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Analysis of Mangrove Forest Changes Using Satellite Image Data on Rupat Island

Analisis Perubahan Hutan Mangrove Menggunakan Data Citra Satelit di Pulau Rupat

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ABSTRACT

Mangrove forest vegetation is spread across several islands in Indonesia, including Rupat Island. Rupat Island is the outermost island in Riau Province, close to Malaysia, and directly faces international waters, namely the Malacca Strait. Rupat Island has two sub-districts, namely Rupat District and North Rupat District. Rupat Island has a very extensive mangrove forest and has a significant contribution. Monitoring changes in mangrove forests is one way of controlling the mangrove forest ecosystem. This research aims to analyze changes in mangrove vegetation area and mangrove density using the MVI algorithm in 2013 and 2023 on Rupat Island, Bengkalis Regency. This research was conducted in the mangrove forest ecosystem on Rupat Island, Bengkalis Regency, Riau Province. The method used in this research is a survey method with observation and field data collection (ground check). Based on image processing results, the area of mangrove vegetation was 13903.03 ha (2013) to 11748.66 ha (2023) and experienced a reduction of 2154.37 ha. Classification based on MVI in sparse density has an area of 5872.46 ha (2013), decreasing to 3422.05 ha (2023); medium density has an area of 2188.84 ha (2013), increasing to 3334.64 ha (2023), and dense density has an area of 5841.73 ha (2013) reduced to 4991.97 ha. Over 10 years, the density of mangrove vegetation has increased in the medium class and tends to decrease in the sparse and dense classes. Based on calculations, the density of mangroves on Rupat Island falls into the tree category, ranging from 1150.00 ind/ha to 1450.00 ind/ha, which is considered good, and the sapling category ranges from 366.67 ind/ha to 1050.00 ind/ha, which is classified as good.

Keywords: Mangrove, Mangrove Density, Citra Landsat, Mangrove Vegetation Index

ABSTRAK

Vegetasi hutan mangrove tersebar di beberapa pulau di Indonesia, salah satunya adalah Pulau Rupat. Pulau Rupat merupakan pulau terluar di Provinsi Riau yang berdekatan dengan negara Malaysia dan berhadapan langsung dengan perairan internasional yaitu Selat Malaka. Pulau Rupat memiliki 2 kecamatan yaitu Kecamatan Rupat dan Kecamatan Rupat Utara. Pulau Rupat memiliki hutan mangrove yang sangat luas dan memiliki kontribusi yang besar. Pemantauan perubahan hutan mangrove merupakan salah satu pengendalian terhadap ekosistem hutan mangrove. Penelitian ini bertujuan untuk menganalisis perubahan luas vegetasi mangrove dan kerapatan mangrove dengan algortima MVI pada tahun 2013 dan 2023 di Pulau Rupat, Kabupaten Bengkalis. Penelitian ini dilakukan di ekosistem hutan mangrove di Pulau Rupat, Kabupaten Bengkalis, Provinsi Riau. Metode yang digunakan dalam penelitian ini adalah metode survei dengan observasi dan pengambilan data lapangan (*ground check*). Berdasarkan hasil pengolahan citra, luas vegetasi mangrove seluas 13903,03 ha (2013) menjadi 11748,66 ha (2023) dan mengalami pengurangan sebesar 2154,37 ha. Klasifikasi berdasarkan MVI pada kerapatan jarang memiliki luas 5872,46 ha (2013) berkurang menjadi 3422,05 ha (2023), kerapatan sedang memiliki luas 2188,84 ha (2013) bertambah menjadi 3334,64 ha (2023), dan kerapatan rapat memiliki luas 5841,73 ha (2013) berkurang menjadi 4991,97 ha. Kerapatan vegetasi mangrove dengan jangka waktu 10 tahun mengalami kenaikan pada kelas sedang dan cenderung mengalami penurunan pada kelas jarang dan rapat. Berdasarkan perhitungan kerapatan mangrove di Pulau Rupat masuk dalam kategori pohon berkisar 1150.00 ind/ha hingga 1450.00 ind/ha tergolong baik dan kategori anakan berkisar 366.67 ind/ha hingga 1050.00 ind/ha yang tergolong baik.

