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Research Article

The Use of Vegetation Indices on Temporal Mangrove Condition: A Case Study on Timbulsloko and Bedono, Demak

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Abstract

Mangrove forests in Timbulsloko and Bedono have very dynamic conditions, due to tidal flooding and land subsidence that occur in these areas. Meanwhile, mangrove forests in the Timbulsloko and Bedono Village play an important role in preventing abrasion which often occurs in these areas. The importance of the mangroves function in this area makes it crucial to monitor their condition. Monitoring the condition of mangroves can be done by looking at their density through the vegetation index. Therefore, this study aimed to determine the best vegetation index to be used in the Timbulsloko and Bedono villages to monitor mangroves in 2016-2018, 2020, and 2022. The method in this research consisted of two stages, namely sentinel 2 image processing and the field survey. Image processing was used to determine the condition of mangroves based on several vegetation indices. Meanwhile, data collection in the field was utilized to validate several vegetation indices used in this study and conducted with the hemispherical photography method. Linear regression analysis was used to determine the most suitable vegetation index to be applied in the study area. The study found that NDVI vegetation index had the highest accuracy value, followed by SAVI, EVI, and MVI. The use of NDVI to see the changes in mangrove conditions showed an increase in the total area in each category. So, it can be concluded that the area and density of mangrove forests in the Bedono and Timbulsloko villages increased every year

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1. Introduction

Mangrove is an organism that has adapted to survive harsh environments (Onyena and Sam, 2020). Mangrove forest provides many benefits ecologically, physically, economically, and socially. Indonesia is one of the countries with the largest mangrove area in the world (Cahyaningsih *et al*., 2022). One of the mangrove forests in Indonesia is in the villages of Timbulsloko and Bedono. Timbulsloko and Bedono villages are located in Sayung District, Demak Regency. The area of mangrove forests in this location is change rapidly due to land conversions that make mangrove forests as housing, corporation, paddy fields, and shrimp. The crucial factor for the decline of mangrove forests in this area is the occurrence of tidal floods and land subsidence which are difficult to control. According to Muskananfola *et al*. (2020), the Sayung area is a coastal area that has been badly damaged due to changes in the coastline due to massive erosion and tidal flooding, from 2011–2018 there was a net shoreline movement of −290 m. The GPS survey showed that the vertical displacement in Demak ranging from 0.8 to 17.91 cm/year in 2018 (Yuwono *et al*., 2019). However, on the one hand, many parties have planted mangroves to restore the function of mangrove forests in coastal areas by NGOs, students, government, and local residents. According to Handayani *et al*. (2020), since 1990, mangrove planting has been conducted by several parties.

Due to the importance of mangrove ecosystems and dynamic changes in mangrove ecosystems requires mangrove monitoring to maintain and conserve mangrove forests. Monitoring changes in mangrove ecosystems can be done manually in the field, but this requires more money, effort, and time. Monitoring mangrove conditions using remote sensing has been widely used with vegetation index (Baloloy *et al*., 2020).

Since mangroves are found along the border of land and sea, three main objects contribute to pixel compositions in remote sensing images: vegetation, soil, and water (Kuenzer *et al*., 2011). So, we need a special algorithm that can map vegetation to the exclusion of other objects. Vegetation cover mapping will provide valuable information for understanding environmental conditions. Vegetation cover mapping is needed for vegetation protection and restoration program (Muhsoni *et al*., 2018). The vegetation index is a spectral index used in vegetation mapping. Each vegetation index can better represent vegetation than an individual band because it contains a specific expression (Baloloy *et al*., 2020). Several algorithms that can be used to see mangrove density are NDVI, MVI, EVI, and SAVI. NDVI is an algorithm that has long been used to view mangrove density and has high accuracy, according to Tran *et al*. (2022) NDVI has an accuracy test of more than 80% and has been used by 82% of researchers worldwide to map mangrove density. NDVI works by measuring the greenness of vegetation which correlates with the chlorophyll content of leaves so that the best bands used for NDVI analysis are the infrared band and the red band (Purwanto and Eviliyanto, 2022).

Mangrove Vegetation Index (MVI) is a new algorithm developed by Baloloy *et al*. (2020). MVI uses Near Infrared (NIR), Shortwave Infrared (SWIR), and green bands. Theseindex distinguished mangroves from other types of vegetation and land cover by their greenness and humidity (Conopio *et al*., 2021). Enhanced Vegetation Index (EVI) has a high sensitivity to variations in canopy structure, which is considered more representative for estimating mangrove density values with very dense canopy density (Juniansah *et al*., 2018). Soil-Adjusted Vegetation Index (SAVI) works by predicting NIR emission transfer for non-vegetated areas, thereby normalizing soil substrate variations and ensuring that vegetation measurements are unaffected by them (Rhyma *et al*., 2020). Through the incorporation of a ground brightness correction, SAVI minimizes the effects of the noise in the ground (Cao *et al*., 2014). Vegetation mapping from an image is interpreted by the differences in the green color of the leaves and the spectral characteristics of the canopy (Xue and Su, 2017). Each vegetation has its advantages and disadvantages, in each region, it will produce different vegetation index accuracy values, so a validation process is needed. In this study, the validation process was carried out by taking Leaf Area Index (LAI) data using the hemispherical photography method in the field. Validation is commonly performed by measuring vegetation characteristics in situ, such as density cover, Leaf Area Index (LAI), mangrove biomass, growth, and vigor (Xue and Su, 2017).

In most studies, vegetation indices are only used for single shoot analysis and so never really figured out how the changing of the area in term of different times. Suwanto *et al*. (2021) conducted research about mangrove density using NDVI in 2021, Neri *et al*. (2021) conducted research about mangrove density using MVI in 2019, Pamungkas (2022) conducted research about mangrove density using NDVI, EVI, and SAVI in 2021. This study was expected to describe spatial changes in terms of different times. For sustainable management of mangroves, it is important to map the condition of mangroves over time (Li *et al*., 2020).

