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CHANGES IN LAND COVER AND MANGROVE VEGETATION DENSITY IN SIANTAN DISTRICT, MEMPAWAH REGENCY

Perubahan Tutupan Lahan dan Kerapatan Vegetasi Mangrove di Kecamatan Siantan, Kabupaten Mempawah

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ABSTRACT

One of the mangrove forests in Mempawah Regency is located in Siantan District. Mangrove forests have ecological, social, and economic functions to support the lives of living things that live around them. The extent and density of mangrove vegetation are essential parameters to determine the condition of mangroves in Siantan District to recommend rehabilitation that needs to be pursued. Data were collected from Landsat 7 images in 2010 and Landsat 8 images in 2021 with guided classification and visual interpretation to obtain a map of changes in mangrove land cover in 2010-2021. Vegetation density was obtained through Landsat Normalized Difference Vegetation Index (NDVI) analysis, divided into five density classes: very dense, dense, medium, sparse, and unvegetated. This study found that the secondary mangrove forests in Kecamatan Siantan decreased by 176.35 hectares during 2010-2021, turning into shrubs, open land, and plantations, especially in former pond areas. The most extensive deforestation turned 107.18 hectares of secondary mangrove forest into shrubs. Reforestation occurred during 2010-2021 amounted to 123.55 hectares. Natural or artificial bare land turned into 71.44 hectares of mangrove ecosystem. In 2010, the dense class dominated the mangrove forest density (60.03%) but decreased in 2021 (14.9%). A sparse class of density was not detected in 2010, but in 2021, the area of sparse density was 148.53 hectares, composed of shrubs and coconut plantations.

Keywords: Landsat imagery; Mangrove land cover; Mangrove vegetation density; NDVI

ABSTRAK

Salah satu hutan mangrove di Provinsi Kalimantan Barat terletak di Kecamatan Siantan, Kabupaten Mempawah. Hutan mangrove memiliki fungsi ekologi, sosial, dan ekonomi untuk mendukung kehidupan makluk hidup yang tinggal di sekitarnya. Luasan dan kerapatan vegetasi mangrove menjadi parameter penting untuk mengetahui kondisi mangrove di Kecamatan Siantan untuk merekomendasikan rehabilitasi yang perlu diupayakan. Penelitian bertujuan untuk menganalisis perubahan tutupan lahan dan kerapatan vegetasi di kawasan mangrove Kecamatan Sintan. Data yang dibutuhkan yaitu Citra Landsat 7 tahun 2010 dan Citra Landsat 8 Tahun 2021 dengan klasifikasi terbimbing dan interpretasi visual maka diperoleh peta perubahan luasan hutan mangrove tahun 2010-2021. Kerapatan vegetasi diperoleh melalui analisis Landsat Normalized Difference Vegetation Index (NDVI) yang dibedakan menjadi 5 kelas kerapatan yaitu sangat lebat, lebat, sedang, jarang, dan tidak bervegetasi. Penelitian ini menemukan bahwa terjadi deforestasi dan degradasi hutan mangrove. Hutan mangrove sekunder di Kecamatan Siantan mengalami penurunan luas sebesar 176.35 hektar selama tahun 2010-2021. Lahan beralih menjadi semak belukar, tanah terbuka, dan perkebunan terutama pada kawasan bekas tambak. Deforestasi sebesar 107.18 hektar mengubah hutan mangrove sekunder menjadi semak belukar. Reforestasi terjadi selama tahun 2010-2021 seluas 123.55 hektar. Tanah terbuka secara alami atau buatan (penanaman) beralih menjadi ekosistem mangrove seluas 71.44 hektar. Tahun 2010 hutan mangrove didominasi kerapatan lebat (60.03%) tetapi tahun 2021 kerapatan lebat hanya mencapai 14.9 %. Kerapatan jarang tidak terdeteksi pada tahun 2010, tetapi tahun 2021 luasan kerapatan jarang adalah 148.53 hektar yang merupakan semak belukar dan perkebunan kelapa.

Kata kunci: Citra landsat; Kerapatan vegetasi mangrove; Tutupan lahan mangrove; NDVI

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A. INTRODUCTION

Mangrove forests are a natural phenomenon that grows on the coast's border between land and water. Various plant species have demonstrated extraordinary adaptations to survive in often hostile environments, with characteristics such as the water's saltiness and the sea's ebb and flow. However, the existence of mangrove forests does not merely reflect biological aspects but the struggle to maintain the balance of fragile ecosystems on the coast. Function Mangroves can be viewed from ecological, economic, social, and biodiversity functions. Mangroves act as protectors of land and ecosystems from the threat of abrasion (Bryan-Brown et al., 2020). Mangrove vegetation can reduce wind speed and sea waves. Residential settlements near the coast are at risk of seawater intrusion. The presence of mangrove vegetation can prevent seawater from entering the waterland of residents (Sillanpaa et al., 2017).

