Temporal Analysis of Mangrove Canopy Cover of High Resolution Satellite Imagery on the West Coast of Bangkalan Regency, Madura East Java

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Abstract

Temporal Analysis of Mangrove Canopy Cover Using High Resolution Satellite Imagery on the West Coast of Bangkalan Regency

Mangroves are plants that live in muddy substrates, muddy sand, sand to tidal areas. These plants have important roles for marine organisms, carbon sequestration, as shoreline protectors from waves or erosion and sediment filters before entering the sea. The influence of human activity in the form of conversion of mangrove land to other forms or caused by natural disasters is a dangerous threat to the mangrove ecosystem. The magnitude of mangrove cover change is an important component so information is needed on changes in the spatial and temporal distribution of mangrove cover. This study aims to temporally analyze mangrove cover using high-resolution satellite imagery on the West Coast of Bangkalan Regency. This research uses secondary data in the form of Planetscope high-resolution satellite images from 2018 - 2023. The data will be processed to determine changes in mangrove area using Fv (Fractional Vegetation Cover). Calculation of the Fv (Fractional Vegetation Cover) value is done from the results of the minimum and maximum values of NDVI (Normalized Difference Vegetation Index). The results showed that there was a change in mangrove cover which was initially included in the FVC (Full Vegetation Coverage) class in 2022 with an area of 41.12 Ha to the HVC (High Vegetation Coverage) class with an area of 84.82 Ha in 2020. At the Arosbaya location, the highest Fv value occurred in 2019 with an area of 206.48 Ha. Reduction of mangrove area occurred in Sepulu and Arosbaya sub-districts due to land use change and sedimentation.

Keywords: *Arosbaya, Fractional Vegetation Cover, Planetscope high-resolution satellite Figures, Sepulu*

INTRODUCTION

Mangroves are taxonomically diverse assemblages of vegetation that are mostly woody plants, tolerant of salinity environments, living in the intertidal zone, ankurnd distributed in tropical and subtropical regions along coasts and river estuaries. (Primavera *et al*., 2018).. The existence of mangroves is maintained to maintain ecological balance in the coastal water environment. Mangroves act as natural biofilters, binding agents, and pollution traps. (Rohmawati *et al*., 2022). Mangrove ecosystems are one of the largest forest ecosystems in the tropics and subtropics. These plants have important roles for marine organisms, including carbon sequestration, shoreline protection from waves or erosion, and sediment filtration before entering the sea (Yuanita *et al*., 2021).

Canopy cover is a limiting factor in plant life that can be a barrier to light penetration into the plant ecosystem. The percentage of canopy cover is important to study because it is one of the indicators used to determine the condition, growth, damage, and rate of decline of coastal vegetation on a regular basis. (Schaduw, 2019). Tree crowns are conditions formed by overlapping branches and tree leaves. Mangrove canopy can affect the photosynthesis process by changing the shape and density of the canopy. The denser the crown, the more difficult it is for sunlight to penetrate the tree crown. This causes mangroves with saplings and seedlings to get less sunlight intake. (Sadono, 2018). A method that can be used to determine crown width in an ecosystem is *hemispherical* photography (Pretzsch *et al*., 2015).. The condition of the mangrove forest ecosystem can be assessed using several parameter methods such as vegetation density, diversity, biomass, and canopy closure (Suwanto *et al*., 2021). The condition of mangrove ecosystems can also be observed using satellite Figures that are analyzed with several vegetation indices. The most widely used vegetation index is NDVI (Normalized Difference Vegetation Index), which has a strong correlation with mangrove vegetation density (Razali *et al*., 2019).

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Satellite Imagery is one of the most advanced technologies for monitoring vegetation cover change due to its temporal resolution and timely updates. (Wikantika & Darmawan, 2023). Planetscope began operations in 2017 with a spatial resolution of 3 meters for the multispectral channel. This Imagery has a spectral channel consisting of four channels: blue, green, red, and near infrared. Planet offers a three-channel product line for Planetscope Imagery: Basic Scene products, Ortho Scene products, and Ortho Tile products. The influence of human activities in the form of land-use change or natural disasters is a dangerous threat to mangrove forest ecosystems, resulting in changes in mangrove cover (Mondal *et al*., 2021). The magnitude of mangrove cover change is an important component, so information is needed on changes in the spatial and temporal distribution of mangrove cover. In research conducted by Kurniawansyah *et al*., 2023 using *PlanetScope Dove-R* sensor Figures showed that the mangrove area in 2017-2019 was 77.40 ha, 81.24 ha, and 50.91 ha, respectively, with the dominance of dense classification density each year. Research on *fractional vegetation cover* has been conducted by (Rachman & As-Syakur, 2023) showed that there was a change in mangrove cover in the estuary of the Porong River which was likely due to the sedimentation process by mudflow from the volcanic disaster.

Madura Island is an island consisting of a main island and 123 islands that form a cluster stretching in coastal areas, lowlands to highlands where there are 138 villages that have mangroves in 2021 (Mahmud, 2023). Bangkalan Regency on Madura Island has a mangrove ecosystem on the west coast that has the potential to be managed and developed. The mangrove area on the west coast of Bangkalan Regency is spread across two sub-districts, namely Sepulu District and Arosbaya District. Sepulu District is an area that has a mangrove ecosystem in Bangkalan Regency, precisely located in Labuhan Village Mangrove Ecotourism (Restuadi & Tamami, 2023). This area is an educational tourism site where several types of mangroves can be found, such as: Sonneratia alba, Rhizophora stylosa, Rhizophora apiculata, Rhizophora mucronata, Ceriops tagal, Avicennia marina. Arosbaya sub-district is an area that has coastal characteristics and is overgrown with mangroves along its coast (BPS, 2018). One of the areas that has mangrove ecosystem potential in Bangkalan Regency is Arosbaya with an area reaching 119.3 ha in 2014 (Zainuri *et al*., 2014). There are ± 12 types of mangrove species found in Arosbaya District, including: Avicennia alba, Avecennia lanata, Sonneratia caseolaris, Xylocarpus granatum, Ceriops tagal, Rhizophora apiculata, Rhizophora stylosa, Rhizophora mucronata, Sonneratia alba, Lumnitzera littorea, Aegiceras corniculatum, and Camptostemon schultzii (Hur *et al*., 2021).

