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The affinity of mangrove species using Association and Cluster Index in North Coast of Jakarta and Segara Anakan of Cilacap, Indonesia

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Abstract. *Hilmi E, Sari LK, Cahyo TN, Muslih, Mahdiana A, Samudra SR. 2021. The affinity of mangrove species using Association and Cluster Index in North Coast of Jakarta and Segara Anakan of Cilacap, Indonesia. Biodiversitas 22: 2907-2918.* The affinity of mangrove species using association and cluster index describe relationship among mangrove species. The species association and clustering explain the degree of utilization of resources and space by mangrove species. The association and cluster also describe specific species adaptation in mangrove ecosystems. This paper was aimed to analyze species affinity using association and clustering index of mangrove species. The association index used *Chi-square equation* and the clustered index used Euclidian distance analysis. The results showed that (i) mangrove density in Segara Anakan (166-4000 trees ha^{-1}) > North Jakarta (220-1100 trees ha^{-1}). (ii) *Nypa fruticans, Avicennia marina, Rhizophora stylosa and Rhizophora apiculata* dominated in Segara Anakan of Cilacap, and *Rhizophora stylosa and Avicennia marina* dominated in North Jakarta (iii) The association index had 12 pairs of negative species association and 17 pairs of positive species association, but most of mangrove vegetations had no association. (iv) mangrove ecosystem in Segara Anakan and North Jakarta had four clusters with Euclidean distance (ED score) 484 to describe cluster between *Bruguiera parviflora-Bruguiera sexangula* until 76430847 to describe cluster among *Bruguiera gymnorrhiza, Bruguiera parviflora, Ceriops decandra, Exoecaria agallocha, Nypa fruticans, Ceriops tagal, Rhizophora stylosa,* and *Sonneratia caseolaris*

Keywords: Mangrove association, mangrove clustering, mangrove density, , North Coast of Jakarta Segara Anakan Lagoon

INTRODUCTION

The affinity of mangrove species explains the relation of mangrove species to use resources and space in mangrove habitat (Ludwig and Renold, 1988). The species affinity can be described by many indexes including the species association and cluster. Mangrove clustering and association describe the relation and adaptation models of ecosystems using similarity, distance and specific correlation among species (Hilmi et al. 2015; Ludwig and Renold, 1988). The concepts are developed by a dissimilarity pointer known as the Euclidian distance index (Ludwig and Renold, 1988). Essentially, cluster analysis employs hierarchical and non-hierarchical methods (Ludwig and Renold 1988). Meanwhile, mangrove association provides an assessment tool to species relationships (coefficient variation) between various species. The phenomenon also demonstrates the importance of inter-species correlation and further underscores the ability to combine robust or vulnerable bonds (Ludwig and Renold, 1988). These relationships are introduced to aid structural development (Joshi and Bhatt 2015). Chi-Square index calculates the potential mutual existence of species (E(a)) and is compared by the number plot where the species are discovered (Ludwig and Renold, 1988; Macintosh et al. 2002; Rougier et al. 2005). Furthermore, species relationship mangroves (using associations and clusters index) are essential for effective mangrove forest management (Pham et al. 2019), and are also used to analyze potentials of plant density and species distribution (Ludwig and Renold, 1988), where homogeneity or similarity in ecosystems exist (Cochard et al. 2008).

The affinity of mangrove species (using association and cluster indexes) are analyzed to describe specific relationships among major species, minor species, and association species like *Avicennia alba, A. marina, Sonneratia alba, S. caseolaris, Rhizophora apiculata, R. mucronata, Rhizophora stylosa, Bruguiera gymnorrhiza, B. sexangula, B parviflora, Nypa fruticans, Ceriops decandra, Ceriops tagal, Acrosticum corniculatum, Heritiera littoralis, Exocecaria agallocha* and *Xylocarpus granatum*. The specific of mangrove species relationships showing an adaptation pattern of mangrove species which are largely influenced by sea tide, water inundation and salinity, soil texture, marine pollution, garbage and social activities (Hilmi et al. 2015, 2017; Sari et al. 2016;). Generally, the environmental factors contribute to the cluster pattern, species distribution and correlation (Hilmi et al. 2019; Owuor et al. 2019; Leng and Cao 2020). The cluster and association will develop specific structure of mangrove ecosystem

(Leng and Cao 2020), specific growth and productivity (Njana 2020), functional model of mangrove structure (Njana 2020), environment adaptation (Leng and Cao 2020), degradation and potential of biodiversity (Owuor et al. 2019), organism habitat (Owuor et al. 2019), potential of above and below-ground biomass, canopy covering, crown leaf spread and tree density (Dencer-Brown et al. 2020).

The mangrove species affinity in Segara Anakan of Cilacap and North Coast of Jakarta are developed to explain the potency of mangrove density, mangrove clusters and mangrove association. The mangrove density, clustering and association provide the zoning base for the density, species distribution and environment characteristics. The specific relationship and mangrove species adaptation reflect the ability of mangrove ecosystem to reduce impact of sea tide, water inundation, and salinity. The purpose of this paper was to analyze species affinity based on mangrove clustering and association in an ecosystem using density, species distribution, and environment characteristics.

MATERIALS AND METHODS

Research site

This research was conducted in Segara Anakan Lagoon (West and East) as well as in the mangrove ecosystem of Nort Coast of Jakarta. In addition, the location is characterized by the mangrove, terrestrial, estuary ecosystems and also by certain rivers, including Donan, Sapuregel, Kembang Kuning, Citanduy, Cimeneng and Cikonde (Hilmi et al. 2017; Hilmi et al. 2019). The Segara Anakan mangrove environment comprises two locations, including Segara Anakan (West and East). These regions are dominated by *Avicennia alba, A. marina, Sonneratia alba, S. caseolaris, Rhizophora apiculata, R. mucronata, B. gymorrhiza, B. sexangula, B parviflora, Nypa frutican, Ceriops decandra, Ceriops tagal, Acrosticum corniculum, Heritiera littolaris, Exocecaria agallocha and Xylocarpus granatum* (Hilmi, et al. 2017; Hilmi 2018; Hilmi, Sari, and Amron 2020). Meanwhile, the North Coast of Jakarta consists of Muara Angke Wildlife Reserve (SMMA), Angke Kapuk Nature Park (TWA) and Kapuk Angke-Kapuk forest. Conservation (HLAK) and Muara Angke Wildlife Reserve (SMMA) (Hilmi, et al. 2017) are occupied by *Rhizophora stylosa, Rhizophora apiculata, and Avicennia marina* (Hilmi et al. 2017). East Segara Anakan is occupied by 22 stations, while the West is home to 20 research units. Meanwhile, Jakarta's North Coast is influenced by Angke and Ciliwung waters and Java sea (Hilmi et al. 2017). Furthermore, the present study focuses on mangrove clustering in Angke Kapuk, and is categorized into 6 stations (Figure 1 and Table 1).