The mangrove forest in Mempawah Regency covers an area of 1521 hectares in several sub-districts. Siantan District has the most extensive mangrove forest, covering 45.69% of the total mangrove area in Mempawah Regency or an area of 695 hectares. The second place with the largest mangrove area is Sungai Pinyuh District (24.4% or 371 ha). Next is Sungai Pinyuh (22.03%) and Sungai Kunyit (7.9%). However, due to the increase in population and human activities, mangrove forests are experiencing disturbances in the form of conversion of mangrove forests to non-mangroves. This happens because mangrove forests hold economically beneficial potential for meeting needs and increasing income (Carugati et al., 2018).

Actions to protect the mangrove ecosystem play an integral role in realizing the Sustainable *Development Goals* (SDGs). Mangrove forests are not just beautiful natural landscapes but are the foundation for various essential aspects of sustainability. One of the most influential SDG goals is the 13th goal, which relates to action on climate change. Mangrove ecosystems function as significant carbon sinks, helping to reduce greenhouse gas emissions and protecting coasts from the adverse impacts of floods and storms. We actively contribute to global efforts to tackle climate change by preserving and restoring mangrove forests. SDG's goal 14, which emphasizes the sustainability of life underwater, is also closely related to mangrove forests. This ecosystem is an essential habitat for marine organisms like fish and shrimp. Therefore, protecting mangrove ecosystems means supporting the sustainability of marine and marine ecosystems that are rich in natural resources (Handayani et al., 2023).

Biodiversity, the focus of SDG's 15th goal, also benefits from mangrove forests. These ecosystems provide homes for various plants, birds, and other land animals, contributing to the overall preservation of biodiversity. In addition, social and economic aspects are also involved. SGD's first goal, which targets eradicating poverty, can be supported by mangrove forests because the ecosystem provides livelihoods and resources for local communities that depend on marine products, such as fish, shrimp, and firewood. If mangrove forests are protected, the continuity of livelihood and welfare of local communities can be guaranteed (Rachman et al., 2023).

Changes in the area of mangrove forest cover in the coastal regions of Siantan District always experience a significant decline, often accompanied by a decrease in mangrove tree canopy density. Factors contributing to this decline include rampant illegal logging in the region. It has caused the loss of valuable mangrove vegetation. The decline in mangrove forest areas, a direct effect of illegal logging, threatens coastal ecosystems. This results in ecological losses, such as reduced habitat for marine organisms and reduced protection from coastal erosion. These losses can also have a significant impact on local communities who depend on mangrove resources for their livelihoods and daily lives (Dwi et al., 2021).

A decrease in mangrove tree canopy density can also result in more profound damage to the mangrove ecosystem. The impacts include the loss of coastal protection functions and the ability of mangrove forests to absorb carbon dioxide, which in turn affects climate change. Therefore, strict monitoring, protection, and supervision efforts are critical to mitigate illegal logging and ensure the continuity of the mangrove ecosystem in Siantan District and the surrounding coastal areas. In the mangrove area of Siantan District, Tanjung Burung Beach is experiencing worrying coastal erosion. Beach erosion, a natural process in which ocean waves erode coastlines, has seriously threatened coastal ecosystems. The negative impacts of this abrasion are genuine, reflected in the loss of valuable land and damage to aquatic ecosystems that are an integral part of life in this region. The decreasing area of mangrove forests can impact reducing the function of mangroves. Thus, it can be a threat to the sustainability of the lives of people living around mangrove forest areas (Rousdy et al., 2021).

Research on mangrove cover changes has not been carried out previously in Mempawah Regency. Research has been carried out regarding the diversity of mangrove vegetation in Mempawah Regency, with the results finding 11 types of vegetation (Prastomo et al., 2017). Apart from research on vegetation types, many other studies have been conducted on the perceptions and socio-economics of communities in the mangrove area of Mempawah Regency. This research aimed to analyze changes in mangrove cover and vegetation density so that deforestation and mangrove degradation can be measured in Siantan Hilir District, Mempawah Regency.

B. METHODS

This research was conducted in the mangrove forest of Siantan District, Mempawah Regency. The objects of this research were the area, land cover, and vegetation density in the mangrove forest in Siantan District, Mempawah Regency. The primary data obtained were land cover and mangrove vegetation density data for 2010 and 2021. The primary data source was obtained from Landsat 7 Imagery for 2010 data and Landsat 8 Imagery for 2021. Land cover was obtained through visual interpretation, while vegetation density used the Landsat Normalized Difference Vegetation Index (NDVI). Landsat image processing goes through pre-image processing and image processing stages. Pre-image processing of Landsat images includes radiometric correction, cropping, sharpening, and band combination (Segarra et al., 2020; Belgiu & Csillik, 2018). Image cropping was carried out to adjust the boundaries of the research location based on the 2020 1:50000 Scale Siantan District Administrative Map. In addition, image cropping can reduce data storage on the computer. This study's visual interpretation of Landsat imagery uses true color: composite bands 453 for Landsat 7 imagery and 564 for Landsat 8 imagery. Using true color makes it easier for interpreters to recognize objects (Kesaulija et al., 2023).

