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Hybrid engineering effectivity evaluation according to the changes in mangrove area and sedimentary rate in the eroded area of Sayung Regency, Demak, Central Java

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Abstract. Gigantic abrasion occurred in the Sayung Coast had severely damaged the ecosystems and the coastal area reached 1.5 km and 6 m depth. One of the mitigation efforts that had applied in the Sayung Coast is Hybrid Engineering (HE), which is constructed in the front of the coastline. That structure can be slip off by the water flow yet cannot reflect the waves. The first HE was built in the Timbulsloko Village in 2013 that needs to be evaluated sustainably. The evaluation of HE effectivity is essential moreover these structures will be applied to the other areas impacted abrasion. The correlation between sedimentary rate data (obtained from ^{210}Pb natural isotopes analysis) and the changes in mangrove area is the best way to assess the effectivity of HE. The average of sedimentary rate before HE construction (2011-2013) reached 0.195 cm/year and enhanced about 0.4 cm/year in 2016. Those data are in accordance with the addition of the mangrove forest area (from 409 Ha in 2013 becomes 455.79 Ha in 2015). The existence of HE proves that its effectivity to trap the sediment and to minimalize the physical pressure from oceanographic factors are the best way to mitigate erosion, resulting in restored natural green belt in Sayung coast.

1. Introduction

Historically, most of Java north coast areas have the unstable soil structures which was a swamp formation in the past [1]. Erosion and coastline changes become the issues suffered the most along the coastal area [2] due to the damaged mangrove area several last decades [3]. One of the most impacted areas is Demak regency that suffered a massive coastal damage, coastline changes, and erosion as well, obliterating several villages such as Bedono, Timbulskolo, Sriwulan etc. in Sayung Sub-District [4]. The erosion occurred reached 495.80 Ha [5] resulting in damaged mangrove area, impacted the coastal settlements, eliminated pond area, declined coastal resources, generated social-economy problems, and degraded environment [6,7].

Conventional hard structure solutions are ineffective, needs a high cost, and cannot adapt with the climate change [3], while building with nature can be the best solution that may be applied in the damaged area. Building with nature is an integrated coastal zone management approach that provides resilience by combining intelligent engineering and ecological rehabilitation and introducing sustainable land use [8], one of the methods implemented is Hybrid engineering (HE).

HE serves to trap sediment carried overland during flood and ebb phases [9] which was built since 2013 in Timbulsloko Village. It shows a good impact nowadays where the sedimentation enhanced significantly behind the HE structures that supports the media for mangrove cultivation [8]. This permeable structure serves to restore coastal conditions through natural processes such as sedimentation so that the conditions of hydrodynamics and ecology will return to their provenance state and stimulate the increase in land previously eroded [10].

HE development is planned to be applied on the other coastal eroded areas in Demak Regency. Therefore, before the implementation, an assessment of HE effectivity in trapping the sediments is essential which is done by comparing the sedimentary rate data resulted from the natural radioisotope analysis ^{210}Pb and analyzing mangrove area changes within a certain period. Sedimentary rate that is determined using the natural radioisotope ^{210}Pb has been carried out in several areas affected erosion [11,12,13]. The comparison between sedimentary rate and mangrove area changes data are expected to be a basis for consideration in assessing HE effectivity.

2. Materials and Methods

2.1. Study sites

This research was conducted in the Sayung coastal area includingTimbulsloko and Surodadi Villages with different periods in 2016 and 2018 respectively. The study area positioned at 110° 26'40"E - 110° 36' 40"E and 6° 48' 20"S - 6° 56' 40"S (Figure 1). Sediment coring was done on September 5-6th 2016 in two stations (ISTD-01 and ISTD-02). Following those measurements, on April 11-12th 2018 we conducted coring survey in two locations as well (SRD-01 and SRD-02). Those stations were chosen because it represents the area impacted abrasion where HE is erected. Samples taken were then analyzed using isotope 210Pb according to sediment source and sedimentary process.

