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The Mangrove Landscape and Zonation Following Soil Properties and Water Inundation Distribution in Segara Anakan Cilacap

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Abstract

The mangrove zoning and landscape express the correlation between mangrove vegetation (*density, biodiversity and species distribution*) *with environment factors like as water inundation, seatide, and soil properties. The research was conducted in Segara Anakan Lagoon to analysis community structure and mangrove landscape based on species distribution, biodiversity, environment factors, and mangrove zoning. The results showed that* (*a*) *Segara Anakan Lagoon had 4 mangrove zone's were dominated by Sonneratia alba, Rhizophora mucronata, Avicennia marina, Rhizophora apiculata, Rhizophora styllosa, and Nypa frutican;* (*b*) *the structure of ecosystem was showed by trend of mangrove ecosystem with equation* $y = 35.34x^2 \; 923.85x + 12817$ *with* x = *time* (*year*) *and* y = *mangrove area* (*ha*), *mangrove density between 1333367 ind* ha^{-1} (*West Segara Anakan*) *and 899–567 ind* ha^{-1} (*East Segara Anakan*), *dominated species were Nypa frutican, Rhizophora stylosa, Rhizophora apiculata, and Aegiceras corniculatum and mangrove biodiversity between 2,572,65* (*moderate*); (*c*) *structure of environment factor showed single and semi double-type tides, water debit between 0.360.73* $m\ s^{-1}$; *water depth between 0.20–23.7 m and water inundation between 480cm; soil texture was clay and loam, soil nitrate of 1.5 mg 100* g^{-1}, *soil phosphate of 1.5 mg 100* g^{-1}, *C organic of 1.31%, soil pH of 6–7, and soil salinity of 6.5–10 ppt.*

Keywords: *community structure, mangrove landscape, mangrove density, environment factors, dominated species*

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Introduction

Segara Anakan Lagoon is a semi-closed seawater ecosystem since preserved by Nusakambangan Islands, and takes the seawater supply from the Indian Ocean and freshwater supply from many rivers like as Donan, Citanduy, Cikonde, and Sapuregel river (Hilmi et al., 2019a; 2020). This condition is a trigering factor to support potential of seatide, water inundation, pH, salinity, soil texture, and soil fertilize. The potential of soil and water factors give impact toward the mangrove zonasi and landscape in Segara Anakan Lagoon. This conditions also show the abnormal of mangrove structure and zoning in this mangrove ecosystem (Sinfuego & Buot, 2014; Datta & Deb, 2017).

Basically, mangrove zonation describe a specific structure of mangrove ecosystem using variables of species disribution, species density, and environment factors. The mangrove zone and landscape are influenced by water salinity (Hoppe-Speer et al., 2011; Kantharajan et al., 2018), soil factor (Domínguez-domínguez et al., 2019), soil salinity, pH, soil fertility, water quality (Shiau et al., 2017a; Hilmi et al., 2019b), soil texture (Khadim et al., 2019), sea tide, sea current, seawater inundation, phosphate, sulfate, nitrate and nitrogen (Shiau et al., 2017a; Cheng et al., 2019), freshwater supply, and soil carbon (Barreto et al., 2016; Dai et al., 2018; Xiong et al., 2018). However, the mangrove landscape following the patern of the mangrove zone, species distribution and structure community also refer to the adaptation of mangrove species toward changing of environment factors (Giri et al., 2015), the potential of sedimentation (de Oliveira et al., 2015; Sari et al., 2016), heavy metal pollution (de Oliveira et al., 2015), nitrate buffers (Liu et al., 2019), and oxygen stress (Asaeda & Barnuevo, 2019). Mangrove landscape explains the community structure, species zonation (Sreelekshmi et al., 2018), mangrove stability, and health (De Valck & Rolfe, 2018), mangrove association, and clustering (Hilmi, 2018). In many areas, the mangrove community also is influenced by exsistence of *Rhizophora* spp., *Avicennia* spp., *Bruguiera* spp., *Aegiceras* spp., *Ceriops* spp., and *Sonneratia* spp. as major species of mangrove ecosystem.

Mangrove ecosystem also is influenced by abnormal factors like as sedimentation and pollution. Mangrove species must have the best adaptation patterns to reduce high sedimentation and pollution in Segara Anakan Lagoon. The

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specific adaptation of mangrove species also are developed to reduce impact of mangrove degradation (Ferreira et al., 2015; Kantharajan et al., 2018), sedimentation (Sari et al., 2016), pollution, and minor species expansion (Smee et al., 2017). Based on the data of several research show that in Segara Anakan Lagoon (SAL) has high sedimentation (sediment rate between 4.26103.60 g day^{-1} and total sedimentation 0.228.05 million ton year^{-1}) (Sari et al., 2016), mixed semi-diurnal tide, seawater current (0.360.73 m s^{-1}), inundation level (076 cm), water salinity (30.9934.01 ppt) and pH (6.767.02) (Sari et al., 2016; Hilmi et al., 2019b) and be dominated species by *Rhizophora* spp., *Avicennia* spp., and *Nypa frutican*. The mangrove landscape and zonation following soil properties and water inundation distribution in Segara Anakan Cilacap is develop by relation among species distribution, biodiversity, mangrove density with environment factors. This paper aimed to analysis mangrove landscape and zone's using mangrove density, mangrove covering, mangrove adaptation and distribution soil properties, oceanography and water quality as main variables.

Methods

Research area This research was conducted in Segara Anakan Lagoon (SAL) which was arranged by the mangrove, river (Donan River, Sapuregel River, Kembang Kuning River, Citanduy River, Cimeneng River, and Cikonde River), terrestrial and estuary ecosystems (Hilmi et al., 2019a; 2019b), and Nusakambangan Island as perserved area. This research collect data on 37 stations that were 17 stations in Esat Segara Anakan Lagoon/E-SAL which were distributed in Kalipanas, Donan River, Sapuregel, Pelawangan Timur, and Kembang Kuning River, and 20 stations in West Segara Anakan Lagoon/W-SAL were distributed in Ujung Gagak, Majingklak, Klaces, Ujung Alang, and Kali Semak (Table 1 and Figure 1). The research in SAL was conducted between 2019–2021 to analysis mangrove density, soil water, sea tide, and sea water inundation.