Land Cover Classification

The land cover classification was carried out through visual interpretation, which included the stages of detecting, identifying, and recognizing objects through interpretation elements for digitization. Interpretation elements pay attention to color, hue, shape, size, shadow, pattern, site, and association (Qasim et al., 2016). The basis for land cover classification referred to the Regulations of the Directorate General of Forestry. The output of the image classification process was obtained in the form of a tentative map. The tentative map becomes the base map for determining land cover classification, which will then be determined by pinpointing direct observation locations and carrying out ground checks to validate land cover in the field, resulting in a land cover map.

Vegetation Density

Vegetation density analysis considers vegetation conditions in the field. Mangrove forests in Mempawah Hilir District tend to have various vegetation types with varying growth classes. Vegetation density classes consider the NDVI (Sun et al., 2019). This index was suitable for varying densities, so it does not consider soil as a background, such as when using the Landsat Soil Adjusted Vegetation Index (SAVI). Calculation of the NDVI was based on the reflection of objects in the red and near-infrared spectrum channels. In the Landsat 8 image, the red band was in band 4, and the near-infrared was in band 5. NDVI formula is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

Where NIR refers to the spectral value of Near Infrared, and RED refers to the spectral value of the red channel.

To determine the mark density header mangroves, use the NDVI results calculation. Then, the NDVI class value was reclassified (reclassified) into 3 classes: sparse, medium, and dense density. Table 1 evaluates the density level of the mangrove canopy based on the NDVI value.

Table 1. Canopy density classification

NDVI value	Canopy Density Level
0.43 ≤ NDVI ≤ 1.00	Thick/high density
0.33 ≤ NDVI ≤ 0.42	Medium density
-1.0 ≤ NDVI ≤ 0.32	Rare/low density

Source: Department of Forestry (2005)

Ground Check and Accuracy

Groundcheck was carried out by direct observation at the research location on the targeted object. Observation points were determined based on access to the area and the distribution of land cover forms that have been previously interpreted. Ground checks on land cover were carried out by taking observation points, documenting or photographing land cover, and interviewing the shape and changes in land cover. Interviews were conducted to obtain information on the truth of visual analysis. Ground checks for vegetation density were carried out with a fisheye camera. The photos were analyzed using Caneye Software to obtain data on the percentage of vegetation cover (Juniansah et al., 2018). There were 30 samples taken, which were then divided for statistical analysis and accuracy testing of the canopy density map. Based on the mangrove mapping guidelines published by the Geospatial Information Agency (BIG), the total number of samples was a minimum of 30 samples. Considering the mangrove forest area, two samples were added to make 32

samples. Land cover accuracy was measured using matrix confusion with a minimum accuracy limit of 85%. If the accuracy was less than 85%, reinterpretation was carried out.

C. RESULTS AND DISCUSSION

The satellite images used to analyze changes in mangrove forest areas, namely Landsat 7 and Landsat 8 obtained from the official USGS website, do not need geometric correction because the level 1T product is an image that has been corrected both geometrically and radiometrically, level 1 data is available to users is an image that is corrected both radiometrically and geometrically. The inputs used from both sensors and spacecraft are GCP and DEM. The result is a product that is free from geometric distortion from sensors (viewing angle effects), satellites (height deviation from nominal), and the earth (curvature rotation, relief). Moreover, it was radiometrically corrected to remove relative detector differences, dark current bias, and some artifacts. Level 1 images are presented in DN (Digital Number) form, so they can easily be converted into Spectral Radiance and TOA Reflectance (Kosasih et al., 2019).

The combination used is 4-2-1 for Landsat 7 imagery in 2010 and 5-3-2 for Landsat 8 imagery in 2021. The wavelengths in these band combinations are shown in Table 2. Band Combination Near Infrared (NIR) is better for detecting coastlines and measuring biomass. The green band clarifies vegetation, while the blue band is good for mapping sea depth and seeing the difference between empty land and plants (Dzakiyah & Prasasti, 2019).

Table 2. Combination of bands used in Landsat 7 and Landsat 8 imagery

Landsat 7	Landsat 8
4 = NIR (0.77-0.9)	5 = NIR (0.85-0.88)
2 = Greens (0.52-0.6)	3 = Greens (0.53-0.59)
1 = Blue (0.45-0.52)	2 = Blue (0.45-0.51)

Landsat 7 and Landsat 8 images of path 122, row 60 were cropped according to the administrative boundaries of Siantan District. The aim was to focus more on the research area. Cropping the image also reduces the shp file size, making the laptop work excellent. Digital and manual analysis processes have become faster.