2.2. Sedimentary rate analysis

Total activity of ^{210}Pb is obtained from one of its derivatives that is ^{210}Po assuming the balance between them. The sample destruction follows the procedure from Sanchez et al. (1993) with a slightly modification by Arman et al. (2013). The enumeration process is done in the same period tabulating the deviation. Supported ^{210}Pb is determined from the value of ^{210}Pb in the bottom layer that is constant, so that the unsupported ^{210}Pb is obtained bydeviating of ^{210}Pb total and supported ^{210}Pb [16]. Moreover, the mangrove area changes annually are obtained from [17] which will be used to compare with sedimentary rate data to assess the HE effectivity.

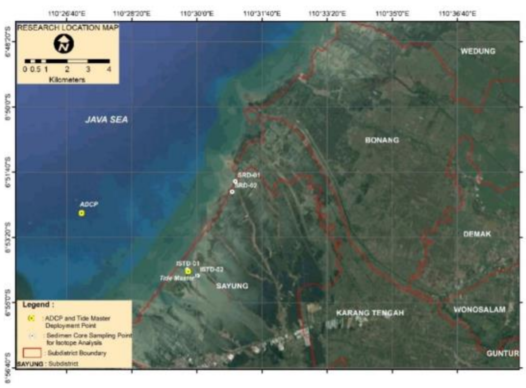

Figure 1. Research location map

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3. Results and Discussions

The value of supported ^{210}Pb at ISTD-01 station reaches 39.33 Bq.Kg-1 while at ISTD-02 station reaches 40.05 Bq.Kg-1 (Figure 2). These results are higher than the brand new analysis reaching 25.22 Bq.Kg-1 and 31.07 Bq.Kg-1 at station SRD-01 and SRD-02 respectively (Figure 3). The unsupported ^{210}Pb profile shows the unstable value between those two analysis periods. Generally, the value of unsupported 210Pb declines in accordance with the addition of depth up to 8 cm. Based on those results, the sedimentary rate calculation is done using CRS (Constant Rate of Supply) method [12].

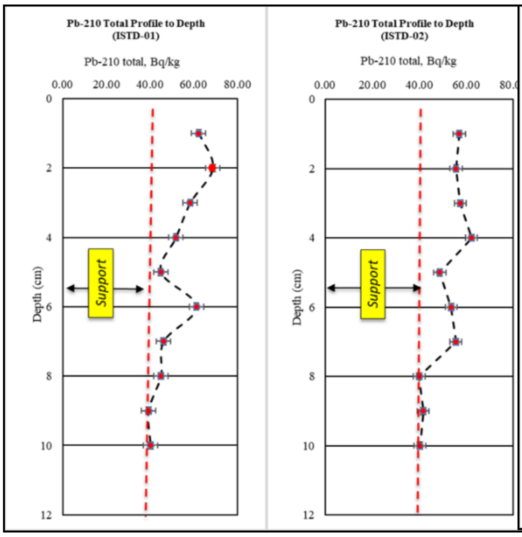

Figure 2. Total ^{210}Pb and supported ^{210}Pb at station ISTD-01 and ISTD-02 (Timbulsloko)

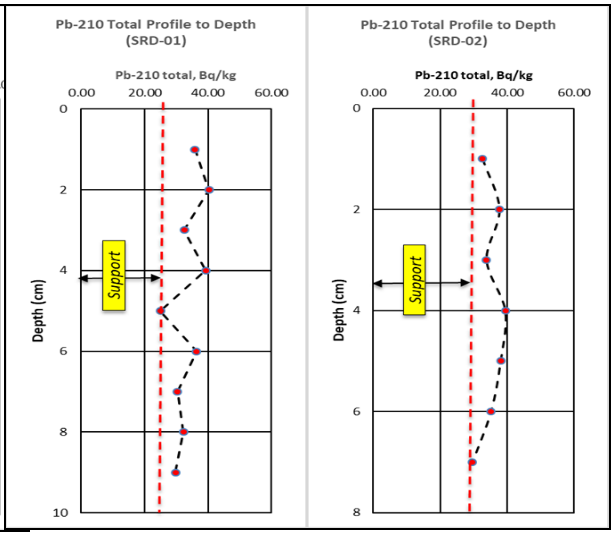

Figure 3. Total ^{210}Pb and supported ^{210}Pb at station SRD-01 and SRD-02 (Surodadi)

