Physical and chemical characteristics of soil in mangrove ecosystem based on differences habitat in Banda Aceh and Aceh Besar

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Abstract. Mangrove is a plant type influenced by tides action along the tropical coastlines. The tidal type will affect the soil properties, growth of soil microorganisms, and mangrove distribution. The purposes of the study were to analyzing the characteristics of mangrove soil in different habitat type including physical and chemical properties. The research was conducted in mangrove rehabilitation as site 1 and non-rehabilitation as site 2. This research was conducted from April 2020 to September 2020. Analysis of soil properties were consisted of substrate texture, pH, salinity, Organic Carbon, N-total, and P-available. These analyses carried out in Soil Laboratory, Faculty of Agriculture, Universitas Syiah Kuala. The determining of sampling location was done by using random stratified sampling method. Data were collected at 6 stations divided into 3 stations each site. The criteria for each station was based on tidal inundation. Each station was sampled randomly at three depths, namely 0-15 cm (top layer), 15-30 (sub layer) cm, and 30-45 cm (bottom). Soil textures in study areas were loamy sand, sandy loam, dusty loam, and clay in site 1, while in site 2 the soil textures were sandy loam, sandy clay loam, loamy sand, and dusty loam. The high sand and low clay percentage produce the average of organic carbon in the medium, low and very low categories, the organic carbon ranged from 0.25% to 2.18% in site 1 and 0.62% to 1.73% in site 2. The N and P content in site 1 and site 2 were ranged from 0.02% to 0.13%; 25.30% to 68.15% and from 0.04% to 0.11%; 2.60% to 37.85%, respectively. The pH average of mangrove soils indicated that the pH category was neutral, slightly alkaline, slightly acidic in site 1. In site 2 the pH categories were slightly alkaline, neutral, slightly acidic, and acidic. The soil salinity values at different sites indicated high and very high salinity.

1. Introduction
Mangrove ecosystem is one of important coastal ecosystems dominated by some mangrove tree species that grow and develop in salinity and oxygen fluctuated. There are interrelationships between mangrove vegetation and soil characteristics. The species age, litter production, and organic detritus deposited in the forest floor will increase soil profile [1]. These vegetation formers are typed physiologically
adaptable trees relative to high salinity [2], structure and soil composition affected by tidal. Mangrove soil is a result of interaction between abiotic factors and biotic factors, abiotic factors that influence mangrove soil particularly is tidal action and biotic factors such as organism activities [3]. Furthermore, the morphological, physical, and chemical soil characteristics are result of interactions between some factors i.e. topography, climate, hydrodynamic, tidal margin and sea level changes [4]. The soil under mangrove vegetation is classified as extreme in terms of salinity, oxidation, acidity, nutrient availability, soil particle size, and tidal effects [5]. On the other hand, mangrove soils differ under different location based on some environmental condition [6]. The tidal inundation pattern was affected soil properties that can control mangrove species zonation [7].

Soil is essential part of the aquatic ecosystem because it provides nutrients not only for vegetation growth but also appropriate habitat for micro and macro organism. Moreover, meiofauna are the numerically dominant in mangrove sediments as the most estuarine habitats [8]. The fertility of the mangrove soil is due to the organic material contained, where the organic materials comes from mangrove vegetation avalanches.

Mangrove grown land are generally in a fine textured soil, low maturity level, high salt content and alkalinity, and often contains a layer of sour sulfate [9]. Mangrove land, as well as land on other ecosystems can serve as benchmarks to see potential and productivity [10]. Environmental factors are very influential on the existence and growth of mangrove forests [11]. Aceh Province can be found mangrove rehabilitation and non rehabilitation along the coastal. The mangrove species, vegetation age, and tidal oscillation would be impact for soil mangrove properties, then will influence the mangrove zone and inhabitant fauna. Furthermore, land physical properties is a responsible factor for the transportation of water and dissolved materials in the soil [12]. Hence, this study is aimed to analyze the physical and chemical characteristics of mangrove soil in the different mangrove ecosystem.