Mangrove Forest Land Cover in 2010 and 2021

In 2010, the land cover was dominated by secondary mangrove forests, covering an area of 737.79 hectares or 60.78% of the total area of mangrove forests in Siantan District (Figure 3). Land cover in the form of ponds in 2010 covered 18.67 hectares (1.54%). This pond is a shrimp pond owned by an individual. In the northern and western parts of the pond, the land cover in the form of bushes covers an area of 153.59 hectares or 12.65%. Bushes are also found in the southern part of Peniti Luar Village, especially along the river. The results of the field *ground check* showed that the land in the area was used as a community plantation. Areas near rivers are more strategic for plantation areas because they are easier to access than mangrove areas where rivers do not pass. Residents are transported to plantation land using water motorbikes or motorized wooden boats. The type of plant that is most commonly found in the banana tree. At the back of the plantation area, a Jeruju plant, *Rhizophora* spp., and *Sonneratia alba* were found. Land cover in the form of open land is found in the area behind the coastline, which is a muddy area covering 104.98 hectares or 8.65%.

In 2021, secondary mangrove forests will decrease by 52.8 hectares (Figure 3). Secondary mangrove forests are still found in the northern part of the mangrove forests in Siantan District. The field survey results showed that *Rhizophora* was found in this area spp., *Avicennia* spp., *Nypa* spp., and Jeruju. Land cover in the form of ponds in 2021 was not found because ponds in mangrove forest areas were left alone, and profits from the pond business were reduced. This triggers the growth of mangrove plants such as *Rhizophora* spp., so some of the former pond land has turned into a mangrove ecosystem. This is in line with the results of research in the Bontang Mangrove Park area, where pond land was no longer found because mangrove plants overgrew it in the form of *Sonneratia alba* and *Rhizophora* spp (Harjanto et al., 2019). Apart from becoming a mangrove ecosystem, some former areas have also turned into bushes. The shrubs in the mangrove forests of Siantan District are overgrown with ferns and plants that spread across the ground. (Harjanto et al., 2019). In Landsat imagery, shrubs are recognized by their slightly smooth texture and yellowish-green color. The area of shrubs increased by 31.66 hectares in 11 years, or at the time of research, it reached 15.25% of the total area of mangrove forests.

The former pond land has undergone quite significant changes. Apart from being a mangrove and bush ecosystem, the former pond area has been turned into a coconut plantation managed by a company. In 2010, no plantations were found, whereas in 2021, coconut plantations had reached 123.85 hectares or 10.19% of the mangrove forest area in Siantan District. Coconuts have a higher economic value because all of their parts can be used as production materials. Coconut plantations in Siantan District located in mangrove forests are used to produce sap processed into brown sugar. Even within the company, there are brown sugar processing activities. Coconut trees do not require expensive

maintenance like other plantations, and the profit obtained is higher because they are not seasonal crops. This is one of the factors considering the conversion of land into coconut plantations (Dongoran, 2020).