Soil water factor analysis The analysis of soil water were (a) soil water salinity (ppt) using the conductive-photometric method/Hand Refractometer, (b) soil pH using Potentiometric method/pH meter (APHA, 2005; 2012); (c)

Table 1 Research stations

West Segara Anakan			East Segara Anakan		
Stations	Coordinate		Stations	Coordinate	
	Latitude (S)	Longitude (E)		Latitude (S)	Longitude (E)
Sungai Ujung Gagak	07°40′13″	108°48′43″	Kali panas 1	07°40′22.17″	109°00′56.36″
Sungai Lorogan	07°40′44″	108°48′30″	Kali panas 2	07°40′28.91″	109°00′40.57″
Sungai Majingklak	07°40′32″	108°48′01″	Kali panas 3	07°40′20.60″	109°00′33.62″
Sungai Mauara Cawitali	07°41′46″	108°47′41″	Kali panas 4	07°40′18.26″	109°00′32.52″
Sungai Kebuyutan	07°41′13″	108°47′45″	Kali panas 5	07°40′41.12″	109°00′33.98″
Sungai Batu Macan	07°41′38″	108°47′46″	Donan 1	07°40′33.98″	108°59′58.10″
Sungai Jongor	07°40′23″	108°48′20″	Donan 2	07°40′23.79″	108°59′56.90″
Sungai Muara Legok	07°39′48″	108°48′13″	Donan 3	07°41′15.79″	108°59′43.22″
Sungai Kayu Mati	07°39′50″	108°48′27″	Donan 4	07°42′10.17″	108°59′23.75″
Sungai Langkap	07°38′48″	108°48′44″	Donan 5	07°42′46.06″	108°59′29.10″
Sungai Karang Braja	07°40′59″	108°48′47″	Donan 6 (Sleko)	07°43′48.07″	108°59′10.78″
Sungai Klaces	07°41′05″	108°49′47″	Pelawangan Timur	07°43′20.95″	108°58′07.45″
Sungai Inti Ujung Gagak	07°40′34″	108°49′47″	Sapuregel 1	07°41′53.33″	108°57′46.71″
Sungai Muara Bagian	07°40′58″	108°51′42″	Sapuregel 2	07°41′47.97″	108°57′37.81″
Sungai Muara Masigitsela	07°41′24″	108°50′46″	Sapuregel 3	07°42′54.20″	108°57′42.07″
Sungai Pertigaan Ujung Alang	07°41′44″	108°51′39″	Kembang kuning1	07°43′12.88″	108°57′14.24″
Sungai Ujung Alang	07°42′00″	108°51′42″	Kembang kuning2	07°43′07.52″	108°57′03.97″
Sungai Dermaga Ujung Alang	07°42′06″	108°51′53″			
Sungai Kali Semak	07°42′30″	108°52′57″			
Sungai Pertigaan Sudiro	07°42′32″	108°53′38″			

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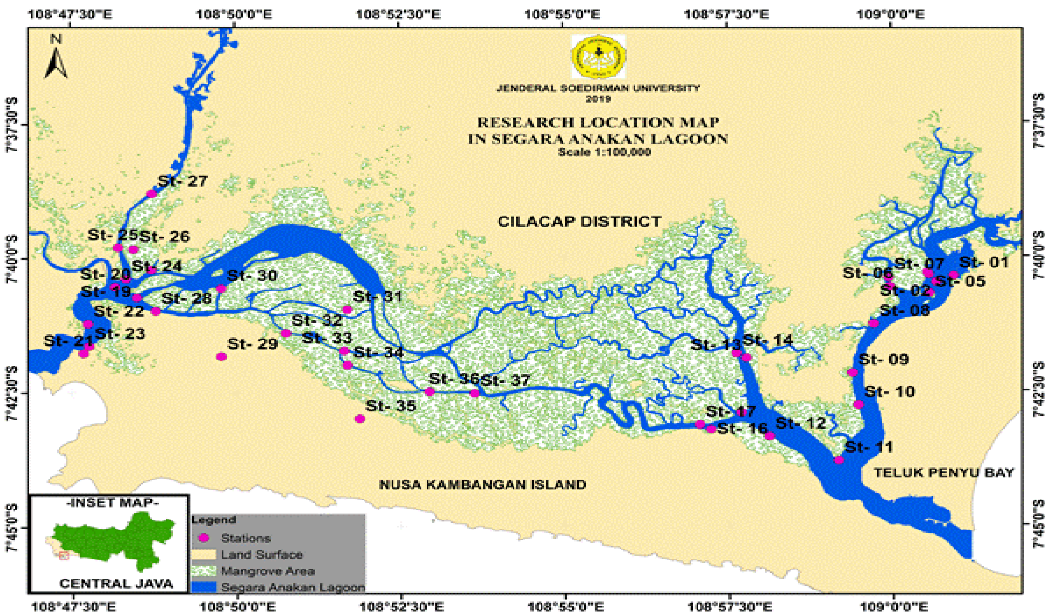

Figure 1 Research area.

Soil texture (%) using Gravimetric method (APHA, 2005; 2012); (d) Nitrate (NO_3^{-1}) (mg 100 g^{-1}) using Brucine method (APHA, 2005; 2012), (e) Phosphate (PO_4^{-3}) (mg 100 g^{-1}) using ascorbic acid method (APHA, 2005; 2012); and (f) Organic–C (%) using Weakly and Black method.

Seatide, currrent speed and seawater inundation ***Seatide*** analysis used tidal data of Navigation District Class III Cilacap. The data were first processed using Microsoft Excel with *Admiralty* tidal behavior calculation method; ***Current speed*** used water column current speed measurement with AEM213-D electro-magnetic current meter instrument; ***Water depth*** used water column depth measurement method with 2 instruments consisting of multi-beam echo sounder and tin pendulum (*dreadloading*); and ***Water inundation*** (cm) analysis used the tide and inundation stick method to record inundation and tidal scale of stick.

