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Application of remote sensing and GIS for mapping changes in land area and mangrove density in the Kuri Caddi Mangrove tourism, South Sulawesi Province, Indonesia

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Abstract. *Rosalina D, Hawati, Rombe KH, Surachmat A, Awaluddin, Amiluddin M, Leilani A, Asriyanti. 2023. Application of remote sensing and GIS for mapping changes in land area and mangrove density in the Kuri Caddi Mangrove tourism, South Sulawesi Province, Indonesia. Biodiversitas 24: 1049-1056.* One element of the coastal ecosystem crucial to preserving aquatic production and sustaining coastal dwellers' way of life is the mangrove. Several variables, including temperature, salinity, pH, natural disasters, and human activity, can affect mangrove forests and create changes. In the Kuri Caddi Mangrove ecotourism, Maros Regency, South Sulawesi, mangrove density was calculated, and changes in land area were mapped. From October to November 2022, this study was carried out. The Shapefile (SHP) format was used in the GIS (Geographic Information System) program to calculate changes in the area of mangrove land, and the NDVI (Normalized Difference Vegetation Index) method was employed to calculate density. The Kuri Caddi Mangrove tourism, Marusu Sub-district, Maros Regency, mangrove forest land area increased by about 0.7 Ha between 2014 and 2017, according to an analysis of changes in the area there. From 2017 to 2021, significant changes were indicated by adding 4.05 Ha of land. Supporting environmental conditions and other aspects relating to human activity cause changes in land area. Because mangroves are still growing after rehabilitation, the NDVI values for 2014 and 2017 show a negligible increase in density. However, changes in the NDVI value will start to climb in 2021. The highest NDVI values will be 0.593, 0.652, and 0.691 in 2014, 2017, and 2021, respectively.

Keywords: Change in land area, Kuri Caddi, mangrove, mapping

INTRODUCTION

Indonesia is a country that has the largest mangrove forest in the world (Akhrianti 2019). Mangrove forest is a coastal wetland ecosystem located in the intertidal transition zone between marine and terrestrial realms. It is commonly situated in estuaries, deltas, creeks, lagoons, and swamps, especially in tropical and subtropical areas. Some experts define the term "mangrove" differently, but principally it refers to the same thing, i.e., mangroves are plants in tidal areas and live as communities (Quevedo et al. 2022; Katili et al. 2017). Mangrove, as a component of the coastal ecosystem, plays an important role in maintaining aquatic productivity and supporting the lives of residents in coastal areas (Oktorie et al. 2019; Sari and Rosalina 2016). Mangroves play important roles in the ecosystem, especially regarding ecological, environmental, biological, medical, and economic values. They are predominantly important as habitats for diverse flora and fauna, including rare species, and they are also fertile nurseries that provide breeding grounds for marine life and its communities (Ibharim et al. 2015). Mangroves are highly productive ecosystems for other living things, including spawning grounds for fish, nutrient supply and regeneration, the water cycle, and carbon storage. Biological aspects of mangrove ecosystems play a role in maintaining the stability of coastal biodiversity's productivity and availability. Mangrove also absorbs pollutants, especially organic materials, and supply organic materials for the aquatic environment. In addition, mangroves can absorb carbon in the atmosphere and store it in biomass and sediment, so mangroves play a major role in global climate change mitigation (Pricillia et al. 2021; Hermon et al. 2018). Therefore, the Mangrove ecosystem is an ecosystem that is vulnerable to the process of changeing its physical condition and the number of areas. These ecosystems can experience changes in area due to increased human activities and high population growth (Irawan et al. 2021; Rosalina et al. 2022).

Preservation of mangrove ecosystems in Indonesian territory can be done by knowing changes in the area of mangrove forests so that this can increase knowledge about the condition of mangrove ecosystems in the region (Darmawan et al. 2020; Wang et al. 2018). Temperature, salinity, pH, natural disasters, and human activity are a few of the variables that might affect how long mangrove forests are sustainable. Because of these conditions, mangrove forests degrade to the point where they cannot naturally recover (Bathmann et al. 2021; Eddy et al. 2021). However, mangrove seedlings can be grown and replanted in the degraded area. Moreover, different species of mangroves can be introduced and used in learning activities in schools near the mangrove area. More sustainable hatcheries can be managed while considering the environment's suitability, such as the type of substrate and salinity (Katili et al. 2017).