2. Method implementation

2.1. Research location
The research conducted in mangroves areas along the coastline of Banda Aceh and Aceh Besar, it was started from February 2020 to October 2020. The determination of the station was done by using random stratified sampling method which was dividing the research location into several strata based on the mangrove characteristics. Stratified random sampling is a process of sampling through a process of dividing the population into several different strata [13]. Data were collected at 6 stations divided into 3 stations in mangrove rehabilitation (station 1, 2, and 3) as site 1 and 3 stations in non rehabilitation (station 4, 5, and 6) as site 2. The characteristics of each station based on tidal action. Station 1 and 5 were always inundated both at high tide and at low tide, station 2 and 4 were inundated at high tide and exposed to air at low tide, and station 3 and 6 were exposed to air both at high tide and low tide. Stations 1, 2, 3, 4, 5, and 6 were located in Lambadeuk, Dayah Teungoh, Gampong Pande, Ruyung, Lamreh, and Gampong Lampanah, respectively (Figure 1).

2.2. Sampling of mangrove soil
The soil samples were taken randomly in each station at three depths, namely 0-15 cm, 15-30 cm, and 30-45 cm where every depth represented the top soil, sub, and bottom soil, respectively [14]. There are differences in soil depth have been studied in several research i.e. Ambeng et al [15] took soil samples from three different depths (0-15 cm, 15-30 cm, and 30-45 cm); Pupin and Nahas [16] divided into 0-5 cm and 5-10 cm, Akpan-Idiok and Solomon [17] took soil samples at a depth of 0-20 cm. Mangrove soil properties were analyzed at Soil Laboratory, Agricultural Faculty, Universitas Syiah Kuala consisted of substrate texture, pH, salinity, organic carbon, N-total, and P-available. The organic carbon contents were analyzed based on Schumacher [18] and the compositions of substrate were examined based on standard pipette method. Furthermore, texture of substrate was gained by using textural triangle according to percentage of sand, silt, and clay fraction [19].
Figure 1. Map showed the research location

3. Result and Discussion

3.1. Soil Texture (percentage of sand, dust, clay)
Soil texture shows the percentage of sand weight (particles between 0.05-2.00 mm), silt (0.002-0.05mm) and clay (<0.002 mm) [20; 21]. Soil texture can be determined by combining the percentages of sand, dust, and clay. The soil fractions were different not only in research location but also in soil depth. The results showed sand fraction was higher in mangrove rehabilitation compared with mangrove nonrehabilitation particularly in station 1 (Figure 2), it was assumed because mangrove rehabilitation is an area that significantly affected by tsunami last 2004 which brought lots of sand beaches that are close with the rehabilitation area. Similarity, Kusmana and Zulkifli [23] found in the planned area of rehabilitation has a loamy sand texture class because the area is dominated by sand (83.8%). Some previous study found that percentage of sand is higher than silt and clay [22; 24; 25]. In detail, table 1 explained the soil texture in study area.

Figure 2. Soil Fraction (%) of Soil in mangrove ecosystem

Silt fraction ranged from 10% to 65% in site 1, and ranged from 15% to 51% in site 2. Silt fraction was highest in station 3 for the 30-45 cm in depth (station 3.3). Clay fraction ranged from 5% to 55 % and it was highest in station 3 for 15-25 cm in depth (station 3.2). High silt and clay in the soil assumed
may be because the activity of sediment transported through the river in the station [26]. The previous research reported by Azis [27] also showed that the soil texture dominated by clay and sand.

