Omni-Akuatika 19 (1): 88-104, 2023
ISSN: 1858-3873 print / 2476-9347 online

*Research Article*

journal homepage: http://ojs.omniakuatika.net

# The distribution of mangrove area, mangrove density, and species diversity on the North Coast of Jakarta

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*Received 23 January 2023; Accepted 24 July 2023; Available online 5 August 2023*

## *ABSTRACT*

The distribution of mangrove area, density, and species diversity on the North Coast of Jakarta indicate the mangrove adaptation to live and grow in permanent water inundation areas. Therefore, this research aimed to analyze the distribution and mapping of the mangrove ecosystem in permanent water inundation area using the index of mangrove density, diversity, and geographical information system. The results showed that soil water salinity ranged from 5.6 to 7.0 ppt, water salinity ranged from 0.1 to 9.8 ppt, soil water pH ranged from 6.25 to 7,0, water pH ranged from 5.83 to 6.5, soil nitrate ranged from 12.2 to 22.8 mg/L, soil phosphate ranged from 1.7 to 14.8 mg/L, soil pyrite ranged from 0.12 to 0.3 mg/L, and soil texture varied from silt loam to silty clay loam. The mangrove ecosystem on the North Jakarta was dominated by a very rare density and low–moderate diversity, with a density between 440–1,250 trees/ha. The distribution of mangrove area also showed a very rare density from 0.18 ha (2000) to 166.95 ha (2020), a rare from 197.03 ha (2000) to 359,72 ha (2020), the moderate from 263.65 ha (2000) to 351.09 ha (2020), the dense from 591.78 (2000) to 273.92 ha (2020), and the very dense from 486.35 ha (2000) to 98.91 ha (2020). The mangrove ecosystem in the North Coast Jakarta was dominated by *Avicennia marina, Rhizophora mucronata, Rhizophora apiculata, Rhizophora stylosa, Nypa frutican, Sonneratia alba and Sonneratia caseolaris*. The conclusions of this research showed that the mangrove ecosystem inJakarta is degraded because it is dominated by rare- very rare of mangrove density.

**Keywords**: *mangrove distribution, mangrove density and diversity, North Coast of Jakarta, permanent water inundation*

## ABSTRAK

Sebaran luasan mangrove, kerapatan dan keanekaragaman jenis di Pantai Utara Jakarta menunjukkan adaptasi mangrove untuk hidup dan tumbuh di daerah genangan air yang permanen. Oleh karena itu, penelitian ini bertujuan untuk menganalisis sebaran dan pemetaan ekosistem mangrove di daerah genangan air permanen dengan menggunakan indeks kerapatan, keanekaragaman mangrove, dan sistem informasi geografis. Hasil penelitian menunjukkan salinitas air tanah berkisar antara 5,6-7,0 ppt, salinitas air 0,1-9,8 ppt, pH air tanah 6,25-7,0, pH air 5,83-6,5, nitrat tanah 12,2-22,8 mg/L, fosfat tanah 1,7-14,8 mg/L, pirit tanah 0,12-0,3 mg/L, dan tekstur tanah bervariasi dari lempung lanau hingga lempung liat berdebu. Ekosistem mangrove di Jakarta Utara didominasi oleh kerapatan sangat jarang dan keanekaragaman rendah-sedang dengan kerapatan antara 440–1.250 pohon/ha. Sebaran kawasan mangrove juga menunjukkan kerapatan sangat jarang dari 0,18 ha (2000) menjadi 166,95 ha (2020), jarang dari 197,03 ha (2000) menjadi 359,72 ha (2020), sedang dari 263,65 ha (2000) sampai 351,09 ha (2020), padat dari 591,78 (2000) menjadi 273,92 ha (2020), dan sangat padat dari 486,35 ha (2000) menjadi 98,91 ha (2020). Ekosistem mangrove di Pantai Utara Jakarta didominasi oleh *Avicennia marina, Rhizophora mucronata, Rhizophora apiculata, Rhizophora stylosa, Nypa frutican, Sonneratia alba* dan *Sonneratia caseolaris*. Kesimpulan dari

http://dx.doi.org/10.20884/1.oa.2023.19.1.1061

penelitian ini menunjukkan bahwa ekosistem mangrove di Jakarta mengalami degradasi, karena didominasi oleh kerapatan yang sangat jarang dan jarang serta luasan mangrove yang semakin berkurang.

**Kata kunci**: sebaran mangrove, kerapatan dan keanekaragaman mangrove, Pantai Utara Jakarta, genangan air permanen

## 1. Introduction

Jakarta has many type of ecosystem, including the mangrove ecosystem, brackish water ecosystem, beach, seagrass, and coral ecosystems (Onrizal et al. 2005; Yanuartanti et al. 2015; Hilmi et al. 2021d, 2022b). In Jakarta, the mangrove ecosystem is a main ecosystem that has many functions to reduce risk of tidal flooding, seawater intrusion and abrasion. Beside that, mangrove ecosystem in Jakarta has fuction to support activity of fishing activity, ecotourism and aquaculture activity. As a coastal ecosystem, the mangrove ecosystem also is influenced by freshwater from Ciliwung and Angke River (Hilmi et al. 2021d, 2022a) and seawater from the Java Sea (Yanuartanti et al. 2015; Hilmi et al. 2017a), permanent tidal inundation (Hilmi et al. 2021d, 2022b), seawater intrusion (Hilmi et al. 2017a), water and heavy metal pollution (Hilmi et al. 2017c) and anthropological factors (Ariani et al. 2016).

Jakarta city as coastal area also is influenced by many disasters (Hilmi 2018; Nur and Hilmi 2021) like as the tidal flooding (Bomer et al. 2020; Hilmi et al. 2022a), and permanent water inundation (Hilmi et al. 2021d, 2022b). Base on coastal disasters, the existence of mangrove ecosystem plays important role and function to reduce coastal disasters. In addition, the mangrove also has social, economic and ecological services such as fish and aquatic organism habitat (Smee et al. 2017; Lapolo et al. 2018; Dencer-Brown et al. 2020), carbon conservation (Rachmawati et al. 2014; Duncan et al. 2016; Hilmi et al. 2017b), ecotourism (Dijk et al. 2016; Soares et al. 2018), and fishing activities (Dijk et al. 2016).

The distribution of mangrove ecosystems using indicators of mangrove area, mangrove and species density, and species diversity (Ismail et al. 2018; Hilmi et al. 2021b, d) are used to analyze species adaptation to live and grow in the coastal area. The potential of mangrove area, density and diversity are needed to reduce the impact of the permanent water inundation area (Hilmi et al. 2022b), sea water intrusion, tidal flooding and support the ecosystem services.

