MAPPING OF NDVI INDEX BASED MANGROVE AREA AND DENSITY CHECTARENGES USING LANDSAT 8 SATELLITES IMAGES IN NORTHERN COASTAL AREA OF EAST JAVA PROVINCE, INDONESIA

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ABSTRACT

Mangrove ecosystems are important for maintaining ecological balance in coastal areas. To monitor changes in mangrove area and density, remote sensing technology with Landsat 8 and NDVI Index was used. The research focuses on the North Coast of East Java, from 2019-2024, on the coast of Surabaya, Sidoarjo, Pasuruan, Probolinggo, and Situbondo. The purpose of this study is to analyze changes in mangrove area and density. The survey method was conducted with Landsat 8 images and in situ data in 2024. There are 5 observation station points with the determination of station points using purposive sampling technique. Accuracy test using RMSE. The area of mangroves on the coast of Surabaya, Sidoarjo and Pasuruan from 2019 to 2024 ranged from 1611.88 ha-2270.41 ha. The highest cover area was in 2024 and the lowest in 2019. Mangroves with sparse NDVI category ranged from 46640.61 ha-53284.95 ha. Moderate NDVI ranged from 4313.25 ha-6984.72 ha and dense NDVI ranged from 493.29 ha-4711.5 ha. The area of mangroves on the coast of Probolinggo and Situbondo increased from 2019-2024, which amounted to 1487.05 ha-1885.79 ha. Mangroves with sparse NDVI category have an area between 51367.12 ha-54852.64 ha. Moderate NDVI ranged from 5564.87 ha-54852.64 ha and high NDVI ranged from 668.18 ha-1585.52 ha. The results show that there are changes in the area and density of mangroves on the north coast of East Java every year. These changes need to be monitored annually to address the decline in mangrove area and density quickly and appropriately.

Keywords: *Coastal, Landsat 8, Mangroves, NDVI*

1. INTRODUCTION

Mangroves can be defined as a group of plants consisting of various species and families that share similar morphological and physiological adaptations to their habitat, which is influenced by the tidal processes of seawater (Hakim & Darusman, 2015). Indonesia hectares a total mangrove area of 7.7 million hectares, accounting for more than 20% of the world's mangrove area. However, only 47.9% of this area is in good condition, while the remaining 52.1% is unfortunately damaged (Ministry of Environment and Forestry, 2015).

Based on these data, the total area of mangroves in good condition is smaller then the damaged area. This imbalance threatens the critical ecological functions of mangrove ecosystems. If this trend continues, the degradation of mangrove areas will lead to a significant reduction in their essential ecological services (Syamsu *et al.*, 2018).

Over time, mangrove areas experience changes in size and density, which can occur both naturally and due to human intervention (Wilujeng *et al.*, 2022). Monitoring these changes is essential and can be effectively achieved using remote sensing technology. One satellite particularly suitable for this purpose is the Landsat 8 satellite.

The north coast of East Java, including the coastal cities of Surabaya, Pasuruan, Probolinggo, and Situbondo, is home to mangrove ecosystems (Hidayah, 2011). According to the Department of Fisheries and Marine Affairs of East Java Province (2011), the mangrove area in Surabaya covered 579.89 hectares in 2000 but degraded to 378.19 hectares by 2010. This decline is attributed to intensive land-use changes driven by human activities (Syamsu *et al.*, 2018).

Similarly, Hidayah & Wiyanto (2013) reported that the mangrove area in Sidoarjo measured 1,236.42 hectares in 2002, but this area had decreased to 1,203.35 hectares due to illegal logging and the conversion of mangroves into ponds (Prasenja, 2018). In Pasuruan, mangrove forests are often used as waste disposal sites by the local community, contributing to their degradation. Land-use changes, particularly the conversion of mangrove areas into ponds, further exacerbate the decline (Pratiwi *et al.*, 2022).

