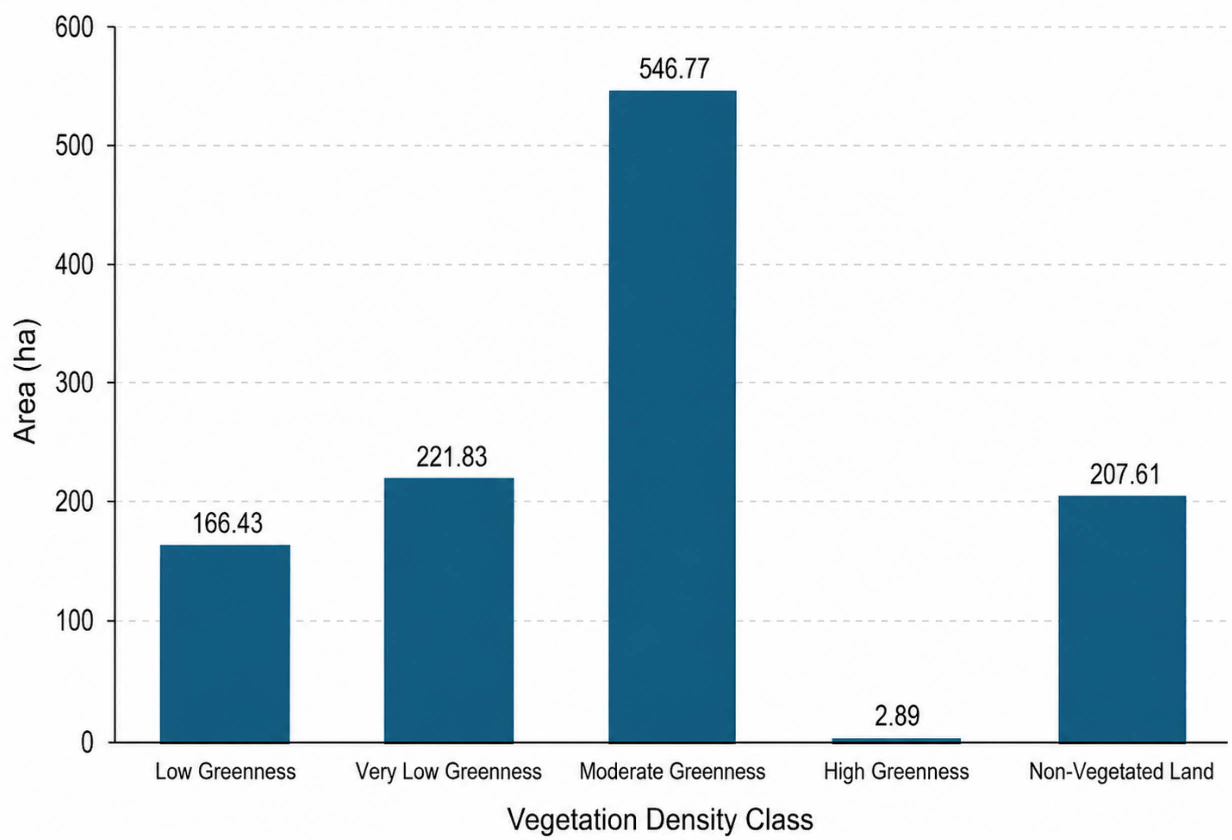

Figure 2. Distribution of Vegetation Density in Sibolga City in 2025 (Source: Data Processing, 2026)

The graph in Figure 2 emphasizes the quantitative comparison between classes, which proves the massive physical development that erodes green land in Sibolga City. The dominance pattern of moderate-density vegetation and the lack of high-density classes is in line with findings in other coastal cities in Indonesia. This is also in line with findings in Ambon City using a Landsat-based NDVI approach, which showed a similar spatial pattern with the dominance of the middle-density class in hilly areas (Lasaiba & Tetelepta (2023). Meanwhile, research Simarmata et al. (2021) on the east coast of Lampung using the transformation of the NDVI, NDWI, and SAVI indices to identify the density of mangrove vegetation in the Sentinel imagery also confirmed that coastal areas with development pressure tend to have very limited high-density classes.

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Dynamics and Factors Causing Changes in Vegetation Density

The spatial structure of vegetation in Sibolga City indicates urbanization pressures that clash directly with the limitations of flat land due to the city's topography, which is sandwiched between the west coast of Sumatra and the steep hills of Bukit Barisan. This pressure is born from the accumulation of several factors that reinforce each other, as summarized in Table 2.

