

Ecological status of threatened mangroves *Ceriops decandra* and *Merope angulata* in mangrove ecosystem Segara Anakan Lagoon, Central Java, Indonesia

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Abstract. Mangrove ecosystem Segara Anakan Lagoon (SAL), is the largest mangrove ecosystem in Java that is occupied by various types of mangroves. Several studies have shown the deforestation of mangrove in SAL which caused the decrease of mangrove biodiversity and species density. This study aims to obtain updated information on the distribution and density of two mangrove species found in SAL that are listed in the IUCN, which are *Ceriops decandra* (Threatened) and *Merope angulata* (Least Concerned). This research was conducted with the stages of literature study and analysis of satellite imagery using Sentinel 2 and the NDVI equation to obtain the change of mangrove cover and density. The literature study found that *C. decandra* was mostly distributed in the eastern and central sites of the Lagoon, while *M. angulata* was distributed in the center site. According to the spatial analysis, the density of *Ceriops decandra* was found >0,5 while *Merope angulata* is distributed in the center site with a medium density categorized. The degradation of the mangrove ecosystem in 2023 was estimated to be 10.493,64 ha. The information provided in this study is expected to improve conservation and protection actions for the sustainability of the threatened mangroves species in SAL.

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1 Introduction

The mangrove forests have a high potential function to be used and provide service protection and benefits for the local community. Mangrove resources in Indonesia cover a huge area reaching 22% of the total mangrove forest area in the world with high species diversity [1]. Currently, the area of mangrove ecosystems in Indonesia has decreased by about 30-50% with a deforestation rate of 52.000 ha yr⁻¹ [2]. Mangrove deforestation is identified as caused by land use change, pond development, agriculture, industry, abrasion, and excessive logging [3,4].

Java Island, Indonesia, has the largest remaining mangrove forest namely Segara Anakan Lagoon in the Cilacap Regency-South Coast of Java Island. Segara Anakan Lagoon is ecologically important because this site is high in biodiversity of coastal ecosystems such as mangroves, saltwater marshes, intertidal mudflats, and open water [5,6,7]. Socially and economically, the existence of the Segara Anakan lagoon strongly supports the livelihoods of coastal communities in the coastal fisheries sector [8,9].

Several studies reported that the mangrove-vegetated area in Segara Anakan is estimated to be 6.126,28 ha [10, 11]. Mangrove degradation in Segara Anakan occurs due to sedimentation, land use change for rice fields, fishponds, agriculture, settlements, industrial areas, and other land cover [6]. The impact of mangrove degradation in Segara Anakan causes biodiversity to be degraded and reduced, including the diversity and population of vegetation and coastal biota in mangrove [12,13,14,15]. One of them is threatened mangrove vegetation which is reported in the Segara Anakan mangrove area. The type of mangrove *Ceriops decandra* with *Near Threatened* status while the *Merope angulata* type has *Least Concern* status included in the International Union for Conservation of Nature (IUCN) red list [16,17,18].

The existence of threatened mangroves is quite important, considering that *Ceriops decandra* is a type of major mangrove that grows in tides zone areas, while *Merope angulata* is a type of derivative mangrove that can grow in zoning exceeded by tides. Naturally, the population of critical mangroves is a small number because of their limited distribution and specific habitat [19]. The ecological and distribution condition of threatened mangroves is also important to know because it can be used as inventory and identification to conduct the conservation program. Community participation is also important in mangrove ecosystem management. So that the existence of these types remains sustainable [20].

The Government and other stakeholders have made some efforts to recover environmental degradation by applying management programs and producing regulations in Segara Anakan [21]. One of them is the Cilacap Regency Regional Regulation No. 6 of 2001 which stated that Segara Anakan is a conservation zone area. However, mangrove degradation in Segara Anakan still continues to increase. The existence of important ecosystems and distinctive habitats aimed at protecting critical habitats for certain species can add value to the conservation efforts [20,22], which in this case can protect the existence of mangrove ecosystems in Segara Anakan.