Choosing the correct vegetation index for mangrove mapping is essential because each region validates its index differently. This study aimed to determine the best vegetation index that can be used in the Bedono and Timbulsloko villages, Demak, and to use the best vegetation index for periodic monitoring of mangroves in 2016, 2018, 2020, and 2022. Therefore, this study was expected to provide the basis for sustainable mangrove management in Bedono and Timbulsloko villages, Demak.

2. Materials and Methods

2.1 Study Location

This study located in Timbulsloko and Bedono Villages, Demak District, Central Java (Figure 1). Timbulsloko Village has an area of 461 ha, while Bedono Village has an area of 551,673 ha. This area is characterized by low topography, which is only 0 to 3 meters above sea level. This low topography has resulted in various problems in this area, particularly tidal floods, which have resulted in changes in the mangroves area. This area is a plain formed from alluvial soil deposits which are relatively young and there are many industrial buildings and residential areas, thus increasing the loading of alluvial soil which is still possible for compaction to occur which causes land subsidence. This area experienced land subsidence of 4.55 ± 1 cm/year.

2.2 Material

This study used primary data and secondary data. Primary data includes data on mangrove species and photos of mangrove canopy cover taken in the field from 3 to 4 December 2022 and Sentinel 2 satellite image data recorded for 2016, 2018, 2020, and 2022 as the secondary data. The specifications of the Sentinel 2 band are varied with their wavelength and spatial resolution (Table 1). The research was conducted starting in 2016 because in that year a similar study had not been carried out in this area. The tools used in this research were the Global Positioning System (Garmin eTrex 10SEA and Garmin 65s), measuring tape, transect quadratic, mapping software, and camera.

2.3 Method

This research was conducted in two stages, namely Sentinel 2 satellite image data processing and field survey. Sentinel 2 satellite image data processing was done to determine the mangroves' condition based on several vegetation indices. Sentinel 2 satellite image data processing was conducted before and after data collection in the field. Meanwhile, the process of collecting data in the field aimed to validate several vegetation indices.

2.3.1 Sentinel 2 satellite image processing

The satellite image processing process was divided into two stages, namely before the field survey and after the field survey. Image processing before the survey consisted of radiometric correction, masking (separation of land and sea), and classification of mangroves and non-mangroves. Then, Sentinel 2 satellite image that has been processed was used to determine the location of data collection points in the field. The radiometric correction was aimed at restoring the image pixel values to their original values, due to atmospheric disturbances. The radiometric correction was performed using the Dark Object Subtraction (DOS) method. The DOS method assumes that there are other objects in the images produced by satellites, this is caused by atmospheric scattering (Rumora *et al*., 2020). The Dark Object Subtraction (DOS) method can eliminate or correct additive fog components in each band (Helmi *et al*., 2018). This method was chosen because it was relatively simple and did not require a lot of input, because it only uses the approach that the reflectance value of the entire image pixels was reduced by the reflectance value of the darkest object. Masking or separating of land and sea was done to separate land and water so that the image interpretation process is not disturbed. Mangrove and non-mangrove classifications were conducted with the supervised classification method. The supervised classification method is a method that aims to transform digital satellite imagery values into certain classes (Khatami *et al*., 2016).

The image processing after the survey involved applying several vegetation indices to determine mangrove density conditions and validating them to determine the best vegetation index for Timbulsloko and Bedono. This study used four different vegetation indices, namely NDVI, EVI, SAVI and MVI. NDVI is done by dividing the value of the Near Infrared band minus the value of the red band by the sum between the Near Infrared band value and the red band (Equation 1). Enhanced Vegetation Index (EVI) is a vegetation index that was developed to minimize the effect of canopy background and atmospheric variation, which is better than NDVI, calculated using the reflectance of the blue (blue), red (red), and near infrared (NIR) bands (Equation 2). Soil Adjusted Vegetation Index (SAVI) is an algorithm developed from NDVI by suppressing the influence of the ground background on the canopy brightness level (Equation 3). MVI uses the Near Infrared (NIR), Shortwave Infrared (SWIR) and green band (Equation 4). This index takes the different greenness and humidity of mangroves into account to distinguish them from other types of vegetation and land cover (Conopio *et al*., 2021).

