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Quantifying the Impact of Changes to the Segara Anakan Lagoon Indonesia Over 30 Years

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A B S T R A C T

The Segara Anakan Lagoon in Cilacap, as one of the natural ecosystems in Java, has undergone drastic changes in the last three decades. This study investigates the dynamics of its area change using 30 years of multitemporal satellite imagery. The Normalised Difference Water Index (NDWI) method is used to detect changes in water bodies. The analysis showed a significant decrease in the surface area of the lagoon, which was significantly influenced by increased sedimentation. This sedimentation is closely linked to human activities in the upstream area, including logging and land conversion. Based on the NDWI analysis, it is known that the lagoon area changed from -6,486.80 ha in 1990 to 2819.21 ha in 2003 (-3,667.60 ha) and the reduction of the lagoon in 2003-2021 is -2819.21 ha. There is a significant decrease in the water content over time. This study investigates the importance of conservation measures and sustainable management to protect Segara Anakan Lagoon from the continuing negative impacts of sedimentation.

Keywords: mangrove, NDWI, sedimentation, Segara Anakan

1. Introduction

Segara Anakan is a lagoon located behind the island of Nusakambangan, facing the Indian Ocean. The area has a natural mangrove forest and the lagoon is a centre of biodiversity. The material on the bottom of the lagoon is of terrestrial rather than marine origin. This area, also known as the "littoral margin", has a salinity derived from a mixture of seawater and fresh water. Biologically, the lagoon ecosystem is extremely rich. Only about 13% of the world's land area is lagoon (DKP, 2007). Segara Anakan in Cilacap is one of Indonesia's most important lagoons, surrounded by mangrove forests and tidal flats that provide significant ecosystem diversity and environmental services. However, like many other coastal areas around the world, Segara Anakan faces environmental challenges due to changes in sedimentation rates and changes in mangrove land cover. These changes affect not only the biodiversity and productivity of the ecosystem, but also the communities that depend on these resources (Su et al., 2012).

In the current era of digital technology, multi-temporal satellite imagery has become an important tool for monitoring and assessing coastal dynamics. The main advantage of this technology is its ability to provide a broad view of areas that are difficult to access and to monitor changes over time. Therefore, multitemporal satellite imagery provides an objective picture of how sedimentation rates and mangrove land cover change over time in Segara Anakan (Asbridge et al., 2016).

Segara Anakan faces a serious problem of increasing sedimentation from land-based sources. The area and depth of the Segara Anakan lagoon continue to decrease. This is caused by forest exploitation in the upstream area, which does not prioritise conservation aspects. (KPSKSA, 2009) The main source of sedimentation in Segara Anakan comes from rivers such as the Citanduy, Cibeureum and Cikonde, while a small amount comes from coastal sedimentation. According to research by the Directorate General of Local Government of the Ministry of the Interior and PKSPL-IPB (1999), the Citanduy River contributes 740,000 m3 of sedimentation annually to Segara Anakan, while the Cikonde River contributes about 260,000 m3 annually. Thus, the total sedimentation entering Segara Anakan reaches about 1 million m3 per year. Continued sedimentation can raise the water level in the Citanduy and other rivers that flow into Segara Anakan, increasing the potential for flooding in the area. In addition, siltation caused by sedimentation threatens to degrade the ecological condition of Segara Anakan. According to BPKSA (2006), Segara Anakan currently covers only about 500 hectares.

Understanding the dynamics of sedimentation and mangrove cover is essential for designing effective conservation and management strategies. In this context, research using multitemporal satellite image analysis in Segara Anakan, Cilacap, can provide valuable insights into how natural processes affect mangrove cover.

2 Materials and Methods

The materials used in this research are satellite imagery and ground check data. Satellite images were divided into three, namely Landsat 5 in February 1990, Landsat 7 in January 2003, and Sentinel 2B in April 2021 in Segara Anakan, Cilacap Regency, Central Java. Ground check activities are carried out with coordinate points using GPS (Geographical Positioning System) that have been determined to cross check between satellite image data and field conditions.