Previous research on mangrove cover using high-resolution satellite imagery has been carried out, including the phenomenon of mangrove cover change that occurred on Sebatik Island using SPOT 6 and Landsat 8 high-resolution satellite image data in 2005 and 2016. The results showed that there was an increase in mangrove area in 2005 and 2016 reaching 31.27% (Gaol and Susilo, 2018). Similar research also conducted by Kharisma *et al* 2023 in Lasalepa District, Muna Regency showed that there was an increase in mangrove area in the 2015-2020 period. The study used Landsat 8 OLI and Sentinel-2A Level 1C satellite images. The use of Sentinel 2A satellite imagery was used in research conducted by Damsir *et al* 2023. The results showed that the area of mangrove ecosystems in Lampung Province was 9,054.9 ha consisting of a dense density class of 8,520 ha, a medium density class of 358.6 ha, and a sparse density class of 176.3 ha. This study aims to analyze changes in canopy cover in mangrove ecosystems temporally using high-resolution Imagery.

MATERIALS AND METHODS

This research was conducted at Labuhan Mangrove Educational Tourism located in Sepulu and Arosbaya Districts, Bangkalan, East Java. The research location is shown in Figure 1. This research uses field data collection which is carried out by making several plots and making transects measuring 10m x 10m. This was done to determine the mangrove canopy cover at the research site using hemishpherical photography method and HP front camera with 1:1 size and perpendicular direction to the sky. In addition, using *Planetscope* high-resolution satellite Figure data developed by *Planet*.

Table 1. List of band frequencies of Planetscope high-resolution satellite Imagery

Band - 4	*Imagery fromPS2*	*Imagery fromPS2.SD*	*Imagery from PSB.SD*
Band 1 = Blue	Blue: 455 – 515 nm	Blue: 464 - 517 nm	Blue: 465 - 515 nm
Band 2 = Green	Green: 500 - 590 nm	Green: 547 - 585 nm	Green: 547 - 585 nm
Band 3 = Red	Red: 590 - 670 nm	Red: 650 - 682 nm	Red: 650 - 680 nm
Band 4 = Near -Infrared	NIR: 780 – 860 nm	NIR: 846 - 888 nm	NIR: 845 - 885 nm

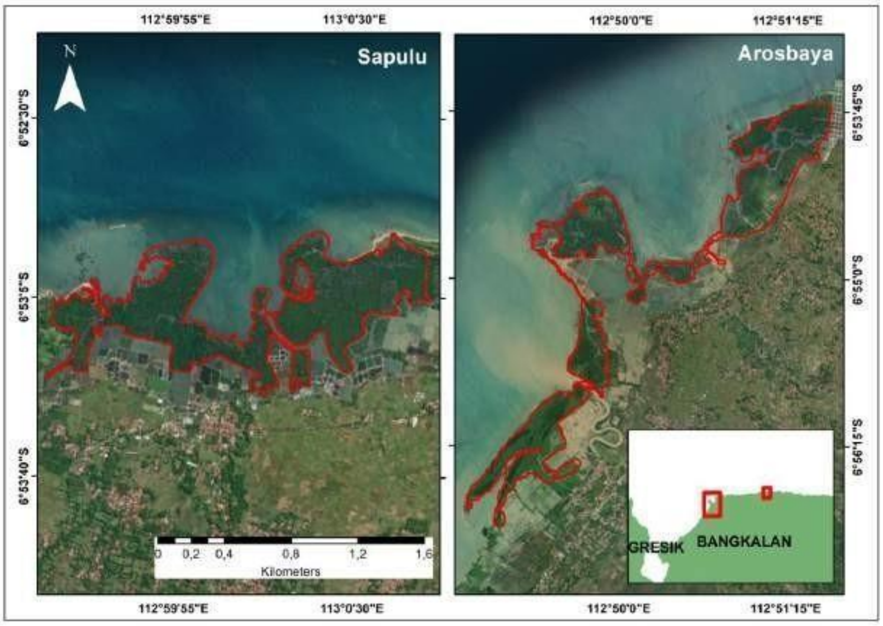


Figure 1. Research Location Map

This satellite Figure has a multispectral imaging instrument with a spatial resolution of 3-5 meters. This study uses the product surface reflectance (band 4) from 2018-2023. The data from this Figure is a composite where the red band and the NIR band must be reset. The result of the band split is to calculate NDVI (Normalized Difference Vegetation Index) and Fv (Fractional Vegetation Cover) values. Here's a list of band frequencies for Planetscope high-resolution satellite Imagery (Table 1).

This research uses the NDVI (Normalized Difference Vegetation Index) vegetation index to determine vegetation cover. NDVI is an Figure calculation used to determine greenness. The NDVI value is a value for determining the greenness of leaves with infrared wavelengths, which is very good as a start of dividing vegetation areas. NDVI basically calculates the amount of absorption of solar radiation by plants, especially leaves (Freddy *et al*., 2015). The formula for calculating NDVI classification from satellite Imagery is as follows (Rouse., 1974):

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

NIR is the NIR band channel in high-resolution Imagery (NIR band) and RED is the red band in high-resolution Imagery. Where the NIR band is band 4 in Planetscope high-resolution satellite Imagery and the RED band is designated as band 3. The results of the NDVI value calculation will be classified into 5 classes consisting of unvegetated land (-1 - 0.12), very low greenness (0.12 - 0.22), low greenness (0.22 - 0.42), medium greenness (0.42 - 0.72) and high greenness (0.72 - 1) (Kawamuna *et al*., 2017). Furthermore, a fractional vegetation cover (FV) analysis was conducted to determine changes in mangrove cover. This method assumes that a pixel consists of two components: soil and vegetation. Fv is formulated as follows (Zhang *et al*., 2013):

$$Fv = \frac{(NDVI-NDVIs)}{(NDVIv-NDVIs)}$$

NDVI is the NDVI value of pure non-vegetation pixels, and NDVIv is the pure value of vegetation pixels. NDVIv is the maximum value of NDVI and represents high vegetation cover. Meanwhile, the minimum value of NDVI represents non-vegetation cover, which can be soil, water, or buildings that are not vegetation. Based on these values, the FV results will be classified into 5 classes consisting of Non Cover (NC) (> -1), Low Vegetation Cover (LVC) (-1 - 0.26), Medium Vegetation Cover (MVC) (0.26 - 0.5), High Vegetation Cover (HVC) (0.5 - 0.9), and Full Vegetation Cover (FVC) (0.9-1).(Peng, 2012) . Furthermore, to determine the analysis of mangrove land cover change, unification based on class was carried out, which then determined stages 1-5 of decline in 2018 and 2023.