The age of sediment deposit in all station varies. The bottom layer (6-7cm) at station ISTD-01 that is located behind the mangrove area shows the deposition occurred in 1916, interpreting the age of the sediment reached 100 years. Whilst the upper-most layer shows that the deposition occurred in 2008. A different result observed at station ISTD-02 that is positioned in the front of mangrove area, showing the oldest deposition occurred in 1957 (59 years) in the bottom layer (5-6 cm) and in 2011 in the upper-most layer. At station SRD-01 the oldest deposition occurred in 1902 (the depth of 8-9 cm) and in 2013 in the upper-most layer respectively. While at station SRD-02 the deposition age is older that occurred in 1895 (the depth of 6-7 cm) and in the upper-most layer the deposition is recorded in 2016.

The absolute value of deposition age in each sediment layer is then converted into sedimentary rate value. The average of sedimentary rate in Timbulsloko shows the variation values. At station ISTD-01 and ISTD-02, the same value of sedimentary rate is observed reaching 0.06 cm/year. While in Surodadi, the average value is higher reaching 0.15 cm/year and 0.14 cm/year at station SRD-01 and SRD-02 respectively. These conditions are caused by the existence of massive estuaries, resulting in bigger sedimentation sourced from land.

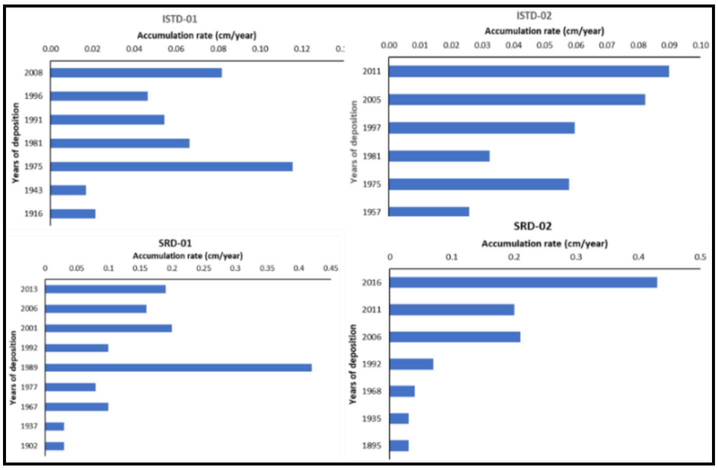

Figure 4. The sedimentary rate of Sayung coast according to natural radionuclide analysis ^{210}Pb

According to the sedimentary rate (Figure 4), at station ISTD-01, in 1975 occurred the increasing of the rate significantly reached 0.12 cm/year. While the rate tends to be higher at station ISTD-02 reached 0.09 cm/year in 2011. The rate declined in 1943 (0.02 cm/year) and in 1957 (0.03 cm/year) in those stations respectively. During 1895-1992, the average of sedimentary rate at station SRD-02 is very low reached 0.04 cm/year. The sedimentary rate enhancement identified during 2006-2016 becomes 0.28 cm/year.

These conditions show that the mangrove restoration and coastal protection had begun during 2006-2016. At station SRD-01, the lowest sedimentary rate identified during 1902-1977 reached 0.06 cm/year, however in 1989 the rate elevated dramatically reached 0.42 cm/year which became deteriorate during 1992-2013. These conditions are caused by the physical factors muffled by HE, resulting in higher sedimentation behind the structures [10].

Based on those results, we conclude that the sedimentary rate was started to increase since 2000 which correlates with mangrove area changes occurred during 1974-2013 (Figure 5). The low sedimentary rate in Sayung coast obviously occurred during 1974-2000. Technology advances and city development threatened the existence of mangrove area; moreover the land use changes are worsening the existing condition. After the huge damages during several years, the governments conscious to rehabilitate the mangrove forest along Demak coastline. The mitigation had begun in 1997/1998 through the area development model of mangrove cultivation [18].