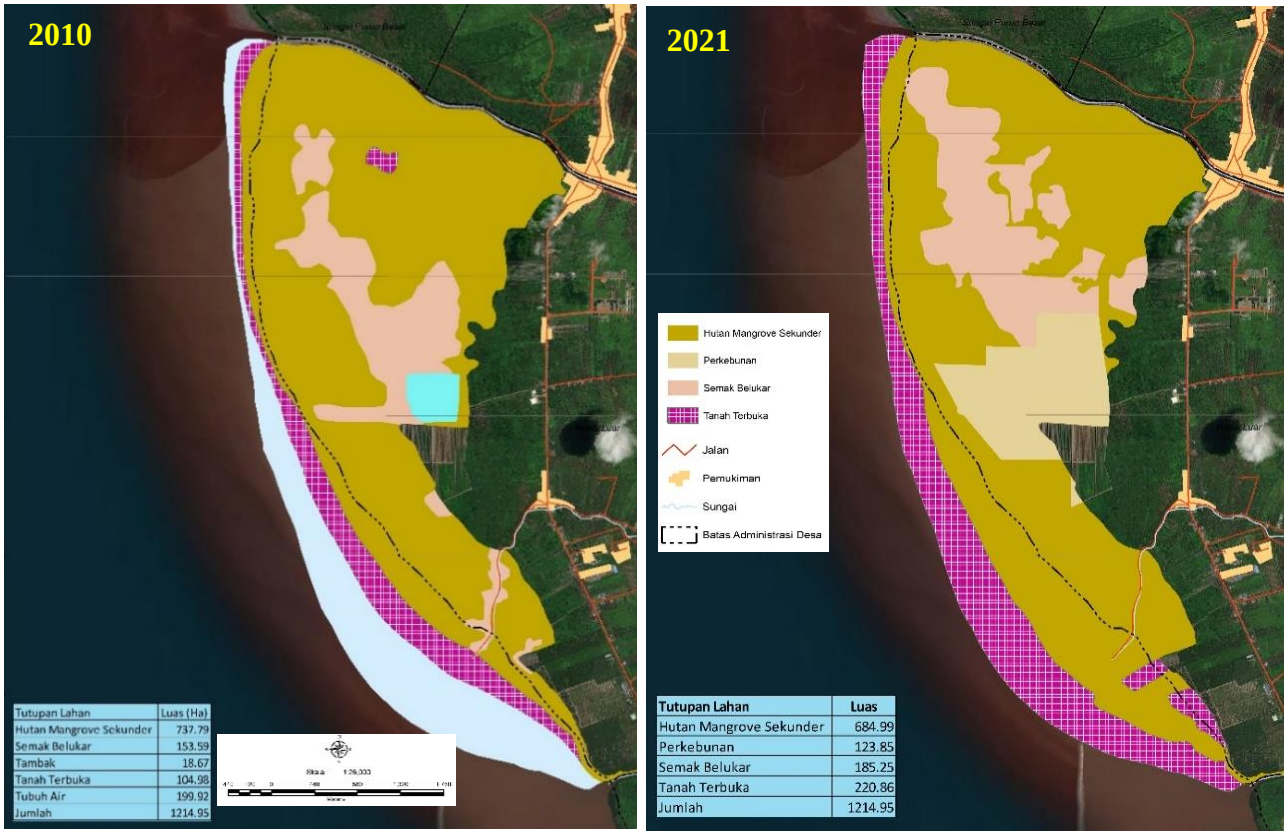

Figure 3. Map of mangrove forest land cover in Siantan district in 2010 and 2021

Analysis of Changes in Mangrove Forest Land Cover 2010-2021

Based on the 2010 and 2021 mangrove forest land cover maps, deforestation and reforestation in the mangrove forest area in Siantan District can be analyzed as shown in Figure 4. Based on Table 3, deforestation occurred in secondary mangrove forests. An area of 176.75 hectares of secondary mangrove forest land was turned into bushes, open land, and plantations. The largest secondary mangrove forest turned into bushes of 107.18 hectares or 14.5% of the total area. The open land area increased from secondary mangrove forests to 15.11 hectares and plantations to 54.06 hectares. If we look at the spatial pattern, deforestation predominantly occurs on land around former ponds due to the development of coconut plantations. The deforestation in the mangrove forest in the southern part of Peniti Luar Village was caused by the development of residents' agricultural activities, especially in estuary areas and riverbanks.

Reforestation also occurred during 2010-2021, covering an area of 123.55 hectares in the mangrove forest area in Siantan District. The greatest reforestation occurred on open land, with 71.44 hectares of open land becoming secondary mangrove forests. Apart from open land, 25.15 hectares of bushes and 26.96 hectares of water bodies have been turned into mangrove ecosystems. Spatial reforestation occurs in areas behind the coastline. This is due to the mangrove planting program in Peniti Luar Village near the river mouth and the natural growth of mangroves. The preservation and continuity of the mangrove ecosystem need attention because the function of mangroves as a support for human life is essential (Lestariningsih et al., 2021)A deforestation map provides an overview of where mangrove rehabilitation efforts must be carried out. The development of coconut plantations in mangrove forest areas needs to be limited to prevent damage to the ecosystem, and the sustainability of mangrove forests in Siantan District needs to be considered.

Mangrove Forest Vegetation Density, Siantan District, 2010

The density of mangrove vegetation in Siantan District, Mempawah Regency, was analyzed using the NDVI vegetation index. The imagery used is Landsat 7 imagery for vegetation density analysis in 2017 and Landsat-8 imagery for vegetation density analysis in 2021. Both images have near-infrared bands and 11 bands that can be used for vegetation indices. Humans can only see color in visible waves (0.4-0.7 m), so healthy and good vegetation appears green to the human eye. However, the highest reflection provided by vegetation is in the red and near-infrared bands (Pamuji et al., 2023).

