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Mangrove Landscaping As An Adaptation Pattern To Reduce The Impact of Climate Change in Segara Anakan Lagoon, Cilacap Regency Indonesia

***Endang Hilmi* *[1], *Nurul Anwar* [2], *Imam Santosa* [3], *Arif Mahdiana* [1], *Taruna Mona Rachman* [4], *Teguh Wardoyo* [4]**

[1]Departement of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Jenderal Soedirman University, Banyumas, Central Java, Indonesia.
[2]Faculty of Economics, Jenderal Soedirman University, Banyumas, Central Java, Indonesia.
[3]Sociology Departement, FISIP, Jenderal Soedirman University, Banyumas, Central Java, Indonesia.
[4]Geometeorology and Geophysical, Tungul Wulung Station, Cilacap and Magister of Environment Science Program (Postgraduate Program), Jenderal Soedirman University, Banyumas, Central Java, Indonesia.
*Corresponding Author.

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Abstract

Mangrove landscaping in the Segara Anakan Lagoon (SAL) is an adaptation pattern of mangrove ecosystems to live and grow in unstable areas. This research aimed to develop a mangrove landscape to mitigate the impacts of ocean waves, currents, and inundation due to climate change. The study was conducted in SAL and Cilacap Coast (CC) using the environmental properties and climate change data. The data obtained were analyzed using mapping and trendline analyses. The results showed that mangrove landscaping in Segara Anakan had four zones with *Nypa frutican, Rhizophora styllosa, Aegiceras corniculatum, Rhizophora apiculata, Avicennia marina, Sonneratia alba* identified as the best adaptation of mangrove species. Climate change give a high impact on mangrove degradation (degradation 142.1 ha/year), the instability of rainfall intensity with average intensity 3552 mm/year, irregular wind direction with a speed average of 7 knots, and increasing of sea wave and sea level rise (range from 2.7 m to 3.4 m) The results conclude that the mangrove species have ability to live and grow, because the climate change does not affect mangrove growth (the correlation with rainfall intensity = -0,35, with wind speed = 0,18 and sea wave = - 0,34).

Keywords: climate properties, lagoon degradation, mangrove landscaping, sea wave, sea current.

Introduction

Segara Aanakan Lagoon (SAL) is dominated by mangrove and lagoon ecosystems (estuary) [1–3]. They are widely used for various anthropogenic and industrial activities[4], including residential, domestic, and factory waste disposal[5,6,] agricultural, silvofishery, water transportation, fishing area, as well as other economic activities[7,8.] However, anthropogenic and industrial activities have a

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significant impact on mangrove vulnerability. The vulnerability of the mangrove ecosystem in SAL is also influenced by climate change[2,9]

Climate change has a high impact on the lagoon and mangrove stabilization, including the decreasing catches of shrimp, crab, and shell catches[10,11], rapidly influencing for the increasing of human demands and economic growth [12,] reducing the ecosystem services [13,] blocked shipping lanes, as well as reduced fishermen's income and productivity of silvofishery activity[14,15]. Additionally, climate change causes stunting and death of mangrove vegetation [16], along with critical land and soil [17,18,] species distribution, habitat, fishing ground, and socio-economic impacts [19–23.] It also directly impacts oceanography and lagoon stabilization, such as increasing sea tides[24–26,] sea level rise, tidal and water inundation[27–30,] sedimentation, ocean and river current[31–33] as well as ocean wave[34,35]. The direct and indricet impact of climate change give high impact for mangrove and lagoon ecosystem in SAL.

Mangrove ecosystems in SAL are thought to have specific adaptations to mitigate the impacts of environmental conditions, including climate change. The pattern of mangrove adaptation can be developed by mangrove zoning and mangrove landscape. However, current ecological conditions and climate change have still threatened the stability and area of mangrove and lagoon ecosystems in SAL. For example, the data from 1978 to 2016 shows that the lagoon has reduced from 4186,45 Ha in 1978 to 1482,75 Ha in 2016 [36.] Several studies also reported that the degradation of mangroves in Cilacap and SAL is caused by high sedimentation rates[33,36], high levels of pollution[5,37,38] and tidal inundation3, anthropogenic factors including logging and conversion[2,39] as well as climate change [2,40,41.]

Mangrove landscapes in SAL are developed as a type of conservation activity to mitigate the negative impacts of environmental and climate change on ecosystems. The mangrove landscape is specific pattern of mangroves species to increase the ability and adaptability to live and grow in changing environmental and climatic conditions. In contrast, the some research results also develop mangrove landscaping models, for example the mangrove landscape to reduce coastal disaster risk[1], reducing heavy metal pollution risk [38] and carbon conservation [42,] this landscaping model emphasizes mangroves' ability to mitigate climate and environmental change. As a conservation activity, this method aims to decrease the vulnerability of the mangrove ecosystem, support primary productivity, and reduce the impact of sea waves, sea tides, and water inundation[29,30,43,44.] Therefore, this study aims to develop mangrove landscaping as an adaptation pattern to reduce the impact of the sea wave, currents, and water inundation. This research is developed base on the hypothesis that climate and environmental change will reduce the area of mangroves and lagoons. Mangrove landscaping is developed to reduce mangrove degradation through adaptation patterns in areas affected by climate and environmental change.This research was conducted in the Segara Anakan Lagoon of Cilacap Regency from 2008 - 2021, to develop mangrove landscapes in order to mitigate the impacts of ocean waves, ocean currents, and seawater inundation due to climate change, and analyze mangrove degradation mapping as an impact of climate change from the results of vegetation sampling in the period 2013 - 2022.

Materials and Methods

Study site

This study was conducted in Segara Anakan Lagoon (SAL) and Cilacap Coast (CC) with three locations namely (1) mangrove, (2) Lagoon, and (3) coastal ecosystem[3,43] as shown in Fig. 1.

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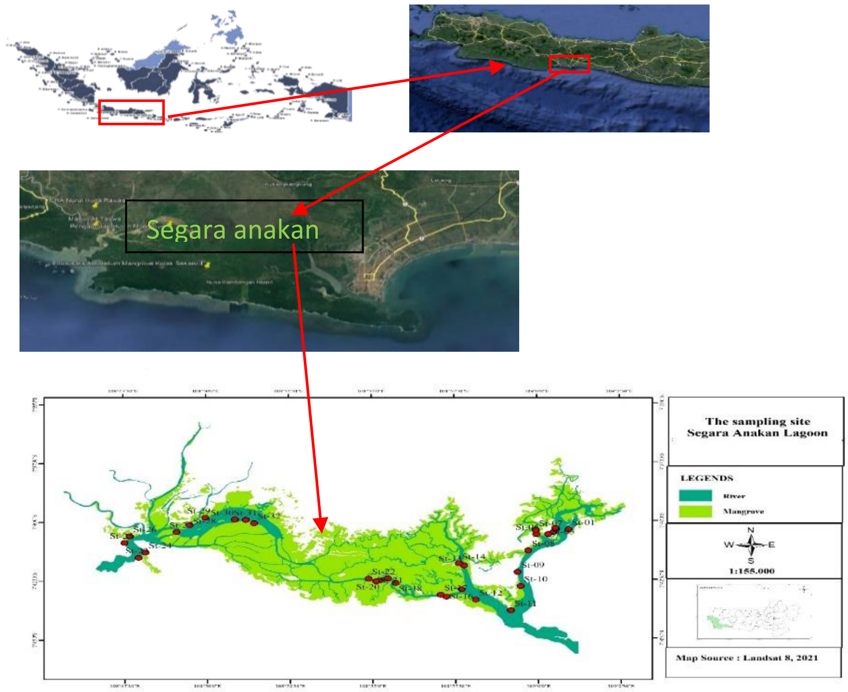

