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Monitoring of Sedimentation on Geosynthetic Bags Installation Area in Banyuurip Mangrove Center, Ujung Pangkah, Gresik, Indonesia

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Abstract

Banyuurip is one of the villages in Ujung Pangkah District which has potential natural resource that is mangrove forests. However, the occurrence of abrasion and conversion of mangrove land has impacted mangrove ecosystem. Rehabilitation efforts by replanting mangroves have been carried out, but they have not been effective in overcoming the current problems. The reduction of mangrove area that led the decreased of mangrove's function can affect the livelihood of the local community, including fishermen. The installation of geosynthetic bags, which are sand-filled bags arranged on the ground, is done as an alternative solution in Banyuurip Village which functions as coastal protection and a sediment trap. The utilization of geosynthetic material is often used to help the coastal problem, the used of geosynthetic material is rarely carried out in mangrove areas. This study aims to determine the sediment characteristics, sedimentation rates, and sedimentation process based on the relationship between current velocity and sedimentation rate. The result shows that generally the type of sediment fraction in this location is silt (79,12% - 80,12%) and the rest is clay. The current installation of geosynthetic bags can result in the land extension from the trapped sediment behind the structure. In addition, the current velocity conditions and the sediment transport process also affect the sedimentation process that occurs. The average sedimentation rates around the geosynthetic bags installation area ranged from 150.72-305.01 $mg.cm^{-2}.day^{-1}$. This study may provide a basic information for further development in Banyuurip Mangrove Center and other mangrove conservation area.

Keywords: *abrasion, geosynthetic bags, sediment accumulation, Mangrove's Area Development*

Introduction

Banyuurip is one of the coastal areas in East Java which has mangrove forests, which become tourist destinations known as Banyuurip Mangrove Center (BMC). BMC was initiated by Tirta Buana's Fishermen, especially Banyuurip Village Mangrove and Environmental Conservation Group, aiming to protect the coastal area of that are prone to abrasion.

In 2004, this area was exposed to abrasion and damage caused by mangrove deforestation for land conversion (Yona *et al*., 2018). Moreover, the location BMC mangrove area was directly exposed to the high waves of the Java Sea, especially during west monsoon that could worsen the abrasion (Sartimbul *et al*., 2019). This proved the importance of the mangrove ecosystem as an essential natural barrier to protect the coastline. The reduction of mangrove area that led to the decreased of mangrove's function resulted in alteration of the ecosystem that can affect the livelihood of the local community, including fishermen (Sartimbul *et al*., 2019). Mangrove rehabilitation has been carried out, however, the result was not significant because of the abrasion thus mangrove propagules can be easily carried away by the river stream (Yona *et al*., 2018).

Therefore, one of the solutions to promote mangrove rehabilitation is to install geosynthetic bags to help reduce high waves exposure and trap sediment in the area behind the Banyuurip Village meeting hall through the Community Partnership Program by Marine Research Exploration and Management (MEXMA) research group in 2019. Geosynthetic bags (geobag) are made of synthetic material form as bags filled with sand that was placed on the ground with a certain structure and purpose (Müller and Saathoff, 2015; Thompson *et al*., 2020).

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This geobag is claimed to be environmentally friendly, because it blends with the natural substrate and allows biota to grow (Sartimbul *et al*., 2019). Biota such as megabenthos epifauna (*Metopograpsus sp., Ostrea edulis, and Fistulobalanus albicostatus*) can grow in this geobag at the 4th month after installation (Sartimbul *et al*., 2021). Geosynthetic bags are known to promote mangrove rehabilitation activities by encouraging the accumulation of sediment through the principle of sedimentation (Lee *et al*., 2014; Ashis, 2015; Lee *et al*., 2018).

The installation of geosynthetic bags in the coastal area of Banyuurip was placed for 15 m long and made of polypropylene, which can tolerate the strong exposure of sunlight. Geobag structures were made from woven membrane materials can trap sediment that led to sedimentation thus provide areas needed for mangrove's growth (Sartimbul *et al.,* 2019). Due to the sustainability of the Community Partnership Program and as one of the forms of activities in this program's monitoring stage, this study aims to know the process and rate of sedimentation resulted from the installation of geosynthetic bags.

