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Land Suitability Analysis for Mangrove Restoration in Muara Gembong District, Bekasi Regency, West Java, Indonesia

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ABSTRACT

Muara Gembong Subdistrict is home for widely known destructed mangrove ecosystem with annual loss of 1000 ha. This Research aimed to analyzed suitability of mangrove rehabilitation in Muara Gembong, Bekasi Regency. The method used were GIS and survey for spatial analysis at two stations. The Parameters measured such as water temperature, salinity, Substrate, bathimetry or topography, and mangrove species. Four suitability criteria, very suitable, suitable, conditionally suitable and unsuitable were used to determine the suitability of mangrove rehabilitation. The results show both station area were very suitable for mangrove rehabilitation.

Keywords:
Mangrove, Muara Gembong, Suitablity, Rehabilitation

INTRODUCTION

Despite being degraded each year, the total amount of mangrove forest in coastal area of Indonesia is still regarded as the largest in the world. Approximately 23% of world's mangrove ecosystem, inhabitat in Indonesia which equals to 3,79 millions hectare [1]. Majority of its degradation is attributed to massive land conversion to aquaculture, cities development including urban and tourism site as well as uncontrolled and unregulated wood logging [2,3]. Data recorded from 2000 to 2014 revealed that Indonesia is the largest contributor on world's mangrove deforestation with up to 311 km^2 loss per year which in total is proportionate to six times of Singapore island area [4].

As a unique ecosystem in both tropical and sub-tropical area, mangrove holds a pivotale role to coastal protection. Ecologically and biologically, it serves as an important site for many species development [5]. Physically, It also protect the coast from wave and filter out pollutants before entering ocean. In addition, mangrove ecosystem brings income economically to local communities from its ecosystem service, fisheries production and ecotourism activities [6]. It is reported that mangrove ecosystem could provide up to $1.6 billions per year to local economy if it's well managed [7]. Mangrove also known as one of potential blue carbon for climate change adaptation and mitigation as it can efficiently sink carbon and trap it for millenia [8].

Muara Gembong District in Bekasi Regency Indonesia was a home for poor managed mangrove ecosystem. According to Bekasi's Department of Agriculture, Fisheries and Maritime Affairs, this area lost 1000 hectare of mangrove annually, leaving only 16% mangrove left in 2016 [9]. The degradation in this area is already in alarming state and efforts to rehabilate it is clearly an urgent need. Here we try to map the suitable location for mangrove restoration site based on its environmental characteristic in order to better predict the probability of succesfulness of restoration activity of mangrove ecosystem in the district.

METHODOLOGY

2.1. Location and Data Collection

The suitability analysis was conducted in two site in Muara Gembong District Bekasi Regency West Java Indonesia. The two station are Bahagia Beach Bay and Bakti Beach Bay. The two location were choosen based on previously mangrove rehabilitation efforts performed by government. The map of the research location can be seen in Figure 1.

