Mangrove Vegetation : Composition & Structure in Bengawan Solo Estuary, Indonesia

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Abstract

Recent damage to the mangrove ecosystem has threatened the existence of this ecosystem. The mangrove ecosystem of the Ujungpangkah area in the Bengawan Solo estuary is one of the few (pristine remaining) mangrove ecosystems in East Java Province of Indonesia. This study aims to investigate the type and structure of mangrove ecosystems in the Ujungpangkah coastal, region Gresik, East Java Province. The ecosystem structure was investigated using mangrove vegetation analysis and spatial analysis using Normalized Difference Vegetation Index system analysis. Based on spatial analysis, the mangrove area in the Ujungpangkah was 1.445 hectares distributed among 4 (four) villages, consisting of high density (650 hectares), medium density (453 hectares), and low density (342 hectares). This area comprised 7 (seven) mangrove species *i.e. Avicenia marina, Rhizopora mucronata, Rhizopora apiculata, Bruguiera cylindrica, Excoecaria agallocha, Sonneratia alba* and *Bruguiera gymnorrhiza*. The *Avicenia marina* and *Rhizopora mucronata* were two mangrove species with the highest important value index at each growth level. The highest value index (71.73%) was attributed to *Avicenia marina* for the tree level, while *Rhizopora mucronata* was dominant at the sapling level (82.55%).

Keywords: Mangroves, Density, Ujungpangkah

Introduction

The Ujungpangkah is located in the northern coast of East Java and has mangrove distribution that is geographically spread over the estuary of the Bengawan Solo River and its existence is very important for aquatic biota, such as spawning, nursery and feeding places. However, an increase in human facilities and industrial development in the Gresik Regency has indirectly impacted the land area, resulting in the reduction of green open space distributed throughout the city. In order to investigate mangrove ecosystem changes, information pertaining to the composition of species and vegetation structure was obtained (Giriraj, Murthy, & Ramesh, 2008). These data are valuable for prediction of possible environmental changes in the future (Aumeeruddy, 1994) as well as for long term management.

Increasing pressure on mangrove forests directly affects their function and environmental services. In fact, the presence of mangrove forests plays an important role in protecting the coastline from abrasion, tsunami damage and seawater intrusion (Thampanya, Vermaat, Sinsakul, & Panapitukkul, 2006; Alongi, 2008), as well as offering on important habitat for terrestrial and aquatic organisms (Skilleter & Warren, 2000; Alongi, 2002; Nagelkerken et al., 2007). The conflict between conservation and exploitation (conversion into other ecosystems) leads to a dilemma in relation to coastal management, because both activities aim to meet the needs of the community directly or indirectly (Suryaperdana, 2011). A growing population and increased industrial activities are responsible for higher ecological pressure in the estuary of the Bengawan Solo River. The ecological pressure causes mangrove ecosystem changes including a reduction of mangrove density. This led to a decrease in fishery production, for example reduction of shrimp fishing due to degradation of the spawning area (Nadia, 2002).

This study aims to investigate the diversity of species and the structure of mangrove vegetation, especially around the estuary of the Bengawan Solo River on the Ujungpangkah coast. This current work is aimed at implementing more effective and efficient strategies for sustainable management of mangrove forests.

Methodology

Time and Location

The study was conducted on the mangrove ecosystem, Ujungpangkah, Gresik, East Java Province of Indonesia. The observed area covers the entire mangrove community around the estuary of the Bengawan Solo River in the coastal village of Ujungpangkah from May 2016 to March 2017. Four Stations were observed at this are i.e. station (1) Banyuurip village, station (2) Pangkah Kulon village, station (3) Pangkah Wetan village, station (4) Ngemboh village. Geographicaly, stations and research transects i.e.

