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Banda Aceh mangrove vegetation structure in 2023 based on NDVI (Normalized Difference Vegetation Index) analysis

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ARTICLE INFO	ABSTRACT
Keywords: Mangrove Vegetation NDVI DOI: 10.13170/depik.14.2.42908	Mangroves are coastal forest ecosystems found in tropical and subtropical regions. such as the city of Banda Aceh. Based on their habitat, mangroves are a type of wetland forest that can store large amounts of carbon. The purpose of this study is to determine the structure of mangrove vegetation in the city of Banda Aceh through NDVI analysis. The analysis method used was NDVI and sample observation using plots. The results of the analysis show that the vegetation structure is directly proportional to the NDVI value. Areas with high NDVI values are dominated by tree, while areas with low NDVI values are dominated by seedling.

Introduction

Mangroves are evergreen forests that can be found on sheltered beaches, river estuaries, tidal flats, and tropical and subtropical swamps (Sandilyan & Kathiresan, 2012). Mangrove ecosystems are capable of storing large amounts of carbon (Donato *et al.*, 2011), which in turn has a positive impact on mitigating greenhouse gas emissions and global climate change (Taillardat *et al.*, 2018).

Banda Aceh the capital city of Aceh Province in North Sumatera Indonesia has many mangrove forests along its coastline (Rahmi *et al.*, 2019). The people of Banda Aceh City utilize mangrove land for fisheries by applying silvofishery techniques, namely fish and shrimp farming within mangrove vegetation (Sugianto *et al.*, 2016). According to Saputra *et al.* (2016) the mangrove area in Banda Aceh before the tsunami was 66.25 Ha and after the tsunami only 47.9 Ha remained. However, according to the RPD document in 2023-2026 concerning the management of Green Open Space, it is stated that the area of mangrove forests in Banda Aceh has ballooned to is 445.48 Ha in 2021 (PERWAL NO. 09, 2022). The difference in mangrove area before the tsunami, after the tsunami, and the its dramatic increase in 2021 tell a story of the dynamics of change that continue to occur in the mangrove area of Banda Aceh.

A simple, easy and fast way to monitor mangrove vegetation is by using remote sensing. Remote sensing is a technique to identify an object on the earth's surface without making direct contact with the object (Green *et al.*, 2000). The NDVI method is one of the remote sensing method that can directly compare the greenness of vegetation (Riko *et al.*, 2019). NDVI analysis will show the density level of a vegetation based on the comparison between the absorbance value and the light reflected by plants, so the NDVI value will represent the density class of a vegetation based on canopy cover (Kartikasari & Sukojo, 2015).

This research aims to analyze vegetation structure, species distribution, and diversity indices in Banda Aceh's mangrove forests using NDVI. Based on the description above, researchers are interested in analyzing the structure of mangrove vegetation in Banda Aceh city based on the results of NDVI analysis. There have been many studies on mangrove vegetation using the NDVI method, including an Gogo *et al.* (2022) on analysis of changes in mangrove ecosystems in Banda Aceh City after the 2004 tsunami. However, these study still leave unanswered questions about the vegetation structure, species distribution and diversity index in each density class of NDVI analysis results in mangrove

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areas. Therefore, it is necessary to conduct further research on mangrove cover analysis.

Materials and Methods

Location and time of research

This research was conducted from July 2023 to December 2023 with map making and NDVI analysis conducted at the Department of Biology FMIPA USK. Furthermore, mangrove vegetation observations were made in the mangrove area of Banda Aceh City (Figure 1).

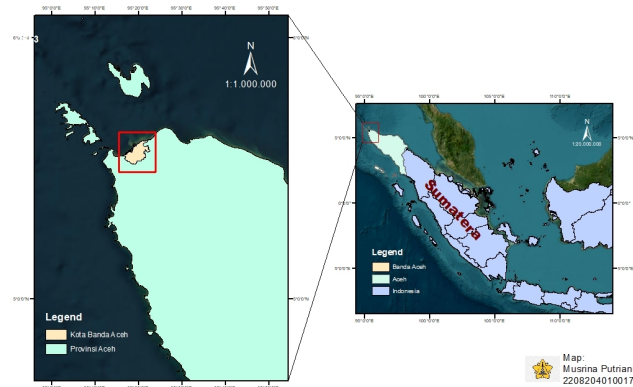


Figure 1. Study area maps

Figure 2 shows a map of the location of mangrove area observations based on the results of NDVI analysis. Figure 2 provides an overview of the research locations in the four sub-districts of Kuta Alam, Kuta Raja, Meuraxa, and Syiah Kuala.

