Assessing mangrove cover shifts in Segara Anakan, Cilacap through Land Use Land Cover based on multitemporal satellite images

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Abstract. Segara Anakan is a large lagoon located on the south coast of Central Java. The high sedimentation rate from the Citanduy River comes with rapid change in land cover, which is a problem and a threat to mangrove ecosystems, such as the conversion of mangrove land for other purposes, like rice fields and ponds. This study aimed to determine changes in the trend of mangrove land cover, land cover use, and changes in mangrove ecosystems in Segara Anakan for 31 years. The method used in this study is supervised classification and then field data and image data validation accuracy. This research was carried out in October 2022 by collecting ground check data in Segara Anakan, Cilacap Regency. Changes in the trend of mangrove land cover for 31 years showed that the area of mangrove land cover in 1990 was largest, with 7955.01 ha (82.51%); in 2003, it was 7134.52 ha (75.33%); it experienced a decrease by 2021, reaching 6946.89 ha (73.64%). Significant land use changes in the 1990-2003 period consisted of mangrove land turning into ponds (535.16 ha), water bodies turning into mangrove areas (435.11 ha), and mangrove areas turning into rice fields (312.25 ha). In the period 2003-2021, significant land changes consisted of mangroves turning into bodies of water (906.47 ha), ponds turning into mangrove areas (572.88 ha), bodies of water turning into mangrove areas (475.72 ha), and mangrove areas turning into ponds (469.1 ha). The impacts that occur due to this degradation are shoreline abrasion, siltation and the formation of new land (accretion), seawater intrusion, and a decrease in biodiversity.

Key Words: coastal forest, land cover change, remote sensing, supervised classification.

Introduction. Mangroves provide ecological functions and ecosystem services such as spawning grounds, nursery grounds, and feeding grounds for many marine species. Mangroves also provide many valuable ecosystem services, including runoff filtration, carbon storage, nutrient cycling, coastal protection, and sediment capture (Suyadi & Manullang 2020). The most crucial function of mangrove ecosystems is to connect land and sea, as well as dampen natural phenomena caused by waters, such as abrasion, waves, and storms, and also to be a buffer for biota life, which is a source of livelihood for the community (Mappanganro et al 2018). However, the delivery of these ecosystem services is threatened by anthropogenic pressures, such as deforestation, land conversion, and localized land use change (human intervention or interference), which has led to substantial mangrove degradation (Schuerch et al 2018).

Mangrove ecosystems in Central Java have diverse physiographic forms and mangrove physiognomy. The forest surrounding the Segara Anakan Lagoon (SAL) is the largest remaining mangrove ecosystem on Java Island (Nordhaus et al 2019). Its area decreased from 13557 ha in 1997 (Tomascik et al 1997) to 9272 ha in 2004 (Ardli & Wolff 2005; Yuwono et al 2007) and 8036.9 ha in 2012 (Listyaningsih et al 2013). SAL has high ecological and economic value, but changes in land use and land cover have increased since 1987 due to increased urbanization and immigration. Near villages in the lagoon, there has been a decrease in mangrove areas due to conversion to rice paddies, rice fields, and aquaculture. 44% of the mangrove area in 1987 had been converted to rice fields by 2006 (Ardli & Wolff 2009). In addition to natural factors such as sedimentation in Segara Anakan, anthropogenic disturbances are also increasing.

Increased development activities such as settlements, industry, rice fields, and ponds have led to the conversion of this mangrove area, exceeding the regenerative capacity for mangrove life (Luqman et al 2013).

Monitoring mangrove land cover change is necessary to determine the boundaries of coastal ecosystems over time and to evaluate the historical causes of mangrove land change. Remote Sensing and Geographic Information System methods offer cost-effective approaches and valuable results, particularly in reconstructing historical mangrove cover change (Pham et al 2019). Remote Sensing data can generate accurate, reliable, and efficient spatial information essential for monitoring mangroves and examining ecosystem responses to anthropogenic drivers and environmental changes (Jayanth et al 2016). In order to assess the historical determinants of mangrove degradation in Segara Anakan, this study utilized remote sensing techniques to analyze, identify, and quantify changes in mangrove forest cover over a period spanning three decades, from 1990 to 2021. The primary goal of this research was to delineate the dynamics of land use and land cover within the Segara Anakan mangrove ecosystem of Cilacap Regency, thereby informing conservation strategies. Accordingly, we established three specific objectives: (1) to generate a series of land use and land cover maps for the years 1990, 2003, and 2021; (2) to measure and categorize the land cover transitions among different classes during the 1990–2021 timeframe; and (3) to elucidate the alterations within the mangrove ecosystem in Segara Anakan Cilacap Regency. Employing remote sensing has proven to be a cost-effective method that yields significant insights into the historical changes in mangrove cover.

Material and Method

Materials. The materials used in this research are satellite imagery and ground check data. Satellite images are 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. The selection of satellite images is based on the quality or clarity of the image capturing the research location, to produce good data output in satellite image data processing.

Description of the study sites. This study was conducted at Segara Anakan area, located on the south coast of Java Island, Cilacap Regency, precisely in the southwest corner of Central Java Province. Geographically, Segara Anakan is located at coordinates 7°34'29.42"-7°47'37" N-S and 108°45'11"-109°2'54"E (Figure 1).