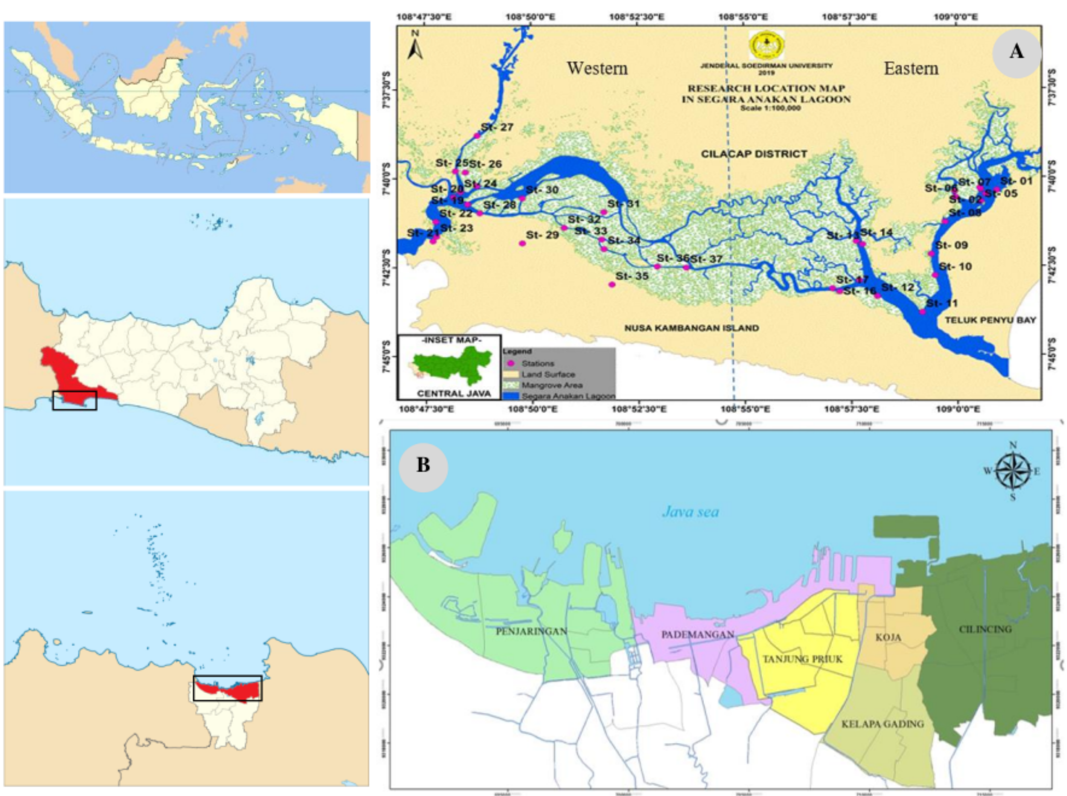


Figure 1. Research area in: A. Segara Anakan of Cilacap, Cilacap, and B. North Coast of Jakarta, Indonesia. Note: ●: Station

Table 1. Research stations

Stations	Coordinate	
	Latitude (S)	Longitude (E)
West Segara Anakan, Cilacap		
Sungai Ujung Gagak	07°40'13"	108°48'43"
Sungai Lorogan	07°40'44"	108°48'30"
Sungai Majingklak	07°40'32"	108°48'1"
Sungai Mauara Cawitali	07°41'46"	108°47'41"
Sungai Kebuyutan	07°41'13"	108°47'45"
Sungai Batu Macan	07°41'38"	108°47'46"
Sungai Jongor	07°40'23"	108°48'20"
Sungai Muara Legok	07°39'48"	108°48'13"
Sungai Kayu Mati	07°39'5"	108°48'27"
Sungai Langkap	07°38'48"	108°48'44"
Sungai Karang Braja	07°40'59"	108°48'47"
Sungai Klaces	07°41'5"	108°49'47"
Sungai Inti Ujung Gagak	07°40'34"	108°49'47"
Sungai Muara Bagian	07°40'58"	108°51'42"
Sungai Muara Masigitsela	07°41'24"	108°50'46"
Sungai Pertigaan Ujung Alang	07°41'44	108°51'39"
Sungai Ujung Alang	07°42'0"	108°51'42"
Sungai Dermaga Ujung Alang	07°42'6"	108°51'53"
Sungai Kali Semak	07°42'30"	108°52'57"
Sungai Pertigaan Sudiro	07°42'32"	108°53'38"
East Segara Anakan, Cilacap		
Kali Panas 1	07° 40' 22.17"	109° 0' 56.36"
Kali Panas 2	07° 40' 28.91"	109° 0' 40.57"
Kali Panas 3	07° 40' 20.60"	109° 0' 33.62"
Kali Panas 4	07° 40' 18.26"	109° 0' 32.52"
Kali Panas 5	07° 40' 41.12"	109° 0' 33.98"
Donan 1	07° 40' 33.98"	108° 59' 58.10"
Donan 2	07° 40' 23.79"	108° 59' 56.90"
Donan 3	07° 41' 15.49"	108° 59' 43.22"
Donan 4	07° 42' 10.17"	108° 59' 23.75"
Donan 5	07° 42' 46.06"	108° 59' 29.10"
Donan 6 (Sleko)	07° 43' 48.07"	108° 59' 10.78"
Pelawangan Timur	07° 43' 20.95"	108° 58' 07.45"
Sapuregel 1	07° 41' 53.33"	108° 57' 46.71"
Sapuregel 2	07° 41' 47.97"	108° 57' 37.81"
Sapuregel 3	07° 42' 54.20"	108° 57' 42.07"
Kembang Kuning1	07° 43' 12.88"	108° 57' 14.24"
Kembang Kuning2	07° 43' 07.52"	108° 57' 03.97"
North Coast of Jakarta		
Ekowisata Mangrove Angke	06°07'18.88"	106°45'18.37"
Hutan Lindung Angke Kapuk	06°06'15.50"	106°45' 05.41"
Hutan Lindung Angke Kapuk	06°06'16.556"	106°45'49.608"
Hutan Lindung Angke Kapuk	06°06'16.614"	106°45'49.619"
Arboretum Mangrove	06°06'41.386"	106°43'57.374"
Ekosistem Mangrove Galatama	06°07'24.733"	106°45'16.124"

Research design

Vegetation sampling

The vegetation sampling employed the cluster technique with the stratification stage, comprising mangrove density and the river basin. Also the number of stations involved in the analysis in East (22 stations) and West Segara Anakan (20 stations) and North Jakarta (6 stations) (Table 1).

