MORPHOLOGIES CHANGES DURING PRE- AND POST- SOUTHWEST SEASON IN MANTANANI BESAR ISLAND, KOTA BELUD, SABAH

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ABSTRACT. *Mantanani Besar Island is one of the community and tourism islands in the west coast of Sabah. It is inhabited by local Ubian people which stated that the island receiving major problem of erosion around the island. Ocean motion (waves and currents) and winds causes the erosion and together with seasonal monsoons change the intensity and formation of waves, winds and the periodic storms. These combinations intensified the geomorphic processes of erosion and accretion along the shoreline. Therefore, the objectives of this study are to determine the beach morphologies (beach profile, volume and angle) and sediment parameters during pre- and post- southwest monsoon (SWM). This study was conducted on May and November 2013 in order to see the beach changes done before and after the peak 2013 SWM (May to September). Beach profiles were measured at 5 stations around the island. Further measurements on beach volume and angle were calculated based on the beach profile readings. Sediment samples were collected at mid tide and analyzed the sediment parameters (mean, sorting, skewness and kurtosis). Results show most of the beach profile increase in post-SWM than in pre-SWM. Significant changes of the beach elevation were found at northern part of the island (st 4 and st 5). Beach volume increases in most of the station with a range from 2.71m^3/m to 9.19 m^3/m while only st 3 experienced sediment loss with -0.75 m^3/m. Beach angle are also increase at most of the station (1^o) but significantly increase at st 5 (4.62^o). Based on the sediment size analysis, mean values are decreasing shows the increase of energy condition. Most of the sediment are moderately sorted and positively skewness. The kurtosis value are vary indicates the presence of other source of sorting. The information gathered on this study is useful for the development along the beach and future management plan of the island.*

KEYWORDS: *beach profile and angle, sediment characteristics, shoreline changes, Mantanani Besar Island*

INTRODUCTION

Coastline is the boundary between land and sea. The shape and position are continuously changing due to ever-changing dynamic environmental conditions (waves, tides, winds and storms) which respond to the shoreline morphology and loose granular sediments (Selvavinayagam, 2009). Analysis of beach morphology can determine the profile or physical attributes of a beach and thus obtain information about the short term trends (accretion and erosion) of coastal area (Dora et al, 2012). Sedimentologist use grain size analysis to classify sedimentary environments and elucidate transport dynamics (Jamil *et al.,* 2004). The processes of erosion and accretion are further intensified with the presence of monsoons.

Effect of monsoon on beach erosion/accretion are vary locally but usually affected mostly in the coastline that bordering South China Sea (Wong, 1981; Mohd Lokman Husain, 1995). In Malaysia, there are two major monsoon regimes every year, northeast monsoon (NEM) which occurs during November to March and southwest monsoon (SWM) that occurs from late May to September (Diman & Tahir, 2012). During NEM, coastal currents flow southward with heavy rain and rough sea while the currents on SWM flows northwards with calmer weather (Nakajima *et al.,* 2015). Based on Wong (1981), "erosion prevails during northeast monsoon while accretion predominates during the southwest monsoon". SWM or non-monsoon season usually signifies relatively drier weather throughout the country in Malaysia. In the exemption for the state of Sabah, it has wetter condition due to the tail effect of typhoons that happen in Philippines (MetMalaysia, 2013)

Local residential and tourism activities are growing in Mantanani Island especially in Mantanani Besar Island. This lead to the importance of Mantanani Besar Island as both community and tourism island. The main problem of Mantanani Besar Island is beach erosion. It affects the community and tourism infrastructures (chalet, houses, jetty and electric poles) that built along the shoreline. Monitoring the changes of beach is necessary for understanding and interpreting the coastal processes in the area. These changes are important as it can act as environmental indicators that directly impact the coastal economic development and land management (Ali, 2010). Therefore, the objectives of this study are to determine the beach morphologies (beach profile, volume and angle) and sediment parameters during pre- and post- SWM of 2013.

METHODOLOGY

[1] Study Area

Mantanani Island is form of three islands which are Mantanani Besar Island, Mantanani Kecil Island and Lingisan Island. It is located at the west coast of Sabah in Kota Belud District facing the South China Sea. Mantanani Besar Island is the biggest island among the islands with an area of 188.1 Ha (DHI, 2013). There are two villages and four jetties to support the local communities and development of the tourism activities in the island.

