



Regular Research

Spatial And Temporal Analysis of Changes in Mangrove Vegetation Area in Jawai District, Sambas Regency During 2013-2023

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Abstract: Monitoring mangrove vegetation is an essential initial step in mangrove management. The aim of this study was to observe the spatial and temporal changes in the coverage and extent of mangrove vegetation in the Jawai District. The method used in this research was remote sensing through geometric analysis of changes in coverage and the density of mangrove vegetation using the Normalized Difference Vegetation Index (NDVI) and Green Chlorophyll Index (GCI) as indicators of mangrove vegetation health. The results of the analysis using Landsat 8 satellite imagery recorded in 2013 and 2023 as input data revealed that the extent of mangrove vegetation coverage experienced both increases and decreases in certain villages. A total of six villages saw an increase in mangrove vegetation covering 171.2 hectares, including Dungun Laut, Sentebang, Sei Nyirih, Parit Setia, Pelimpaan, and Sarang Burung Kuala. Meanwhile, five villages experienced a reduction in mangrove vegetation area, comprising Bakau, Sarang Burung Usrat, Sarang Burung Kolam, Sei Nilam, and Sarang Burung Danau. The village with the largest increase in mangrove area was Parit Setia, with an addition of 45.075 ha, while the greatest decrease occurred in Sarang Burung Usrat, with a reduction of 32.917 ha. Furthermore, the NDVI and GCI values showed a similar pattern, with an increase in index values from 2013 to 2023. When the NDVI value increases, the GCI value also increases. The density of mangrove vegetation based on NDVI ranged from 0.0249 to 0.4300 in 2013, and increased in 2023, ranging from 0.0451 to 0.5117. The GCI values in 2013 ranged from 0.0030 to 1.1628, and in 2023 they ranged from 1.0499 to 2.5708.

Keywords: GCI; mangrove; NDVI

1. Introduction

Mangroves are woody plants that have unique environmental characteristics. These plants grow in environments that are transitional areas between land and sea and are periodically inundated by air due to the ebb and flow [1][2][3]. Mangroves can be found in tropical to subtropical climates in coastal areas,

estuaries, and river delta areas [3][4]. These plants can also form their ecosystems, in this case, the mangrove ecosystem, as well as being an important ecosystem in coastal areas because they have quite high productivity and provide various environmental services both directly and indirectly, including acting as natural coastal protectors and shelters and foraging for various marine organisms [1] [3]

[5]. However, over time, mangroves have also experienced changes in area. Changes that occur can occur naturally or through human intervention. The form of changes in the area that occur can be in the form of additions or reductions in the area [1][4][6]. Changes in the area of mangrove vegetation are predominantly caused by increasing human activity and increasing population growth [6]. In Southeast Asia alone, changes in the area of mangrove vegetation, in this case, the decrease in the area reached more than 130,000 ha during the period 2000-2012 due to land clearing for firewood or charcoal, expansion of oil palm plantations, conversion to cultivated land and urban development [7]. This condition will certainly affect the sustainability of mangroves considering their many benefits both in terms of the environment and the economy [8].

Therefore, data and information are needed for mangrove inventory and environmental monitoring. One form of effort made related to this condition is by conducting monitoring through the application of remote sensing technology [8] [9] [10]. In addition, monitoring mangrove vegetation over a long period is needed to determine the changes that occur as an initial step for its future preservation [10]. The application of remote sensing technology to determine the density and cover of mangrove vegetation using satellite imagery as a form of input data is also critical to determine the existing condition of mangroves to facilitate rehabilitation and environmental conservation [10] [11]. This technology is also quite effective in preventing changes in density and mangrove cover spatially and temporally [12]. Knowing the changes in the area of mangrove vegetation to understand the condition of the mangrove ecosystem in a particular area, is one form of mangrove ecosystem conservation that can be done [6]. In addition, that with an accurate and

fast understanding of the health status spatially and temporally is very important for mangrove conservation and ecological restoration efforts [4]. So based on the explanation, this study is to determine the current condition of mangrove vegetation in Jawai District through analysis of mangrove cover and the density and chlorophyll index produced as an indication of the health of vegetation.