Mangrove trees density

Furthermore, the mangrove trees density in Segara Anakan was evaluated, using the vegetation analysis equation (Cooray et al. 2021; Hilmi 2018; Xiong et al. 2003; Xiong et al. 2018):

$$\text{Mangrove trees density} = \frac{\text{Trees number of mangrove speies}}{\text{area}}$$

The trees density (diameter > 4cm) adopted the line transect method with a sampling plot of 10m x 10m. Table 2 shows the trees density distribution of the plant ecosystem (Hilmi et al. 2020). The data of mangrove density were collected from 10 sampling plots/stations. The potential of mangrove trees density are used to analyze distribution of mangrove density, mangrove association and mangrove cluster

Asociation analysis

The analysis of mangrove vegetation associations between species using contingency tables and are calculated by calculating the value of *Chi-square* (Ludwig and Renold, 1988).

$$\textit{Chi-square} = \frac{N(ad-bc)^2}{(a+b)(a+c)(c+d)(b+d)}$$

Where: a: the number of plots containing vegetation species A and B. b: the number of plots containing vegetation species A only. c: the number of plots containing vegetation species B only. d: the number of plots not have vegetation species A and B. N: The number of plots

$$E(a) = \frac{(a+b)(a+c)}{N}$$

If score of a>E (a) be defined as positive association,
If score of a< E (a) be defined as negative association

Cluster analysis

Cluster analysis is built using similarity and dissimilarity analysis through euclidian distance analysis (Ludwig and Renold, 1988). The analysis of mangrove clusters followed mathematical manipulation using excel software and was justified by Premiere software. The cluster analysis followed stages:

Stage 1

$$ED_{jk} = \sqrt{\sum_{i=1}^{s}(xij - xik)^2}$$

Stage 2

$$D\,(j,k)h = \alpha_1\, D(j,h) + \alpha_2\, D(k,h) + \beta\, D(j,k)$$

Stations	2	3	4	...	n
1	ED_{12}	ED_{13}	ED_{14}		
2		ED_{23}	ED_{24}		
3			ED_{34}		
			...		
n			EDn 4		

Where:
Ed*jk* : Euclidean Distance
i : Species
X*ij* : Density in station-*j*
X*ik* : Density in station-*k*
D : Distance
α1 : 0.625
α2 : 0.625
β : -0.25

Data analysis

The association analysis was illustrated by data tabulation, covering the assessment scores of *Chi-square* and relation. However, the cluster analysis employed dendrogram models and density data tabulation (Ludwig and Renold, 1988), as well as further described the grouping pattern in Segara Anakan alongside the density (Hilmi 2018; Hilmi et al. 2019).

RESULTS AND DISCUSSION

The mangrove trees density

Distribution of mangrove trees density in mangrove stations

The mangrove tree density distribution at several stations on the North Coast of Jakarta and Segara Anakan were presented in Figure 2 and Table 2**.** The obtained data showed a superior ecosystem in Segara Anakan, both West and East, compared to the North Coast of Jakarta. Furthermore, the potential densities in East and West Segara Anakan as well as in the North Coast of Jakarta, occurred between 166-4000 trees ha^{-1}, 133-3000 trees/ha, and 220-1100 trees ha^{-1}, respectively.

The data on Table 2 and Figure 2 and ones from Hilmi et al. (2020) also showed that the potential mangrove tree density divided into (i) East Segara Anakan had 9.1% (very high), 31.8% (high), 40.9% (moderate), and 18,2% (rare) (ii) West Segara Anakan had 5.6% (very high),5.6% (high), 11.1% (moderate), 61.1% (rare) and 16.7% (very rare) and (iii) North Coast of Jakarta had 50% (rare) and 50% (very rare). These data can be predicted that ecosystem mangrove on North Coast of Jakarta was degraded and must be rehabilitated. However, mangrove ecosystem in Segara Anakan also was degraded but is undergoing a secondary succession process.

Essentially, the potential density is related to environmental conditions, including physical or chemical, water and soil, sedimentation, anthropology, as well as conversion of mangrove forests (Syakti et al. 2013; Giri et al. 2015; Sari et al. 2016). Basically, mangrove tree density in Segara Anakan, both East and West, and the North Coast of Jakarta, are influenced by various levels of pollution (Hidayati et al. 2011; Syakti et al. 2013), sedimentation (Sari et al. 2016), conversion (Giri et al. 2015; Orchard et al. 2015; Hilmi et al. 2017; Castillo et al. 2017) and minimal waste potential (Hilmi et al. 2017). The ability of mangrove trees to grow and live in Segara Anakan and North Coast of Jakarta need effort adaptation toward environmental conditions. Many research describes natural regeneration of mangrove ecosystems in Segara Anakan as superior and faster than Jakarta (Hilmi et al. 2015, 2017, 2019). Consequently, the Segara Anakan region is also experiencing a secondary succession, where plant growth occurs rapidly.