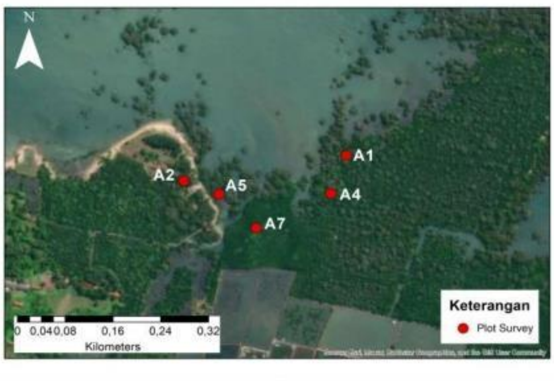
RESULTS AND DISCUSSION

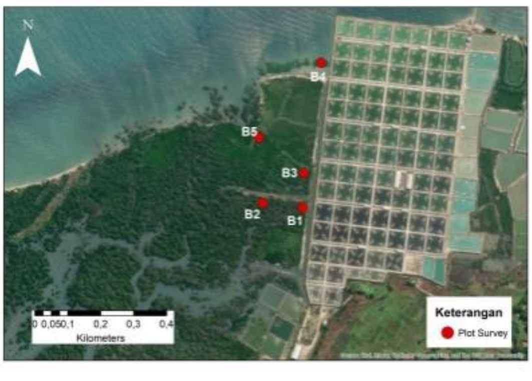
Field data collection in this study was conducted at five points scattered in Sepulu and Arosbaya sub-districts. From the results of data collection with hemisperic photography method, the percentage of mangrove canopy cover can be seen in Table 2. In this study, what needs to be considered is the canopy density of the observed vegetation. The percentage of mangrove canopy cover can be seen in Table 2.

In plot code A1, the average result of mangrove canopy cover is included in the sparse density category of 40.07%. This plot grows a lot of *Avicennia marina* mangrove species. This type of mangrove lives on muddy substrates. In plot A2, the average value of crown closure is 56.60%, which is included in the medium density category. Furthermore, plot A3 is dominated by *Sonneratia alba* mangrove species. Plot A3 has an average mangrove density value of 51.10%, which is included in the medium density category. Plot A4 is also dominated by *Sonneratia alba* mangrove species, with an average mangrove canopy cover of 60.03%, which is included in the medium density category. Plot A5, overgrown by *Rhizopora apiculata* mangrove species. The result of crown cover in this plot is 82.72%, which is included in the high density category.

Table 2. Percentage of mangrove canopy cover

Average Mangrove Canopy Cover (%)		
Plot Code	Sepulu (A)	Arosbaya (B)
1.	40,07	58,16
2.	56,5	62,72
3.	51,1	60,77
4.	60,03	61.,2
5.	82,72	46





(a) (b)

Figure 2. (a) Plot of Mangrove Cover Area in Sepulu Sub-district, (b) Plot of Mangrove Cover Area in Arosbaya Sub-district

The average mangrove canopy cover in plot B1 fell into the medium category at 58.16%. In this plot, many mangrove species were found, including *Rhizopora mucronata*, followed by *Sonneratia alba*. The substrate type in this plot was muddy. In plot B2, *Sonneratia alba* and some *Rhizopora mucronata* trees were found. Mangrove canopy cover conditions in this plot fall into the medium category with a value of 62.72%. Plot B3 was dominated by *Avicennia alba* mangrove species. In addition, other mangrove species were also found, such as *Avicennia lanata*, *Lumnitzera littorea*, and *Avicennia floridum*. The percentage of mangrove canopy closure in this plot is 60.77%, which is categorized as moderate. In plot B4, only *Rhizopora mucronata* mangrove species were found. No other mangrove species were found in this plot. The average mangrove canopy cover in this plot was 61.32%, which falls into the moderate category. The soil substrate type in plot 4 was gravelly sand and some trash was found. This plot is directly adjacent to the beach. Mangroves that grow tall, but sparse, affecting mangrove canopy cover. In plot B5, several types of mangrove species were found, dominated by *Sonneratia alba*. In addition, *Avicennia floridum* and *Ceriops tagal* mangroves were also found. The presentation of mangrove cover in this plot of 46% is included in the rare category category.

The results of the canopy cover presentation research in Sepulu Sub-district were higher than those in Arosbaya Sub-district. In addition, compared to research in Brebes District by Ningrum in 2019 with cover results ranging from 63.05 - 84.63% and research results in Jepara District (Mauludin *et al*., 2017) which had cover ranging from 58.15 - 80.41% showed that in Arosbaya District it was much lower and in Sepulu District it was quite high. In Brebes District dominated by Avicennia marina species and Jepara District dominated by Rhizophora apiculata species have a low percentage of mangrove canopy cover and mangrove density conditions. Sandy, muddy substrate conditions and high salinity are natural habitats for Avicennia marina and Rhizophora apiculata species. The results of research in Bakauheni Waters the percentage of mangrove canopy cover reached 72.04 ± 13.18% - 86.41 ± 1.08% higher because it was dominated by the type of Rhizophora sp which is known as a mangrove with wide leaf morphology so that the resulting percent canopy cover will also be large (Kuncahyo *et al*., 2020).

There are some locations, especially those close to land or open land, coastal areas and rivers, that have little or no greenery. The highest level of greenness occurred in 2022, while a very low level of greenness with no vegetation occurred in 2021. In 2018-2023, the level of mangrove greenness in Sepulu, Labuhan Bangkalan, increased so that the NDVI value in the unvegetated land category decreased. In accordance with Figure 1, it can be seen that in 2022, the north, east and south sides showed a high level of greenness, while the west side showed a low level of greenness. This is due to the mangroves being close to settlements.