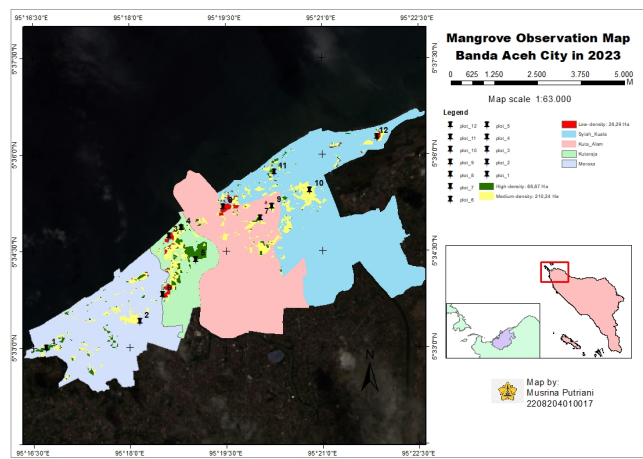


Figure 2. Map of mangrove observation locations in banda aceh city in 2024.

Processing of remote sensing data

Satellite image data processing is done with the following scheme (Figure 3).

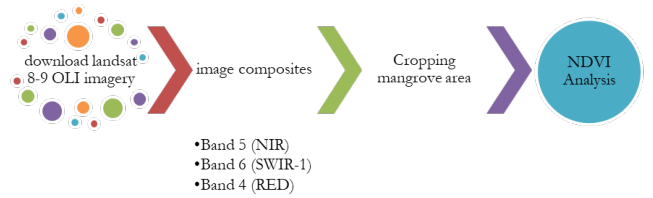


Figure 3. Satellite imagery processing scheme.

The process began with the acquisition of Landsat 8-9 OLI TRIS imagery for 2013 and 2023 from the USGS website, focusing on the Banda Aceh area and selecting images with minimal cloud cover. Atmospheric and radiometric corrections are applied to ensure data accuracy. Satellite imagery captures each color spectrum, which can then be sorted according to user needs, called bands. In this study, NIR, SWIR, and RED bands were used to facilitate vegetation analysis by combining them to obtain a representation of mangrove land. The composite image is then cropped to the administrative boundaries of Banda Aceh City, and a guided reclassification is performed to classify areas into five categories: mangroves, waters, roads, housing, and clouds. The reclassified shapefile is used to isolate mangrove areas for further analysis. NDVI analysis was then carried out on the mangrove areas by comparing the NIR and Red bands to assess vegetation density. The NDVI values are reclassified into density categories (high, medium, low) based on Ministry of Forestry standards, producing a map that visualizes mangrove distribution. Finally, observation points were selected for each density class using a random point tool in ArcGIS to gather data on species composition and diversity, with plots of 10x10 meters placed in each class. The following is the calculation for determining the number of research plots (Geospatial Agency, 2014) (Table 1)

Table 1. Number of sample points based on map scale

Map Scale	Min. number plots	Min. total sample (TSM)
1:25.000	30	50
1:50.000	20	30
1:250.000	10	20

The minimum number of samples in the total mangrove area (ha) was calculated using the following formula (Badan Informasi Geospasial, 2014):

$$A = TSM + \frac{area\ (ha)}{1500}$$

Description:

A: minimum sample size

TSM: total minimum sample

The map scale used in calculating the number of plots refers to the satellite imagery used to analyze NDVI, which is Landsat 8-9 OLI imagery. According to (Geospatial Agency, 2014) the following is the relationship between map scale and satellite imagery (Table 2).