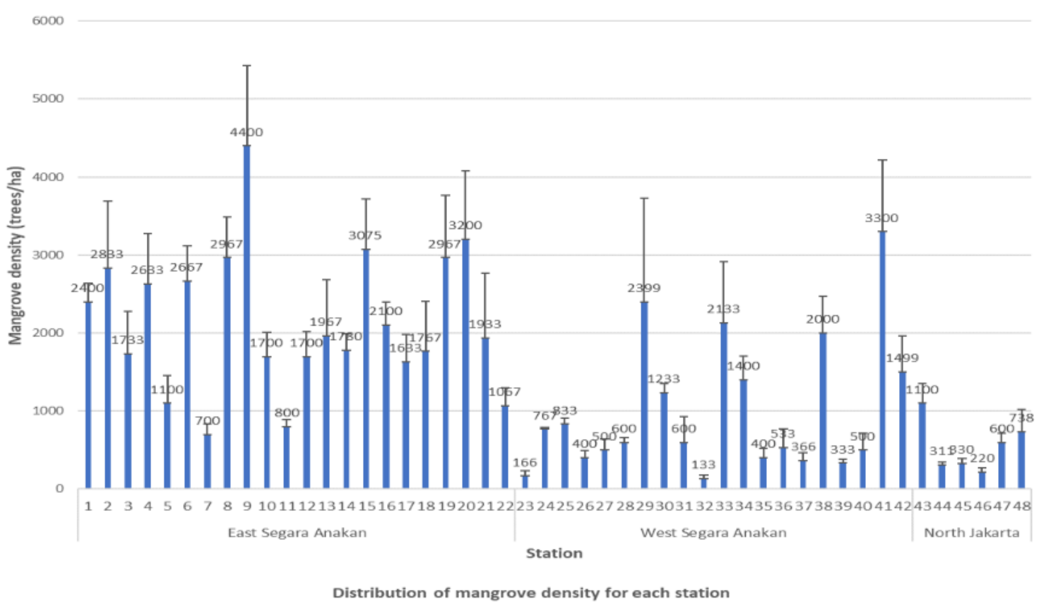


Figure 2. Distribution of mangrove density based on mangrove stations

Table 2. Mangrove density based on distribution of mangrove station

Station	Mangrove density (trees/ha) East Segara Anakan (station)																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Total	2400	2833	1733	2633	1100	2667	700	2967	4400	1700	800	1700	1967	1780	3075	2100	1633	1767	2967	3200	1933	1067
Sd	240	858	542	639	353	448	134	522	1033	306	89	321	717	207	645	300	347	640	797	879	835	229
Class	High	High	Moderate	High	Rare	High	Rare	High	Very high	Moderate	Rare	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate	High	Very high	Moderate	Rare

Station	Mangrove density (trees/ha) West Segara Anakan (station)																			
	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Total	166	767	833	400	500	600	2399	1233	600	133	2133	1400	400	533	366	2000	333	500	3300	1499
Sd	71	24	77	90	145	58	1328	118	330	47	786	305	120	235	96	469	51	212	917	467
Class	Very rarely	Rare	Rare	Rare	Rare	Rare	High	Rare	Rare	Rare	Moderate	Rare	Rare	Rare	Very rarely	Moderate	Very rarely	Rare	Very high	Rare

Station	Mangrove density (trees/ha) North Jakarta (station)					
	43	44	45	46	47	48
Total	1100	311	330	220	600	738
Sd	255	32	66	54	113	278
Class	Rare	Very rarely	Very rarely	Very rarely	Rare	Rare

The other factor influences mangrove trees density is sedimentation. Essentially Sari et al. (2016) also noted higher sedimentation in West Segara Anakan and the East Segara Anakan from 26-103.60 gram day^{-1} and give a total deposit of around 0.22-8.05 million tonnes year^{-1}. The potential sedimentation causes deposit accumulation which contributes to pore-water storage, clay mineral inflammation, low hydrodynamics, sediment deposition, and accretion landscape (Schwarzer et al. 2016; Hilmi 2018; Bomer et al. 2020; Hao Wang et al. 2020). Sari et al. (2016) and Hilmi et al. (2017) reported that the mangrove trees in Segara Anakan also caused accretion between 1.74-2.71 cm year^{-1}, because vegetation density plays a significant role in terms of capture and deposition. Suhendra et al. (2018) and Ross Jones et al. (2016) also explained that sedimentation is a trigger factor for mangrove trees growth, mangrove regeneration and mangrove adaptation The mangrove trees also are influenced by substrate and water quality factors. Meanwhile, the water quality and substrate showed the entire ecosystems with environmental qualities believed to support the mangrove trees development. The potential of substrate and water quality in Segara Anakan and North Coast of Jakarta can be shown in Table 3.

Table 3 showed that (i) soil nitrate is between 0.010-0.22%, (ii) soil phosphate between 6.85-17.65%, (iii) soil pyrite between 1.03-3.10%, (iv) soil pH between 5.7-6.92, (v) soil salinity between 0-7.05, (vi) soil texture had clay, loam, loamy clay, mud, mud clay, (vii) water pH between 5.6-7.07, and (viii) water salinity between 0-40 ppt. These data match the Rachmawati (2019) report of West Segara Anakan, with potentials between 0.078-0.120 mg/L (phosphate), 25-36 ppt (salinity), 6.7-12.8 mg/L, 1.03-1.40% (pyrite), and muddy clay texture. Furthermore, Widowati (2018) data in East Segara Anakan include the range of 1.28-2.88% (pyrite), 18-32.33 ppt (salinity), 19.77-28.91 mg/L (nitrate), 0.1083-0.192 mg/L (phosphate) and muddy clay texture. Based on (Shiau et al. 2017; Q. Yang et al. 2008), the potential for phosphate, nitrate, and fertility appeared moderate, while the pH was slightly acidic. Also, several studies completely showed the potentials for salinity, temperature, phosphate, and soil nitrate with great suitability for mangrove vegetation growth (Barreto et al. 2016; Hilmi, Sari, et al. 2019; Hilmi et al. 2017; Tam et al. 2009; Abdelhakeem, Aboulroos, and Kamel 2016), productivity of fine root and decomposition of organic carbon (Zhang et al. 2021). Consequently, (Djohan 2012; Kusmana and Maulina 2015; Yin et al. 2018) stated the existence of mangrove ecosystems in brackish water, with the salinity ranging from 4-35 ppt (best range occurs from 10-30 ppt), and the optimum phosphate standard from 0.15-0.3 mg/L (Sharafatmandrad and Khosravi Mashizi 2020).

Distribution of mangrove species density

Distribution of mangrove species density is shown in Table 4 and Figure 3. The data in Table 4 and Figure 3 represents the density distribution of mangrove vegetation in Segara Anakan and the North Coast of Jakarta. The major species of mangrove vegetation showed a significant difference between these regions, while the density revealed the dominance level (Huang et al. 2003; Hilmi et al. 2015, 2020; Khadim et al. 2019). Table 3 showed that in the research site were found *Aegiceras corniculatum, Avicennia alba, Avicennia marina, Avicennia officinalis, Bruguiera gymnorrhiza, Bruguiera parviflora, Bruguiera sexangula, callophylum inophylum, Carbera manghas, Ceriops decandra, Ceriops, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia alba, Sonneratia caseolaris, Tespia pulpunea, Terminalia cattapa, Xylocarpus granatum,* and *Xylocarpus moluccensis*. According to Hilmi et al. (2015, 2017), Segara Anakan was comprised of several species ranging from *Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Bruguiera gymnorrhiza, Bruguiera parviflora, Bruguiera sexangula, Aegiceras corniculatum, Avicennia alba, Avicennia marina, Ceriops decandra, Ceriops tagal, Excoecaria agallocha, Heritiera littoralis, Nypa fruticans, Sonneratia alba, Sonneratia caseolaris, Xylocarpus granatum,* and *Xylocarpus moluccensis*. Different from Table 4, Sreelekshmi et al. (2018) stated the occurrence of 18 mangrove types in Kerala, India, categorized into 5 groups. Group 1 was dominated by *Rhizophora mucronate, R. apiculata, Ceriops tagal, Kandelia candel, Sonneratia alba, and S. caseolaris* in the fringing zone. Group 2 and 3 were comprised of *Avicennia marina, A. alba, Lumnitzera racemosa, Acrostichum aureum, Excoecaria agallocha, E. indica, Avicennia officinalis, Bruguiera gymnorrhiza,* and *Aegiceras corniculatum*, in the intermediate region. Group 4 encompassed the Landward regions and is conquered by *Bruguiera sexangula* and *B. cylindrica*. Group 5 occurred in the widespread area with *Acanthus ilicifolius*.