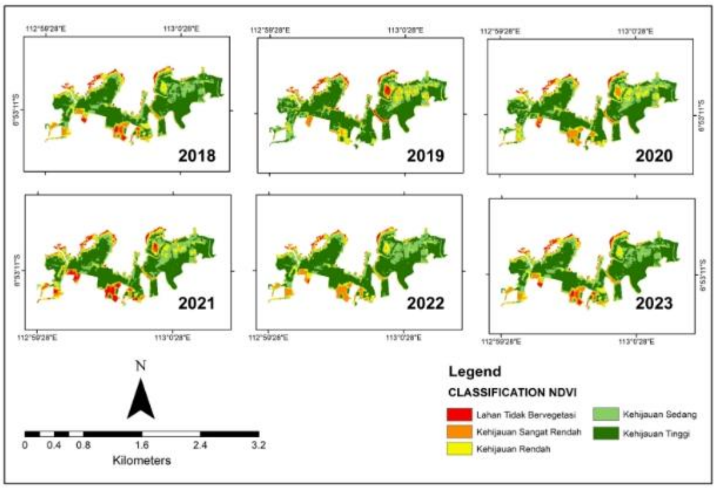
In 2019, there was little change on the southern side of the mangrove forests in Sepulu, Labuhan, and Bangkalan, which experienced a decrease in greenness from moderate to very low as shown in Figure 3 (a). This decrease in greenness is due to land clearing. The decline in greenness levels continued in 2020, in the same year in 2019, and increased on the south side. Greenness levels initially categorized as low became very low due to land conversion to ponds. Land conversion to ponds became more widespread in 2021, resulting in a decrease in greenness from very low to non-vegetated land. However, in 2022, there was an increase in greenness in the same area, and in 2021, greenness was very low category. This is most likely due to the regrowth of mangroves. A decrease in greenness again occurs on the north and east sides in 2023, from high greenness to medium and low greenness.

Figure 3. (b) shows that overall, the results of NDVI calculations of mangrove areas in Arosbaya District show moderate or sufficient density conditions, dense or dense, and have sufficient water moisture in the measured locations. Based on the results of raster calculations using the NDVI algorithm, it can be seen that the mangrove area that has been classified in 2018 is included in the moderate or sufficient category. This can be seen on the east side, adjacent to the shrimp pond. This year, the moderate or sufficient greenness class has an area of 77.61 ha, with an unvegetated land class of 5.09 ha being the highest from 2018 to 2023. In 2019, the high (dense) or dense greenness class dominated with an area of 57.81 ha. The medium greenness class changed to high greenness,

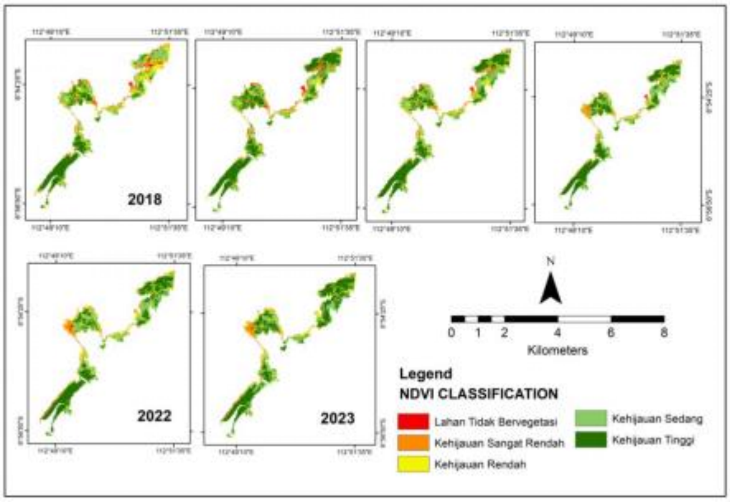
which previously had an area of 40.53 ha. Land that is not vegetated in this year has decreased to 3.11 ha. The level of greenness in 2020 is dominated by the medium or sufficient greenness class, with an area of 49.02 ha. There is a decrease of one class level from high greenness, which has an area of 47.78 ha. This is followed by an increase in the low greenness class of 9.36 ha. However, the non-vegetated land class decreased by 1.77 ha. The following table shows the *NDVI (Normalized Difference Vegetation Index)* area in Sepulu sub-district.

Table 3. NDVI (*Normalized Difference Vegetation Index*) area in Sepulu sub-district

Class	Area (ha)					
	2018	2019	2020	2021	2022	2023
Non-vegetated Land	5,09	3,12	1,78	2,51	1,62	2,09
Very Low Greenness	3,39	1,60	1,87	3,72	2,49	1,83
Low Greenness	1,45	6,78	9,37	8,87	9,00	8,53
Medium Greenish	77,62	40,53	49,02	39,34	33,72	33,93
High Greenness	10,28	57,82	47,79	55,38	62,98	63,45



(a)



(b)

Figure 3. (a) NDVI (*Normalized Difference Vegetation Index*) of Mangrove Forest in Sepulu District, (b) NDVI (*Normalized Difference Vegetation Index*) of Mangrove Forest in Arosbaya District.

