



# SPATIAL ANALYSIS OF VEGETATION DENSITY IN LANGSA CITY USING NDVI INDEX

## ANALISIS SPASIAL KERAPATAN VEGETASI DI KOTA LANGSA MENGUNAKAN INDEKS NDVI

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### Abstract

This study aims to analyze the distribution of vegetation density in Langsa City using the Normalized Difference Vegetation Index (NDVI). The research was conducted from June to October 2024, covering a study area of 21,881.41 ha. The method used is remote sensing, using Sentinel-2A satellite imagery, along with Geographic Information System (GIS) software, specifically ArcGIS, for mapping and spatial analysis. The NDVI classification results show five land cover categories based on NDVI value ranges. NDVI Class 1 (-0.38 to -0.02) includes non-vegetated land and water bodies. NDVI Class 2 (-0.02–0.20) indicates very low greenness, typically consisting of bare land. NDVI Class 3 (0.20–0.38) represents low greenness, which includes built-up areas. NDVI Class 4 (0.38–0.54) includes moderate greenness, typically found in plantations or fields, while NDVI Class 5 (0.54–0.83) represents high greenness, covering areas such as shrubs, forests, and mangroves. This analysis provides valuable information for land use planning and environmental management based on spatial vegetation data. The results of this study are expected to serve as a basis for policy-making that supports the sustainable management and conservation of vegetation in Langsa City.

**Keywords:** Langsa; NDVI; Remote sensing; Spatial; Vegetation

### Abstrak

Penelitian ini bertujuan untuk menganalisis sebaran kerapatan vegetasi di Kota Langsa menggunakan Normalized Difference Vegetation Index (NDVI). Penelitian ini dilakukan pada bulan Juni hingga Oktober 2024 dengan objek penelitian seluas 21.881,41 ha. Metode yang digunakan adalah penginderaan jauh dengan pemanfaatan citra satelit Sentinel-2A, serta perangkat lunak Geographic Information System (GIS) ArcGIS untuk pemetaan dan analisis spasial. Hasil klasifikasi NDVI menunjukkan lima kategori tutupan lahan berdasarkan rentang nilai NDVI. Kelas NDVI 1 (-0.38 sampai -0.02) mencakup lahan tidak bervegetasi dan badan air. Kelas NDVI 2 (-0.02–0.20) menunjukkan kehijauan sangat rendah, yang umumnya berupa tanah kosong. Kelas NDVI 3 (0.20–0.38) menunjukkan kehijauan rendah yang meliputi lahan terbangun. Kelas NDVI 4 (0.38–0.54) mencakup kehijauan sedang yang dapat ditemukan di kebun atau ladang, sedangkan kelas NDVI 5 (0.54–0.83) menunjukkan kehijauan tinggi, yang meliputi kawasan semak, hutan, dan kawasan mangrove. Analisis ini memberikan informasi yang berguna dalam perencanaan penggunaan lahan dan pengelolaan lingkungan yang berbasis pada data spasial vegetasi. Hasil penelitian ini diharapkan dapat menjadi dasar dalam pengambilan kebijakan yang mendukung pengelolaan dan konservasi vegetasi di Kota Langsa secara berkelanjutan.

**Kata Kunci:** Langsa; NDVI; Penginderaan jauh; Spasial; Vegetasi

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## INTRODUCTION

Vegetation index is an algorithm implemented on satellite imagery to reveal characteristics related to vegetation density, such as biomass, leaf area index (LAI), and chlorophyll concentration levels, or other aspects associated with vegetation density (Hidayati et al., 2019). In other words, vegetation index can be described as a mathematical transformation involving multiple channels at a given time to create a new image that provides deeper insights into the characteristics related to vegetation. Normalized Difference Vegetation Index (NDVI) is an index used to measure the amount and condition of vegetation by comparing the reflectance of Near-Infrared (NIR) light with red (R) light from a region (Prayudha et al., 2023). Vegetation index is a formulation in digital remote sensing data processing, specifically used to analyze thematic information related to land areas with vegetation. Several methods for analyzing vegetation indices are available, including Normalized Difference Vegetation Index (NDVI), Green Index (GI), and Wetness Index (WI) (Ruslana et al., 2020). The vegetation index used in this study is NDVI. In this study, satellite imagery from Sentinel-2A was chosen as the main data source due to its high spatial resolution of up to 10 m on key bands such as red and near-infrared, which are essential for calculating NDVI (Dharma et al., 2022). Additionally, Sentinel-2A covers a wide area of up to 290 km<sup>2</sup> and has relatively lower errors compared to other imagery like Landsat, making it more accurate for vegetation monitoring (Philiani et al., 2016). The availability of free and frequently updated data also supports its practical use in this study.