Materials and Methods

This study was done around the geosynthetic bags installation area in the Banyuurip Mangrove Center area, Ujung Pangkah, Gresik. See Figure 1. Data collection was conducted in February - March 2020. The Illustrated of the location for sediment sampling and current data can be seen in Figure 2.

Data collection

A sediment sample was collected using a sediment trap made of PVC pipe with a diameter of 8.5 cm and a height of 30 cm. The sediment traps were placed at 8 points around the geosynthetic bags installation area and left for two weeks. After two weeks, sediment samples were taken and put into plastic sample for analysis in the laboratory. Meanwhile, monitoring of changes in sediment height collected using the wooden benchmark method. The wooden benchmarks were placed 50 cm deep to prevent from being carried away by the current and then it is determined with an initial 20 cm, which according to Mughni (Personal comm.) after three months of installing geosynthetic bags there is an increase in the sediment height of 20 cm. Monitoring of changes in sediment height was done by observing the measuring wooden installed.

Current data collection was done at 3 points near the geosynthetic bags installation area using a Flowatch FL-03 type current meter. The current measurement technique used was the Eulerian approach method with three repetitions. Current data collection was collected when the tide is at a water depth of approximately 1 meter because it's not too deep and assumed to represent the average depth of the waters. Flow data collection and sediment samples were collected three times every two weeks.

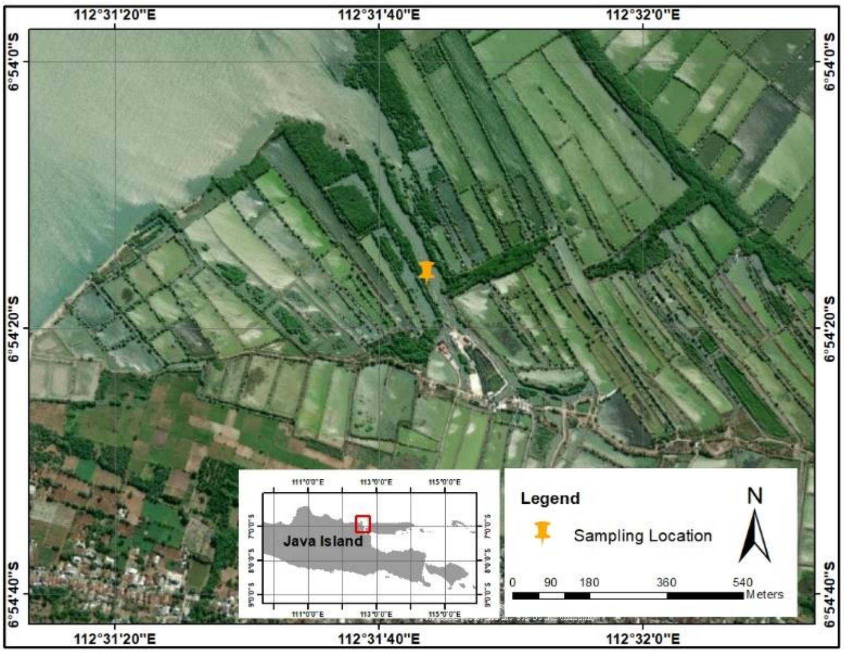

Figure 1. Study Site Location in The Banyuurip Mangrove Center (BMC), Ujung Pangkah, Gresik. The Yellow point shows the sampling location in the geosynthetic bags installation area.