Kata Kunci: Mangrove, Kerapatan Mangrove, Citra Landsat, *Mangrove Vegetation Index*

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INTRODUCTION

Indonesia has vast mangrove forest resources spread across coastal areas in various provinces in Indonesia. Mangrove ecosystems in Indonesia are the largest in the world, covering 23% of all mangrove ecosystems on earth, with an area of 3.56 million ha (KLHK, 2019). Mangroves grow on muddy soils in tidal margins, coastal areas, and river mouths (Hotden et al., 2014). According to Kusmana & Sukristijiono (2016), Mangroves are found in tropical and sub-tropical regions that are sloping and tolerant of salinity. Mangrove forest vegetation is spread across several islands in Indonesia, including Rupat Island. The mangrove forest ecosystem is one of the main components of the coastal ecosystem environment. This is because mangrove forests have a value that is important in supporting life in coastal areas. However, over time, mangrove forests in Indonesia have decreased.

Monitoring changes in mangrove forests is one of the controls on mangrove forest ecosystems. One of the efforts to obtain information about the condition of coastal and marine resources, especially mangrove ecosystems, can be done by utilizing remote sensing technology using satellite imagery. Mangrove forests can be identified by remote sensing, where the land and sea transition area provides a distinctive recording effect compared to other land vegetation objects. With remote sensing, mangrove forests can be easily identified in terms of location and area, and their density can also determine the condition of mangrove forests.

Monitoring mangrove forests using remote sensing technology generally utilizes the Normalized Difference Vegetation Index (NDVI) algorithm. However, the algorithm often shows similar index values between mangroves and dense vegetation. The NDVI algorithm identifies vegetation density based on its canopy appearance. In 2020, a simpler mangrove index algorithm was discovered, the Mangrove Vegetation Index (MVI), which has the main focus of distinguishing mangroves from non-mangroves, such as soil, water, and other vegetation, with precision, without the need for complicated classification techniques, long time, and special expertise (Baloloy et al., 2020). However, this algorithm still has few references and uses in Indonesia.

Using remote sensing data, mangrove forests can be identified in terms of location, extent, and condition by looking at their density. Information on changes in mangrove forest vegetation is essential to understanding the coastal ecosystem's condition. This study aims to analyze changes in the area and density of mangrove forests on Rupat Island based on MVI values in 2013 and 2023.

MATERIALS AND METHOD

This research was conducted in the mangrove ecosystem area of Rupat Island, Bengkalis Regency, Riau Province. The research location map is attached in Figure 1.

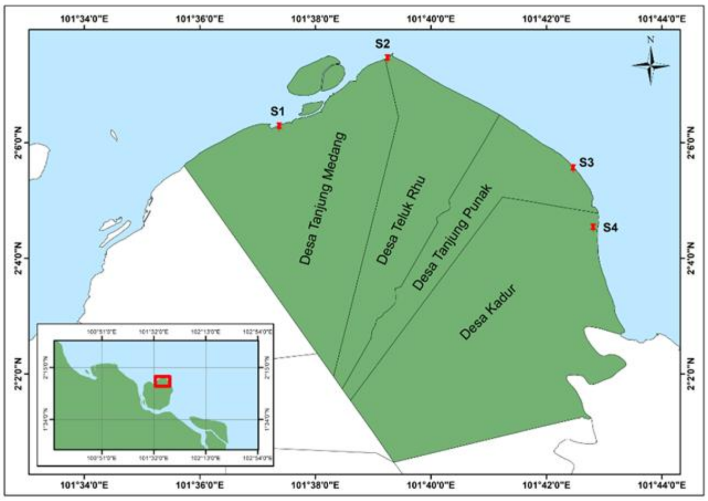


Figure 1. Map of locations and research stations

The tools used in this research consist of hardware such as laptops, Arc, GIS, and Microsoft Excel software. Tools used in field data collection are GPS (Global Positioning System), thermometer, pH meter, hand refractometer, meter and rope. The material used is Landsat image data recording in 2013 and 2023 with a distance of 10 years.