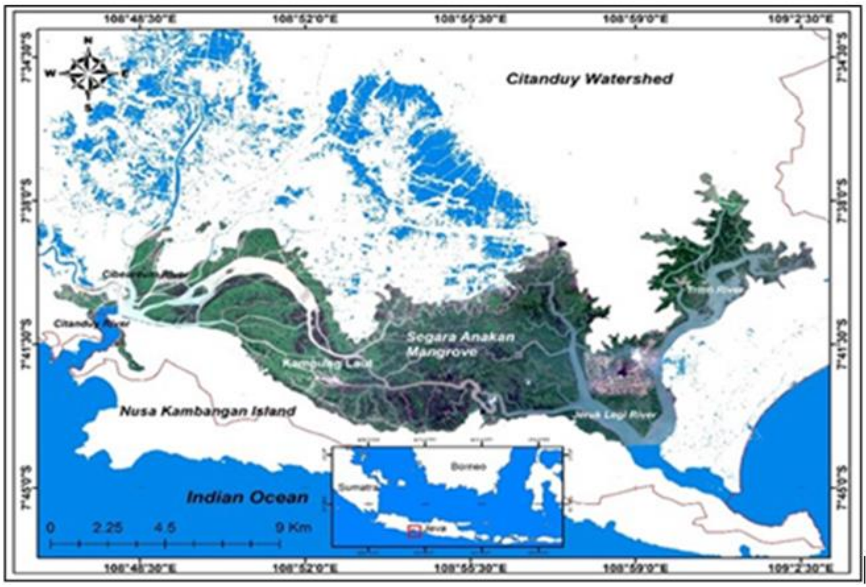

Figure 1. Map of research locations at the Segara Anakan in Central Java Province, Indonesia.

Segara Anakan is a bay in the southern part of Java Island. In front of it, stretching for approximately 30 km east-west is Nusa Kambangan Island, which protects the bay from the waves of the Indian Ocean. Segara Anakan is a lagoon located downstream of the Citanduy watershed. The lagoon is connected to the Indonesian ocean by two channels located on the side of Nusakambangan Island, influenced by tidal movements. The western estuary is the largest estuary, and also serves as the mouth of the Citanduy River.

Remote sensing data and image processing. The imagery data were obtained from Landsat 5 imagery for 1990, Landsat 7 for 2003, and Sentinel-2B for 2021. Table 1 presents the detailed satellite image information used in this study.

Table 1

Specifications of the satellite image data used

Data type	*Bands*	*Resolution (m)*	*Date of acquisition*	*Path/ row*	*Source*
Landsat 5 TM	RGB 453	30	24 February 1990	121/65	USGS
Landsat 7 ETM	RGB 453	30	19 January 2003	121/65	USGS
Sentinel-2B	RGB 8b114	10	16 April 2021	121/65	Copernicus

The research method used to analyze mangrove land cover change is the remote sensing method, namely the satellite image interpretation technique (visual interpretation) with supervised classification and field observation or ground check (Hartoko et al 2022). This research consists of processing and analyzing remote sensing data and is supported by exploratory field ground check data. Exploratory research aims to find information about a topic/problem and reveal something from the field (Mudjiyanto 2018). The explorative, descriptive method collects data by paying attention to the cause and effect of an element and characteristic, which is then analyzed and interpreted (Zakariah et al 2020).

Supervised classification includes a set of algorithms based on the input of object samples (in the form of spectral values) by the operator (Kawamuna et al 2017). This classification is done manually. Before the samples are taken, the analysis operator or user must prepare the classification system. Supervised multispectral classification is done by determining the training area, commonly referred to as the region of interest (ROI). Maximum likelihood classification (MLC) is used. The MLC method can compare and take into account the average value of the diversity between classes and bands. The MLC method is based on similar pixel values and image recognition.

Ground check. Ground check data or direct survey in the field is done with standard methods in the field. Ground check at 20 station points was carried out to compare the coordinates on the image map with direct observation in the field (if at that point there is mangrove or non-mangrove vegetation and to see the actual land use in the field). The coordinates collected from each land cover were used as training points during the classification analysis and accuracy test. The coordinates were collected using a handheld Geographic Positioning System (GPS) (Table 2). The images of each land use field condition obtained during the ground check fieldwork are presented and summarized in Figure 2.

Table 2
The coordinates of the ground check using a Geographical Positioning System (GPS)

No	*Latitude*	*Longitude*	*Actual-condition*
1	108°51'13.91"E	07°39'16.53"S	Rice field
2	108°48'08.16"E	07°40'24.05"S	Rice field
3	108°51'54.8"E	07°42'04.1"S	Rice field
4	108°48'03.46"E	07°40'15.23"S	Rice field
5	108°52'09.27"E	07°41'56.02"S	Rice field
6	108°51'05.92"E	07°41'28.34"S	Fish pond
7	108°52'38.00"E	07°40'40.48"S	Fish pond
8	108°52'38.14"E	07°40'40.65"S	Fish pond
9	108°52'34.53"E	07°40'39.49"S	Fish pond
10	108°52'44.52"E	07°43'06.51"S	Open area
11	108°52'45.41"E	07°43'07.97"S	Open area
12	108°52'13.56"E	07°42'19.65"S	Open area
13	108°52'35.1264''E	07°42'55.23''N	Open area
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

Figure 2. Condition of land cover types in Segara Anakan: (A) rice field, (B) fishpond, (C) (D) mangrove, and (E) open area.