Table 1. Specifications of the Satellite Images Used

Data type	*Bands*	resolution(m)	Date of Acquisition	Path/ Row	Data source
Landsat 5 TM	RGB 543	30	24 February 1990	121/65	USGS
Landsat 7 ETM	RGB 543	30	19 January 2003	121/65	USGS
Sentinel-2	RGB 654	10	16 April 2021	121/65	Copernicus

Landsat 5, 7, and Sentinel 2B satellite images and ground check coordinate data in the field with the location under study, Segara Anakan, Cilacap Regency, Central Java, were obtained from the United State Geological Survey (USGS) through https://earthexplorer.usgs.gov/ and SciHub Copernicus through https://scihub.copernicus.eu/dhus/#/home. Satellite image specifications and ground check coordinates used in this study are presented in Table 1 and Table 2.

Table 2. Ground Check Result Coordinates Using *Geographical Positioning System* (GPS).

No	*Latitude*	*Longitude*	Keterangan Lokasi
1	108°51' 13.91" E	07° 39' 16.53"S	Agriculture
2	108°48' 08.16" E	07° 40' 24.05"S	Agriculture
3	108°51'54.8"E	07°42'04.1"S	Agriculture
4	108°48' 03.46" E	07° 40' 15.23"S	Agriculture
5	108°52' 09.27" E	07° 41' 56.02"S	Agriculture
6	108°51' 05.92" E	07° 41' 28.34"S	Pond
7	108°52' 38.00" E	07° 40' 40.48"S	Pond
8	108°52' 38.14" E	07° 40' 40.65"S	Pond
9	108°52' 34.53" E	07° 40' 39.49"S	Pond
10	108°52' 44.52" E	07° 43' 06.51"S	Settlements
11	108°52' 45.41" E	07° 43' 07.97"S	Settlements
12	108°52' 13.56" E	07° 42' 19.65"S	Settlements
13	108° 52' 35.1264" E	07° 42' 55.23" N	Settlements
14	108° 50' 35.642" E	07° 40' 24.477" S	Mangrove
15	108° 52' 34.022" E	07° 41' 6.396" S	Mangrove
16	108° 55' 1.677" E	07° 40' 54.203" S	Mangrove
17	108° 55' 56.651" E	07° 42' 24.880" S	Mangrove
18	108° 51' 21.846" E	07° 41' 46.376" S	Mangrove
19	108° 52' 19.162" E	07° 42' 3.021" S	Mangrove
20	108° 52' 39.391" E	07° 42' 14.099" S	Mangrove

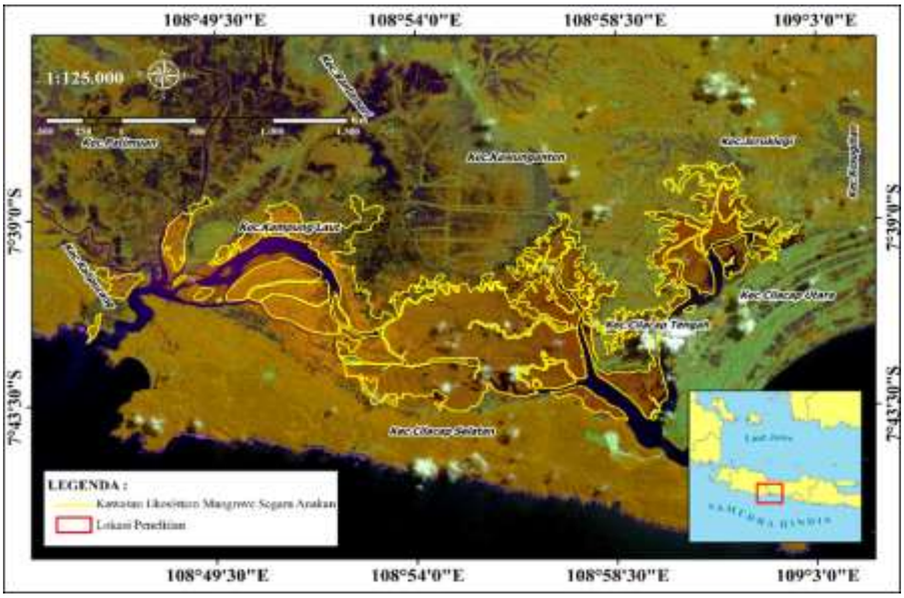

Fig 1. Map of the Research location in the Segara Anakan Lagoon Area, Cilacap Regency