2. Materials and Methods

The area of focus for this research is Jawai District, which is part of the administrative region of Sambas Regency [13]. This study analyzes satellite imagery data recorded by Landsat in the years 2013 and 2023. The obtained data undergoes preprocessing, which includes image correction aimed at improving the visual quality of the image, as well as compositing, which combines color bands to make it easier to identify mangrove vegetation features. The compositing process uses a combination of bands 5, 6, and 4 to facilitate distinguishing mangrove vegetation from other types of vegetation [14]. Subsequently, a geometric analysis is conducted to calculate the mangrove coverage area, allowing for a comparison between the mangrove extent in the 2013 and 2023 satellite data. The next step involves analyzing the density of the mangrove vegetation using the NDVI (Normalized Difference Vegetation Index) method. NDVI can be calculated using the following equation:

$$NDVI = \frac{Near\ Infrared - Red}{Near\ Infrared + Red} \quad (1)$$

Where, in Landsat 8 satellite imagery, Near Infrared is represented by band 5 and Red is represented by band 4. The NDVI value ranges from -1 to 1, with values closer to 1 indicating higher vegetation density. In addition to analyzing the density of mangrove vegetation, a Green Chlorophyll Index (GCI)

analysis is also conducted. It can be calculated using the following equation:

$$GCI = \frac{\text{Near Infrared}}{\text{Green} - 1} \quad (2)$$

Similarly to the NDVI value above, Near Infrared is marked on band 5 and Green is marked on band 3 on the Landsat 8 satellite image.

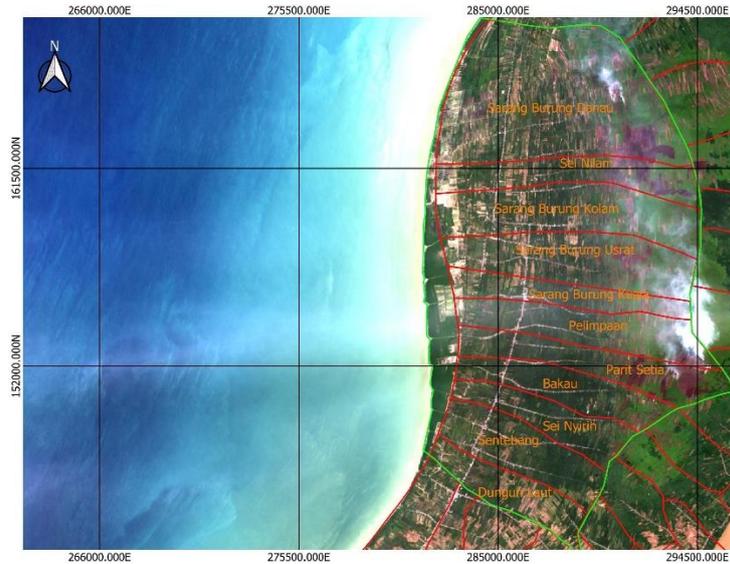


Figure 1. Research area

3. Results

3.1 Spatial and Temporal Changes in Mangrove Vegetation Area

Table 1. Changes in mangrove vegetation area 2013-2023

No	Village	Mangrove area (Ha)		Change for 2013-2023 (Ha)
		2013	2023	
1	Dungun Laut	21.561	31.327	+ 3.766
2	Sentebang	71.520	108.150	+ 36.63
3	Sei Nyirih	55.761	80.085	+ 24.324
4	Bakau	107.192	99.349	- 7.843
5	Parit Setia	126.081	203.203	+ 45.075
6	Pelimpaan	69.560	83.891	+ 18.33
7	Sarang Burung Kuala	128.968	172.043	+ 43.075
8	Sarang Burung Usrat	152.314	119.397	- 32.917
9	Sarang Burung Kolam	129.270	111.5	- 18.47
10	Sei Nilam	37.866	7.979	-29.887
11	Sarang Burung Danau	58.551	55.090	-3.461
Total		958.444	1072.014	

Mangrove vegetation in the Jawai District from 2013 to 2023 was present in all villages within the district's administrative area. The extent of mangrove vegetation varied across the villages during the 2013 and 2023 periods. In 2013, the largest area of mangrove vegetation was in Sarang Burung Usrat village, covering 152.968 hectares. This was followed in

order of size by Sarang Burung Kolam, Sarang Burung Kuala, Parit Setia, Bakau, Sentebang, Pelimpaan, Sei Nyirih, Sarang Burung Danau, Sei Nilam, and Dungun Laut. Dungun Laut village had the smallest area of mangrove vegetation in 2013, with the respective areas being 129.270 ha, 128.968 ha, 126.081 ha, 107.192 ha, 71.561 ha, 69.561 ha, 58.551 ha,

55.761 ha, 37.866 ha, and 21.561 ha. Meanwhile, in 2023, the largest mangrove vegetation area was recorded in Parit Setia village, reaching 203.203 hectares. It was followed by other villages based on the extent of their mangrove vegetation, including Sarang Burung Kuala, Sarang Burung Usrat, Sarang Burung Kolam, Sentebang, Bakau, Pelimpaan, Sei Nyirih, Sarang Burung Danau, Dungun Laut,

and Sei Nilam. The vegetation areas were 119.397 ha, 119.397 ha, 111.5 ha, 108.150 ha, 99.349 ha, 83.891 ha, 80.085 ha, 55.090 ha, 31.327 ha, and 31.327 ha, respectively.