Furthermore, the percentage of sand in the soil surface higher than the sub layer and bottom. The highest sand fraction was in station 1 and 6 with 0-15cm in depth. The high percentage of sand fraction can be caused by high waves from the sea due to its location near the coast [28]. The comparison between all station showed that station 1 and 5 which is always inundated at both high tide and low tide have the high percentage of sand. Station 6 high percentage of sand because the area close to the sea. The average sand percentage of station 1, 2, 3, 4, 5, and 6 were 68%, 50%, 31%, 48%, 53%, 61%. This condition presume because high sand content in both areas caused by mangrove ecosystem next to the sea that brought lots of sand from beach. Andrade et al [24] explained that sand > silt > clay content as being a result of the tidal action in estuarine, which lead to silt and clay transportation, helped by the smaller particle size, thus increasing the percentage of sand in the soil. Commonly mangrove soil are known as mud, which is combination of silt and clay [29].

| Soil Teksture in mangrove rehabilitation | Station |
|----------------------------------------|---------|
| Loamy sand  | Sandy loam | Sandy loam | Sandy loam | Sandy loam | Dusty loam | Dusty loam | Clay loam | Dusty loam |
| 1.1         | 1.2       | 1.3        | 2.1       | 2.2       | 2.3        | 3.1        | 3.2        | 3.3        |

| Soil Teksture in mangrove non rehabilitation |
|-----------------------------------------------|
| Sandy loam | Sandy loam | Sandy loam | Sandy loam | Sandy clay loam | Loamy sand | Sandy clay loam | Dusty loam |
| 4.1        | 4.2       | 4.3        | 5.1       | 5.2        | 5.3        | 6.1        | 6.2        | 6.3        |

Soil texture is the most important physical property of soil which can influence the status of potential water flow, water holding capacity, and fertility potential [30;31]. Furthermore, soil texture can affect the biological stability of organic matter, through its influence on water and oxygen availability, accumulation and isolation from decomposers. Soil textures in study areas were loamy sand, sandy loam, dusty loam, sandy clay loam, and clay however dominated by sandy loam (Tabel 1). Loamy sand and sandy loam were mangrove soil texture in Bulaksetra Pangandaran, East Java [23]. In line with Andrade et al [24] mostly dominated by Sandy loam (moderately coarse) in soil mangrove, Northeastern Brazil as same as observed by Nayar et al. [32] in Pichavaram, west coast of India; Krishna Prasad and Ramanathan [33] in Ponggol, Singapore. Soil with the texture of loamy sand has high sand percentage and it have a larger soil surface area then create the soil pores of sand are greater and have the ability to retain nutrients [34] such as organic carbon. The soil textures of mangrove such as dusty loam and clay explained high silt and clay percentage, clay is considered as soil has high and optimal organic material for tree growth, because of capacity this soil retains more water and nutrients better than sandy soil [28].

3.2. Organic Carbon, N-total and P-available of mangrove soil
Existing organic carbon (OC) has long been known as one of the traits of fertility and productive land. Soil organic carbon (SOC) indicates that the carbon in soils is products of living and activities organisms. The organic carbon was ranged from 0.25% to 2.18%, with the average of 0.9% and 1.23% in mangrove rehabilitation and non rehabilitation, respectively (Figure 3). The value indicated that OC in study area was moderate, very low and low categorizes based on [35] which is very low if the carbon content is <1.00%; low (1-2.00%); moderate (2.01-3.00%); and high (> 5.00%). In line with Chaikaew et al [36] the average of SOC was 0.57 ± 0.09%. Low soil organic carbon related to high sand percentage in study area and low percentage of clay fraction. Clay content has positive correlation with organic matter as a result high OC due to the highest clay content [24]. Moreover, sandy soils have a limited capacity to stabilize organic compounds compared with clay [37]. SOC was low and very low in study area not only because of soil fraction but also litter production. The denser of mangrove vegetation, the
more produced sources of organic material in the form of litter or plant residues that enter into the substrate [35].