The research method used in the analysis of sedimentation rates and mangrove land cover changes is the remote sensing method, namely the satellite image interpretation technique (visual interpretation) with Supervised Maximum Likelihood Classification (MLC) (guided classification) and NDWI (Normalised Difference Wetness Index). The image data used in this study are 30 years of image data, 10 years interval, namely Landsat 5TM satellite image in 1990, Landsat 7 ETM in 2003 and Sentinel 2B in 2021.

The Normalised Difference Water Index (NDWI) method is a method used to compare the level of moisture in satellite images, the NDWI method uses band 3 (green) to assess the strength of plants and water bodies and band 5 (NIR) to highlight the biomass content. The NDWI algorithm is as follows:

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR}$$

Description:

GREEN = Green channel reflectance value

NIR = Infrared channel reflectance value

Normalised Difference Water Index (NDWI) is a method used to identify water bodies. Water bodies tend to absorb visible and infrared wavelengths with high intensity. According to McFeeters (2013), a NDWI value greater than zero indicates the presence of surface water bodies. The use of NDWI in satellite image analysis can provide valuable insights into the dynamics of sedimentation processes in an area and how they change over time. However, it is important to combine NDWI with other observational methods to gain a more comprehensive understanding of the process. This research consists of processing and analysing remote sensing data and is supported by exploratory ground truthing field data. Exploratory research is a research approach that aims to find information about a topic/problem and reveal something from the field as findings that can be used to draw conclusions (Mudjiyanto, 2018). Exploratory descriptive method is a method of collecting data by paying attention to the cause and effect of an element and feature, which is then analysed and interpreted (Zakariah et al., 2020).

3. RESULTS AND DISCUSSION

The results of the analysis of Landsat 5TM imagery in 1990, Landsat 7 ETM imagery in 2003 and Sentinel 2B imagery in 2021. Based on the land cover classification, which is divided into 3 land cover classes. The land cover class is divided into mangrove, land and water. The land cover classification uses the supervised classification method and the NDWI method. The results of the land cover change map in Segara Anakan are shown in Figure 2 using the NDWI method and Figure 3 overlaying mangroves. In addition to the mangrove land cover layout map, there are results of the land cover area of each land cover class determined, the results of the land cover area are presented in Table 3 to Table 6.