Changes in mangrove forest area and density can be calculated manually and utilize remote sensing with satellite imagery (Eddy et al. 2019; Eddy et al. 2022). The area change was calculated using the SHP format, and the density was calculated using the NDVI (Normalized Difference Vegetation Index) method by monitoring mangrove vegetation. This is based on two main properties: mangroves have green matter (chlorophyll), and mangroves grow on the coast (Rhyma et al. 2020; Shimu et al. 2019; Alatorre et al. 2016; Idris et al. 2022). In addition, mangrove land cover is generally spread over coastal areas and has a strong root system that can reduce waves, hold mud, and protect the coast from erosion. The Kuri Caddi Mangrove tourism, formerly a pond area and now overgrown with mangroves, is the main factor in collecting land area and density data using remote sensing. This data collection was carried out to clarify the condition of mangrove forests before and after rehabilitation.

MATERIALS AND METHOD

Location and time of research

Data were collected from October to November 2022 at the Kuri Caddi Mangrove tourism, Maros Regency, South Sulawesi Province (Figure 1). This location was selected due to its conversion function changing from a pond to a mangrove rehabilitation area (a place for education and tourism). Mangrove rehabilitation was carried out in 2014 by activists loving mangroves. The changes in land area and density of mangrove forests were identified by taking 3 sample years, namely 2014, 2017, and 2021. Of the 3 sample years, the area and density of mangrove forests experienced significant changes in 2021.

The Kuri Caddi Mangrove, now the Kuri Caddi Mangrove tourism, has many benefits. One of them is preventing water from entering the ponds and becoming a source of income for the community by catching crabs. This is the basis for surveys in mapping changes in land area and density using remote sensing with the Shapefile (SHP) method and the NDVI method (Figure 2).

Analysis of samples

Analysis of change in mangrove land area

Images of the changing area in the Mangrove forest land can be downloaded with remote sensing image data from *Google Earth Pro* (Figure 3), then using the Shapefile (SHP) format in the GIS application, namely ArcGIS 10.2. Figures of the data to be calculated need to be prepared before analysis, and the following procedures are used: (i) - Image data download of the Kuri Caddi Mangrove tourism area in 2014, 2017, and 2021 were inputted into ArcGIS 10.2. (ii) In the Catalog, Shapefile files (SHP) are created with the Polygon category using the UTM (Universal Transverse Mercator) coordinates of the regional zone according to the geography of the Kuri Caddi Mangrove tourism, namely UTM 51S. Edits are then made to mark the area to be calculated. Next, calculate the geometry to calculate the area of the land in the attribute table.