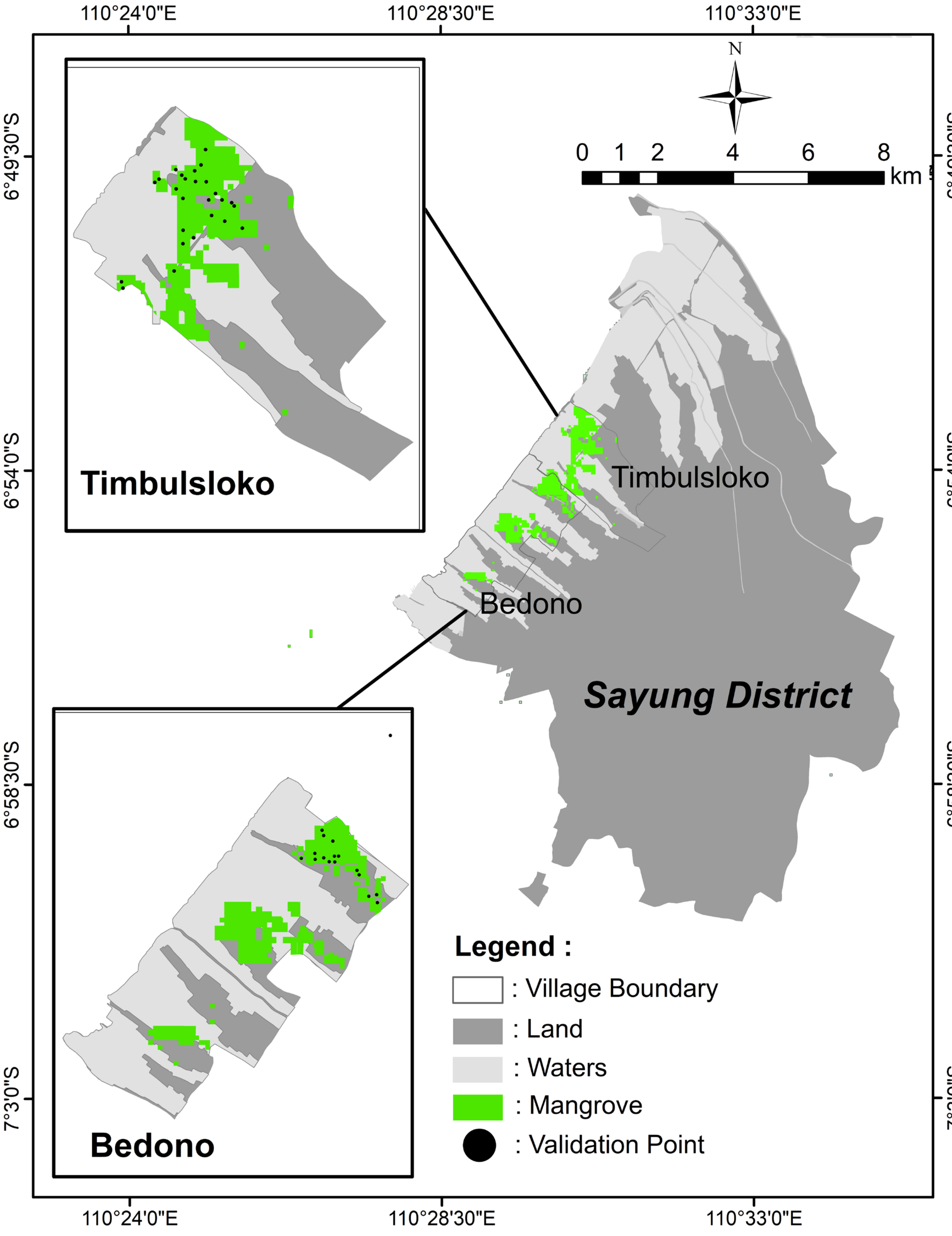

Figure 1. Location of the mangrove distribution study in Timbulsloko and Bedono

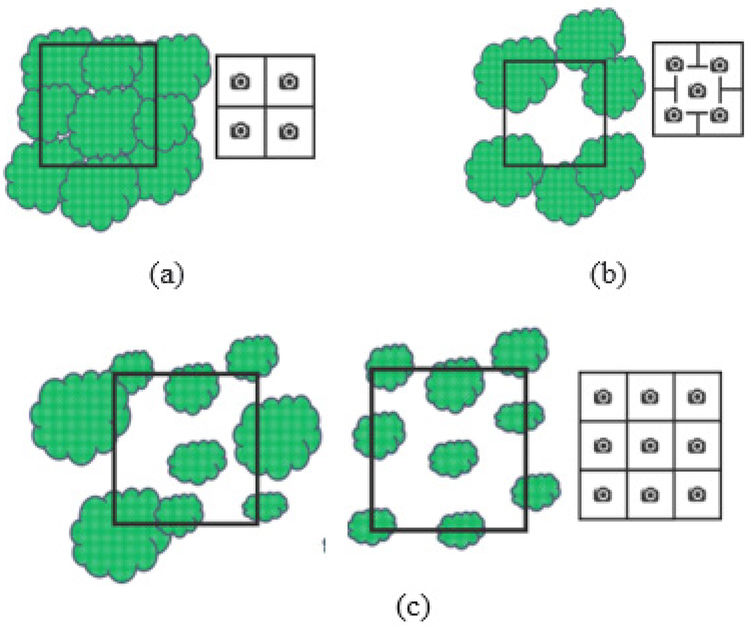

Figure 2. Photos of canopy density (a) high category canopy, (b) medium category canopy, (c) sparse category canopy (Dharmawan *et al*., 2020)