Mangrove density The analysis of mangrove density using mangrove trees with diameter > 4 cm. The collection of mangrove trees used line transect method with a sampling plot with the size of 1010 m. The recording mangrove data were analyzed by density equation following Hilmi et al. (2020) (Table 2).

The data analysis ***The mapping analysis*** The mapping analysis used the image processing of satellite imagery between 1990 until 2017. This analysis used a capturing method with ArcGIS version 10.3, ENVI version 4.07, and Google Earth version 2017. To analyze the mangrove landscape, this research used bassic map from the Landsat 7 (1990–2017), Landsat 8 (analysis 20182019), and RBI (2014). The last analysis was mangrove classification used the combined images with false color composite between band 4, 5 and 3 (RGB).

Biodiversity analysis The mangrove biodiversity divided 3 analysis that were species richness, heterogeneity, and evenness index. The mangrove biodiversity analysis used Margaleff index (to analysis species richness), Shannon Wiener index (to analysis heterogenity), and Evennes index (Magurran, 1996).

The statistical analysis Statistical analysis used trend analysis to choice best equation and stock tabulation analysis to develop data structure following value of average, maximum, minimum, and standard deviation (Haslwanter, 2015).

Mangrove landscape analysis The mangrove landscape analysis was used to describe species distribution of mangrove ecosystem in Segara Anakan Lagoon Cilacap. The mangrove landscape was build using the correlation analysis among species density with water depth level (cm), water inundation (cm), pH, and salinity.

Results and Discussion

The mangrove zoning The mangrove distribution was showed by the mangrove covering, the species density, the biodiversity and diameter distribution. The mangrove distribution describe the potential area and species of mangrove ecosystem in Segara Anakan Lagoon. The mangrove distribution also showed domination species of mangrove ecosystem in Segara Anakan Lagoon.

The potential of mangrove area The mangrove ecosystem in SAL had the trends consisting of 11,888.3 ha (1990), 8,276.1 ha (1997), 6,928.6 ha (2000), and 7,357.8 ha (2017), whereas lagoon ecosystem had potential were 1,511.5 ha (1990), 1,493,7 ha (1997), 1,198,7 ha (2000), and 7,357.8 ha (2017) (Figure 2). The trend of mangrove and lagoon ecosystem had

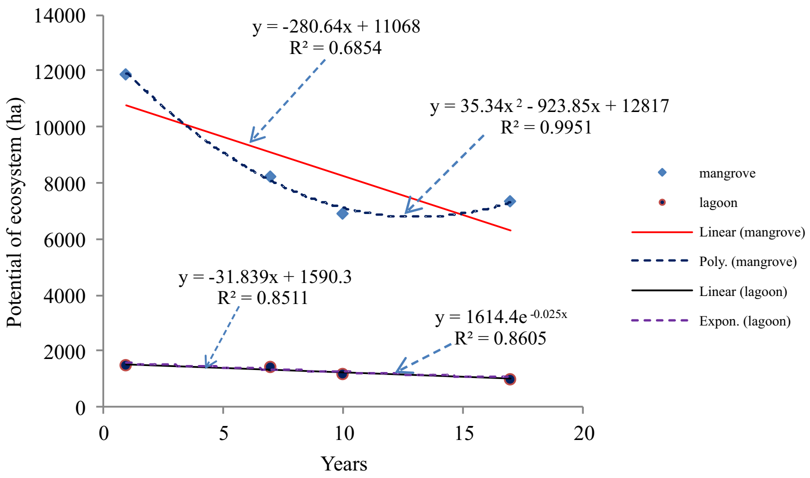

Figure 2 Mangrove distribution trend in Segara Anakan Lagoon.

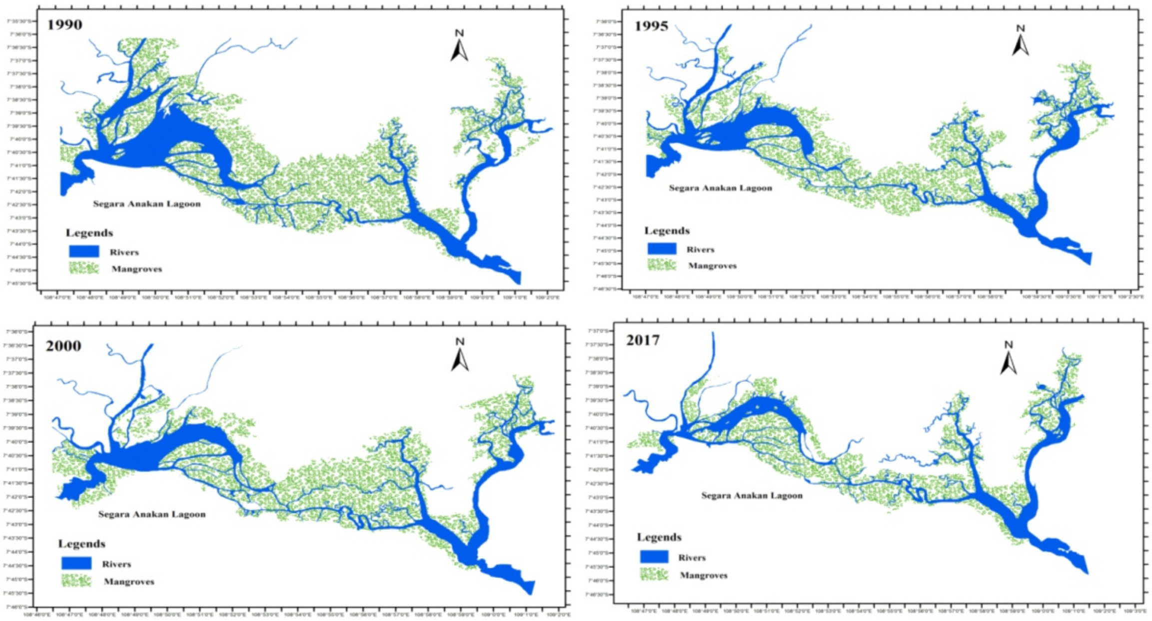

Figure 3 The trend of mangrove distribution in Segara Anakan Lagoon.

negative trend showing the potential degradation of mangrove and lagoon ecosystem in SAL.