In Probolinggo, a coastal city with a 7-kilometer coastline, mangrove forests are shrinking due to land-use chectarenges driven by the construction of residential areas and aquaculture ponds (Syamsu *et al.,* 2018). The area hectares significant potential for tourism development but faces challenges due to mangrove deforestation (Dewi & Mahectarerani, 2018).

In Situbondo, the mangrove area decreased from 320.05 hectares to 290.65 hectares, representing a decline of 9.19% (Suryaningsih & Hudhectare, 2018). This reduction is primarily caused by land conversion for industrial purposes (Budiarti *et al.*, 2019).

The changes in mangrove areas along the north coast of East Java underscore the need for consistent monitoring and management to preserve these ecosystems. Remote sensing technology, particularly using the NDVI (Normalized Difference Vegetation Index), offers a practical approach for monitoring and maintaining mangrove areas..

2. RESEARCH METHODS

This research was conducted in the northern coastal area of East Java. The sampling locations were selected purposively and included Surabaya, Pasuruan, Probolinggo, and Situbondo. The study took place from August to September 2024, incorporating both in-situ sampling and satellite image processing of the mangrove areas using the NDVI index.

The in-situ mangrove vegetation analysis was carried out using transects measuring 10 × 10 meters in each sampling location (Surabaya, Pasuruan, Probolinggo, and Situbondo). The main parameter analysed was tree density. For remote sensing, Landsat 8 satellite images from 2019 to 2024 were utilized for the selected sites. Image data analysis included several steps: image colour composite creation, image cropping, image sharpening, image classification, map layout design. The NDVI analysis was conducted using the formula provided by Kapoh and Papilaya, (2021):

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

Description:

NDVI : Normalized Difference Vegetation Index

NIR : Near Infrared channel spectral values (Band 5)

RED : Red channel spectral values (Band 4)

Tree density analysis was performed using the folowing formula:

$$\text{K} = \frac{ni}{A} \qquad (2)$$

Description:

K : Tree density (ind/ha)

Ni : Total number of individual trees

A : Total area of sampling area (ha)

After analysing the data, an accuracy test was conducted to evaluate the correlation between the satellite image processing results and the actual field conditions (Tablaseray et al., 2018). The test compared NDVI values from satellite data with tree density values obtained in the field. The RMSE (Root Mean Square Error) value was calculated using the following formula:

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(y - y_i)^2}{n}} \qquad (3)$$

Description:

RMSE : Error value

Y : Actual data

Yi : Image processing data

N : Number of data

3. RESULTS AND DISCUSSION

3.1. Mangrove Land Cover in Surabaya, Sidoarjo and Pasuruan 2019 – 2024

Landsat 8 satellite image data from 2019 to 2024 were analysed. Images with less then 25% cloud cover were selected to facilitate accurate analysis of mangrove area and density. The mangrove land area was assessed through a supervised classification process using the maximum likelihood method. This classification produced three land cover categories: mangroves, ponds, and settlements. The result analysis as shown in Figure 1.

In 2019, mangrove area in Surabaya to Pasuruan covered 1,611.88 hectare, reflecting a decrease of 326.59 hectare from 2018. The decline was attributed to low public awareness of mangrove conservation and inadequate governmental supervision (Rodiyah & Agustina, 2018). In 2020, mangrove area on the coast of Surabaya to Pasuruan increased to 2145.65 hectares showing a rise of 533.77 hectares from 2019. This growth corresponded to a reduction in shrimp pond and settlement areas.