The shoreline of Mantanani Besar Island form mainly by sandy beach. According to the villagers, the size of this island is decreasing due to beach erosion. Five sampling station (st) were selected for beach profiling measurement and sediment collections (Figure 1). The sampling sites covering the northern and southern part of the island in order to understand the coastal processes along the island. Most of the sampling station located at area where there are presences of community and tourist activities except for st 5.

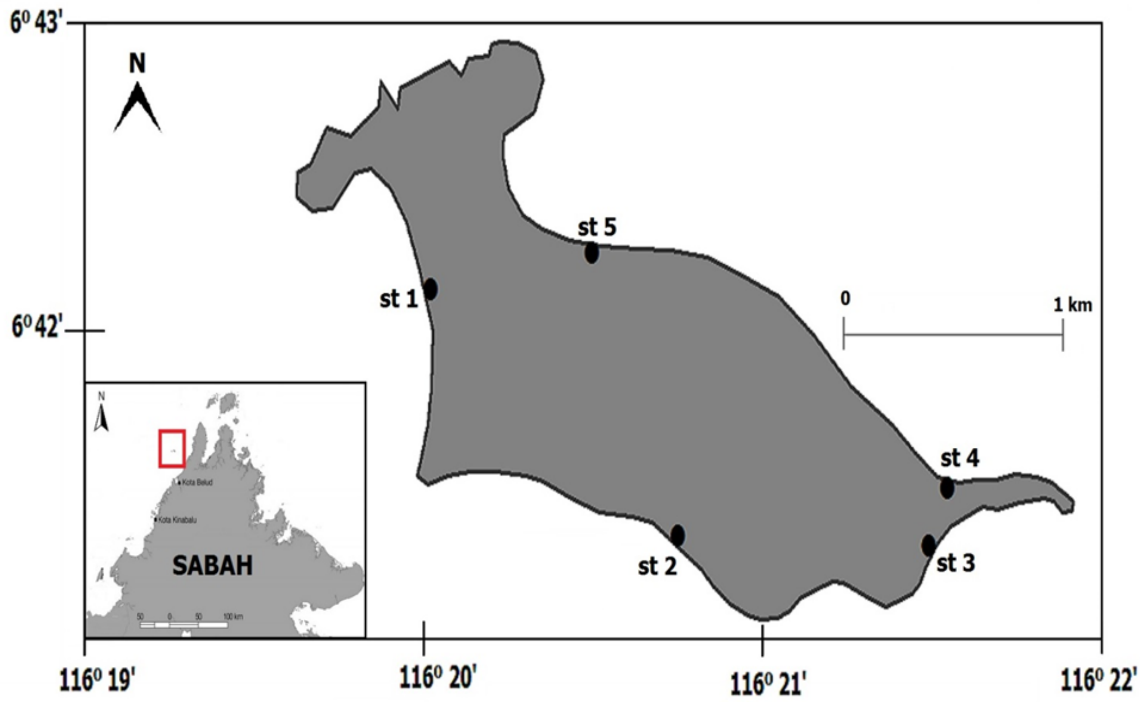

Figure 1: Location of the sampling sites.

The coordinates of each sampling stations were recorded using Global Positioning System (model: Garmin GPSmap 60CSx) (Table 1). The shoreline distance between two stations are calculated as st 1 to st 2, st 2 to st 3, st 3 to st 4 and st 4 to st 5 were ~1.8 km, ~1.4 km, ~1.2 km and ~1.8 km respectively. There are long distance between st 5 to st 1 (~3 km) due to the rocky cliff.

Table 1: Latitude and longitude of each sampling sites

Station	Latitude (N)	Longitude (E)
1	6°42.843’	116°20.657’
2	6°42.459’	116°21.271’
3	6°42.444’	116°21.892’
4	6°42.534’	116°21.939’
5	6°42.901’	116°21.057’

Field sampling and data analysis

Beach profiling was conducted during pre-SWM (2nd May 2013) and post-SWM (14th November 2013) to see the beach changes that affected by peak of the SWM. Beach profiling is used to shape the beach elevation where measuring tape was pulled from the tripod until the water level mark (Poh Leem & Monique, 2012). The heights of the beach were recorded in every 5 m distance interval to determine the beach profile. Total of 10 sediment samples were collected at mid tide area of the beach to differentiate sediment characteristics at the island. These samples represent the sediment characteristics of the study station at Mantanani Besar Island.

