Mangrove cluster as adaptation pattern of mangrove ecosystem in Segara Anakan Lagoon

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Abstract. Segara Anakan Lagoon (SAL) as the specific ecosystem is arranged by the mangrove ecosystem and lagoon ecosystem. The mangrove ecosystem in SAL needs high adaptation to reduce the impact of water tide, water inundation, water salinity, and other factors. This research aimed to analyze mangrove clustering in Segara Anakan Lagoon. The method of this research used Hierarchical Clustering Methods based on mangrove density to analyze cluster adaptation of the mangrove ecosystem. The result showed that (1) The mangrove density (diameter > 4 cm) to analysis mangrove clustering showed that East Segara Anakan had density between 900 - 5425 trees ha-1 (low – very high density) and West Segara Anakan had density between 133 – 3,367 (low – high density). (2) the mangrove clustering showed that West Segara Anakan had three clusters. The first cluster was arranged by clustering of stations {((15.18),(9.17),(3.6)),8}); ((1.2),5)}. The second cluster was arranged by clustering of stations {(((4.10),14,12))}. And the third cluster was arranged by clustering of stations{(((11.20)16));(7.19))}. (b) East Segara Anakan also was formed by three clusters were the first cluster was formed by clustering of stations (2 -((4, 13), 6) ((1.12), (4.13) ((5.10) (7.11))) The second cluster was arranged by clustering of stations (9; ((8.15), (19, (20.21))) The third cluster was formed by clustering of stations (18 (17, (14,16))).

1. Introduction
Mangrove clustering is a mangrove grouping using similarity and dissimilarity analysis which using water and salinity, soil properties, and other factors as variables of this cluster. The index of mangrove clustering uses the index of similarity and dissimilarity known as the euclidian distance index [1][2][3]. The euclidian distance index shows the distance of one factor with another. This clustering with euclidian index using the potential of mangrove density and species distribution [1] as the main factor. The clustering showing homogeneity or similarity in one cluster and heterogeneity among clusters [4]. The method of cluster analysis is the Hierarchical Clustering Methods and the Nonhierarchical Clustering Method [2].
The clustering analysis in this paper is used to analyze the distribution and clustering of mangrove areas in Segara Anakan Lagoon. The mangrove ecosystem in Segara Anakan Lagoon is arranged by Avicennia alba, A. marina, Sonneratia alba, S. caseolaris, , Rhizophora apiculata, R. mucronata, B. gymnorrhiza, B. sexangula, B. praviiflora,,Nypa frutican, Ceriops decandra, Ceriops tagal , Acrosticum corniculatum, Heritiera littolaris, Exocecaria agallocha and Xylocarpus granatum [5], [6]. The mangrove clustering will be used to analysis the adaptation and stability model of the mangrove ecosystem in Segara Anakan using sea tide, water inundation, water salinity, and soil texture as the indicators [5][7][8][9].

The mangrove clustering in Segara Anakan Lagoon is developed to provide the mangrove zoning base on mangrove density, species distribution, and environment characteristics [5][9][11]. This cluster also shows the adaptation capability of the mangrove community to reduce the impact of sea tide, water inundation and water salinity correlate with mangrove zonation [7][12]. The mangrove zonation similar to the cluster pattern also explains the adaptation of mangrove toward the water salinity, substrate, and water inundation. This paper aimed to develop mangrove clustering and zonation in Segara Anakan Lagoon using mangrove density as the main factor.

2. Methods
2.1. Research site
The research was conducted in West Segara Anakan and Segara Anakan Timur. Segara Anakan is arranged by the mangrove, terrestrial, estuary ecosystems, and some rivers like as Donan, Sapuregel, Kembang Kuning, Citanduy, Cimeneng, and Cikonde [5][6] (Figure 1). The mangrove ecosystem in Segara Anakan Lagoon is influenced by freshwater supply from many rivers and seawater supply from the Hindia Ocean. The mangrove ecosystem in Segara Anakan Lagoon is dominated by more than 18 mangrove species [5][7].

![Figure 1. Research area](image-url)
2.2. Research procedures

2.2.1. Vegetation Sampling
Vegetation sampling used cluster technique with stratification stage following mangrove density and river area. The number of stations to analyze vegetation clusters in East Segara Anakan was 22 stations and in West, Segara Anakan was 20 stations.