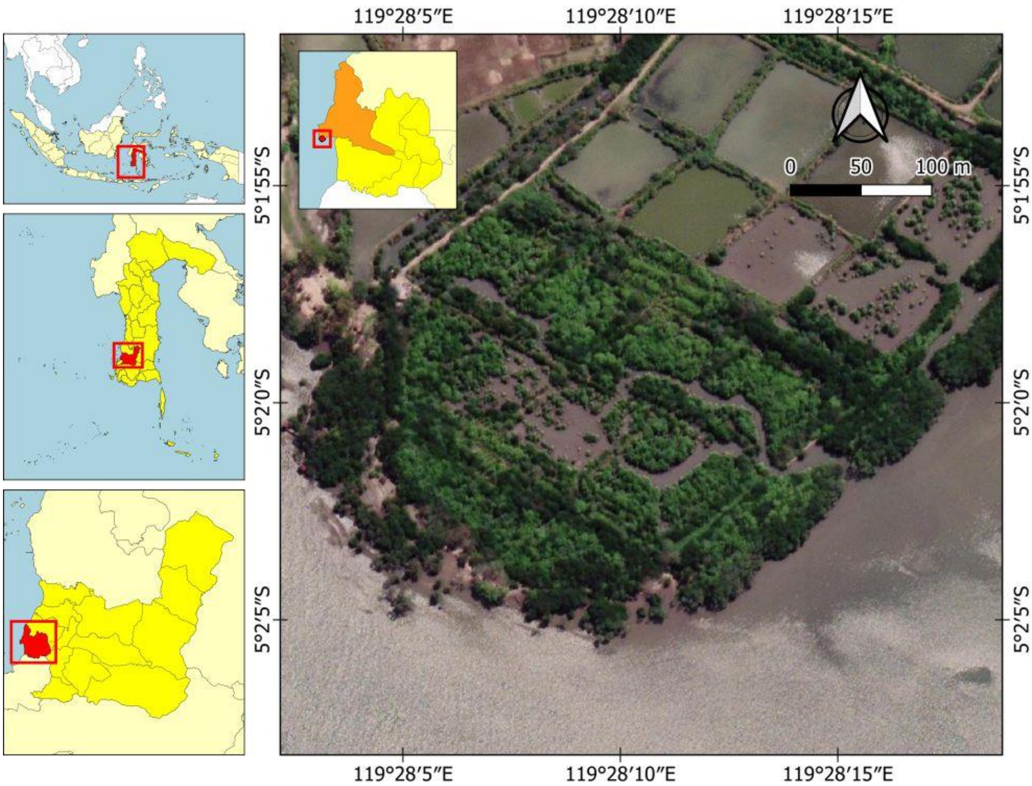


Figure 1. Location points for retrieval of tourism image data of Mangrove Kuri Caddi, South Sulawesi Province, Indonesia

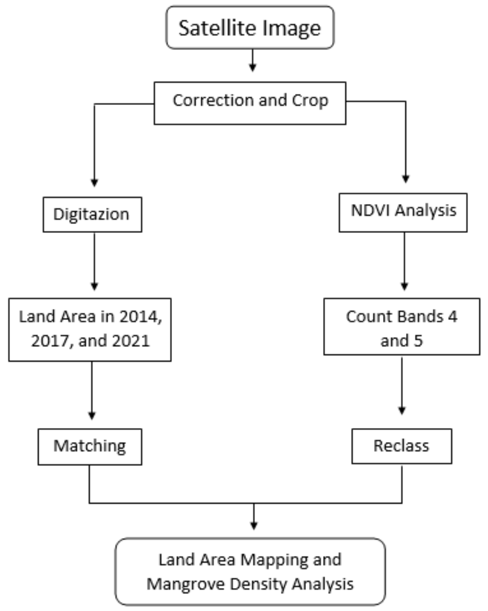


Figure 2. Flowchart of land area mapping and mangrove density analysis

NDVI analysis

The vegetation index is an algorithm applied to satellite imagery to highlight vegetation density or other aspects related to density, for example, biomass, Leaf Area Index (LAI), and chlorophyll concentration. More practically, the vegetation index is a mathematical transformation involving several channels combined at once to produce new images that are more representative in presenting vegetation-related aspects (Pangestu et al. 2021; Xue and Su 2017; Fatiha et al. 2013).

Mangroves are green plants whose density can be calculated by satellite imagery by combining NIR (Near Infra Red) and Red in the band. In analyzing the density results, the USGS image data provider web was required to download the data. The Landsat 8 OLI imagery acted as an image catcher, and ArGIS 10.2 acted as a medium for merging the bands into an NDVI value. The devices used are shown in Figure 4. Determination of Mangrove Forest Density Value was carried out using Landsat 8 OLI image data and the NDVI method:

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

NIR: Spectral Band value of Near Infrared
Red: Spectral Band value of Red

On Landsat 8 OLI, NDVI is the Normalized Difference Vegetation Index; NIR is Band 5, and Red is Band 4.

$$\text{NDVI} = \frac{\text{Band 5 } (\textit{Near Infra-Red}) - \text{Band 4 } (\textit{Red})}{\text{Band 5 } (\textit{Near Infra-Red}) + \text{Band 4 } (\textit{Red})}$$