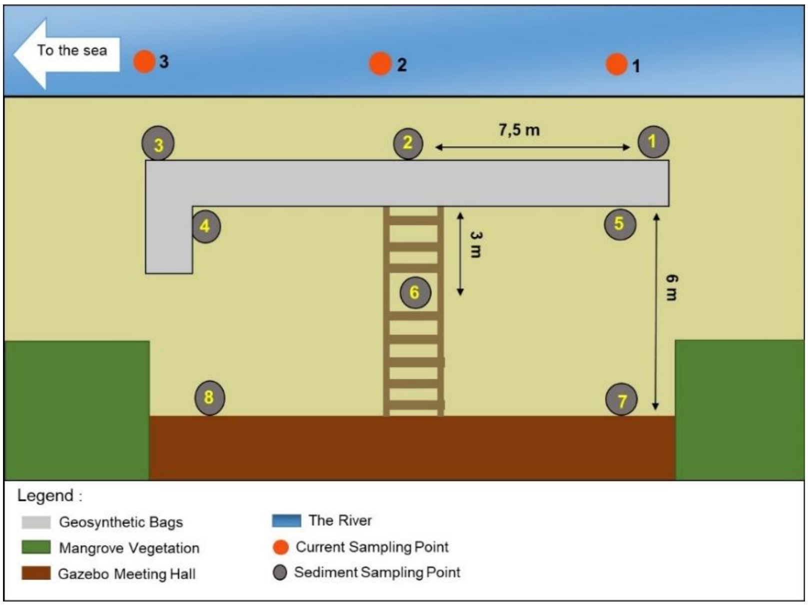

Figure 2. Illustrated of the location for sediment and current sampling. The gray point shows the sediment sampling location which consist of 8 points and the orange point shows the current sampling location which consist of 3 points.

Tidal data collection was collected using secondary data from BIG website. The data used are data in February and March 2020 in Banyuurip waters that processed using the Admiralty method to get Formzahl values to determine the type of tides at the study site.

Sediment sample processing and sedimentation rate

The sediment samples from the field were prepared by drying the sample at 100°C for 45 h and grinding in the laboratory. The sediment sample was tested by soil-specific gravity test and hydrometer test. In the soil-specific gravity test; first, calibrate the pycnometer to get a calibration graph for the determination procedures. Next, divide each dry sample as much as 20 g, then put the sample into a pycnometer and add water to the flask until it is about three-fourths full. Heat the contents in a pycnometer until gently boil, then fill the pycnometer with water and cover it, make sure the air has been removed. Clean and dry the outside of the pycnometer with tissue. Determine and record the mass in gram of pycnometer and contents (W1) and the temperature in degrees Celcius. Soil density test was carried out with 3 times repetition for each sample to obtain the density value of the soil at each sample point.

Hydrometer test was carried out after knowing the density of the soil. Each dry sample was weighed as much as 50 g and prepared a dispersing solution consisting of 1000 ml of water and 40 g of Na-Hexamethaphospat. Soak the sample in the dispersing solution for at least 12 h. The immersed sample was homogenized and transfer into a hydrometer tube and fill with water until 1000 ml. Homogenize the sample in the hydrometer tube then put the hydrometer float with the water level position on the hydrometer buoy scale read as the hydrometer reading. Take a reading at 0 mins; 0.5; 1; 2; 15; 30; 60; 120; and 1440, as well as the temperature measurement in these minutes. The results of the hydrometer readings were recorded in the calculation table to determine the sediment percentage and sediment grain size. The sample then was classified based on the grain size to get the type of sediment at the study site.

The sedimentation rate analysis was done by calculating the amount of sediment trapped. The sediment sample that has been prepared then weighed and calculate using the sedimentation rate formula according to Sihombing *et al.* (2017):

$$\text{LS} = \left(\frac{\text{BS}}{\text{number of days x } \pi r^2}\right)$$

Note: LS= Sediment rates (mg.cm^{-2}.day); BS= Dry Weight sediment (mg); π= 3,14; r= The radius of *sediment trap* (cm^2)

Data analysis

The flow and sediment data were then analyzed using a Hjulstrom diagram to determine sediment transport at the study site. The results of the sedimentation rate, flow velocity, and sediment transport then analyzed to determine the sedimentation process that occurred.