Figure 1. Site Research

The stations were used to analyze mangrove landscaping based on the impact level of the sea wave, currents, water inundation, and environmental conditions. This study also used cluster sampling comprising West and East Segara Anakan. Data were collected from 22 stations in West Segara Anakan consist of Donan (2 stations), Donan-kalipanas (1 station), Donan Pertamina (1 station), Kembang Kuning 1 (3 stations), Kembang Kuning 2 (4 stations), Muara Pelawangan Timur 1 (1 station), Muara Pelawangan Timur 2 (1 station), Sapuregel 1 (1 station), Sapuregel 2 (2stations), Sleko (1 station), Tritih (6 stations) and 20 in East Segara Anakan consist of Sungai Ujung Gagak (1 station), Sungai Lorogan (1 station), Sungai Majingklak (1 station), Sungai Mauara Cawitali (1 station), Sungai Kebuyutan (1 station), Sungai Batu Macan (1 station), Sungai Jongor (1 station), Sungai Muara Legok (1 station), Sungai Kayu Mati (1 station), Sungai Langkap (1 station), Sungai Karang Braja (1 station), Sungai Klaces (1 station), Sungai Inti Ujung Gagak (1 station), Sungai Muara Bagian (1 station), Sungai Muara Masigitsela (1 station), Sungai Pertigaan Ujung Alang (1 station), Sungai Ujung Alang (1 station), Sungai Dermaga Ujung Alang (1 station), Sungai Kali Semak (1 station), Sungai Pertigaan Sudiro (1 station).

Study variables

The variables of mangrove landscaping to reduce the impact of climate change and environmental conditions were (1) mangrove landscaping using the data of species density and species distribution, (2) the climate indicators including rainfall intensity (dry and rainy seson), wind speed and wind direction (3) the ecological impacts of climate change which include sea wave and sea current, mangrove and lagoon degradation, and (4) Environment variables that were water inundation, soil pH, water pH, soil texture and water soil salinity.

Vegetation analysis

The Mangrove samples were taken using a plotted line system (plot size 10 m x 10 m). Mangrove vegetation in each plot will be measured Diameter at Breast Height (DBH) above 4 cm [3] as in Fig. 2.

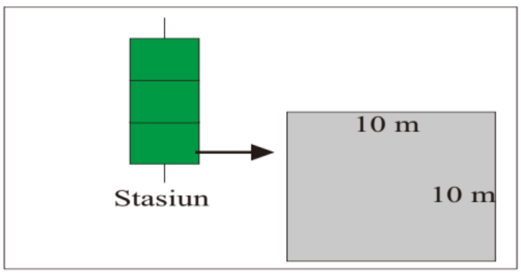

Figure 2. Design of sampling plot method

Each tree will be recorded for the number of individuals to be used in calculating the density of each species, based on the following formula :

$$Di = \frac{\sum_{j=1}^{n} xij}{A}$$

Note
i = Specis –i

j = plot-j

Di = species density-i

Xij = trees species I, plot-j

A = plot area

The analysis of environment properties
The analysis and the measurements of environmental factors at each research station can be seen in Table 1.

Table 1. The methods of environmental factors analysis

No	Environmental factors	Unit	Method/tools	References
1	Temperature	^{O}C	Termometer	APHA (2005)
2	Salinity	Ppt	Handrefractometer	APHA (2005)
3	pH	Unit	pH meter	APHA (2005)
4	Soil texture	%	Gravimetry	APHA (2005)
5	Pyrite (FeS_2)	mg/L	Spektrofotometry	
6	Nitrate (NO_3)	mg/L	Brussin Spektofotometry	
7	Phoshatet (PO_4)	mg/L	Askorbic acid	

The mangrove landscaping
Mangrove landscaping as an adaptation and tolerance pattern against climate change and environmental conditions was analyzed using density (trees/ha) and species distribution. The domination of mangrove species is indicated by the density, adaptation pattern, and environmental characteristics[3,45]

The climate change condition
The climate change was assessed using data collected from 2008 to 2021, including (1) the rainfall data, which can be used to determine several criteria, namely the trend of rainfall for the beginning of the rainy and dry season, total rainfall for the six-month in the rainy season (October - March), and in the dry season (April - September), the length of the rainy and season, as well as the trend of extreme rainfall and rainy days. (2) Rainy season duration was determined by calculating the rainfall/day, with a total value > 50 mm/day, while the length of the dry season was determined by the rainfall/day < 50 mm/day. (3) The trend of rainfall was calculated by the rainfall condition from April to October for the rainy season, and the dry season period from October to April. (4) Heavy rainfall trend was determined by the number of heavy rainfall with rainfall intensity > 50 mm/day. (5) The trend of rainy days was analyzed by the number of rain events in the current year[46–48.]

The mapping of the mangrove and Lagoon ecosystem
The mapping of climate change conditions and impact in the Segara Anakan Lagoon area was carried out using a combination of ArcGIS and geo-metrology, climatology, as well as geophysical analysis, while the base map processing involved using Landsat from 1990 to 2020. Satellite imagery analysis was used to analyze the impact of climate change on the mangrove and lagoon ecosystem. This was achieved by following several mapping stages comprising (a) image cutting, (b) masking, categorizing, and cropping potential areas using NDWI (Normalized Difference Water Index), which is an algorithm to distinguish between land and water areas, remove noise, build color contrast, as well as

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determine the area[49–53.] The NDWI algorithm for mapping the impact of climate change on mangroves and lagoons used color sensor analysis based on the green and infrared bands in the equation system [49,50.] The Eq of algorithmic land-water analysis is $\boldsymbol{NDWI} = \frac{\mathbf{Green-NIR}}{\mathbf{Green+NIR}}$, where Green represents band green (Band 2 pada Landsat 7) and NIR represents band near-infrared (Band 4 pada Landsat 7). (c) The potential analysis area between mangrove and non-mangrove used an unsupervised classification approach with a maximum approach likelihood. (d) The mangrove and lagoon area (ha) was calculated using a vegetation calculating tool, while (e) the mangrove density was determined with NDVI, based on the level of canopy density. The NDVI formula is the reflectance of remotely sensed objects using the analyzed imagery color including the red and near-infrared spectrum channels, with a range of values from -1 to 1. The formula for the normalized difference vegetation index (NDVI) [50–52,54,] is **NDVI = (NIR-RED)/(NIR+RED),** Note: NIR= band near-infrared and RED= band red. The NDVI analysis also used composite images or Band combinations to obtain the image display on each layer of red, green, and blue, as well as radiometric correction, and image contrast sharpening. According to the Ministry of Forestry (2005), the mangrove density can be classified into three classes using NDVI namely Rarely pixel ranging from -1.00 to 0.32, Medium density 0.33 - 0.42, and high density 0.43 - 1.00, indicating that the NDVI value can range between -1 and 1[41,49].