The data on Figure 2 and Figure 3 expressed the fast rate of mangrove destruction in Segara Anakan. The prediction model using best regression model and linier model predicted that potential of mangrove ecostystem in Segara Anakan Lagoon ≤ 5,174,6 ha and potential lagoon ≤ 950.5 ha. Xin et al. (2014) also gives note that more than 1/3 total area of mangrove in India, Indonesia, Sri Lanka, Thailand, and China were degraded.

The prediction analysis on Figure 2 and Figure 3 described that the degradation rate of mangrove ecosystem in Segara Anakan Lagoon reached 108.87–251,7 ha year^{-1}, and lagoon ecosystem reached 26.0–30.0 ha year^{-1}. The mangrove and lagoon degradation in Segara Anakan Lagoon were caused by conversions to fishponds, settlements and industries, ilegal logging, expansion of *Acanthus* (Ardli & Wolff, 2008), sedimentation (Sari et al., 2016), waste pollution disposal and hydrocarbon (Hidayati et al., 2011; Syakti et al., 2013a; 2013b), and accretion (Hilmi et al., 2017). Singh et al. (2013), Victor et al. (2006), and Schwarzer et al. (2016) also estimate the degradation of mangrove ecosystem is caused by conversion, illegal logging, sedimentation, and water pollution including heavy metal pollution

The mangrove density The structure of mangrove density was expressed by mangrove species density and mangrove area. The density of mangrove area was showed by Figure 4 and Table 2. The data showed that potential mangrove density in Segara Anakan Lagoon divided (a) East Segara Anakan Lagoon (E-SAL) between 8995,675 trees ha^{-1}, with average 3047 trees ha^{-1}, and West Segara Anakan Lagoon (W-SAL) had density between 1333,367 trees ha^{-1}, with average

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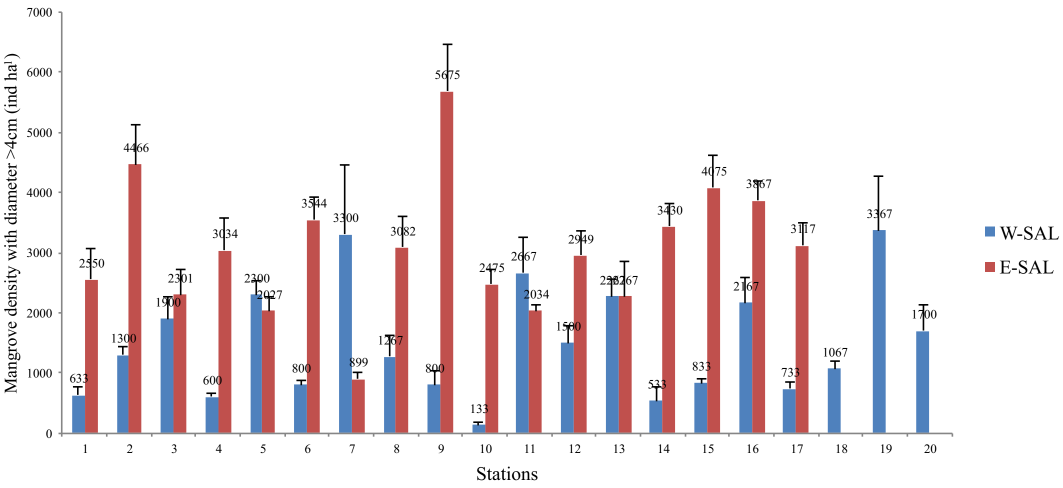

Figure 4 The density of mangrove ecosystem in Segara Anakan Lagoon.

Table 2 Classification of mangrove density levels

Density level	Mangrove density (diameter > 4cm) trees ha^{-1}
Very rare ly	0–390
Rare density	391–1,610
Moderate	1,611–2,220
High density	2,221–3,130
Very high density	> 3,130

1493 trees ha^{-1}. Potential density of mangrove ecosystem in E-SAL more than mangrove ecosystem in W-SAL. The indicators of mangrove degaradation are showed by the narrowing area of lagoon, loosing of organism habitats, expansion of *Acanthus* spp., and *Acrossticum aureum* (Hilmi et al., 2019a; 2020). The others impact are decreasing of fisherman incomes, aquaculture productivity, distrubed transportation, death of organsim aquatic, and othres.

However, the species density of mangrove ecosystem in SAL could be shown on Figure 5. The data showed that E-SAL was dominated by *N. frutican* (average 934 trees ha^{-1}), *Rhizophora stylosa* (average 733 trees ha^{-1}), *Aegiceras corniculatum* (average 471 trees ha^{-1}), and *R. apiculata* (average 395 trees ha^{-1}). Whereas, W-SAL was dominated by *N. frutican* (average 753 trees ha^{-1}), *Avicennia marina* (average 305 trees ha^{-1}), and *A. corniculatum* (average 283 trees ha^{-1}).

The mangrove density and species distribution in SAL could be shown on Table 2. The data explain that mangrove density in E-SAL more dense than W-SAL. The mangrove ecosystem in E-SAL was dominated by high density and very high denity (70.6%), whereas W-SAL is dominated by rare density (55.0%). The species dominant in SAL were *Sonneratia alba, R. mucronata, A. marina, R. apiculata, R. styllosa,* and *N. frutican*.

The distribution of species density in mangrove ecosystem SAL could be shown on Figure 6. The data on Figure 6 showed that the highest distribution of species density in W-SAL were *N. frutican, A. alba, A. marina,* and *S. alba.* Whereas the highest distribution of species density in E-SAL were *N. frutican, S. alba, R. styllosa, A. corniculatum, A. marina* and *R. apiculata.*

Hilmi et al. (2015) also noted that mangrove zonation in E-SAL was dominated by *A. marina* and *A. oficinallis* (Zone 1), *R. mucronata*, *R. apiculata*, and *Ceriops tagal* (zone 2) and *N. fruticans* and *S. casseolaris* (Zone 3) with diversity index between 0.48–1.83 (low–middle). Hilmi et al. (2017) also noted that the carbon potency of mangrove ecosystem in SAL is influenced by exsistence of *Bruguiera praviflora, R. mucronata, B. sexangula, R. apiculata, B. gymnorrhiza* as major species in mangrove ecosystem.