Table 2. Correlation between map scale and satellite imagery resolution

Map Scale	Resolusi on	Satellite	Error Accuracy
25.000	12,5	ALOS	12,5m
50.000	25	ALOS,Landsat pansharp	25m
250.000	125	Landsat	125m

Based on Table 2, Landsat imagery is classified in 250,000 scale imagery with a TSM of 20. Based on this calculation, the number of plots used in this study is 60% of 20, or 12 plots which are then divided into three density classes with 4 plots for each one density class.

Mangrove Observation

Mangrove observations were carried out by purposive sampling based on the density class obtained from the NDVI analysis of the 2023 image. Data collection was conducted using the quadrat plot method with three sub-plots in each plot. The sub-plot sizes were 2 x 2 m, 5 x 5 m, and 10 x 10 m (Figure 4) (Sani et al., 2019). Each of these quadrat sizes represents different data strata. Plots with a size of 2 x 2 m will represent seedling/juvenile data up to <1.5 m in height. Plots of 5 x 5 m will represent saplings or saplings > 1.5 m in height and < 10 cm in diameter. Finally, 10 x 10 m plots will represent tree data (diameter > 10 cm).

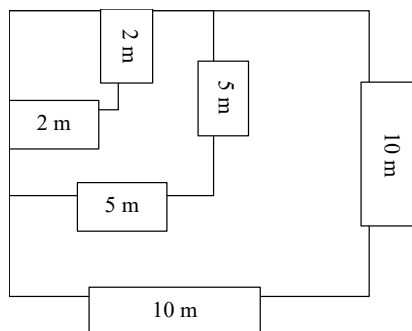


Figure 4. Observation Plot Size

Data analysis

Vegetation index analysis using the NDVI (Normalized Difference Vegetation Index) method was carried out using the following formula (Purwanto et al., 2014).

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Description:

NDVI: Vegetation Index Value

NIR: Near Infrared BAND

RED: Red BAND

The NDVI classification indicates that values from -1 to 0.32 represent low vegetation density, 0.33 to 0.42 indicate medium density, and 0.43 to 1 correspond to high vegetation density (Ministry of Forestry, 2005)

Mangrove area data from NDVI analysis was used to calculate the observation area. Data obtained from observations are described quantitatively using community indices calculated based on the formula in Maguraan (1988), which includes the Shannon-Winner index (H'), evenness index (E), Simpson index (D), and evenness index (J). All data will be displayed descriptively and presented in tables and figures with units of area (ha), and percentage (%).

Results

Mangrove Diversity in Each NDVI Density Class in 2023

Based on the results of the analysis of species diversity in each NDVI density class, the following results are obtained (Figure 5).

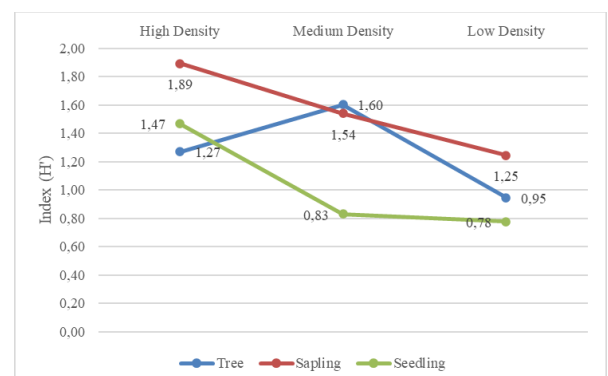


Figure 5. Comparison of H' Value with NDVI value

The results of the analysis showed that in the high NDVI density class, the diversity value on the Shannon-Wiener criterion was classified as moderate (H' 1.27-1.89) in all growth habitus found (Appendix). Magurran (1988) states that if the index

value is 2 or close to 2, then the level of species diversity is classified as moderate. This may be due to the number of species and the number of individuals of each species found in the research location is not much. This is in accordance with what is stated by [Samedi \(2015\)](#) that the value of diversity is the result of the calculation of the number of species. So even though the number of individuals found is quite a lot, if the number of species is small, the diversity value will remain low ([Table 3](#)).