Field data collection was carried out using a survey method with observation and determination of stations carried out by purposive sampling, where the coordinate points were chosen deliberately based on consideration of coastal conditions from the results of image data processing in 2023. Field data collection (ground check) in the form of mangrove density data observed at stations that have been determined by purposive sampling method, where each station consists of three transects which each transect consists of 2 plots in the form of a square with a size of 10 m x 10 m, with the provisions of 10 m x 10 m plots for trees > 10 cm in diameter and 5 m x 5 m plots for saplings < 10 cm in diameter (Onrizal, 2008) are randomly selected.

Stages carried out in image processing with remote sensing technology to produce maps of the extent and density of mangrove forest changes, namely cutting the image to reduce the image's size and facilitate the processing of the observation area following the study area. Image composite is done to combine three bands in an image to simplify and clarify an object identified in the image. The image composite used to analyze the mangrove forest ecosystem combines RGB bands. Image classification is the process of grouping all pixels in an image into classes so that each class presents an identity with specific properties. The classification used is maximum likelihood classification (supervised), a classification method that categorizes pixels by considering the probability factor in a particular class (Sampurno & Thoriq, 2016). The vegetation index is an algorithm applied to satellite imagery. The vegetation index is the amount of vegetation greenness value obtained from digital signal processing of brightness values of several satellite sensor bands (Andana, 2015). The vegetation index in this study uses the Mangrove Vegetation Index (MVI) algorithm with the following formula (Baloloy et al., 2020).

RESULT AND DISCUSSION

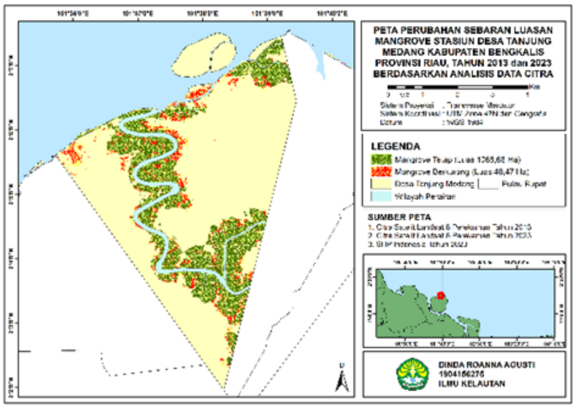
Research site conditions

Rupat Island is one of the outermost islands in Bengkalis Regency, Riau Province, which borders directly with Malaysia. Rupat Island has an area of 1,523.7 km2. This area has peat soil with a thickness of > 30 cm, while other soil types, such as fine-textured and medium-textured clay, are generally scattered along the coast. The results of measuring water quality parameters show the condition of the waters around the mangrove forest area on Rupat Island. The measured parameters include salinity, temperature and pH. The average water quality parameters in the Rupat Island area are 23‰ salinity, 31.5˚C temperature and pH 6.