Table 2. Factors Driving Changes in Vegetation Density in Sibolga City

Motivating Factors	Spatial Evidence in Sibolga City	Impact on Vegetation Density
Growth of port economic activity	Concentration of Non-Vegetated Land (18.14%) around the port area and city center	Conversion of green land into a built-up area permanently
Flat land limitations due to topography	Settlements are pushed to the slopes of the eastern hills which are still in Medium Greening status	Suppressing buffer vegetation reserves in landslide-prone areas
Surface hardening (asphalt, concrete, roof)	Dominance of Low Greenery and Very Low Greenness (33.83% combined) in coastal lowlands	Lowers water catchment capacity and increases the risk of surface runoff
Lack of control over green open space zoning	The High Greening Class remains only 0.25% of the total area of the city	Fragmentation of primary forest canopy in suburban areas

(Source: Author's analysis results, 2026).

Based on Table 2 above, there are several crucial points that can be drawn from the pattern above, including:

1. The most extensive green land conversion occurred on the west coast corridor, which became the center of economic activity and settlements, in line with the city's physical growth direction.
2. The Medium Greening Class (47.77%) currently serves as the "last buffer zone" because it is located on a steep slope that naturally hinders large-scale land clearing, but its status is vulnerable if settlement expansion continues to encroach upward.
3. The remaining High Greenery class figure of 0.25% indicates the fragmentation of primary forest canopy, which is already very severe, far from the ideal conditions of urban green cover.

The condition of massive land conversion to reduce the amount of high-level vegetation, leaving only 0.25% in Sibolga City, is not a stand-alone case. A similar pattern is also found in other cities in Indonesia that are experiencing urbanization pressure on their green land. As the findings Aryastana et al. (2023) in Klungkung Regency show, which recorded a decrease in vegetation density area of 35.11 km² or 11.39% in the 2016-2021 period. This figure is inversely proportional to the increase in settlement area by 29.98 km². The findings show an inversely proportional relationship between settlement expansion and vegetation cover shrinkage, consistent across regions and not limited to coastal cities such as Sibolga.

Similar patterns were also found in the findings in Bekasi City, which noted that the rapid population growth encouraged the development of infrastructure and residential areas, so that the density of buildings continued to increase while the density of vegetation actually shrank throughout the period 2001-2021. That means that the phenomenon of shrinking high vegetation density in Sibolga City is a common symptom of Indonesian cities that grow without adequate green open space zoning control, thus requiring stricter spatial planning policy interventions before the damage becomes permanent.

Implications for Spatial Planning and Disaster Mitigation

The results of this study make a crucial contribution in the form of spatial-based recommendations for urban management in Sibolga City. The finding that more than half of the urban area (51.97%) has been dominated by non-natural landscapes, while the High Greenery class remains only 0.25%, suggests that spatial planning policy interventions can no longer be reactive, but must be immediately directed toward the active protection of remaining vegetation.

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Because the lowlands of the west coast have changed function into a massive non-vegetation area, the Sibolga City Government can no longer rely on the lowlands to add large-scale Green Open Space (RTH). A more realistic strategy is to apply the concept of vertical greenery to buildings in the city center, as well as optimize vegetation planting along road medians and west coast corridors to withstand the rate of microtemperature rise due to the loss of plant chlorophyll cover.

On the other hand, the high percentage of Medium Greenery class (47.77%) in the eastern hilly area must be used as an Absolute Protection Zone in the regional spatial plan. Considering that High Greenness class vegetation is already very rare, the remaining medium-density vegetation on the steep slope is the last fortress of Sibolga City against the threat of hydrometeorological disasters. A total ban on the issuance of building permits (IMB) for new housing in the upper slope areas needs to be legally enforced, as this neglect of the critical condition of the green system will increase the city's vulnerability to the risk of landslides and flash floods that threaten the safety of the lowlands below.

NDVI mapping approach as a basis for determining RTH location is in line with the findings Hariani et al. (2024) in Kuala Pembuang II District, Central Kalimantan, which show that NDVI analysis can be used effectively to identify vegetation patterns and water bodies to support the goal of developing green open spaces as an effort to prevent urban areas from rapidly turning into industrialized land. Their research reinforces that NDVI-based spatial data, as produced in this study, can be directly translated into measurable spatial planning policies.

