Spatial distribution of mangrove using a geographic information system in Aceh Besar

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Abstract. The mangrove forest ecosystem is unique, both because of the subtract of siltation which results in less soil abrasion, high soil salinity, and experiencing a cycle of inundation by tides. Only a few plant species survive in such a place, and most of these species are unique to mangroves because they have undergone a process of adaptation and evolution. It is not widely known how far the mangrove areas are spread in Aceh. Therefore, research needs to be carried out with the aim of knowing the extent of the sustainability of mangrove management in terms of sediment characteristics. Information about the distribution, area and change of mangrove land cover can be determined by spatial analysis using a Geographical Information System (GIS) using ArcGIS. The method used in this research is the transect method and analysed based on the identification of mangrove species. Based on the analysis of the results of the study, it was identified that the mangrove species found in the research location of Peukan Bada sub-district (West Aceh Besar) consist of Rhizophora mucronata and Sonneratia alba, while the mangrove species found in Baitussalam (north Aceh Besar) were Rhizophora mucronata and Sonneratia alba. Meanwhile, based on observations with satellite imagery and location surveys, it was found that the mangroves in Baitussalam sub-district were denser and spread evenly than in the Peukan Bada area.

1. Introduction
Mangrove forests are a coastal resource found along the coastline. Mangroves themselves have an important role, such as a habitat for marine life, a barrier to coastal abrasion and waves [1]. Indonesia has a mangrove area of 3,489,140.68 ha (2015). Of the total area of mangroves in Indonesia, 1,671,140.75 ha of mangroves are in good condition, while 1,817,999.93 ha of mangroves are in a damaged condition [2]. The main problem in mangrove areas is due to several pressures, such as increasing population so that many mangrove areas are cut down and resulting in land conversion [3]. Some of the damage to mangroves can be caused by natural disasters such as the tsunami in Aceh in 2004.

Wetland International Indonesia Program [4], states that data on the extent of mangrove land damaged by the tsunami are very mixed. [5] the damage to mangrove forests due to the tsunami in Aceh is estimated to be 25,000 ha. Data from the National Institute of Aeronautics and Space (LAPAN) [6]...
states that a higher price range is 32,003 ha. The Ministry of Forestry [7] states that the area of mangroves in Aceh that has the potential to be rehabilitated is 24,950 ha.

After the tsunami in Aceh, there have been many rehabilitations of mangroves, from local and foreign organizations, one of which was carried out by the Non-Governmental Organization (NGO) with an area of approximately 28,000 ha. The planting of coastal plants by stakeholders has reached an area of 1,824 ha and can be found along the west coast of Aceh, namely in the districts of Aceh Besar, Aceh Barat, Nagan Raya, and Aceh Selatan. Based on calculations by [4], to date at least 56,502 ha of coastal areas have been planned for rehabilitation. The total area, an area of 27,532 ha, will be planted with mangrove seeds, the rest will be planted with other coastal plants.

Many mangrove rehabilitation programs in the early post-tsunami period were not optimal. This is due to several factors, such as low quality of seeds, unsuitable planting locations, errors in choosing the type of planting and inexperienced implementation [8]. According to [9] this unsuccessfulness is also thought to have occurred due to (a) the stages of rehabilitation planning are not well-developed, (b) spatial planning that is not well understood, (c) unclear land ownership status, (d) lack of understanding the importance of mangroves in protecting the lives of coastal residents from tsunamis or, (e) a combination of these various factors. The supply of seeds and the lack of diversity in mangrove seedlings are also factors in the lack of success. Some types of mangroves that are most often found in the seedling category are *Rhizophora* sp. while not all substrates can be covered with mangroves of this type. *Rhizophora* sp. is able to live and grow in deep and soft mud [10].

Therefore, to identify the extent of the existing mangrove ecosystem, it is necessary to conduct a spatial analysis study of the presence of mangroves. The study was conducted using a Geographic Information System (GIS) to produce digital data that provides information on the characteristics of an area, as well as describing the damage to mangrove lands [11]. The advantage of GIS is the ability to provide data or information relating to spatial (spatial) and time (temporal) in an effective and efficient use [12].

Hence, the use of GIS with the use of satellite imagery is indispensable for sustainable management. Collecting data from year to year is a step that can be used as a reference for managing mangrove areas after the Aceh tsunami. Especially in Pekan Bada and Baitussalam Subdistricts, Aceh Besar District, to determine the success rate of mangrove rehabilitation using GIS analysis. The purpose of this study is to analyze changes in the area of mangrove cover after the tsunami in 2005, 2010, 2015 and 2019 in the study area.

2. Method

2.1. Research Location and Time
Field research was conducted in the mangrove rehabilitation area, the first location was in Baitussalam (A) and the second location was in Peukan Bada (B), Aceh Besar District. Data processing in the GIS laboratory, Faculty of Marine Affairs and Fisheries, Syiah Kuala University. The time of this research is from May to July 2019. The location of this research can be seen in Figure 1.