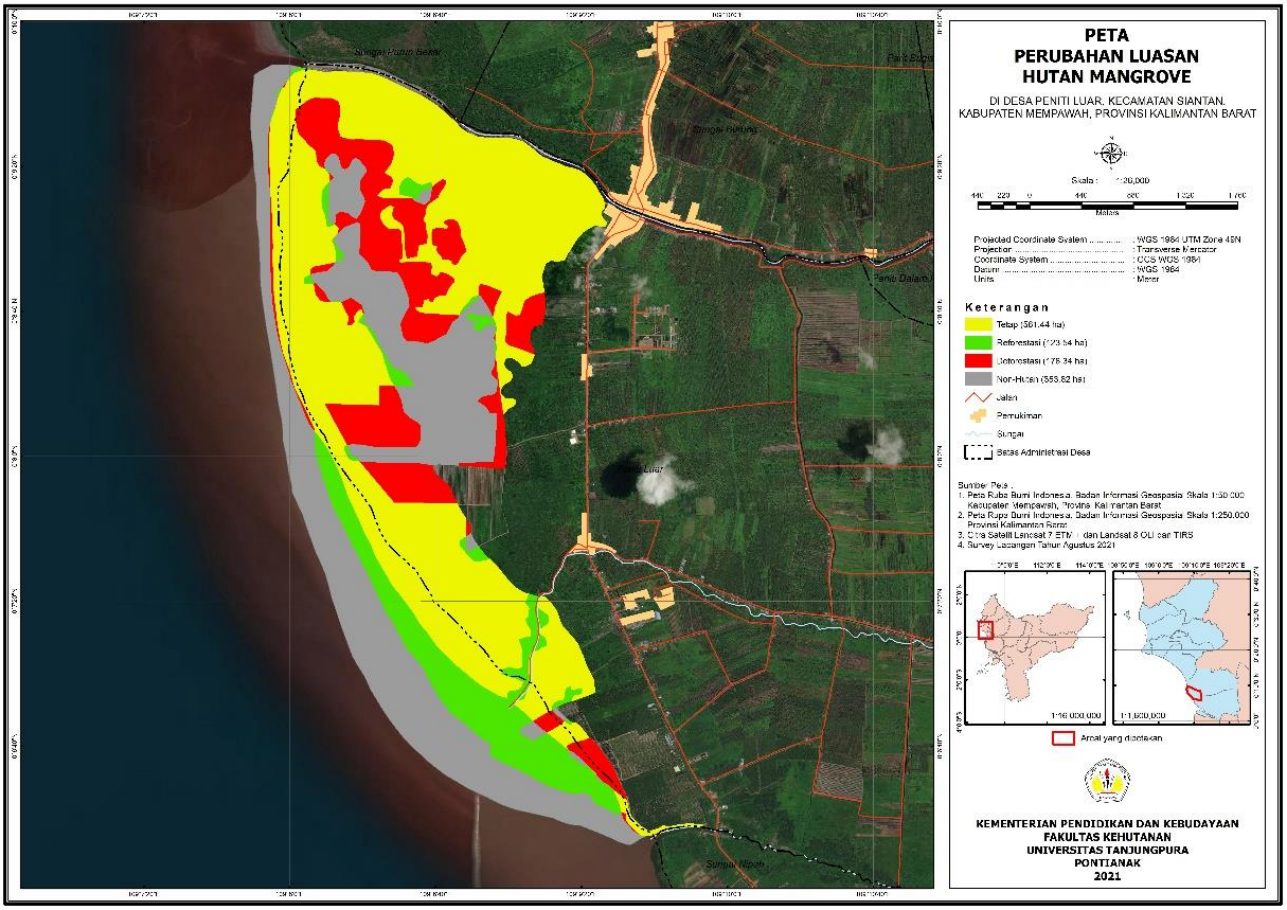

Figure 4. Map of changes in mangrove forest land cover, Siantan District in 2010-2021

Table 3. Deforestation and reforestation of mangrove forest, Siantan District in 2010-2021

	Land Cover Class	2021				Total 2010
		Secondary Mangrove Forest	Shrubs	Open Land	Plantation	
2010	Secondary Mangrove Forest	561.44	107.18	15.11	54.06	737.79
	Shrubs	25.15	76.82	0.49	51.12	153.59
	Pond	0.00	0.00	0.00	18.67	18.67
	Open Land	71.44	1.25	32.29	0.00	104.98
	Body of Water	26.96	0.00	172.97	0.00	199.92
	Total for 2021	**684.99**	**185.25**	**220.86**	**123.85**	**1214.95**

Note: Reduction of mangrove forests (yellow), reforestation (green), and remains in area (red)

Five vegetation indices can be used to measure vegetation density, namely NDVI, SAVI, Atmospherically Resistant Vegetation Index (ARVI), Difference Vegetation Index (DVI), and Ratio Vegetation Index (RVI). Each method has a different algorithm or calculation formula, so the results of vegetation density areas based on class are also different. The NDVI vegetation index analysis has the highest accuracy compared to the other four vegetation index methods, namely 75.61%. This high accuracy is because NDVI can capture changes in plant canopy density better than other vegetation index methods (Bashit, 2019).

The range of NDVI vegetation values is -1 to 1, classified into five classes (Simarmata et al., 2021). Based on Table 4, the density of mangrove vegetation in the Siantan District in 2010 was dominated by a dense density of 728,653 hectares or 60.03% of the total mangrove area that year. Almost all mangrove areas have a dense vegetation canopy, which is mostly secondary mangrove forest land cover. However, in 2021, the dense vegetation canopy density decreased significantly, leaving only 181.37 hectares.