Beach volume and angle were calculated based on the beach profiling in each stations to identify the changes of sediments removal and gain between the two time periods. The calculation of beach volume was based on trapezoid formula (Eq. 1) (Dora et al., 2012).

$$\text{Volume per unit length } (\mathrm{m}^3/\mathrm{m}) = A = \left[\frac{(L1 + L2)}{2}\right] * H \quad \text{................ (1)}$$

(Where, L1 and L2 = length of each base, H = height)

Height and length of the beach are used to calculate the beach angles ($\sin\theta$). The calculation of $\sin\theta$ were adapted from right angle triangle trigonometric formula. Hence, the beach angle can be calculated from $\sin\theta$ (Eq. 2).

$$\sin\theta = \frac{H}{W}$$

$$\theta = \sin^{-1}\left(\frac{H}{W}\right) \quad \text{................................... (2)}$$

(where, H = height, W = width, θ = beach angle)

Beach sediments about 200 g were analyzed using a dry sieve method. Around 100 g of sediments was dried and put into the 7 sieves shaker layer (mesh sizes 2.0 mm, 1.0 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.063 mm and pan). The samples were shaken for 15 minutes as it enough to lead to acceptable reproducibility of results (Folk & Ward, 1957; Jamil *et al.,* 2009). Samples that retained at each sieve are then weighed.

The graph of cumulative percentage versus phi was plotted based on the weight of the sediment. The plotted graph is used to calculate the statistical parameters (mean, sorting, skewness and kurtosis) with percentile 95%, 84%, 75%, 50%, 16% and 5% ($\text{Ø}95, \text{Ø}84, \text{Ø}75, \text{Ø}50, \text{Ø}25, \text{Ø}16$ and $\text{Ø}5$) used in each calculations. Equations and classifications of individual sediment samples were calculated based on GRADISTAT (Blot & Pye, 2001) following logarithmic (original) Folk and Ward (1957) graphical method (Figure 2).

Mean	Standard deviation	Skewness	Kurtosis
$M_Z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$	$\sigma_I = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6 \cdot 6}$	$Sk_I = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$	$K_G = \frac{\phi_{95} - \phi_5}{2 \cdot 44(\phi_{75} - \phi_{25})}$

Sorting (σ_1)		Skewness (Sk_1)		Kurtosis (K_G)	
Very well sorted	<0·35	Very fine skewed	$^+0{\cdot}3$ to $^+1{\cdot}0$	Very platykurtic	<0·67
Well sorted	0·35–0·50	Fine skewed	$^+0{\cdot}1$ to $^+0{\cdot}3$	Platykurtic	0·67–0·90
Moderately well sorted	0·50–0·70	Symmetrical	$^+0{\cdot}1$ to $^-0{\cdot}1$	Mesokurtic	0·90–1·11
Moderately sorted	0·70–1·00	Coarse skewed	$^-0{\cdot}1$ to $^-0{\cdot}3$	Leptokurtic	1·11–1·50
Poorly sorted	1·00–2·00	Very coarse skewed	$^-0{\cdot}3$ to $^-1{\cdot}0$	Very leptokurtic	1·50–3·00
Very poorly sorted	2·00–4·00			Extremely leptokurtic	>3·00
Extremely poorly sorted	>4·00				

Figure 2: Logarithmic (original) Folk and Ward (1957) graphical method (Blot & Pye, 2001)

RESULTS

Beach Profile

All samplings st have the same trends of beach profile except for st 5 (Figure 3). There were increased of sediment at all part of the beach at st 1 especially at high and lower part of the beach (Figure 3a). Similar situation at st 2, except beach erosion occur at middle part (Figure 3b). Loss of sediment occurs almost at entire beach area in st 3 but opposite situation at st 4 where there were accumulated on the beach and change both elevation and distance (Figure 3c-d). St 5 also has increased of beach elevation indicates that this station experiencing accumulation of sediment (Figure 3e). Generally, the beach elevation has increased in most sampling st with significant increase more than 0.5 m in the northern part of this island (st 4 and st 5).