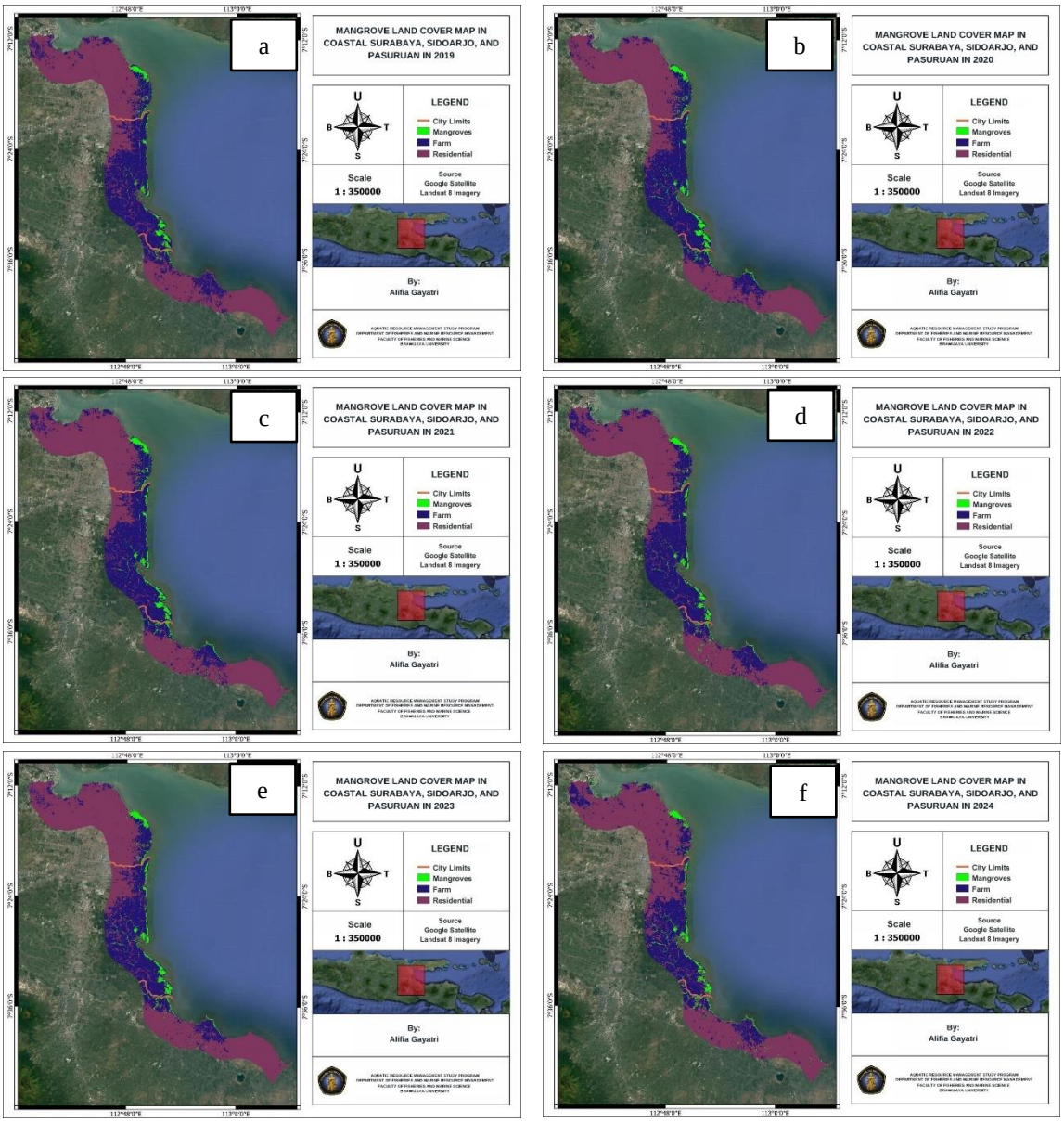

Figure 1. Map of mangrove land cover in coastal Surabaya, Sidoarjo, and Pasuruan in 2019-2024 a) in 2019; b) in 2020; c) in 2021; d) in 2022; e) in 2023; and f) in 2024.

