The correlation between mangrove density and suspended sediment transport in Lamreh Estuary, Mesjid Raya Subdistrict, Aceh Besar, Indonesia

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Abstract. Abrasion and sedimentation of mangrove land transfer in Lamreh estuary is believed to reduce the marine productivity. The objectives of the study were to determine the relationship between mangrove density and suspended sediment transport occurred in the coastal area of Lamreh Estuary. Sampling was conducted on March until May 2014, three substations were established in this site. The 1st Substation was toward the sea, the 2nd substation was in the middle land and the 3rd substation was toward the land. Square transects method used for mangrove sampling and sediment trap used to ensnare sediment. Three species found in this area were Rhizophora apiculata, Bruguiera gymnorrhiza, and Avicennia marina. Furthermore, Rhizophora apiculata dominated in this area. The highest density was Bruguiera gymnorrhiza with average 11 ind/100m² and the lowest density was Heritiera littoralis with average 1 ind/100m² in the 2nd substation. The highest sediment transport was in 1st substation and the lowest was in the 3rd substation. Sediment transport in the 1st substation for one month was 5.54 to 6.63 g/cm²/day with mangrove density was 12 ind/100m² and sediment transport in the 3rd substation was 4.87 to 5.52g/cm²/day with mangrove density was 32 ind/100m². The correlation between mangrove density and suspended sediment transport in this area was a negative correlation with the correlation between the two coefficients was ranged from -0.999-0.863 till. The Negative correlation was indicated resources would the high density decrease mangrove sediment transport and the opposite.

1. Introduction
Mangroves play an important role as ecological and economic functions in conserving biological diversity and providing timber and non-timber forest products. Mangroves are critical to sustainable production by coastal fisheries and are important indicators of coastal changes [1].

Aceh Besar has varied biodiversity coastal area. Aceh Besar has 1,155 Ha area of coral reef and 133,94 Ha area of mangrove ecosystems [2]. One area of Aceh Besar that have mangrove ecosystem is in Lamreh estuary at Mesjid Raya subdistrict of Aceh Besar regency precisely in coastal areas Amat Rhangmanyang.
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Aceh Besar has varied biodiversity coastal area, where it has 1,155 Ha area of coral reef and 133.94 Ha area of mangrove ecosystems [2]. One area of Aceh Besar that have mangrove ecosystem is in Lamreh estuary at Mesjid Raya subdistrict of Aceh Besar regency precisely in coastal areas of Amat Rhangmanyang. Coastal conditions in this region were alarmed because of abrasion which occurs at the estuary was spread. Abrasion was also got worse because of mangroves land conversion into fishponds. The measurement of fishponds land area in research sites is ± 14.215 Ha. The roots of mangrove trees will retain sediment or mud that swept away so there will be sedimentation around the mangrove trees. Root forms of Rhizophora sp. are the anchor and solid also let the formation of sediment. This root makes the process of catching up mud in the Rhizophora sp. run perfectly. When reverse flow, particles of mud hampered by the roots [3]. Sediment transport occurs caused by waves, ocean currents or a combination of both. A beach will experience erosion or sedimentation depend on the balance of sediment entering at high tide and out of the beach at low tide [4]. The low density of mangrove will lead a high sediment transport that can affect to the brightness of water. The low brightness and high turbidity caused by a number of floating sediments transported by currents and tides.

It is feared the affect of silting of the estuary and marine productivity in this region. The last study on coastal areas in the region Karangsong Indramayu regency in 2012 showed that where higher mangrove density would result in lower sediment transport and opposite, a density of mangroves in the area ranges from 500-600 stands/Ha, while transport of sediment ranged from 0.07 to 0.26 g/cm²/day [4].

Therefore, the aims of the present study were to determine the density of mangroves and sediment transport as well as to examine the correlation between the density of mangrove and suspended sediment transport that occurs in the Lamreh Village, sub-district Mesjid Raya, district Aceh Besar. This research is expected to provide information along with data vegetation and conditions of mangroves contained in Lamreh Village and how sediment transport that occurs in the area when associated with mangrove density.

2. Materis and Methods
2.1 Time and site
This research was conducted in the area of mangrove forest Lamreh Village, sub-district of Mesjid Raya, Aceh Besar District (5°36’34,900”N and 95°32’14,500”E). Analysis of concentration suspended sediment was carried out in the Soil Laboratory, Faculty of Agriculture, Syiah Kuala University. This study was conducted from March to May 2014. Map of study is presented in Figure 1.