![Organic Carbon, P and N of Soil in rehabilitation and non rehabilitation](image)

**Figure 3.** Organic Carbon, P and N of Soil in rehabilitation and non rehabilitation

The comparison of SOC value indicated that site 2 has higher SOC than site 1 because of age and mangrove density. It was speculated that site 2 would have the capacity to produce a large amount of organic matter from litter. In comparison of SOC was slightly different with depth. Commonly, SOC was higher in the soil surface than sub layer and bottom. In the present study recorded that SOC higher not only in the soil surface but also in the bottom. SOC tend to be concentrated on topsoil, as most of the supply or soil organic carbon input is from litter which is at the top of the land, meanwhile at a depth of 30-100 cm, the amount of supply from litter is less than result soil organic carbon is low [38].

Soil nitrogen (N) is an essential element for plants. Organic material is the source of nitrogen in the ground. The nitrogen role is to improve vegetative growth of plants [39]. The nutrient content ranged from 0.02 to 0.11 and categorized into low nitrogen content in both site. The decreasing in nitrogen content is proportional to abundance of mangrove roots [40], low Nitrogen total in the soil because it is reused by mangroves for its growth [38]. Fajar [41] also reported low nitrogen content in the mangrove soil 0.33-0.35%. P value has varied value and it was categorized as medium, high and very high in site 1 and very low, low, moderate, high and very high in site 2. Sofawi [42] reported P concentration was high due to oil palm plantation activities. Bismark et al [43] stated that the biomass in mangrove soils will increase if it contains high N and P elements. Low the P content indicate low organic matter in study area. The content of available P comes from organic matter and minerals in the soil and it essential to produce flowers, fruits, seeds and strong roots and stems [44].

3.3. **pH and salinity of mangrove soil**

The average of soil pH in site 1 showed a neutral category, although at both station 1 and 2 (bottom layer) has the pH value of 7.9 (slightly alkaline), 5.9 (slightly acidic). The soil pH in non rehabilitation also showed neutral category although almost in all station with different in depth explained pH with slightly alkaline, but acidic in station 6.3. pH with a value range of 6 to 7 is a suitable pH for mangrove
growth [42]. Human disturbance in the form of excavation, which led to soil oxidation might have caused the generation of extremely acidic soil [25]. Furthermore, pH was always low in the sub-surface soil layer (20-40 cm) [45]. The most optimal pH level is neutral with a value of 6.6 to 7.5, pH neutral is easy for plants to absorb nutrient element, and pH content slightly acidic due to its existence mangrove vegetation renovation by soil microorganisms that produce organic acids thereby lowering soil pH [44].

Figure 4. pH and Salinity (μscm⁻¹) of soil in rehabilitation (site 1), and non rehabilitation (site 2)

The electrical conductivity method (DHL) is a method that provides more accurate information about soil salinity [46]. The salinity values at each station with different depths indicate high and very high salinity, with a range of 3 to 16.4 μscm⁻¹. Soil salinity describes the salt content contained in the soil, this salt content can affect soil physical and soil parameters such as soil texture and pH [46]. Very high salinity content can affect water movement and mineral distribution, thereby reducing water uptake by plants and other living things. Commonly, mangrove sediments contain extremely low nutrient availability and high salinity [47]. Soil salinity increased with decreasing distance from the tidal coast [48].

4. Conclusion
Soil texture in rehabilitation and non-rehabilitation were dominated by sandy loam. Nevertheless, soil texture was different in depth, particularly in station 3 and 6 which were exposed to air both at high and low tide. The percentage of sand fraction was higher than silt and clay in the soil surface. In terms of soil nutrient properties, organic carbon in medium, low and very low categories in both sites, N value was categorized into low nitrogen content. P value has varied value and it was categorized as medium, high and very high in rehabilitation and very low, low, moderate, high and very high in mangrove non rehabilitation. The average pH value of mangrove soil indicated the pH category was neutral, slightly alkaline, slightly acidic, and acidic. The salinity values based on different sites and depths indicated high and very high salinity. Overall, this study indicates that the different mangrove habitats show the different results in physiochemical soil properties and the finding proved that the soil characteristics could be support for living of mangrove itself, micro and macro organisms.

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