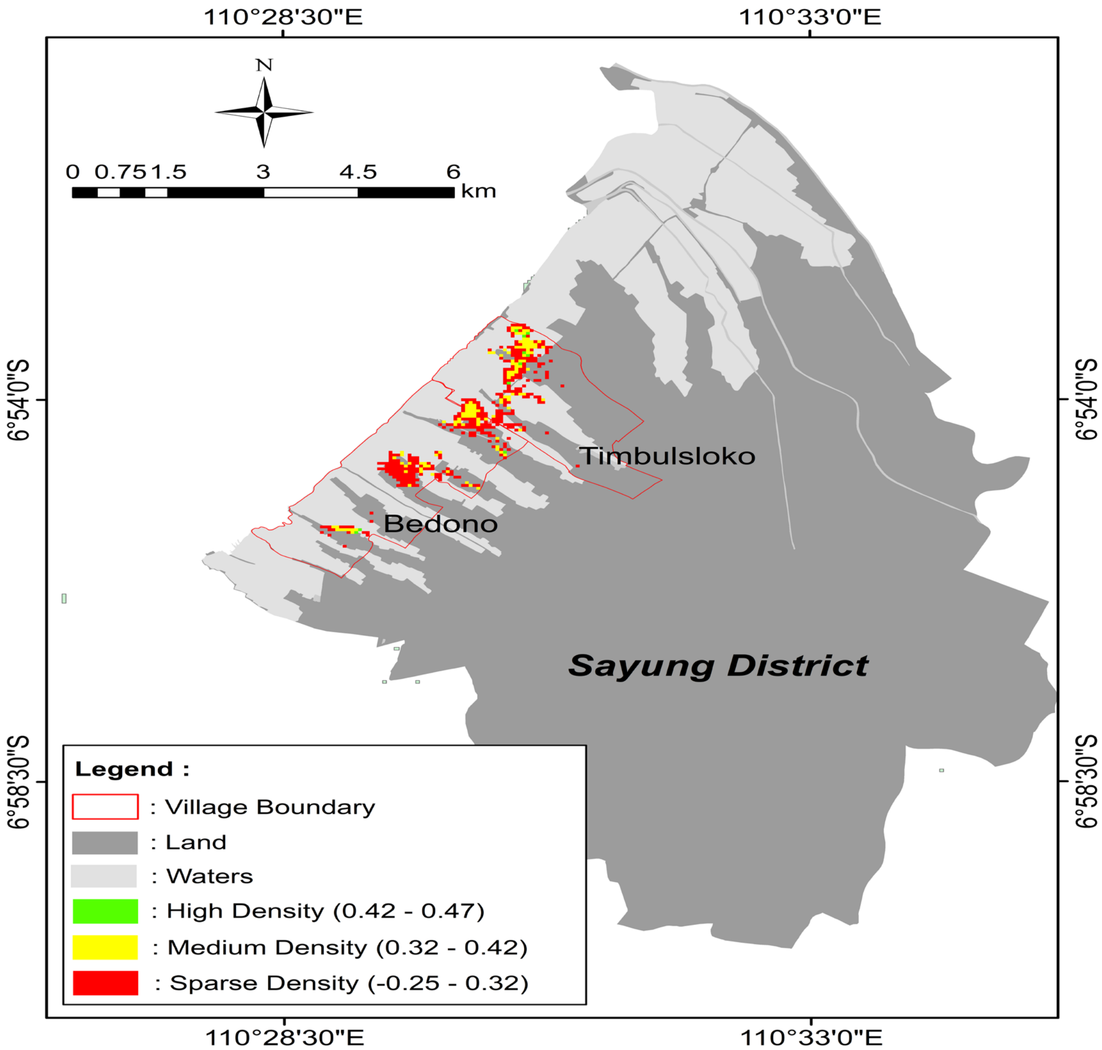

Figure 3. Condition of mangrove density based on the NDVI

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

: .....(1)

Where :

NIR : near infrared band (band 8 in Sentinel 2)

Red : red band (band 4 in Sentinel 2)

$$EVI = 2.5\ (\frac{NIR-Red}{NIR+(6\ x\ Red)-(7.5\ x\ Blu}$$

.....(2)

Where :

NIR : near infrared band (band 8 in Sentinel 2)

Red : red band (band 4 in Sentinel 2)

Blue : blue band (band 2 in Sentinel 2)

$$SAVI = \frac{(NIR-Red)}{(NIR+Red+L)}\ x\ (1+L)$$

.....(3)

Where :

NIR : near infrared band (band 8 in Sentinel 2)

Red : red band (band 4 in Sentinel 2)

L : soil brightness correction factor (0.5)

$$MVI = \frac{NIR-Green}{SWIR-Green}$$

.....(4)

Where :

NIR : near infrared band (band 8 in Sentinel 2)

Green : green band (band 3 in Sentinel 2)

SWIR : shortwave infrared band (band 11 in Sentinel 2)

2.3.2 Field data collection

The mangrove density validation process in the field was conducted by taking LAI data using the hemispherical photography method. This method was selected because it could be performed more easily, quickly, and non-destructively to measure forest canopy structural parameters, involve gap fraction, clumping index, and LAI (Li *et al*., 2020). In this study, 40 sampling points were taken to validate the mangrove vegetation index. The data taken in the field were mangrove species data and canopy density using the hemispherical photo method. Field data was collected using a quadratic transect measuring 10 m x 10 m. Photos were taken four to nine times in one plot (Figure 2), this depended on the level of canopy density in one plot. In a plot with a dense density, four photos were taken, five photos were taken in a plot with medium density, and nine photos were taken in a plot with a sparse density.

2.3.3 Canopy density calculation

Canopy density was calculated using hemispherical photo data obtained in the field. Photos were analyzed using ImageJ software to see the percentage of canopy cover. This software works by separating vegetation and non-vegetation. Vegetation areas are turned black while non-vegetated areas are turned white. As a result, the pixels of black and white will be displayed in the image, and canopy cover density will be determined based on the ratio of black pixels produced by the image (Rhyma *et al*., 2020).

2.4 Data Analysis

An accuracy test was conducted to determine the best vegetation index for Timbulsloko and Bedono areas. Linear regression analysis was used to determine the most suitable vegetation index to be applied in the study area. Analysis of linear regression was used to determine how much the independent variable can explain the dependent variable, through the following formula:

$$Y = a + bx$$

.....(5)

Where:

Y : variable of dependent

a : coefficient of regression (y value if x = 0)

b : coefficient of regression

x : variable of independent

3. Results and Discussion

3.1 Results

3.1.1 Calculation of mangrove density using several vegetation indices

Calculation of mangrove density values based on several vegetation indices (NDVI, EVI, SAVI, MVI) was conducted using mapping software. Based on the calculation from each vegetation indices, it can be concluded that each vegetation indices have a different range of density values (Table 2). The NDVI vegetation index has a density value between -0.25 to 0.47 (Figure 3). The EVI vegetation index has a density value between 0.71 and 2.61 (Figure 4). The SAVI vegetation index has a density value between -0.11 to 0.42 (Figure 5). The MVI vegetation index has a density value between – 1.15 to 0.19 (Figure 6). The green color indicates high density, the yellow color indicates medium density, and the red color indicates sparse density.

3.1.2 Validation of mangrove density in the field

The mangrove density values were calculated in the field by processing canopy density photo data using the hemispherical photography method at 40 sampling points (Table 3). Based on canopy density photo processing using ImageJ software, the Leaf Area Index value of mangroves in the Timbulsloko and Bedono Villages ranged from 46.75% to 87%. The mangrove species found were *Avicennia marina, Avicennia alba, Rhizophora mucronata*, and *Rhizophora apiculata*.