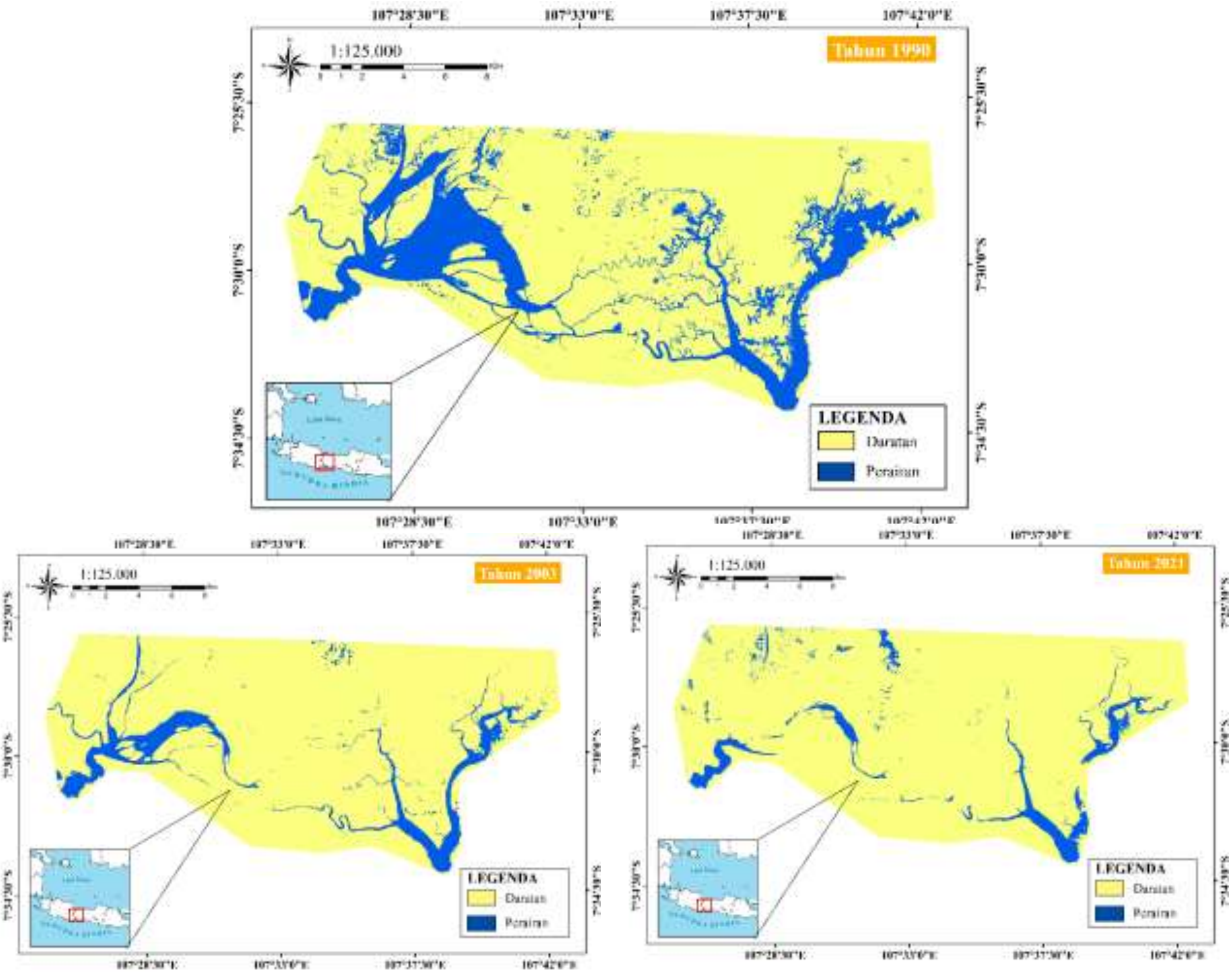

Fig 2. Area change using NDWI of Segara Anakan over 30 years; a)1990, b)2003, c)2021

Table 3. Segara Anakan Land Cover in 1990, 2003, and 2021

Land Cover Classification	1990		2003		2021	
	Ha	**%**	**Ha**	**%**	**Ha**	**%**
Mangrove	7.955,01	20,86%	7.134,52	19,12%	6964,89	18,75%
Land	23.686,22	62,12%	27.353,01	73,32%	28.156,59	75,81%
Waters	6.486,8096	17,01%	2819,21	7,56%	2019,15	5,44%
Total	38.128,04	100,00%	37.306,74	100,00%	37.140,62	100,00%

Table 4. Changes in Segara Anakan Land Cover in 1990, 2003, and 2021

Land Cover Classification	1990 (Ha)	Δ 1990 - 2003 (Ha)	2003 (Ha)	Δ 2003 - 2021 (Ha)	2021 (Ha)
Mangrove	7.955,01	-820,49	7.134,52	-169,63	6.964,89
Land	23.686,22	3.666,79	27.353,01	803,58	28.156,59
water	6.486,81	-3.667,60	2.819,21	-800,06	2.019,15
Total	38.128,04		37.306,74		37.140,62

Table 5. Sedimentation rate of Segara Anakan in 1990, 2003 and 2021

Land Cover Classification	**1990**		**2003**		**2021**	
	Ha	**%**	**Ha**	**%**	**Ha**	**%**
Land	23.686,22	78,50%	27.353,01	90,66%	28.156,59	93,31%
water	6.486,8	21,50%	2.819,21	9,34%	2.019,15	6,69%
Total	30.173,03		30.172,22		30.175,74	