Statistic analysis

This research used statistic analysis including trend line analysis, determination index, average, deviation standard, stock and tabulation system [3,29,55.] The statistical analysis were used to analysis species distribution in climate change area, trend of lagoon and mangrove degradation, distribution rainfall intensity and wind direction.

Results and Discussion

Mangrove landscaping

Mangrove landscaping is a pattern of tolerance and adaptation of mangrove species to reduce the impact of climate change and environmental conditions as shown in Table 2 and Fig. 3. The Table 2 shows that Segara Anakan and Cilacap Coast mangrove species can be divided into three groups. The first group consisting of *Nypa frutican, Rhizophora styllosa, Aegiceras corniculatum, Rhizophora apiculata, Avicennia marina, and Sonneratia alba* had a high density of >1000 trees/ha, indicating that the mangrove species are tolerant of climate change. In contrast, the fourth group, composed of *Aegiceras floridum, Bruguiera parviflora, Ceriops tagal,* and *Xylocarpus moluccensis* had the lowest adaptation to climate changes as indicated by the lowest density of <400 tress/has.

Based on the results, *Nypa frutican*, *Rhizophora styllosa*, *Aegiceras corniculatum*, *Rhizophora apiculata*, *Avicennia marina*, *and Sonneratia alba*, as the major species, can live and grow in fragile conditions, including climate change, sedimentation, and water pollution caused by heavy metal and oil spillage [10,56–59.] These mangrove species had good and specific adaptations to reduce the impact of environmental and climate change, including the ability to develop species clustering, zonation, and association [3,30.]

Table 2. The mangrove adaptation and tolerance from climate change in Segara Anakan Lagoon

Zone	Mangrove species	mangrove Adaptation	Environment characteristic
1	*Nypa frutican* (Nf) *Rhizophora stylosa* (Rs) *Aegiceras corniculatum* (Ac) *Rhizophora apiculata* (Ra) *Avicennia marina* (Am) *Sonneratia alba* (Sa)	High adaptation because having density >1000 trees/ha (moderate density) , high distribution, dominant species	Water inundation 10 cm-150 cm, water pH between 5-7.03, soil pH between 5 – 6,5, soil texture loamy clay, clay, muddy clay, and sandy loam, and water salinity 10 ppt – 30 ppt Pyrite (2,13 ± 0,48 %), phosphate (15,70 ± 4,10 mg/l), nitrate (25,95 ±3,06 mg/l)
2	*Bruguiera gymnorrhiza* (Bg) *Rhizophora mucronata* (Rm) *Sonneratia caseolaris* (Sc) *Xylocarpus granatum* (Xg)	moderate adaptation because have a density of> 700trees/ha (rare density), medium distribution,	Water inundation 10 cm-50 cm, water pH between 6.0-7.5, soil pH between 5 – 6.5, soil texture clay and muddy clay, and water salinity <10 ppt – 15 ppt Pyrite (2,47 ± 0,33 %), phosphate (15,38 ± 3,07 mg/l), nitrate (25,47 ± 3,19 mg/l)
3	*Avicennia alba* (Aa) *Ceriops decandra (Cd)*	low adaptation because have a density of> 400 trees/ha (rare density), lower distribution, minor species	Water inundation 10 cm – 80 cm, water pH between 6.0-7.5, soil pH between 6 – 6.5, soil texture clay and muddy clay, and water salinity <10 ppt – 25 ppt Pyrite (1,99 ±0,59%), phosphate (15,07 ± 1,69 mg/l), nitrate (24,59 ± 3,44 mg/l)
4	*Aegiceras floridum (Af)* *Bruguiera parviflora (Bp)* *Ceriops tagal (Ct)* *Xylocarpus moluccensis (Xm)*	lowest adaptation because have a density of < 400 trees/ha (very rare), lowest distribution, recessive species	Water inundation 10 cm-30 cm, water pH between 6.0-7.5, soil pH between 5 – 6.5, soil texture clay and water salinity <10 ppt – 15 ppt Pyrite (2,51 ±,0,42 %) phosphate (16,67 ± 2,05 mg/l), nitrate (23,91 ± 3,36 mg/l)

The result showed different dominant species than the previous study by[7] in Merbau and Rangsang Island. Five mangrove species dominated Segara Anakan, but only three species namely *Rhizophora apiculata, Sonneratia alba, and Xylocarpus granatum* were dominant in Merbau Island as well as *Aegiceras corniculatum, Avicennia alba,* and *Rhizophora apiculate* in Rangsang Island [7]. This is presumably due to variations in ecological conditions such as a small island with a semiclosed estuary[51] as well as differences in pyrite, nitrate, phosphate, water pollution, pH, and water salinity. Previous studies also reported different dominance of mangrove species in several regions [9,60]. The data in Segara Anakan also showed that nitrate and phosphate potential in zone 1 > zone 2 > zone 3 > zone 4, but pyrite potential is relatively not different. This condition affects the species distribution and density of mangrove species in Segara Anakan Cilacap.

In detail, mangrove landscaping in Segara Anakan Cilacap can be illustrated into four zones as shown in Fig. 3. According to previous reports, mangrove landscaping in the study area started with *Agiceras Floridum, Avicennia Alba, Avicennia Marina, Sonneratia Caseolaris, and Sonneratia Alba* at the first zone [3,29]. These landscaping patterns indicate the different abilities of mangrove species to adapt and tolerate sedimentation and climate change pressures.

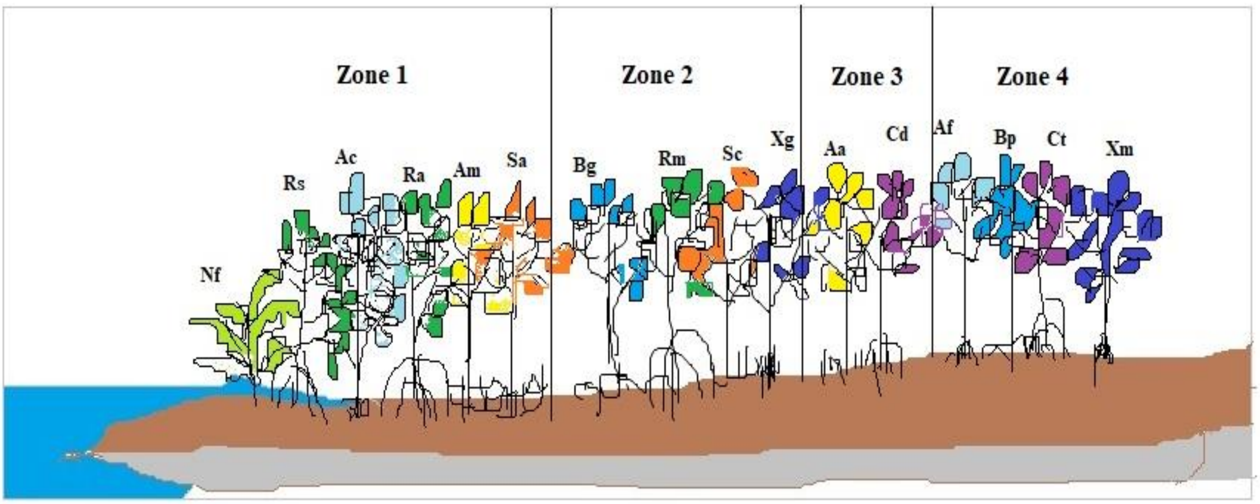

Figure 3. The mangrove adaptation pattern to reduce the impact of climate change

Note : **zone 1** : *Nypa frutican (Nf), Rhizophora styllosa (Rs), Aegiceras corniculatum (Ac), Rhizophora apiculata (Ra), Avicennia marina (Am), Sonneratia alba (Sa).* **Zone 2** : *Bruguiera gymnorrhiza (Bg), Rhizophora mucronata (Rm), Sonneratia caseolaris (Sc), Xylocarpus granatum (Xg)*. **Zone 3** : *Avicennia alba (Aa), Ceriops decandra (Cd)*. **Zone 4** : *Aegiceras floridum (Af), Bruguiera parviflora (Bp), Ceriops tagal (Ct), Xylocarpus mollucensis (Xm)*