After NDVI analysis, Reclass was carried out based on the NDVI values obtained (High, Moderate, and Low) based on calculating density class intervals according to the following formula (Setiawan et al. 2013).

$$KL = \frac{xt - xr}{k}$$

KL is an interval class, xt is the highest value, xr is the lowest, and k is the desired class. Because the Kuri Caddi Ecotourism area is classified as not wide, a more detailed classification is needed, namely as many as six classes. This method made it easy to determine which were mangrove and non-mangrove forests. The six classifications used were: Very Rare, Rare, Moderate-Rare, Medium-Dense, Dense, and Very Dense. Process classifier on Vegetation index :

NDVI -1.00 – -0.42 = Very rare
NDVI -0.56 – -0.23 = Rare
NDVI -0.15 – 0.30 = Moderate-Rare
NDVI 0.31 – 0.60 = Medium-Dense
NDVI 0.48 – 0.66 = Dense
NDVI 0.60 – 0,70 = Very Dense

The NDVI value is in the range of -1 to 1. characteristics of specific absorption on chlorophyll and the structure of stomata in leaves as a red-edge effect on vegetation influence this value. Low and high NDVI values represent vegetation density. Soil has a relatively constant reflectance at the wavelengths used for the NDVI equation, which results in an NDVI value close to zero. In vegetation, NDVI is often in the range of 0.1-0.6 (Fawzi and Husna 2021).

A B C

Figure 3. Mangrove Kuri Caddi, South Sulawesi Province, Indonesia on: A. 2014, B. 2017, and C. 2021