Mangrove diversity and diameter distribution The last indicator of community structure is the mangrove diversity and diameter distribution will be shown on Table 3. Based on the mangrove diversity showed that Segara Anakan Cilacap had moderate diversity both of species richness and heterogenity but had homogen distribution. However, based on diameter distribution showed that mangrove ecosystem in Segara Anakan had highest diameter distribution between 0–10 cm (Table 4).

The trigerring factors of mangrove zone *Sea tide, water depth and water current* The lagoon ecosystem in Segara Anakan had the semi diurnal until mixed prevailing semi-diurnal of sea tides (in Eastern SAL) and mixed prevailing semi-diurnal of sea tides (in Western SAL), water debit or current speed of between 0.210.87 m s^{-1} and water depth of between 0.24–20.17 m (Table 5 and Figure 7). The research of Anthony (2004) notes that the river debit data of more than 0.2 m s^{-1} which is not different with that of Segara Anakan.

The *first indicator* is the sea tide types. Based on the Formzahl value, Segara Anakan Lagoon has semi diurnal to mixed prevailing semi-diurnal tide with different (asymmetric) shapes between the first and the second tide. The data range between 10403 cm (sea tide) and 30157 cm (MSL). This condition caused the river and tidal debit still lower than 1 m s^{-1}(Mazda et al., 2007). *The second indicators*

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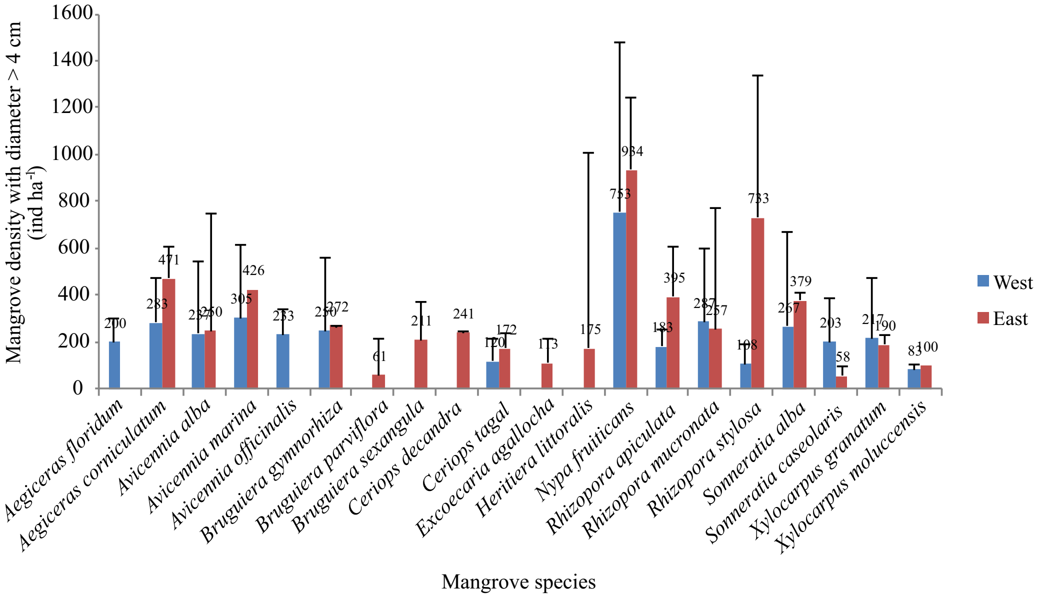

Figure 5 The species density of mangrove ecosystem in Segara Anakan Lagoon.