Table 3. Diversity value (H' Index)

Stratum	Index H'		
	High Density	Medium Density	Low Density
Tree	1,27	1,60	0,95
Sapling	1,89	1,54	1,25
Seedling	1,47	0,83	0,78

Slightly different from the results obtained in the medium density class, where the seedling habitus obtained a diversity index value that included low criteria (H' 0.83). While in the tree and sapling habitus the diversity index is classified as moderate (H' 1.54-1.60). If you look again, there are only three types of mangroves with seedling habitus found in the Medium density plot (Appendix). This certainly greatly affects the value of the diversity index. [Karnanda et al. \(2016\)](#) states that if there are species that dominate an observation area, this will affect the diversity value. This happens because diversity is obtained by comparing the number of species as well as the number of individuals of each species in the observation area.

Then in the low density class, it was found that the diversity index value showed low criteria (H' 0.78-0.95), except for the tree habitus. Tree habitus in this low density class has a diversity value that belongs to the medium category with a value of H' (1.25). The difference in the diversity value of this growth habitus may be due to the management of mangrove areas that continue to be restored but only planted with homogeneous species. This causes the diversity value in the tree habitus to be higher than in the seedling and sapling habitus as a young habitus that has not yet become a mature tree.

The structure of mangrove vegetation is also formed like vegetation in general, from the habitus of seedlings, saplings, trees, epiphytes, lianas, to lower plants ([Giesen et al., 2006](#)). However, most mangrove vegetation is only found in three growth stages, namely seedlings, saplings and trees. This is then the basis for determining the size of mangrove

observation plots ([Kusmana et al., 2008](#)). Furthermore, based on observations, the mangroves found consisted of 12 species from 6 different families ([Table 4](#))

Table 4. Species found in this research

Species	Family
<i>Rhizophora stylosa</i>	Rhizophoraceae
<i>Rhizophora mucronata</i>	
<i>Rhizophora apiculata</i>	
<i>Ceriops tagal</i>	
<i>Bruguiera gymnorrhiza</i>	Acanthaceae
<i>Avicennia marina</i>	
<i>Avicennia alba</i>	
<i>Avicennia officinalis</i>	
<i>Nypa fruticans</i>	Arecaceae
<i>Acrostichum aureum</i>	Pteridaceae
<i>Xylocarpus granatum</i>	Meliaceae
<i>Sonneratia caseolaris</i>	Lythraceae

[Rahmah et al. \(2015\)](#) found six types of mangroves on the coast of Banda Aceh City, namely *R. apiculata*, *R. mucronata*, *R. stylosa*, *A. alba*, *Avicennia lanata* and *Sonneratia alba*. This shows that the type of mangrove in Banda Aceh City has also increased. The results of diversity analysis, overall mangrove areas in Banda Aceh City according to Shannon-Wiener criteria classified into areas with high diversity (H' 2.10) ([Figure 5](#)). This high index value is caused by the discovery of many species. [Rahmah et al. \(2015\)](#) research in Banda Aceh City found six mangrove species, while this study found 12 mangrove species.

2. Mangrove Composition in Each NDVI Density Class in 2023

High NDVI density

In the high NDVI density class, eight mangrove species were found, *A. alba*, *A. aureum*, *A. marina*, *B. gymnorrhiza*, *C. tagal*, *N. fruticans*, *R. mucronata*, and *R. stylosa*. The high NDVI class is dominated by tree strata, followed by sapling and seedling strata. This is evidenced by the number of individuals found in the observation area ([Figure 6](#)). This proves that NDVI analysis takes into account the density of a vegetation by taking into account the height of a plant. In accordance with what was found [Ruan et al. \(2022\)](#) in the temporal analysis of Asian mangroves in 2000-2018, where NDVI values are directly proportional to growth habitus.