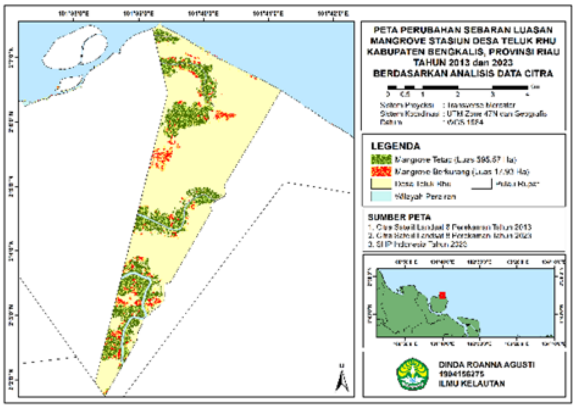
Based on observations in the field, the types of mangroves found on Rupat Island are very diverse. At four stations on Rupat Island, there are 14 types of mangroves, namely *Rhizophora mucronata, R.apiculata, R.stylosa, Sonneratia alba, S.caseolaris, Avicennia alba, A.lanata, A.marina, Bruguiera gymnorrhiza, Lumnitzera racemosa, L.littorea, Xylocarpus granatum, Ceriops tagal,* and *Nypa fruticans.*

Changes in Mangrove Forest Vegetation Area 2013 - 2023

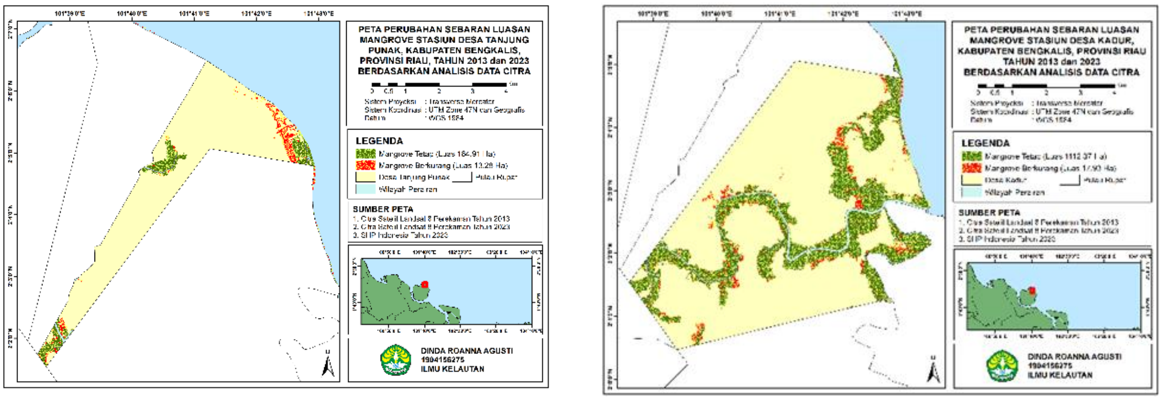
The results obtained from processing Landsat 8 image data recording in 2013 and 2023 at each station are overlaid into one layer so that the changes that occurred over 10 years can be seen clearly. Station I (Tanjung Medang Village) in 2013 had a mangrove area of 1114.15 ha and in 2023 of 1065.68 ha, meaning there is a decrease in the mangrove area of 48.47 ha within 10 years. Station II (Teluk Rhu Village) in 2013 had a mangrove area of 613.50 ha to 595.57 ha in 2023, meaning a decrease in the mangrove area of 17.93 ha. Station III (Tanjung Punak Village) decreased by 13.28 ha from 198.19 ha in 2013 to 184.91 ha in 2023. Station IV (Kadur Village) mangrove area in 2013 was 1308.91 ha; in 2023, it decreased to 1112.37 ha, a decrease in mangrove area that occurred by 196.54 ha.



(a)