Accuracy assessment. The recommended accuracy assessment, according to Jaya (2010), is kappa accuracy. This is because the calculation of kappa accuracy takes into account almost all parts contained in the matrix. In kappa accuracy, there are two estimators of overall accuracy, namely producer accuracy and user accuracy.

According to Richards (1993), in classification using the MLC method, training areas should be used to see the statistical characteristics of each category to be classified. The MLC method's classification process is based on calculating the probability density for each land cover category.

P(i|x) = [P(x|i)P(i)]/P(x)

Where: P(i|x) - conditional probability of a class i calculated under the condition that the vector x is unconditional (likelihood); P(x|i) - conditional probability of a vector x calculated with unconditional class; P(i) - probability of class i appearing in the satellite image or pixel; P(x) - probability of the vector x.

According to the guidelines for processing multispectral satellite data digitally supervised for classification compiled by the National Aeronautics and Antarctic Institute (LAPAN) in 2015, the image classification is considered correct if the calculation of the classification accuracy assessment level must not be lower than 75%. The diagram of the satellite image processing process is presented in Figure 3.

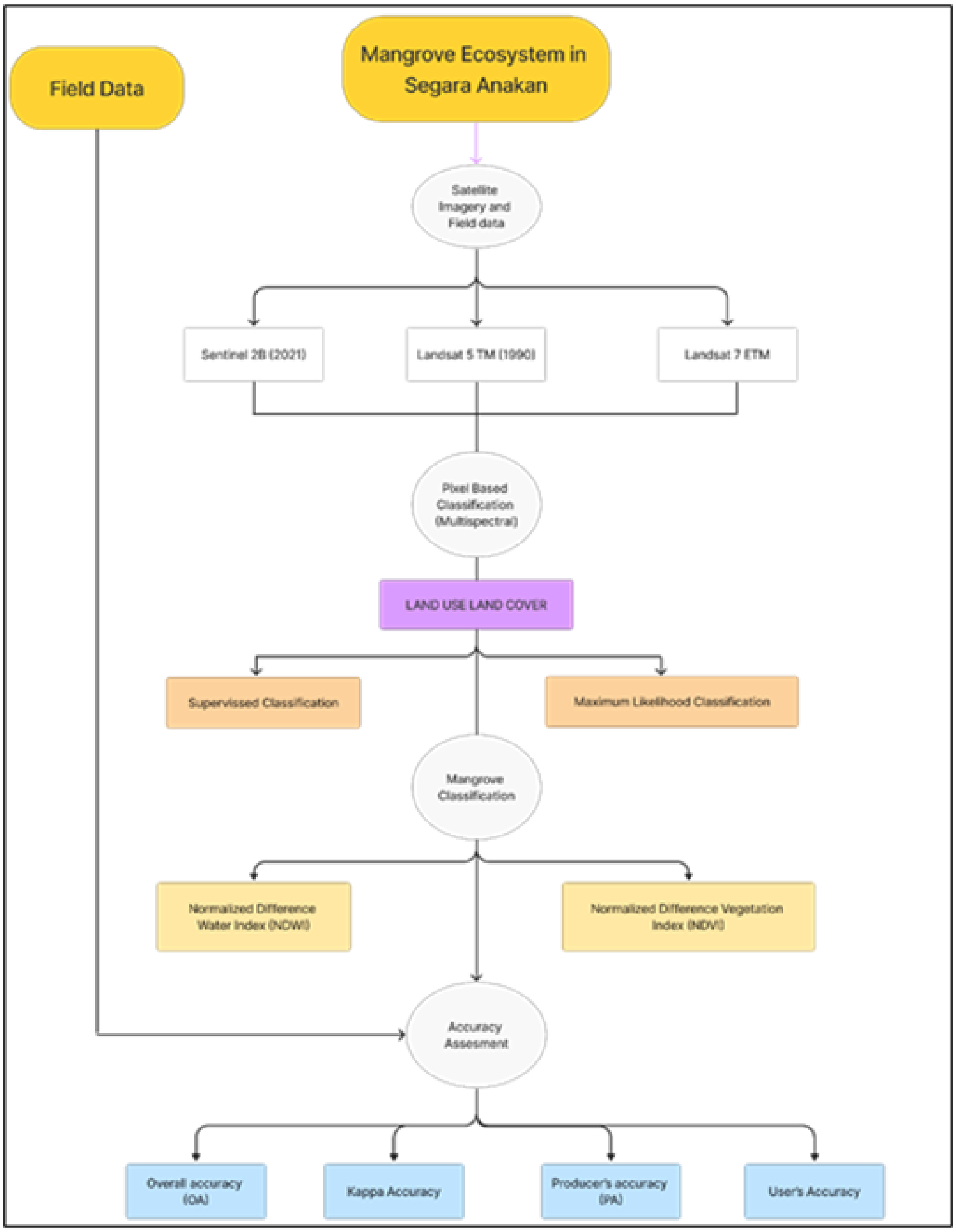

Figure 3. Work flow of land use and land cover.