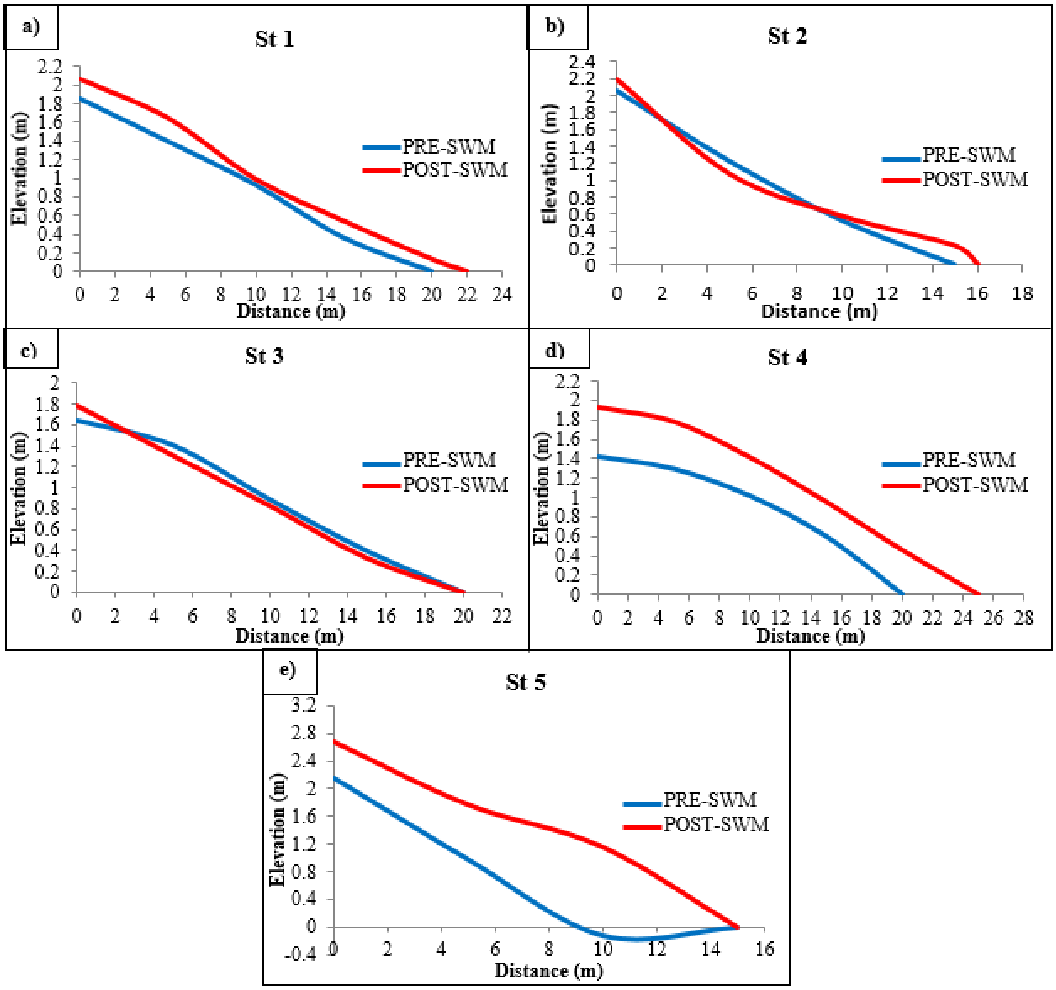

Figure 3: Beach profile at different sampling station

Beach volume

Volume of sandy beach in pre- and post- SWM is shown in Table 2. The range of beach volume during pre-SWM was 11.08 m^3/m and 18.98 m^3/m . Meanwhile, in post-SWM the beach volume was range from 16.92 m^3/m and 26.89 m^3/m. The changes of beach volume during the 6 month interval showed that accretion occur at all station except st 3 (Table 2).

Table 2: Changes of beach volume in pre- and post- SWM.

Station	Pre-SWM (m^3/m)	Post-SWM (m^3/m)	Changes (m^3/m)
1	18.98	23.60	4.62 (Accretion)
2	15.74	18.45	2.71 (Accretion)
3	17.67	16.92	-0.75 (Erosion)
4	17.7	26.89	9.19 (Accretion)
5	11.08	17.02	5.94 (Accretion)

Beach Angle

Entire beach angles in each station have increased during pre- to post- SWM (Table 3). St 5 has the highest angle among the station both in pre-SWM (8.28°) and post-SWM (12.90°). The beach angle changes less than 1° in other stations.

Table 3: Beach angle during pre- and post- SWM.