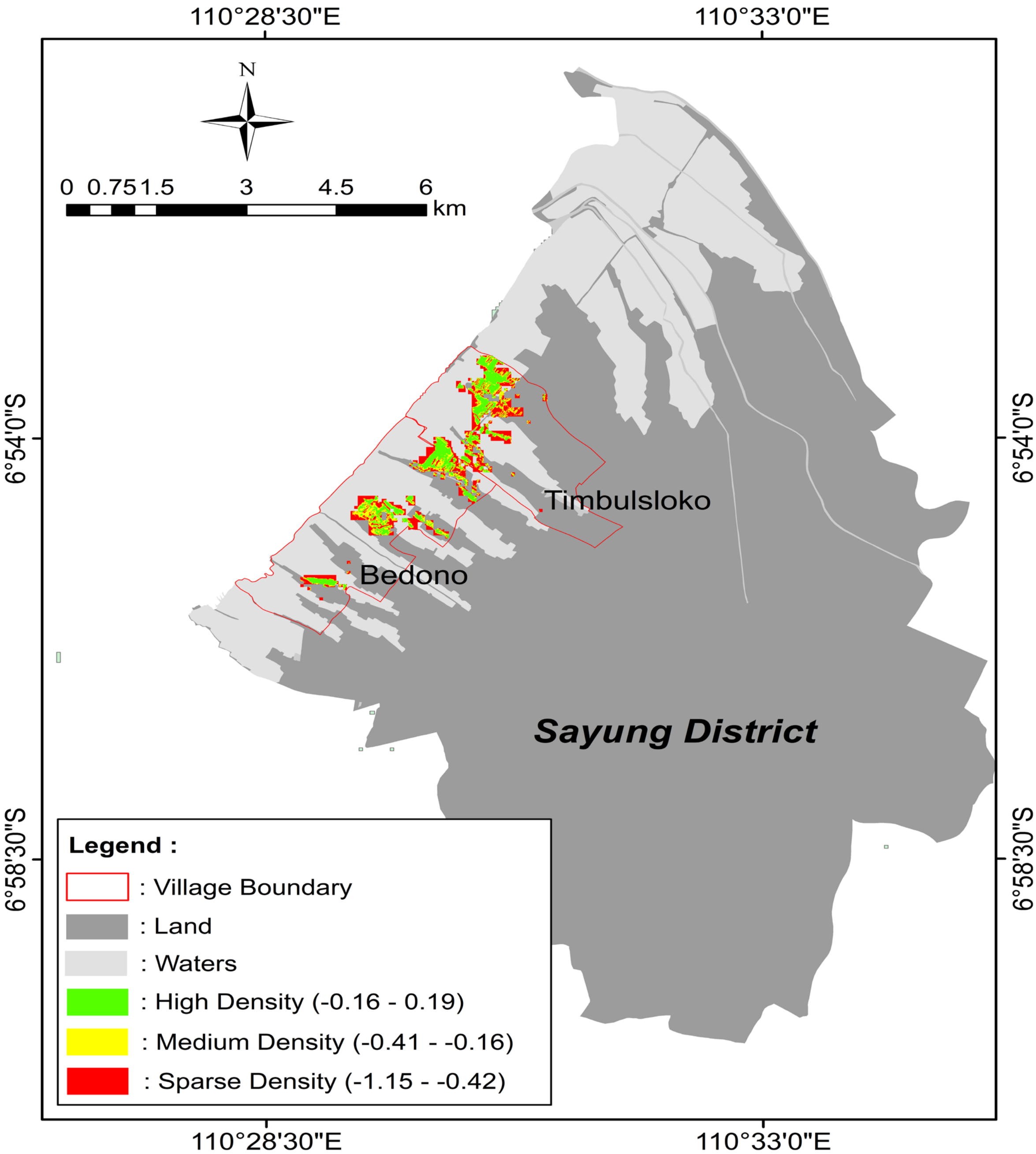

Figure 4. Condition of mangrove density based on the EVI

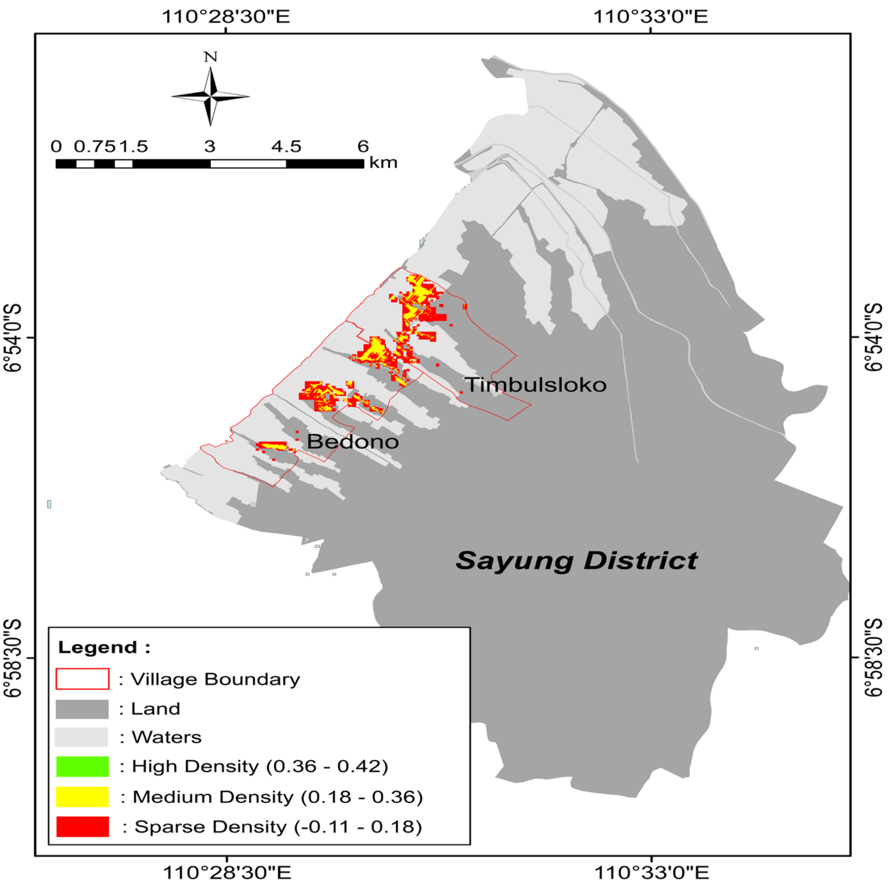

Figure 5. Condition of mangrove density based on the SAVI

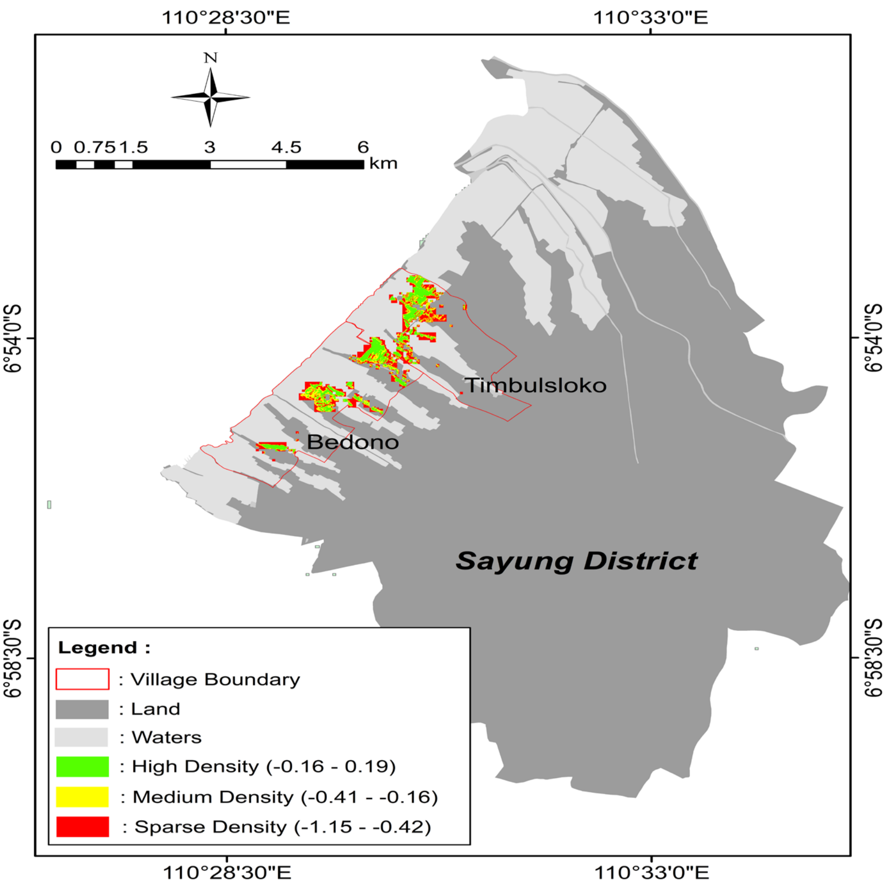

Figure 6. Condition of mangrove density based on the MVI

Table 1. Sentinel 2 Satellite image characteristics

Band Name and Specification	Wavelength (mm)	Spatial Resolution (m)
Band 1 – Coastal Aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation Red Edge	0.705	20
Band 6 – Vegetation Red Edge	0.740	20
Band 7 – Vegetation Red Edge	0.783	20
Band 8 - NIR	0.824	10
Band 8A – Vegetation Red Edge	0.865	20
Band 9 – Water Vapour	0.945	60
Band 10 – SWIR – Cirrus	1.375	60
Band 11 – SWIR	1.610	20
Band 12 - SWIR	2.190	20

Field measurements of mangrove density were used to validate the four vegetation indices. A validation test was conducted using linear regression analysis. The results showed that the NDVI vegetation index had an R^2 value of 0.80 and an r-value of 0.89, EVI had an R^2 value of 0.46 and an r-value of 0.68, SAVI had an R^2 value of 0.47 and an r-value of 0.69, and MVI had an R^2 value of 0.30 and an r-value of 0.34. So, it can be concluded that the most suitable vegetation index used for mapping mangrove density in the Timbulsloko and Bedono areas was the NDVI vegetation index.

3.1.3 The use of vegetation index to monitor changes in mangrove conditions

Based on NDVI, the area of each category of mangroves changed in 2016, 2018, 2020, and 2022 (Table 4). In 2016 the mangroves in the sparse category covered an area of 115.92 ha, the medium category covered an area of 24.48 ha, and the dense category covered an area of 1.08 ha. In 2018, mangroves in the sparse category covered an area of 111.44 ha, the medium category covered an area of 38.88 ha, and the dense category covered an area of 1.08 ha. In 2020, mangroves in the sparse category covered an area of 125.64 ha, the medium category covered an area of 41.04 ha, and the dense category covered an area of 3.6 ha. In 2022, mangroves in the sparse category covered an area of 143.64 ha, the medium category covered an area of 65.52 ha, and the dense category covered an area of 24.48 ha.