2.2. Research Methods
In general, this research uses descriptive method. The descriptive method is a method for describing or analyzing a study. This method aims to systematically, factually and accurately describe the research location [13]. Mapping of mangrove cover density using an on-screen visual method. The advantage of this method is that it can speed up and be accurate in data management [14].

Damage to mangrove ecosystems is generally caused by environmental biophysical factors [15] and community socio-economic factors. To find out the factors, it is necessary to collect primary and secondary data. This can be done using qualitative descriptive methods. The parameters that need to be observed in this study include: area size and type of cover.

Determining the location of the study was carried out by using purposive sampling method where the sampling location was the location selection that was in accordance with the research. Determining
the location of the observation can represent the condition of the entire research location and make it easier for researchers [16]. The field service stage was carried out to observe the vegetation structure and the general condition of the mangrove land in the form of mangrove types and mangrove land cover. Then the field data can clarify the image interpretation data.

The data processing is carried out by visual interpretation of the image on screen, overlay and layouting. Visual on-screen using ArcGIS software which functions to define the boundaries of each mangrove cover by delineating the computer screen (on-screen-digitizing). This stage uses image interpretation in the form (hue or color, pattern, shape, texture, association and results of field observations). Then an overlay was carried out at each study location to study mangrove vegetation cover. The final step is layouting which is a display of maps, charts, tables and graphical data. Layouting was carried out after the mangrove cover and zoning analysis process resulted in a sustainable design map for the rehabilitation of mangrove areas in Peukan Bada and Baitussalam.

![Figure 1. Map of Research Location.](image)

2.3. Data Analysis

Based on the density standard and mangrove cover according to the Minister of Environment Decree No. 21 of 2004 can be seen in Table 1 as follows:

| Criteria       | Coverage (%) | Density (plant/ha) |
|----------------|--------------|--------------------|
| Good           | Very dense   | ≥ 75               | ≥ 1500             |
| Not-favorable  | Moderate     | ≥ 50 - < 75        | ≥ 1000 - < 1500    |
| Rusak          | Rarely       | < 50               | < 1000             |

In this study, each parameter was divided into 4 classes, namely: Very suitable class was given a value of 4, appropriate class was given a value of 3, the conditional appropriate class was given a value of 2 and not suitable was given a value of 1. Furthermore, each parameter was weighted based on literature study for use in research or determining the level of land suitability. The criteria used in this study are elevation (m), number of mangrove species, subtract, salinity, and temperature (°C).
2.3.1. Land Suitability Value

Table 2. Land Suitability Value

| Suitability value | Category      | % suitability interval |
|-------------------|---------------|------------------------|
| 1                 | (S1) Perfectly fit | 75 – 100               |
| 2                 | (S2) Fit       | 50 – 75                |
| 3                 | (S3) Conditional fit | 25- 50                |
| 4                 | (S4) Not fit   | < 50                   |

Based on the score for each parameter, an assessment is carried out to determine whether the land is suitable for mangrove rehabilitation planning with the following formula: 

\[
\text{Score} = \left( \frac{\text{Total score}}{\text{The highest score}} \right) \times 100\% 
\]

so that the category determination is obtained based on the percentage of the suitability interval as shown in Table 2.

3. Result and Discussion

3.1. Analysis of the extent and distribution of mangroves

3.1.1. Mangrove in Baitussalam Sub-district

To determine the change in the area of mangrove forest in the research location, from the four years of observation, the 2005 mangrove forest area data were used as baseline value. The distribution of mangroves in the rehabilitation area in Baitussalam District in 2005 with different areas of cover at the three stations. The land cover at station 1 is 1.5 ha, at station 2 is 1.2 ha, and at station 3 is 0.30 ha. This can be seen in Figure 2A and Table 3.

Based on Figure 2 show that there has been an increase in the area of mangroves in the rehabilitation area in Baitussalam District from 2005 to 2019. The most significant increase in mangrove growth occurred at station 2 in 2019. More so Details about the extent and distribution of mangrove forests in the study location are presented in the graphs of Figure 3. It can be concluded that the success rate of the mangrove rehabilitation area can be categorized as good from 2005 to 2019.
Table 3. The Extent of Mangrove in Study Area of Baitussalam Sub-district

| Location      | Mango Extent (Ha) in year | 2005 | 2010 | 2015 | 2019 |
|---------------|---------------------------|------|------|------|------|
| Baitussalam   |                           |      |      |      |      |
| Station 1     |                           | 1.52 | 1.46 | 1.76 | 3.20 |
| Station 2     |                           | 1.20 | 4.27 | 12.85| 18.64|
| Station 3     |                           | 0.30 | 1.92 | 1.48 | 4.51 |
| Peukan Bada   |                           |      |      |      |      |
| Station 4     |                           | 0.00 | 0.00 | 0.42 | 0.42 |
| Station 5     |                           | 0.00 | 0.39 | 0.61 | 0.90 |
| Station 6     |                           | 0.00 | 0.00 | 0.00 | 1.14 |

Figure 3. Mangrove area in Baitussalam Sub-district in 2005, 2010, 2015 and 2019.