Results and Discussion

Mangrove cover in 1990, 2003, and 2021. The land cover classes are divided into settlements, rice fields, mangroves, ponds and water bodies, using the supervised classification method. The results of the mangrove cover map in Segara Anakan are presented in Figure 4A-C. In addition to the mangrove land cover layout map, the results of the cover area of each class of land cover that has been determined are presented in Table 3. Figure 4 presents the layout of mangrove cover maps in Segara Anakan for 31 years with 10-year intervals from 1990 to 2021. The map results from processing Landsat 5TM imagery in 1990, Landsat 7 ETM imagery in 2003, and Sentinel 2B imagery in 2021.

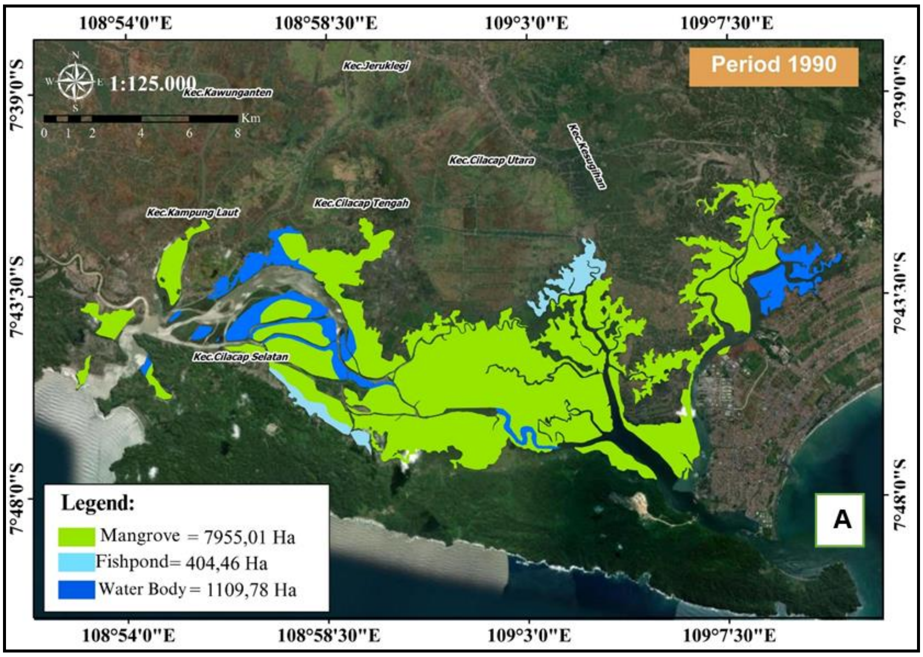

Figure 4A. Land cover mangrove in Segara Anakan in 1990.

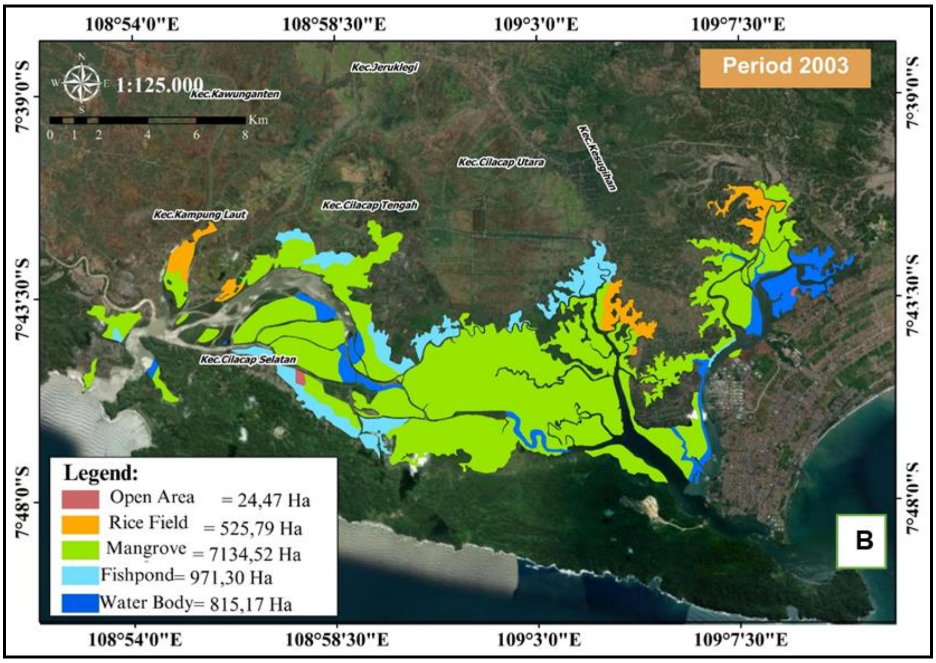

Figure 4B. Land cover mangrove in Segara Anakan in 2003.