3.2 Discussion

Timbulsloko and Bedono have quite extensive mangrove forests in Central Java, based on the satellite imagery data processing, these two areas have a mangrove of 234.8 ha in 2022. Mangrove forest in this area play a very important role in overcoming various environmental problems in this area, especially tidal floods. Mangroves act as a flood barrier, prevent abrasion, and store the most carbon among land plants (Harini *et al*., 2019). Initially, the mangrove in this region grew well, until in 1980 there was a change of land into fishponds which damaged the mangrove forest (Damastuti *et al*., 2022). Another cause of damage to mangroves in this area is land subsidence and sea level rise which results in erosion and flooding, according to Marfai (2014) sea level rise in Demak reach to 5 mm/year. Industrial development in the Demak region will affect the excessive use of groundwater and result in land subsidence which results in land areas being more easily submerged by floods. Various mangrove rehabilitation programs have been implemented in these two villages since 1999 by various parties, including the Demak Environment Service, the Demak Agriculture Service, the Demak Maritime Affairs and Fisheries Service, NGOs, educational institutions, and the private sector (Damastuti and de Groot, 2019). In addition, public awareness of the mangrove forests in this area has also increased over time. Based on the interviews that the author conducted, two out of five residents gave up their land to be planted with mangroves.

Mangroves have an essential role in this area, so monitoring their status every year and developing a strategic plan for their rehabilitation is important. One of the most effective ways to monitor mangroves is by using remote sensing. Mangrove mapping using remote sensing can be done by utilizing the mangrove vegetation index algorithm. The result showed that NDVI had a higher validation value compared to the other vegetation indices to map mangrove density in these two locations.