3.2 Density Index and Chlorophyll Values of Mangrove Vegetation Based on the NDVI (Normalized Difference Index Vegetation) and GCI (Green Chlorophyll Index) Methods

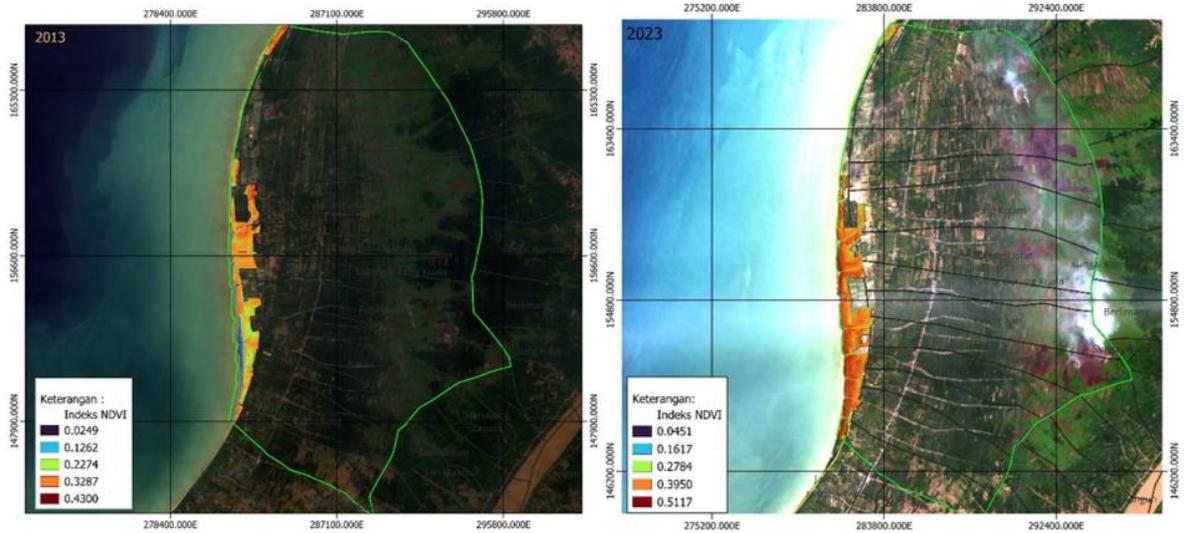


Figure 2. NDVI 2013 dan 2023 Value

The NDVI index value shows the same pattern as the increase in vegetation area. The lowest NDVI values are found in Sentebang, Sei Nyirih, Bakau, Parit Setia, Dungun Laut and Pelimpaan Villages with an NDVI index value of

0.0249 in the 2013 period. Then in 2023 the lowest NDVI value increased to 0.0451 which can be found in Sei Nilam and Sarang Burung Danau Villages.