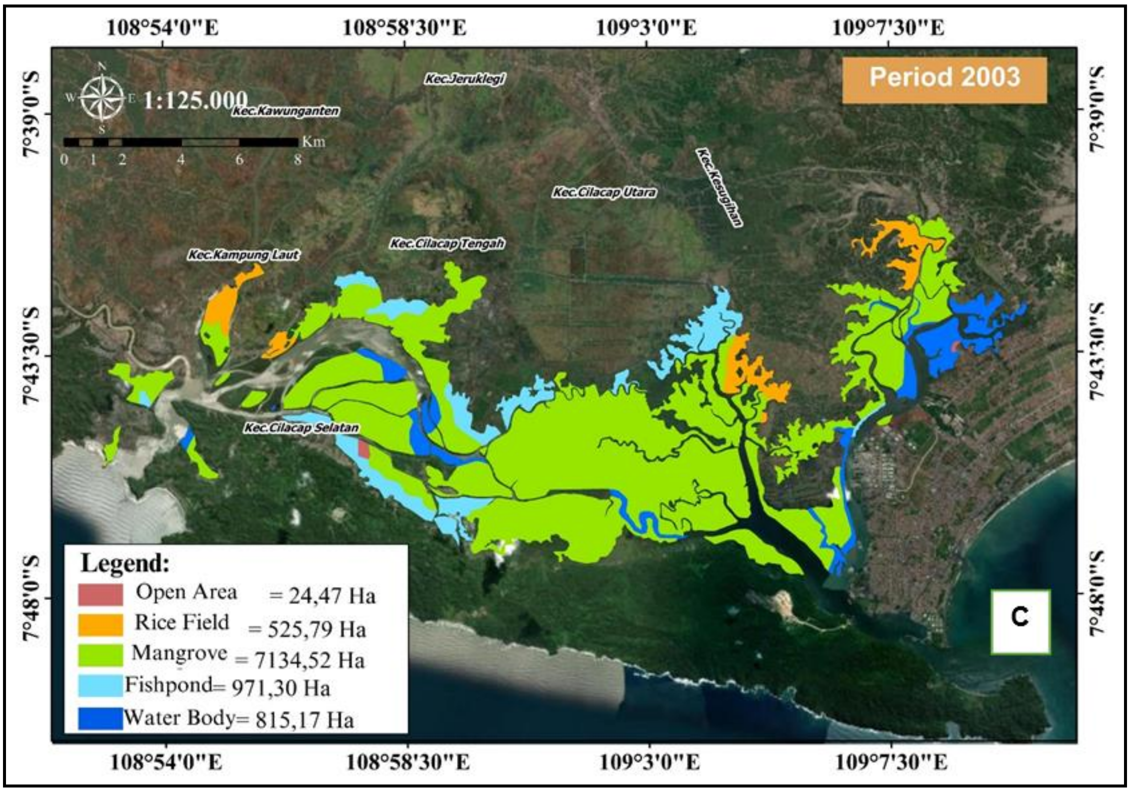

Figure 4C. Land cover mangrove in Segara Anakan in 2021.

Mangrove land cover had the highest area in 1990, namely 7955.01 ha (82.51%). In 2003, it was 7134.52 ha (75.33%) and in 2021 it decreased to 6946.89 ha (73.64%). In addition, the area of the water body has significantly increased from 1109.78 ha in 1990 to 1452.27 ha in 2021. Finally, the area of ponds between 1990-2003 increased by 566.84 ha and in 2021 decreased to 165.80 ha.

Table 3

The area of land cover types in Segara Anakan in 1990, 2003, and 2021

Land cover type	*Area in 1990*		*Area in 2003*		*Area in 2021*	
	ha	*%*	*ha*	*%*	*ha*	*%*
Mangrove	7955.01	82.51	7134.52	75.33	6964.89	73.64
Fishpond	404.46	4.2	971.3	10.26	805.51	8.52
Open Area	-	0	24.47	0.26	20.54	0.22
Rice Field	171.52	1.78	525.79	5.55	214.96	2.27
Water Body	1109.78	11.51	815.17	8.61	1452.27	15.35
Total	9640.77	100	9471.25	100	9458.17	100

Figure 5 shows the changes in land cover from 1990 to 2021. The changes in land cover area used comparisons with 10-year intervals, from 1990 to 2003 and from 2003 to 2021. From 1990 to 2003, the mangrove cover area experienced a significant reduction of 820.49 ha, followed by a reduction in the area of water bodies of 294.61 ha. The most significant land area addition in 1990-2003 was represented by ponds, with an area of 566.84 ha, then rice fields, with 354.27 ha. The most significant land area addition in 2003-2021 was represented by water bodies, with 637.11 ha. The largest land reduction in the 2003-2021 period was represented by paddy fields, with 310.83 ha, mangrove land with 169.63 ha, pond land with 165.8 ha, and finally residential land with 3.93 ha.