Result and Discussion

Characteristics of sediment types

The type of sediment at the study site is dominated by silt sediment. The largest value of silt sediment was at sample point 2 at 80.29% and the smallest at sample point 8 at 79.12%. The results of the analysis sediment characteristics at the study sites are presented in Table 1.

The type of tide

The results of the formzahl values in February and March were 11.82 and 8.03. Based on these results, the tidal type in Banyuurip coastal was the diurnal tide, because it has an F value> 3.00, which in one day there is one ebb and flood tide. The tidal charts in February and March 2020 were presented in Figure 3. and Figure 4.

Characteristic of current velocity

The results of the current measurement at the study sites showed that the highest current velocity was at point 3 which is equal to 0.16 $m.s^{-1}$ and the lowest at point 1 of 0.10 $m.s^{-1}$. There are 4 categories of current velocity, slow currents ranging from 0-0.25 $m.s^{-1}$, moderate current categories with a range of 0.25 - 0.50 $m.s^{-1}$, categories of fast currents ranging from 0, 50-1 $m.s^{-1}$ and very fast current category over 1 $m.s^{-1}$ (Chasanah *et al.*, 2017). The average current velocity at the study sites ranges from 0.11-0.15 $m.s^{-1}$, so the current velocity is classified as slow current. The results of the current velocity measurement can be seen in Table 2.

The type of sediment transport

The grain size of the sediments at the study site was found to be in the range of 0.004-0.005 mm, so in the Hjulstrom diagram the grain size of the sediment was classified as a type of unconsolidated mud. On tidal mudflat, the unconsolidated mud is known can provide shoreline protection by attenuating wave energy in the near shore (Shi *et al.*, 2017). The Hjulstrom diagram shows that every sediment can be transported and eroded with suitable current velocity. In this study site, Hjulstrom diagram shows that the type of the sediment can be eroded with the current velocity and transport process at the study site was a form of "erosion of unconsolidated mud" transport. See Figure 5.

Table 1. The type of Sediment at study site location

Sampling point	Percentage (%)			Type of Sediment
	Sand	Silt	Clay	
1	0,00	79,75	20,25	Silt
2	0,00	80,29	19,71	Silt
3	0,00	79,30	20,70	Silt
4	0,00	79,75	20,25	Silt
5	0,00	79,74	20,26	Silt
6	0,00	79,37	20,63	Silt
7	0,00	79,21	20,79	Silt
8	0,00	79,12	20,88	Silt

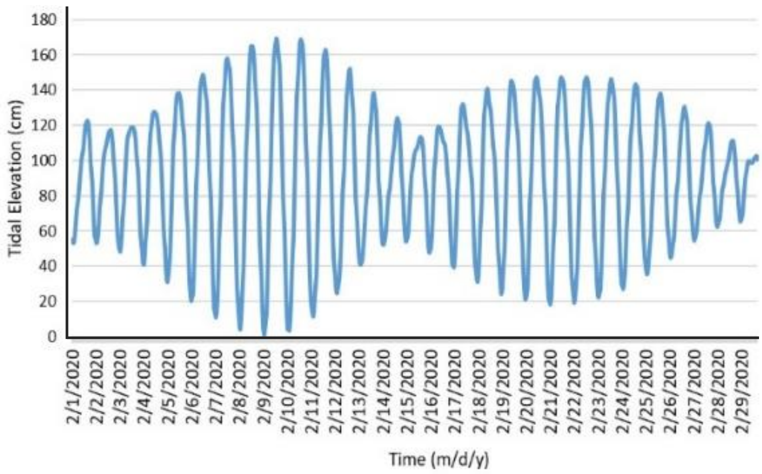

Figure 3. The Tidal Chart in February 2020 in Banyuurip Village.