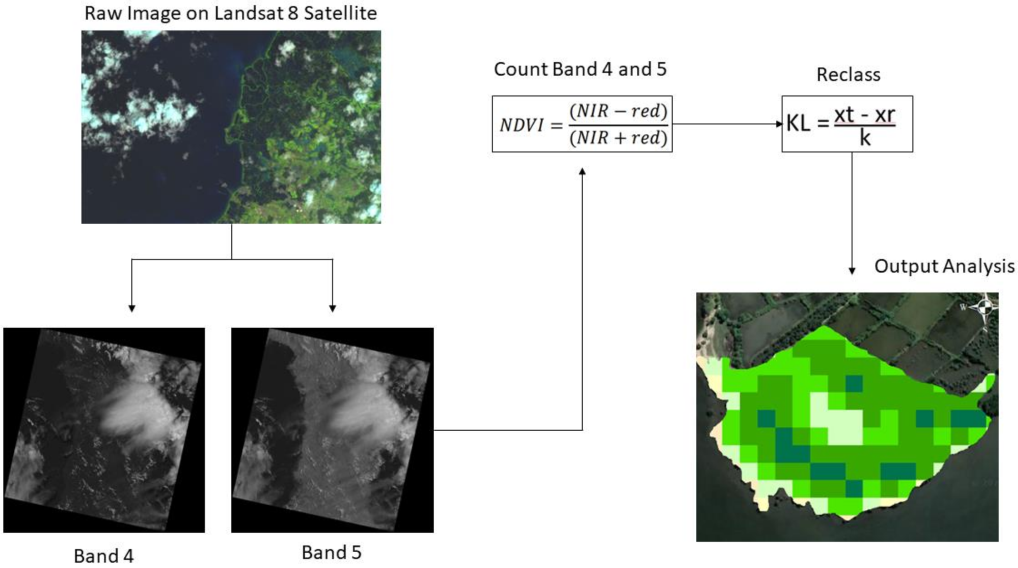


Figure 4. Logarithm analysis of NDVI

RESULTS AND DISCUSSION

Changes in mangrove areas in 2014, 2017 and 2021

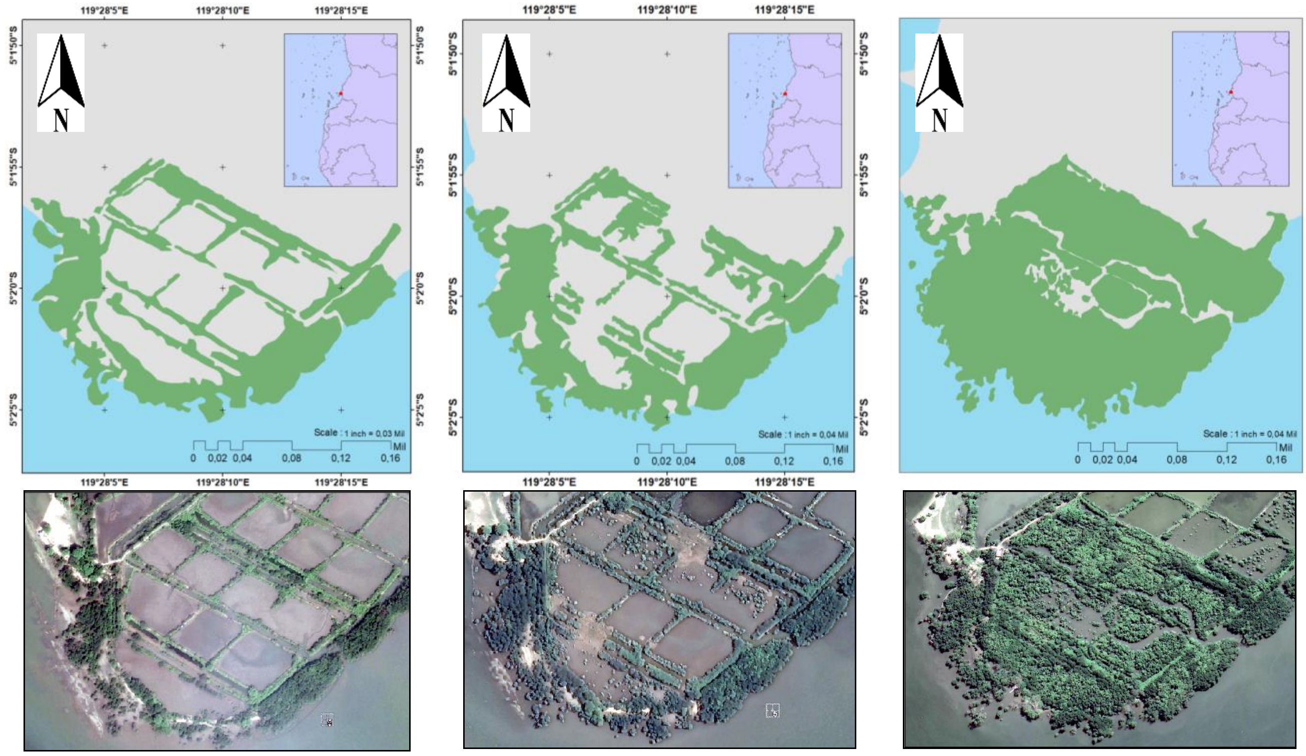
Table 1 displays changes in the area of mangrove forest land. The picture data analysis results show that the Kuri Caddi Mangrove tourism area's land area changed significantly between 2014 and 2021. Mangrove forest covered 4.97 Ha of land in 2014 (Figure 5.A), 5.67 Ha of land in 2017 (Figure 5.B), 4.97 Ha of mangrove forest in 2014 (Figure 5.A), and 9.72 Ha of mangrove forest in 2021 (Figures 5.B-C). The Kuri Caddi Mangrove tourism's land area has changed due to rehabilitation efforts by community members and activists who cared about mangroves, which started in 2014. The region is now a tourist destination and a mangrove learning site. The mangrove ecosystem can support contributions in ecological, social, and economic aspects that affect the resilience of the coastal environment in facing various sorts of threats; mangrove rehabilitation offers long-term advantages that can provide coast protection (Sutton-Grier et al. 2015; Orchard et al. 2016). Numerous rehabilitation initiatives have been made, drawing the consideration of various parties, for example, studies by Nusantara et al. in 2015 in Karawang Regency and Siringoringo et al. in 2018 in Pemanukan, Subang Regency. The mangrove land area increase is also influenced by the distribution of mangrove seeds which thrive and spread around green areas (primary mangrove forests) (Ma et al. 2019). According to Iman (2014), several types of mangrove vegetation found around the Kuri Caddi Mangrove tourism Research Site are *Aigieceras.* sp, *Avicennia alba, Avicennia lanata, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, Ceriops tagal, Exoecaria agallocah, Lumnitzera racemosa, Rhizopora apiculata, Rhizopora mucronata, Rhizopora stylosa,* and *Sonneratia alba.*