The existence of the IUCN-listed mangrove species in Segara Anakan can add important value to conservation efforts in this area. Understanding the ecological status of *C. decandra* and *M. angulata* therefore is essential to support the conservation strategy. This study aims to obtain updated information of the distribution and density of the two IUCN-listed mangroves in Segara Anakan Lagoon using a combination of satellite approach and literature study. Hopefully the information can be useful for future conservation management in the Segara Anakan lagoon area.

2 Material and methods

2.1 Description of the Study Site

The coverage area evaluated is the mangrove area in the Segara Anakan lagoon with observation limits at 3 location points, West, Central, and East parts, with coordinates 7035' – 7046" S dan 1080 45" – 1080 01" E (Figure 1).

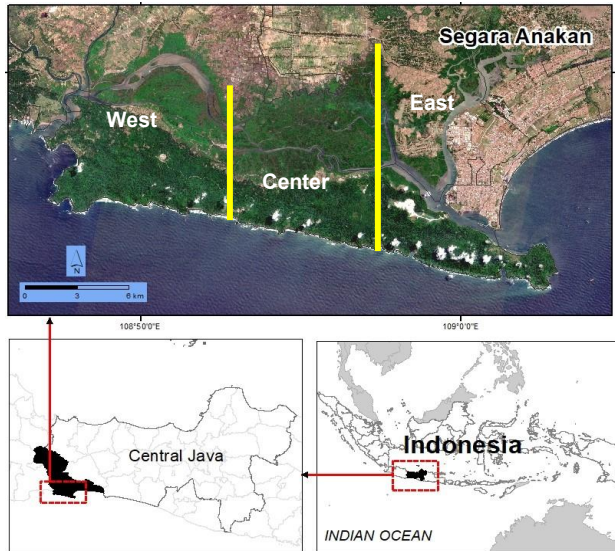


Fig. 1. Map of the study area in Lagoon Segara Anakan (Source : Basemap from Sentinel 2A image date: August 29th 2023 (<https://scihub.copernicus.eu/>) and Administration boundary from BIG (<https://tanahair.indonesia.go.id/portal-web>))

2.2 Methods

Data collection was carried out using a literature study, while the ecological status and distribution of threatened mangroves in three sites of Segara Anakan (west, centre and east) were determined descriptively according to several studies. Then the mangrove land cover and mangrove density are conducted using image analysis.

2.2.1 Mangrove and Land Cover

Land cover information was obtained from modified Land Cover maps/ Land Use generated by Esri from the website [arcgis\[dot\]com](http://arcgis.com). The map comes from Sentinel-2 ESA imagery with a spatial resolution of 10m in 2022 but does not specifically mention the mangrove class. Mangroves are included in flooded vegetation, namely areas with any type of vegetation that are mixed with seawater for most of the year, seasonally flooded areas. Examples include flooded mangroves, emerging vegetation, rice fields, and other irrigated agriculture. To determine the mangrove area, the Mangrove Vegetation Index (MVI) algorithm is used. This MVI is used to map mangrove areas accurately and quickly from Sentinel-2A imagery. The three of Sentinel-2 bands used are Near Infrared (NIR), Green, and Short Wave Infrared (SWIR) using the following algorithm:

$$|NIR[\textit{minus}]Green \textit{divide by} SWIR[\textit{minus}]Green| \tag{1}$$

MVI is used to distinguish differences in greenness and humidity of mangroves from terrestrial vegetation and other cover of land. The threshold of MVI for mangrove areas ranges from 4.5 to 16.5 [23]. To gain information on changes in mangroves in different years, remote sensing image interpretation. The information was based on values of digital recorded in data from remote sensing. The material used in this research is mangrove vegetation data obtained through literature and processing satellite images. The Sentinel 2A satellite image was recorded on August 29 2023 which was obtained via the official website <https://scihub.copernicus.eu/>. This research uses Version 3.22 of QGIS software downloaded from the QGIS website. QGIS is Free and Open Source software for Geographic Information Systems that can run on Linux, Windows, Unix and Android and supports raster and vector formats. The Indonesian database of administrative boundaries of Cilacap Regency, East Java, was downloaded from the Agency of Geospatial Information (BIG) website.