The distribution of density, diversity, and area in many coastal areas also show the mangrove adaptation to live and grow in area with heavy metal and water pollution (Zhang et al. 2019a; Chai et al. 2020), tidal inundation (Bullock et al. 2017; Ahmed et al. 2021; Hilmi et al. 2022b), poor water quality (De Valck and Rolfe 2018; Hilmi et al. 2021e), soil conditions (Domínguez-domínguez et al. 2019), and anthropological factors (Markle and Chow-Fraser 2016; Cheng et al. 2018). The adaptation and ability of mangrove ecosystem support the sustainability and stability of the mangrove ecosystem which have correlation with many functions and aspects including the economy, ecology, social, and cultural.

Basically the ecosystem services of mangrove ecosystem give reflection of human beings, welfare, and nature (Comberti et al. 2015; Elmqvist et al. 2015). Müller et al. (2020), Zhou et al. (2020) and Hugé et al. (2020) also stated that the mangrove functions also directly or indirectly contribute to human wellbeing through the ecological, social economic, fresh water and food, regulating services, groundwater recharge, flood storage, water quality, carbon storage, wildlife habitat, organic waste reduction, fisheries, ecotourism, cultural and education resources (Matthews 2016; Yan et al. 2016). Mangrove ecosystem also has positive contribution to climate regulation, and nutrient cycling (Ramyar 2019; Tost et al. 2019; Sharafatmandrad and Mashizi 2020; Wang et al. 2020).

Moreover, the distribution of mangrove density, diversity, and area on the coast of Jakarta must be developed to analyze the condition of mangrove ecosystem. The data of mangrove distribution is used to maintain the functions and ecosystem services of mangrove ecosystem (Dijk et al. 2016; Duncan et al. 2016; Hilmi et al. 2017b; Hu et al. 2020). Basically, Jakarta has many type of mangrove ecosystems that are protected forest, greenbelt, arboretum, and wildlife reserve area (Hilmi et al. 2021b, 2022b). Due to unfavorable conditions, mangrove ecosystems must have high adaptation to reduce the impact of permanent water inundation (Yanuartanti et al. 2015; Hilmi et al. 2022b), tidal flooding (Hilmi et al. 2022a), seawater intrusion (Hilmi et al. 2017a), supporting of mangrove ecotourism (Dijk et al. 2016; Soares et al. 2018), fishing activity, and buffering of settlement. This research aimed to analyze the distribution and mapping of mangrove ecosystem in permanent water inundation area using index of mangrove density, diversity, and geographical information system.

## 2. Material and Methods

### 2.1. Time and Research Site

This research was conducted in two stage activities that were (1) the mapping analysis using the satellite imagery 2000, 2010 and 2020, (2) the vegetation and environment analysis were conducted from January to July 2022 The research location was focused in the North Coast of Jakarta which was divided into 9 stations, namely Protected Forest of Muara Angke, Rehabilitation area (Elang of Muara Angke), Greenbelt area (Galatama of Muara Angke), Ecotourism of Muara Angke, Greenbelt area of Tol Sediyatmo, and Arboretum of Muara Angke, as shown in Fig. 1 and Table 1.

The data used 10 sampling plots for each station, from 9 stations and the size of the sampling plot of mangrove trees was 10 m × 10 m (Kantharajan et al. 2018; Hilmi et al. 2020, 2021d). The sampling plots were used to collect the mangrove density, mangrove species and environmental properties.

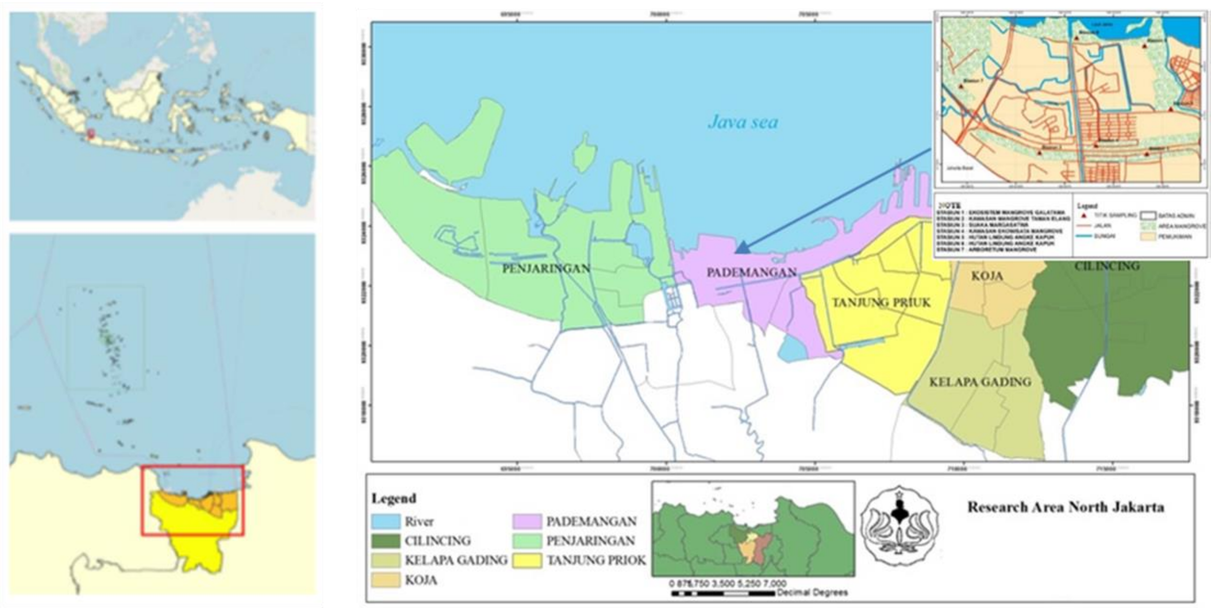


**Fig. 1**. Research area.

**Table 1**. The station on research area

| Stations | Coordinate's | |
|---|---|---|
| | **Latitude (S)** | **Longitude (E)** |
| 1. Mangrove ecotourism area | 06˚07'18.880" | 106˚45'18.370" |
| 2. Angke Kapuk preservation forest 1 | 06˚06'15.500" | 106˚45' 05.410" |
| 3. Angke Kapuk preservation forest 2 | 06˚06'16.556" | 106˚45'49.608" |
| 4. Angke Kapuk preservation forest 1 | 06˚06'16.614" | 106˚45'49.619" |
| 5. Mangrove Arboretum | 06˚06'41.386" | 106˚43'57.374" |
| 6. Mangrove greenbelt (galatama 1) | 06˚07'24.733" | 106˚45'16.124" |
| 7. Mangrove greenbelt (galatama 2) | 06° 07' 22.82'' | 106°45' 56.03'' |
| 8. Mangrove preservation (Taman Elang) | 06° 07' 24.24'' | 106°44' 55.19'' |
| 9. Suaka Margasatwa (SM) of Muara Angke | 06° 06' 56.94'' | 106° 46' 09.21'' |

**2.2. Research Variable**

The research variables were mangrove density, diversity, area and environmental properties (including water quality, and soil properties). These variables were used to analyze the distribution and mapping analysis of the mangrove ecosystem in North Coast of Jakarta.