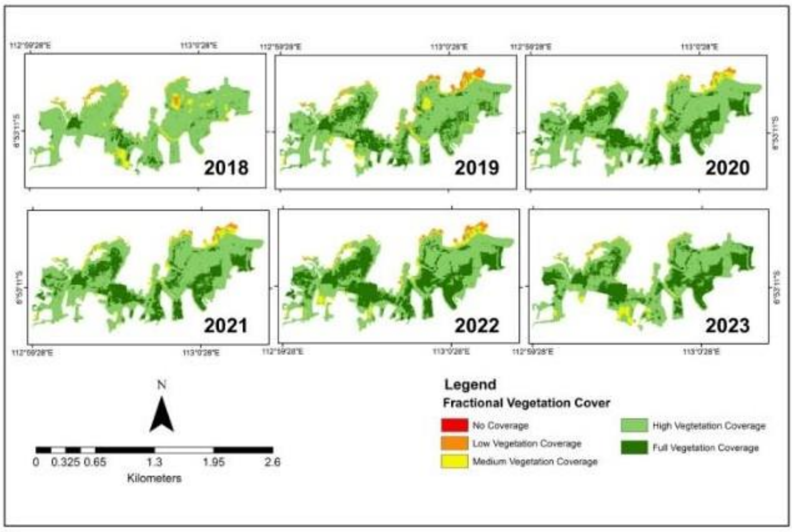
Table 3. shows the level of mangrove greenness based on NDVI values. In 2018, the greenness class had an area of 5.09 ha. This class has the lowest area from 2018 to 2023. While the medium greenness class has an area of 77.62 ha, unvegetated land and land with low greenness have the highest area throughout the year at 5.09 ha and 13.44 ha respectively. In addition, the medium greenness class has an area of 3.39 ha. The high greenness class experienced an increase in area of 57.81 ha in 2019. The increase in this class was followed by a decrease in area from the non-vegetated class to the medium greenness class by 3.11 ha, 1.60 ha, 6.77 ha, and 40.53 ha. Meanwhile, in 2020, the high greenness class decreased in area by 47.78 ha, followed by an increase in the low and medium greenness classes by 9.36 ha and 49.02 ha, respectively. In addition, the unvegetated area of the very low greenness class decreased in area by 1.77 ha, while the very low greenness class increased in area by 1.87 ha. The high or dense greenness class increased to 55.37 ha in 2021. This was followed by the medium greenness class which decreased to 39.34 ha and the low greenness class which decreased to 8.86 ha. In 2022, the high greenness class increased to 62.98 ha. The medium greenness class decreased in area to 33.72 ha, followed by the very low greenness class to 2.49 ha. However, the low greenness class increased in area to 8.99 ha and the non-vegetated land class to 1.62 ha. The area of mangrove greenness based on NDVI values in 2023 is dominated by the high or dense greenness class of 63.44 ha, which is the highest greenness class from 2018 to 2023. The medium greenness class decreased in area to 33.93 ha. The very low and low greenness classes also decreased to 1.83 ha and 8.52 ha, respectively. However, the non-vegetated land class increased to 2.08 ha. The expansion of pond land is the cause of the reduction in the level of greenery of mangrove vegetation. The following is a table of *NDVI (Normalized Difference Vegetation Index)* area in Arosbaya District.

Table 4. shows the greenness of mangroves based on NDVI values; in 2018, the greenness class value was 121.78 ha. The medium greenness class dominated this year with an area of 224.36 ha. While low and very low greenness classes have an area of 36.92 ha and 9.20 ha. The non- vegetated land class in this year is 16.96 ha. In 2019, the high or dense greenness class increased to 269.13 ha, which is the highest greenness class from 2018 to 2023. This is followed by the medium high greenness class, which decreases to 95.64 ha, and the low greenness class, which decreases to 19.43 ha. The high greenness class experienced a decrease in area to 164.18 ha. However, the low greenness class and medium greenness class increased in area by 26.47 ha and 207.20 ha, respectively. Meanwhile, the non-vegetated class and very low greenness class decreased in area by 5.80 ha and 5.58 ha, respectively. In 2021, the high greenness class increased to 217.67 ha. The medium greenness class decreased in area by 145.26 ha, while the very low greenness class and low greenness class increased to 9.90 ha and 28.52 ha, respectively. Meanwhile, the unvegetated land class became 7.87 ha. Table 4 shows that in 2022, the area of highly vegetated land decreased by 212.08 ha. Meanwhile, unvegetated to moderately green land also increased in area by 10.39 ha, 29.04 ha, and 150.79 ha. However, the unvegetated land class decreased to 6.92 ha. The area of mangrove greenness based on the NDVI value class in 2023 was dominated by the high or dense greenness class, which amounted to 219.01 ha. Moderate greenness class decreased in area to 146.05 ha. The very low greenness class and low to no vegetation also experienced a decrease in land area, namely 9.44 ha, 28.62 ha, and 6,121 ha. Expansion of the pond land is the cause of the reduction in the level of greenery in mangrove vegetation.

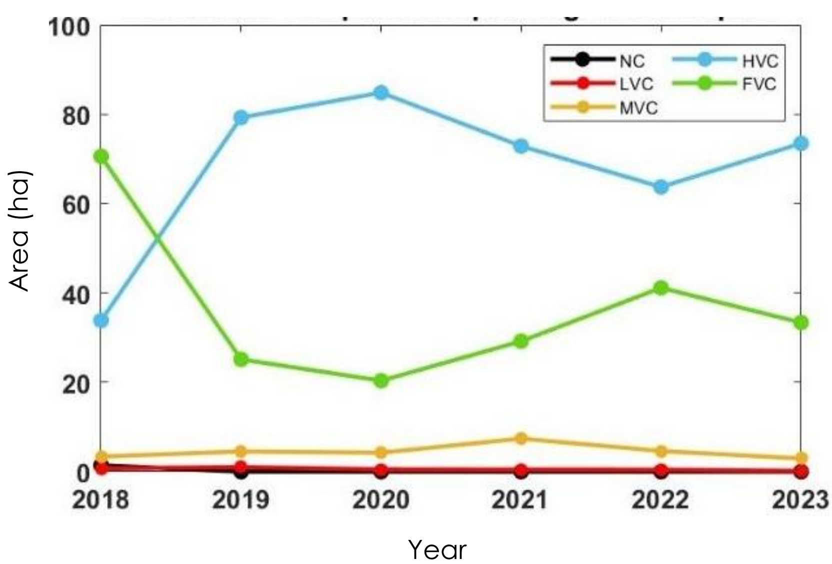
Table 4. *NDVI (Normalized Difference Vegetation Index)* area in Arosbaya Sub-district

Class	Area (ha)					
	2018	2019	2020	2021	2022	2023
Non-vegetated Land	16,96	18,92	5,80	7,87	6,92	6,12
Very Low Greenness	9,20	6,06	5,58	9,90	10,39	9,44
Low Greenness	36,92	19,43	26,47	28,52	29,04	28,62
Medium Greenish	224,36	95,64	207,20	145,26	150,79	146,05
High Greenness	121,78	269,13	164,18	217,67	212,08	219,01

The results of research on changes in the area of mangrove density levels based on NDVI values in Sepulu District and Arosbaya District are higher than research in Arakan Village, South Minahasa, North Sulawesi (Philiani *et al*., 2016) which has an area ranging from 824,566.01m^2 in the tight class, medium class (133,622.41m^2), sparse class (12,004.92m^2), very sparse class (10,494.23m^2), and the smallest in the very tight class (24.45m^2) and the results of research (Rempil *et al*., 2021) in Pagatan Besar Village has an area in the very sparse class ranging from 3.44 ha, the sparse class with an area of 29.53 ha, the medium class with an area of 75.23 ha, the dense class reaching 143.01 ha and the very dense class 138.32 ha. In addition, research (Hamuna *et al*., 2018) shows that the condition of mangroves in Youtefa Bay is dominated by a medium class around (152.73 ha), a tight class (38.63 ha), a sparse class (38.63 ha) and a very sparse class (41.76 ha). Mangrove density in Youtefa Bay is included in the medium density category and good ecosystem health conditions, but the mangrove area has decreased.