In 2010, almost the entire mangrove forest area in Siantan District was dense, as shown in the map in Figure 4, whereas in 2021, only dense density was found in the northern secondary mangrove forest. The types of plants often found in this area are Jeruju, *Nypa* spp., and *Avicennia* spp. Some high density is found in secondary mangrove forest land cover, and some in the bush. In 2010, moderate density was found in the front mangrove forest directly adjacent to the sea. The vegetation density is moderate along the coastline, with an NDVI vegetation index of 0.33-0.42. An area of 184,229 hectares of mangrove forest (15.18%) in Siantan District in 2010 had a medium density. Apart from regions along

the coastline, moderate density was found in pond land cover and shrubs. In 2010, the non-vegetated area was quite large, reaching 24.80% (300,978 hectares) of open land, mud, or water.

Table 4. The density of mangrove vegetation in Siantan District in 2010-2021

Density	2010		2021	
	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)
Heavy	728,653	60.03	181.37	14.94
Currently	184,229	15.17	635.33	53.82
Seldom	0	0.00	148.53	12.24
Not Vegetated	300,978	24.80	230.63	19.00
		100		100

The density of mangrove vegetation in Siantan District in 2021 is significantly different compared to 2010 (Figure 4). Based on the NDVI index, no sparse vegetation density was found in 2010. However, in 2021, sparse density with an index value of -1-0.32 covered an area of 148.53 hectares (12.24%). Vegetation density is rare on former pond land and bushes in the middle of the mangrove forest. Part of the mangrove forest in the southern part of Peniti Luar Village in 2010 was a secondary mangrove forest, but in 2021, it will turn into open land. This caused the vegetation density to rise in 2010 and become low in 2021. Siantan District, especially in Peniti Luar Village, saw changes in the land cover of the central mangrove forest

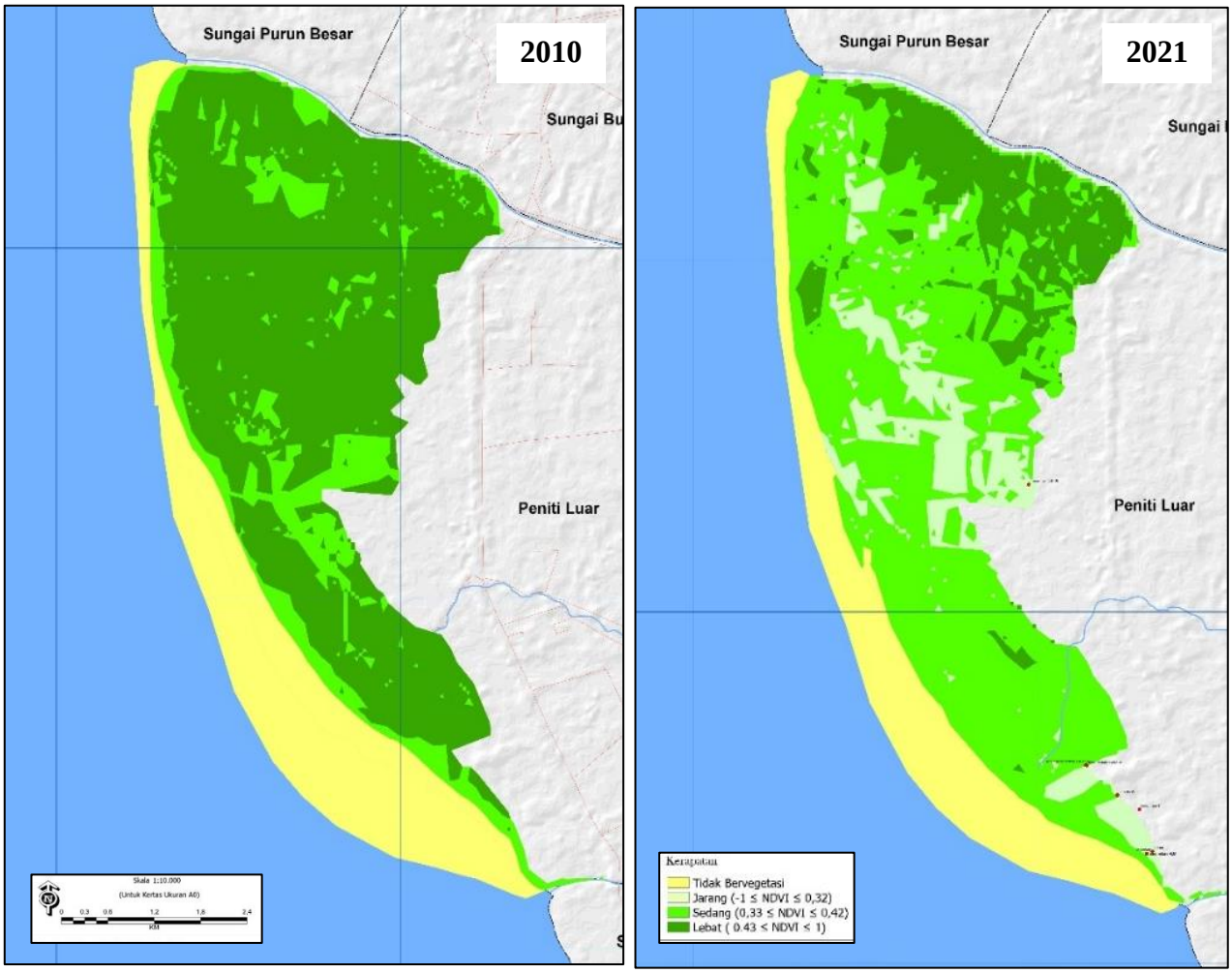

Figure 4. Map of mangrove forest vegetation density in Siantan District in 2010 and 2021