Station 1 transect 1 at $6^0$54'12.79''S – $112^0$31'41.64''T

Station 1 transect 2 at $6^0$54'04.96''S – $112^0$31'33.61''T

Station 1 transect 3 at $6^0$54'07.76''S – $112^0$31'30.66''T

Station 2 transect 1 at $6^0$51'28.68''S – $112^0$32'00.46''T

Station 2 transect 2 at $6^0$53'06.19''S – $112^0$32'14.72''T

Station 2 transect 3 at $6^0$53'14.89''S – $112^0$32'08.04''T

Station 3 transect 1 at $6^0$52'35.46''S – $112^0$36'24.54''T

Station 3 transect 2 at $6^0$52'46.72''S – $112^0$36'28.52''T

Station 3 transect 3 at $6^0$53'01.39''S – $112^0$36'36.51''T

Station 4 transect 1 at $6^0$54'27.53''S – $112^0$30'15.11''T

Station 4 transect 2 at $6^0$54'29.02''S – $112^0$30'14.70''T

Station 4 transect 3 at $6^0$54'29.79''S – $112^0$30'14.27''T

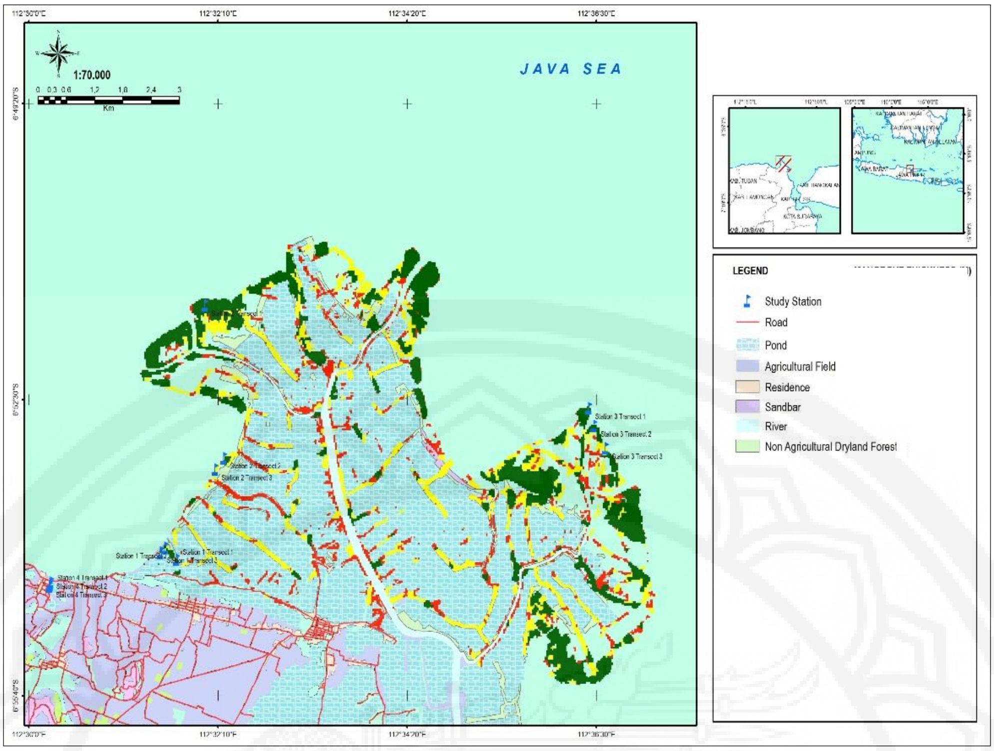

Figure 1 Map of Research

Analysis of Mangrove Ecosystem Status

A combination of line transect and plotted line using the method of Kusmana (1997), transect was used to identify the potential of the mangrove ecosystem on the Ujungpangkah coast. Kusmana (1997) stated that combination method of line transect and plotted line transect was established perpendicular to coastline to the land with a width of 10 m and its length depending on field conditions (distance of mangrove forest on the coast with mangrove forest border with land behind mangrove forest). Regeneration of mangroves for vegetation analysis was characterized as follows:

a. Seedling tree: from seed to sapling (less than 1.5 m in height)
b. Sapling tree: tree with a height of 1.5 m and $\leq$ 10 cm in diameter
c. Mature tree: tree with $\geq$ 10 cm in diameter.
d. Ground plants: other vegetation (grass, herbs and shrubs)

Furthermore, subplots for each regeneration level were described as follows:

a. Seedling tree : 2 × 2 m
b. Sapling tree: 5 × 5 m
c. Mature tree: 10 × 10 m

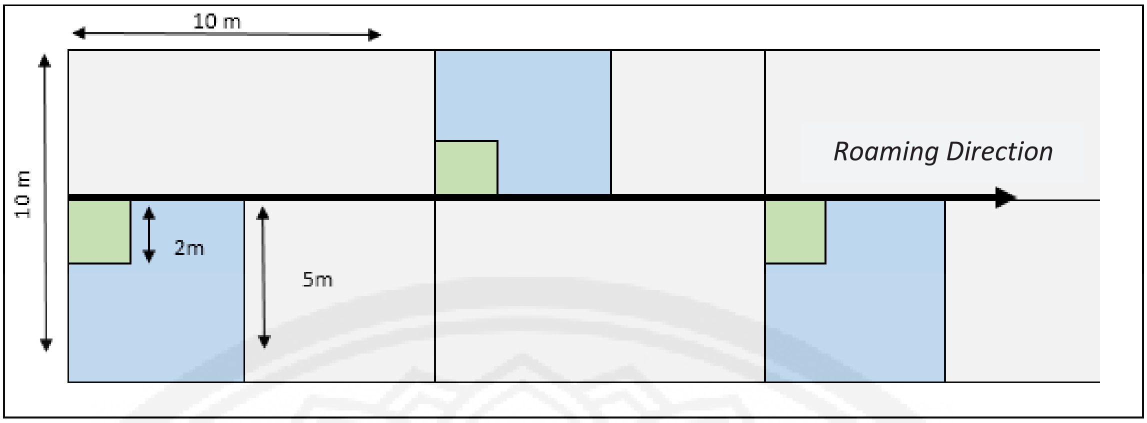

Figure 2 Combined design method for line transect and plotted line transect (Onrizal, 2008)

All individual of mangrove plants in subplots were identified and counted, and especially for tree height, stem diameter, branch free height and total tree height were recorded. The tree diameter was determined at 1.3 m above ground level or 10 cm above buttress (for *Bruguiera*) or stilt root (for *Rhizopora*) considering that buttress and stilt root were at a height of $\geq$1.3 m, which was known as DBH (diameter at breast height). The quantitative vegetation parameters, used in determining importance value index (IVI), were calculated using the following formula:

a. Population Density (D)

$$D = \frac{\sum \text{number of individuals}}{\text{Total area sampled}}$$

b. Relative Population Density (RPD)

$$RPD = \frac{\text{Density for a species}}{\text{Total density for all species}} x\ 100\%$$

c. Frequency (F)

$$F = \frac{\text{Number of plots in which a species occurs}}{\text{Total number of plot sampled}}$$

d. Relative Frequency (RF)

$$RF = \frac{\text{Frequency value for a species}}{\text{Total frequency value for all species}} x\ 100\%$$

e. Dominance (D), determined only for tree levels

$$D = \frac{\text{Total of basal area of each tree of a species from all plots}}{\text{Total area of all the measured plots}}$$

f. Relative Dominance (RD) (%)

$$RD = \frac{\text{D for a species}}{\text{Total dominance for all species}} x\ 100\%$$

g. Importance Value Index (IVI)

- For tree levels: IVI = Relative Density + Relative Frequency + Relative Dominance
- For seedling, sapling, and ground plants: IVI = Relative density + Relative Frequency

h. Basal Area (BA)

$$BA = \frac{\pi * R^2}{\text{Number of all subplots}} = \frac{1}{4}\pi * D^2$$

R is radius of stem diameter and D is DBH of basal area, which was then converted to square.

Mangrove Vegetation Analysis using NDVI Algorithm

NDVI (Normalized Difference Vegetation Index) algorithm was used to determine mangrove density. Satellite images were obtained from Landsat 8 OLI / TIRS for the recording year 2015. NDVI data layer was defined as:

$$NDVI = \frac{NIR - R}{NIR + R}$$

In Landsat 8 OLI/TIRS image, bands used were presented below:

$$NDVI = \frac{\text{Band 5} - \text{Band 4}}{\text{Band 5} + \text{Band 4}}$$

NDVI analysis was followed by classification based on NDVI values using reference of mangrove identification manual published by the Ministry of Forestry (2006) as follows:

1. Dense canopy density ($0.43 \leq NDVI \leq 1.00$)
2. Medium canopy density ($0.33 \leq NDVI \leq 0.42$)
3. Rare crown density ($-1.00 \leq NDVI \leq 0.32$)