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In 2021, mangrove area on the coast of Surabaya to Pasuruan expanded further becomes 2,200.3 hectare, an increase of 54.65 hectare from 2020. This improvement was linked to successful rehabilitation programs (Annisa *et al.,* 2019). In 2022, the mangrove area at the coast of Surabaya to Pasuruan reached 2,167.85 hectares, reflecting a 175.66 hectare increase from 2021. However, increased population growth led to land-use changes, including conversion to settlements, which still posed challenges (Maharani *et al.,* 2021).

In 2023, the mangrove area at the coast of Surabaya to Pasuruan becomes 2167.85 hectares. There was an increase of 175.66 hectares from 2022. This resulted due to the decrease in shrimp pond area that has been changed into mangrove rehabilitation area. In 2024, the mangrove area at the coast of Surabaya to Pasuruan expanded to 2,270.41 hectares, an increase of 102.56 hectares from 2023. This growth resulted from joint efforts by the government and the community in managing and protecting mangrove ecosystems through rehabilitation and revitalization initiatives (Haryani, 2013). These activities include the development of mangrove nurseries area, seedling and planting mangroves (Haryani, 2013).

3.2. Mangrove Land Cover in Probolinggo and Situbondo 2019 – 2024

Mangrove area analysis was conducted on Landsat 8 image data from 2019 to 2024 through unsupervised classification using the K means method. K-Means is the number of output clusters or spectral classes (assume k clusters) determined by the analyst (Raharja, 2023). The classification process resulted in four land cover classes: water body, mangrove, vegetation, and built-up land. The result analysis as shown in Figure 2.

Mangrove area located on the coast of Probolinggo and Situbondo covered 1,487.05 ha. Studies showed that the area decreases compared to 2018, when Probolinggo had 864.45 ha (Putra, 2019) and Situbondo had 936.42 ha (Pratiwi *et al.,* 2019). This phenomenon basically occurred within a year (2018 to 2019).

In 2020 the mangrove area located on the coast of Probolinggo expanded to 1571.09 hectares. There was an increase of 84.28 hectares from 2019. Replanting efforts helped stabilize soil and protect coastlines from erosion and storms (Baksir *et al.,* 2018). In 2021 the mangrove area at the coast of Probolinggo and Situbondo expanded into 1771.33 hectares. This increase was due to the addition of mangrove area of 200.24 hectares, as the impact of conservation activities carried out by local communities, governments, or other groups from the year before (Irawan & Agussalim, 2019).

In 2022 the mangrove area on the coast of Probolinggo and Situbondo declined into 1,663.98 hectares, as a result of decrease of 107.35 hectares compared to 2021. The drop was attributed to land conversion for agriculture, settlements, and ponds, as well as pollution from industrial and household waste, which adversely affected soil and water quality (Irawan and Malau, 2016; Dharmawan et al., 2020). In 2023 the mangrove area at the coastal areas of Probolinggo and Situbondo expanded into 1671.05 hectares. There was an increase of 125.07 hectares from the previous year of 2022. The increase in mangrove area in general was due to the management and protection of mangrove ecosystems by the community and the government (Hidayah, 2011).

In 2024, the mangrove area at the coastal of Probolinggo and Situbondo grew to 1,885.79 hectares, with an increase of 214.74 ha from 2023. Involvement of local communities in rehabilitation projects and replanting mangrove seedlings in degraded areas contributed to this growth (Rahmadi & Auliani, 2020; Sukojo and Arindi, 2018). previously damaged or degraded mangrove land (Sukojo and Arindi, 2018).

3.3. Mangrove Density Calculation Using NDVI Index in Surabaya, Sidoarjo and Pasuruan 2019-2024

Mangrove density was mapped using remote sensing techniques with the NDVI index, which integrates data from red and near-infrared spectral bands (Hardianto *et al.,* 2021). NDVI classifications were based on the Forestry BAPLAN 2005 standard:
Sparse: NDVI values from -1 to 0.32.
Moderate: NDVI values from 0.33 to 0.42
Dense: NDVI values from 0.43 to 1.