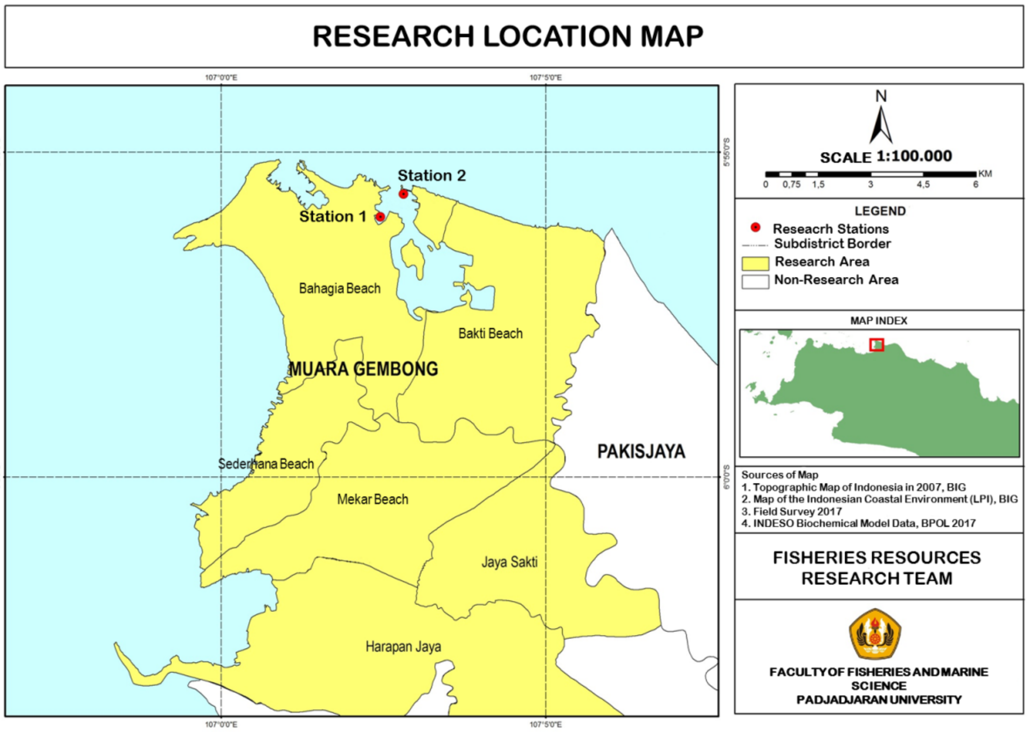

Figure 1. Research Station Location at Muara Gembong District

The research was performed in two different stages which include data collection on site and spatial data analysis for map generation. The primary data comprises with environmental parameter and water quality data that are significantly affecting mangrove. Secondary data obtained from misclenaous resources consisting land topographycall characteristic, land elevation and substrate type. Type and source of data used in this research can be seen in table 1.

Table 1. Type and Sources of Data

No	Parameter	Unit	Tools	Measurement Method	References
1	Land Elevation	%	GPS	In Situ	[10]
2	Number and Mangrove Species	-	-	In Situ	
3	Substrate	Type	Ekman Grab and Shovel	Segitiga Tekstur	[11]
4	Salinity	Ppt	Refractometer	In Situ	[12]
5	Temperature	°c	Thermometer	In Situ	

1.2. Land Suitability Analysis

Land suitability analysis for mangrove restoration was based on environmental and water quality data which meet the minimun requirement to support mangrove physiological development. The analysis consisted of four categorized, very suitable (S1), suitable (S2), conditionally suitable (S3) and unsuitable (N). Requirement for each criteria is based on Iman [13] and can be seen in table 2.

Tabel 1. Mangrove Land Suitability Criteria

No	Parameter	Very Suitable (S1)	Suitable (S2)	Conditionally Suitable (S3)	Unsuitable (N)	Ref.
1	Land Elevation (m)	0-0,05	0,05-0,55	0,55-0,78	<0	[14]
2	Number and Mangrove Species	>5	2-4	1	0	[15]
3	Substrate	Silt-Clay	Fine sand	Medium sand - coarse sand	Gravel	[16]
4	Salinity(ppt)	20-30	10-20	30-37	<9 ; >38	[17]
5	Temperature (°c)	26-28	21-26	18-20	<18 ; >28	

Parameters that can provide a stronger influence as a limiting factor for mangrove rehabilitation techniques are given higher weight. To get the weight value of each parameter used equation as shown below and the results of the weighting and score values can be seen in Table 3.

$$Wj = \frac{n - rj + 1}{\sum(n - rp + 1)}$$

With: Wj: Parameter Weight n : Number of Parameter
rj : Rank rp : Parameter

Table 2. Mangrove Land Rehabilitation Suitability Matrix

No	Parameter	Weight	Category	Criteria	Scale	Score
1	Land Elevation (m)	0,33	0-0,05	Very Suitable	4	1,32
			0,05-0,55	Suitable	3	0,99
			0,55-0,78	Conditionally Suitable	2	0,66
			<0 ; >0,78	Unsuitable	1	0,33
2	Number and Mangrove Species	0,27	>5	Very Suitable	4	1,08
			2-4	Suitable	3	0,81
			1	Conditionally Suitable	2	0,54
			0	Unsuitable	1	0,27
3	Substrate	0,2	Silt-Clay	Very Suitable	4	0,8
			Fine Sand	Suitable	3	0,6
			Medium-Coarse	Conditionally Suitable	2	0,4
			Gravel	Unsuitable	1	0,2
4	Salinity (ppt)	0,13	20-30	Very Suitable	4	0,52
			10-22	Suitable	3	0,39
			30-37	Conditionally Suitable	2	0,26
			<10 ; >38	Unsuitable	1	0,13
5	Temperature (°c)	0,07	26-28	Very Suitable	4	0,28
			21-26	Suitable	3	0,21
			18-20	Conditionally Suitable	2	0,14
			<18 ; >28	Unsuitable	1	0,07

Assessment to determine the suitability of mangrove rehabilitation land based on the score of each parameter is calculated using the following equation

$$Evaluation\ Score\ Value = \frac{Total\ score\ in\ location}{Highest\ score} \times 100\%$$

In accordance to that, the determination of categories can be decided based on the percentage of land suitability intervals as shown in Table 4.