Table 6. Changes in sedimentation rate of Segara Anakan in 1990, 2003, and 2021

Land Cover Classification	**1990 (Ha)**	**Δ 1990 - 2003 (Ha)**	**2003 (Ha)**	**Δ 2003 - 2021 (Ha)**	**2021 (Ha)**
Land	23.686,22	3.666,79	27.353,01	803,58	28.156,59
water	6.486,81	-3.667,60	2.819,21	-800,06	2.019,15
Total	30.173,03		30.172,22		30.175,74

Based on the data in the table above, it is known that the area of Segara Anakan lagoon has shrunk and the area of water in land has increased significantly in the last 30 years. The results of the area obtained based on the table above, mangrove land cover in 1990 had the highest area, namely 7,783.49 ha (82.20% of the total area), then in 2003 it was 7,134.52 ha (69.52%) and decreased in 2021, namely 6,946.89 ha (73.64% of the total area). In addition, the rate of sedimentation or change in Segara Anakan Lagoon is quite significant, from 1990 to 2003, the land area increased by 3,666.79 ha and the water area decreased by 3,667.60 ha. From 2003 to 2021, the land area will increase by 803.58 ha and the water area will decrease by 800.06 ha.

Changes in the area of Segara Anakan Lagoon in Cilacap have been the focus of many studies in recent decades. According to Wahyudi et al. (2017), sedimentation, especially from human activities in the upstream area, has played an important role in the changing dynamics of the lagoon. Logging and land conversion in the watershed have led to increased soil erosion, which then leads to sediment accumulation in the lagoon (Saputra et al., 2018;). Further research by Dewi et al. (2016) also found that due to sedimentation, the average depth of the lagoon decreased, which in turn affected its surface area. This condition, coupled with increased human activity around the coastal area and lack of conservation efforts, has resulted in significant changes to the lagoon ecosystem (Purnomo and Suryawati, 2017). This study highlights the importance of sustainable management and watershed restoration to mitigate the negative impacts of sedimentation on the Segara Anakan Lagoon.

The Segara Anakan Lagoon, one of the most important ecosystems in coastal Cilacap, is facing major challenges due to increased sedimentation. Based on the analysis, the change in area The lagoon can be significantly linked to the rapid sedimentation process. Over time, sediments carried by river flows, especially from upstream areas, are continuously deposited on the bottom of the lagoon, resulting in siltation. As a result, areas that were previously part of the lagoon's water surface become flat or muddy, leading to a reduction in the overall water surface area. This phenomenon not only disrupts the ecological balance, but also affects the livelihoods of neighbouring communities, especially the fishermen who depend on the lagoon's existence. Increased human activity, such as deforestation and agriculture in upstream areas, is believed to be one of the main factors accelerating this sedimentation process. Therefore, sustainable conservation and management efforts are needed to restore and maintain the sustainability of the Segara Anakan Lagoon.

Segara Anakan.