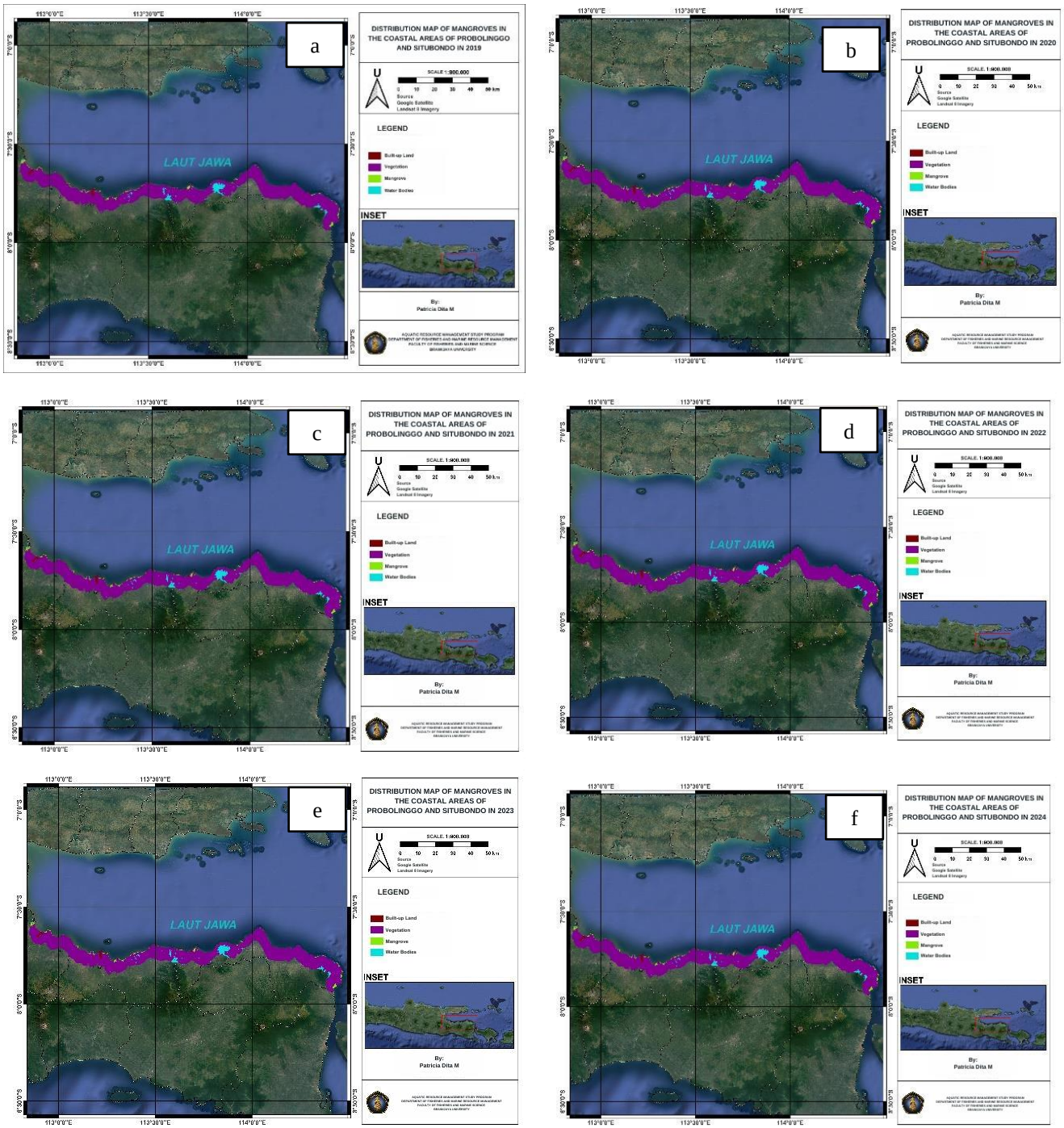

Figure 2. Map of mangrove land cover in coastal Probolinggo and Situbondo in 2019- 2024 a) in 2019; b) in 2020; c) in 2021; d) in 2022; e) in 2023; and f) in 2024.