(a)



(b)

Figure 4. (a) Fv (Fractional Vegetation Cover) in Sepulu sub-district, (b) changes in Fv (Fractional Vegetation Cover) area in Sepulu sub-district.

In general, there are changes in mangrove vegetation in Sepulu, Labuhan, and Bangkalan in several places, such as around beaches, rivers, and open land. Figure 4. (a) shows the results of the calculation of FV values based on Planetscope high-resolution satellite Imagery from 2018 to 2023. The results of this calculation are divided into five categories, ranging from No Cover (NC) to Full Vegetation Cover (FVC). The results show that mangrove forests with FVC in Sepulu sub-district are mostly located in two areas, namely near the coast and rivers. The annual composite fluctuates from 2018 to 2023, especially in the nearshore and river areas. The results of the mangrove forest change analysis are shown in Figure 4.

Figure 4. (b) Graph of overall mangrove Fv change in Sepulu sub-district, the highest Fv level occurs in 2022, mostly near the coast and river, with an area of 41.12 ha. This year, mangroves close to land and river banks are classified as NC (Non Cover) and LVC (Low Vegetation Cover). The most dominant class in the interior of the mangrove area is FVC (Full Vegetation Cover), followed by the HVC (High Vegetation Cover) class on the east and north sides. The HVC (High Vegetation Cover), LVC (Low Vegetation Cover) and MVC (Medium Vegetation Cover) classes are most dominant near North Beach. From 2018 to 2021, mangrove change occurred on the north coast. During this period, areas classified as NC and LVC became MVC and HVC. This indicates that the mangroves started to grow from saplings to saplings in that year. Meanwhile, in 2023, on the North side, there was a change of two classes to HVC. In addition, mangrove cover in the central part has increased.

Based on Figure 4. (b) each class on average experienced changes in area in 2018-2023. The Fv (Fractional Vegetation Cover) value decreased, but the HVC (High Vegetation Cover) value increased. Meanwhile, there was no significant increase in vegetation cover in the NC class during the study. The LVC class decreased in area from 0.98 ha in 2019 to 0.44 ha in 2023. The decrease in the class from 2018 to 2023 was due to the conversion to higher classes, namely MVC, HVC, and FVC. The opposite condition occurred in 2023, where the FVC class decreased while the LVC class and HVC class increased. This can be seen in Figure 4. (b) changes in mangrove vegetation cover area. Figure 4. (a) shows changes in the Fv class of mangrove vegetation during 2018-2023. Based on the results of the analysis using fractional vegetation cover, it shows that mangrove vegetation experienced a slight increase. Significant changes were found in the northern nearshore and southern inland areas. In the central part of the North, the mangrove cover change decreased from FVC to HVC. A similar situation also occurred in the east, from FVC to HVC. The total land area that has changed from FVC to HVC is approximately 95.73 ha. Meanwhile, the northern side, which is close to the coast, experienced a decrease in FVC class from MVC to LVC. On the western side, there was an increase of 295 Fv classes dominated by a 1-level increase near the coast. The FVC class is inversely proportional to the HVC class; if FVC increases, the HVC value will decrease, and vice versa. NC (*Non Cover*) from 2018 to 2023 has increased. While the LVC (*Low Vegetation Cover*) class decreased in 2019, namely 0.98 ha from 1.61 ha in 2018, and then in the following year it decreased. The MVC (*Medium Vegetation Cover*) class was highest in 2021 with an area of 7.38 ha and increased in 2023 to 8.45 ha. The classes that have decreased have been converted up 1 to 2 steps to the next FVC class.

Based on the processing results (fractional vegetation cover), Fv can be seen in Figure 5. (a) In 2018, the Fv value was very low compared to previous years. The west side has a high Fv value compared to the east side. In 2019, the Fv value in Arosbaya increased from MVC to FVC. It can be seen that the east and west sides have turned green evenly. This year has the highest Fv value compared to 2018-2023. However, in 2020-2023, there is a decrease in the Fv value, especially on the north side. This is due to land use change into ponds that are expanding every year. Although the west side is still included in the Fv class that survived from 2018-2023. In 2023, on the east side, the Fv value increased slightly compared to 2022. This can be seen in Figure 5. (b) graph of changes in mangrove vegetation cover area. Overall changes in mangrove vegetation cover in Arosbaya sub-district, Bangkalan, can be seen in Figure 5 (b). Changes in mangrove vegetation cover, or Fv, increased and decreased. NC and LVC continued to decrease throughout 2018-2023. Meanwhile, the MVC class decreased in 2019. However, it continued to increase until 2023. Figure 5.(b) shows that the HVC and FV classes intersect in 2019. If the HVC value is high, the FV value will be low, and vice versa, if the FVC value is high, the HVC value will be low. The highest HVC class occurs in 2023, while the highest Fv class occurs in 2019.

The identification of the converted classes and their values can be seen in Table 5 in Figure 4. (a) The diagonal part is depicted as the unchanged Fv class. Values above the diagonal indicate an increase and below a decrease. This matrix shows that HVC is the largest Fv category with no change in area, which is about 66.15 ha. Based on the results from Figure 4. the dominant HVC land cover is the mangrove area in the middle side. There was a maximum change in the HVC to FVC class of 24.74 ha, and LVC to HVC increased by 3 steps, which is 0.82 ha. Further changes occurred in the LVC to FV and NC to HVC classes of about 53.24 ha. The dominant changes that occurred reached 3 to 4 occurred in the pond area in Figure 8. The most extensive class decrease occurred in the HVC to FVC class of 2.64 ha and MVC to HVC change of 2.49 ha. Land use change from mangrove forest to ponds is mostly a decreasing stage, following the results of Fv changes during 2018-2023 in Figure 6.