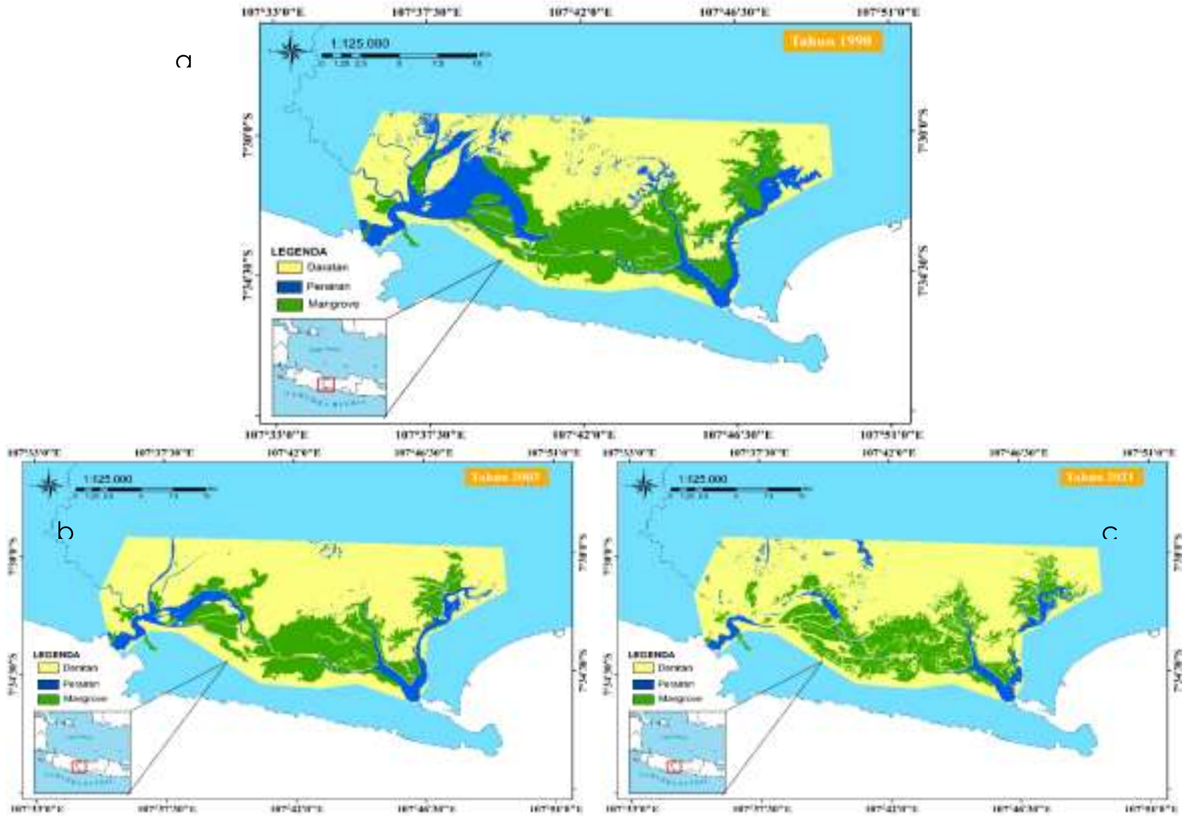

Fig 3. Overlay of mangrove and sedimentation rate changes in Segara Anakan Over 30 Years a)1990, b) 2003, c)2021

Based on Figure 3, it is clear that changes in the area of Segara Anakan and the mangrove area are correlated and affect the ecosystem in Segara Anakan. In 1990, the water was still dominant as a whole and the mangroves were still clearly visible. From 2003 to 2021, the waters shrank and sedimentation occurred until new land formed in Segara Anakan, where the mangrove area also experienced significant degradation.

The Segara Anakan lagoon in Cilacap has experienced significant changes in area over time. The main factor is sedimentation, accelerated by human activities. In upstream areas, uncontrolled deforestation has led to increased soil erosion, resulting in more sediment being carried into the lagoon by river flows (Susilo et al., 2014). In addition, land conversion for agriculture and infrastructure development has altered water flow dynamics, increasing the sediment load entering the lagoon (Hartono, 2010). Climate change, which affects rainfall patterns, also contributes to the intensification of erosion and sedimentation (Isdianto and Luthfi, 2021).

Declining environmental awareness in society, leading to less sustainable practices, exacerbates the problem (Suryawati et al., 2020). All of these factors contribute to the siltation of the lagoon, reducing its surface area and threatening the viability of its ecosystems References must be listed at the end of the paper. Do not begin them on a new page unless this is absolutely necessary. Authors should ensure that every reference in the text appears in the list of references and vice versa. Indicate references by (Van der Geer, Hanraads, & Lupton, 2000) or (Strunk& White, 1979) in the text. Some examples of how your references should be listed are given at the end of this template in the 'References' section, which will allow you to assemble your reference list according to the correct format and font size.

4. Conclusion

The changes in the area of Segara Anakan have changed significantly over the last 30 years based on satellite imagery. The shrinkage or siltation of the area of Segara Anakan lagoon has a percentage of 15% shrinkage from 1990 to 2021. The area of Segara Anakkan waters has an area of 6,486.8 ha (21.50% of the total area), then in 2003 it was 2,819.21 ha (9.34% of the total area) and decreased to 2,019.15 ha (6.69% of the total area) in 2021. Sedimentation also affects mangrove cover, with a significant reduction of 648.97 ha in the period 1990-2003 and a reduction of only 169.63 ha in the period 2003-2021. Natural and anthropogenic factors are the two main drivers of change in the area of Segara Anakan.

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