From 2019 to 2024, the mangrove density showed year-to-year variations. Areas with sparse NDVI categories ranged from 24.66 hectares to 217.8 hectares, moderate categories ranged from 963.81 ha to 1,507.77 ha, and dense categories ranged from 532.62 ha to 971.82 ha, as shown in Figure 3 and Table 1.

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Table 1. Mangrove Density (ind/ha) by NDVI Class Category

Year	Mangrove Density by NDVI		
	Sparse	**Medium**	**High**
2019	24.66	963.81	645.39
2020	59.13	1154.52	971.82
2021	108.72	1237.68	904.59
2022	60.21	1458.81	532.62
2023	92.97	1507.77	60.95
2024	76.14	1449.09	815.85

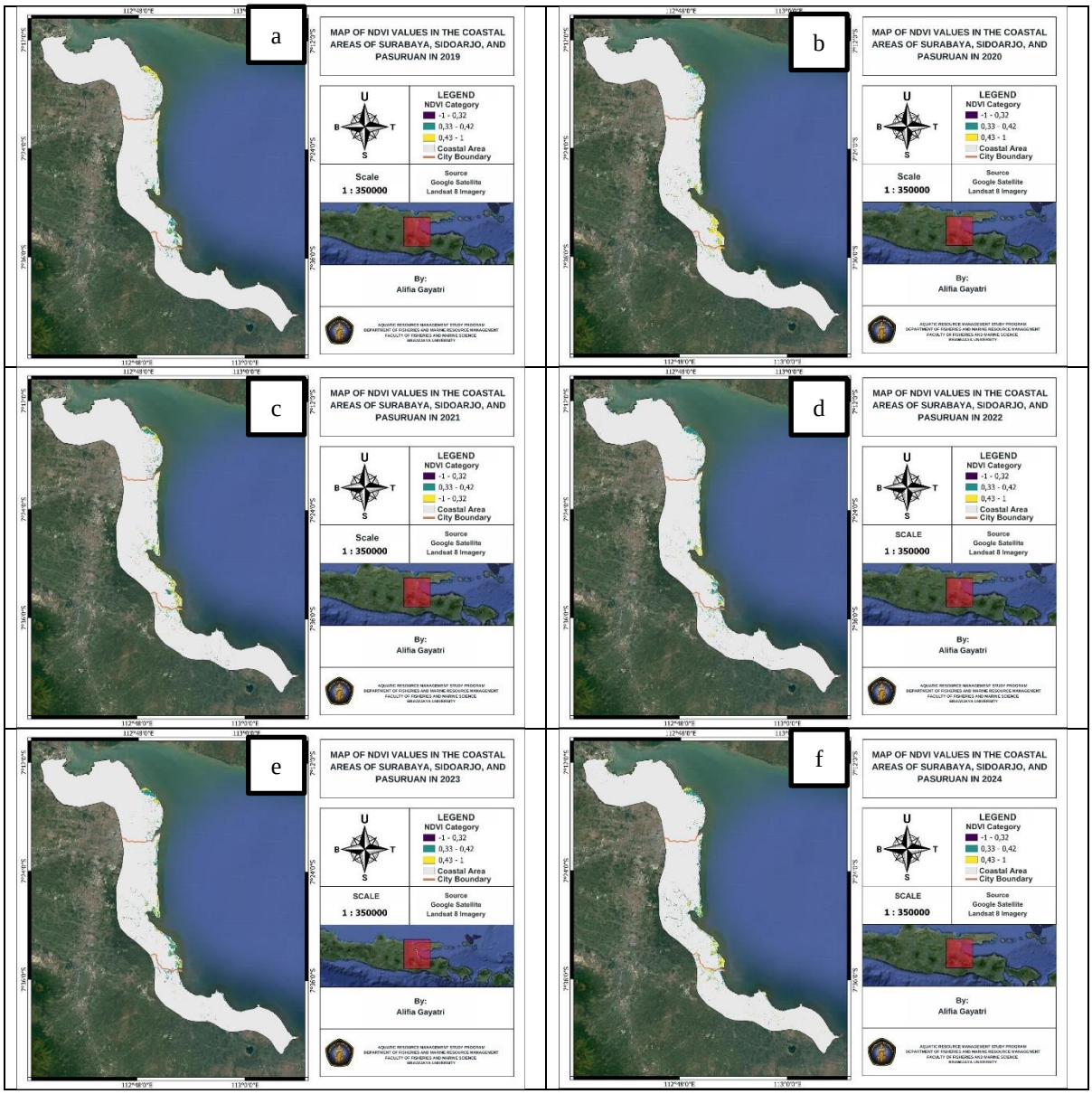

Figure 3. Map of NDVI Values in Surabaya to Pasuruan Coastal Areas in 2019- 2024
a) in 2019; b) in 2020; c) in 2021; d) in 2022; e) in 2023; and f) in 2024.

3.4 Mangrove Density Calculation Using NDVI Index in Probolinggo and Situbondo 2019 – 2024

The result of mangrove forest density at Probolinggo and Situbondo from 2019 to 2024 that calculated using NDVI is divided into 3 classes: sparse, medium and high. The result as shown in Figure 4 and Table 2. The NDVI values with sparse categories were ranges from 51367.12 to 54852.64 hectares. While values of NDVI that considered moderate NDVI were ranges from 5564.87 to 6982.71 hectares. Mangroves with high NDVI values were ranges from 668.18 to 1585.52-hectare coordinate value in actual conditions (Utomo & Bakri, 2023).

Figure 4. Map of NDVI Values in coastal Probolinggo and Situbondo in 2019- 2024 a) in 2019; b) in 2020; c) in 2021; d) in 2022; e) in 2023; and f) in 2024.

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Table 2. Mangrove Density (ind/ha) by NDVI Class Category

Year	Mangrove Density by NDVI		
	Medium	High	Sparse
2019	53159.19	5564.87	747.81
2020	53357.07	5876.39	668.18
2021	55263.23	5705.69	1567.98
2022	51367.12	6265.54	1132.50
2023	54757.89	5709.70	1456.34