3.1.2. Mangrove in Peukan Bada Sub-district

The distribution of mangrove rehabilitation located in the Peukan Bada Subdistrict area from 2005, 2010, 2015 and 2019 with observations from Landsat 8 ETM + satellite imagery. The distribution of mangroves in the Peukan Bada area in 2005 has not seen any mangroves in the research location, namely at station 4, station 5 and station 6, this can be seen in Figure 4A.

In Figure 4B, the results of satellite imagery observations in 2010 have seen mangroves at location 5 with an area of 0.27 ha of mangroves, while at station 4 and station 5 have not seen any mangroves. The mangrove area in 2015 at the observation location at station 4 was 0.42 ha, and the mangrove area at station 5 was 0.61, while at station 6 there were no visible mangroves at that location (Figure 4C). In 2019, mangroves in the Peakan Bada sub-district have already appeared in the three observation locations, this can be seen in Figure 4D. Based on the figure, it can be seen that the distribution of the mangrove area at station 4 is 0.42, at station 5 is 0.90 ha, and station 6 is 1.14 ha.

Based on the analysis of the distribution of mangrove land cover located in Peukan Bada District from satellite images in Figure 4.6, Figure 4.7, Figure 4.8, and Figure 4.9, it shows that there has been an increase in mangrove area at station 5 from 2010 to 2019 when compared to the distribution mangrove at station 4 and station 6 (Figure 5). Peukan Bada sub-district has mangroves with the tree category only found at station 5, while at stations 4 and 6 the mangroves are still in the category of seedlings. This is due to the difference in the growth rate of each species planted in the rehabilitation area.
3.2. Value of Mangrove Land Suitability

The value of mangrove land suitability determines whether a rehabilitation area is feasible or not for sustainable management. The suitability of the mangrove rehabilitation area is shown in Table 4. Based on Table 4, the distribution of mangrove rehabilitation land suitability values shows a dominant match between S3 (conditionally appropriate) and N (unsuitable) with a suitability range between 15.13 - 69.54%.

Baitussalam Sub-district at station 2 has a good suitability value, namely S2 (appropriate) which is indicated by the suitability of core parameters such as smooth substrate and more mangrove species. From an area of 52.48 Ha it can be obtained for S2 (suitable) covering an area of 36.39 Ha, N (Not Suitable) covering an area of 7.94 Ha at station 1 and an area of 8.15 Ha at station 3. The suitability of mangrove rehabilitation land can be seen in Station 2 is a rehabilitation area which has a good success rate compared to other stations because the station is already a complex ecosystem where various kinds of birds, monkeys and other biota live. The mismatch of mangrove land at station 1 was caused by the...
condition of the field that was always inundated by high tides, mangrove species that were not suitable for sediment so that the rehabilitation area was not successful. At station 3 the types of mangroves that were planted were successful but not significant. This is evident in the number of seedlings growing compared to tillers and trees even though mangrove planting has been carried out after tsunami. The conversion of land functions also resulted in the unsuccessful rehabilitation of mangroves, so that the rehabilitation area was decreasing over time.

Table 4. Value of Land Suitability for Mangrove Rehabilitation.

| Location         | Total Score | The Highest | % of Interval | Value of Suitability |
|------------------|-------------|-------------|---------------|----------------------|
| Baitussalam      |             |             |               |                      |
| Station 1        | 52.48       | 7.94        | 15.13         | N                    |
| Station 2        | 36.39       | 69.34       |               | S2                   |
| Station 3        | 8.15        | 15.53       |               | N                    |
| Pekan Bada       |             |             |               |                      |
| Station 4        | 3.88        | 0.84        | 21.65         | N                    |
| Station 5        | 1.90        | 48.97       |               | S3                   |
| Station 6        | 1.14        | 29.38       |               | S3                   |

Peukan Bada Sub-district, from an area of 3.88 hectares, has S3 (conditionally appropriate) of 1.9 hectares at station 5 and an area of 1.14 hectares at station 6, and N (unsuitable) of 0.84 hectares. Overall, the average conformity value is 33.33%, which indicates the S3 suitability value (conditionally compliant), so it can be said that it is quite supportive if it is to be used as a mangrove rehabilitation area although in its implementation it is necessary to pay attention to which points are indeed suitable for rehabilitation.

4. Conclusions
Based on observations with satellite imagery and location surveys, it can be seen that the mangroves that grow in the area of Baitussalam Sub-district are denser and spread evenly at all observation locations, while in the Peukan Bada Sub-district rehabilitation area found only at one station (station 4) which is growing well. Suitability of mangrove rehabilitation land in the two research locations is categorized to the conditions of S3 with a value of 33.33%.

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