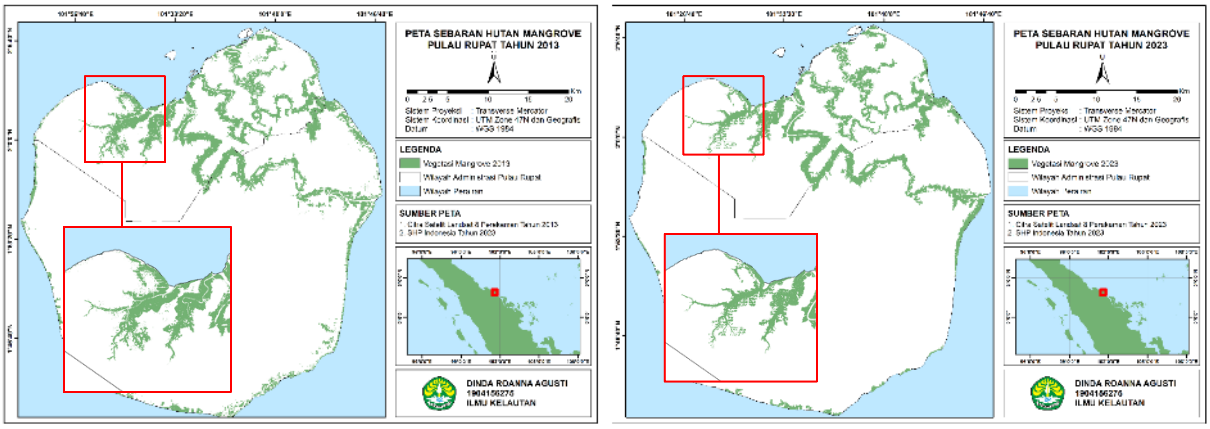
(b)



(c) (d)

Figure 2. Mangrove Vegetation Area from 2013 to 2023, (a) Tanjung Medang Village, (b) Teluk Rhu Village, (c) Tanjung Punak Village, and (d) Kadur Village

Next, the results of image data analysis with observations of Rupat Island, based on the results of image analysis obtained from an area of mangrove forest on Rupat Island in 2013 of 13903.03 ha, in 2013 in Figure 3 point a, that mangroves are widely spread in the western part of Rupat Island. Next, 2023 shows a decrease in the area of mangrove forests, which is reduced to 11748.66 ha. Figure 3, point b, shows a change in the mangrove area, where the mangrove area in the western part of Rupat Island has decreased. Changes in the area of mangrove forests on Rupat Island in the last 10 years, namely 2013 and 2023, based on the results of overlaying on ArcGis, found that mangrove forest vegetation on Rupat Island decreased in terms of area by 2154.37 ha.



(a) (b)

Figure 3. Mangrove Vegetation Area of Rupat Island from 2013 to 2023 Based on Image Data Analysis (a) 2013 (b) 2023

The condition of mangrove forest vegetation on Rupat Island tends to show a reduction in the area of mangrove forest vegetation. The reduction in area occurred due to land use changes in the last 10 years. The reduction in mangrove area on Rupat Island is closely related to mangrove land use and the utilization of mangrove trees themselves (Figure 4).