2024	54852.64	6982.71	1585.52

3.4 Mangrove Density and Factors Influencing Decline

Several factors contribute to the decline of mangrove populations, primarily human activities such as converting mangrove land into aquaculture ponds (Sihombing *et al.,* 2017). Key causes of mangrove forest reduction include illegal logging, natural factors, and land conversion for various purposes. Among these, aquaculture is a major driver of mangrove forest destruction in Indonesia.

Efforts to increase mangrove density can be achieved through rehabilitation initiatives involving active community participation. Collaboration between the government, private sector, and non-profit organizations plays a critical role in implementing effective mangrove management strategies (Rahma *et al.,* 2019).

3.5 Accuracy Test

RMSE analysis between in situ mangrove density data with the remotely sensed based NDVI data revealed mangrove density values ranging from 0.09 to 0.18, for the data in the year between 2019 till 2024, while image data processing for 2024 produced NDVI values between 0.13 and 0.39.

The RMSE value obtained for this study was 0.18 which was less than 0.5, indicating a high level of accuracy. A lower RMSE value reflects greater alignment between field observations and satellite data, confirming the reliability of the analysis. because the lower the RMSE value, the higher the level of accuracy.

4. CONCLUSION

This study concludes that the mangrove area on the research location which were at especially the coasts of Surabaya, Sidoarjo, and Pasuruan experienced significant changes from 2019 to 2024, with noticeable increases in some years. During this period, mangrove cover ranged from 1,611.88 to 38,542.84 hectares. Similarly, mangrove vegetation density demonstrated fluctuations, showing increases in specific years..

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