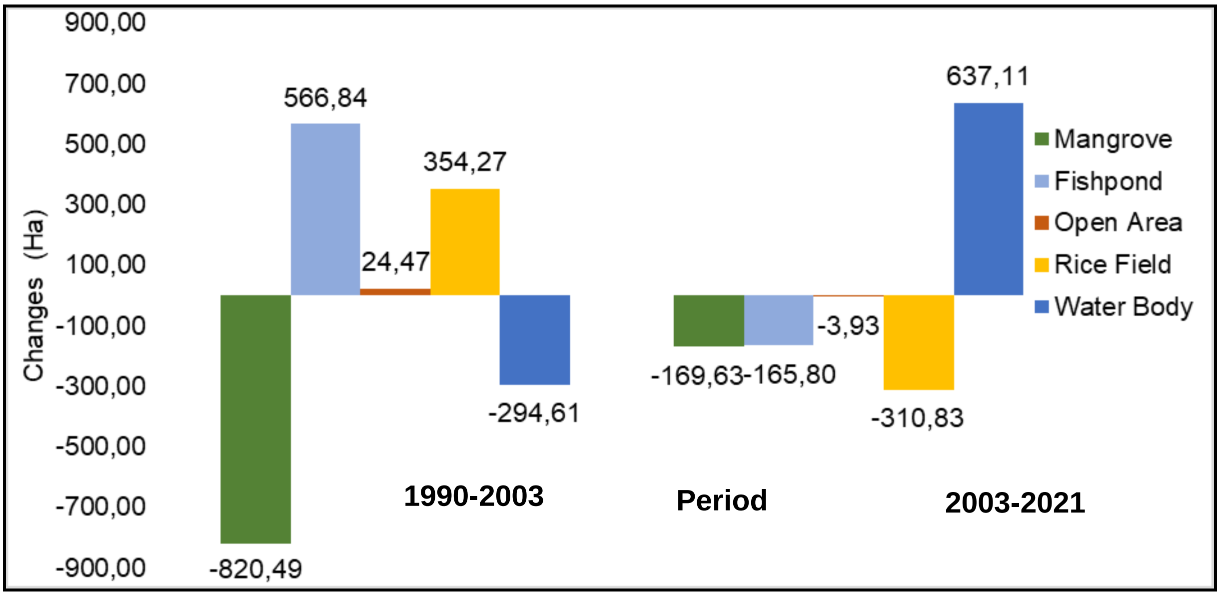

Figure 5. Change trend of Segara Anakan mangrove land cover from 1990 to 2021.

Land cover change between 1985–2000 and 2000–2020. Land cover change shows that from 1990-2003, mangrove land was mainly converted into ponds (Figure 6A), covering an area of 535.16 ha. During the same period, the degradation and conversion of mangroves into rice fields amounted to 312 ha. For 7868.43 ha, there was no change. In the 2003-2021 period, the mangrove area experienced the most significant degradation and conversion to water bodies, amounting to 906.47 ha (Figure 6B). In addition, about 572.88 ha of ponds were converted to mangrove land. In this second period, the conversion of water bodies into mangrove areas encompassed 475.72 ha. There was no land conversion for 6175.79 ha. The overall land use change is presented in Table 4.

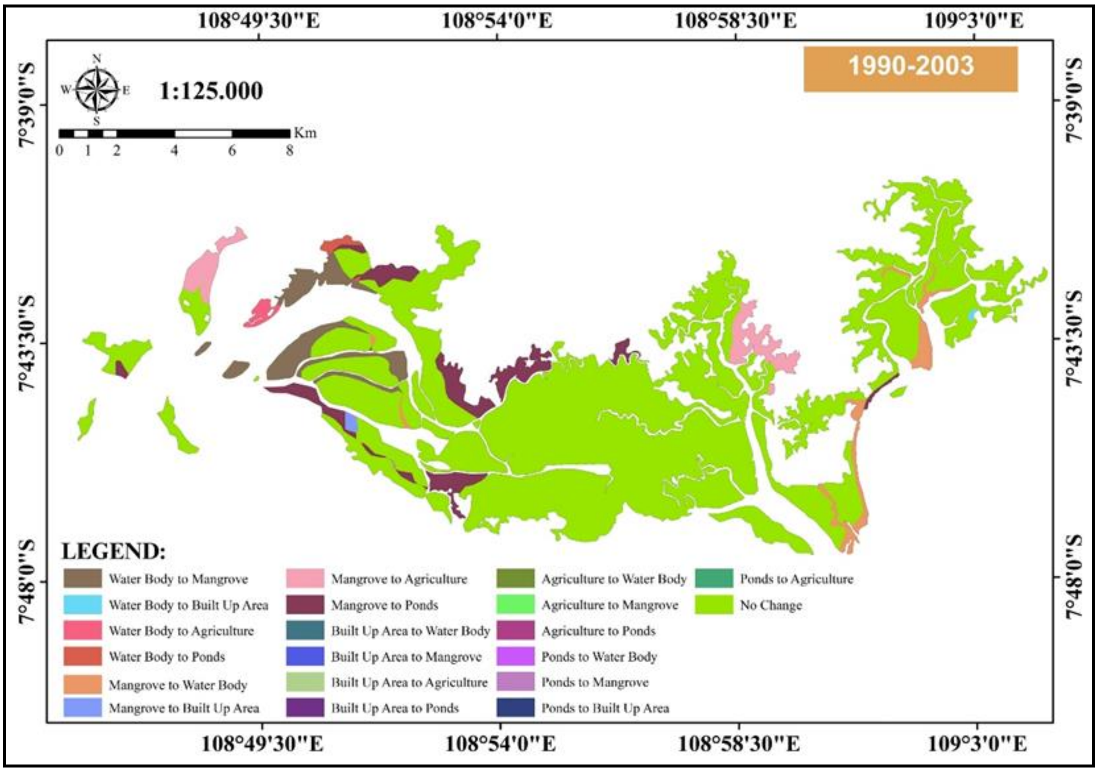

Figure 6A. Segara Anakan mangrove land cover between 1990-2003.