The pre-converted Fv class of the identification results can be seen in Table 6 in Figure 5. The diagonal part is depicted as the unchanged Fv class. Values above the diagonal indicate an increase and below a decrease. This matrix shows that HVC is the largest Fv category that has not changed in area, which is about 266.64 ha. Based on the results of Figure 5. HVC land is dominated by mangrove cover on the north and east sides. There was a maximum change in HVC to FVC class of 14.61 ha, and LVC to HVC increased by 3 steps, which is 6.29 ha. Further changes occurred in the LVC to FVC and NC to HVC classes of approximately 62.8 ha. The most extensive class decreases occurred in the HVC to FVC class by 17.60 ha and the MVC to HVC transition by 14.61 ha.

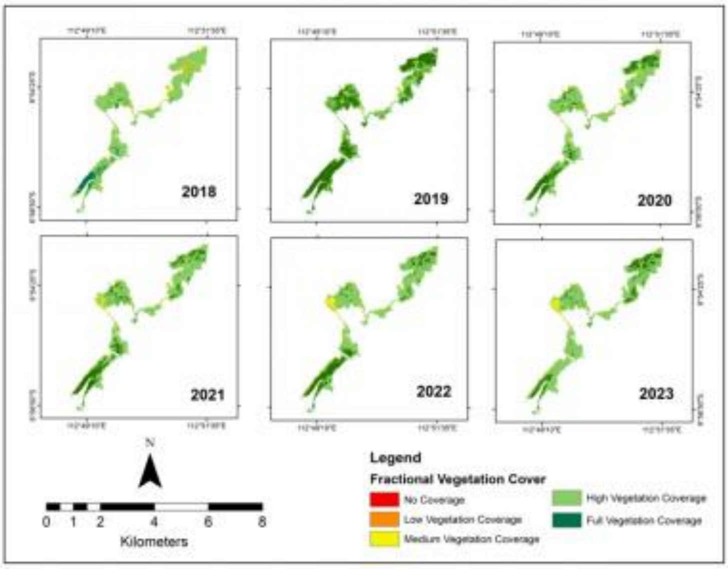
The results of research on changes in Fractional Vegetation Cover (Fv) of mangroves in Sepulu District and Arosbaya District are higher than the research (Pietersz *et al*., 2024) in the mangrove ecosystem of Negeri Passo, Teluk Ambon Dalam has an area of 21.66 ha with dense canopy cover conditions. This condition is influenced by mangrove species that grow such as R. apiculata, B. parviflora and S. caseolaris have dense mangrove canopy cover. This can also be seen in the mangrove ecosystem of Betahwalang Village, Demak Regency, which has a relatively dense crown cover condition (Purnama *et al*., 2020). Meanwhile, the condition of mangrove canopy cover which is classified as sparse is dominated by the S. alba species in the mangrove ecosystem of Middleburg-Miossu Island, West Papua (Nurdiansah and Dharmawan, 2021). High and low mangrove canopy cover is also caused by changes in ecological functions through land expansion for development in mangrove areas (Marasabessy *et al*., 2021). In addition, human activities can also decrease mangrove density and cover (Renta *et al*., 2016). Naturally, changes in mangrove area occur due to the influence of sedimentation and abrasion, while the consequences of human activities such as land expansion for various interests such as; reclamation, conversion of ponds, settlements, and the marine tourism industry (Marasabessy *et al*., 2020).

Table 5. Coverage change detection matrix (ha) (2018-2023)

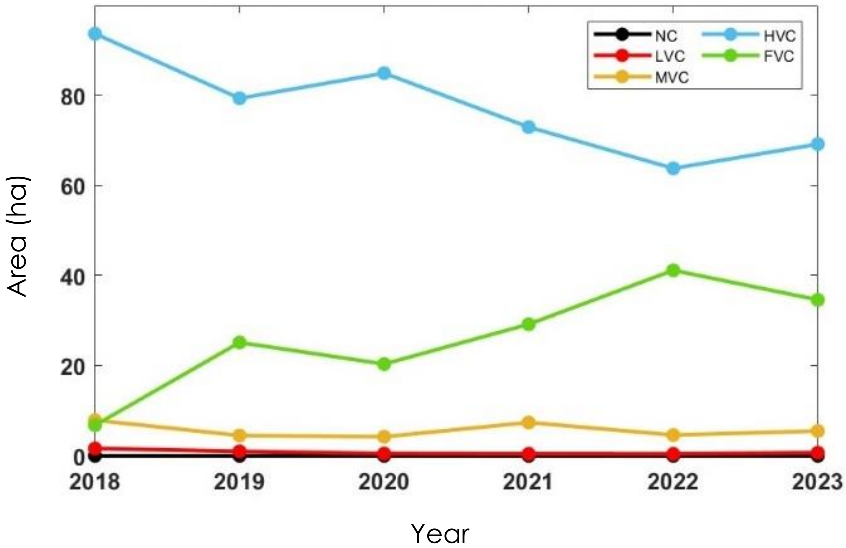
Class	Year					
	2018	2019	2020	2021	2022	2023
NC					0,00	0,00
LVC		0,21	0,49	0,88		1,57
MVC		0,33	1,99	5,38	0,09	7,79
HVC		0,11	2,92	60,50	29,87	93,39
FV	0,00		0,02	2,14	4,61	6,76
Total	0,00	0,64	5,41	68,89	34,57	109,52

Table 6. Coverage change detection matrix (ha) (2018-2023)

Class	Year					
	2018	2019	2020	2021	2022	2023
NC				0,02	0,02	0,04
LVC		1,29	3,57	6,29	0,07	11,22
MVC	0,00	0,38	5,87	22,99	1,37	30,61
HVC	0,06	1,57	14,61	266,64	49,28	332,16
FV	0,01	0,00	0,15	17,60	16,82	34,57
Total	0,06	3,23	24,20	313,53	67,56	408,59

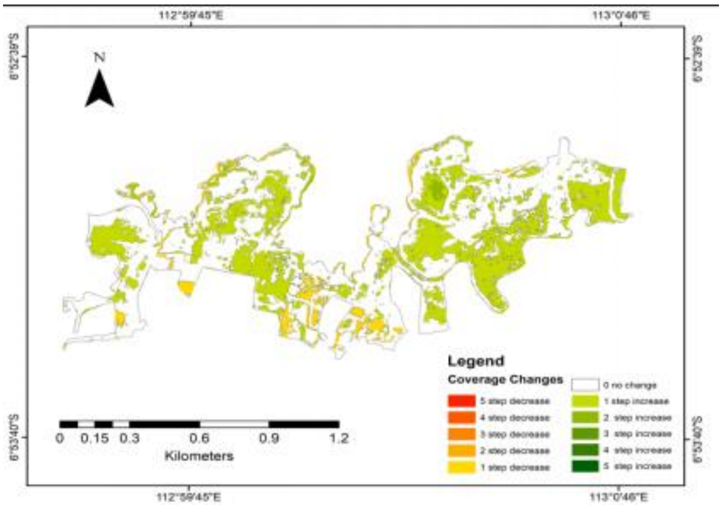


(a)