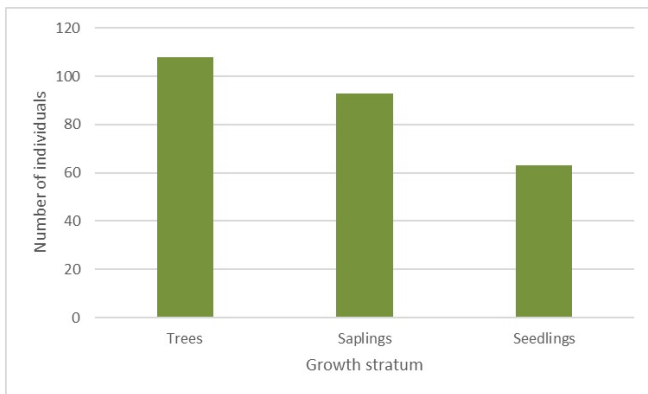


Figure 6. Growth Strata at High NDVI Density

Medium NDVI Density

In the moderate NDVI density class, nine mangrove species were found, *A. alba*, *A. aureum*, *A. marina*, *A. officinalis*, *B. gymnorhiza*, *N. fruticans*, *R. apiculata*, *R. mucronata*, and *S. caseolaris*. In this class, the dominating growth stratum is the sapling stratum with the most individuals found compared to the tree and seedling strata (Figure 7).

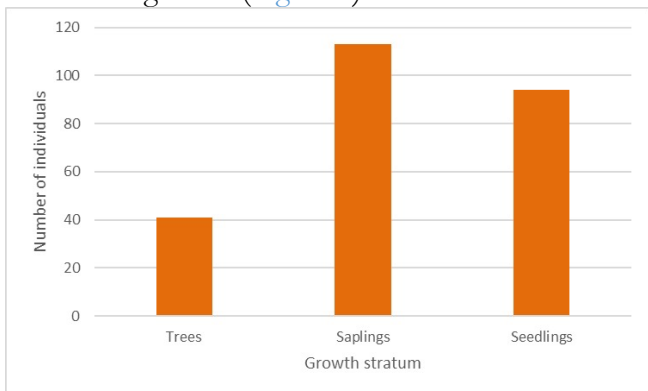


Figure 7. Growth Strata at Medium NDVI Density

If you look back at the basic theory of NDVI classes, the medium class is the middle class between the high and low classes. In mangrove vegetation can also only be distinguished three growth strata, namely trees, saplings and seedlings (Kusmana, 2009). So this finding is also in accordance with the opinion of Ruan et al. (2022) where the NDVI value is directly proportional to the growth habitus.

Low NDVI Density

In low density class, eight mangrove species were found, *A. aureum*, *A. marina*, *N. fruticans*, *R. apiculata*, *R. mucronata*, *R. stylosa*, *S. caseolaris*, and *X. granatum*. Furthermore, based on the results of the calculation of the number of individuals, in this class the dominating growth stratum is the seedling stratum (Figure 8).

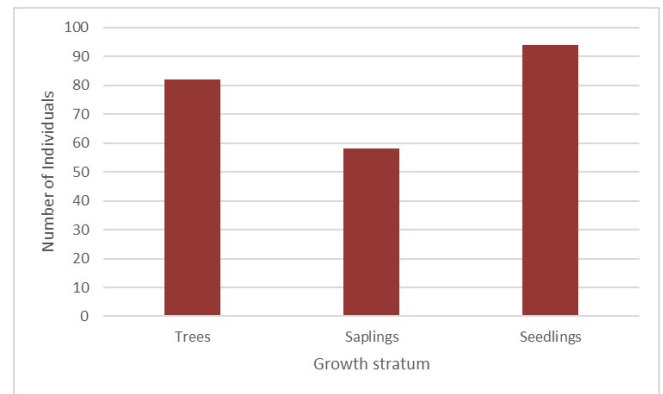


Figure 8. Growth Strata at Low NDVI Density

Discussion

The method applied in this study to detect mangrove ecosystems through distribution analysis is indispensable for the preparation of sustainable mangrove management strategies, especially in the city of Banda Aceh (Hogarth, 2015). NDVI analysis used to detect mangrove vegetation density is important for estimating future mangrove growth rates (Riko et al., 2019). This information is essential for policymakers and environmental planners to make informed decisions that ensure the long-term preservation and resilience of coastal ecosystems.

The results of NDVI analysis are used as a reference in mangrove classification using the vegetation density classification method through with the NDVI threshold value (Putra, 2018). NDVI is analyzed based on the boundaries of mangrove areas from image composites which are then used as the basis for cutting bands that will be used to perform NDVI analysis. Asimilar study has been carried out by Febrianto et al. (2022) who conducted NDVI analysis of the area of interest, namely mangroves. The results of NDVI analysis show three classes of mangrove vegetation density, namely High, Medium and Low (Figure 9).