In general, the spectral response from satellite imagery shows sensitivity to vegetation density (which includes Leaf Area Index), tree canopy structure, and water content in plant leaves. An increase in vegetation density can be observed from open land to the succession stage, although reflectance in the visible spectrum may decrease due to the increase in leaf area and absorption. The relationship between spectral response in the visible and near-infrared range with vegetation density can be interpreted through the use of vegetation indices (Hickmah et al., 2021). This concept has become an important method for analyzing satellite images for mapping vegetation and environmental change (Wishnuputri et al., 2024). NDVI basically measures the slope between the original value of the red band and the infrared band in space with the red band value and infrared value in each image pixel (Karmila et al., 2020). This is consistent with the statement by Philiani et al. (2016) that vegetation indices are also a mathematical combination of the red band and NIR band, which has long been used as indicators of vegetation condition and presence, commonly known as NDVI. According to Que et al. (2019), in monitoring vegetation density, the red band and NIR band are used.

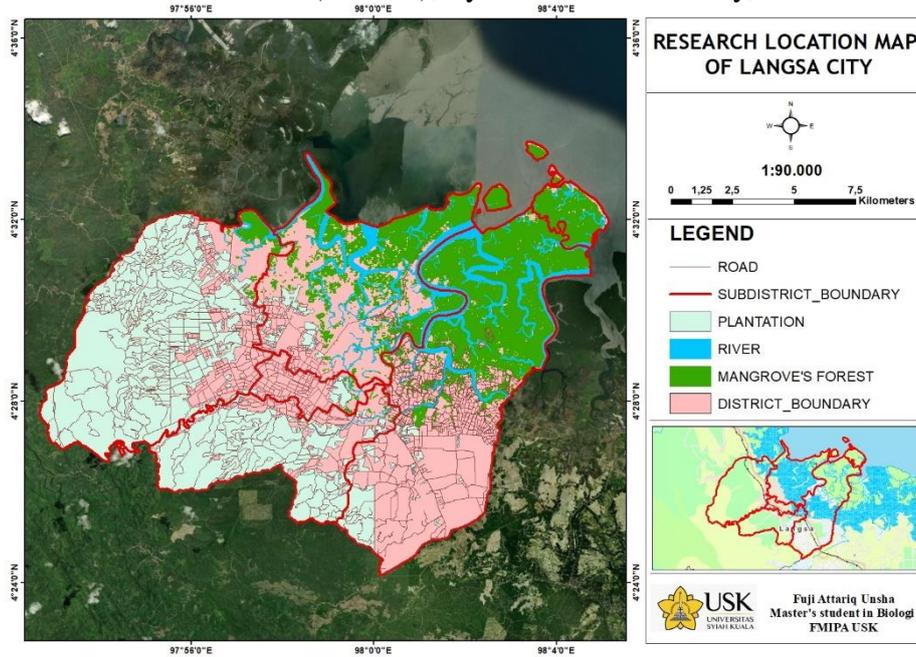
Langsa City, located between 04° 24' 35.68"–04° 33' 47.03" North Latitude and 97° 53' 14.59"–98° 04' 42.16" East Longitude, covers an area of 262.41 km<sup>2</sup>. The city is characterized by diverse land uses, including urban areas, agricultural lands, forests, and wetlands, with mangrove forests playing a significant role in the local ecology. These ecosystems contribute to biodiversity, support carbon sequestration, and require effective monitoring for sustainable management (Central Bureau of Statistics (BPS) Langsa City, 2023). Remote sensing and Geographic Information Systems (GIS) offer several advantages, such as cost-effectiveness, accessibility, and the ability to monitor large and remote areas, making them ideal tools for assessing land use changes and vegetation density (Widyantara & Solihuddin, 2020). Armanda et al. (2021) also argue that one way to obtain data regarding resource potential is by utilizing remote sensing technology. This study aims to complement existing data by assessing land density based on vegetation index in Langsa City, using remote sensing to enhance our understanding of land cover dynamics and inform better environmental planning and conservation efforts.