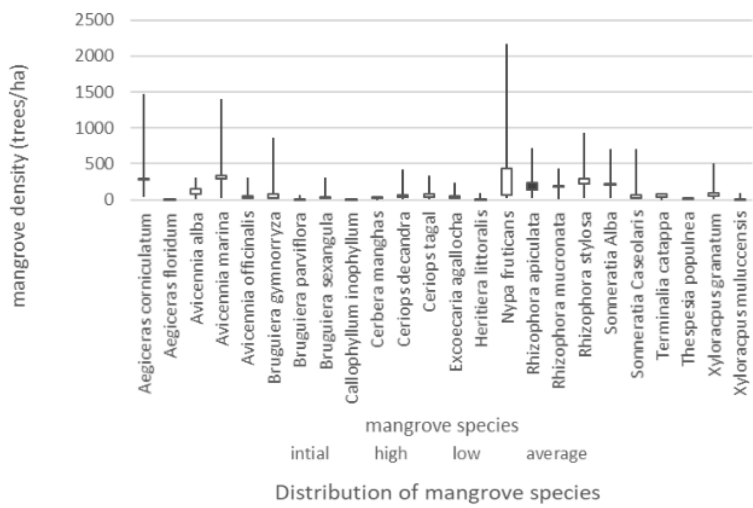
Table 3. Environment characteristics of mangrove ecosystem

Environment variables	Segara Anakan of Cilacap		North Coast of Jakarta
	West	East	
Soil nitrate (%)	0.049-0.161	0.095-0.22	0.010-0.016
Soil phosphate (%)	8.76-15.44	6.85-17.65	7.15-16.32
Soil pyrite (%)	1.03-1.24	1.60-2.88	1.20-3.10
Soil ph	6.67-6.92	5.91-6.25	5.7-6.4
Soil salinity (ppt)	5.85-7.05	5.21-7.01	0-5
Soil texture	Clay, loam, mud, mud clay	Clay, loam, mud, mud clay	Clay, loamy clay, mud clay
Water ph	5.85-7.05	6.83-7.07	5.6-6.9
Water salinity (ppt)	31-40	18-31	0-15
Water temperature	24-29	26-30	24-31

Table 4. Distribution of species density in mangrove ecosystem

Species	Mangrove density (trees/ha)			
	Segara Anakan		North Jakarta	
	Average	Stdev	Average	Stdev
Aegiceras corniculatum	290	246		
Aegiceras floridum	4	4		
Avicennia alba	145	124		
Avicennia marina	289	240	393	348
Avicennia officinalis	45	43		
Bruguiera gymnorryza	143	126	20	14
Bruguiera parviflora	5	5		
Bruguiera sexangula	36	35		
Calophyllum inophyllum			11	1
Cerbera manghas			35	7
Ceriops decandra	64	60		
Ceriops tagal	74	61		
Excoecaria agallocha	18	19	90	40
Heritiera littoralis	8	9		
Nypa fruticans	804	625	65	35
Rhizophora apiculata	227	186	35	7
Rhizophora mucronata	172	142	208	269
Rhizophora stylosa	346	291	228	288
Sonneratia alba	227	208		
Sonneratia caseolaris	101	88	23	15
Terminalia catappa			73	29
Thespesia populnea			19	1
Xyloracpus granatum	92	86		
Xyloracpus muluccensis	11	10		

Mangrove species density possibly influences species diversity, richness, uniformity (Arumugam et al. 2016; Azman et al. 2021) and plant structure (Sreelekshmi et al. 2018; Haitao et al. 2018; Wang et al. 2019) in addition to the adaptability to heavy metal pollution (Hilmi, Siregar, and Syakti 2017; Syakti et al. 2013), oil pollution (Syakti et al. 2013), sedimentation (Sari et al. 2016), salinity (Hilmi et al. 2020; Hilmi, Kusmana, et al. 2017; Win et al. 2019), texture, sea-level rise (Fu et al. 2018), and water quality (Bullock et al. 2017; Karl and Church 2017). The mangrove in Segara Anakan of Cilacap (SAL) and North Coast of Jakarta (NCJ) were dominated by major species like *Rhizophora apiculate, Rhizophora mucronate, Rhizophora stylosa, Avicennia marina*, and *Nypa fruticans*. The adaptation models of mangrove species in SAL and NCJ are related to the capacity to develop root systems, particularly in reducing erosion impact, sedimentation, nutrient cycling and pollution (Bullock et al. 2017; Yang et al. 2018). In mangrove ecosystem, the species density can represent the succession, geomorphology, external disturbances, ecophysiology, and competition (Bullock et al. 2017; Fu et al. 2018). Furthermore, species domination describes the adaptation of pioneer species, e.g *Sonneratia* spp and *Avicennia* spp, with dominant species, including *Rhizophora* spp., *Bruguiea* spp., *Ceriops* spp., and *Nypa fruticans* (Cooray et al. 2021; Fu et al. 2018).



Species	Intial	High	Low	Average	Species	Intial	High	Low	Average
Aegiceras corniculatum	290	1,467	30	290	*Excoecaria agallocha*	18	233	5	54
Aegiceras floridum	4	10	0	4	*Heritiera littoralis*	8	100	0	8
Avicennia alba	73	300	15	145	*Nypa fruticans*	65	2167	20	434
Avicennia marina	289	1400	25	341	*Rhizophora apiculata*	235	725	20	131
Avicennia officinalis	22	300	5	45	*Rhizophora mucronata*	172	433	15	190
Bruguiera gymnorryza	20	867	10	82	*Rhizophora stylosa*	228	933	25	287
Bruguiera parviflora	3	67	0	5	*Sonneratia Alba*	227	700	20	227
Bruguiera sexangula	18	300	5	36	*Sonneratia Caseolaris*	23	700	5	62
Callophyllum inophyllum	5	11	0	11	*Terminalia catappa*	37	90	0	73
Cerbera manghas	18	40	0	35	*Thespesia populnea*	19	20	0	19
Ceriops decandra	32	420	10	64	*Xyloracpus granatum*	46	500	4	92
Ceriops tagal	37	333	10	74	*Xyloracpus muluccensis*	5	100	0	11