2.2 Sampling procedure
The purpose sampling method was used to determinate the station based on the desired goal. This study uses three substation observations. In each substation, research performed 3 repetitions for each retrieval of data. The 1st substation was toward the sea, the 2nd substation was in the middle land and the 3rd substation was toward the land. The substation was determined by assuming there are differences in the density of the mangrove on each substation. The distance between the substation was 10 m or more adapted to the density of mangrove in the research substation, while the distance for each repetition which was 5 m. Determination of the substation observations perpendicular watershed (estuary) from the sea towards the land.
2.3 Research procedure

2.3.1 Measurement of mangrove density

The sampling of mangrove density was collected using the square transects 10 x 10 (m) as a randomly determined plot in each sampling site. In this study, mangrove identified only for trees category due to high density at the study site.

According to Onrizal [5] transect size used in the analysis of mangrove vegetation is 10x10 m² with a diameter of trees >10 cm with a height >1.5 m, the size transects of 5x5 m² for sampling with a diameter <10 cm and height >1.5 m, the size transects of 2x2 m² to seedlings with a height <1.5 m.

2.3.2 Measurement of suspended sediment transport

Measurements of sediment transport using a sediment trap made by PVC pipe with a diameter of 3 inches and a height of 11.5 cm and at the top of the PVC pipe installed baffles (barriers) and at the bottom by a cover. The Measurement of sediment transport performed on each test mangrove vegetation repetition. Sediment transport was measured by using a sediment trap which has been tied to a timber using a rope and then plugged in at a height of 20 cm from the bottom waters or adjusted to the lowest ebb in those waters [4]. Data collection was performed 1 time per week during the first month of the study so that is four times the sampling of sediment.

Sediment was trapped by sediment trap then inserted into the sample bottle and analyzed in the Soil Laboratory, Faculty of Agriculture, Syiah Kuala University. Sediments carried out from the field was added to the above screening tool has been equipped with Whatman filter paper a pore size of 0.45 μm, this is to separate the sediment and water contained in the sample. The filter paper is taken and put in the oven for 17 hours with the temperature ± 150°C to remove the water content in the sediment. Sediment and filter paper that had been put in a desiccator oven and left a few minutes then weighed how much weight with the digital scales.
2.4 Data analysis

2.4.1 Mangrove vegetation

Mangrove density usually refers to the measure of how much a mangrove plants which are in a fixed amount in a space (usually in three-dimensional space). The density (Di) is the stands type-i all types in a unit area.

\[ D_i = \frac{n_i}{A} \]  

where \( D_i \) = density (ind/m²), \( n_i \) = the total number individuals of all type-i and \( A \) = the total area of sampling.

The relative density (RD\(_i\)) is the ratio between the number of stand types-i (\( n_i \)) and total stands of all types (\( \sum n \)):

\[ RD_i = \frac{n_i}{\sum n} \times 100 \]  

\( RD_i \) = Relative density (ind/m²), \( n_i \) = number of individuals of all types-i and \( \sum n \) = The total number of all individuals.

2.4.2 Suspended Sediment Transport

Samples sediment would analyze in the laboratory and calculated by the following formula [6]:

\[ V = \frac{W}{L \times t} \]  

and

\[ W = a - b \]  

\( V \) = Transport sediment (g/cm\(^2\)/day), \( W \) = dry weight of sediment (g), \( L \) = cross-sectional area of sediment trap (cm\(^2\)), \( t \) = how long install sediment trap (day), \( a \) = final weight of the filter paper and sediment weight after heating (g) and \( b \) = weight of filter paper after heating (g).

2.4.3 Product moment correlation analysis

This correlation technique is used to find the relationship and prove the hypothesis relationship between two variables when the both of data interval or ratio variable shaped and data resources of two or more variables are the same.

\[ r = \frac{\Sigma xy}{\sqrt{(\Sigma x^2)(\Sigma y^2)}} \]  

\( r \) = correlation between the variables \( x \) to \( y \), \( x = (x_i - \bar{x}) \) and \( y = (y_i - \bar{y}) \).

3. The Result and Discussions

3.1 The composition and the density of Mangrove

The composition of mangrove found in sub observation station consists of four families and five species, Avicenniaceae namely Avicennia marina (19%), Euphorbiaceae namely Excoecaria agallocha (17%), Rhizophoraceae namely Rhizophora apiculata (38%) and Bruguiera gymnorrhiza (26%), Sterculiaceae namely Heritiera littoralis (1%). Mangroves are generally known for being a depositional sites for sediment and associated carbon and nutrients. Thereby, mangroves aid in the protection of adjacent seagrass and coral reef ecosystems from the negative impacts of nutrient enrichment and sedimentation. The role of mangroves in enhancing sedimentation, which often results in expansion of mangrove habitats, is well known. Above-ground root systems and stems enhance sediment deposition that further promotes mangrove growth and expansion [8]. Conversion of mangroves for aquaculture, agriculture, urban development, and subsistence use is causing a rapid decline in their extent. Tidal wetlands such as mangroves are also threatened by long-term forcings such as sea level rise (SLR), in conjunction with decreased sediment supply and reduced landward accommodation space [9].
Table 1. Average density and relative density of mangroves