Results

Mangrove Vegetation

The mangrove vegetation was observed in 4 stations in which 3 transects were made for each station considering representation of species, substrates and village administration areas. We found various results on each station. Station 1 (Banyuurip Village) showed 6 species namely *Avicenia marina*, *Rhizopora mucronata*, *Rhizopora apiculata*, *Bruguiera cylindrica*, *Excoecaria agallocha*, and *Sonneratia alba*. At Station 2, a total of 6 species were found namely *Avicenia marina*, *Rhizopora mucronata*, *Rhizopora apiculata*, *Bruguiera cylindrica*, *Sonneratia alba* and *Bruguiera gymnorrhiza*. Station 3 (Pangkah Wetan Village) had similar mangrove species found in the Station 2. Additionally, 2 species namely *Bruguiera gymnorrhiza* and *Rhizopora mucronata* were found in Station 4 making a total of 7 species. The results show that different mangrove thickness in each sampling area was observed, namely Banyuurip Village (63.3 m), Pangkah Kulon Village (260 m), Pangkah Wetan Village (206.7 m) and Ngemboh Village (20 m). The highest tree density (27.12%) was attributed to *Avicenia marina*, while the lowest tree density (0.24%) was attributed to *Excoecaria agallocha*. We also found that the highest relative frequency (25.49%) of a mangrove tree was for *Rhizopora mucronata*, while the lowest (1.83%) was observed for *Excoecaria agallocha*. Furthermore, the highest relative dominance (26.03%) of the mangrove tree was for *Avicenia marina*, while the lowest (0.20%) was for *Excoecaria agallocha*. The highest IVI for mangrove tree was *Avicenia marina* with an index of 71.73% as presented in Table 1.

Table 1 Vegetation analysis of mangrove tree

Species	RPD (%)	RF (%)	RD (%)	IVI (%)
Avicenia Marina	27.12	18.58	26.03	71.73
Rhizopora apiculata	8.53	10.87	7.92	27.32
Rhizopora Mucronata	23.51	25.49	21.25	70.25
Excoecaria agallocha	0.24	1.83	0.20	2.27
Sonneratia alba	18.97	16.55	16.08	51.60
Bruguiera silindrica	4.63	7.59	2.70	14.92
Bruguiera gymnorrhiza	17.00	19.10	25.82	61.91

The results demonstrated that the highest density of sapling tree was found in *Rhizopora mucronata* with relative density of 28.67%, while *Bruguiera gymnorrhiza* showed the lowest density (7.52%). The highest relative frequency (24.97%) was for *Avicenia marina*, while the lowest (11.63%) was found for *Rhizopora apiculata*. Furthermore, *Rhizopora mucronata* was the dominant sapling with a relative dominance of 29.11%, while the species having the lowest relative dominance (7.59%) was *Bruguiera gymnorrhiza*. The highest IVI (82.55%) for any sapling level was for *Rhizopora mucronata*. Data of vegetation analysis of sapling level for all species is presented in Table 2.

Table 2 Vegetation analysis of sapling level

Jenis	RPD (%)	RF (%)	RD (%)	IVI (%)
Sonneratia alba	27.12	24.67	26.65	78.44
Rhizopora apiculata	15.92	11.63	16.32	43.86
Avicenia marina	20.78	24.97	20.33	66.08
Bruguiera gymnorrhiza	7.52	13.96	7.59	29.07
Rhizopora mucronata	28.67	24.78	29.11	82.55

Spatial Analysis using NDVI

The study sites were located in 4 coastal villages in Ujungpangkah, Gresik, which were geographically located at coordinates 06º 56 ′S and 112º 35′E. The boundaries of Ujungpangkah are the Java Sea in the north, Sidayu District in the east, Sidayu District in the south, and Panceng Sub-district in the west (Source: District of Ujungpangkah, 2016). The results revealed that mangrove vegetation was density in the coastal area of Pangkah Wetan Village and Pangkah Kulon Village; with medium in density Banyuurip Village; and low density in Ngemboh Village. The area of dense, medium and rare density was 650 hectares, 453 hectares, and 342 hectares, respectively.