Tabel 3. Mangrove Land Rehabilitation Suitability Classes

No	Suitability Class	% Suitability
1	S1 (Very Suitable)	75-100
2	S2 (Suitable)	50-75
3	S3 (Conditionally Suitable)	25-50
4	N (Unsuitable)	0-25

1.3. Spatial Analysis

Spatial analysis in determining the suitability of aquatic land is divided into three stages, namely the interpolation stage, the reclassification stage and the overlay stage. Spatial analysis is done after land suitability analysis. The interpolation stage is the stage of estimating the value of environmental parameters based on sample data measured at both stations, with the Inverse Distance Weight (IDW) interpolation technique. The IDW method is more appropriate for interpolating physical data on coastal areas because it does not produce values beyond the sampled data [18]. This method assumes that each input point has a local effect so that it gives great weight to cells closest to the point compared to cells that are far from the point. The next stage is overlaying. Methods that can be used in research include overlapping methods between administrative maps and interpolation maps of water parameter data including physical, biological or chemical factors. Next, a matching method is performed between the characteristics of the waters and the suitability requirements for the land.

RESULTS AND DISCUSSION

3.1. Parameter Suitability

The parameters of the suitability of mangrove rehabilitation are environmental conditions and water quality in Muara Gembong District water can show land suitability in general. The value of each parameter falls into four categories, which are very suitable (S1), suitable (S2), conditionally appropriate (S3) and not suitable (N). The results of measurements of environmental parameters and water quality are presented in Table 5.

Table 4. Average Value of Mangrove Land Rehabilitation Suitability

Station	Land Elevation (m)	Number and Mangrove Species	Substrate	Salinity (ppt)	Temperature (°c)
Station 1	0^{s1}	2^{s2}	Sand clay^{s2}	22^{s1}	32^{s2}
Station 2	0^{s1}	2^{s2}	Sand clay^{s2}	32^{s3}	32^{s2}

The height of a land greatly affects the type of mangrove vegetation. At the study site, the mangrove rehabilitation area had an average height of 40 m with a maximum height of 200 m [19]. Based on the measurement results in the field, the height range of the mangrove rehabilitation area was 0-2.7 m. Both stations which are mangrove planting areas that are directly affected by abrasion, are very suitable land for mangrove rehabilitation, because the elevation value of the land is 0. Manrove found during the study there are two types, namely

Pidada (*Sonneratia alba*) and *Rhizophora mucronata*. According to Muharam [20] mangroves of the genus Rhizophora are the most widely planted mangroves during rehabilitation, because they are easy to breed and adapt well to the environment.

The type of substrate is one of the determining factors for the success of a mangrove rehabilitation effort. Most mangrove species grow well in muddy soils rather than sandy or rocky soils. At the study site, the substrate found was sandy loam and silt. Clay and silt are fine substrate fractions that can form mud. The types of mangroves used for planting activities in the Muara Gembong District area are *Rhizophora mucronata*. According to Kelana et al [21] species of *Rhizophora mucronata* often found in areas with muddy substrates and rich in nutrients. Based on the research results obtained, this parameter is included in the category of very appropriate and quite appropriate.

Salinity is one of the factors that determine the development of mangroves, therefore, the zonation of each mangrove habitat is always different according to local environmental conditions. Salinity at the study site ranged from 22 to 32 ppt. According to Jesus [22] Mangroves can survive in the range of 31-34 ppt if they are in a zone directly facing the sea. Prominent habitat characteristics in the area of mangrove ecosystems, forming mangrove zoning, mangroves can survive from the front zone near the sea to the zone far from the sea with a range of salinity in the water that wet the zone between 2-22 ppt. Based on this, the station in general research into the very appropriate category to conditionally suitable. While for temperature, ranges at each research station in Muara District is in accordance with the existing mangrove habitat conditions. The temperature range depends on the density and cover of the mangrove canopy at the observation station during the day, which is in the range of 32^{0}C.

1.4. Mangrove Rehabilitation Land Suitablity

The value of each parameter is then assessed based on the land suitability matrix that has been made. The results of the assessment and percentage of suitability showed that the Muara Gembong sub-district was categorized as very suitable (S1) and quite appropriate (S2) for mangrove rehabilitation land. The suitability of mangrove rehabilitation land in detail can be seen in Table 6.