Mangrove landscaping is also affected by sea currents, water inundation, sedimentation, sea tide, and ocean wave. Sea currents affect mangrove and aquatic organism distribution due to differences, changes, and distribution of food web structure, water catchment area, tidal inundation, hydrology, nutrients inputs, and source of alternative energy [31,32]. The most adverse impact of climate change, sea waves, sea currents, sea tide, sedimentation, and water inundation is altering the structure and distribution of mangrove species, clustering and association, as well as degradation of the mangrove ecosystem [3,43,61,62]. Moreover, climate change, sea waves, sea level rise, sea currents, and other oceanography factors affect the vulnerability and adaptation of the mangrove ecosystem[26,63]. Climate impacts also affect the physiological and morphological characteristics of mangrove species as a pattern of adaptation of mangrove species in response to climate change impacts [64]. The data also showed that *Nypa frutican, Rhizophora apiculata, Aegiceras corniculatum, Rhizophora stylosa, Avicennia marina* and *Sonneratia alba* show the high ability to reduce impact of climate change, sea current, ocean wave, and water inundation

Indicators of climate change

Rainfall intensity of the dry and rainy season

As shown in Table 3, the Rainfall intensity in Cilacap and Segara Anakan Lagoon during the dry and rainy seasons ranged between 2208±502 mm/year and 5435±1372mm/year respectively. The average rainfall in the rainy season was between 1533 and 2558 mm/year, and the dry season was 180 and 1096 mm/year. Moreover, the highest rainfall intensity occurred in 2010 at 5069 mm/year and in 2016 at 5435 mm/year Fig. 4. The highest rainfall intensity in the rainy season occurred in 2009 – 2010, with an intensity between 2429 mm/year – 2558 mm/year but in the dry season, it ranged from 1091-1096 mm/year in 2014 and 2017. The average of rainfall intensity 3552 ± 1000 mm/year (high intensity), with rainfall intensity in rainy seaseon 1987 ± 378 and dry season 912 ± 254 mm/year

The potential of rainfall intensity has various impacts, including heavy and tidal flooding[26,65,] storm surge, inland flood, El Nino and la Nina events [66,] temperature change (micro and macro impact), as well as crop-specific agricultural productivity [67.] The negative impacts of high rainfall intensity include decreased vegetation productivity [67,68,] triggering of denitrification and not assimilation [69], nitrite leaching in depleted soils [70] and high impact on the water budget[71], The rate of total water change in the aquifer is estimated to be an average of 37.5 mm year^{-1} with an increase in rainfall of 7.0 mm year^{-1} [71]

Table 3. The trend of rainfall intensity in Cilacap Regency (high intensity, rainy season and dry season)

Year	**Intensity of rainfall (mm/year)**			
	Rainfall totals	stdev	Rainy season	dry season
2008	2208	750	2208	180
2015	2276	502	1679	597
2018	2354	530	1538	1001
2011	2874	592	1676	1002
2012	3015	673	2307	709
2013	3159	720	1533	1055
2017	3494	810	2398	1096
2009	3588	850	2558	1030
2014	3846	902	2227	1091
2019	3883	910	1678	980
2020	3981	911	1688	1001
2021	4552	1005	2213	1015
2010	5069	1047	2429	1053
2016	5435	1372	1691	956
average	3552		1987	912
Stdev	1000		374	254

Data in Fig. 4 shows the fluctuating trend of rainfall intensity wherein the highest occurred in 2010 and 2016, while the lowest was observed in 2008 and 2015. Furthermore, Fig. 4 shows that the rainfall intensity in the dry season was lesser than in the rainy season. The highest potential of rainfall intensity occurred in 2017 for both seasons, while the lowest was observed in 2008 and 2013 for the dry and rainy seasons respectively Fig. 5.

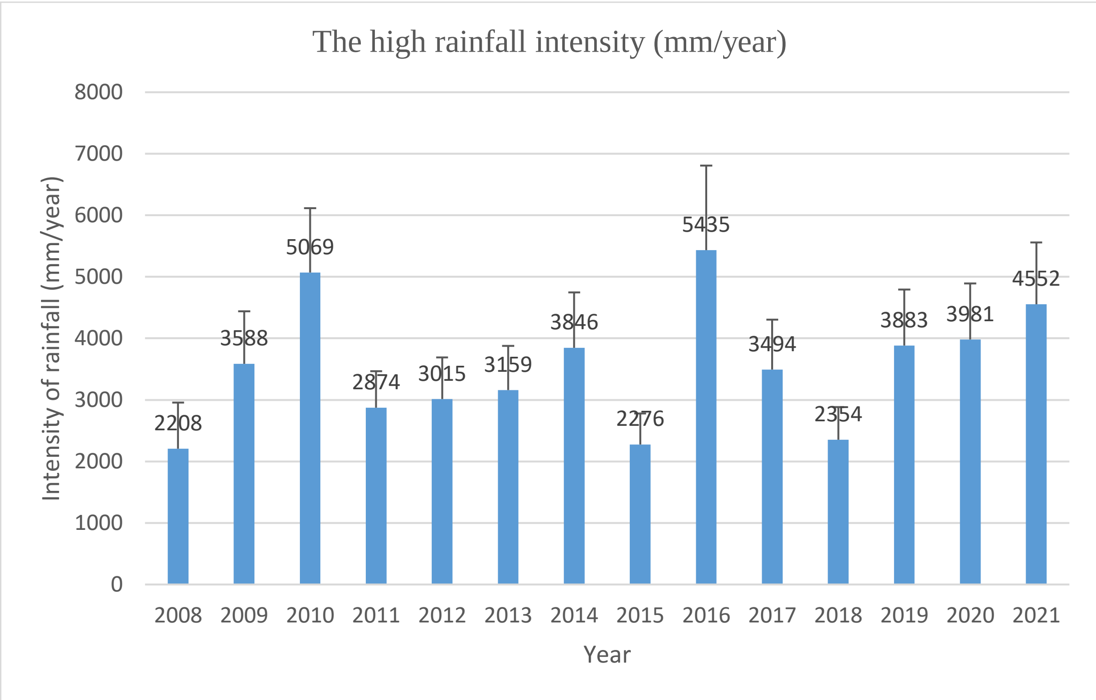

Figure 4. The trend of rainfall intensity in Cilacap Regency

The potential rainfall intensity in the dry and rainy seasons is related to the different conditions of evapotranspiration [72,]. which triggers land grabbing, critical land, and land damage [18], affecting soil water balance, maize production, and potential adaptation measures [17]. Others issues and impacts of potential rainfall include changes in macroclimatic conditions, inputs of nutrients, freshwater, and sediments, coastal watersheds, sea-level rise, and storm activity with a strong influence on the hydrology, ecological functioning, physicochemical environment, and species composition in many ecosystems[73–75]

