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| **Research Article**

Analysis of Mangrove Vegetation Density Based on SPOT-7-Based Normalized Difference Vegetation Index (NDVI) in Simeulue Regency

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Abstract: This study aims to analyze the density of mangrove vegetation in Simeulue Barat District, Simeulue Regency, to assess the condition of mangrove ecosystems in coastal areas. Mangroves play a crucial role in maintaining coastal ecological balance, protecting the coast from abrasion, and supporting the lives of marine life and coastal communities. This study uses a quantitative, descriptive-spatial approach based on remote sensing utilizing SPOT-7 satellite imagery. The data used are secondary data, including SPOT-7 Level-2 Surface Reflectance imagery from 2022, administrative boundary maps, and other supporting data. The analysis was carried out by calculating the Normalized Difference Vegetation Index (NDVI) value using the Near Infrared (NIR) and Red (RED) channels to identify the level of greenness and vegetation density. The resulting NDVI values were classified into vegetation density classes using the class interval method based on the Sturges formula to ensure proportional representation of data distribution, ranging from non-vegetation to very dense vegetation. The results show that the NDVI value in the study area ranges from -0,701408 to 0,725727, representing variations in land cover from water bodies to very dense mangrove vegetation. Based on the classification results, the Simeulue Barat District is dominated by very dense vegetation, indicating that the mangrove ecosystem is relatively well-maintained. This finding provides important spatial information for coastal management planning and mangrove conservation. This study recommends integrating NDVI with other vegetation indices and conducting field verification to improve the accuracy of future analyses.

Keywords: Mangrove Vegetation Density; NDVI; Remote sensing; Simeulue Barat District; SPOT-7

1. INTRODUCTION

Mangrove ecosystems are among the most productive in the world, playing a crucial role in maintaining coastal ecosystem balance (Bai'un et al., 2021). Mangroves function to prevent coastal abrasion, absorb carbon, provide habitat for various bird species, and serve as nursery grounds for fish, shrimp, and plankton-eating marine organisms (Nanlohy et al., 2020). This is consistent with the findings of G. Sihombing et al. (2025), who reported that areas with high mangrove density tend to experience lower levels of coastal abrasion. In addition to their ecological functions, mangroves have high economic and social value because they provide wood, building materials, and medicines, and support fishing and ecotourism (Apriani et al., 2022). In Asia itself, mangroves play a crucial role in improving the welfare of coastal communities, as more than 70% of the population depends on coastal resources for food and employment (Hidayat et al., 2021). Therefore, the preservation of the mangrove ecosystem is essential to the sustainability of coastal communities.

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Nationally, Indonesia has the largest mangrove area in the world. According to the 2021 National Mangrove Map published by the Ministry of Environment and Forestry (KLHK), the total area of mangrove in Indonesia is 3,364,080 hectares, with potential mangrove habitat covering 756,183 hectares. Thus, the total area of mangrove ecosystems in Indonesia is 4,120,263 hectares, consisting of 82% existing mangroves and 18% potential mangrove habitat (Direktorat Konservasi Tanah dan Air et al., 2021). However, mangrove areas in Indonesia have experienced a significant decline due to human-induced pressures, including land conversion, illegal logging, and coastal infrastructure development. As a result, the area of mangrove forests continues to decline from year to year. The condition of mangrove degradation that impacts the structure and density of vegetation is also demonstrated (Dalimunte et al., 2025), who emphasized that differences in the level of ecosystem damage reflect the ecological conditions of coastal areas. According to data from the Ministry of Environment and Forestry, as reported by Gustami (2023), in 2019, the mangrove area was 3.31 million hectares. Despite this considerable potential, the sustainability of mangrove ecosystems continues to be threatened by serious challenges to their ecological and economic functions.