**2.3. Research procedures**

2.3.1. Mangrove sampling

The mangrove sampling used a one-stage cluster sample with the transect method (Kusmana 1997; Hilmi et al. 2019, 2021c) to analyze tree density and the physical-chemical environmental factors based on the potential of permanent water inundation. To analyze mangrove tree density, a total of 90 sampling plots were obtained from 9 stations. The mangrove plot had a size of 10 m × 10 m, which was used to evaluate tree density with a diameter > 4 cm.

2.3.2. Environment sampling

The environment sampling was conducted through a clustering method, including (1) soil texture and (2) water quality with the related salinity, pH, phosphate, nitrate, and pyrite (Nusantara et al. 2015; Xiong et al. 2018; Xiao et al. 2019). The environmental sampling was taken based on the mangrove samples, with 20 sampling plots to analyze the environmental variables.

**2.4. Data analysis**

2.4.1. The density and diversity Indicators of mangrove vegetation

The density and diversity were conducted using the equations expressed by (Hilmi et al. 2017b, 2019, 2021d), which include:

(a) Mangrove density. The analysis density used the vegetation analysis using the equation (Xiong et al. 2018; Hilmi et al. 2021d; Cooray et al. 2021):

$$\text{mangrove density} = \frac{\textit{Tree number of mangrove speies}}{\textit{area}}$$

To analyze the mangrove density classification, the formulation of (Hilmi et al. 2019) was used as shown in Table 2.

(b) Dominance index**.** Dominance index used important value of mangrove, which can be divided into frequency, dominance, and relative density (Kusmana 1997; Hilmi et al. 2015, 2017b, 2021d).

$$\text{Vegetation index}: \frac{\textit{Domination index}-i}{\textit{total value of domination}} + \frac{\textit{Density}-i}{\textit{total value of density}} + \frac{\textit{frequency index}-i}{\textit{Total value of frequency}}$$

Where i = species-i

(c) Diversity Index. The diversity index only used the Shannon wiener analysis (Magurran 1996; Hilmi et al. 2015) with the equation stated below:

$$H' = -\sum_{i=1}^{s}(pi)(log_2 pi)$$

where H' is Shanon wiener index, Pi is proportion of mangrove trees -i, and s is number of species.

2.4.2. Mapping analysis of mangrove density and area on the North Coast of Jakarta

The mapping analysis of mangrove density and area was conducted using Landsat 2000, 2010, and 2020. The analysis used ENVI and Arc GIS program with stages were radiometric corrections, satellite cropping, masking analysis, supervised classification with maximum likelihood, and *Normalized Difference Vegetation Index* (NDVI) to analyze mangrove density using the red band and electromagnetic spectrum based on equation $NDVI = (NIR - red)$ $(NIR + red)$, where NIR = NIR: band near-infrared and RED: band red. The mangrove density following the calculation of NDVI with categories are pixel score 0.43 ≤ NDVI ≤ 1.00 = high density, 0.33 ≤ NDVI ≤ 0.42 = moderate density, and -1.0 ≤ NDVI ≤ 0.32 = lower density.

**Table 2**. The mangrove density classification

| Mangrove density Class | Mangrove density (trees/ha) | |
|---|---|---|
| | Min | Max |
| Very rare | 0 | 390 |
| Rare | 391 | 1610 |
| Moderate | 1611 | 2220 |
| Dense | 2221 | 3137 |
| Very dense | > 3137 | |

## 3. Results and Discussion

### 3.1. *Environmental factors of the mangrove ecosystem on the North Coast of Jakarta*

The environmental factors of the mangrove ecosystem on the North Coast of Jakarta were shown in Table 3. The Table 3 explained that the characteristics were (1) temperature between 24.6-31.5oC, (2) salinity of soil water ranged from 5.6 to 7.0 ppt, (3) salinity of water 0.1-9.8 ppt, (4) pH score of soil water 6.25-7.0, (5) pH score of water between 5.83-6.5, (6) dissolve oxygen 1.4-3.5 mg/L, (7) soil nitrate 12.2-22.8 mg/L, (8) soil phosphate 1.7-14.8 mg/L, (9) soil pyrite 0.12-0.3 mg/L, and (10) soil texture ranged from silt loam to silty clay loam. The data give information that the coastal area in North of Jakarta has good suitability to support the growth of mangrove ecosystem. According to Hilmi (2018), Onrizal et al. (2005), and Yanuartanti et al. (2015), the environmental properties in North Coast Jakarta has similarity to the mangrove habitat in Segara Anakan Lagoon (SAL). The Segara Anakan Lagoon had a soil pH of 5.3-6.19 (acid–normal), the soil textures are from clay-dusty to clay, the salinity was between 5 and 18‰, soil nitrate ranged from 0.010 to 0.22%, soil phosphate of 6.85-17.65%, soil pyrite of 1.03-3.10%, soil pH of 5.7-6.92, water pH 5.6-7.07. Other investigations reported that West Segara Anakan, has 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 (Rachmawati et al. 2014), while 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 (Widowati 2018).

Previous research showed that mangroves can be grown in an environment with different properties, which include soil textures of coarse, sandy and clay, salinities between 2 and 30‰, and pH values of 4-8 (Krauss et al. 2008; Yanuartanti et al. 2015; Hilmi et al. 2021d). Hilmi et al. (2021e) and Hilmi et al. (2019) also reported that the mangrove ecosystem in Segara Anakan Lagoon is divided into two ecosystems, where the first area is dominated by phosphate of 9.56-19.72%, C-organic of 1.161-0.49% and pyrite of 0.03–2.88%. Meanwhile, the second area is dominated by water salinity between 13.5-32.33 ppt, pH of 5.73-7.53, soil texture was clay and