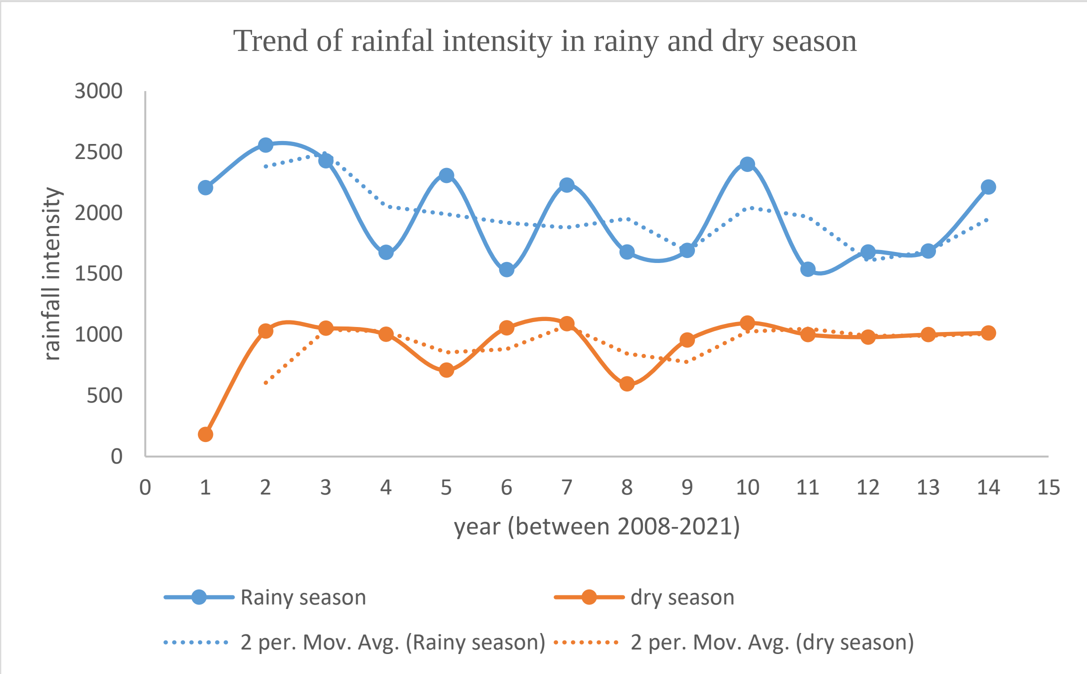

Figure 5. The trend of rainfall intensity in the rainy and dry season

The wind speed

Fig. 6 shows that the wind speed in Segara Anakan and Cilacap Regency based on data from 2009 to 2018 ranged between 5 knots and 9 knots. It also presents the monthly wind speed alteration in a year, and from January to February, the average wind speed was 7 knots. A significant wind speed increase occurred from May to August, from 7 knots to 9 knots, while the highest was observed in June and August (east monsoon season), which reach 9 knots.

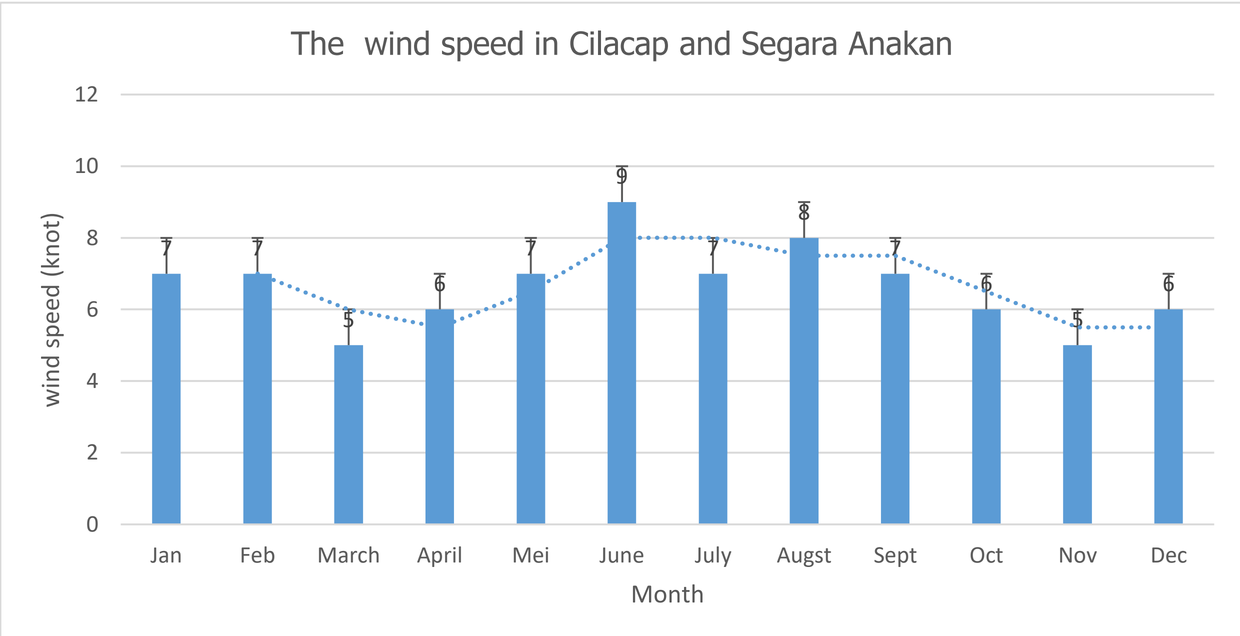

Figure 6. The trend of wind speed in Cilacap and Segara Anakan

The wind speed and direction as shown in Fig. 7 influence fishing activities by communities and fishermen's adaptation to different technology and methods [20,76,77]. The data showed that the highest wind speeds tend to occur in June and August (the easterly season) reaching 9 knots, and this is a barrier

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to fishing activities in Cilacap and Segara Anakan Lagoon. Previous studies [19] and [20] also stated that wind speed has a negative impact and becomes a limitation for fishermen to develop a good adaptation to reduce climate change and support commercial fishing [21]. Furthermore, wind speed has a high impact on sea level rise [27,28], ocean waves [34,35], water inundation, sea tide, and river current [31]. The direction also influences river current energy [31–33,] as well as food chain [31,] organisms, mangrove [16,] pollution [59,78] and fishing area distribution [21]