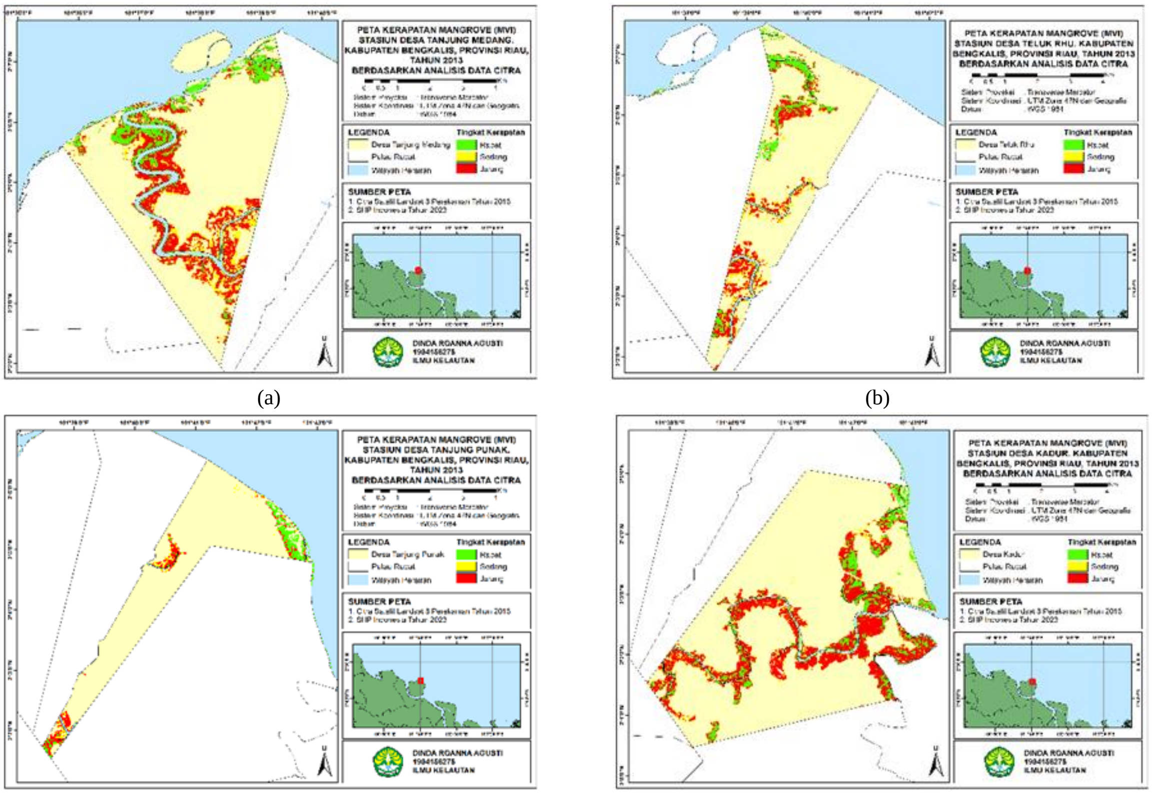
Based on the four stations observed, the reduction in mangrove area occurs due to the transfer of land functions such as shrimp farming and illegal logging of mangrove trees by surrounding communities that can cause mangrove forests to become deforested, consequently increasing the risk of coastal abrasion. According to Suyono et al. (2015), the occurrence of coastal abrasion is triggered by the reduction of mangrove forests in a place, and coastal abrasion also plays an important role in reducing the extent of mangrove forests, which are influenced by several factors, including the ecological, social, economic and cultural heritage of the local community. According to Agusrinal et al. (2015), mangrove forest damage occurs due to two things, namely human activities and natural factors. Human activities that cause mangrove damage are large-scale logging of mangrove forests used as settlements, making charcoal as a livelihood for the surrounding community, building materials, land tenure by the community, land clearing for shrimp farming, agriculture, mining, and industry. The influence of human activity on land cover change can have negative consequences. The influence of human activity is negative if human activity in the area disturbs and ignores land functions (Puspita et al., 2021). The pressure on mangrove forests comes from the human desire to convert mangrove forest areas into tourist areas, lodging for migrants, residential settlements, opening of ponds, and infrastructure development, which causes the reduction of mangrove forest areas from time to time.

Figure 4. Form of mangrove land conversion

If sustainable forest utilization is not wise, it is feared that it can reduce forest functions (Batubara & Affandi, 2017). The negative impact arising from the over-utilization of mangrove forests is the physical damage or loss of mangrove ecosystems, resulting in a decrease in the ecological, social, and economic functions of mangrove forests.

Mangrove density based on MVI values from 2013 to 2023

The results of mangrove density analysis using the MVI method at each station on Rupat Island over 10 years from 2013 to 2023 were carried out by classifying mangrove forest density based on MVI values. Changes in the mangrove vegetation density index at each station and Rupat Island using the MVI method can be seen in Figures 5-7.