| Substation | Name of Species           | Di (ind/100m²) | RDi (%) |
|------------|---------------------------|----------------|---------|
| 1          | Avicennia marina          | 1              | 8.33    |
|            | Bruguiera gymnorrhiza     | 1              | 8.33    |
|            | Excoecaria agallocha      | 2              | 16.67   |
|            | Rhizophora apiculate      | 8              | 66.67   |
| Total      |                           | 12             | 100     |
| 2          | Avicennia marina          | 2              | 8.33    |
|            | Bruguiera gymnorrhiza     | 11             | 45.83   |
|            | Excoecaria agallocha      | 2              | 8.33    |
|            | Heritiera littoralis      | 1              | 4.17    |
|            | Rhizophora apiculate      | 8              | 33.33   |
| Total      |                           | 24             | 100     |
| 3          | Avicennia marina          | 10             | 31.25   |
|            | Bruguiera gymnorrhiza     | 5              | 15.63   |
|            | Excoecaria agallocha      | 8              | 25      |
|            | Rhizophora apiculate      | 9              | 28.13   |
| Total      |                           | 32             | 100     |

Note: Di = density of the mangrove, RDi = Relative density mangrove

The most dominant mangrove composition contained in the type R. apiculata by 38% and the composition of the non-dominant mangrove is H. littoralis 1%. R. apiculata are found because this type is better to use resources or ability to adjust to the location of a place of life and the species can live in varied habitats. In addition, this type of R. apiculata in location was mangrove rehabilitation that was grown by local people after a tsunami. The composition H. littoralis was low among the sites allegedly because the substrate is not supported for this species thrive. This is supported by Noor et al., [7] saying that these species occupy the edges or adjacent to the lowland forests or rocky coasts.

Substation 1st had the mean lowest density of mangrove, the mean highest density is in substation 3rd. It is suspected because of mangrove in substation 3rd protected from the pounding waves so mangroves grow better. Substation 1st is dominated by species R. apiculata, the substation 2nd by B. gymnorrhiza and substation 3rd by A. marina. The differences level of dominance is suspected because a difference in the substrate of each sub-station for each species thrive and also natural factors and human factors. R. apiculata in substation 1st has the highest density with a value of mean density 8 ind/100m² and a relative density value is 66.67%. The value average for the lowest density of trees category in this substation is B. gymnorrhiza and A. marina. It is suspected the species is cleared for the transferred land into fishponds.

In the substation 2nd, the value average of the highest density is B. gymnorrhiza with the density of 11 ind/100m² and relative density of 45.83%. This is presumably because the substrate location is very supportive of this species to thrive. At the location of these species live in flooding at high tide. B. gymnorrhiza able to live in different conditions of salinity that it is almost fresh until salty with a variety of tidal inundation and particularly liked the substrate muddy, sandy or peaty mud sometimes. Indawan et al., [10] mentioned that B. gymnorrhiza more suited to the region inside with new substrates are formed either on clayey soil, muddy and topsoil. In substation 2 found species that are not found in other substation are H. littoralis with a density of 1 ind/100m² and a relative density of 4.17%. The low density of this species is suspected because of the environment that does not support this species to thrive. H. littoralis found in substations have grown side by side with B. gymnorrhiza.

The highest density in the substation 3rd contained in A. marina is 10 ind/100m² and a value of relative density 31.25%. A. marina found on the banks of the tidal and also has a high tolerance to salinity levels.
According to Noor et al., [7] A. marina has roots breath fires dense, close and very effective to catch mud. The lowest density value to the substation 3 contained in the species B. gymnorhiza density levels 5 ind/100m² and a relative density of 15.63%. Low-density value for the species is presumably because the substrate is not suitable for mangrove to growing and there are several of these species harvested for the land transfer.

3.2 Suspended sediment transport
The transport processes are controlled by the tides, freshwater discharge, waves, winds and topography of the estuary. The transport of suspended sediments in a well-mixed estuary is different from that in a partially stratified or a stratified estuary [14]. Transport suspended sediment (Figure 2) in the region during the study period showed an increase at each measurement time. The highest sediment transport in the substation 1 and the lowest in the substation 3. In substation 1 average sediment transport is from 5.54 to 663 g/cm²/day, substation 2 from 5.46 to 5.93 g/cm²/day and a substation 3 from 4.87 to 5.52 g/cm²/day.