## MATERIALS AND METHODS

### Study Area

This research was carried out in the Mangrove Forest Area of Langsa, located in Langsa City, Aceh Province (Figure 1). The data collection, processing, and analysis were conducted between

September and October 2024 at the Conservation Biology Laboratory, Biology Department, Faculty of Mathematics and Natural Sciences (FMIPA), Syiah Kuala University, Banda Aceh.



**Figure 1.** Research location map

### Tools and Materials

The study utilized several instruments, such as a digital camera, Global Positioning System (GPS), observation forms, Google Earth, writing tools, and a computer or laptop equipped with ArcGIS 10.8 software. The research materials included shapefile data of Langsa City, administrative maps of the city, and Sentinel-2A satellite imagery, which was obtained via Google Earth Engine (GEE).

### Data Collection Method

The approach employed in this study is remote sensing, a method used to estimate mangrove carbon reserves through satellite imagery and NDVI analysis. The satellite images utilized are from the Sentinel-2A satellite. These Sentinel-2A images were downloaded via Google Earth Engine, covering five bands: Blue, Green, Red, Near Infrared (NIR), and Shortwave Infrared (SWIR). Each band was downloaded and saved in Google Drive from an account registered with GEE before being retrieved for further analysis. The image processing included creating a composite of the Red, NIR, and SWIR bands to calculate the NDVI. Classification was carried out using the Iso Cluster Unsupervised Classification technique.

### Initial Preparation

The initial preparation began with conducting a preliminary survey directly in Langsa City. The purpose of this survey was to gather information on land use and research objects within the area. The locations for data collection were determined based on direct observation of the research site in Langsa City. This survey is a crucial first step to understand the conditions and characteristics of the research area before more in-depth data collection takes place.

### Image Data Processing

The Sentinel-2A satellite image data were downloaded through the Google Earth Engine (GEE) platform using a pre-written JavaScript script. This process involved defining the Area of Interest (AOI), retrieving reflectance surface images, setting the date range for the images to be downloaded, and selecting specific bands, namely Band 2 (Blue), Band 3 (Green), Band 4 (Red), Band 8 (NIR), and Band 11 (SWIR). The available bands in GEE were downloaded and saved on a Google Drive account registered with GEE. The downloaded images, which consisted of multiple bands, were then

analyzed using ArcMap 10.8 software. The analysis phase includes band composition. Image classification was then performed on the composite images using the Iso Cluster Unsupervised Classification method to extract land use data for Langsa City. The data was converted from raster format to polygon using the Build Model. The area of Langsa City was calculated in hectares. The coordinate system used was DGN 1995 Indonesia TM-3 Zone 47.1, and NDVI values were then calculated along with their respective classifications.

### Data Analysis

The data in this study were analyzed both descriptively and quantitatively. Descriptive analysis is presented in the form of tables, diagrams, and figures. Quantitative analysis was performed using the NDVI equation. The NDVI formula, as defined by Rouse in 1973 and referenced by Sasmito and Suprayogi (2015), is as follows  $NDVI = \frac{BandNIR - BandR}{BandNIR + BandR}$ . Where NDVI= Normalized Difference Vegetation Index; and NIR= Near Infrared; and R= Red. NDVI values range from -1 to 1. The NDVI values are classified into four categories: -0.61–1.00= high greenery level; -0.31–0.60= moderate greenery level; -0.01–0.30= low greenery level; and -(1.00)–0.00= non-vegetation.

The data from the table above is also in accordance with the statement by Tampubolon et al. (2019) that the NDVI value ranges from -1 to 1. Water, empty land and buildings and other non-vegetation elements are classified as low NDVI (negative) while high levels of green vegetation are classified as high NDVI (positive). This is in line with the statement of Philiani et al. (2016) NDVI values range from -1 to 1, with a classification of -1 to 0 including the non-vegetation group and 0 to 1 including the vegetation group.

## RESULTS

The Sentinel-2A satellite imagery is capable of measuring the NDVI for mangrove vegetation. Using the Unsupervised Classification approach, vegetation density mapping has been produced, categorizing the land cover into five different classes across the Langsa City area. These categories include bodies of water, barren land, built-up areas, shrubs/plantations, and forested areas. Spectral analysis, conducted by applying the NDVI model in Langsa City, revealed a variation of values ranging from -0.38 to 0.83. This data provides a detailed view of the spectral value distribution across different regions of Langsa City, which will be used to assess the vegetation density specifically in the study area. The vegetation index values for Langsa are shown in Table 1 below.