(a) (b) (c) (d)

Figure 5. MVI Mangrove Density Map at Each Station on Rupat Island in 2013; (a) Tanjung Medang Village, (b) Teluk Rhu Village, (c) Tanjung Punak Village, (d) Kadur Village

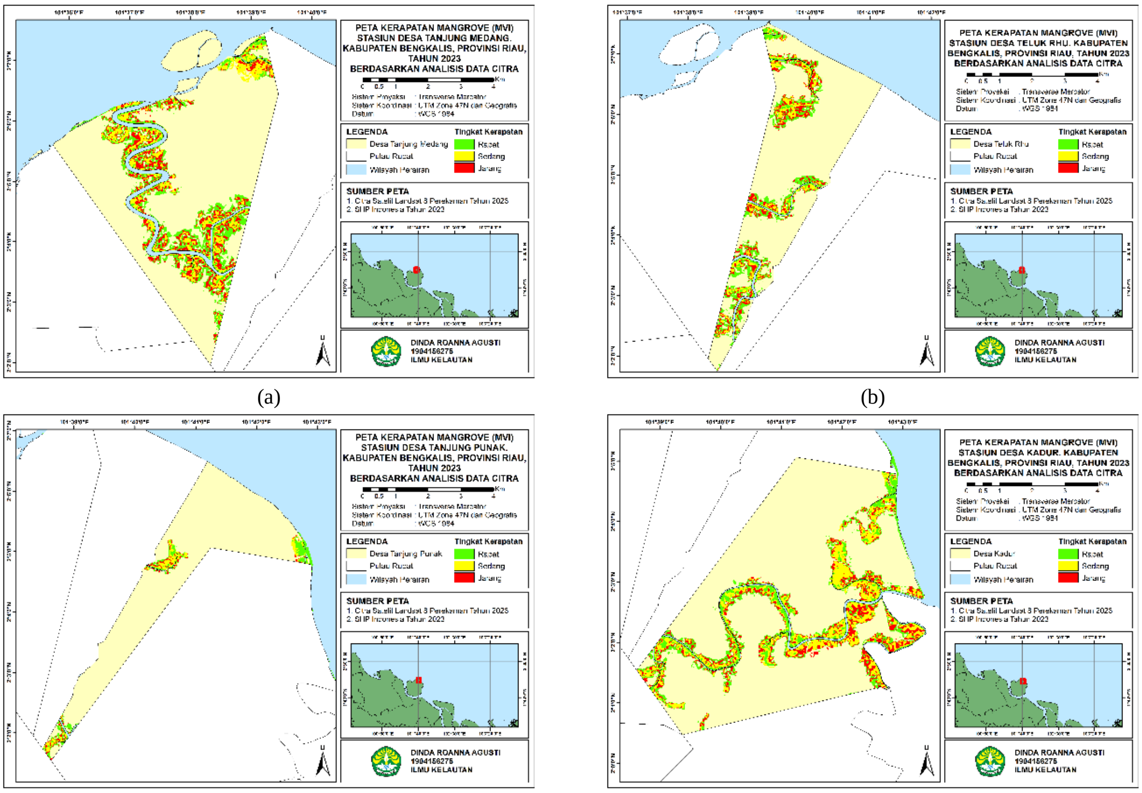


Figure 6. MVI Mangrove Density Map at Each Station on Rupat Island in 2023; (a) Tanjung Medang Village, (b) Teluk Rhu Village, (c) Tanjung Punak Village, (d) Kadur Village