This study has several limitations that need to be considered when interpreting the results. The analysis uses Landsat 8 satellite imagery from one point in time (2025), so it cannot depict temporal trends in vegetation density or project future rates of degradation. In addition, the spatial resolution of the Landsat 8 image (30 meters) may mask variations in vegetation density at the microscale, especially in densely populated areas with small yards. In addition, the classification of vegetation density classes in this study has also not been validated by field surveys (ground truth), so the accuracy of the boundaries between NDVI classes is still estimated. These limitations open up space for further research that combines multi-temporal analysis, higher-resolution imagery, and field verification to strengthen the validity of spatial policy recommendations in Sibolga City.

4. CONCLUSION

This study shows that the vegetation density condition in Sibolga City is dominated by the medium greenery class, with an area of 546.77 ha (47.77%), while the high greenery class covers only 2.89 ha (0.25%) of the total land area. The accumulation of unvegetated land, very low greenery, and low greenery reached 51.97%, which indicates that most urban areas have been under pressure due to the development of built-up areas. The distribution of vegetation shows that hilly areas still function as ecological buffers, while coastal areas are the center of land conversion for settlements and economic activities. The application of the Normalized Difference Vegetation Index (NDVI) method based on Landsat 8 imagery has been proven to be able to effectively describe the spatial conditions of vegetation density so that it can be the basis for supporting spatial planning, protection of green open spaces, and environmental management policy making oriented towards sustainable development.

The Sibolga City Government needs to utilize the results of vegetation density mapping as a basis for spatial planning policy formulation, especially in protecting hilly areas that still have relatively good vegetation and increasing the provision of green open space in urban areas that have been dominated by built-up land. Efforts to rehabilitate vegetation and control land use transfer need to be prioritized to maintain the ecological function of the region and reduce the risk of hydrometeorological disasters. Further research is recommended using satellite imagery with higher spatial resolution, applying multi-temporal analysis to identify changes in vegetation density over time, and conducting ground truth to improve the accuracy of NDVI classification results and strengthen the resulting policy recommendations.

5. REFERENCE LIST

Ally, H., & Daniswara, A. P. (2023). Analisis spatio-temporal dampak pertumbuhan penduduk pada indeks NDVI di Kota Surakarta. Innovative: Journal Of Social Science Research, 3(6), 6057–6067. https://j-innovative.org/index.php/Innovative/article/view/7552

Amri, I., & Giyarsih, S. R. (2022). Monitoring urban physical growth in tsunami-affected areas: A case study of

http://doi.org/10.63639/ykp.v2i1.155

Banda Aceh City, Indonesia. Geojournal, 87(3), 1929–1944. https://doi.org/10.1007/s10708-020-10362-6

Anestis, G., & Stathakis, D. (2024). Urbanization trends from global to the local scale. In Geographical information science (pp. 357–375). Elsevier. https://doi.org/10.1016/B978-0-443-13605-4.00010-2

Angel, S. (2023). Urban expansion: theory, evidence and practice. Buildings & Cities, 4(1). https://doi.org/10.5334/bc.348

Aryastana, P., Widya, I. G. N. A., DAna, G. W. P., Suyasa, I. P. S., & Tamara, W. W. A. (2023). Estimasi Perubahan Tutupan Lahan Dengan Menggunakan Normalized Difference Vegetation Index (Ndvi) Di Kabupaten Klungkung Provinsi Bali. Jurnal Teknik Gradien, 15(01), 45–51. https://doi.org/10.47329/teknik_gradien.v15i01.1014

Devi, N. S., & Santosa, P. B. (2022). Analisis Geospasial Perubahan Ruang Terbuka Hijau Wilayah Kota Purwokerta dari Tahun 2013 sampai 2020. JGISE: Journal of Geospatial Information Science and Engineering, 5(2), 121–131. https://doi.org/10.22146/jgise.74620

Dewi, A. R., Taryana, D., & Astuti, I. S. (2023). Pengaruh perubahan kerapatan bangunan dan vegetasi terhadap Urban Heat Island di Kota Bekasi menggunakan citra penginderaan jauh multitemporal. Jurnal Integrasi Dan Harmoni Inovatif Ilmu-Ilmu Sosial, 3(6), 604–625. https://doi.org/10.17977/um063v3i6p604-625

Duranton, G., & Puga, D. (2023). Urban growth and its aggregate implications. Econometrica, 91(6), 2219–2259. https://doi.org/10.3982/ECTA17936

Farias, G. D., Bremm, C., Bredemeier, C., de Lima Menezes, J., Alves, L. A., Tiecher, T., Martins, A. P., Fioravanço, G. P., da Silva, G. P., & de Faccio Carvalho, P. C. (2023). Normalized Difference Vegetation Index (NDVI) for soybean biomass and nutrient uptake estimation in response to production systems and fertilization strategies. Frontiers in Sustainable Food Systems, 6, 959681. https://doi.org/10.3389/fsufs.2022.959681