A mangrove rehabilitation program has begun in 2000 encouraging the society to continue the program [19]. It proves that in 2000 the sedimentation increased in accordance with the enhancement of mangrove area at the same time. Figure 4 also shows since 1974 the mangrove area started to deteriorate which occurred until 1997. Those conditions might be caused by the land use changes from mangrove area to be pond clusters [20]. The declination of mangrove area correlates with the sedimentary rate at station ISTD-01 (from 0.12 cm/year becomes 0.05 cm/year).

Besides rehabilitation, in 2013 had built a coastal protection in the form of HE [3]. That effort gives a good impact in the enhancement of sedimentary rate in Timbulsloko. According to Figure 6, during 2013-2015 mangrove area increased significantly (from 409 Ha becomes 455.79 Ha) followed by the sedimentation enhancement (from 0.2 cm/year becomes 0.43 cm/year). Unfortunately, in 2012 the mangrove area reduced (from 425 Ha becomes 387 Ha) caused by the environmental degradation [20].

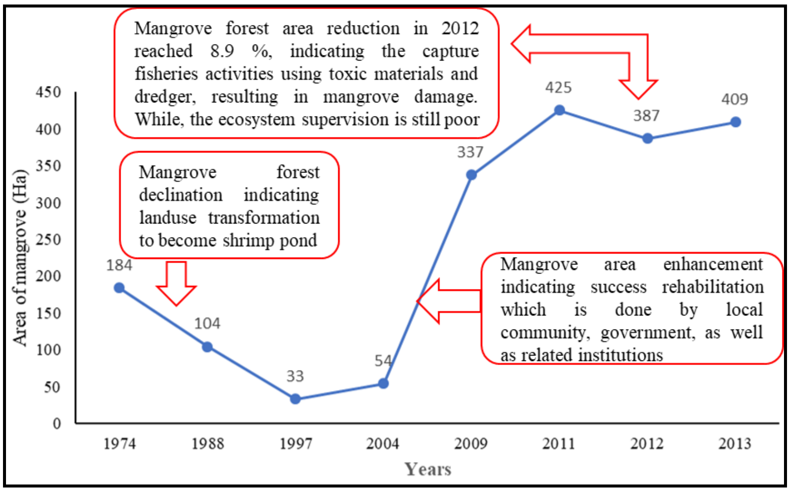

Figure 5. The graph of the fluctuation of mangroves area in the Sayung coast (Source: Department of Marine Affairs and Fisheries Demak Regency, 2013 and Faturrohmah & Marjuki, 2017)

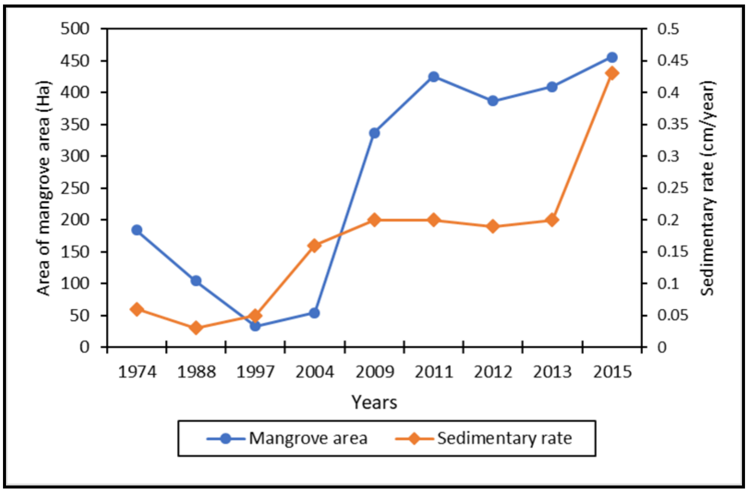

Figure 6. Correlation between mangrove area and sedimentary rate

4. Conclusion

Efforts to rehabilitate the coastal areas from abrasion and tidal flood occurrences in Sayung coastal area in the form of HE have a positive impact on sedimentary rate enhancement (from 0.2 cm/year becomes 0.43 cm/year). Other than that, the existence of sediment accumulation serves the media for mangrove cultivation so that the area of mangrove is also increased (from 409 Ha in 2013 becomes 455.79 Ha in 2015). It can be concluded that the implementation of HE is very effective to help the coastal rehabilitation process in the area impacted abrasion in Sayung.

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