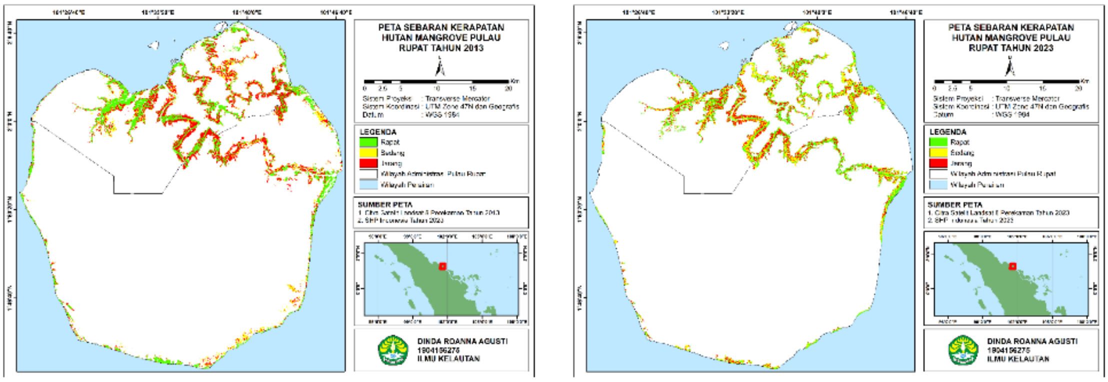


Figure 7. MVI Mangrove Density Map on Rupat Island (a) 2013, and (b) 2023

The Mangrove Vegetation Index (MVI) is a new index developed to perform fast and accurate mangrove mapping without requiring time-consuming, complex classification techniques. MVI visually separates mangrove vegetation from non-mangrove species, bare land, and buildings. Index calculations through MVI are performed using SWIR1, NIR, and green bands. Three multispectral bands were selected to be formulated into the MVI (Baloloy et al., 2020).

The MVI value spreads from 0 to 16 based on the calculation results. According to Habibie et al. (2021), a value close to 0 in MVI describes a non-vegetated area or low-density vegetation, while a value close to 16 in MVI describes a vegetation area cover or high-density vegetation. The analysis was conducted by classifying the MVI values. In classifying MVI values, the highest and lowest values were obtained and then divided into three classes.

Based on the results of image processing using the MVI algorithm and analysis within 10 years, it produced a different appearance. In 2013, mangrove density sparse density had an area of 5872.46 ha, reduced to 3422.05 ha in 2023; moderate density in 2013 had an area of 2188.84 ha, increased to 3334.64 ha in 2023; and dense density in 2013 had an area of 5841.73 ha reduced to 4991.97 ha in 2023. Mangrove vegetation density within 10 years increased in the medium class and tended to decrease in the sparse and dense classes. Several factors can cause changes in density, such as threats to mangrove forest vegetation, both naturally and through human activities, one of which is illegal logging for charcoal production, carried out almost daily. Another factor is the growth of mangrove seedlings over time, which can increase mangrove density.

The pressure from the surrounding mangrove environment threatens mangrove forest vegetation. In 2013, it was detected that the density of the sparse class category was the most dominant. This is due to the high utilization of mangrove trees on a large scale as raw material for making charcoal, building wood, and firewood, which are the livelihood of the surrounding community. According to Achmad et al. (2019), one of the causes of the reduction in mangrove forest density is that more and more people are utilizing mangrove forests, both in terms of land and the need for benefits from mangrove forest species themselves, as well as exploitation carried out by the community for economic purposes such as logging mangrove wood for firewood to make charcoal. People's lives close to and directly related to mangrove ecosystems encourage people to utilize them to meet their daily needs.

CONCLUSION

The area of mangrove forest vegetation has decreased within 10 years; station I is 48.47 ha, station II is 17.93 ha, station III is 13.28 ha, station IV has decreased by 196.54 ha, and on Rupat Island, there is a reduction of 2154.37 ha. Reduction in mangrove areas is caused by land use changes, such as the construction of shrimp ponds and illegal logging of mangrove trees by the surrounding community. Mangrove density in 2013 sparse density had an area of 5872.46 ha, reduced to 3422.05 ha in 2023; medium density in 2013 had an area of 2188.84 ha, increased to 3334.64 ha in 2023, and dense density in 2013 had an area of 5841.73 ha reduced to 4991.97 ha in 2023. Mangrove forest density based on the MVI algorithm within 10 years undergoes changes that can be influenced by several factors, such as illegal logging can cause a decrease in density, while the growth of mangrove seedlings over time can increase density.

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