**Table 3**. The environmental factors of mangrove ecosystem in North Coast of Jakarta

| stations | environmental properties | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | temperature ($^oC$) | Salinity (ppt) | | pH | | DO | Soil Nitrate | Soil Posphate | Soil Pyrite | Soil texture | | |
| | | Soil water | Water body | Soil water | Water body | mg/l | | | | Sand | Silt | Clay |
| Mangrove ecotourism area | 24.6 | 6.4 | 0.1 | 6.65 | 5.9 | 1.8 | 12.3 | 7.15 | 0.12 | 11.8 | 72.8 | 15.4 |
| Angke Kapuk Protected forest 1 | 27.5 | 6.9 | 1.7 | 6.8 | 5.9 | 1.6 | 14.2 | 10.8 | 0.2 | 9.9 | 72.6 | 17.5 |
| Angke Kapuk Protected forest 2 | 29.0 | 7.0 | 7.8 | 6.8 | 6.3 | 2.0 | 14.3 | 12.2 | 0.3 | 13.3 | 69.1 | 17.6 |
| Angke Kapuk Protected forest 3 | 29.1 | 7.0 | 7.6 | 7.0 | 6.2 | 2.2 | 13.2 | 12.9 | 0.2 | 12.3 | 69.2 | 18.5 |
| Mangrove Arboretum | 28.8 | 6.9 | 9.8 | 6.8 | 6.4 | 2.1 | 11.7 | 14.8 | 0.2 | 11.9 | 70.2 | 18.0 |
| Galatama mangrove area 1 | 29.8 | 7.0 | 7.2 | 6.9 | 6.5 | 2.5 | 12.2 | 13.1 | 0.2 | 11.8 | 68.2 | 20.0 |
| Galatama mangrove area 2 | 31.5 | 5.9 | 4.2 | 6.4 | 6.3 | 3.5 | 22.8 | 2.3 | 0.25 | 11.6 | 66.8 | 21.6 |
| Elang Mangrove greenbelt | 28.6 | 5.6 | 1.0 | 6.3 | 5.8 | 1.8 | 17.4 | 2.0 | 0.26 | 12.6 | 77.1 | 18.2 |
| Suaka Marga Satwa Muara Angke | 28.5 | 6.0 | 8 | 6.4 | 6.2 | 1.4 | 15.9 | 1.7 | 0.18 | 11.6 | 67.8 | 20.6 |

loam, nitrate was 0.128-0.191%, phosphate of 10.44-13.77%, and C-organic ranging from 1.16 to 1.47%. Mangrove also can be grown on water inundation with physical and chemical parameters, which include water temperature of 25.0-30.5oC, water salinity of 6.0-7.5 ppt, water pH of 5.0-6.4, soil pH 6.0-7.0 with a muddy clay texture, soil nitrate of 11.5-14.5 mg/l, soil phosphate between 8.2-16.0 mg/l and soil pyrite of 1.0-3.0% (Hilmi et al. 2022b). Onrizal and Kusmana (2008) stated that in North of Sumatra, mangrove environmental characteristics are temperature of 31oC, pH 6-7, and salinity at 30 ppt.

Several reports also showed the existence of mangrove ecosystems with good growth in brackish water, with the salinity, ranging from 10 to 30 ppt, and nitrate > 10 mgl-1, phosphate standard from 0.15-0.3 mg/L (Kusmana and Maulina 2015; Sari 2016; Yin et al. 2018; Hilmi et al. 2021d). The other references stated that mangrove has good performance with the physical and chemical parameters, which include water pH of 7-8.5, soil pH at 4.5-6.5, water and soil salinity of 34 ppt, nitrate > 10 mg/L, phosphate 0.05–0.5 mg/L, and pyrite feasible >1.2 ppm (Surat Keputusan Menteri Lingkungan Hidup No. 51, 2004; Peraturan Pemerintah No. 82, 2021).

### 3.2. Trees Density and Diversity of Mangrove ecosystem

The density and diversity of the mangrove ecosystem on the North Coast of Jakarta are presented in Table 4. The data showed that the ecosystem in North Jakarta was dominated by

**Table 4**. The density and diversity of mangrove ecosystem in North Coast of Jakarta

| Stations | Mangrove species | Mangrove density | | Mangrove Domination | | Diversity (H') | |
|---|---|---|---|---|---|---|---|
| | | trees/ ha | Category | Percent | Category | Score | Category |
| Mangrove ecotourism area | *Avicennia marina* | 200 | Very Rare | 74.93 | Low | 1.63 | Low |
| | *Ficus superba* | 10 | Very Rare | 4.23 | Very Low | | |
| | *Bruguiera gymnorhiza* | 30 | Very Rare | 6.58 | Very Low | | |
| | *Carbera manghas* | 10 | Very Rare | 7.95 | Very Low | | |
| | *Exceocaria agallocha* | 10 | Very Rare | 4.41 | Very Low | | |
| | *Terminalia cattappa* | 40 | Very Rare | 17.49 | Very Low | | |
| | *Rhizophora mucronata* | 410 | Rare | 73.14 | Low | | |
| | *Rhizophora stylosa* | 150 | Very Rare | 23.61 | Very Low | | |
| | *Sonneratia caseolaris* | 200 | Very Rare | 87.66 | Low | | |
| | Total | 1060 | Rare | | | | |
| Angke Kapuk Protected forest 1 | *Rhizophora apiculata* | 6 | Very Rare | 7.67 | Very Low | 0.63 | Low |
| | *Rhizophora mucronata* | 900 | Rare | 157.31 | Dominance | | |
| | *Rhizophora stylosa* | 29 | Very Rare | 12.79 | Very Low | | |
| | *Sonneratia caseolaris* | 224 | Very Rare | 122.23 | Dominance | | |
| | Total | 1159 | Rare | | | | |
| Angke Kapuk Protected forest 2 | *Ficus superba* | 10 | Very Rare | 112.19 | Dominance | 0.94 | Low |
| | *Bruguiera gymnorhiza* | 20 | Very Rare | 17.43 | Very Low | | |
| | *Rhizophora mucronata* | 50 | Very Rare | 29.94 | Very Low | | |
| | *Sonneratia alba* | 160 | Very Rare | 140.45 | Dominance | | |
| | Total | 240 | Very rare | | | | |
| Angke Kapuk Protected forest 3 | *Avicennia marina* | 30 | Very Rare | 15.64 | Very Low | 0.45 | Low |
| | *Bruguiera gymnorhiza* | 30 | Very Rare | 14.13 | Very Low | | |
| | *Rhizophora mucronata* | 1020 | Rare | 183.04 | Dominance | | |
| | *Sonneratia caseolaris* | 60 | Very Rare | 87.19 | Low | | |
| | Total | 1140 | Rare | | | | |