Station	Pre-SWM ($^{\circ}$)	Post-SWM ($^{\circ}$)	Changes ($^{\circ}$)
1	5.34	5.40	0.06
2	7.86	7.87	0.01
3	5.26	5.71	0.45
4	4.10	4.84	0.74
5	8.28	12.90	4.62

Sediment Size Data Analysis

Same sediments type at st 3-5 in both pre- and post- SWM but st 1 and st 2 were changed from fine sand (pre-SWM) to median sand (post-SWM) (Figure 4a). Sediments were moderately sorted at all stations in pre-SWM but vary in post-SWM (Figure 4b). During both months, positive skewness was at st 3 and 4 while negative skewness was at st 5 (Figure 4c). At st 1, the sediment skewness changes from symmetrical (pre-SWM) to positive (post-SWM) and vice versa at st 2. The kurtosis value at st 1 and 2 were increase from platykurtic (pre-SWM) to leptokurtic (post-SWM) (Figure 4d). On the other hand, st 5 value decrease from leptokurtic (pre-SWM) to platykurtic (post-SWM). The kurtosis value during pre- and post- SWM for st 3 and 4 were in the range of platykurtic and leptokurtic sediment respectively.

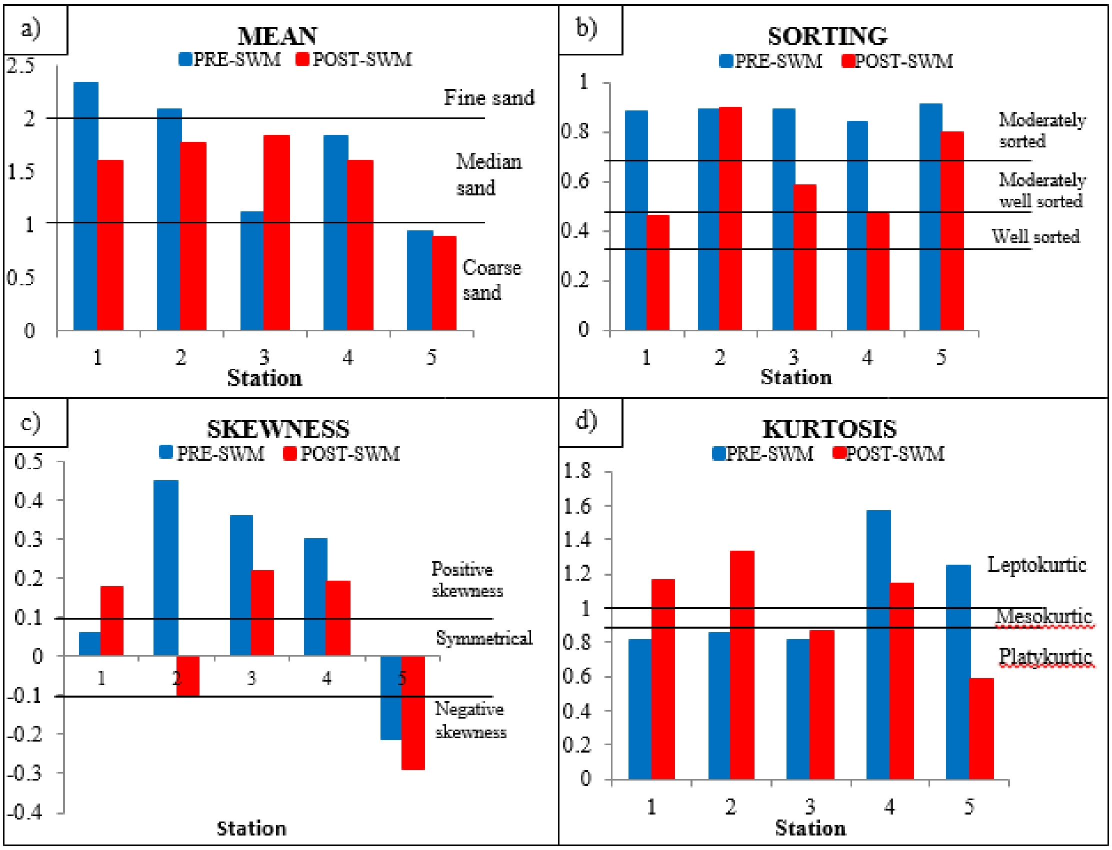

Figure 4: Sediment characteristics of Mantanani Besar Island

DISCUSSION

Beach Profile, Volume and Angle

The beach elevation and width measured in pre-SWM is lower than in post-SWM with difference of more than 0.5 m in some stations (st 4 and st 5). This indicates that there is accumulation of sediment on the beach in post-SWM in exemption of st 3. The changes of beach profiles can be clearly seen from the changes at beach volume and angle. The increase of volume from pre-SWM to post-SWM shows sediment gain while decreasing value considered being eroded. The increase in volume causes the beach to become steeper. Increase in both elevation and width of the beach profile shows small increase of angle while the increase on only elevation causes the beach to become steeper than the others. Difference beach angle along the study area was related to the beach erosion and accretion process (Dora et al., 2011). Beach that has a low angle (flat slope) has the tendency to experienced erosion while higher angle (steep slope) might undergo a period of accretion (De Lange, 2012). This is due to the coverage of area during wave breaks or tidal process were bigger at flat slope rather than in steep slope. The erosion process that occurs at st 3 affected by the longshore transport. Currents that move northward hit the beach at an angle creates the longshore currents (Stanica and Ungureanu, 2010) which carries sediments towards the sand bar that located at most eastern of Mantanani Besar Island.

Sediment Characteristics

Mean is an indicator to measure the magnitude of force and it is applied by wind, wave and current. It reveals the energy conditions which resulting in their deposition (Ganesh *et al.,* 2013). Fine and median sediment deposited under low to moderate energy condition while stronger energy condition deposited coarser sediment (Dora *et al.,* 2011). The mean size of the sediment in pre-SWM ranged from fine, median to coarse but in post-SWM the range of mean size is only medium to coarse. The difference in range of mean size between pre-SWM and post-SWM shows that the energy condition around the island were higher during peak SWM especially at st 1 and 2. St 5 remain to receive stong energy forces.