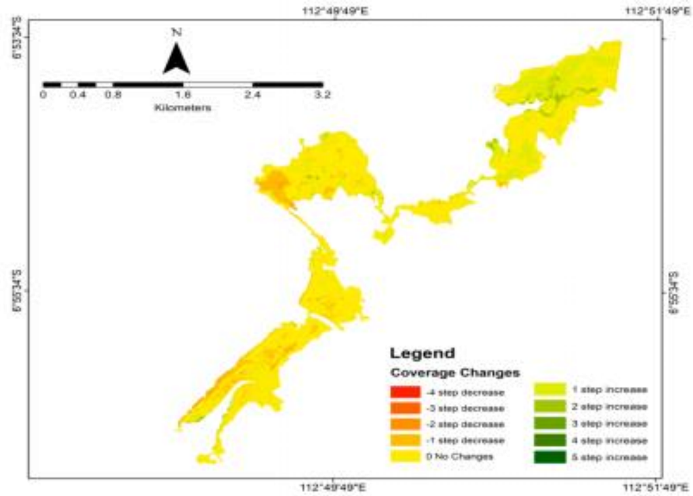


(b)

Figure 5. (a) Fv (Fractional Vegetation Cover) in Arosbaya sub-district, (b) changes in Fv (Fractional Vegetation Cover) area in Arosbaya sub-district.



(a)



(b)

Figure 6. (a) Results of changes in Fv during 2018-2023 for Sepulu sub-district, (b) Results of changes in Fv during 2018-2023 for Arosbaya sub-district.

Changes in mangrove vegetation cover in Sepulu sub-district during 2018-2023 are shown in Figure 6 (a). This change is on the South side adjacent to rice fields and ponds. The area experienced a decrease of 1 class. On the North side there is an increase in mangrove vegetation cover by 1 class adjacent to the coastal area. Mangrove vegetation cover increased in Sepulu sub-district due to conservation in the area. This makes the mangroves increase and can be maintained. Overall, mangrove vegetation cover in Sepulu sub-district experienced 1 class increase and some areas experienced no change. Figure 6 (b) shows that there was a significant change in mangrove vegetation cover from 2018 to 2023 in Arosbaya sub-district, Bangkalan. On the north side on the left, there is a fairly tall building that has changed because it has decreased by 3 classes. This decrease was caused by the transition of land use into ponds. In addition, the west side also decreased by 3 classes due to reduced sedimentation in the mangrove forest. While in the eastern part, there was an increase of 2-3 classes. This class increase was caused by additional sedimentation and the results of mangrove replanting. However, the southern part actually experienced a decrease in class. The remaining mangrove forest did not experience significant changes from 2018 to 2023. The reduction of mangrove area that occurred in the study area was caused by land conversion into ponds. In accordance with research Prakoso *et al*., the main factor triggering the reduction of mangrove land is caused by land conversion into ponds that have an impact on the carrying capacity of the environment for mangrove growth and development. Reduction of mangrove land area in Sepulu District is influenced by human activity in the form of expansion of shrimp pond areas that are increasing every year. In addition, the influence of natural factors and damage will degrade mangroves. The presence of large waves, east winds, and prolonged dry season can also affect changes in mangrove areas.

During 2018-2023, mangrove vegetation cover and mangrove area based on NDVI values decreased. The total change in mangrove area in Sepulu sub-district is 109.83 ha. While in Arosbaya Sub-district, the total change in mangrove area is 409.25 ha. This was caused by community activities such as the conversion of mangrove areas into ponds, as happened in Arosbaya Sub-district. In 2018, there was still no pond development in this area. However, in 2019, land use change occurred until 2023. Other causes of the decline in mangrove area and greenness are the construction of new docks and direct utilization of mangrove trees. (Sukojo *et al*., 2017).. The increase in mangrove area in Sepulu occurred due to mangrove replanting activities (Semedi, 2023). (Semedi, 2023). In addition, this area is included in a tourist area that has good management and social references, such as mangrove planting. The causes of the decline in mangrove area that occurred during 2018-2023 in Sepulu and Arosbaya Districts are in line with research conducted by Kurniawansyah *et al*., 2022, that the decrease in mangrove area was followed by an increasingly sparse mangrove density level.

The distribution of mangrove cover based on the calculation of Fv (Fractional Vegetation Cover) in Sepulu and Arosbaya sub-districts during 2018-2023 is spread along the coast. This is shown in Figure 6 (a). Based on this method, several locations were found to have changes in mangrove area, especially in the pond area. The increase in mangrove area is caused by sediment. Increased sedimentation in coastal areas causes the growth of new mangrove locations. The growth of mangrove plants is supported by the supply of sediment from river flow that provides substrate and nutrients (Lovelock., 2017). In addition, the process that causes the decline of mangrove cover is the conversion of land into ponds and the expansion of settlements. Human activities such as aquaculture, agriculture, and settlement exacerbate the transition from coastal to inland areas.

CONCLUSIONS

High-resolution satellite Figures from Planetscope can analyze changes in mangrove forest cover on the West Coast of Bangkalan from 2018 to 2023. Based on the results of the research analysis, the highest mangrove density with an area of 63.44 ha occurred in 2023 and the lowest in 2018 with an area of 10.28 ha in Sepulu District. Meanwhile, in Kecamatan Arosbaya, the highest was 219.02 ha, while the lowest was 121.79 ha in 2018. In addition, mangrove cover changed from NC-MVC class to dense vegetation. HVC and FVC vegetation was found in the nearshore area. The decrease in vegetation cover is due to land conversion into ponds, and the increase in vegetation cover is due to mangrove replanting and increased sedimentation. The conclusion should clearly indicate the results obtained, their strengths and weaknesses, and the possibility of further development. The conclusion should be in the form of a paragraph.

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