2.2.2 Mangrove density

Information on mangrove density was obtained from Normalized Difference Vegetation (NDVI) data. NDVI is an index that describes the level of greenness of a plant. In the extraction process, NDVI values are based on calculating Near Infra Red with Red reflected by plants. The following is the equation for calculating NDVI:

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{2}$$

Where:

NDVI = Normalized Difference Vegetation Index

NIR = Near-infrared spectral channel value

RED = Red spectral channel value

The higher the NDVI value (closer to 1), the better the vegetation condition (has a high density). On the other hand, if the NDVI value is lower, the vegetation conditions will be less and may even indicate non-vegetation conditions. NDVI can be used to determine forest vegetation and non-forest vegetation areas. By using this method, high or low density of vegetation such as forests can be known [24]. NDVI has an index value ranging from -1 which is non-vegetation and 1 which is a vegetation object. Determination of the density level is obtained based on the distribution of data in the field which is classified into 3 (three) classes, namely rare, medium and dense.

3 Result and discussion

3.1 Mangrove land cover in Segara Anakan Lagoon

Based on Sentinel-2 analysis, ecosystem mangroves in Segara Anakan have decreased into rice fields, settlements, and agriculture as the majority land while the aquaculture sector and illegal logging also exist in this area. The result shows that currently, the area mangrove has 6.696,4 ha which is distributed in the Segara Anakan area (Figure 2).

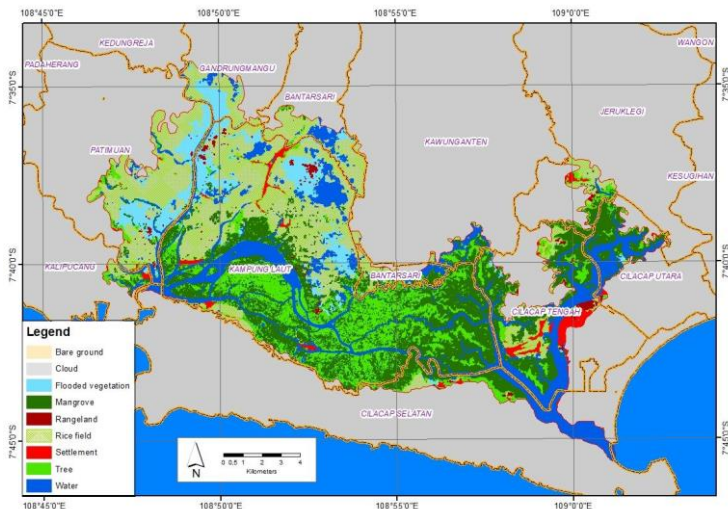


Fig. 2. Mangrove land cover in Segara Anakan Lagoon (Source: Data analysis, 2023, from Esri Landcover map and Sentinel 2A image)

Figure 2 shows the distribution of land cover in Segara Anakan lagoon, the largest area is rice fields, which is around 32% in the western part of Segara Anakan while the mangrove ecosystem has a total area of 27% which is spread out widely distributed in the west, central and eastern sites. Mangrove land in Segara Anakan continues to be degraded as human activities increase year to year. Land cover in Segara Anakan shows that the mangrove and rice fields area declined in line with the settlement and agriculture increase with values of 2,7% and 15% respectively. The development of settlement is seen in the east, west, and central sites, with the largest development being in the east. The change of mangrove area into agriculture is also found in three sites and the largest is in the centre (Figure 3). According to the statement of [25], the area of mangroves, lagoons, rivers, and mudflats in Segara Anakan is inversely proportional to the increase of settlements, rice fields, ponds, and industrial areas.