Table 2. Mangrove density value based on vegetation index

Sampling Point	Longitude	Latitude	Vegetation Index			
			NDVI	EVI	SAVI	MVI
1	110.5079	-6.88984	0.21	2.3	0.31	0.04
2	110.5085	-6.88928	0.36	2.22	0.29	0.02
3	110.506	-6.88973	0.11	1.83	0.16	-0.1
4	110.5061	-6.89157	0.35	1.92	0.25	-0.1
5	110.5095	-6.89411	0.22	2.05	0.27	-0.9
6	110.5092	-6.89264	0.38	2.29	0.31	-0.01
7	110.5044	-6.89064	0.36	2.14	0.28	0.04
8	110.504	-6.89095	0.36	2.05	0.26	0.02
9	110.5066	-6.89026	0.35	1.45	0.14	0.2
10	110.5079	-6.89087	0.01	0.94	0.01	-0.5
11	110.509	-6.89088	0.47	2.45	0.32	0.1
12	110.5124	-6.89534	0.22	1.29	0.1	-0.36
13	110.5107	-6.89467	0.30	1.81	0.21	-0.23
14	110.5117	-6.89321	0.11	1.23	0.03	-0.29
15	110.5105	-6.89262	0.12	1.55	0.15	-0.36
16	110.5114	-6.8929	0.12	1.39	0.11	-0.23
17	110.5099	-6.89202	0.13	0.88	0.01	-0.43
18	110.5077	-6.89625	0.28	1.16	0.05	-0.3
19	110.5089	-6.88782	0.43	2.35	0.32	0.1
20	110.5069	-6.89061	0.39	1.89	0.23	-0.1
21	110.5067	-6.89553	0.39	2.13	0.28	-0.06
22	110.5067	-6.89682	0.45	2.06	0.27	-0.04
23	110.5059	-6.89942	0.30	1.74	0.2	-0.08
24	110.5007	-6.90217	0.37	2.25	0.31	0.05
25	110.5	-6.90363	0.04	2.14	0.28	-0.03
26	110.5009	-6.90107	0.33	1.99	0.25	-0.01
27	110.5	-6.90393	0.38	2.21	0.29	-0.01
28	110.5008	-6.90045	-0.09	0.95	-0.01	-0.63
29	110.5059	-6.89942	0.38	2.05	0.25	-0.02
30	110.4993	-6.90478	0.35	2.22	0.3	0
31	110.4978	-6.90533	-0.12	1.74	0.2	-0.1
32	110.5079	-6.89138	0.23	1.78	0.1	-0.18
33	110.5004	-6.90275	0.40	2.04	0.28	-0.03
34	110.5064	-6.90947	0.28	2.1	0.26	-0.1
35	110.5007	-6.90027	-0.09	1.46	0.13	-0.3
36	110.5064	-6.91037	0.38	2.22	0.31	0
37	110.5014	-6.90044	0.36	2.12	0.28	-0.01
38	110.5041	-6.90671	0.11	1.68	0.19	-0.1
39	110.4993	-6.90545	0.23	1.98	0.25	-0.01
40	110.4993	-6.90478	0.42	2.22	0.3	0

Table 3. Mangrove density value based on measurements in the field (LAI value)

Sampling Point	Longitude	Latitude	LAI Value (%)
1	110.507854	-6.88984	78.75
2	110.508464	-6.88928	78.56
3	110.506043	-6.88973	67.45
4	110.506067	-6.89157	77.9
5	110.50947	-6.89411	72.15
6	110.509195	-6.89264	79.5
7	110.504426	-6.89064	77
8	110.504016	-6.89095	78
9	110.506609	-6.89026	75.43
10	110.507921	-6.89087	62.83
11	110.508952	-6.89088	87
12	110.512435	-6.89534	69
13	110.51074	-6.89467	74
14	110.511654	-6.89321	72
15	110.510474	-6.89262	65.2
16	110.511426	-6.8929	68.75
17	110.509856	-6.89202	56.75
18	110.507737	-6.89625	73
19	110.508904	-6.88782	83.15
20	110.50694	-6.89061	79.75
21	110.50673	-6.89553	79
22	110.506715	-6.89682	82.25
23	110.505861	-6.89942	66.6
24	110.50072	-6.90217	78.8
25	110.500011	-6.90363	60.5
26	110.500935	-6.90107	78
27	110.499986	-6.90393	83.5
28	110.500793	-6.90045	46.75
29	110.505861	-6.89942	83
30	110.499296	-6.904775	79
31	110.497757	-6.905331	56.7
32	110.507942	-6.891381	60.4
33	110.500358	-6.902751	80
34	110.506362	-6.909471	73
35	110.500737	-6.900272	47
36	110.506438	-6.91037	86
37	110.501438	-6.900438	76.5
38	110.504145	-6.906708	54
39	110.499336	-6.905451	64.8
40	110.499294	-6.904776	78.1

Table 4. Changes in mangrove area per density category

Category	Mangrove Area (ha)			
	2016	2018	2020	2022
Sparse	115.92	111.24	125.64	143.64
Medium	24.48	38.88	41.04	65.62
High	1.08	1.08	3.6	24.48

Vegetation has a good reflectance value toward Near Infrared (NIR) light (Rhyma *et al*., 2020). The NDVI value was calculated by looking at the best reflectance value of NIR light from chlorophyll and red light absorbed by green tissue (Evangelides and Nobajas, 2020). The use of NDVI to map mangrove density has been widely used by researchers and tends to have high accuracy. (Muhsoni *et al*., 2018) conducted a study using NDVI with Sentinel 2 imagery in Majungan Village, Pademawu District, Pamekasan which obtained an R^2 value of 0.85, Aulia *et al*. (2022) obtained an R^2 value of 86.92 in Segara Anakan Cilacap, and Wachid *et al*. (2017) obtained an r-value of 0.77 in Jor Bay.