Hardianto, A., Dewi, P. U., Feriansyah, T., Sari, N. F. S., & Rifiana, N. S. (2021). Pemanfaatan Citra Landsat 8 Dalam Mengidentifikasi Nilai Indeks Kerapatan Vegetasi (NDVI) Tahun 2013 dan 2019 (Area Studi: Kota Bandar Lampung). Jurnal Geosains Dan Remote Sensing, 2(1), 8–15. https://doi.org/10.23960/jgrs.2021.v2i1.38

Hariani, Y., Susi, T., Ruthena, Y., Sutrisno, H., & Perkasa, P. (2024). Analisis NDVI untuk Mengidentifikasi Lokasi RTH Dalam Mencegah Perubahan Lingkungan Menjadi Industrialisasi. Jurnal Ilmiah Ecosystem, 24(2), 301–316. https://doi.org/10.35965/eco.v24i2.4543

Lasaiba, M. A., & Tetelepta, E. G. (2023). Analisis Spasial Kerapatan Vegetasi Kota Ambon Berbasis Normalized Difference Vegetation Index (Ndvi). Jurnal Pengembangan Kota, 11(2), 124–139. https://doi.org/10.14710/jpk.11.2.124-139

Mahtta, R., Fragkias, M., Güneralp, B., Mahendra, A., Reba, M., Wentz, E. A., & Seto, K. C. (2022). Urban land expansion: the role of population and economic growth for 300+ cities. Npj Urban Sustainability, 2(1), 5. https://doi.org/10.1038/s42949-022-00048-y

Nugroho, C., Agustang, A., & Pertiwi, N. (2022). Dinamika Pertumbuhan Kawasan Permukiman Kota Jambi. Jurnal Ilmiah Mandala Education, 8(1). https://doi.org/10.36312/jime.v8i1.2664/

Semeraro, T., Scarano, A., Buccolieri, R., Santino, A., & Aarrevaara, E. (2021). Planning of urban green spaces: An ecological perspective on human benefits. Land, 10(2), 105. https://doi.org/10.3390/land10020105

Shinta, S. (2024). Pengaruh Urbanisasi terhadap Perubahan Kondisi Sosial dan Ekonomi di Indonesia. Jurnal Swarnabhumi: Jurnal Geografi Dan Pembelajaran Geografi, 9(1), 47–55. https://doi.org/10.31851/swarnabhumi.v9i1.10068

Simarmata, N., Wikantika, K., Tarigan, T. A., Aldyansyah, M., Tohir, R. K., Fauziah, A., & Purnama, Y. (2021). Analisis transformasi indeks NDVI, NDWI dan SAVI untuk identifikasi kerapatan vegetasi mangrove menggunakan citra Sentinel di pesisir timur Provinsi Lampung. JURNAL GEOGRAFI Geografi Dan Pengajarannya, 19(2), 69–79. https://doi.org/10.26740/jggp.v19n2.p69-79

Sinaga, O., Mubarak, M., & Elizal, E. (2021). Pemetaan Sebaran Suhu Permukaan Laut Kota Sibolga, Provinsi Sumatera Utara Menggunakan Satelit NOAA/AVHRR. Ilmu Perairan (Aquatic Science), 9(1), 1–5. https://doi.org/10.31258/

Sudarso, P., Makkawaru, Z., & Tira, A. (2023). Alih fungsi tanah pertanian menjadi kawasan pembangunan perumahan dalam rangka penataan ruang wilayah Kabupaten Gowa. Indonesian Journal of Legality of

http://doi.org/10.63639/ykp.v2i1.155

Law, 6(1), 65–73. https://doi.org/10.35965/ijlf.v6i1.3838

Surya, B., Salim, A., Hernita, H., Suriani, S., Menne, F., & Rasyidi, E. S. (2021). Land use change, urban agglomeration, and urban sprawl: A sustainable development perspective of Makassar City, Indonesia. Land, 10(6), 556. https://doi.org/10.3390/land10060556

Yang, K., Sun, W., Luo, Y., & Zhao, L. (2021). Impact of urban expansion on vegetation: The case of China (2000–2018). Journal of Environmental Management, 291, 112598. https://doi.org/10.1016/j.jenvman.2021.112598

Zhao, Q., & Qu, Y. (2024). The retrieval of ground NDVI (normalized difference vegetation index) data consistent with remote-sensing observations. Remote Sensing, 16(7), 1212. https://doi.org/10.3390/rs16071212

http://doi.org/10.63639/ykp.v2i1.155