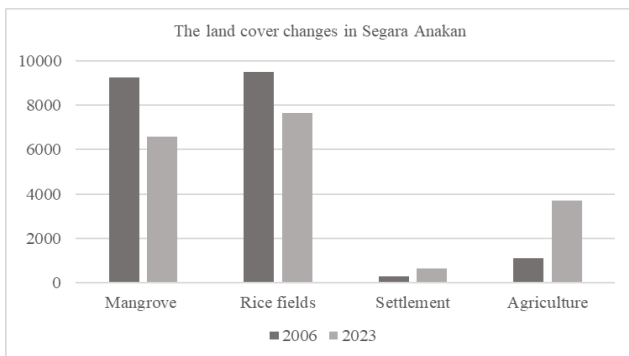


Fig. 3. Land cover changes in Segara Anakan (Source: Data analysis 2023 and [25])

Segara Anakan has had land changes in the mangrove area since 1978. Recorded in 1978, the area of mangroves in Segara Anakan was 17.090ha then in 1987 there was a decrease to 15.827.6ha, or a decrease every year with a rate of -0,8%. The mangrove area continuously

degraded and reduced, in 1995 the mangrove area became 10.974ha then in 2003 the mangrove area became 9.597ha [25].

The update from the results of this study in 2023 is the condition of the mangrove area is about 6.596,36ha, or a decrease of 10.493,64ha or a reduction of 61,3% over the years (Figure 4).

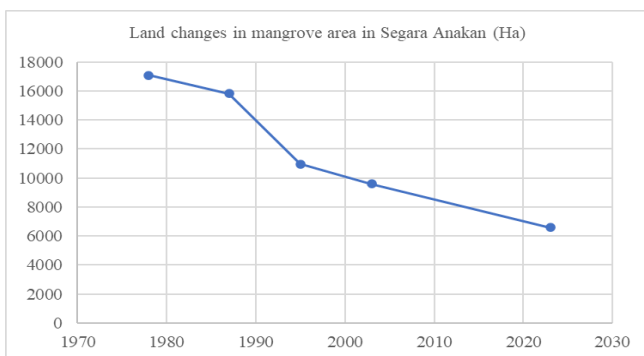


Fig. 4. Land changes in mangrove area (Source: Data analysis 2023 and [25])

The wide change mangrove land in Segara Anakan is changed to ricefields by 42%, cultivation by 2,5%, agriculture by 5,4%, and industry by 1%. In addition, there are also natural factors, such as the high sedimentation with an estimate of 1-3 million tons/year [12].

3.2 The ecological status of *Ceriops decandra* and *Merope angulata* in Segara Anakan Lagoon

One of the special characteristics of the mangrove ecosystem in Segara Anakan Lagoon is in the estuary, which is influenced by several rivers such as the Citanduy River, Cibereum River, Cimeneng River, Palindukan River, Cikonde River, Sapu Regel River, Donan River. Therefore, the confluence of freshwater from rivers and saltwater from the Indian Ocean causes the water area to become brackish. This condition is a good habitat for mangrove vegetation to grow and form an ecosystem. Many studies were recorded including the type of mangrove species in Segara Anakan Lagoon. The most mangrove-dominant of tree and sapling at three sites is *Avicennia marina* as the natural mangrove stand of Segara Anakan [26].

Based on literature study and result of this analysis showed that the biodiversity of mangrove ecosystems in Segara Anakan Lagoon is in healthy condition but rapidly decreasing due to human activities and natural factors such as sedimentation. This condition has an impact on the existence of mangrove species. In Segara Anakan there are threatened mangrove species, namely *Ceriops decandra* and *Merope angulata*, it's reported that there is a decrease in population in the two types of mangroves.

Both are types of mangrove plants that grow in the tropics. *Ceriops decandra* is a true mangrove species of the family Rhizophoraceae while *Merope angulata* is of the family Rutaceae. Both species live in different habitats, where *Ceriops decandra* can grow in the marine intertidal zone while *Merope angulata* in terrestrial areas.

The distribution map of both mangroves as a result from analysis Sentinel 2 images and based on several research results found that the distribution of *Ceriops decandra* mangroves was on the east and center sites of Segara Anakan Lagoon while the type of *Merope angulata* was found on the center site as shown in Figure 5.