The NDVI algorithm was used to map mangrove density condition over time and found that the mangrove area increased in each category. In 2018, there was a decrease in the area of the sparse category of mangroves by 13 ha, an increase in the medium category by 50 ha, and the value remained the same in the high category. In 2020, there was an increase in the area of the sparse category of mangroves by 40 ha, an increase in the medium category of 6 ha, and an increase in the area of the high category by 7 ha. In 2022, there was an increased area for the sparse category of mangroves by 50 ha, an increase in the medium category by 38 ha, and an increase in the high category by 58 ha.

The addition of area in the sparse category occurred due to the new plantings where there was no mangrove vegetation before (Figure 7). In 2016 there was a flash flood in the Sayung District area which resulted in several houses being washed away and the community's ponds being damaged. After the disaster, rehabilitation programs were started, such as mangrove planting programs, hybrid engineering (construction of bamboo to reduce offshore waves and catch sediment from land and sea), and green belts by the government (Perdana *et al*., 2019). The minimum disturbance from human activities and environmental disasters will result in mangrove species growing to their maximum height (Setyadi *et al*., 2021). With this disaster, the community also began to be aware of planting and maintaining mangrove ecosystems so that they could strengthen the condition of their villages. The awareness of the surrounding community to plant mangroves makes the condition of mangroves increase every year.

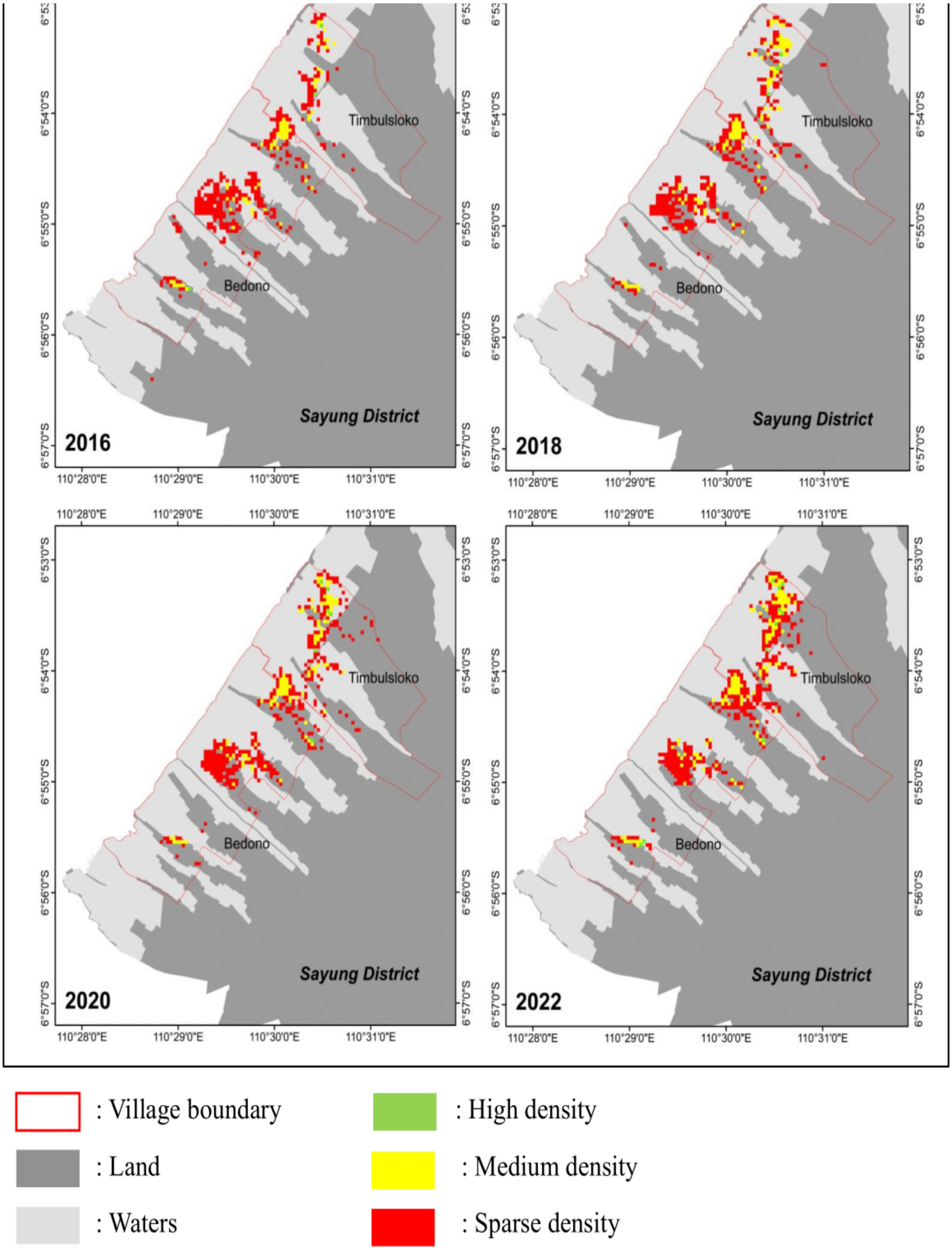

Figure 7. Monitoring changes in mangrove density condition using NDVI

4. Conclusion

The use of several vegetation indices to see the density of the mangrove canopy produced range of different values. The NDVI vegetation index had the highest accuracy value, followed by SAVI, EVI, and MVI. Based on the calculation of mangrove density using NDVI, it showed that there has been an increase in the total area in each mangrove density category. This means that the mangroves area in the Timbulsloko and Bedono have increased from 2016, 2018, 2020, and 2022. The increase in the area and density of mangroves is caused naturally and artificially.

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Authors' Contributions

Each author has contributed to the research process and manuscript writing. Zahra; collected and processed data, arranged the manuscript, and produced the figures. Rudhi; designed the project and conducted revision of the manuscript. Helmi; devised the project and the main conceptual ideas. All author discussed the result and contributed to the final manuscript.

Conflict of Interest

All authors announce that they have no conflicts of interest.

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