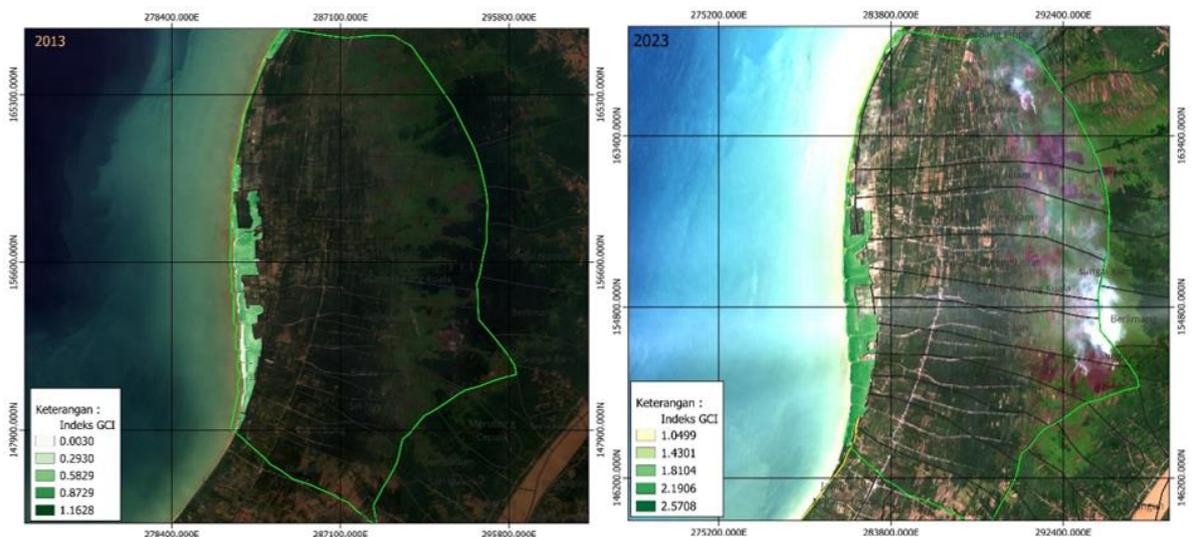


Figure 3. GCI 2013 dan 2023 Value



The chlorophyll value index using the GCI method shows a similar thing, namely an increase in the GCI index value from 2013 to 2023. However, the lowest GCI value can be found in all villages in the Jawai District with an index value of 0.00330.

4. Discussion

4.1 Mangrove area

Based on the analysis of Landsat 8 satellite imagery data from 2013 and 2023, mangrove vegetation in Jawai District can be found in all villages within the district. According to the BPS data, the administrative area of the Jawai District consists of 11 villages [15]. These villages include Dungun Laut, Sentebang, Sei Nyirih, Bakau, Parit Setia, Pelimpaan, Sarang Burung Kuala, Sarang Burung Usrat, Sarang Burung Kolam, Sei Nilam, and Sarang Burung Danau. From 2013 to 2023, the extent of mangrove vegetation experienced changes, with five villages experiencing a decrease in area and six villages experiencing an increase (Table 1). The 5 villages that saw a reduction in mangrove vegetation are Bakau, Sarang Burung Usrat, Sarang Burung Kolam, Sei Nilam, and Sarang Burung Danau. Meanwhile, the villages that experienced an increase in vegetation area are Dungun Laut, Sentebang, Sei Nyirih, Parit Setia, Pelimpaan, and Sarang Burung Kuala.

From Table 1, it can be seen that of the five villages that experienced a decrease in the area of mangrove vegetation, Sarang Burung Usrat Village ranked first as the village that experienced the highest decrease in area among other villages during the 2013-2023 period, which was 32,219 ha. This was followed by Sei Nilam Village, Sarang Burung Kolam, Bakau, and Sarang Burung Danau Villages. The decrease in mangrove vegetation can be attributed to land conversion [16]. The reduction in mangrove vegetation area in Jawai District is predominantly caused by land conversion into ponds, plantations, and the

utilization of mangrove wood, leading to the transformation of mangrove land into open land [17]. In Sarang Burung Usrat Village, which has the highest reduction in mangrove vegetation area, land conversion is driven by the expansion of ponds and open land intended for agriculture and plantations, as well as the extraction of mangrove wood. This phenomenon also occurs in Sei Nilam and Sarang Burung Kolam Villages. In Bakau Village, mangrove land is converted into open land, which will later be used for agriculture and plantations. In Jawai District, besides aquaculture commodities, rice farming, dragon fruit plantations, and oil palm plantations are also key economic sectors in the region [15]. Thus, to increase production, one of the steps taken is land conversion. In Sarang Burung Danau Village, mangrove land has been converted into ponds, making it the village with the largest pond area in Jawai District. However, land conversion into ponds often has a negative impact on mangrove vegetation [18].

Meanwhile, in the six villages that experienced an increase in vegetation area during the 2013-2023 period, the highest increase in area was in Parit Setia Village, which reached 45,075 Ha. Then the next sequence is followed by Sarang Burung Kuala Village, Sentebang, Sei Nyirih, Pelimpaan, and Dungun Laut. However, when viewed from the total area during the period, there was an increase in the vegetation area of 113.57 Ha. The vegetation area in 2013 was 958.444 ha, and in 2023, the area increased to 1082.014 ha. Furthermore, in the area of mangrove vegetation in 2013, the highest area was in Sarang Burung Usrat Village and the lowest area was in Dungun Laut Village. In 2023, the village with the highest vegetation area was

Sarang Burung Kuala, and the lowest was Dungun Laut Village. There are changes around mangrove vegetation influenced by natural factors and human activities [8] [11]. Natural factors can be caused by the accretion of the coastline, which results in an increase in habitat for mangrove plants, abandoned fishponds, or open land undergoing succession, which also occurs in Jawai District [17]. The expansion of mangrove vegetation caused by human activities is carried out through mangrove vegetation reforestation, which has already been initiated by relevant institutions and the local community. And this factor predominantly contributes to the expansion of mangrove vegetation in Jawai District [17][19]. This condition also indicates that mangrove management through reforestation has begun to show positive results, as evidenced by the expansion of mangrove vegetation.