Simeulue Regency is an archipelago located in Aceh Province, directly facing the Indian Ocean. Data from the Aceh Maritime Affairs and Fisheries Agency indicate that the mangrove ecosystem area in Simeulue Regency is estimated at approximately 799.69 hectares. A 2015 Marine field survey by the Ministry of Fisheries (KKP) identified five main mangrove species: Rhizophora apiculata, Avicennia marina, Scyphiphora hydrophyllacea, Cerbera manghas, and Acanthus ilicifolius (Novriansyah et al., 2024). One area with a mangrove ecosystem is in the Simeulue Barat District, where parts of the coastal area are covered in mangrove vegetation and have significant marine resource potential. This condition is an important basis for the need to study the condition and density of mangrove vegetation in this region.

Monitoring of mangrove vegetation in various regions still relies on field surveys, which are time-consuming, costly, and labor-intensive. The Normalized Difference Vegetation Index (NDVI) approach based on Landsat 8 imagery can be an appropriate solution for analyzing mangrove vegetation density. The use of the Normalized Difference Vegetation Index (NDVI) to spatially assess mangrove density and environmental quality has been successfully applied in various coastal areas of Indonesia (Sihombing et al., 2025). NDVI is an image-derived index used to quantify vegetation greenness (Simarmata et al., 2021). NDVI uses differences in reflectance in the red (Red) and near-infrared (NIR) spectral bands to quantify vegetation greenness. This method can generate accurate spatial information regarding variations in mangrove vegetation density in the Simeulue Barat District of Simeulue Regency. The results of this analysis are expected to describe current vegetation conditions comprehensively and to inform decision-making on the conservation and management of coastal natural resources, particularly in efforts to preserve the mangrove ecosystem as an essential component of environmental sustainability and the welfare of the surrounding community.

2. RESEARCH METHODS

This study employed a quantitative, descriptive-spatial approach based on remote sensing to analyze vegetation density using the Normalized Difference Vegetation Index (NDVI). The NDVI method is used to assess greenness or vegetation density from red (R) and near-infrared (NIR) spectral reflectance data in satellite imagery. NDVI is used as an indicator of vegetation density in the study area. The data collected in this study were secondary. These data were obtained from existing sources, including publications by relevant agencies and other supporting literature. This study utilized entirely secondary data obtained from primary data in the form of SPOT-7 Level-2 Surface Reflectance (SR) imagery from 2022 downloaded from the USGS Earth Explorer website, administrative boundary maps of the study area from the Geospatial Information Agency (BIG) or BPS, or InaGeoportal, and references from Google Earth for visual validation. The data analysis techniques used in this study were:

a. Analysis *Normalized Difference Vegetation Index* (NDVI)

To determine the level of vegetation greenness. NDVI can indicate vegetation parameters, including green leaf biomass and green leaf area, which are proxies for vegetation distribution. The index ranges from -1 to 1 and represents the density of vegetation cover. Generally, an index closer to 1 indicates dense vegetation,

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and less than zero indicates water and clouds (Simarmata et al., 2021 Dharma et al., 2022). To determine the vegetation index, use the following equation.

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

Description:

NDVI	=	Normalized Difference Vegetation Index
NIR	=	Near Infrared Spectral Band Value
RED	=	Red Spectral Band Value

b. Vegetation Density Classification (Image Classification)

The NDVI values obtained from SPOT-7 image processing were then used to identify and classify the levels of mangrove vegetation density in the study area. This classification aims to describe variations in vegetation cover spatially based on differences in the resulting greenness index values. In this study, vegetation density classes were quantitatively determined using the class-interval method. This method was chosen to ensure that the boundaries between density classes accurately represent the NDVI data conditions in the study area. According to Sturges (1926), class intervals are obtained by dividing the difference between the highest and lowest NDVI values by the number of vegetation density classes used, thus ensuring a more proportionate classification of the data conditions in the study area (Fudloly et al., 2020). The calculation of vegetation density class intervals was carried out using the following formula:

$$KL = \frac{xt - xr}{k}$$

Description:

KL	=	Vegetation density class interval
xt	=	Highest NDVI value
xr	=	Lowest NDVI value
k	=	Number of vegetation density classes used

The number of vegetation density classes in this study was set at five: very sparse, sparse, moderate, dense, and very dense. Five classes were selected because they depict a gradual gradient of mangrove vegetation density, ranging from non-vegetated areas to areas with very dense mangrove cover. This division is considered sufficiently representative to capture the heterogeneous variation in mangrove ecosystem conditions, particularly in coastal regions with distinct land cover types, including water, open land, settlements, and mangrove forests. Furthermore, the use of five density classes facilitates the interpretation of spatial analysis results without sacrificing essential details in the resulting NDVI variation. Thus, the vegetation density classification results provide a more accurate picture of mangrove conditions in the West Simeulue District and support the subsequent analysis of vegetation density distribution and dominance.