**Table 1.** Normalized Difference Vegetation Index (NDVI) classification values in Langsa City

Class	NDVI range	Category	Land cover
1	-0.38–(-0.02)	Non-vegetated	Water bodies
2	-0.02–0.20	Very low greenery	Barren land
3	0.20–0.38	Low greenery	Built-up areas
4	0.38–0.54	Moderate greenery	Plantation/farm
5	0.54–0.83	High greenery	Shurbs/forest

Based on the data information in Table 1, the classification results using the NDVI vegetation index method in Langsa City show a range of values that reflect various land use types. The NDVI range observed spans from -0.38 to -0.02, indicating the presence of water bodies. Values between -0.02 and 0.20 indicate barren land with minimal vegetation, while the range from 0.20 to 0.38 reflects built-up areas, including residential zones. Areas with NDVI values between 0.38 and 0.54 are classified as plantations, while values from 0.54 to 0.83 indicate forested areas, including mangrove forests.

To ensure the accuracy of land cover classification based on NDVI values, a field verification (ground check) was conducted at several coordinate points derived from the processed satellite imagery in ArcGIS. These points were selected based on stratified sampling across the NDVI value ranges identified in the study. Field visits were carried out to verify the actual land cover types corresponding to each NDVI class, including mangrove forests, secondary forests, plantations, built-up areas, and barren land. This ground truthing process allowed us to validate and refine the classification categories derived from the NDVI values, ensuring ecological relevance and

minimizing misclassification. While NDVI is a useful indicator of vegetation density and health based on reflectance values, it does not directly identify vegetation species or types. Therefore, the combination of remote sensing data and field observations was essential to strengthen the ecological interpretation of NDVI-based vegetation classification.

This NDVI value distribution forms the basis for the vegetation class classification, where most areas exhibit variations between vegetation, settlements, barren land, and water bodies. Class 1 includes areas with no vegetation, such as water bodies. Class 2 identifies areas covered by barren land. Class 3 represents areas with residential settlements that include some vegetation. Class 4 denotes areas with shrubs and plantations, while Class 5 encompasses areas with shrubs and forested land. Mapping of density distribution with a range of NDVI values for land use in Langsa City can be seen in Figure 2.



**Figure 2.** Normalized Difference Vegetation Index (NDVI) vegetation density map of Langsa City

Based on the vegetation index distribution map using the NDVI model of Langsa City presented above, it can be observed that areas with high vegetation density are characterized by high index values (Table 1), represented by green color (Figure 2). The vegetation grows densely and is clearly visible, with the green color indicating the appearance of leaves. In the context of this study, one of the areas showing high vegetation density includes a part of the mangrove forest area, which is the research site. The NDVI classification process uses an unsupervised classification method through remote sensing, meaning the classification is performed without direct field intervention and can be validated through field checks to ensure data accuracy. This method is applied on a larger scale and relies on algorithms to identify patterns within the image data and automatically classify them based on these patterns. The unsupervised classification technique is advantageous as it does not require prior knowledge of the land cover classes. Additionally, the use of remote sensing data allows for efficient and large-scale mapping of vegetation, which is essential for monitoring land use changes over time. Furthermore, field verification is crucial to ensure the classification results align with the actual conditions on the ground.

Normalized Difference Vegetation Index (NDVI) leverages the difference between Near-Infrared (NIR) and red (Red) reflectance from objects in the image. NIR wavelengths affect the chlorophyll content in vegetation. By using NDVI, mangrove vegetation can be distinguished more clearly because it has a higher NDVI value, indicating a higher presence of chlorophyll. This allows

for the estimation of carbon stock potential in mangrove vegetation. NDVI is also a standard product of the National Oceanic and Atmospheric Administration (NOAA), the agency managing weather satellites orbiting Earth. Therefore, this value is essential for vegetation mapping and monitoring.