4.2 NDVI and GCI value

The NDVI value shows an increase in the value of the vegetation density index, in this case the NDVI value. The NDVI value in 2013 ranged from 0.0249 to 0.4300, and in 2023, it ranged from 0.0451 to 0.5117. The difference in the vegetation index value, in this case, the NDVI value, ranges from 0.02 - 0.08. Changes in NDVI values can be caused by human activities related to climate change [20]. However, the influence of human activities plays a more important role in the changes in NDVI values. In addition, the NDVI value for 2013 showed a sparse to moderate density level. The sparse mangrove vegetation density ranges from 0.0001 - 0.25, while the value ranges from 0.25 - 0.5 [21]. Meanwhile, the NDVI value in 2023 shows a density level dominated by moderate-to-dense density levels. Mangrove vegetation density at the dense density level ranges from 0.50 - 1.00. The vegetation density that reaches a dense level indicates that the mangrove vegetation in the Jawai District area is still

considered healthy. Vegetation with a high vegetation density value or included in the dense category was included in the healthy category [22]. This makes it possible to restore mangroves by replanting them in this area. One of the strategic plans from the West Kalimantan Marine and Provincial Office is to replant Mangroves in Sambas Regency [23]. Human activity is a factor that influences changes in NDVI values both directly and indirectly. The indirect influence referred to is the influence of human activity, which will then have an impact on soil moisture and temperature parameters, ultimately affecting NDVI [24]. Of all the villages in this sub-district, the villages with the highest NDVI values are in Sarang Burung Usrat Village and Sarang Burung Kolam Village in both observations in 2013 and 2023. The NDVI value in 2013 for these two villages was 0.4300, and the NDVI in 2023 was 0.5117. Mangrove areas in these two villages show different conditions. In Sarang Burung Kolam Village, there is an increase around mangrove vegetation, and Sarang Burung Usrat Village has a decrease in the area of mangrove vegetation from 2013 to 2023. The lowest NDVI value was observed in Sei Nyirih, Bakau, and Parit Setia Villages in 2013, with NDVI values of 0.0249. This condition increased in 2023, with the lowest NDVI value increasing to 0.0451, which was only found in mangrove vegetation in Sarang Burung Danau Village.

And for the distribution of GCI values is shown (Figure 3) the same pattern as the previous NDVI values. The GCI value in 2023 is higher than the GCI value in 2013. The GCI value in 2013 ranged from 0.0030 to 1.1628, whereas in 2023, the value ranged from 1.0499 to 2.5708. The chlorophyll content represented by the GCI can reveal the physiological condition of vegetation, and what is meant in this case can also be used to measure the health level of mangrove vegetation [25]. The difference in values during this period ranging

from 1.04 - 1.4. This can mean that the status of mangrove vegetation from the results of the 2023 data analysis is healthier than the status of mangrove vegetation from the results of the 2013 data analysis in the Jawai District Area. The increase in the GCI value of vegetation can be attributed to the high area of vegetation cover [24]. The area of mangrove vegetation cover in Jawai District tended to increase in 2023 compared to that in 2013. If observed, the GCI value tends to increase in line with the increasing value of the vegetation density index, namely NDVI. Indirectly, it can be said that with increasing vegetation density, the chlorophyll produced also increased. In this case, it is marked by an increasing GCI value.

5. Conclusions

The total area of mangrove vegetation in the Jawai District shows an increase during the period 2013-2023. When viewed per village area, the area of mangrove vegetation shows non-uniformity; in this case, five villages experience a decrease in vegetation area and six other villages experience an increase in vegetation area. The density value of mangrove vegetation, in this case NDVI, showed an increase from 2013 to 2023. NDVI ranged from 0.0249 to 0.4300 in 2013, and this value increased in 2023, ranging from 0.0451 to 0.5117. The value of GCI also showed the same pattern. The 2013 GCI value ranged from 0.0030 to 1.1628, and the 2023 GCI value ranged from 1.0499 to 2.5708. Therefore, it can be said that the higher the NDVI value, the higher the GCI value. Based on NDVI and GCI values, mangrove vegetation can still be categorized as healthy. By monitoring the area and identifying vegetation conditions through NDVI and GCI values, this will help in the future management of mangroves in Jawai District specifically and Sambas Regency in general for the next management strategy. Previously, the

management strategy only considered the extent of the mangrove area.

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