Figure 3. Distribution of species in mangrove stations

The dominant species in Segara Anakan include *Nypa frutican*, with an individual potential of 804 ± 625 trees/ha, while *Rhizophora stylosa, Rhizophora apiculata, Aegiceras corniculatum, Soneratia alba,* and *Avicennia marina* (moderate), with potential abundance ranging from 227-290 trees/ha and others are recessive species. Meanwhile, the North Coast of Jakarta is predominantly *Avicennia marina, Rhizophora mucronata,* and *Rhizophora stylosa,* with an abundance of 228n-393 trees/ha, and others are not widespread. Based on Hilmi et al. (2015), *Avicennia* spp. and *Sonneratia* spp. are common in West Segara Anakan, while *Rhizophora apiculata, Nypa fruticans,* and *Aegiceras corniculatum* reside extensively in the East. The species dominance gives indication has greatly adapted toward habitat conditions. For instance, *Sonneratia alba* and *Avicennia* spp. are very prevalent in regions with substrates and are directly in close water proximity (Avelar et al. 2017; Yin et al. 2018), *Rhizophora* spp. and *Bruguiera* spp. thrive in less flooded areas with relatively soft substrates (Hilmi et al. 2017). Meanwhile, *Nypa fruticans* dominance is due to the ability to replicate in groups with high density, specifically around river estuaries (Hilmi 2018). Leopold et al. (2013) also reported that the domination species have correlated with carbon absorption, oxygen, and nutrients from the soil and air and species relationship to develop a clustering pattern and species association (Pham et al. 2019). The species domination also influenced potential of root biomass, biomass productivity, density, and growth, the formation of stand structure and spatial distribution (Ahmad et al. 2016)

The mangrove association

The mangrove association shows a robust connection among the species and provides the framework for the analysis. Table 4 represents the association phenomenon in Segara Anakan. The mangrove association (positive, negative, and not associated) in North Coast of Jakarta and Segara Anakan are developed by three criteria that are (i) the avoidance of similar habitat, (ii) mutual basic biotic and abiotic environmental needs, (iii) one or more of these species are interconnected, either by attraction or rejection (Ludwig and Renold 1988). The positive and negative associations of mangrove species in Segara Anakan of Cilacap and Nort Coast Jakarta also described indicating the expectation of coexistence or mutual refusal to coexist.

The association of mangrove ecosystem in Table 4 showed (i) 12 pairs of negative associated, including *A. alba-Ae.corniculatum, A. marina-Ae. corniculatum, A. marina-C. decandra, A. marina-C. tagal, A. marina -N. frutican, B. sexangula-X. granatum, C. decandra-N. fruticans, C. tagal-S. caseolaris, C. tagal-S. alba, N. fruticans-S. alba, A. alba-C. tagal, and A. alba-N. fruticans,* (ii) 17 pairs of positively-associated mangrove vegetation, including *A. marina-A. alba, A. marina-S. caseolaris, A. marina-S. alba, A. alba-S. caseolaris, A. alba-S. alba, B. parviflora-B. sexangula, B. parviflora-S. caseolaris, B. parviflora-S. alba, B. sexangula-S. alba, C. decandra-C. tagal, C. tagal-N. frutican, R. apiculata-R. mucronata, R. apiculata-R. stylosa, S. alba-B. sexangula, S. caseolaris-S. alba, S. caseolaris-B. sexangula, and E. agallocha-X. granatum,* (iii) most mangrove vegetation is not associated, almost reached positive or negative association. Most mangrove vegetations are not associated, indicating the tendency to form clusters among similar species. Kurniawan, Undaharta, and Pendit (2008) noted: (i) High-frequency pairs do not regularly produce positive associations; (ii) Pairs of types with low frequencies do not necessarily generate negative relations. Moreover, the data showed 2 association types in Segara Anakan, and are known to develop zonation or not show any correlation.

Positive association describes strong relationship between species in same habitat. Positive association also occurs when mangrove species have a collective relationship, or join other species because have similar needs (Kurniawan et al. 2008). As a consequence, a positively connected species tends to generate a definite spatial relationship with other kinds (Ludwig and Renold 1988). This condition shows a robust relationship of mangrove species with others varieties. Furthermore, two species with similar adaptions are constructed and presented in a grouping pattern. Previous studies described the association by presenting the adaptation between two species in mutual existence with similar habitat, due to related adjustment to associated environmental parameters, including sunlight, water, and soil (Hilmi et al. 2015)

Kairo et al. (2008), Petrakis et al. (2016), Khadim et al. (2019), and Azman et al. (2021) clarified the species pairs do not constantly produce positive relationships. Moreover, plant groups with high occurrence, are not commonly generating extensive positive association. In similar conditions, low presence does not repeatedly demonstrate a negative correlation with other species. Negative association shows no tolerance for coexisting in related ecosystem or have no mutually beneficial relationships. Essentially, the survival of several species in the community instigates the possibility of competition and development of species compositions or clusters. In the mangrove ecosystem, the cluster is shown as a mangrove zoning to illustrate the connection between several mangrove types (Hilmi et al. 2015, 2017).

Potential mangrove associations are influenced by the relationships among species, pollution and human activities (Pham et al. 2019). For instance, the decline in Avicennia alba-Sonneratia alba (Association I) by 20.1% and an increase of Rhizophora apiculata (Association II) by 34.7% were caused by aquaculture and other human activities (Pham et al. 2019). Other factors are potential of soil carbon sequestration (Chen et al. 2021) and human activity causes degradation of nutrients and microorganisms, sedimentation and logging (Sun et al. 2020).

Furthermore, mangrove association and ecosystem potential tend to influence the habitat, biodiversity, and potential wildlife fauna. These situations further impacted on buffer zones of retaining nutrients (Li et al. 2016; Hao Wang et al. 2020) and also provided the spawning habitat, nursery ground habitat, and feeding base for several faunas (Nagelkerken et al. 2008; Jones et al. 2015; Abdelhakeem et al. 2016).