## DISCUSSION

Remote sensing technology is an effective method for monitoring land changes in an area over time to obtain information about objects, areas, or phenomena through data analysis (Tarolli & Mudd, 2020). The results of the NDVI classification indicate varying vegetation density across Langsa City, particularly in the mangrove forest area. The high NDVI values represent areas with dense vegetation, which corresponds to the presence of mangrove forests and other vegetative types. The use of NDVI, as seen in this study, proved to be effective in distinguishing areas with higher vegetation density, as it is sensitive to chlorophyll content and vegetation structure. This method has been widely accepted as a reliable tool in remote sensing for vegetation monitoring and land cover classification (Annisa et al., 2019).

One of the key advantages of using NDVI in this study is its ability to differentiate between mangrove vegetation and other land cover types, which is crucial in estimating carbon stock potential. The higher NDVI values observed in mangrove forests indicate a significant amount of chlorophyll presence, directly correlating with the carbon sequestration potential of these areas. These findings align with previous studies suggesting that mangrove forests have a high capacity for carbon storage due to their dense vegetation and ability to accumulate organic matter over time (Mayuftia et al., 2013).

The NDVI classification results generated through this approach can also serve as a reference for comparison with carbon stock measurements using Sentinel-2A imagery and direct field-based carbon stock assessments. These classification results are derived from an automatic classification process carried out using ArcGIS software. This aligns with Tucker's (1986) statement *in* Annisa et al. (2019), which suggests that classification in remote sensing data processing can produce thematic maps, visual representations of image portions grouped into specific classes that represent similar object categories. A commonly used method in this phase is the NDVI.

Additionally, the application of ArcGIS for NDVI classification allowed for an efficient and systematic approach to classifying large areas, such as Langsa City's mangrove forests. The use of remote sensing tools, as noted by Widyantara and Solihuddin (2020), offers several advantages, including cost-effectiveness, broad coverage, and the ability to monitor remote areas. The data obtained through this process also serve as an excellent basis for comparing with in-field carbon stock measurements, ensuring data accuracy and providing a more comprehensive view of the area's ecological status.

The potential for utilizing NDVI to estimate carbon stocks is a valuable contribution to environmental management, especially in regions with significant mangrove ecosystems. The integration of remote sensing techniques with GIS provides a robust framework for assessing and monitoring changes in vegetation density over time. This study contributes to a growing body of research that supports the use of remote sensing technologies for ecological conservation, land management, and carbon offsetting efforts.

Processing NDVI for mangrove vegetation involves using data from specific bands, such as band 4 (red), band 5 (near-infrared), and band 11 (far-infrared). The objective of this step is to generate visualizations in RGB (Red, Green, Blue) format, facilitating the separation of mangrove vegetation from other terrestrial plants. The digital values of the NDVI can be used to estimate the presence of mangrove vegetation in a particular area. Comprehensive information about vegetation conditions can be obtained from the resulting NDVI values (Mayuftia et al., 2013). This is consistent with the statement by Annisa et al. (2019) that image sharpening is performed to enhance the clarity of objects in the image, making them sharper and more distinct.

Despite the strengths of the NDVI approach, some limitations exist. The resolution of satellite imagery may not capture fine-scale variations in vegetation, and ground-truthing remains necessary to validate the remote sensing data. Future studies could incorporate higher resolution imagery or

advanced classification techniques to enhance accuracy. Additionally, expanding the scope of this research to include other types of vegetation could provide a more comprehensive understanding of the region's ecological health.

## CONCLUSION

The analysis of the NDVI values in Langsa City has successfully classified the land cover into five distinct categories: water bodies, barren land, built-up areas, plantations, and forests, including mangrove areas. The NDVI values ranged from -0.38 to 0.83, reflecting variations in vegetation density across the city. These classifications provide valuable insights into the distribution and condition of vegetation in Langsa, particularly the mangrove forests, which are crucial for environmental conservation and biodiversity. The findings highlight the significant role of NDVI as a reliable tool for monitoring land cover and vegetation dynamics.

Based on the results of this study, it is recommended to further monitor the health and density of mangrove forests in Langsa using periodic NDVI analysis. Continuous satellite imaging could help detect any changes in land use or vegetation cover, especially in critical areas prone to deforestation or urban expansion. Additionally, further research could explore the relationship between NDVI values and carbon sequestration in mangrove ecosystems to better understand their contribution to climate change mitigation. Collaboration with local authorities and environmental organizations would be essential to implement sustainable land management practices in Langsa, with a focus on preserving its valuable mangrove habitats.

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