2.2.2. Mangrove density
The mangrove density is a parameter to analyze dominated species, mangrove zonation, species adaptation, and species density [5][7]. Many methods to analyze mangrove density, include The line transect method. The mangrove density with line transect method in Segara Anakan used vegetation analysis using equation (1) [13].

\[
Density = \frac{\text{Trees number of mangrove specie}}{\text{area}} \quad \ldots \ldots (1)
\]

The mangrove density with a line transect method used the size of the sampling plot 10m x 10m. The sampling plot was used to analyze the potential of mangrove density with a diameter > 4 cm). After the collected data will be analyzed mangrove density classification. The density classification of mangrove ecosystem following Table 1 [10].

| density level         | Mangrove density (diameter>4cm) trees ha\(^4\) |
|-----------------------|-------------------------------------------|
| Very rare             | 0                                         | 390          |
| Rare                  | 391                                       | 1610         |
| Moderate              | 1611                                      | 2220         |
| High density          | 2221                                      | 3130         |
| Very high density     | > 3130                                    |              |

2.2.3. Cluster analysis
The cluster analysis was used to explain the distribution of mangrove distribution area using mangrove density as an indicator. The clustering analysis gives information on the distance analysis among mangrove areas using equations (2) and (3) [1]. The cluster analysis is built using similarity and dissimilarity analysis through euclidian distance analysis followed stage [1]. Table 2 shows the mangrove density classification

\[
ED_{jk} = \sqrt{s \sum_{i=1}^{5} (x_{ij} - x_{ik})^2} \quad \ldots \ldots (2)
\]

\[
D (j,k)h = \alpha_1 D(j,h) + \alpha_2 D(k,h) + \beta D(j,k) \quad \ldots \ldots (3)
\]
Table 2. Classification of mangrove density

| Stations | 2   | 3    | 4     | ... | 22    |
|----------|-----|------|-------|-----|-------|
| 1        | ED_{12} | ED_{13} | ED_{14} |     |       |
| 2        | ED_{23} | ED_{24} |       |     |       |
| 3        |       | ED_{34} |       |     |       |
| 22       |       |       |       |     | ED_{22} |

Notes
- \( Ed_{jk} \): Euclidean Distance
- \( i \): species
- \( X_{ij} \): density in station-\( j \)
- \( X_{ik} \): density in station-\( k \)
- \( D \): Distance
- \( \alpha_1 \): 0.625
- \( \alpha_2 \): 0.625
- \( \beta \): -0.25

The cluster analysis drew the dissimilarity of mangrove density among sampling areas in Segara Anakan. The cluster analysis also explained the model mangrove adaptation toward the substrate, water salinity, and water inundation in Segara Anakan.

2.3. Data Analysis

The data analysis to show the mangrove clustering used two models analysis that was dendrogram model and data tabulation model [1]. The mangrove clustering used dendrogram model and tabulation model were used to illustrate the grouping pattern of mangrove areas in Segara Anakan followed mangrove density [11][14].

3. Result and Discussion

3.1. The class of mangrove density

The class of mangrove density in Segara Anakan Lagoon was divided into a class of species density and the density of station followed mangrove density with diameter > 4 cm. Species density shows the level of species dominance in Segara Anakan Cilacap [5][13]. The species density of mangrove vegetation in Segara Anakan could be shown in Table 3.

The data showed that \( Nypa frutican \) had the highest density (high dominance) to explore the area with density between 11,300 – 17,210 trees ha\(^{-1}\). Meanwhile, the other species dominated in East Segara Anakan were \( Rhizophora styllosa, Rhizophora apiculata, Aegiceras corniculatum \) dan \( Avicennia marina \) which had density between 4,880 – 9,700 trees ha\(^{-1}\). And for West Segara Anakan was dominated by \( Avicennia marina, Avicennia alba, Sonneratia caseolaris \) dan \( Sonneratia alba \) with density between 1.800 – 4.000 trees ha\(^{-1}\). [7] writes that \( Rhizophora apiculata, Nypa frutican and Aegiceras corniculatum \) have high dominance in East Segara Anakan, and \( Avicennia \) spp, and \( Sonneratia \) spp dominated in West Segara Anakan.

And the data on Table 2 also showed that the mangrove species in Segara Anakan Cilacap were \( Aegiceras corniculatum, Avicennia alba, Avicennia marina, Bruguiera gymnorrhiza, Bruguiera parviflora, Bruguiera sexangula, Ceriops decandra, Ceriops tagal, Excoecaria agallocha, Heritiera littoralis, Nypa fruticans, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, \)
Sonneratia alba, Sonneratia caseolaris, Xylocarpus granatum, Xylocarpus moluccensis. The mangrove species in this data are not different with research by [5] and [7].