Changes in mangroves have been clearly seen 2014, 2017, and 2021. This was confirmed by Suwanto et al. (2021), who stated that mangrove restoration significantly contributes to maintaining mangrove diversity, biomass, and coverage. This follows the opinion of Purwanto et al. (2022) that mangrove rehabilitation activities show a level of success. The benefits of mangroves in the Kuri Caddi Mangrove tourism are starting to be observed, namely preventing water from entering the ponds and increasing crab catches as a source of income for the Kuri Caddi people. The benefits the community has felt cannot be separated from the supporting factors for mangrove rehabilitation in the Kuri Caddi Mangrove tourism, namely the natural factors of waves, tides, and quality parameters in the area, such as water pH, soil pH, and temperature. Khairuddin et al. (2016) said that increases in CO2 and sea surface temperature greatly affect the existence of mangroves. Sutanto et al. (2022) stated that damage to mangrove forests on Bintan Island is caused by climate change and coastal activities such as forest reclamation and logging. This follows the opinion of Suciani et al. (2020), who stated that the area of mangroves has decreased due to human activities (anthropogenic factors) and natural conditions.

Waves and currents can change the structure and function of mangrove ecosystems. In locations with large waves and currents, mangrove forests usually experience abrasion resulting in a reduction in the forest area. Waves and currents also directly affect species distribution; for example, fruit or *Rhizophora* seedlings are carried by waves and currents until they find a suitable substrate to plant and eventually grow (Yun et al. 2022).

Table 1. Increase in mangrove land area in 2014, 2017 and 2021

Year	Mangrove area (ha)	Area change (ha)
2014	4.97	0
2017	5.67	+ 0.7
2021	9.72	+ 4.05



2014 **A** **2017** **B** **2021** **C**

Figure 5. Mangrove land area in: A. 2014, B. 2017, C. 2021

The pH value of water shows a negative algorithm value of the activity of hydrogen ions in a liquid and is an indicator of the merits of the aquatic environment. In general, the death of aquatic organisms caused by a low pH value is higher than the mortality caused by a high pH value. A pH value of 5.5 - 6.5 and > 8.5 includes less productive waters, waters with a pH of 6.5-7.5 are included in productive waters, and a pH of 7.5-8.5 includes highly productive waters (Rahardjanto et al. 2020). Another opinion from (Soeprobowati et al. 2016; Suciani et al. 2020) stated that the pH range for mangrove growth is 7.5-8.8. The results of mapping changes in the area of mangrove land showed significant changes in ph that is good for growth. Therefore, the mangroves can be said to match the pH level of the water in that area, especially when mangroves grow in sea areas and ponds.

Soil pH value is also one of the factors needed for mangroves to develop properly. From the significant growth of the mangroves, it can be said that the pH of the soil in the Kuri Caddi area, the mangroves were rehabilitated, was classified as productive. Generally, the pH of mangrove soil ranges from 6 to 7 and sometimes drops below 5. Soils in mangrove areas are usually acidic due to a large amount of decomposed organic matter. Rahmadi et al. (2020) clarified that the pH range between 6.0-7.0 is fairly neutral. Temperature also plays an important role in the growth of mangroves. The temperature range for several mangrove species, such as *A. marina*, grows well at temperatures of 10-20ºC. On the other hand, *Rhizophora stylosa*, *Ceriops* spp, *Excoecaria agallocha*, and *Lumnitzera* spp can grow optimally at temperatures between 26 to 28ºC. From the results of Iman's research (2014), there are types of mangroves that grow well at temperatures of 10-20ºC in the Kuri Caddi Mangrove tourism so that the temperature in the area follows productive temperature levels. According to the Ministerial Decree. LH No. 51 of 2004, mangroves have a temperature limit of around 20-30ºC.