| Stations | Mangrove species | Mangrove density | | Mangrove Domination | | Diversity (H') | |
|---|---|---|---|---|---|---|---|
| | | trees/ ha | Category | Percent | Category | Score | Category |
| Mangrove Arboretum | *Rhizopora stylosa* | 800 | Rare | 119.8 | Dominance | 1.26 | Moderate |
| | *Excoecaria agallocha* | 50 | Very Rare | 19.15 | Very Low | | |
| | *Bruguiera gymnorhiza* | 30 | Very Rare | 15.45 | Very Low | | |
| | *Nypa fruticans* | 40 | Very Rare | 8.73 | Very Low | | |
| | *Terminalia catappa* | 80 | Very Rare | 29.05 | Very Low | | |
| | *Rhizopora mucronata* | 10 | Very Rare | 4.74 | Very Low | | |
| | *Callophyllum inophyllum* | 10 | Very Rare | 4.75 | Very Low | | |
| | *Avicennia marina* | 190 | Very Rare | 60.6 | Low | | |
| | *Soneratia caseolaris* | 40 | Very Rare | 26.16 | Very Low | | |
| | Total | 1250 | Rare | | | | |
| Galatama Mangrove Area 1 | *Avicennia marina* | 370 | Very Rare | 168.57 | Dominance | 1.48 | Moderate |
| | *Cerbera manghas* | 40 | Very Rare | 14.53 | Very Low | | |
| | *Rhizopora mucronata* | 40 | Very Rare | 10.32 | Very Low | | |
| | *Rhizopora stylosa* | 40 | Very Rare | 14.71 | Very Low | | |
| | *Bruguiera gymnorhiza* | 10 | Very Rare | 5.75 | Very Low | | |
| | *Sonneratia caseolaris* | 10 | Very Rare | 7.4 | Very Low | | |
| | *Terminalia catappa* | 90 | Very Rare | 22.17 | Very Low | | |
| | *Excoecaria agallocha* | 90 | Very Rare | 35.73 | Very Low | | |
| | Total | 690 | Rare | | | | |
| Galatama Mangrove Area 2 | *Rhizopora stylosa* | 170 | Very Rare | 112.66 | Dominance | 1.48 | Moderate |
| | *Rhizopora apiculata* | 40 | Very Rare | 26.01 | Very Low | | |
| | *Sonneratia caseolaris* | 20 | Very Rare | 24.08 | Very Low | | |
| | *Rhizopora mucronata* | 10 | Very Rare | 10.95 | Very Low | | |
| | *Avicennia marina* | 110 | Very Rare | 65.91 | Low | | |
| | *Nypa fruticans* | 90 | Very Rare | 60.4 | Low | | |
| | Total | 440 | Rare | | | | |
| Elang Mangrove Greenbelt | *Avicennia marina* | 500 | Rare | 219.91 | High Dominance | 0.928 | Low |
| | *Sonneratia caseolaris* | 10 | Very Rare | 9.88 | Very Low | | |
| | *Thespesia populnea* | 20 | Very Rare | 8.44 | Very Low | | |
| | *Rhizopora stylosa* | 60 | Very Rare | 31.44 | Very Low | | |
| | *Excoecaria agallocha* | 130 | Very Rare | 30.34 | Very Low | | |
| | Total | 720 | Rare | | | | |
| Suaka Marga Satwa | *Avicennia marina* | 520 | Rare | 199.58 | High Dominance | 0.897 | Low |
| | *Rhizopora mucronata* | 190 | Very Rare | 64.91 | Low | | |
| | *Rhizopora stylosa* | 110 | Very Rare | 35.51 | Very Low | | |
| | Total | 820 | Rare | | | | |

Avicennia marina, Rhizophora mucronata, Rhizophora apiculata, Rhizophora stylosa, Nypa frutican, Sonneratia alba, and Sonneratia caseolaris. Meanwhile, Bruguiera gymnorhiza, Carbera manghas, Exceocaria agallocha were identified as low dominance trees, and Ficus superba, Terminalia cattapa, Callophyllum inophyllum, Cerbera manghas were identified as associate mangroves. The domination of Avicennia spp, Sonneratia spp, Rhizophora spp and Nypa frutican are caused by the good adaptation pattern of these species to life and grow in permanent of water inundation, the water pollution, and muddy clay texture. The data also described that the mangrove had only two categories that were rare and very rare density. The rare density was discovered in the Mangrove ecotourism area, Angke Kapuk Preservation Forest, Mangrove Arboretum, while the very rare categories were found in Galatama Mangrove Area, Elang Mangrove Greenbelt, and Suaka Marga Satwa Muara Angke.

The number of species of mangrove ecosystem on the North Coast of Jakarta is slightly different with Segara Anakan which has more mangrove species including Aegiceras corniculatum, Avicennia alba and marina, Bruguiera gymnorrhiza, parviflora and sexangula, Ceriops decandra and tagal, Rhizophora apiculata mucronata, and stylosa, Excoecaria agallocha, Heritiera littoralis, Nypa fruticans, Sonneratia alba and caseolaris, as well as Xylocarpus granatum and moluccensis (Hilmi et al. 2019, 2021d). Sreelekshmi et al. (2018) discovered that the mangrove ecosystem in Kerala, India has 18 mangrove species such as Rhizophora apiculata, Ceriops tagal, Kandelia candel, Sonneratia alba, and Sonneratia caseolaris, Avicennia marina, Avicennia alba, Lumnitzera racemosa, Acrostichum aureum, Excoecaria agallocha, Exoecaria indica, Avicennia officinalis, Bruguiera gymnorrhiza, and Aegiceras corniculatum, Bruguiera sexangular, Bruguiera cylindrica, and Acanthus ilicifolius. However, Onrizal et al. (2005) reported that the number of species of mangrove ecosystem in North Sumatra is 11 major, 4 minor, and 1 associate species, which are Avicennia marina, Avicennia alba, Bruguiera sexangula, Bruguiera cylindrica, Ceriops tagal, and Ceriops decandra.

According to Setyadi et al. (2021), the number species of mangrove species in Mimika, papua was 66, consisting of 20 major, 10 minor, and 36 associate. These include Rhizophora apiculata, Avicennia marina, Bruguiera gymnorrhiza, Camptostemon schultzii, Bruguiea parviflora, Sonneratia alba, Xylocarpus granatum, Rhizophora apiculata, and Nypa fruticans. Hidayat et al. (2017) stated that Segara Anakan Lagoon Cilacap has 14 species, which include 9 major and 5 minor species from 10 genera of 8 families which divided into Rhizophoraceae (4 species), Acanthaceae (2 species), and Lythraceae (2 species). Leng and Cao (2020) also stated that the mangrove forest in Hainan China is dominated by Bruguiera sexangula, Rhizophora apiculata, Sonneratia alba, Excoecaria agallocha, Bruguiera. sexangula and Xylocarpus granatum. Njana (2020) also discovered that the mangrove ecosystem in Tanzania is dominated by Avicennia marina, Ceriops tagal, Heritiera littoralis, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, and Xylocarpus granatum. Furthermore, the mangrove ecosystem in Langsa is dominated by 19 major species (8 families) and 6 minor species (6 families) (Iswahyudi et al. 2020). Rahadian et al. (2022) also identified 9 families, which include Avicenniaceae, Rhizophoraceae, Sonneratiaceae, Rubiaceae, Combretaceae, Malvaceae, Asclepiadaceae, Convolvulaceae, as well as Aizoaceae, and 16 species, consisting of 8 major and another 8 associated species.