Table 6. Index values and suitability classes for mangrove rehabilitation Results

Station	Suitability Value (%)	Suitability Class
1	83%	Suitable (s2)
2	76,5%	Suitable (s2)

1.5. Analysis of Spatial Mangrove Rehabilitation

Based on the suitability value of each of the above parameters and based on the results of the overlay that has been done, a water suitability map is obtained (Figure 2). Spatial analysis results show that in Muara Gembong Subdistrict, particulary in the two research location, is wholefully suitable for mangrove rehabilitation,. the quite appropriate category has a land area of 180,74 ha.

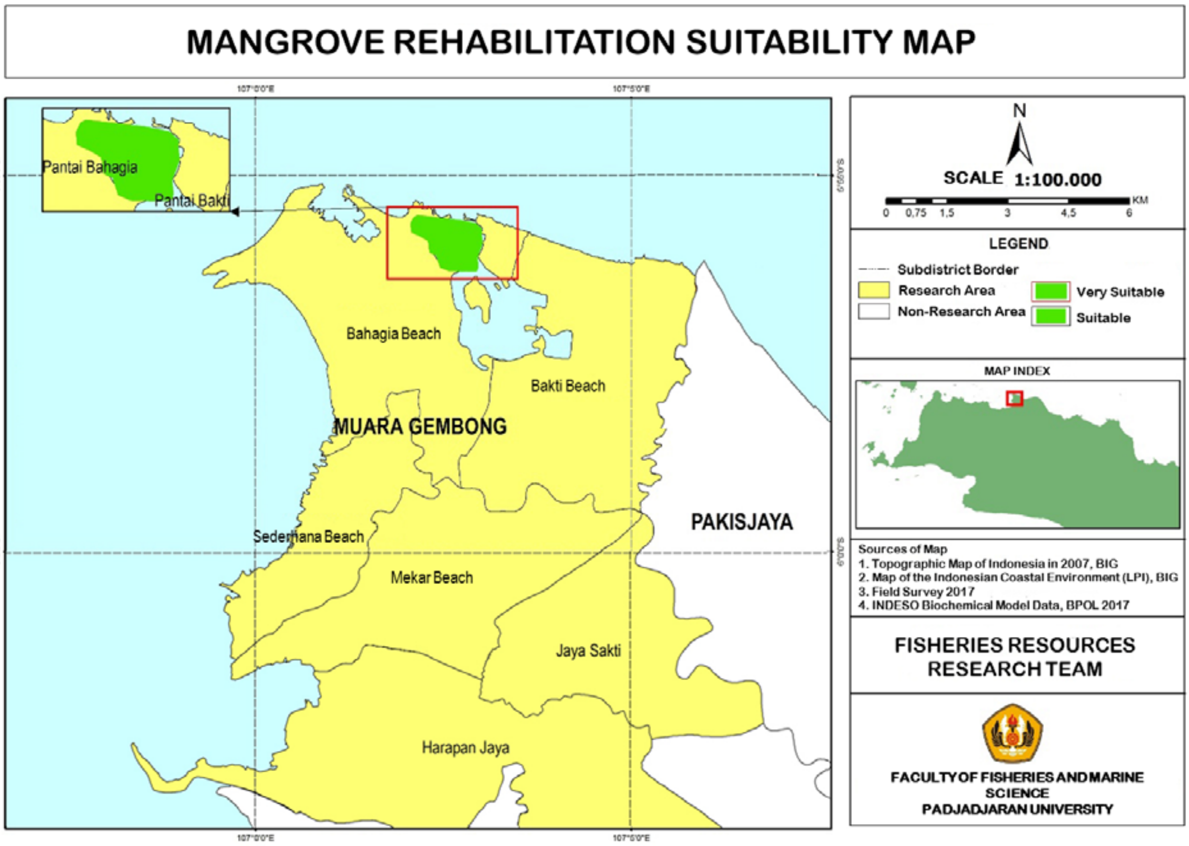

Figure 2. Mangrove rehabilitation land suitability map in Muara Gembong District

CONCLUSION

Muara Gembong Subdistrict is an area that experiences very severe abrasion. To anticipate the impact of abrasion which is getting worse, it is necessary to rehabilitate mangroves. The results of the analysis showed that the mangrove rehabilitation included the appropriate category (S2) with an area of 180.74 Ha (Both Stations),

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