![Figure 2. Suspended sediment transport for one month in the research location](image)

The high sediment transport that occurs on the substation 1 allegedly due to the low density of the mangrove in this substation. The ability of mangrove roots to trap sediments are extremely low in addition the strong current in estuary also erodes banks of the estuary, causing sediment carried on zone mangrove. The current in substation 1 ranged from 0.21 to 0.19 m/s and tide ranging between 10-59 cm. The tide occurs in this area is the type of daily tidal double or semi-diurnal tide. Low tide occurs in substation 2 on March 29, 2014 (Week 1) is 60 cm (retroactively to the tide) at 16.00 pm with a current speed of 0.05 m/s.

Arief [11] says that in the current state of the tide greatly affect the formation of the substrate. This current is causing narrower mud because of the current in a state of the high tide and low tide that can inhibit the deposition of silt. At high tide, the waves brought mud to the rear mangrove zone, and when there is low tide, mud-sludge is taken drawn back, while the first sand settles. This is because the larger particles settle faster than smaller particles and strong currents maintain particles in suspension longer than the current weak.

Low sediment transport in the substation 3 due to the high density of mangroves in the region. The average current in substation 3 was from 0.15 to 0.19 m/s. A. marina domination the substation has an important role in ensnaring sediment. It is supported by Murtiono et al, [12] which says that the
Mangrove types Api-api (Avicennia sp.) were able to entrap sediment greatest, then followed by mangrove types Bogem (Sonera sp.) and further mangrove types of Bakau (Rhizophora sp.).

Mangrove addition to functioning as a protective shoreline and prevent seawater intrusion also act as a trap sediment with its roots. This is supported by Triatmodjo [3] say that the roots of the mangrove trees will retain sediment or mud that swept away so that there will be sedimentation around the mangrove trees. Root form of Rhizopora sp. is the anchor and close also led to the formation of sediment. Rooting makes the process of catching dust particles in the stands of Rhizophora sp. running perfectly when there is a reverse flow, the dust particles hampered by the roots-the roots.

Coastal areas in Lamreh village are in the waters north of Aceh directly facing the Indian Ocean has three distinct seasons. The season is east, west season and season transition. During the first month of the study in March-April, Lamreh village coastal areas experienced a transitional season of east-west. Environmental conditions in the transitional season or transition season are relatively stable, but at certain times could rain. Rains that occurred in this region will increase suspended sediment transport that occurs. This is visible from suspended sediment transport is increasing every week.

3.3 Relationship between mangrove density and transport sediment

The correlation between the two coefficients (density mangrove and suspended sediment transport) was negative indicating that the higher density, the lower mangrove sediment transport that occurs in this region and opposite when mangrove has low density will make sediment transport in this region high. The correlation value in coastal areas of Lamreh village ranged from -0.863 to -0.999 indicate the density of mangroves and suspended sediment transport have very strong relationships. Relationships with the density of mangrove and suspended sediment transport are presented in Table 2.

| Aspect                  | Sediment        |
|------------------------|-----------------|
|                        | Week 1 | Week 2 | Week 3 | Week 4 |
| R                      | -0.863 | -0.997 | -0.993 | -0.999 |
| R²                     | 0.74477 | 0.99401 | 0.98605 | 0.998 |
| Product moment         |        |        |        |        |
| correlation            | 74%    | 99%    | 99%    | 100%   |

The highest correlation value in this region was in weeks 4 and the lowest value contained was in week 1. The correlation values at week 4 were 100%, this suggests that at weeks 4 mangrove on the region's ability to trap sediment worth 100%, while correlation values at week 1 were 74%. The difference in a correlation value of mangrove to ensnare sediments every week suspect for several other environmental factors, such as tides, currents and also the season that occurs in the region.

It's like Widjojo [13] and Irham [15] say that shore sediment transport raised by waves, ocean currents or a combination a both, while sediment transport at the estuary caused by tidal currents, waves, and currents freshwater rivers. The rate of sediment transport in coastal areas affected by the characteristics of the sediment, slope of the beach, the size of waves and currents.

4. Conclusion

Mangroves found in the study site is Rhizophora apiculata, Brugueira gymnorrhiza, Avicennia marina, Excoecaria agallocha, Heritiera littoralis. The most dominated was Rhizophora apiculata. The high sediment transport in the substation 1st with the low mangrove density and the low sediment transport was in substation 3rd with the high mangrove density. The correlation between mangrove density and suspended sediment transport has a negative correlation, this means that the higher density of mangrove will decrease sediment transport.
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