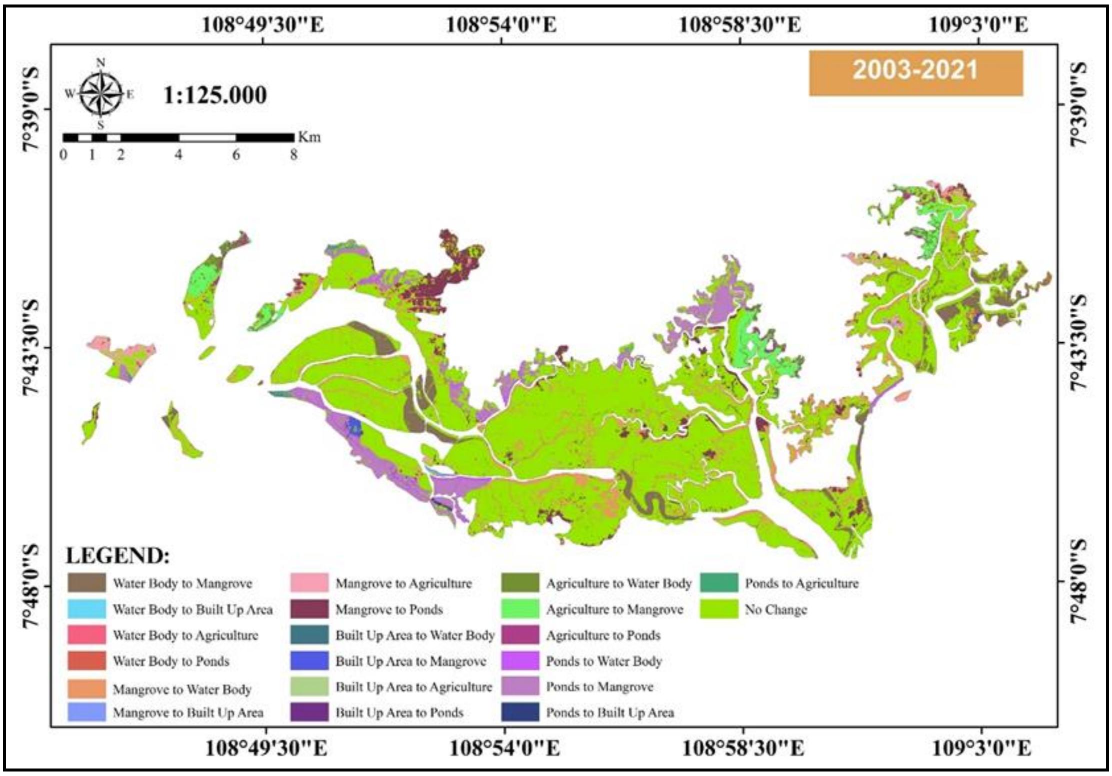

Figure 6B. Segara Anakan mangrove land cover between 2003-2021.

Table 4

Land use in Segara Anakan between 1990 and 2021

Land cover changes	*1990 – 2003 (ha)*	*2003-2021 (ha)*
Water body to mangrove area	435.11	475.72
Water body to open area	5.73	0.14
Water body to rice fields	42.02	4.80
Water body to fish ponds	31.75	23.28
Mangrove areas to water body	219.99	906.47
Mangrove areas to open areas	18.74	9.85
Mangrove areas to rice fields	312.25	124.20
Mangrove areas to fish ponds	535.16	469.10
Open areas to water body	0	2.94
Open area to mangrove area	0	16.24
Open area to rice fields	0	0.52
Open area to fish ponds	0	3.05
Rice fields to water bodies	0	98.86
Rice fields to mangrove areas	0	292.58
Rice fields to ponds	0	64.40
Fish ponds to water body	0	122.33
Fish ponds to mangrove area	2.07	572.88
Fish ponds to open area	0	8.64
Fish ponds to rice field	0	20.01
Not changed	7868.43	6175.79

Table 4 shows the changes in Segara Anakan land use from 1990-2021. Significant changes in land use in the 1990-2003 period were mangrove land turning into ponds (535.16 ha), bodies of water turning into mangrove areas (435.11 ha), and mangrove areas turning into rice fields (312.25 ha). Whereas for the 2003-2021 period, significant land changes were mangrove areas turning into bodies of water (906.47 ha), ponds turning into mangrove areas (572.88 ha), bodies of water turning into mangrove areas (475.72 ha), and mangrove areas turning into ponds (469.1 ha).