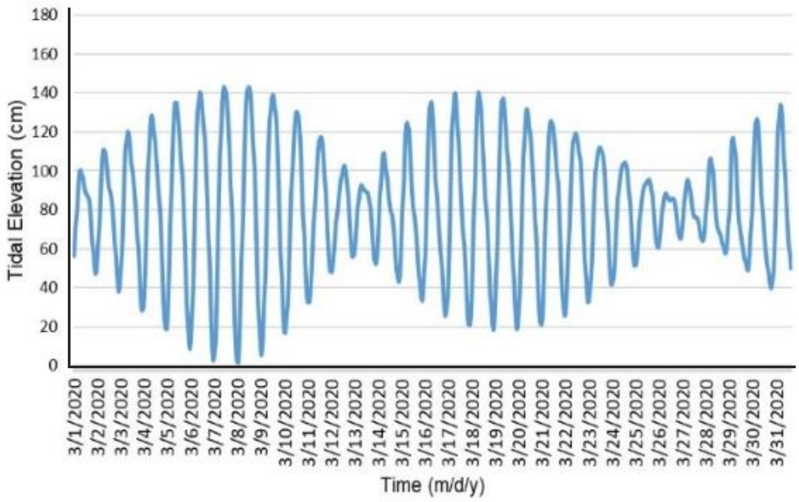

Figure 4. The Tidal Chart in March 2020 in Banyuurip Village

Table 2. The current velocity at study site location

Sampling point	Current velocity ($m.s^{-1}$)			
	11/2/2020	25/2/2020	10/3/2020	The Average
1	0,10	0,10	0,12	0,11 ± 0,01
2	0,12	0,13	0,14	0,13 ± 0,01
3	0,14	0,15	0,16	0,15 ± 0,01

Sedimentation rates

The sedimentation rate is the velocity of sediment deposition in the bottom surface layer of the unitary area of time (Botwe *et al.*, 2017). The results of the sedimentation rate measurement are presented in Table 3. The highest sedimentation rate was at point 5 of 475.37 $mg.cm^{-2}.day^{-1}$ and the lowest at point 8 with a value of 137.41 $mg.cm^{-2}.day^{-1}$. The average sedimentation rate between sampling points ranged from 150.72 $mg.cm^{-2}.day^{-1}$ to 305.01 $mg.cm^{-2}.day^{-1}$. The most significant average sedimentation rate is an area directly protected by the geosynthetic bag structure. This is following the opinion of Prayogi *et al.* (2016), the area that protected by a coastal protection structure that has a function to help reduce high waves and trap sediment will give a higher average sedimentation rate because the water conditions support the sediment deposition occurs higher. See Figure 6.

During the observation, the addition of sediment around the geosynthetic bags installation area occurred dynamically. As stated by Fitri *et al.* (2019), wherein areas with muddy substrate the sediment deposition pattern occurs more dynamically than the sand substrate, which also influence by current velocity (Nurkhasanah et al., 2019). Furthermore, the mangrove species *Rhizophora mucronata* can live and grow around additional land resulting from the installation of geosynthetic bags because it has larger and taller propagules so it will be able to withstand the current conditions and the addition of sediment.

Besides, several species of biota were found in the geosynthetic bags at the study site such as *Metopograpsus* sp., *Ostrea edulis*, and *Fistulobalanus albicostatus*. It is shown that the geosynthetic bags installed are environmentally friendly and capable for biota to live and grow (Sartimbul *et al*., 2021).

Sedimentation process around geosynthetic bags installation area

Sedimentation forms a complex system of several types of interrelated processes, that involve erosion, transport and deposition (Tipper, 2016). In estuary the transport and trapping fine sediment is controlled by various factors, such as, flow patterns, tidal dynamics, river discharge and particle dynamics (Li *et al*., 2016). Based on observations of currents around the geosynthetic bags installation area, the currents that occur at the time of the flood tide show a movement pattern originating from the direction of the sea towards the upstream of the river, where when the current hits the geosynthetic bag's structure in areas 3 and 4 there is a change in the direction of the current which then returns parallel with the structure of a geosynthetic bag. Meanwhile, the current that occurs at ebb condition shows a pattern of movement originating from the upstream of the river back towards the sea. At ebb condition, the current that hits the geosynthetic bags in areas 1 and 5 will experience a slight change in direction which is not too significant, but in area 4 there will be a change in the direction of the current which rotates slightly following the shape of the geosynthetic bags.