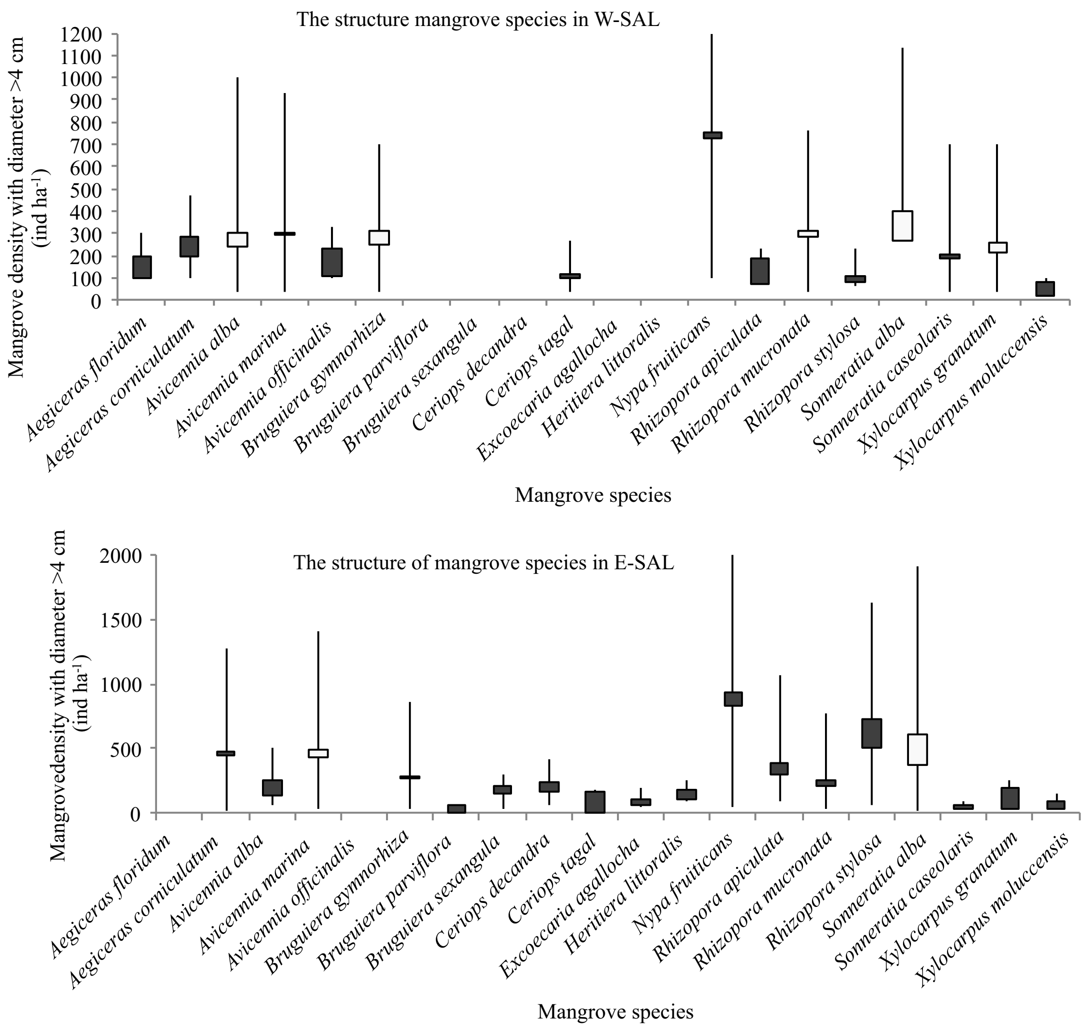

Figure 6 Distribution of mangrove species density in Segara Anakan Lagoon.

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Table 3 The mangrove density and species distribution in SAL

Density level*		Density (trees ha^{-1})		Percent covering		Species dominant	
		E-SAL	W-SAL	E-SAL	W-SAL	E-SAL	W-SAL
Very rare density	Max	120	143	1.2	5.0	*Xylocarpus mollucensis*, *Heritiera litoralis*, *Sonneratia caseolaris*	*Xylocarpus mollucensis*, *Aegiceras floridum*, *Rhizophora apiculata*
	Min	75	123				
Rare density	Max	950	1233	11.8	55.0	*Brugueira sexangula*, *Xylocarpus granatum*, *Bruguiera parviflora*	*Rhizophora stylosa*, *Ceriops tagal*, *Avicennia officinalis*, *Bruguera gymnorrhiza*, *Aegiceras corniculatum*
	Min	850	543				
Moderate	Max	2,087	2,156	17.6	15.0	*Ceriops decandra*, *Ceriops tagal*, *Avicennia alba*	*Xylocarpus granatum*, *Rhizophora mucronata*, *Sonneratia alba*, *Avicennia alba*
	Min	1,847	1,688				
High density	Max	3,009	2,633	35.3	15.0	*Bruguiera gymnorrhiza*	*Sonneratia caseolaris*
	Min	2,383	2,189				
Very high density	Max	4,833	3,380	34.1	10.0	*Sonneratia alba*, *Rhizophora mucronata*, *Avicennia marina*, *Rhizophora apiculata*, *Rhizophora stylosa*, *Nypa frutican*	*Avicennia marina*, *Nypa frutican*
	Min	3,264	3,286				

*The grouping of mangrove density used the Hilmi et al. (2020) method

Table 4 Mangrove diversity and diameter distribution in SAL

SAL	Percent of distribution of diameter class *					Biodiversity		
	0–4	5–9	10–20	21–30	>30	Species richness	Heterogenity	Evenness
East	0.3	97.3	2.1	0.3	0.0	1.70	2.57	0.87
West	20.3	79.5	0.2	0.0	0.0	2.09	2.65	0.79

*Diameter class following Hilmi et al. (2020) (mangrove trees are mangrove vegetation with diameter > 4 cm)

are the river current and water depth. The data showed that Segara Anakan Lagoon (SAL) had the river debit of between 0.210.8 ms^{-1} and the lagoon optimum water depth of < 23.76 m. The data were lower than the potential river debit in Cocoa ck (Aucan & Ridd, 2000). This condition was caused by the existence of Nusakambangan Island as a buffer of SAL from sea current and wind current.

This data showed that Segara Anakan Lagoon is the semi closed hydrodynamic of water current and river debits which is influenced by the interaction among river debit, tidal wave, mangrove ecosystem, sediment distribution, and waste disposal (Hilmi, et al., 2017; Suhendra et al., 2018). Table 3 also showed the river current and river debit in Segara Anakan Lagoon ranging of between 0.340.75 m s^{-1}.

Distribution of soil factors *Segara Anakan* Lagoon had dominated soil texture was clay and loam; nitrate distribution of between 0.1280.191%, phosphate of between 9.5614.95%, C-organic ranging between 1.161.49%; pH of between 5.737,53 and water salinity of between 13.519.5 ppt (E-SAL) and nitrate distribution of between 0.0780.133%, phosphate of between 10.4413.77%, C-organic ranging between 1.161.47%; pH of between 6.207.53, and water salinity of between 13.519.5 ppt (W-SAL) (Table 5).

The data showed that (1) C-organic in W-SAL similar value with E-SAL, (2) potential pH in W-SAL higher than E-SAL, (3) nitrate potential in W-SAL less than E-SAL, (4) water salinity in W-SAL less than E-SAL, and (5) phosphate potential in W-SAL higher than E-SAL.

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Table 5 Sea tides, current, and water depth classification

Factor	Eastern	Western
Sea tide		
Formzahl score	0.702–0.720	0.1633–0.222
Sea tide classification	Semi diurnal until mixed prevailing semi-diurnal	Mixed prevailing semi-diurnal
Sea tide range	10–403 cm	35–165 cm
MSL (cm)	33–157 cm	30–110 cm
Current and water depth		
Current and river debit	0.34–0.75m s^{-1}	0.21–0.8 m s^{-1}
Angular direction	46.85–345.76°	15.0–354.0°
Water depth	< 23.76 m	< 20.2 m