Table 3. Species density of mangrove ecosystem in Segara Anakan Cilacap

| Mangrove species       | Density (trees ha⁻¹) | Mangrove species       | Density (trees ha⁻¹) |
|------------------------|----------------------|------------------------|----------------------|
| Aegiceras corniculatum | 7,747                | Aegiceras floridum     | 300                  |
| Avicennia alba         | 2,000                | Avicennia corinaculatum | 1,133                |
| Avicennia marina       | 4,883                | Avicennia alba         | 2,133                |
| Bruguiera gymnorhiza   | 2,783                | Avicennia marina       | 3,967                |
| Bruguiera parviflora   | 67                   | Avicennia officinalis  | 933                  |
| Bruguiera sexangula    | 633                  | Bruguiera gymnorhiza   | 1,000                |
| Ceriops decandra      | 1,445                | Ceriops tagal          | 600                  |
| Ceriops tagal          | 1,638                | Nypa fruticans        | 11,300               |
| Excoecaria agallocha   | 233                  | Rhizophora apiculata   | 367                  |
| Heritiera littoralis   | 133                  | Rhizophora mucronata   | 1,433                |
| Nypa fruticans        | 17,210               | Rhizophora styllosa    | 433                  |
| Rhizophora apiculata   | 6,857                | Sonneratia alba       | 1,867                |
| Rhizophora mucronata   | 3,962                | Sonneratia caseolaris  | 2,633                |
| Rhizophora stylosa     | 9,702                | Xylocarpus granatum    | 1,300                |
| Sonneratia alba       | 3,408                | Xylocarpus moluccensis | 167                  |
| Sonneratia caseolaris  | 233                  |                        |                      |
| Xylocarpus granatum    | 767                  |                        |                      |
| Xylocarpus moluccensis | 33                   |                        |                      |

3.2. The class density of the mangrove ecosystem

The density of mangrove areas in Segara Anakan showed that East Segara Anakan had more dense mangrove vegetation compared than West Segara Anakan (Table 3). The data on Table 3 showed that East Segara Anakan Cilacap had very high density (40.9%) > high density (31.8%) > moderate (18.2%) and rare (2%). Meanwhile West Segara Anakan had rare class (60%) > moderate and high density (15%) > very high density (10%). [7] suggest that the potential density of East Segara Anakan is higher than West Segara Anakan. [8], [15] note that the low level of mangrove density in West Segara Anakan is due to high sedimentation rates with a score of 26 gram day⁻¹-103.60 gram day⁻¹ and total sediment reached 0.22-8.05 million ton year⁻¹.

Base on the data from [16] writes the mangrove ecosystem in West Segara Anakan has nutrient matter that is nitrate between 6.7 – 12.8 mg l⁻¹, phosphate between 0.078 – 0.120 mg l⁻¹ and pyrite between 1.03 – 1.40 %, salinity 25 – 36 ppt, and muddy clay texture. Whereas East Segara Anakan has nitrate between 19.77–28.91 mg l⁻¹, phosphate between 0.1083 – 0.192 mg l⁻¹, pyrite between 1.28 – 2.88 %, Salinity between 18-32.33 ppt, and muddy clay texture [17]. And [18] stated that mangrove ecosystems exist in brackish water with the salinity ranging between 4-35 ppt. [19] also explained that mangrove plants grow well with a salinity of between 4 – 35 ppt (the best range is between 10 -30 ppt), high standard nitrate > 10 mg l⁻¹ [20], and optimum standard of phosphate between 0.15 – 0.3 mg l⁻¹ [21].
Table 4. The density of mangrove area in Segara Anakan Cilacap

| Station | Density (trees ha\(^{-1}\)) | Class of density     | Station | Density (trees ha\(^{-1}\)) | Class of density |
|---------|----------------|---------------------|---------|----------------|-----------------|
| Donan   | 4,367          | High density        | Lorogan | 1,300          | Rarely          |
| Donan   | 2,100          | Moderate            | Majingklak | 1,900      | Rarely          |
| Donan   | 3,033          | High density        | Mauara Cawitali | 600        | Rarely          |
| Donan   | 1,867          | Moderate            | Kebuyutan | 2,300      | High density    |
| Donan   | 3,400          | High density        | Batu Macan | 800       | Rarely          |
| Donan   | 900            | Rarely              | Jongor | 3,300          | Rarely          |
| Donan   | 3,033          | High density        | Muara Legok | 1,267      | Rarely          |
| Donan   | 5,425          | High density        | Kayu Mati | 600        | Rarely          |
| Sleko   | 2,475          | Dense               | Langkap | 133         | Rarely          |
| Sleko   | 1,933          | Moderate            | Karang Braja | 2,667      | High density    |
| Sleko   | 2,800          | High density        | Klaces | 1,500          | Rarely          |
| Sleko   | 2,267          | Very high density   | Inti Ujung Gagak | 2,267     | Rarely          |
| Sleko   | 3,260          | Very high density   | Muara Bagian | 433        | Rarely          |
| Sleko   | 3,975          | Very high density   | Muara Masigitsela | 833   | Rarely          |
| Sleko   | 3,867          | Very high density   | Pertigaan Ujung Alang | 2,167 | Moderate |
| Sleko   | 2,867          | High density        | Ujung Alang | 733        | Rarely          |
| Sleko   | 3,233          | Very high density   | Dermaga Ujung Alang | 1,067   | Rarely          |
| Sleko   | 3,867          | Very high density   | Kali Semak | 3,367      | Very high density |
| Sleko   | 3,300          | Very high density   | Pertigaan Sudiro | 1,700     | Moderate |
| Sleko   | 2,000          | Moderate            |         |               |                 |

3.3. The cluster of mangrove density

The cluster of mangrove density in Segara Anakan Cilacap including West Segara Anakan and Timur can be seen in Figure 2 and Figure 3. The cluster of mangrove density is arranged following the dissimilarity index which is shown by the euclidean distance index [1].