3. RESULTS AND DISCUSSION

a. Vegetation Density Identification Based on NDVI

NDVI processing produces an NDVI map that depicts the spatial distribution of vegetation. Based on the results of SPOT-7 image processing in 2022, the NDVI value in Simeulue Barat District, Simeulue Regency, ranges from -0,701408 to 0,725727 (Figure 1). The statistical analysis results are shown in Table 1

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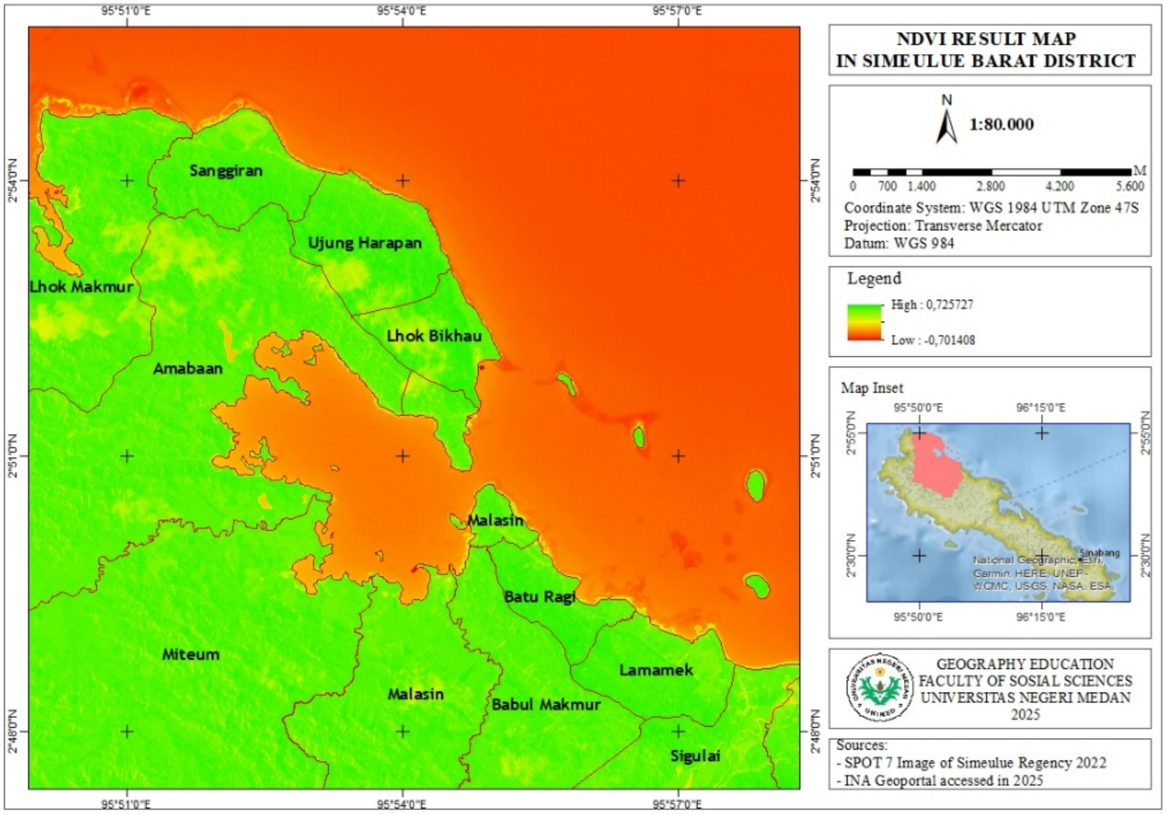