Table 6 Distribution of soil properties

Location	Nitrate		Phosphate		C-Organic		pH		Salinity		Texture
	Value (%)	Distribution (%)	Value (%)	Distribution (%)	Value (%)	Distribution (%)	Value	Distribution (%)	Value (ppt)	Distribution (%)	
E-SAL	0.095–0.127	18	6.85–9.55	18	0.96–1.15	6	5.45–5.72	12	7.0–13.0	18	Clay loam, silty clay, Clay
	0.128–0.191	71	9.56–14.95	65	1.16–1.49	65	5.73–6.26	65	13.5–19.5	41	
	0.192–0.222	6	14.96–17.65	12	1.50–1.66	23	6.37–6.53	23	20.0–27.0	36	
	> 0.222	5	> 17.65	5	>1.66	6	>6.53	0	>28.0	5	
W-SAL	0.049–0.077	15	8.76–10.43	10	0.99–1.15	10	5.52–6.19	20	7.0–13.0	20	Clay loam, silty clay, Clay
	0.078–0.133	80	10.44–13.77	70	1.16–1.47	80	6.20–7.53	60	13.5–19.5	50	
	0.134–0.161	5	13.78–15.44	15	1.48–1.63	5	7.54–8.20	20	20.0–27.0	25	
	> 0.161	0	> 15.44	5	>1.63	5	>8.20	0	>28.0	5	

The relation among mangrove zone and landscape with trigerring factors The correlation between mangrove density with trigerring factors showed that dissolve oxygen, water pH, sea tide and soil salinity had moderate correlation with mangrove density (Table 6). According to Kusmana & Maulina (2015), Nelson et al. (2009), and Hilmi et al. (2017), soil texture and soil salinity have big impact for mangrove distribution and landscape.

Base on data of sea tide, water depth, water current and soil factors in Segara Anakan Lagoon showing the suitable habitat to support mangrove growth. The suitable habitat of mangrove in SAL are shown by ***the first indicator*** seatide. Seatide in Segara Anakan semi diurnal to mixed prevailing semi-diurnal tide with data range between 10403 cm (sea tide) and 30157 cm (MSL). The seatide condition is very suitable to support mangrove growth (Mazda et al., 2007; Hilmi et al., 2015).

The second indicator is the river current and water depth. The potential river current between 0.210.8 m s^{-1} and the lagoon optimum water depth of < 23.76 m is very suitable condition to support mangrove live. Cahyo, (2012) also writes that the W-SAL has current and river debits 0,6768 m s^{-1} with direction 240,1 (southwest) (low tide) and 0,1578 m s^{-1} with direction 8,3 (north) (high tide).

The last indicators are distribution of soil factors. Soil factors like as soil salinity, pH, and soil texture have high influence to develop the species distribution in mangrove ecosystem (Castillo et al., 2017; Datta & Deb, 2017). Kusmana and Maulina (2015) stated salinity as first soil indicator is a big factor to influence mangrove distribution, because salinity causes disseminating mangrove plants, canopy opening, species distribution, species density, species composition and inhibiting nitrogen assimilation, and mangrove plants grow well with the salinity of 1030 ppt. The second factor is soil pH. The soil pH in Segara Anakan Lagoon had ranges between 5.796.27 (acid– neutral). Hilmi et al. (2019a) stated that mangrove grows well on pH of between 68.5. Then, the other soil properties are Nitrate, Phosphate and C-organic. These data showed that Segara Anakan had high soil fertility to support the mangrove growth (Xiong et al., 2018), because SAL had the nitrate of between 0.110.33% (highly potential); phosphate of between 9.4713.8% (highly potential) and C-organic of between 1.151.48%.

Mangrove landscape in Segara Anakan Lagoon Species distribution of mangrove ecosystem in Segara Anakan Lagoon (SAL) was divided into three classes that were (1)

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dominant species consisting of *A. alba, A. marina, N. frutican*, *R. apiculata,* and *R. mucronata;* (2) co-dominant species consisting of *S. alba, S. caseolaris, B. gymorrhiza*, *C. tagal, A. Cornicultum, B. sexangula, C. decandra*, and *B. praviflora;* and (3) minor species consisting of *Heritiera littolaris, Exocecaria agallocha*, and *Xylocarpus granatum* (Table 7).

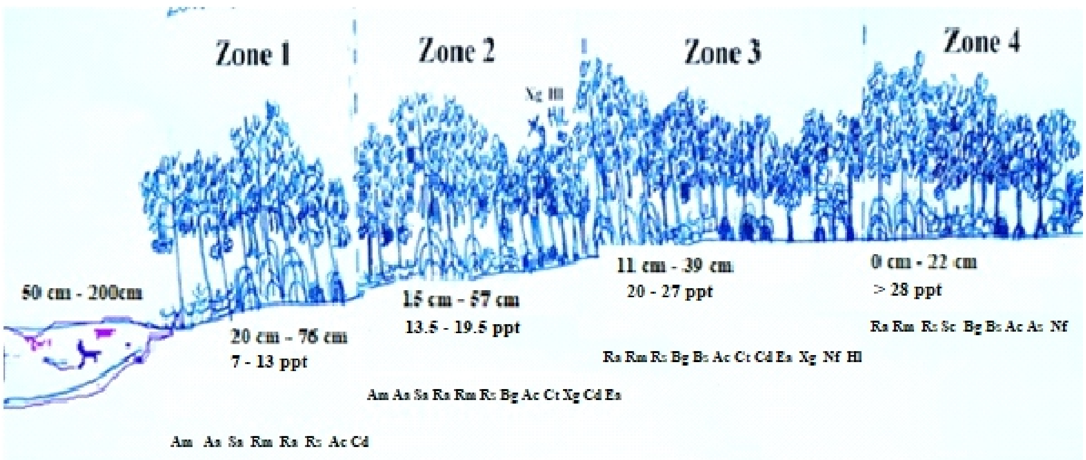
The dominant species on mangrove ecosystem showing best species adaptation to life in Segara Anakan. The mangrove ecosystem in SAL had potential of sea tide (50–200 cm), water inundation (076 cm), potential soil nitrate (0.15–0.29 %), soil phosphate (8.5–16.5%), soil salinity (7.0 >28ppt), and pH (5.5–7.5). Based on the indicators of dominant species, species density, adaptation of soil salinity, soil pH, soil nitrate, soil phosphate, C-organic, sea tide and water depth, developing of the mangrove landscape in SAL can be shown in Figure 8.