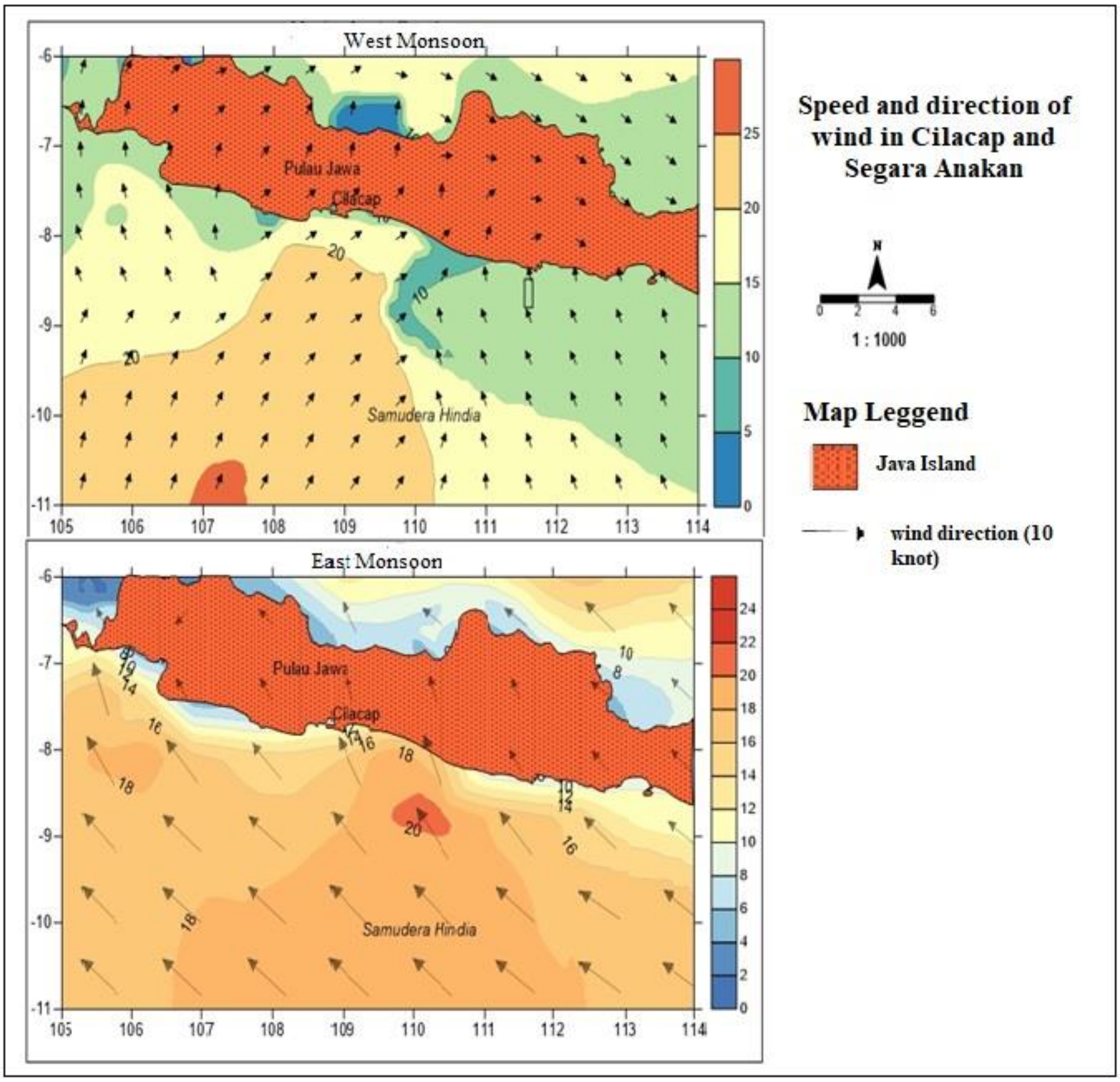

Figure 7. The wind direction in Cilacap and Segara Anakan

Impact of climate change

Ocean waves and sea current

Fig. 8 shows that the average wave height around the southern waters of Cilacap ranged from 2.7 m to 3.4 m, and the highest waves occurred in July and August. This condition is different between the east and west seasons because the wave height in the east season is lower than in the west season wind [34,35.]

Based on data processing using the European Center for Medium-Range Weather Forecasts (ECMWF) for a period of 12 years (2009-2021), the average sea wave height in the waters and the South Indian Ocean of Java in the West wind season is between 1.1 m to 1.5 m, while in the East season, it ranges from 1.2 to 1.7 m. Another important oceanography indicator is the sea current and the average speed of ocean currents is based on data processing results of

ECMWF for 12 years (2009-2021). The data showed that in the West season, the ocean currents in the South Indian Ocean of Java moved from the East to the Southeast with an average speed of 0.25 to 0.50 m /sec or 0.5 to 1 knot. In comparison, during the East Season, the ocean currents moved from the West to the Southwest with an average speed of 0.1 to 0.3 m/sec or 0.2 to 0.5 knots.

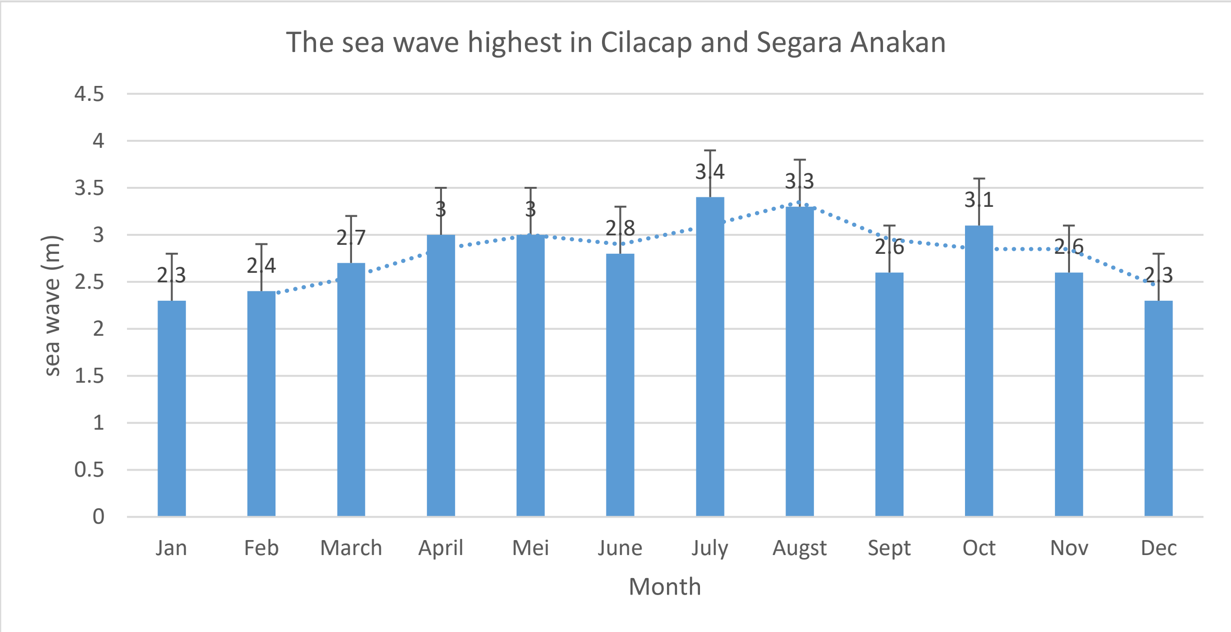

Figure 8. The sea wave highest in Hindia Ocean, Cilacap Regency

The sea wave and sea currents are the main cause of tidal flooding and sea level rise, which usually occur in July, August, and October. The highest wave tends to influence the stability of the lagoon, water inundation, bathymetry, as well as mangrove degradation, coral reef, seaweed, sea grass, habitat degradation of the aquatic organism, and terrestrial organism [34,35,43.] The combined effect of sea level rise, climate change, increased high waves, tidal flooding, and other oceanography variables can lead to habitat loss [27,28]

Mangrove and Lagoon degradation

The impact of climate change on mangrove and lagoon degradation is illustrated in Fig. 9 and Table 4. The Segara Anakan Lagoon is the estuary of 8 large and 17 small rivers, including the Citanduy, Cibereum, Cimeneng, Palindukan, Dead Wood, and Cikujang rivers in the western zone. Furthermore, the Panikel, Cigintung, Ujung Alang, Dangal, Sapuregel, and Kembang Kuning rivers influence the middle zone, while the eastern zone has the Cigintung and Donan rivers. The existence of many rivers in Segara Anakan has led to a negative trend in the lagoon ecosystem, evidenced by a degradation trend from 2.469,42 ha (1990) to 763.71 ha (2020). The negative trend of mangrove and lagoon in Segara Anakan had equation y = -86,195x + 1779,8 with determintation index (R^2 = 0,6). This trend also indicates that the sustainability of mangrove and lagoon ecosystems is highly threatened.