Based on the mangrove density and diversity, the ecosystem in North Jakarta was dominated by very rare density and low–moderate diversity. The rare density was discovered in the mangrove ecotourism area, preservation area, and arboretum area with a value of 1060–1250 trees/ha. Meanwhile, the very rare density is dominated in Galatama, Elang Greenbelt, and Suaka Margaswatwa

**Table 5**. The distribution of mangrove area in The North Coast of Jakarta

| Mangrove density | 2000 | | 2010 | | 2020 | |
|---|---|---|---|---|---|---|
| | Area (Ha) | percent (%) | area (Ha) | percent (%) | area (Ha) | percent (%) |
| Very rare | 0.18 | 0.01 | 7.20 | 0.54 | 166.95 | 15.41 |
| Rare | 197.03 | 12.80 | 64.00 | 4.81 | 359.72 | 33.20 |
| Moderate | 263.65 | 17.13 | 320.14 | 24.08 | 351.09 | 32.40 |
| Dense | 591.78 | 38.46 | 632.00 | 47.54 | 273.92 | 25.28 |
| Very density | 486.35 | 31.61 | 306.00 | 23.02 | 98.91 | 9.13 |
| Grand Total | 1538.80 | 100.00 | 1322.13 | 99.46 | 1083.64 | 100.00 |

areas with a value of 440–820 trees/ha. The mangrove diversity was dominated by low diversity spread over the Ecotourism, Preservation, Elang Greenbelt, and Suaka Margaswatwa area, while the moderate diversity was in the Arboretum and Galatama and West Segara Anakan Lagoon (W-SAL) had 1493 trees/ha (529-2428 trees/ha) (Hilmi et al. 2021a). Whereas the mangrove diversity in North Coast of Jakarta had slightly different with mangrove ecosystem in Timika Papua, because Setyadi et al. (2021) note that

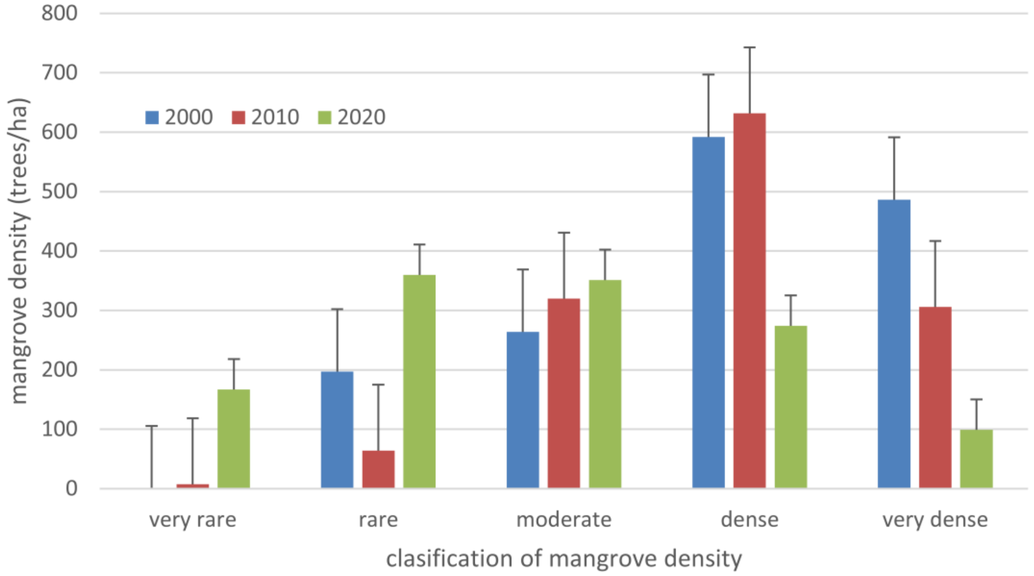


**Figure 2**. The total of mangrove density classification in the North of Coast Jakarta

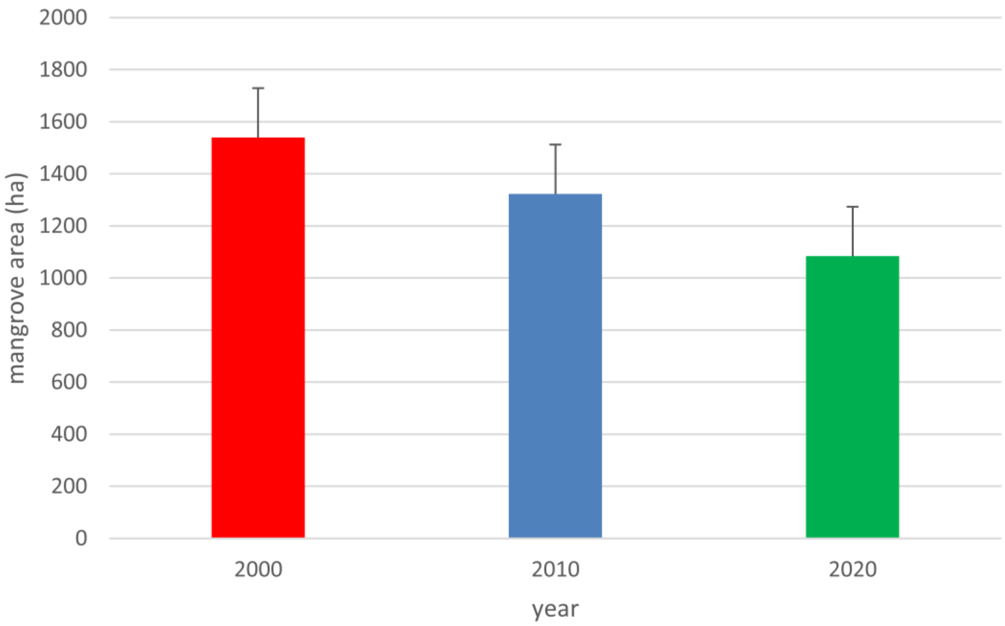


**Figure 3**. The total distribution of mangrove area in the North Coast of Jakarta.

areas. The data of mangrove density and diversity on the North Coast of Jakarta had lower potential than the mangrove ecosystem in Segara Anakan, because East Segara Anakan Lagoon (E-SAL) has an average density of 3047 trees/ha (1853-3941 trees/ha), Shannon-Weiner diversity indices (H') in Mimika Papua ranged from 0.62 to 1.19 and the Evenness Index (J') varied from 0.09 to 0.18.