The mangrove landscape patterns in SAL describe specific distribution of mangrove species, which were influenced by species adaptation toward soil properties, oceanography factors and water quality. The mangrove landscape in Segara Anakan Lagoon consisted of **Zone 1**: *A. marina, A. alba, S. alba, R. mucronata, R. apiculata, R. stylosa, A. corniculatum, C. decandra;* **Zone 2**: *A. marina, A. alba, S. alba, R. mucronata, R. apiculata, R. stylosa, B. gymnorrhiza, A. corniculatum, C. tagal, X. granatum, C. decandra, E. agallocha;* **Zone 3**: *R. apiculata, R. mucronata, R. stylosa, B. gymnorrhiza, B. sexangula, A. corniculatum, C. tagal, E. agallocha, X. granatum, N. frutican, H. littoralis*; **Zone 4**: *R. apiculata, R. mucronata,*

Table 7 Correlation index mangrove density and trigering factors

	Class correlation		Correlation coeficient	Environment variables
Correlation with mangrove density	Type of correlation	Positive	0.0360 to 0.4960	Water temperature, soil organic, soil salinity, soil pH
		Negative	-0.0679 to -0.5942	Dissolve oxygen, water pH, water salinity, nitrate, phosphate, water depth, seatide
	Grade of correlation*	Absolute	1	
		Very high	0.8–<1	
		High	0.6–<0.8	
		Moderate	0.4–<0.6	Dissolve oxygen, C-organic
		Low	0.2–<0.4	Water temperature, soil pH, water pH, nitrate, soil sal
		Very low	0.0–<0.2	water salinity, phosphate
		Uncorrelated	0	

*Following Walpole and Myers (1995)



Note: *A. corniculatum* (Ac), *Alstonia scholaris* (As), *A. alba* (Aa), *A. marina* (Am), *B. gymnorrhiza* (Bg), *B. sexangula* (Bs), *C. decandra* (Cd), *C. tagal* (Ct), *Exoecaria agallocha* (Ea), *H. Littorea* (Hl), *N. frutican* (Nf), *R. Mucronata* (Rm), *R. Apiculata* (Ra), *R. Styllosa* (Rs), *S. alba* (Sa), *S. caseolaris* (Sc), *Xylocarpus molucensis* (Xm)

Figure 8 The pattern of mangrove landscape.

R. stylosa, B. gymnorrhiza, B. sexangula, A. corniculatum, S. caseolaris, A. scolaris, and *N. frutican*.

The mangrove landscape in Segara Anakan Lagoon had different patterns with the mangrove landscaping proposed by Waston (1928) and Snedaker (1982), because this pattern used the combination of environmental factors (seawater tide, water inundation, texture, and soil water salinity) with the existence of domination, co-domination, and minor species. This landscape also describe specific distribution of mangrove species in Segara Anakan Lagoon. The specific distribution was arraanged by ability of mangrove species to life and grow in other zones, like as *R. apiculata, R. mucronata,* and *R. stylosa.* However, Waston (1928) used only water inundation as the main factor. But, basically, water inundation also impacts on water circulation, potential oxygen, and nutrient supply, water salinity, sediment transportation, pH, and soil texture (Asaeda & Barnuevo, 2019). Water inundation significantly influences the mangrove growth (Hoppe-Speer et al., 2011; Kusmana & Maulina, 2015), maximum photosynthesis process, and stomata opening (Hoppe-Speer et al., 2011). Snedaker (1982) also writes zonation as an expression of plant succession, a response to geomorphic change, physiological response to tide maintained gradients and a consequence of differential propagule dispersal only describe mangrove zonation following mangrove forest type, abundance propagule dispersal, light appears, distribution substrate, salinity, and sea tide factor.

The other reasons to describe different patern between mangrove landscaping in SAL with Waston (1928) patern, because the mangrove landscaping in SAL was influenced by mangrove degradation with degradation rate 108.87 ha year^{-1}, combine oceanografic factors between seatide, water depth, water inundation and rivers current. This factors will influencing mangrove adaptation and mangrove regeneration (Mazda et al., 2007) to adapt supply of phosphate, sulfate, nitrogen, and nitrate (Hoppe-Speer et al., 2011; Shiau et al., 2017b; Cheng et al., 2019; Wang et al., 2019), fresh water supply (Barreto et al., 2016; Dai et al., 2018; Xiong et al., 2018), water pH and water salinity (Khadim et al., 2019), and the other factors are the soil properties. Xiong et al. (2018) noted that based on the perspective of salinity, texture and soil fertility, Segara Anakan Lagoon is adequately available to support the mangrove growth, because has suitable salinity (betwen 435 ppt), suitable pH (between 6.0–90), suitable texture (clay and clay loam), and moderatehigh potential of C-organic, phosaphate, and N total (Djohan, 2012; Kusmana & Maulina, 2015; Xiong et al., 2018).

Conclusion

A. alba, A. marina, N. frutican, R. apiculate, and *R. mucronata* are dominant species in Segara Anakan Lagoon, whereas *S. alba, S. caseolaris, B. gymorrhiza, C. tagal, A. cornicultum, B. sexangula, C. decandra*, and *B. parviflora* are co-dominant species. *H. littolaris, E. agallocha*, and *X. granatum* are minor species. Mangrove landscape in SAL has a spesific patern following the ability of mangrove species to life in many zonations. Mangrove landscape in Segara Anakan Lagoon divided into 4 zones, that are **Zone 1** includes *A. marina, A. alba, S. alba, R. mucronata, R. apiculata, R. stylosa, A. corniculatum, C. decandra;* **Zone 2** includes *A. marina, A. alba, S. alba, R. mucronata, R. apiculata, R. stylosa, B. gymnorrhiza, A. corniculatum, C. tagal, X. granatum, C. decandra, E. agallocha;* **Zone 3** can be grow by *R. apiculata, R. mucronata, R. stylosa, B. gymnorrhiza, B. sexangula, A. corniculatum, C. tagal, E. agallocha, X. granatum, N. frutican, H. littoralis*; **Zone 4** includes *R. apiculata, R. mucronata, R. stylosa, B. gymnorrhiza, B. sexangula, A. corniculatum, S. caseolaris, A. scolaris,* and *N. frutican*.

Recommendation

The mangrove landscape uses several indictors of environment factors, mangrove density and species distribution can be used to support mangrove rehabilitation program. The mangrove landscape also is used to support mangrove dynamic activity and to draw mangrove adaptation in the mangrove ecosystem.

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