Secondary mangrove forest cover and some shrubs have turned into coconut plantations covering an area of 123.85 hectares, as shown in Figure 5. The mangrove forest area behind *Avicennia* spp. has been converted into a coconut plantation. On this land, the vegetation density is medium and sparse. The area of medium-density mangrove forests increased by 451,101 hectares to become dominant at 53.83%. In 2021, non-vegetated land decreased by 70,348 hectares, from 300,978 (24.8%) in 2010 to 230.63 hectares (19%) with medium vegetation density. This change occurred predominantly in the mangrove forest bordering Sungai Nipah Village and is the river's estuary. The vegetation that

dominates in this area is *Rhizophora* spp., which is the result of planting carried out by the local community in the context of mangrove rehabilitation. This is in line with the research results (Buwono, 2017) which states that *Rhizophora* spp. experienced good growth and development in river estuary areas because the scattered seeds could grow well on muddy and sandy substrates at river estuaries.

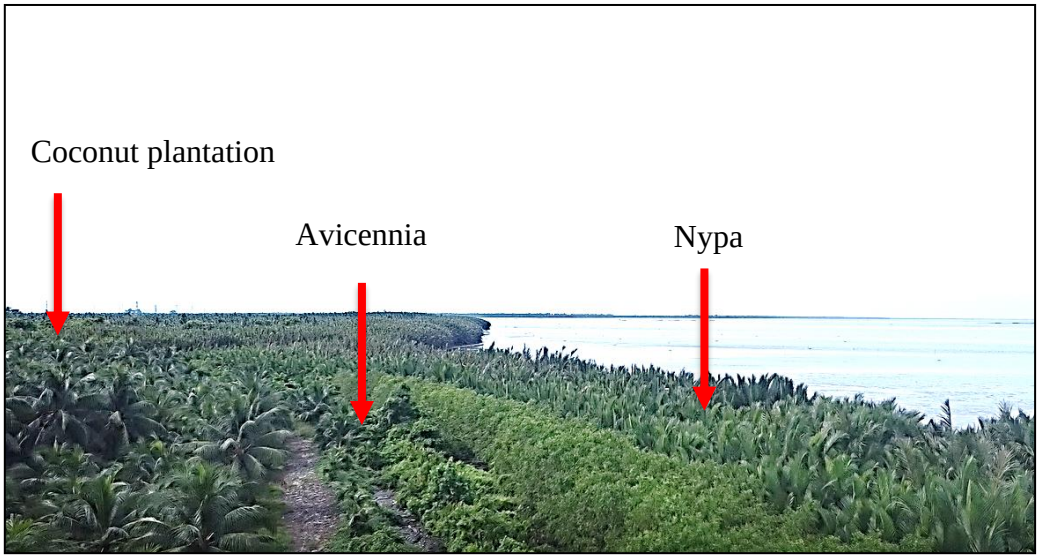

Figure 5. Mangrove forest area and coconut plantations

Direct observation in the field (ground check) was carried out at 30 sample points selected randomly based on the vegetation density class produced by NDVI analysis of the Landsat image. The density of the dense or dense class is taken as 6 points, medium as 15 points, and rare as 8 points. Ground checking of mangrove canopy density was carried out using a fisheye camera lens shot from below the canopy. Ground check results show that all sample points have vegetation density per the vegetation density results of NDVI analysis. Thus, the accuracy results reached 100%, which indicates that the NDVI vegetation index can be used to measure the density of mangrove forest vegetation in Siantan District.

D. CONCLUSIONS

The conclusions obtained from this research are:

1. In 2010, the area of mangrove forests in Siantan District reached 1214.95 hectares, with land cover in the form of secondary mangrove forests, shrubs, ponds, open land, and water bodies. In 2021, plantation land was developed, and no ponds were found.
2. In 2010, the dense class dominated the density of mangrove forest vegetation in Siantan District at 60.03%. However, in 2021, the dense vegetation density will remain at 14.95%. Density is dominated by the medium class, and sparse density is found on former pond land and bushes.
3. Deforestation of mangrove forests in 2010-2021 occurred in secondary mangrove forests, becoming shrubs, open land, and plantations, especially in the northern part of the mangrove forest and former pond land. Efforts to rehabilitate mangroves in this area are needed as a conservation effort, involving the community as mobilizers and implementers. Reforestation occurs in shrub land cover, water bodies, and open land due to efforts to plant mangroves that grow naturally.

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