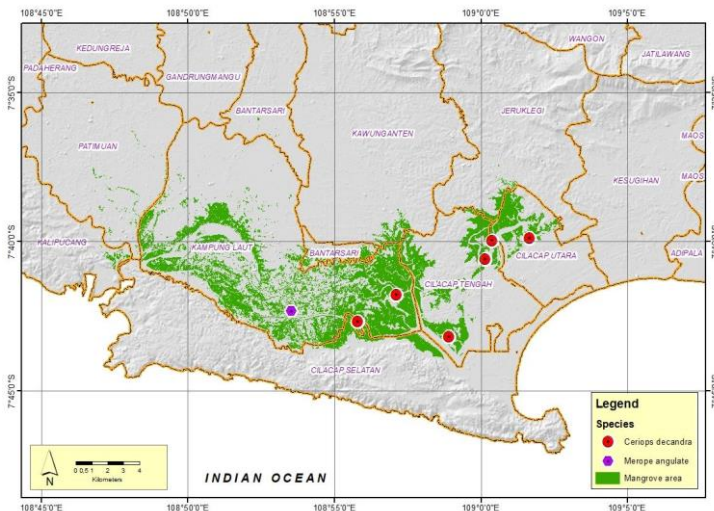


Fig. 5. The distribution of threatened mangrove species *Ceriops decandra* and *Merope angulata* (Sources: Data analysis, 2023, basemap Digital Elevation Model (DEM) from <https://tanahair.indonesia.go.id/demnas>) and mangrove location based on [27,28,17])

The result from research [28] shows that *Ceriops decandra* has a DBH range of about 1,91-35,69 with tree density of about 0,17; basal area means of $0,05 \pm 0,004$ and dominance range of 1,80. The value of importance value index (IVI) of *Ceriops decandra* is 3,97% [29]. It means this type has an important role in the ecosystem. Based on these data, the type of *Ceriops decandra* was found in the form of trees and saplings with ecological conditions in environmentally appropriate. Meanwhile, the biodiversity index of *Merope angulata* around 0,05 based on research [17] with a density index categorized as medium dense (Figure 5). Further research is needed to find out the ecological data of these types.

Species density of C. decandra and M. angulata in Segara Anakan

Based on NDVI equation result analysis, the mangrove density in Segara Anakan Lagoon has a range from $<0,3$ to $>0,5$. The highest density value of about $>0,5$ or around 50-60% was predicted to be dense at the center and east sides (Figure 6). This value can indicate an ecological status that mangrove vegetation in Segara Anakan in a better level of health of mangrove.

In figure 6 shows the density of mangroves in the central side has a high density, namely Ujungalang Village, Kampung Laut District, with a high-density value range of 41,3% covering an area of 2.722,6ha based on Sentinel 2 images analysis. Furthermore, the mangrove area on the east side, precisely in Kutawaru Village, Central Cilacap District, has a high mangrove density of 16,9% with an area of 1.120ha. Segara Anakan mangrove on the west side which has a density value of $>0,5$ is Klaces Village in Kampung Laut District of 11,8% with an area of 775,7 ha. The lowest density value is on the east side, which is around 0,001% with an area of 0,07ha in Tritih Wetan Village, Jeruk Legi District.

The results of mangrove density from [10] in 2017 showed the highest value was on the west site while the central and eastern parts had medium density values. The results of this study show the opposite value. This condition shows that mangroves in the Central and Eastern Regions have grown for approximately six years, but unfortunately, the condition of high-density mangroves in the west is reduced due to changes in land for human activities.