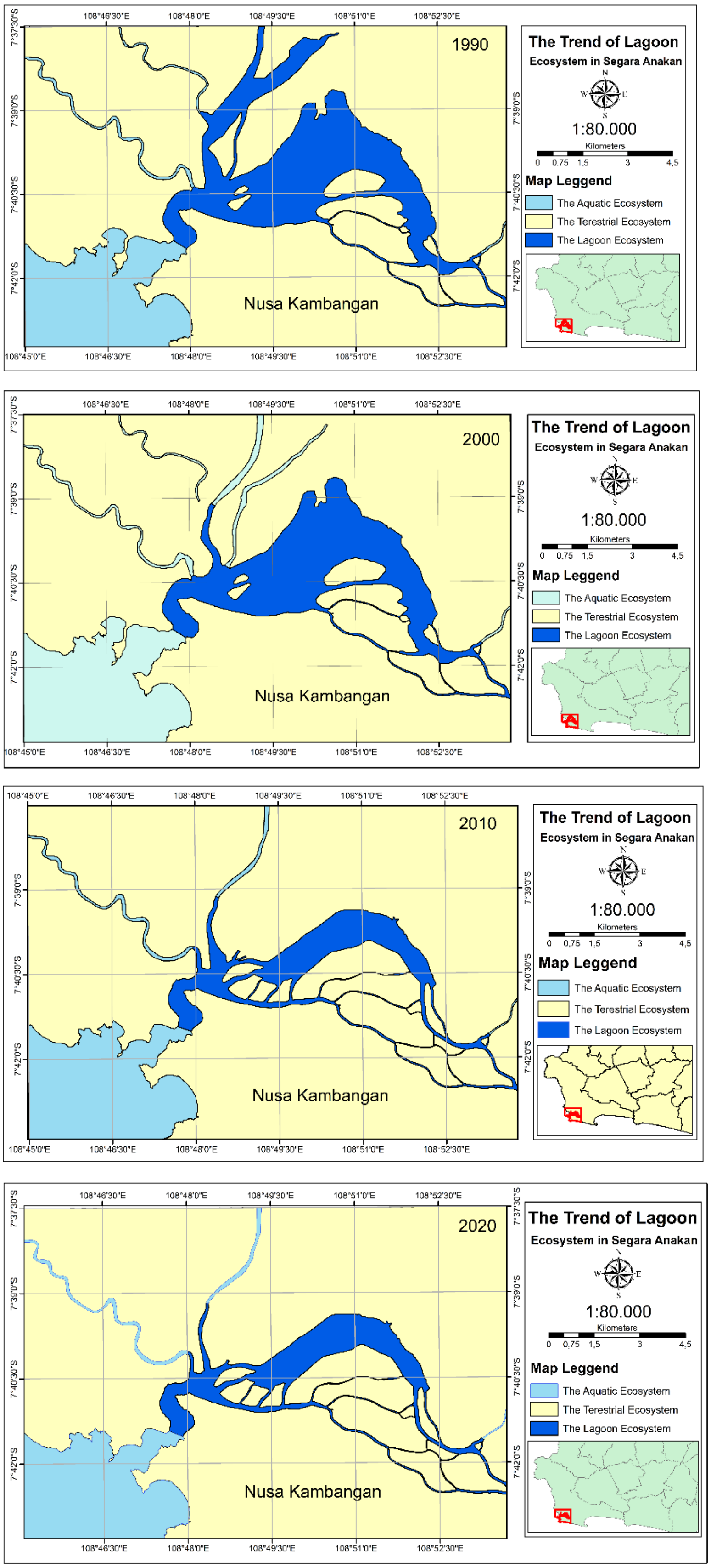

Figure 9. The lagoon trend in Segara Anakan Lagoon

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The data in Table 4 shows that the decreasing trend of the lagoon ecosystem reached 56.86 ha/year. The highest decrease occurred from 1990-2000, reaching 891.39 ha/10 years, and from 2016-2017, reaching 108.52 ha/year. Previous studies [33,36] showed that the degradation of lagoon and mangrove in Segara Anakan Lagoon (SAL) Cilacap for 38 years (1978-2016) reached 2703.7 ha or at a rate of 71.15 ha/year [2,3,36]. Meanwhile, the degradation of the lagoon also harms the mangrove ecosystem. The mangrove ecosystem increased from 2,394.54 ha in 1978 to 4,250.70 ha in 1994, and then to 3,892.77 ha in 2001. It also reduced to 3,818.34 ha in 2009, 3,645.54 ha in 2011, and 2,862.81 ha in 2016 [2,33].

Table 4. Trend of the Segara Anakan Lagoon

Year	lagoon	decreasing trend
1990	2.469,42	
2000	1.578,03	-891,39
2008	1.157,91	-420,12
2009	1.159,57	1,66
2010	1.161,30	1,73
2011	1.096,81	-64,49
2012	1.084,43	-12,38
2013	1.025,58	-58,85
2014	1.025,50	-0,08
2015	1.019,70	-5,80
2016	930,41	-89,29
2017	821,89	-108,52
2020	763,71	-58,18

Bassically the lagoon and mangrove degradation is influenced by the other factors, because the correlation between mangrove and lagoon degradation with with rainfall intensity = -0,35 (low correlation), with wind speed = 0,18 (low correlation) and sea wave = - 0,34(low correlation) (Table 5). The other research show that the degradation of lagoon and mangrove ecosystems in Segara Anakan is also caused by sedimentation (as main factor) and the environment. For example, sedimentation is influenced by climate change and sediment transport from various rivers. A previous study [36] reported that the increasing rate of new land in SAL from 1994 to 2014 was 41.2 ha year^{-1}, with the sedimentation process reaching 484.14 ha year^{-1} from 1994 to 2003 and 339.7 ha year^{-1} from 2003 to 2014.

Table 5. The correlation lagoon/mangrove degradation with climate change factors

	lagoon	rainfall	wind speed	sea wave
lagoon	1			
rainfall	-0,3474	1		
wind speed	0,187507	-0,00632	1	
sea wave	-0,34472	-0,14529	0,480296	1

Another study [22] noted that reducing the impact of climate change requires integrated water resource management and conservation of water activity. According to a previous report, [23] climate change has a high impact on lagoons, as indicated by the area inflow which changed from 22.1 km3 to 15.9 km3, lagoon salinity increase from 1.4 ppt to 2.6 ppt, and the lagoon water temperature is projected to rise by 2—6ºC. The trend of lagoon degradation presented in Fig 10 follows the sedimentation rate. The Segara Anakan lagoon had a negative trend with equation $y = -4,3833x^3 + 105,12x^2 - 803,94x + 2973,7$ ($R^2 = 0,9184$). The data in Fig. 10 explain that the trend of mangrove and lagoon area decline is in the form of a polynomial equation, which means that the rate of mangrove and lagoon area decline is relatively high.