The dendogram model showing mangrove clusters with criteria that are the smaller of euclidian distance (ED) shows the lower and smaller of dissimilarity or higher similarity among locations. The
lower ED and dismilarity have mean that two sites will be entered into single cluster. The data on Figure 2 and 3 showed that (1) West Segara Anakan had 3 large clusters namely cluster 1 was arranged by stations ((15,18);(9,17);(3,6)) dan ((1,2);6)), Cluster 2 consisting of stations ((4,10);14));12) and cluster 3 was arranged by stations ((11,20));16): (7,19). Whereas (2) East Segara Anakan also had 3 large clusters that were cluster 1 composed by stations ((1,12);((3,22);((5,10);(7,11)));((4,13);6), cluster 2 arranged by stations ((8,15);((20,21),19));9) dan cluster 3 was composed by stations ((14,16);17;18)).

![Dendogram of density cluster in mangrove ecosystem Segara Anakan.](image)

**Figure 2.** Dendogram of density cluster in mangrove ecosystem Segara Anakan.  
Note: A = West Segara Anakan, B = East Segara Anakan.

The cluster followed pattern of species dominance and species cluster of each station. West Segara Anakan showed that stations 15 and 18 had the highest similarity and lower ED, because had a relatively similar density with scores between 832 trees ha$^{-1}$ - 966 trees ha$^{-1}$. This with dominance species that were *Avicennia alba*, *Avicennia marina*, *Avicennia ovicinalis* and *Nypa fruticans*. Then stations 9 and 17 had high similarity with ED index 399,7 and density between 600 trees ha$^{-1}$ and 732 trees ha$^{-1}$. Stations 3 and 6 also had high similarity with ED index 328,6 and mangrove density
between 1.899 trees ha$^{-1}$ and 1.266 trees ha$^{-1}$. Species dominant in these stations were also similar that were *Avicennia alba*, *Avicennia marina*, *Sonneratia caseolaris* dan *Nypa fruticans*. This pattern will be applied to other clusters.

**Figure 3.** Ploting of density cluster in mangrove ecosystem Segara Anakan  
*Note*: A = West Segara Anakan, B = East Segara Anakan

The similar pattern also is used to develop mangrove cluster in East Segara Anakan. East Segara Anakan also had 3 large clusters pattern for example were stations 1 and 12 entered on cluster 1, because had highest similarity with lowest ED index 126,5 and mangrove density between 2400 trees ha$^{-1}$ and 2800 trees ha$^{-1}$. These stations had relatively similar of species dominance, that were
Avicennia marina and Rhizophora apiculata. Stations 3 and 22 had high similarity with ED 800 and mangrove density between 2100 trees ha\(^{-1}\) and 1367 trees ha\(^{-1}\) with dominant species were Rhizophora mucronata and Nypa fruticans. And then stations 5 and 10 had Euclidian distance index 512.8 with mangrove density 1867 trees ha\(^{-1}\) and 2475 trees ha\(^{-1}\), and species dominant were Avicennia marina, Avicennia alba, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, and Sonneratia Alba.

4. Conclusion
Mangrove in Segara Anakan Lagoon has good density except West Segara Anakan, because West Segara Anakan has rarely density (60 %). Dominant species in Segara anakan consists of Nypa frutican, Rhizophora stylosa, Rhizophora apiculata, Aegiceras corniculatu and Avicennia marina (East Segara Anakan) and Nypa frutican, Avicennia marina, Avicennia alba, Sonneratia caseolaris and Soneratia alba (West Segara Anakan).

The mangrove cluster in Segara Anakan both of West Segara Anakan and East Segara Anakan have 3 large clusters. This clusters showing the adaptation pattern of mangrove vegetation toward the environment condition in Segara Anakan Lagoon, including adaptation to water, substrate, and oceanography characteristics.

Aknowledgement
We would like to thank for Dr. Ir. Isdy Sulystio, DEA (Dean of Fisheries and Marine Science Faculty Unsoed), LPPM Unsoed to support grant with Unggulan Research (2019) and researcher colleague for providing his advice for this research. We would also like to thank anonymous reviewers for their helpful and constructive comments which greatly helped us improve our manuscript.

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