### 3.3. The distribution of mangrove area on the North Coast of Jakarta

The distribution of mangrove area on the North Coast of Jakarta is presented in Table 5, Figs. 2 and 3. The data showed that the very rare, rare, and moderate density of the mangrove ecosystem had an increasing trend, but the dense and very dense had decreasing trend. The very rare density had potency from 0.18 ha (2000) to 166.95 ha (2020), rare density from 197.03 ha (2000) to 359,72 ha (2020), the moderate density from 263.65 ha (2000) to 351.09 ha (2020), the dense had potency 591.78 (2000) to 273.92 ha (2020), and the very dense with 486.35 ha (2000) to 98.91 ha (2020).

The data showed that the mangrove ecosystem was degraded because it had increasing moderate-very rare density and decreasing dense and very dense density. The factors of degradation were permanent water inundation (Hilmi et al. 2021d, 2022b), tidal flooding (Hilmi et al. 2022a), anthropology effect (Onrizal et al. 2005; Yanuartanti et al. 2015; Kuvaini et al. 2017), garbage, micro and macro plastic (Syakti et al. 2013; Dangan-Galon et al. 2016), sweater tide, and oceanography (Yanuartanti et al. 2015; Hilmi et al. 2022a, b).

Fig. 3 also described that the mangrove area on the North Coast of Jakarta tends to decrease from 1538.99 ha (2000) to 1250.59 ha (2020).The degradation of mangrove ecosystem in Jakarta is caused by the conversion of mangrove ecosystem to settlement, market buiding, and others activities. The other factors are permanent water inundation, garbage and water pollution Similarly, Sari et al. (2016) stated that the lagoon area in Segara Anakan Lagoon has an increasing trend from 1.199 ha (2003) to 1.043 ha (2016) or 156 ha/13 year, with 12 ha/year. A different result was obtained in Iswahyudi et al. (2020) stating that the ecosystem in Langsa, Aceh has a mangrove area from 4188.50 ha (2007) to 4512.78 ha (2013).

### 3.4. The mapping analysis of mangrove area distribution on the North Coast of Jakarta

The mapping analysis of mangrove area distribution on the North Coast of Jakarta was developed using the data from 2000, 2010, and 2020. Fig. 4-6 showed the degradation area of the mangrove ecosystem, the increasing area of very rare density, and the rare density of the mangrove ecosystem.

The degradation trend of mangrove ecosystem in North of Jakarta was caused by mangrove conversion (Orchard et al. 2015; Salampessy et al. 2015; Pham et al. 2018),