This condition require the conservation and rehabilitation of mangrove and lagoon ecosystems in Segara Anakan

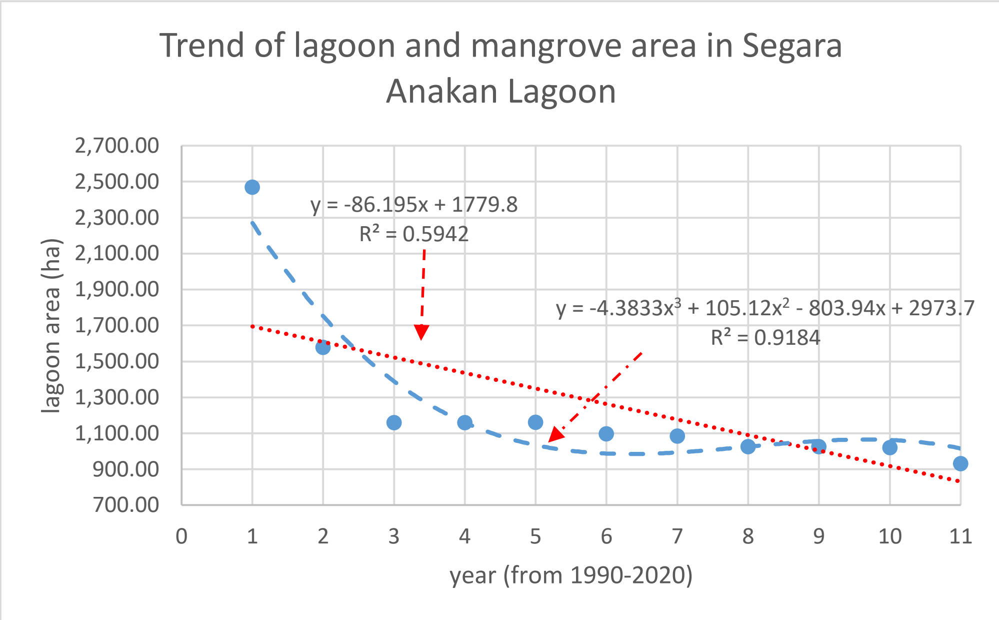

Figure 10. The impact of climate change on the lagoon degradation

Conclusion

The mangrove landscaping in Segara Anakan as mangrove adaptation pattern to reduce climate change impact is arranged by *Nypa frutican*, *Rhizophora styllosa*, *Aegiceras corniculatum*, *Rhizophora apiculata*, *Avicennia marina*, and *Sonneratia alba* as the first zone. Furthermore, *Bruguiera gymnorrhiza* (Bg), *Rhizophora mucronata* (Rm), *Sonneratia caseolaris* (Sc), *Xylocarpus granatum* (Xg) forms the second zone, while *Avicennia alba* (Aa), *Ceriops decandra (Cd)* constitute the third zone. The fourth zone consists of *Aegiceras floridum (Af), Bruguiera parviflora (Bp), Ceriops tagal (Ct), and Xylocarpus moluccensis (Xm).* Mangrove landscapes are also built to reduce sedimentation rates, tides, increased ocean currents and waves as a result of climate change impacts.

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Jenderal Soedirman University.

Authors' Contribution Statement

E. H. made the protocol of this study and as the first and corresponding author (expert of mangroves and coastal ecosystems.). N. A. performed the analysis of environmental conditions. I. S. supports the social implications of climate change. A. M. supports the impact of climate change for fishing ground and fishing activity.T. M. R. designs the impact of climate change and T. W. supports the analysis of climate change indicators. All authors interpreted the data, and read the manuscript carefully and approved the final version of their manuscript.

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المناظر الطبيعية لأشجار الأيكة الساحلية كنمط للتكيف لتقليل تأثير تغير المناخ في المناظر الطبيعية لأشجار المانغروف كنمط للتكيف للحد من تاثير المناخ في سيجارا أناكان لاجون ، ريجنسي سيلاكاب اندونيسيا

إندانج هيلمي [1] ، نورول أنور [2] ، الإمام سانتوسا [3] عارف مهديانة [1] ، تارونا منى رحمان [4]، تيجوه واردويو [4]

[1]برنامج إدارة الموارد المائية وبرنامج Magister SDA ، كلية المصايد وعلوم البحار ، جامعة جينديرال سوديرمان.
[2]كلية الاقتصاد والماجستير في برنامج علوم البيئة (برنامج الدراسات العليا)، جامعة جينديرال سوديرمان.
[3]قسم علم الاجتماع FISIP وماجستير في برنامج علوم البيئة (برنامج الدراسات العليا) ، جامعة جينديرال سوديرمان.
[4]علم الأرصاد الجوية والجيوفيزيائية ، محطة تونغول وولونغ ، سيلاكاب وماجيستير في برنامج علوم البيئة (برنامج الدراسات العليا) ، جامعة جينديرال سوديرمان.

الخلاصة

مناظر الطبيعية لأشجار الأيكة الساحلية في Segara Anakan Lagoon (SAL) هي نمط تكيف للنظم البيئية لأشجار الأيكة الساحلية للعيش والنمو في مناطق غير مستقرة .يهدف هذا البحث إلى تطوير المناظر الطبيعية لأشجارها للتخفيف من آثار موجات المحيطات والتيارات والفيضان بسبب تغير المناخ .أجريت الدراسة في SAL و Cilacap Coast (CC) باستخدام الخصائص البيئية وبيانات تغير المناخ .تم تحليل البيانات التي تم الحصول عليها باستخدام تحليل الخرائط وخط الاتجاه .أظهرت النتائج أن المناظر الطبيعية لأشجار الأيكة الساحلية في سيجارا أناكان تحتوي على أربع مناطق مع Nypa frutican و Rhizophora Styllosa و Aegiceras corniculatumو Rhizophora apiculata و Avicennia marina و Sonneratia alba التي تم تحديدها كأفضل تكيف لأنواع الأيكة الساحلية .يؤثر تغير المناخ بشكل كبير على تدهورها (التدهور 142.1 هكتار / سنة) ، وعدم استقرار كثافة هطول الأمطار بمتوسط كثافة 3552 ملم / سنة ، واتجاه الرياح غير المنتظم بمتوسط سرعة 7 عقد ، وزيادة موجة البحر وارتفاع مستوى سطح البحر)تتراوح من 2.7 م إلى 3.4 م) خلصت النتائج إلى أن أنواع الاشجار لديها القدرة على العيش والنمو ، لأن تغير المناخ لا يؤثر على نموها (الارتباط مع كثافة هطول الأمطار = -0،35 ، مع سرعة الرياح = 0 ، 18وموجة البحر = - 0،34).

الكلمات المفتاحية: خصائص المناخ، تدهور البحيرة، المناظر الطبيعية من غابات المانغروف، موجة البحر، تيار البحر.