The current of flood tide at the study site will bring the transported sediment in the form of a suspension to the geosynthetic bags installation area, the presence of a geosynthetic bag structure that functions to dampen waves will make the area behind it calmer and support sediment deposition. In the area when the current velocity begins to decrease, the fine sediment will begin to settle (Hidayati et al., 2017; Setiawan et al., 2019). At ebb condition, the flow will make sediment particles return and be transported in the waters, but with the presence of geosynthetic bags, sediment will be trapped behind the area. The Geosynthetic structure will reduce the wave energy becomes lower and hold the sediment transport, because the position of the structure enables the sediment transporting but restraint the sediment from the returning back, so it will result in additional land through the accumulation

Table 3. Sedimentation rates around geobags installation area

Sampling point	Sedimentation rates (mg.cm^{-2}.day^{-1})			
	11/2/ 2020	25/2/2020	10/3/2020	The average
1	169,02	183,54	295,25	215,94 ± 56,40
2	179,77	167,43	290,96	212,72 ± 55,55
3	162,76	178,77	292,00	211,18 ± 57,52
4	201,01	244,93	454,86	300,27 ± 110,78
5	181,18	258,49	475,37	305,01 ± 124,53
6	160,37	213,68	319,22	231,09 ± 66,01
7	144,91	143,01	174,90	154,28 ± 14,60
8	147,73	137,41	167,02	150,72 ± 12,27

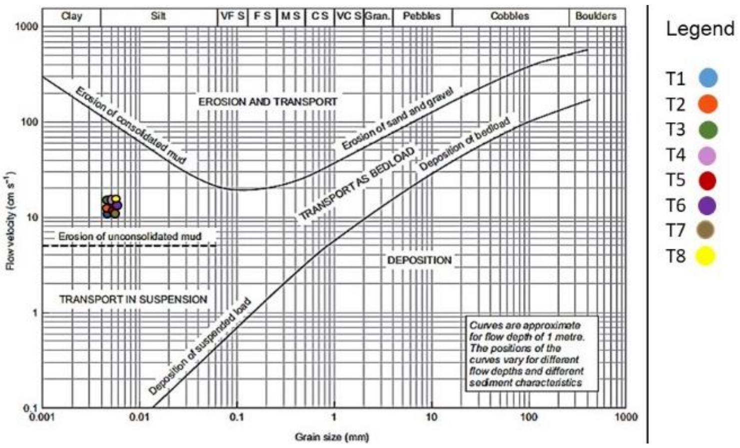

Figure 5. Hjulstrom Diagram in Banyuurip Village, Ujung Pangkah, Gresik.

Table 4. The result of changes in sediment height at geosynthetic bags installation area

Sampling point	11/2/2020	25/2/2020	10/3/2020
	Sedimen height (cm)	Sediment height (cm)	Sediment height (cm)
1	22	24	27
2	22,5	24,5	27
3	22	23,5	26
4	26	30	35
5	25	28	32,5
6	25	29	33
7	22,5	24	26
8	22	23	25