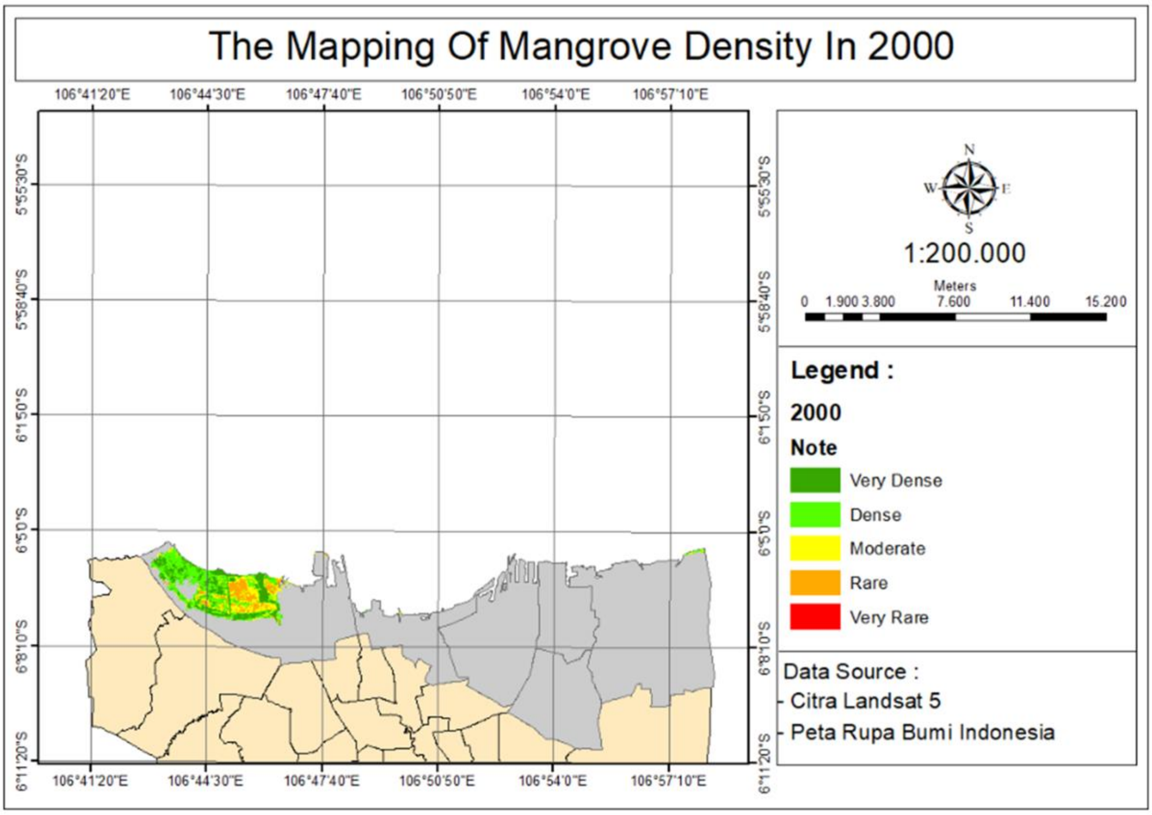


**Figure 4**. The mapping of mangrove ecosystem in the North Coast of Jakarta in 2000.

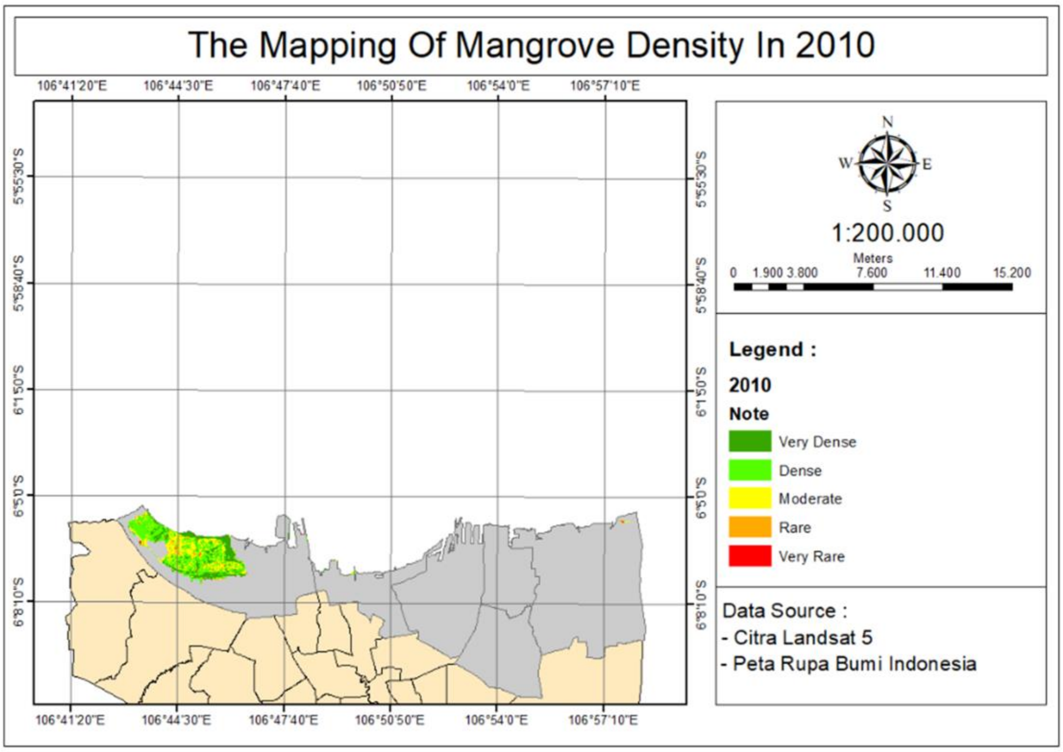


**Figure 5**. The mapping of mangrove ecosystem in the North Coast of Jakarta in 2010.

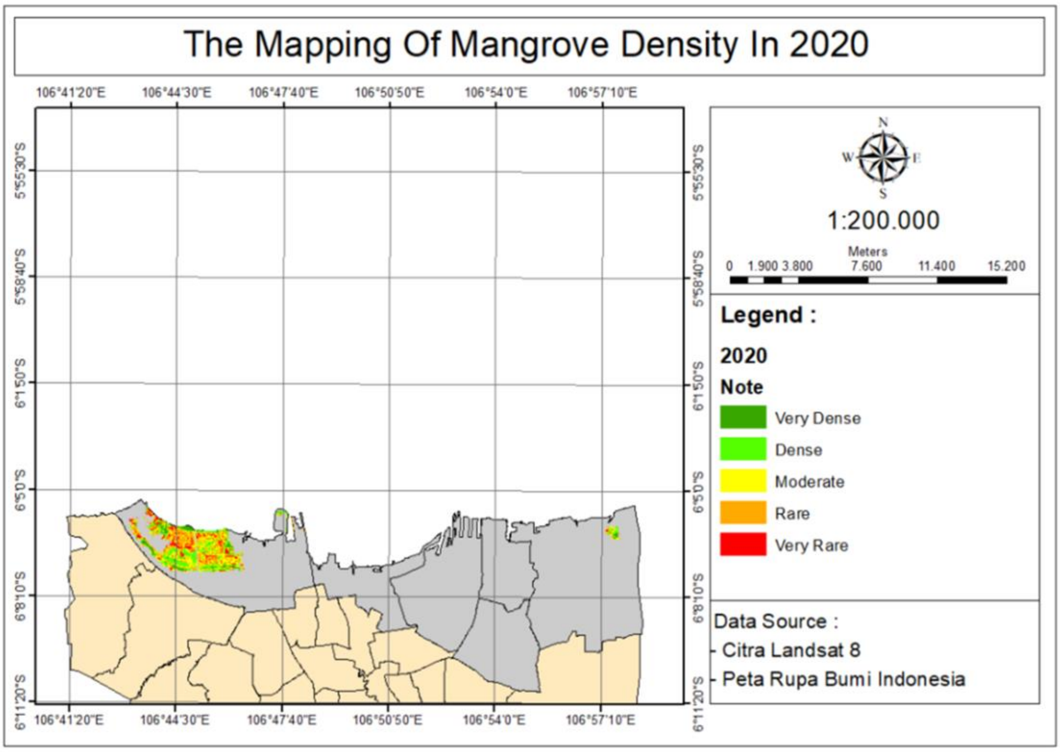


**Figure 6**. The mapping of mangrove ecosystem in the North Coast of Jakarta in 2020.

permanent inundation (Bullock et al. 2017; Bathmann et al. 2021; Hilmi et al. 2021d, 2022b), tidal flooding (Giri et al. 2015; Hilmi et al. 2022a) garbage and water pollution, This is similar with degradation in many areas of mangrove ecosystem which caused by conversion, land sedimentation (Sari et al. 2015, 2016; Nur and Hilmi 2021), community activity (Asbridge et al. 2015), industry activity (De Valck and Rolfe 2018) and water pollution (Prastyo et al. 2017; Zhang et al. 2019b) and oceanographic factors.

Bassically, the impact of decreasing mangrove in Jakarta is land subsidence (Takagi et al. 2021; Hilmi et al. 2022a), seawater intrusion (Morgan and Werner 2015; Suhartono et al. 2015; Hilmi et al. 2017a), abrasion (Randy et al. 2015; Hilmi 2018; Nur and Hilmi 2021), tidal flooding (Marois and Mitsch 2017; Hilmi et al. 2022a), and sedimentation (Sari et al. 2016; Hilmi et al. 2021e).

## 4. Conclusion

The mangrove ecosystem in Jakarta has 14 mangrove species that are *Avicennia marina,* Rhizophora *mucronata, Rhizophora apiculata, Rhizophora stylosa, Nypa frutican, Sonneratia alba,* and *Sonneratia caseolaris*, *Bruguiera gymnorhiza, Carbera manghas, Exceocaria agallocha Ficus superba, Terminalia cattapa, Callophyllum inophyllu* and *Cerbera manghas* with density between 440–1250 trees/ha. The mangrove ecosystem in Jakarta is dominated by rare (359,72 ha or 33,20 %) and moderate density (351,09 ha or 32,40 %). The mapping analysis also show that the increasing potential of moderate and rare density, but the decreasing density of mangrove dense and very dense.

## Acknowledgements

The authors express gratitude to Director Post Graduate School, Dean of Fisheries and Marine Science Faculty, Unsoed, Head of PT Succofindo, and Ketua LPPM Unsoed for the Riset Terapan Grant 2022, also to colleagues for the joint work and the anonymous constructive reviews, which significantly improved this manuscript

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