Figure 1. NDVI Result Map in Simeulue Barat District, Simeulue Regency
(Source: SPOT-7 Image Processing Results, 2025)

Table 1. Results of NDVI Statistical Value Analysis Based on Vegetation Density in West Simeulue District, Simeulue Regency

Min	Max	Mean	Stdev
-0,701408	0,725727	-0,1291	0,5269

(Source: SPOT-7 Image Processing Results, 2025)

Based on the raster statistics, the average NDVI value is -0.1291 with a standard deviation of 0,5269. The negative mean value indicates that most of the area in the image is non-vegetated, in this case, sea waters. The negative minimum value (-0,701408) suggests the presence of the non-vegetated regions or areas with less dense vegetation. Liliesano et al. (1997) NDVI values that are in the negative to near-zero range generally indicate areas that have no vegetation or have low vegetation cover. This negative value can occur on surfaces such as water, buildings, roads, or open areas that are not covered by vegetation (Hardianto et al., 2021).

On the other hand, the mean NDVI value is -0,1291; a negative mean value indicates that most of the area in the image is non-vegetated, in this context, marine waters. According to Zhang et al. (2021) a mean value in the mid-range between 0 and 1 indicates the presence of sufficient vegetation, but not in a very dense or minimal state (Lasaiba et al., 2023). The relatively high standard deviation (0.5269) indicates that the observed variation in this area is diverse, ranging from seawater to dense forests (Putri et al., 2020). This condition is consistent with the ecological characteristics of Simeulue Barat District, which comprises coastal, residential, and mangrove forest areas.

b. Classification of Mangrove Vegetation Density Based on NDVI Values

The results of NDVI processing of remote sensing images reveal clear variations in mangrove vegetation density in the West Simeulue District, Simeulue Regency. The resulting NDVI values range from -0.701408 to

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0.725727, indicating differences in surface conditions, ranging from non-vegetated areas to high-density mangrove areas. To identify the level of mangrove vegetation density, NDVI values are classified into five interval classes using the Sturges (1926) method with an interval width of 0.285427, which includes very sparse (including non-vegetated areas), sparse, moderate, dense, and very dense classes. The classification of vegetation density is shown in Table 2.

Table 2. NDVI Value Range for West Simeulue District, Simeulue Regency

NDVI Value Range	Density Classification
-0,701408 – -0,415981	Very Sparse
-0,415981 – -0,130554	Sparse
-0,130554 – 0,154873	Moderate
0,154873 – 0,440300	Dense
0,440300 – 0,725727	Very Dense

(Source: SPOT-7 Image Processing Results, 2025)

Based on this classification range, the distribution of mangrove vegetation density is then visualized using an NDVI classification map. The resulting NDVI classification map is shown in Figure 2.