Table 4. The mangrove Asosiation in Segara Anakan of Cilacap

Vegetation relationship	Chi-square	E(A)	Association
A. alba-Ae.corniculatum, A. marina-Ae. Corniculatum, A. marina-C. decandra, A. marina-C. tagal, A. marina-N. frutican, B. sexangula-X. granatum, C. decandra-N. frutican, C. tagal-S. caseolaris, C. tagal-S. alba, N. frutican-S. alba, A. alba-C. tagal, A. alba-N. fruticans	4.02-11.81	1.82-8.73	Negative
A. marina-A. alba, A. marina-S. caseolaris, A. marina-S. alba, A. alba-S. caseolaris, A. alba-S. alba, B. parviflora-B. sexangula, B. parviflora-S. caseolaris, B. parviflora-S. alba, B. sexangula-S. alba, C. decandra-C. tagal, C. tagal-N. frutican, R. apiculata-R. mucronata, R. apiculata-R. stylosa, S. alba-B. sexangula, S. caseolaris-S. alba, S. caseolaris-B. sexangula,, E. agallocha-X. granatum	4.07-18.16	0.09-12.09	Positive
Ae. corniculatum-A. lanata, Ae. corniculatum-A. officianalis, Ae. corniculatum-B. gymnorrhiza, Ae. corniculatum-B. parviflora, Ae. corniculatum-B. sexangula, Ae. corniculatum-C. decandra, Ae. corniculatum-R. apiculata, Ae. corniculatum-R. mucronata, Ae. corniculatum-R. stylosa, Ae. corniculatum-S. caseolaris, Ae. corniculatum-L. Racemosa, Ae. corniculatum-E. agallocha, Ae. corniculatum-X. granatum, A. alba-A. lanata, A. alba-A. officianalis, A. alba-B. gymnorrhiza	0.03-2.92	0.06-2.33	Not associated
A. alba-B. parviflora, A. alba-B. sexangula, A. alba-C. decandra, A. alba-C. tagal, A. alba-N. frutican, A. alba-R. apiculata, A. alba-R. mucronata, A. alba-R. stylosa, A. alba-L. Racemosa, A. alba-E. agallocha, A. alba-X. granatum, A. lanata-A. officianalis, A. lanata-B. gymnorrhiza, A. lanata-B. parviflora, A. lanata-B. sexangula, A. lanata-C. decandra, A. lanata-C. tagal, A. lanata-R. apiculata, A. lanata-R. mucronata, A. lanata-R. stylosa, A. lanata-L. Racemosa, A. lanata-E. agallocha, A. lanata-X. granatum, A. marina-A. officianalis, A. marina-B. gymnorrhiza, A. marina-B. parviflora, A. marina-B. sexangula, A. marina-R. mucronata, A. marina-R. stylosa, A. marina-L. Racemosa, A. marina-E. agallocha			
A. marina-X. granatum, A. officinalis-B. gymnorrhiza, A. officinalis-B. parviflora, A. officinalis-B. sexangula, A. officinalis-C. decandra, A. officinalis-C. tagal, A. officinalis-R. apiculata, A. officinalis-R. mucronata, A. officinalis-R. stylosa, A. officinalis-S. caseolaris, A. officinalis-S. alba, A. officinalis-L. Racemosa, A. officinalis-E. agallocha, A. officinalis-X. granatum, B. gymnorrhiza-S. caseolaris, B. gymnorrhiza-S. alba, B. gymnorrhiza-L. Racemosa, B. gymnorrhiza-E. agallocha, B. gymnorrhiza-X. granatum, B. parviflora-L. Racemosa, B. parviflora-E. agallocha, B. parviflora-X. granatum, B. sexangula-C. decandra, B. sexangula-C. tagal, B. sexangula-R. mucronata, B. sexangula-R. stylosa, B. sexangula-L. Racemosa, B. sexangula-E. agallocha, C. decandra-R. stylosa, C. decandra-S. caseolaris, C. decandra-S. alba, C. decandra-L. Racemosa, C. decandra-E. agallocha, C. decandra-X. granatum, C. tagal-R. mucronata, C. tagal-R. stylosa, C. tagal-L. Racemosa, C. tagal-E. agallocha, C. tagal-X. granatum, N. frutican-L. Racemosa, N. frutican-E. agallocha, N. frutican-X. granatum, R. apiculata-S. caseolaris, R. apiculata-S. alba, R. apiculata-L. Racemosa, R. apiculata-E. agallocha, R. apiculata-X. granatum, R. mucronata-S. alba, R. mucronata-L. Racemosa, R. mucronata-E. agallocha, R. mucronata-X. granatum, R. stylosa-L. Racemosa, R. stylosa-E. agallocha, R. stylosa-X. granatum, S. caseolaris-L. Racemosa, S. caseolaris-E. agallocha, S. caseolaris-X. granatum, S. alba-L. Racemosa, S. alba-E. agallocha, S. alba-X. granatum			
Ae. corniculatum-A. alba, Ae. corniculatum-A. marina, Ae. corniculatum-N. frutican, A. lanata-N. frutican, A. marina-R. apiculata, A. officinalis-N. frutican, B. gymnorrhiza-C. decandra, B. gymnorrhiza-C. tagal, B. gymnorrhiza-N. frutican, B. parviflora-C. decandra, B. parviflora-C. tagal, B. parviflora-N. frutican, B. sexangula-N. frutican, C. decandra-R. apiculata, C. decandra-R. mucronata, C. tagal-R. apiculata, N. frutican-R. apiculata, N. frutican-R. mucronata, N. frutican-R. stylosa, N. frutican-S. caseolaris, R. mucronata-S. caseolaris, R. stylosa-S. caseolaris, R. stylosa-S. alba	0.03-11.81	0.06-8.73	Not associated to negative association
Ae. corniculatum-S. alba, A. alba-A. marina, Ae. corniculatum-C. tagal, A. alba-S. caseolaris, A. alba-S. alba, A. lanata-A. marina, A. lanata-S. caseolaris, A. lanata-S. alba, A. marina-S. alba, B. gymnorrhiza-B. parviflora, B. gymnorrhiza-B. sexangula, B. gymnorrhiza-R. apiculata, B. gymnorrhiza-R. mucronata, B. gymnorrhiza-R. stylosa, B. parviflora-R. apiculata, B. parviflora-R. mucronata, B. parviflora-R. stylosa, B. sexangula-R. apiculata, B. sexangula-S. caseolaris, R. mucronata-R. stylosa, L. racemosa-E. agallocha, L. racemosa-X. granatum	0.03-18.16	0.06-12.09	Not associated to positive association