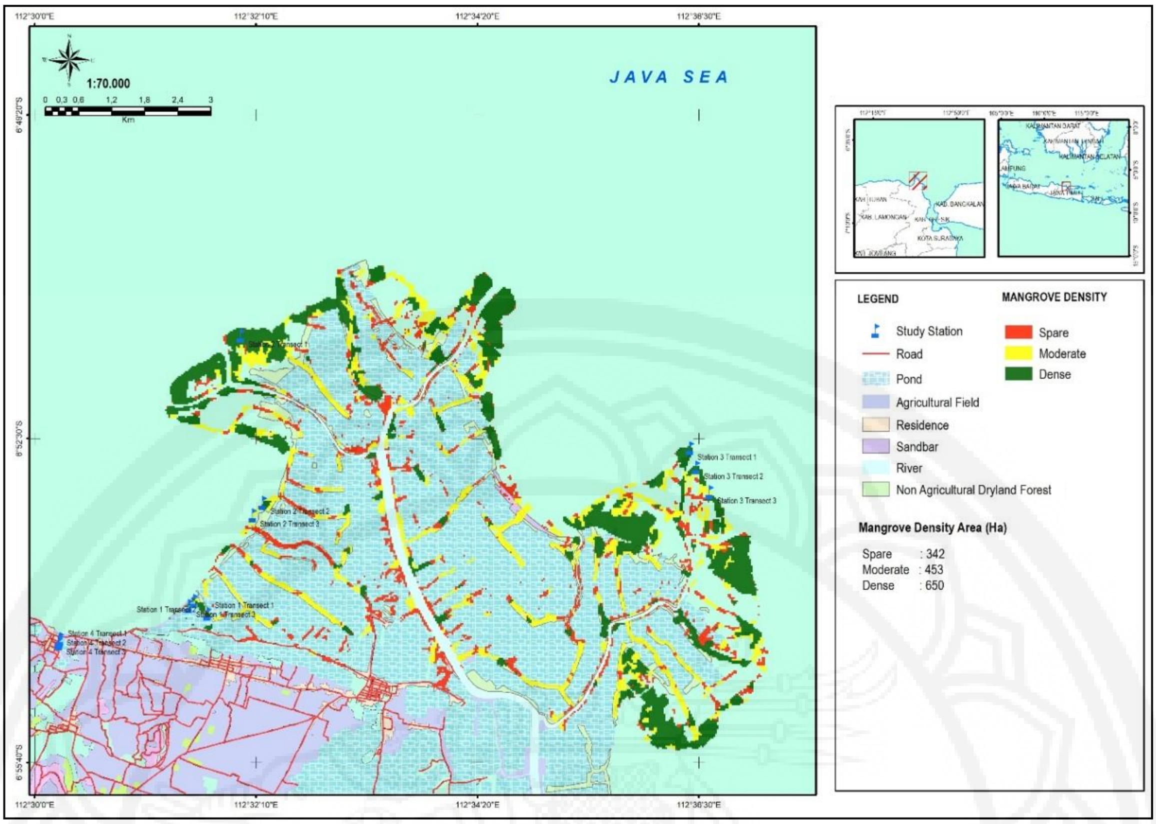

Figure 3 Density of mangrove vegetation at Ujungpangkah, Gresik, East Java

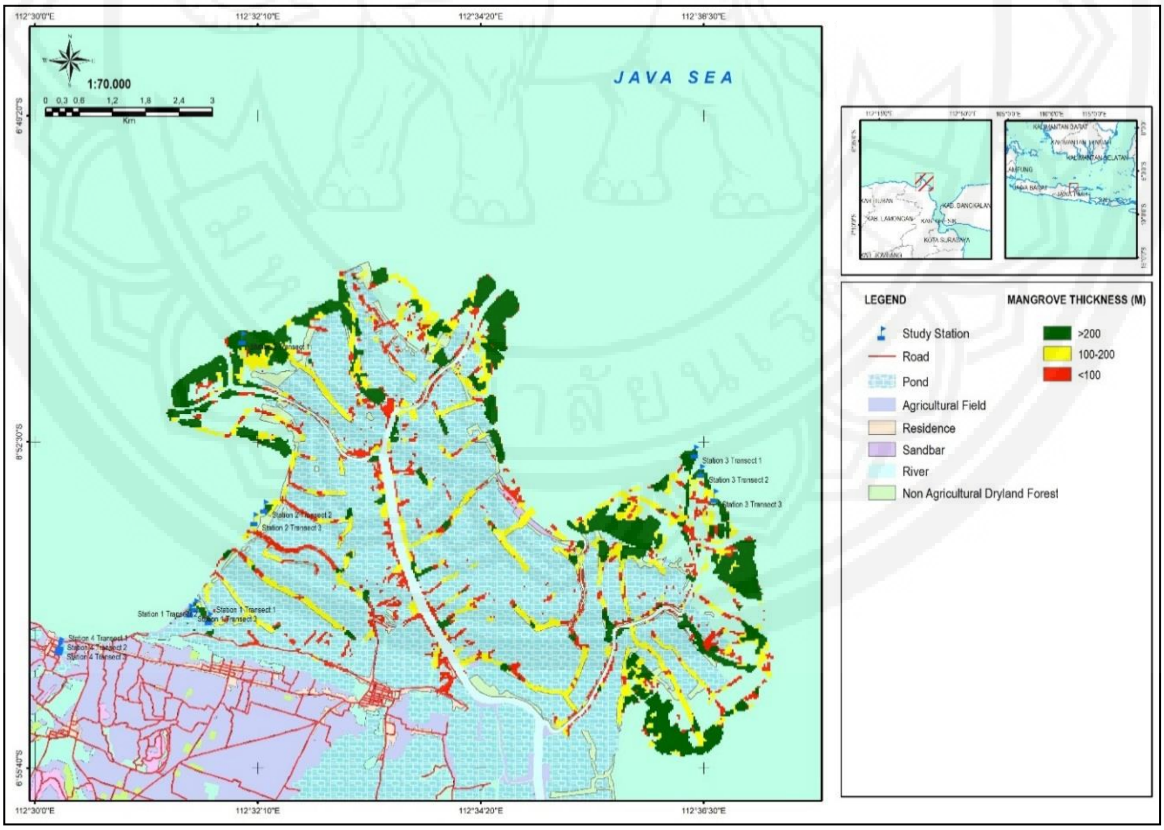

Figure 4 Thickness of mangrove vegetation at Ujungpangkah, Gresik, East Java

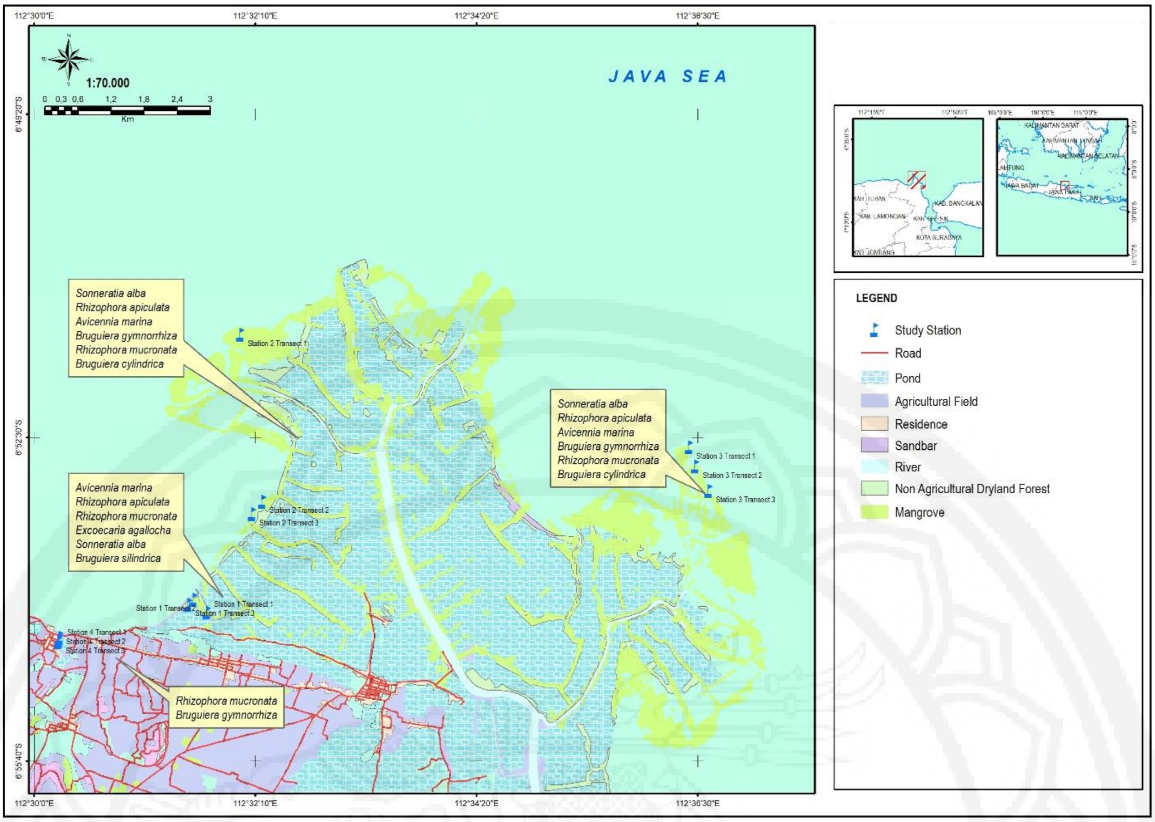

Figure 5 Distribution of mangrove species at Ujungpangkah, Gresik, East Java

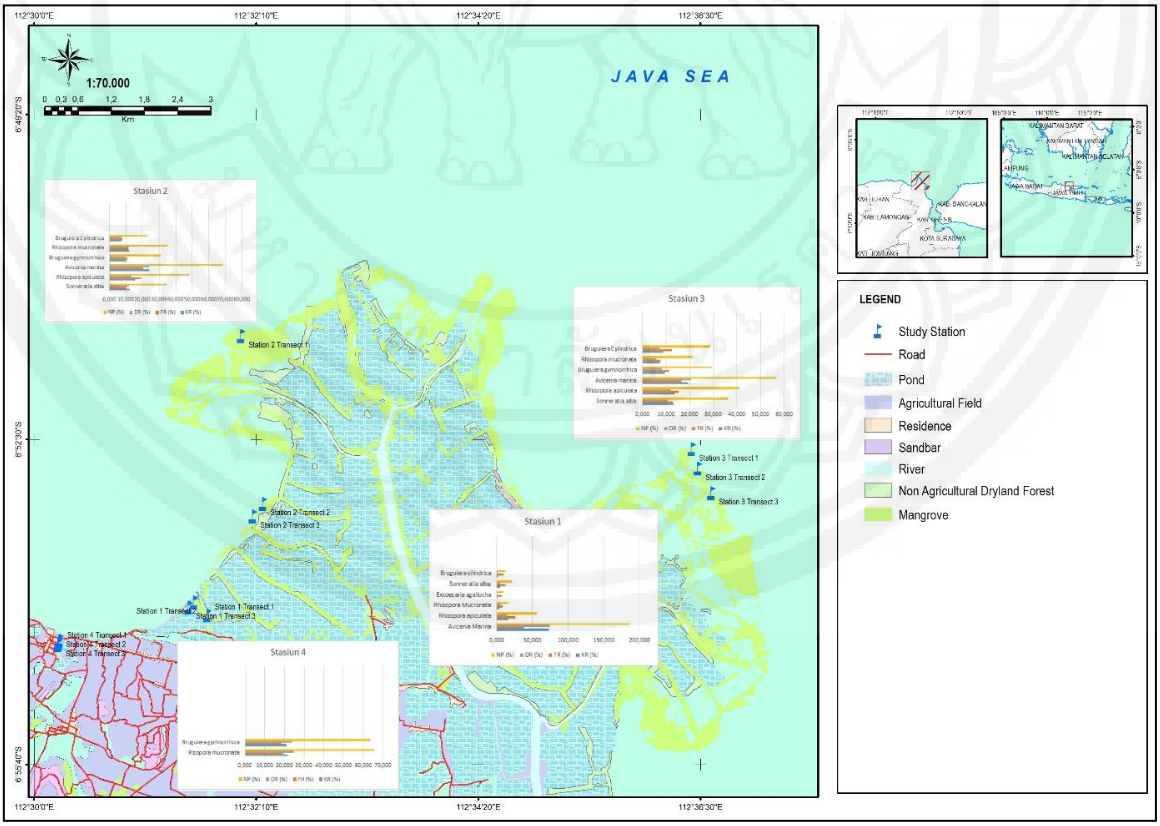

Figure 6 Mangrove condition observed at Ujungpangkah, Gresik, East Java

Discussion

There are 7 mangrove species in Ujungpangkah, namely *Avicenia marina*, *Rhizopora mucronata*, *Rhizopora apiculata*, *Bruguiera cylindrica*, *Excoecaria agallocha*, *Sonneratia alba* and *Bruguiera gymnorrhiza*. The Avicenia marina dominates in the Ujungpangkah area due to salinity conditions that correspond to the ideal conditions of 15 ppt. This is consistent with research conducted by Habib Hasani that the best salinity level for *Avicenia marina* growth is 5-15 ppt and the best media composition is sand. The combination of salinity and the substrate also yields the best growth of seedlings. However, substrate conditions in the Ujungpangkah vary and *Avicenia marina* fits on a varying substrate, which is consistent with Halidah where it is known that *Avicenia marina* can grow on coarse, deep mud. The limited number of mangrove species was a consequence of increased antropogenical activities that converted mangrove habitat into other functions, thus greatly decreasing the mangrove area. In the Ujungpangkah, major causes for mangrove degradation are increased aquacultural activities and industrialization. Antropogenical activities can permanently degrade the mangrove ecosystem (Setyawan, Indrowuryatno, Wiryanto, Winarno, & Susilowati, 2004). This limited area of mangrove could be also affected by natural factors because the estuary of Bengawan Solo River is narrow, which is ideal as mangrove habitat.