NDVI

The results of Landsat 8 image data processing regarding the level of vegetation density in the Kuri Caddi Mangrove tourism, Maros Regency, which is divided into six classifications, each year has a different density level, which can be seen in Figure 6.

The Kuri Caddi Mangrove Ecotourism in 2014 showed the NDVI classification with a maximum density of 0.593 (Figure 7). NDVI values in 2014 which were brown, light yellow, and yellow with the classification Very Rare, Rare, and Medium-Rare, indicated pond areas. On the other hand, non-mangrove, where the value only reached -0.732, -0.563, and -0.155, respectively. Areas colored light green to bright green with Medium-Dense, Dense, and Very Dense classifications indicated mangrove areas with density values of 0.312, 0.483, and 0.593, respectively. The density value of mangrove forests in 2014 was still low because the mangrove forest land has not been rehabilitated.

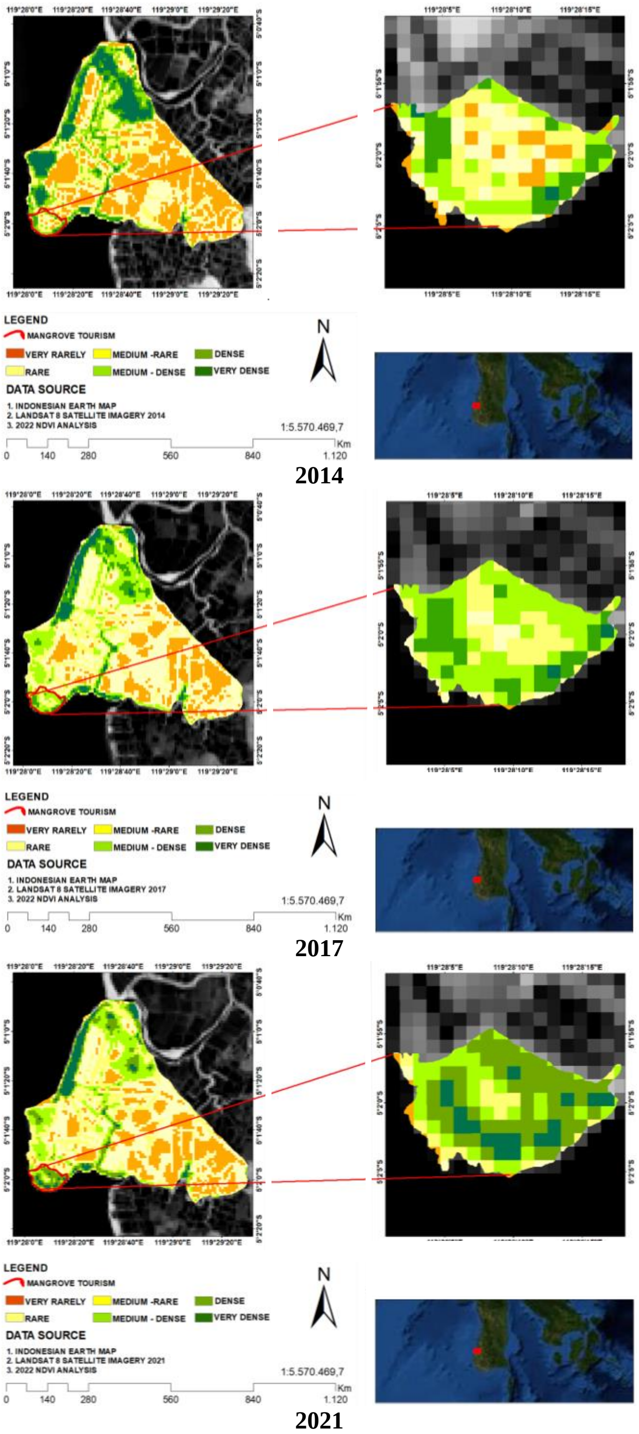
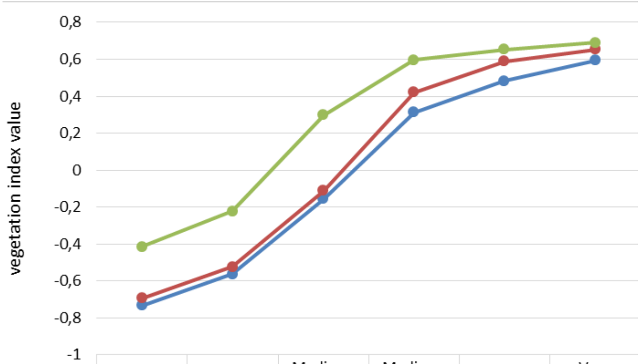