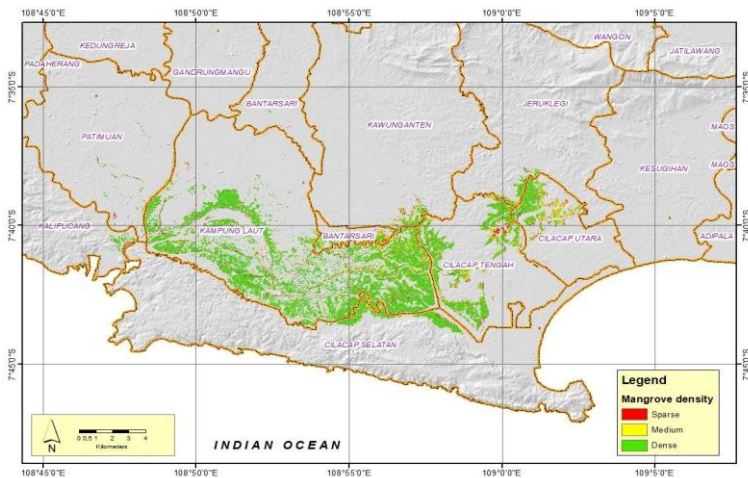


Fig. 6. Mangrove density in Segara Anakan (Source : Data analysis, 2023, basemap Digital Elevation Model (DEM) from <https://tanahair.indonesia.go.id/demnas>)

Segara Anakan has a density and number of various types of mangroves. Mangroves on the east site are denser than the west [27]. The results of [29] showed that the observations in the Segara Anakan lagoon mangroves, found 14 types of mangroves including threatened species of mangroves, namely *Ceriops decandra* with an importance value index for trees of 0%, saplings of 7,16% and seedlings of 3,97%. This index value is relatively small compared to the dominating species in the saplings, namely *Avicennia alba* has an important index value for trees of 80,93%, saplings of 30,73%, and seedlings of 12,11%.

According to [30] who conducted research in the Segara Anakan Lagoon in 2005, the species *C.decandra* was found to be 0.033+/- 0.22 ind/m², while [31] who conducted research in 2015 at the same location found the that the species density was reduced to 0.016 +/- 0.03 ind/m², with similar result of 0.17 ind/m² reported by [28] who conducted study at the same location in 2016. The results implied that after a decade, the density of *C.decandra* has decreased, likely due to continued deforestation in Segara Anakan Lagoon. However, according to our NDVI analysis in 2023, the species *C.decandra* was found to be relatively dense (>0.5), although validation on the field must be conducted to identify the trend of increase or decrease in density. Unfortunately for species *M.angulata*, only a little information was found regarding the density of this species. However, according to NDVI analysis, the density was categorized as medium, although further study is needed to discover their existence.

Maintaining the existence of threatened mangroves

Healthy mangrove conditions must be maintained so as not to be degraded by human needs. The existence of threatened mangroves has an impact and benefits on environmental sustainability. Its existence must be protected from the impact of deforestation [32]. Trees that still survive and still exist can produce propagules for replanting to increase their growth. This activity is an implementation of conservation programs.

According to the land cover result, the mangrove area continues to decrease along with increasing settlement and agriculture. There is a need for a recovery program by replanting mangroves, especially for threatened species. The ecological and distribution condition of threatened mangroves is also important to know because it can be used as inventory and identification to conduct the conservation program. Community participation is also

important in mangrove ecosystem management. So that the existence of these types remains sustainable.

4. Conclusion

The updated information of this study which is the result analysis showed that degradation of the mangrove ecosystem in Segara Anakan Lagoon in 2023 was estimated to be 10.493,64 ha or a reduction of 61,3% over the years. The density of both threatened mangroves was predicted to be dense with a range of >0,5 at the centre and east sites. Kampung Laut district has a high-density value range of 41,3% covering an area of 2.722,6ha. The distribution of *Ceriops decandra* is found in the east and centre sites while *Merope angulata*'s distribution is on the centre site.

This study suggests for further study to have detailed survey related to threatened mangroves. The accuracy of mangrove interpretation results needs to be improved by ground checking into the field and using other proven classification methods to get more accurate results. Mangrove vegetation should be periodically monitored to get the rate of changes, record the abundance, the presence and analyze in more detail the effect of increasing human activity.

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