The IVI value of *Avicenia marina* for a tree category was 71.73%, and it was present in 3 observatory stations, namely Banyuurip Village, Pangkah Kulon Village, and Pangkah Wetan Village. *Avicenia* is also reported to grow from the estuary to the upstream region in North Coastal Australia (Duke, Ball, & Ellison, 1998). This species was more effective in binding sediment in comparison with *Rhizophora* present in the estuary of the Vellar River, India (Kathiresan, 2003). *Avicenia marina* in the Ujungpangkah exists more in the watershed and estuary regions of the Bengawan Solo River, and binds sediments flowing into the Bengawan Solo River. In addition, *Rhizopora mucronata* was found in all stations and showed the highest IVI (82.55%) for the sapling class. The existence of sapling clusters remarkably affected ecological sustainability of a mangrove ecosystem. Generative reproduction of *Rhizoporaceae*, with propagule morphology, was commonly viviparous or growth by attaching to the parent tree thus having a lot of nutrient in its cotyledon (Duke et al., 1998; Setyawan et al., 2004). Furthermore, propagule mangroves could exist in a floating condition, which easily spread to other areas with the aid of seawater currents (Duke et al., 1998; Hogart, 1998). The total species in this location are lower than those conducted by Irawan (2005) in Luwuk Banggai waters with a total of 27 species, Jamili, Dede, Ibnul, and Edi (2009) in the waters of Keledupa Island at Wakatobi with a total of 8 species, and Ardiansyah, Rudhi, and Nirwani (2012) in the Bambangan Village at Sebatik Island with a total of 19 species, and similar to Rahman (2014) in the Kembar village of Maminasa are seven species consisting of *Bruguiera cylindrica*, *Bruguiera gymnorhiza*, *Rhyzophora apiculata*, *Rhyzophora mucronata*, *Rhyzophora stylosa*, *Sonneratia alba* and *Xylocarpus granatum*. Nevertheless the total species in this location is still higher when compared with research conducted by Witjaksono (2002) in Kendari bay, and Susanto, Thin, and Hery (2013) around Suramadu bridge Surabaya, each consisting of only 5 species.

The mangrove density map (Figure 3) was obtained by overlaying mangrove coverage map with vegetation density map from NDVI analysis. The classification in the overlayed map was performed to obtain mangrove density in accordance with the categories. Categorization was made according to regulation of Directorate General of Field Rehabilitation and Social Forestry, Department of Forestry (2006), including sparse, medium, and dense. The results demonstrated that the total mangrove area in the Ujungpangkah was 1445 hectares comprised of sparse 342 ha (24%), medium 53 ha (31%) and dense 650 ha (45%). Furthermore, the mangrove thickness map employed gave the mangrove suitability index (Hutabarat, Yulianda, Fahrudin, Harteti, & Kusharjani, 2009), which in classified as high >200 meter, medium 100- 200 m, and low <100 m. Figure 4 showed that high thickness was observed in Pangkah Wetan and Pangkah Kulon Village, while medium and low thickness was found in Banyuurip Village and Ngemboh Village, respectively. On results showed that density and thickness of mangrove was dynamic, and susceptible to changes. Issa (2008) reported that the SIG could assist evaluation and visualization of changes in mangrove coverage area caused by a growing human population and urbanization, through three conditions: changes in mangrove coverage, presence and dominance of other plants (coconut tree and *Palmiacea*), and shrubs.

The state of the mangroves in Pangkah Wetan, Pangkah Kulon and Banyuurip Villages were relatively good, while the mangrove area in station 4 Ngemboh Village was damaged, indicated by the sparse density, low thickness and limited species diversity. The degradation and destruction risks have been closely associated with human activities (Vuilleumier & Prelaz-Droux, 2002; Sierra, Campos, & Chamberlin, 2002). In Ngemboh Village, the dominant settlement reduced the mangrove population. The criteria and indicators for sustainable forest management can be considered as the common standards for forest conservation incluiding mangroves habitat among global community because the criteria and indicators target the achievement of forest protection as well as human oriented forest functions such as timber use and recreational use in a sustainable way (Mrosek, 2001).

Conclusion

The mangrove area in the Ujungpangkah of East Java province in Indonesia was determined by spatial analysis was 1445 hectares, which was spread over 4 villages. The study found that mangrove density in this study area could be classified into dense (650 hectares), medium (453 hectares), and sparse (342 hectares). The area was composed of 7 mangrove species namely *Avicenia marina*, *Rhizopora mucronata*, *Rhizopora apiculata*, *Bruguiera cylindrica*, *Excoecaria agallocha*, *Sonneratia alba* and *Bruguiera gymnorrhiza*. The *Avicenia marina* and *Rhizopora mucronata* showed the highest IVI on tree level (71.73%) and sapling level (81.55%).

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