Figure 6. NDVI analysis for 2014, 2017 and 2021

In 2017, it revealed little change in the NDVI density analysis, with the highest density value of 0.652 (Figure 7). The NDVI values in 2017 were brown, light yellow, and yellow with the classifications: Very Rare, Rare, and Moderate-Rare with values of -0.694, -0.523, and -0.112, respectively; these were non-mangrove areas which include ponds or land. While areas colored light green to bright green were classified as Medium-Dense, Tight, and Very Dense classifications with values of 0.422, 0.589, and 0.652; these are mangrove forest areas.



	Very rarely	Rare	Medium-Rare	Medium-Dense	Dense	Very Dense
2014	-0,732	-0,563	-0,155	0,312	0,483	0,593
2017	-0,694	-0,523	-0,112	0,422	0,589	0,652
2021	-0,414	-0,223	0,298	0,596	0,654	0,691

Figure 7. NDVI change for 2014, 2017 and 2021

In 2021, it was shown that the NDVI density categorization of mangroves in the Kuri Caddi Ecotourism Area had improved, with the highest classification value of 0.691, compared to 2014 and 2017 at 0.593 and 0.652, respectively (Figure 7). The 2021 NDVI density classification was quite different from the previous year because mangrove forests were included in yellow to dark green areas. While non-mangrove forest areas were only classified as Very Low and Rare (brown and light yellow), respectively, with values of -0.414 and -0.223. The NDVI classifies Moderate-Rarely, Medium-Dense, Dense, and Very Dense as having values of 0.298, 0.596, 0.654, and 0.691, respectively. As noted by Pasaribu et al. (2020) and Peereman et al. (2021), there is a linear relationship between the total density of mangrove vegetation and the level of mangrove canopy cover.

According to Lagomasino et al. (2015) and Landeros et al. (2018), areas with a high level of green saturation (dark green) are areas that still have a lot of vegetation because the vegetation index itself describes the level of greenery of plants in factual. Following the opinion (Snyder et al. 2019; Rahmat et al. 2022), the NDVI method compares vegetation's greenness in satellite imagery data standards. This index is a mathematical combination between the red band (Red) and NIR (Near Infrared Radiation). NDVI has a value range of -1 to 1. A value of -1 indicates water, and a value of +1 indicates vegetation; a value close to 0 is open land (Hendrawan et al. 2018). We cannot use minus values for emissivity processing. That is the basis for water having a high emissivity value, almost equal to vegetation (Ruan et al. 2022).

In conclusion, the analysis of changes in mangrove land in Kuri Caddi, Marusu Sub-district, Maros Regency, from 2014 to 2017 showed an increase in land area of around 0.7 Ha. However, from 2017 to 2021, significant changes can be observed in the form of an additional 4.05 Ha of land. Changes in the land area occurred because of environmental parameters that supported and factors of human activities that carried out rehabilitation. In 2014 and

2017, the increase in density had not shown a significant change because mangrove plants were still in the growth stage after rehabilitation, while in 2021, changes in the NDVI value began to increase. The highest NDVI values in 2014, 2017, and 2021 were 0.593, 0.652, and 0.691, respectively.

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