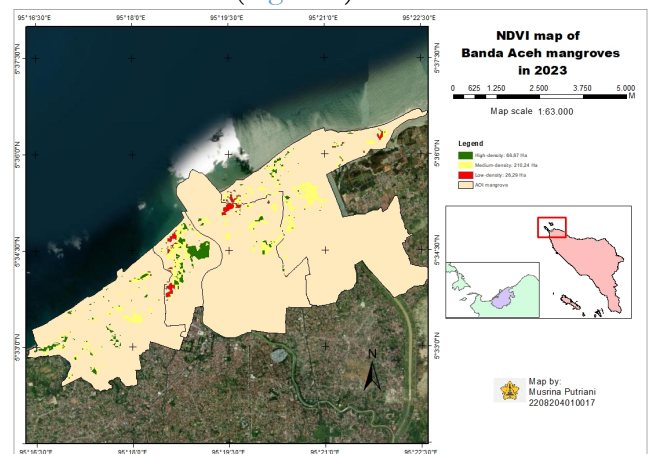


Figure 9. NDVI analysis results map

Furthermore, based on the observation of growth stratification in general, it was found that the sapling stratum was the most dominant stratum found in the mangrove area of Banda Aceh City. Based on the analysis of research data, the overall stratification of mangrove plants in the study area is shown in Figure 10.

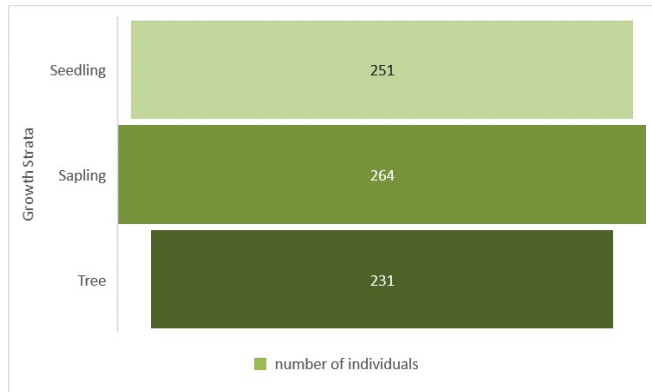


Figure 10. Mangrove Growth Strata

Figure 10 shows the stratification of mangrove growth in Banda Aceh City, where in the Tree stratum, there are 231 individuals of mangrove species found. At the sapling stratum 264 individuals were found, while at the seedling stratum 251 mangrove individuals were found. Based on the significant number of individuals in the more dominant sapling strata, the regeneration status of the Banda Aceh City mangrove area cannot be said to be good. Good regeneration status if the density of seedling strata individuals is greater than the sapling strata and the sapling is greater than the pole strata and the pole is greater than the tree strata (Naidu & Kumar, 2016).

Fitrianiingsih *et al.* (2016) mentioned that the calculation of NDVI density involves a comparison of the value of the height of the growth strata. This is in accordance with what was found in this study where three mangrove growth strata were detected in the NDVI analysis process according to their respective stratification. Something similar has also happened in Natar District, South Lampung Regency, where open land has low NDVI values while agricultural land and plantations have higher NDVI values (Rachman *et al.*, 2021). Stratification is the process of grouping plants in an ecosystem based on the layers in which they grow (Odum & Barrett, 2005). These growth layers are grouped based on the height at which the plants grow in an ecosystem area. This grouping is important for analyzing the future of a vegetation against ecosystem changes (Toni, 2009). In the mangrove forest ecosystem, plant stratification is grouped into three strata, namely seedlings, saplings and trees (Setyawan *et al.*, 2008).

Conclusion

The study of mangrove ecosystems in Banda Aceh showed three different categories of mangrove vegetation density: High, Medium and Low, based on NDVI analysis. The study also proved that NDVI values are directly proportional to growth habitus. Observations showed that sapling strata were found to be the most dominant, as well as areas with medium density NDVI values.

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