Accuracy assessment. The results of the accuracy assessment are presented in Table 5. Processing accuracy was 100% for the open area and rice field classes. This indicates that the pixels from that class did not enter other classes. The average accuracy of the classification was 90%. Kappa accuracy uses all the elements in its calculation matrix, having a value of 86.2%, resulting in a high level of suitability, because the resulting coefficient values reach >0.8, namely 0.86 (86.2%). The kappa accuracy value of 86.2% proves that land cover mapping can be trusted because the accuracy value is >85% (Romadoni et al 2023).

Table 5

Accuracy assessment maximum likelihood classification

No	*Classified data*	*Producer accuracy (%)*	*User accuracy (%)*	*Overall accuracy (%)*	*Kappa (%)*
1	Open area/Built up Area	100%	75%		
2	Ponds	83%	100%	90%	86.2%
3	Mangrove	88%	100%		
4	Rice field	100%	75%		

Land use in Segara Anakan between 1990-2021. Land use and land cover in Segara Anakan over the past 30 years have seen dynamic and significant changes. The transformation of land use activities was accelerated by the immigration of farmers and fishermen, who significantly increased the population of the area. According to the Ministry of Home Affairs (2012), the population growth rate in Segara Anakan is around 1.65% per year. Changes in land cover and land use, particularly the reduction of native mangrove forests, have significantly altered the ecosystem around the Segara Anakan lagoon. The conversion of mangrove forests into rice fields in the Segara Anakan area is caused by the high migration of people who enter and change the livelihood patterns of the population from fishermen to farmers (Segara Anakan Area Resource Management Office 2019). The high population migration was also triggered by the potential of land in the Segara Anakan area, which is very wide and fertile. The large number of mangrove forest conversions into rice fields motivates other communities to cultivate this field, so that more mangrove forest land is converted (Yulianti et al 2013).

The conversion of mangrove forests to ponds in the Segara Anakan region was first triggered by a significant investment in 1980-1990 to develop intensive aquaculture, followed by increased communities, many mangrove forests being converted on a large scale. However, the investment was later stopped because the results obtained by the investors were different from what was expected. However, the former pond land is still widely used by the community for inland fisheries cultivation in the form of fish ponds. The conversion of mangrove forests into settlement land in the Segara Anakan area is due to the increasing population with a large number of incoming migrants, increasing the population's need for land (BPS Cilacap 2010).

Anthropogenic activity as the main driver of mangrove loss in Segara Anakan. Human activities contribute the most to the destruction of mangrove forests. Conversion of mangrove forests for fisheries, plantations, rice fields, salt ponds, settlements, industry, and illegal logging are the main anthropogenic activities that cause the degradation and loss of mangrove forests in Indonesia (Ilman et al 2011). The impacts of such degradation are shoreline abrasion, siltation and accretion, seawater intrusion, and decreased biodiversity.

Anthropogenic activities in Central Java that have reduced the ecological role of mangrove forest ecosystems involve fisheries/ponds, rice fields, development and building areas, logging, food, animal feed, medicinal materials, industrial raw materials, and tourism (Setyawan & Winarno 2006). Mangroves can also be used as an alternative to animal feed. More specifically, mangrove leaves can be crushed and ground into animal feed powder containing nutrients, perfect for the growth of livestock such as cows, goats, or poultry (Suryaningsih 2019). The causative factor of anthropogenic influence occurs due to the rapid increase in population growth and is then accompanied by increased utilization of mangrove land for economic activities that can support the lives of residents. Land use in Segara Anakan Citanduy for fisheries, agriculture, industrial, and domestic activities causes higher pressure on the mangrove ecosystem (Dewi et al 2016).

Anthropogenic activities or the existence of human intervention makes mangrove ecosystems need sustainable development. Sustainable development should meet the needs of today's life without damaging or reducing the ability of future generations to meet their needs (WCED 1987). Community-based mangrove management strategy by including the community in enacted policies is expected to be more targeted. Rahardjo (1996) revealed that a based community implies management of direct community involvement in managing natural resources in an area (Holden et al 2014). The importance of spatial planning is proportionally adjusted to the existing potential data. For this, zoning can be done, for example, sustainable areas (conservation), residential areas, primary and secondary production areas, and conversion areas. The division of these areas must be formulated with the Segara Anakan bureaucracy. This is very important, so that the designated areas are not misused.

The management of the Segara Anakan environment must be carried out in an integrated manner, not only to include physical and social dimensions but also to pay attention to all links in the chain of life as an open system (Hariyadi 2018). Therefore, the necessary physical effort involves addressing the physical and ecological aspects of the Segara Anakan region at the same time. In general, mangrove natural resource management techniques and mangrove cultivation techniques influence the sustainability of mangrove forest areas in Central Java Province. According to Zainuri et al (2017), the strategy needed to preserve mangroves is to implement conservation-based fisheries activities and increase public awareness about the role of mangroves in community economic development.

Conclusions. Land use and land cover changes in the mangrove area of Segara Anakan impact the ecological function of mangrove areas, which have been significantly and detrimentally altered due to various forms of human intervention. These include the conversion of mangrove areas into ponds, destructive illegal logging activities, and the harmful transformation of these areas into rice fields.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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