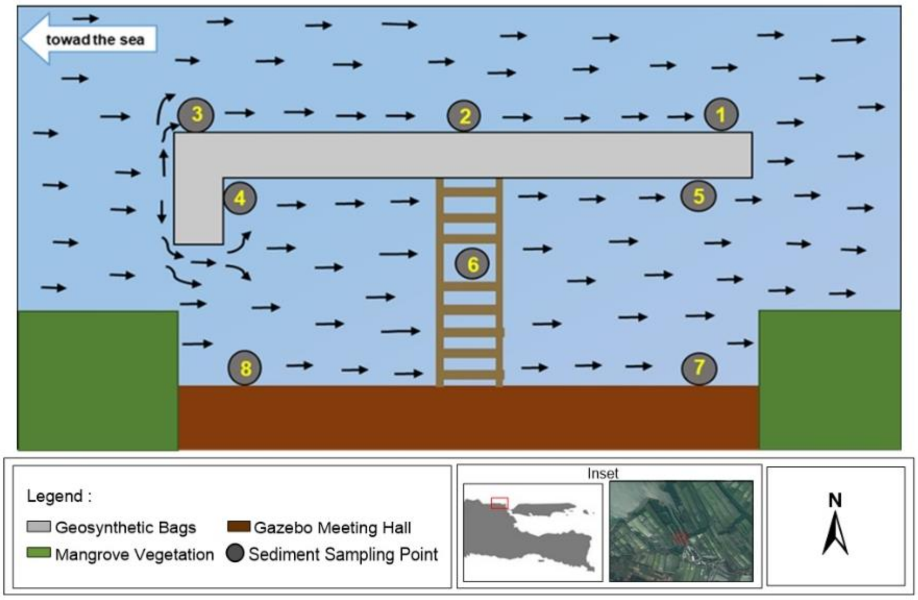

Figure 6. Illustration of the direction of tide around geosynthetic bags installation area. the currents that occur at the time of the tide show a movement pattern originating from the direction of the sea towards the upstream of the river.

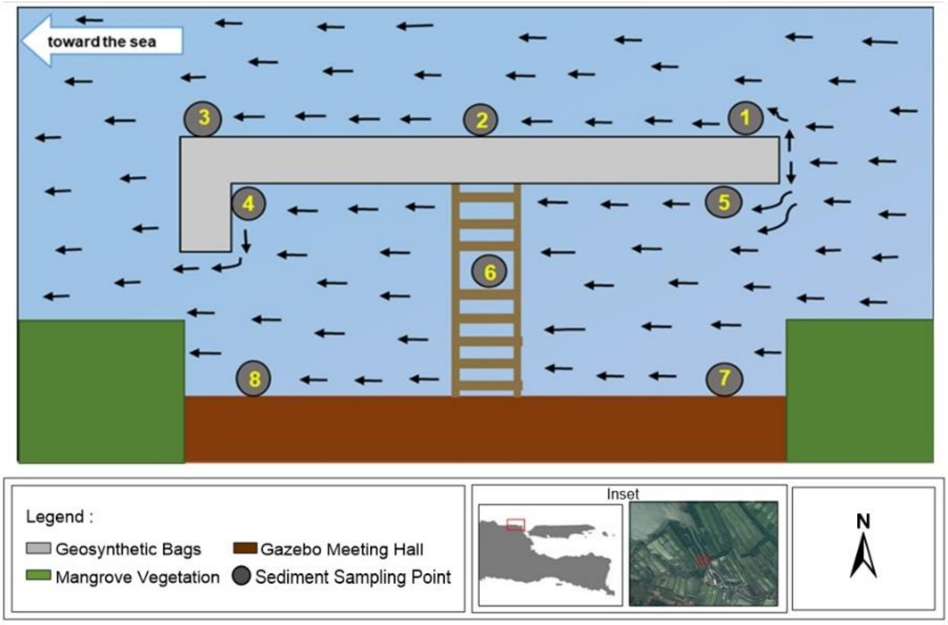

Figure 7. Illustration of the direction of ebb around geosynthetic bags installation area. The current that occurs at ebb condition shows a pattern of movement originating from the upstream of the river back towards the sea.

of sediment (Munandar et al., 2020; Sulaiman and Hidayat, 2020; Sulaiman et al., 2015; Tayade et al., 2015). Changes in sediment height in the installation of the geosynthetic bag area are presented in Table 4.

Conclusion

Types of sediment in the Banyuurip Mangrove Conservation area are generally silt and the rest are clay. The installation of geosynthetic bags at the study site results in the addition of sediment from the retained sediment and sedimentation behind the structure. The current velocity conditions and the sediment transport process also affect the sedimentation process that occurs. The addition of sediment around the geosynthetic bag installation area occurred dynamically. This study may provide basic information in sustainable development for the

Banyuurip Mangrove Center and other mangrove conservation areas.

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