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, seaitide, 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 dominated by Sonneratia alba, Rhizophora mucronata, Avicennia marina, Rhizophora apiculata, Rhizophora stylosa, and Nypa frutican; (b) the structure of ecosystem was showed by trend of mangrove ecosystem with equation y = 35.34x - 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 0.360–0.73 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

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 triggering 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 distribution, 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 pattern 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 Vaalck & Rolfe, 2018), mangrove association, and clustering (Hilmi, 2018). In many areas, the mangrove community also is influenced by existance 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
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 semidiurnal 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 preserved 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 | Coordinate | East Segara Anakan | Coordinate |
|--------------------|------------|--------------------|------------|
| Stations           | Latitude (S) | Longitude (E)     | Stations   | 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 Cavitali | 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°42’34.20” | 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”   |                |             |                |
Seatide, current 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.

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 basic 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).

Soil texture (%) using Gravimetric method (APHA, 2005; 2012); (d) Nitrate (NO$_3^-$) (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.

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
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 linear model predicted that potential of mangrove ecosystem 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 degradation in Segara Anakan Lagoon were caused by conversions to fishponds, settlements and industries, illegal 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...
1493 trees ha\(^{-1}\). Potential density of mangrove ecosystem in E-SAL more than mangrove ecosystem in W-SAL. The indicators of mangrove degradation 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, disturbed transportation, death of organism aquatic, and others.

However, the species density of mangrove ecosystem in SAL could be shown on Figure 5. The data showed that the highest distribution of species density in 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 934 trees ha\(^{-1}\)), and A. corniculatum (average 395 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 density (70.6%), whereas W-SAL is dominated by rare density (55.0%). The species dominant in E-SAL were N. frutican, A. alba, A. marina, and R. apiculata. Whereas the highest distribution of species density in E-SAL were N. frutican, S. alba, R. stylosa, 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. officinalis (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 existence of Bruguiera praviflora, R. mucronata, B. seangula, R. apiculata, B. gymnorrhiza as major species in mangrove ecosystem.

### Table 2 Classification of mangrove density levels

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

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).

### Mangrove diversity and diameter distribution

The first indicator is the sea tide types. Based on the Formzahl value, Segara Anakan Lagoon has semi diurnal to mixed prevailing semi-diurnal between 0.2 m s\(^{-1}\) which is not different with that of Segara Anakan. The second indicators

### 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 different with that of Segara Anakan.
Figure 5  The species density of mangrove ecosystem in Segara Anakan Lagoon.

Figure 6  Distribution of mangrove species density in Segara Anakan Lagoon.
are the river current and water depth. The data showed that Segara Anakan Lagoon (SAL) had the river debit of between $-1.0210.8$ 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.

Table 3 The mangrove density and species distribution in SAL

| Density level* | 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 littoralis, Sonneratia caseolaris |
|                 | Min 75 123       | Xylocarpus mollucensis, Aegiceras floridum, Rhizophora apiculata |
| Rare density    | Max 950 1233 11.8 55.0 | Bruguiera sexangula, Xylocarpus granatum, Bruguiera parviflora |
|                 | Min 850 543      | Rhizophora stylosa, Ceriops tagal, Aegiceras officinalis, Bruguera gymnorrhiza, Aegiceras corniculatum |
| Moderate        | Max 2,087 2,156 17.6 15.0 | Ceriops decandra, Ceriops tagal, Avicennia alba |
|                 | Min 1,847 1,688  | Xylocarpus granatum, Rhizophora mucronata, Sonneratia alba, Avicennia alba |
| 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, Nypa frutican |
|                 | Min 3,264 3,266  | |

*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 |

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

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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 $0.340.75$ ms$^{-1}$.

**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.
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     | 0.34–0.75 m 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 | Nitrates | Phosphates | C-Organics | pH | Salinities | Texture |
|----------|----------|------------|------------|----|------------|---------|
|          | Value (%) | Distribution (%) | Value (%) | Distribution (%) | Value (%) | Distribution (%) | Value (%) | Distribution (%) | Value (%) | Distribution (%) | Texture |
| 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 triggering factors

The correlation between mangrove density with triggering 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 acidic–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)
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.

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Table 7 Correlation index mangrove density and trigering factors

| Class correlation | Correlation coefficient | Environment variables |
|-------------------|-------------------------|-----------------------|
| 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, sea tide |

| Type 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)

Figure 8 The pattern of mangrove landscape.
R. stylosa, B. gymnorrhiza, B. sexangula, A. corniculatum, S. caseolaris, A. sclaris, 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 arranged 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 substrates, salinity, and sea tide factor.

The other reasons to describe different patterns between mangrove landscaping in SAL with Waston (1928) pattern, because the mangrove landscaping in SAL was influenced by mangrove degradation with degradation rate 108.87 ha/year, combine oceanografic factors between seadite, 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 (between 435 ppt), suitable pH (between 6.0–9.0), suitable texture (clay and clay loam), and moderate-high potential of water inundation, texture (clay and clay loam), and moderate-high potential of soil water salinity (Djohan, 2012; Kusmana & Maulina, 2015; Xiong et al., 2018).

Conclusion

A. alba, A. marina, N. frutican, R. apiculata, and R. mucronata are dominant species in Segara Anakan Lagoon, whereas S. alba, S. caseolaris, B. gymnorrhiza, C. tagal, A. corniculatum, B. sexangula, C. decandra, and B. parviflora are co-dominant species. H. littoralis, E. agallocha, and X. granatum are minor species. Mangrove landscape in SAL has a specific pattern 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. sclaris, and N. frutican.

Recommendation

The mangrove landscape uses several indicators of environmental 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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