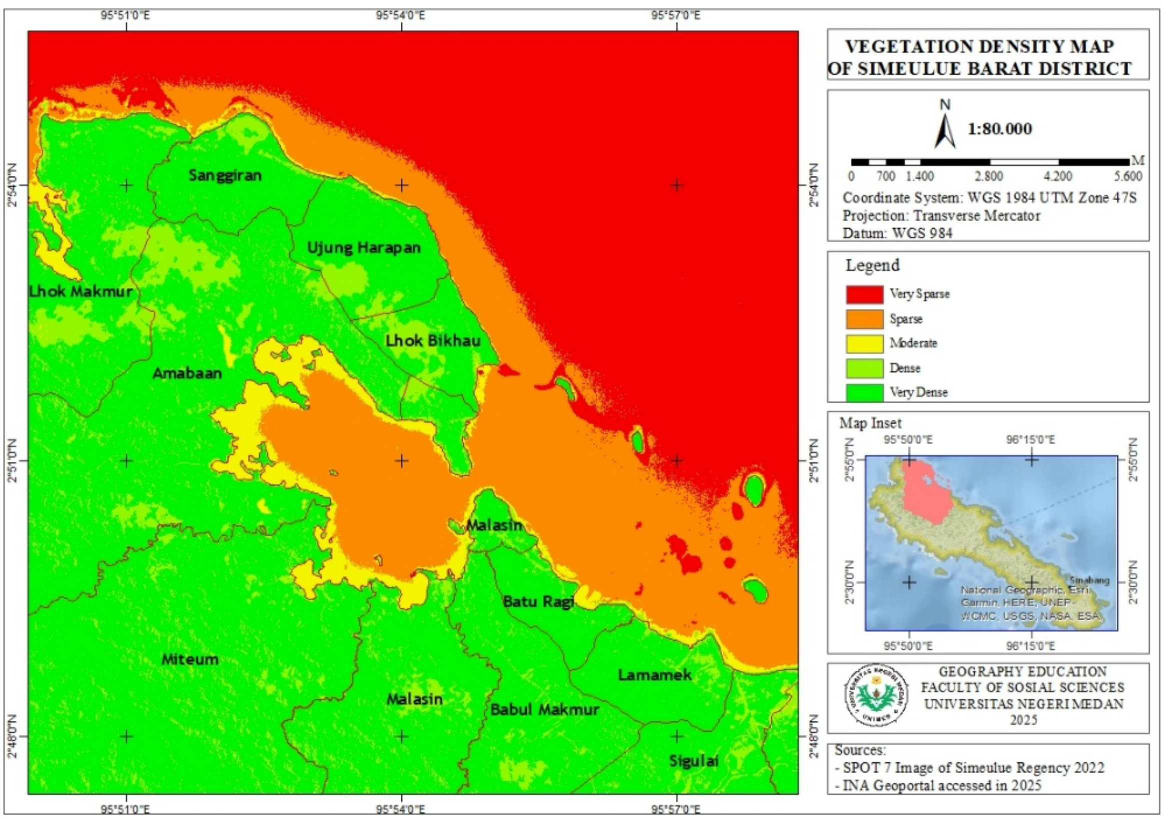

Figure 2. Vegetation Density Map of Simeulue Barat District, Simeulue Regency
(Source: SPOT-7 Image Processing Results, 2025)

Based on NDVI map results from SPOT-7 imagery for the Simeulue Barat District, Simeulue Regency, the NDVI values range from -0.701408 to 0.725727. This range of values indicates that the vegetation density conditions in the study area are quite diverse, ranging from very sparse, sparse, moderate, dense, to very dense areas.

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In general, the Simeulue Barat District area is dominated by a very dense vegetation class, with NDVI values in the range 0,440300–0,725727. The dominance of this class indicates that vegetation cover in the area remains well maintained, particularly in mangrove forests and in areas with minimal development. Meanwhile, some other areas fall into the dense category, with NDVI values of 0,154873–0,440300, indicating the presence of vegetation that remains relatively healthy. The moderate category is in the range of -0,130554 – 0,154873 appears in areas with lower vegetation cover. The sparse class, with NDVI values ranging from –0.415981 to –0.130554, is found in areas with sparse vegetation or open land with minimal plant cover. Additionally, some areas fall into the very sparse category, with NDVI values of –0.701408 to –0.415981, corresponding to seawater cover.

4. CONCLUSION

Research on mangrove vegetation density in Simeulue Barat District, based on NDVI values, yielded several significant findings. The study showed that NDVI values in Simeulue Barat District, Simeulue Regency, ranged from -0.701408 to 0.725727, reflecting variations in land cover from very sparse areas to very dense mangrove vegetation. The vegetation density classification results indicated that most areas were classified as very thick, indicating relatively healthy and well-maintained mangrove conditions. These findings confirm that the mangrove area in Simeulue Barat, Simeulue Regency, plays a vital ecological role and requires sustainable management to maintain the quality of existing vegetation cover. The research results can be used as a basis for coastal conservation planning and spatial use control. Future research is recommended to combine NDVI with other vegetation indices and conduct field validation to strengthen the interpretation of the results.

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