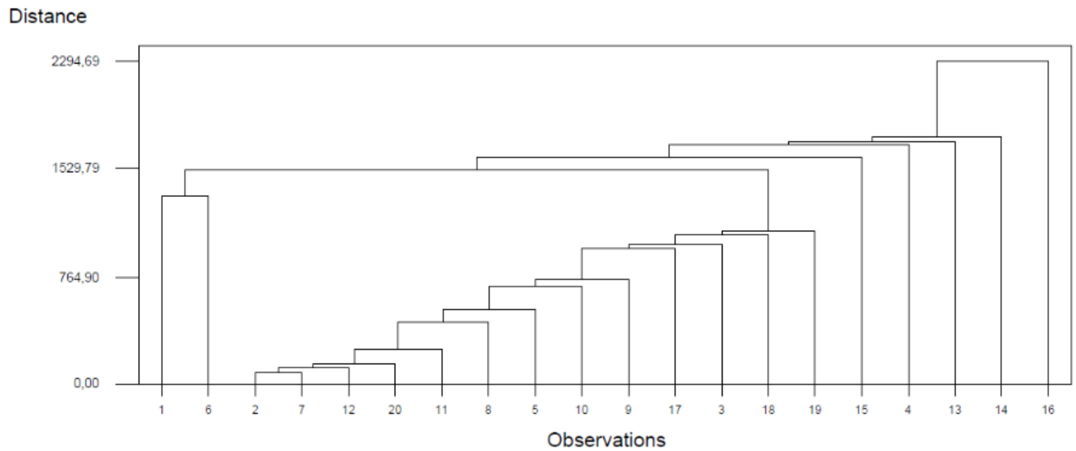


Figure 4. Dendogram of species cluster in mangrove ecosystem Segara Anakan, Cilacap, Indonesia. Note: 1. *Aegiceras corniculatum*, 2. *Aegiceras floridum*, 3. *Avicennia alba*, 4. *Avicennia marina*, 5. *Avicennia officinalis*, 6. *Bruguiera gymnorrhiza*, 7. *Bruguiera parviflora*, 8. *Bruguiera sexangula*, 9. *Ceriops decandra*, 10. *Ceriops tagal*, 11. *Excoecaria agallocha*, 12. *Heritiera littoralis*, 13. *Nypa frutican*, 14. *Rhizophora apiculata*, 15. *Rhizophora mucronata*, 16. *Rhizophora stylosa*, 17. *Sonneratia alba*, 18. *Sonneratia caseolaris*, 19. *Xylocarpus granatum*, 20. *Xylocarpus moluccensis*.

Table 5. Clustering of mangrove species

No	Euclidian Distance (ED) score	Mangrove species clustering
1.	456	Bp-Bs
2.	1290	BpBs-Cd
3.	3336	Af-Hl
4.	11344	Ea-Nf
5.	113548	BpBsCd-EaNf
6.	257450	Ao-Sa
7.	283884	BpBsCdEaNf-Ct
8.	641463	AfHl-Xm
9.	722247	BpBsCdEaNfCt-Bg
10.	1138205	AfHlXm-Xg
11.	1948256	AfHlXmXg-Aa
12.	3168590	AfHlXmXgAa-Rm
13.	3178790	BpBsCdEaNfCtBg-Rs
14.	3980595	BpBsCdEaNfCtBgRs-Sc
15.	4096101	Ae-Ra
16.	7204671	AoSa-Am
17.	9645962	BpBsCdEaNfCtBgRsSc-AfHlXmXgAaRm
18.	21142200	BpBsCdEaNfCtBgRsSc-AoSaAm
19.	76430847	BpBsCdEaNfCtBgRsScAfHlXmXgAaRm-AeRa

Note: Ac: *Aegiceras corniculatum*, Ae: *Aegiceras floridum*, Aa: *Avicennia alba*, Am: *Avicennia marina*, Ao: *Avicennia officinalis*, Bg: *Bruguiera gymnorryza*, Bp: *Bruguiera parviflora*, Bs: *Bruguiera sexangular*, Ci: *Callophyllum inophyllum*, Cm: *Cerbera manghas*, Cd: *Ceriops decandra*, Ct: *Ceriops tagal*, Ea: *Excoecaria agallocha*, Hl: *Heritiera littoralis*, Nf: *Nypa fruticans*, Ra: *Rhizophora apiculate*, Rm: *Rhizophora mucronata*, Rs: *Rhizophora stylosa*, Sa: *Sonneratia alba*, Sc: *Sonneratia caseolaris*, Tc: *Terminalia catappa*, Tp: *Thespesia populnea*, Xg: *Xyloracpus granatum*, Xm: *Xyloracpus muluccensis*

Cluster of mangrove density

The cluster of mangrove density can be shown in Table 5 and Figure 4. The data in Table 5 and Figure 4 showed the cluster of mangrove density in West and East Segara Anakan, Cilacap. This arrangement follows the dissimilarity pattern, as illustrated by the Euclidian distance index (Ludwig and Renold, 1988).

Based on the potential mangrove density at each station in Segara Anakan, 3 primary clusters with ED values between 254-3,498, were created (Rachmawati 2019) and also structured, due to the dominance of *Avicennia marina, Avicennia alba, Rhizophora apiculate, Rhizophora stylosa, Rhizophora mucronate, and Sonneratia caseolaris, and Nypa fruticans*. Also, East Segara Anakan showed 3 clusters with potential ED between 512.8-4,580.2, with the common types of *Avicennia marina, Avicennia alba, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, and Sonneratia alba* (D Widowati 2018).

Cluster analysis in Segara Anakan, Cilacap and North Coast of Jakarta indicate a pattern of species grouping and kinship in reducing environmental impact factors, including sedimentation (Sari et al. 2016; Bullock et al. 2017; Bomer et al. 2020), tides (Bomer et al. 2020), hydrodynamic oceanography (Bomer et al. 2020), water logging (Fu et al. 2018), soil stability (Fu et al. 2018), carbon, CO_2 and organic matter (Leopold et al. 2013), natural disasters (Hilmi 2018; Win et al. 2019) as well as other environmental factors, including salinity, pH and soil fertility (Ahmed et al. 2021). The adaptation was reflected in the presence of root patterns, biomass potential (Ahmed et al. 2021), nutrient absorption (Pham et al. 2019), nutrient decomposition (Leopold et al. 2013), and the ability to trap sediment and nutrients (Fu et al. 2018). These abilities and adaptation circumstances have significantly impacted the formation of species clusters, association pattern, structure, vertical and horizontal distribution, biodiversity, as well as zoning (Hilmi et al. 2015; Arumugam et al. 2016; Hilmi 2018; Sreelekshmi et al. 2018; Win et al. 2019).

In conclusion, the potential mangrove density in East and West Segara Anakan occur between 166-4,000 trees ha^{-1} and 133-3,000 trees ha^{-1}, respectively, while the North Coast of Jakarta ranged from 220-1,100 trees ha^{-1}. As a consequence, the predominant species in Segara Anakan were *Nypa fruticans (high dominant), Rhizophora stylosa, Rhizophora apiculata, Aegiceras corniculatum, Soneratia alba and Avicennia marina (moderate*). Meanwhile, the North Coast of Jakarta was mostly occupied by *Avicennia marina, Rhizophora mucronata and Rhizophora stylosa*. The mangrove ecosystem generated 12 and 17 species pairs, with negative and positive association, respectively. However, most sets were neutral, indicating the tendency to form groups based on species similarity or zoning. Furthermore, the cluster analysis showed the formation of 4 mangrove clusters, with the closest unit as *Bruguiera parviflora-Bruguiera sexangula*.

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