Sorting is a measured of standard deviation referring to the flunctuations in kinetic energy or velocity conditions of the depositing agent (Kumar *et al.,* 2010). It gives an indication of effectiveness of the depositional medium in separating sediment of different classes (Okeyede & Jibiri, 2013). The values of sediment sorting in both pre- and post- SWM are range from moderately sorted to well sorted (Figure 4b). The sediment sorting was better after the SWM where the values of sorting decreasing from pre- to post- SWM indicate better percolations and evenly spread sediment.

Skewness is the degree of symmetrical distribution. It can determine the predominance of either coarse or fine sediments at an area (Ganesh et al., 2013). Most of the skewness values are leans toward positive skewness and only a few parts are negatively skewed (Figure 4c). Positive skewness indicates the deposition or introduction of fine sediments in sheltered low energy and negative skewness is the opposite of positive skewness (Rajasekhara *et al.,* 2008; Ganesh *et al.,* 2013). Most of the values of skewness are decreasing in post-SWM showed the loss of fine sediment or increased in coarse sediment. Fine sand still the dominance of the beach while coarse sand started to be increasing.

Kurtosis is the measure of peak of a sediment distribution (Friedman, 1962; Dora *et al*., 2012). It is the ratio of sorting in 'tails' of the curve to the central portion (Okeyede & Jibiri, 2013). The kurtosis values is ranged from platykurtic to leptokurtic (Figure 4d). Values (high or low) of kurtosis shows that part of the sediment achieved its sorting elswhere in a high energy environment (Friedman, 1962).

Tail effect of typhoon

Morphologies and sedimentary changes at Mantanani Besar Island may be related to the strongest typhoon (Typhoon Haiyan) recorded in the history that affected central Philippine on 3 November 2013 until 11 November 2013. It has the winds speed of 315 kilometers per hour and the storm surge of 5 meters high (Maps of World, 2013). The tail effect of this typhoon contributed to a wind speed of 50 to 60 kilometers per hour with the wave height that can reach until up to 4.5 meters in Sabah water as it passed from Philippines to Vietnam (Berita Harian, 2013). The effects of strong winds may lead to winnowed of fine sediments and strong wave wash away fine sediment while introduce coarser sediment to the beach.

CONCLUSION

The short observation in this study indicates that accumulation of sediment occurs along the beach even though the villagers reported that the size of the island is decreasing due to erosion. Beach morphologies are increasing from pre- to post- SWM shown that Mantanani Besar Island is experiencing accretion except for st 3 which experienced erosion. The difference sediment characteristics during pre- and post- SWM indicate high energy condition during SWM. Fine sediment is still the dominance at the beach with more compacted sediment arrangement while receiving other sources of sorting from high and low energy environment. Changes at Mantanani Besar Island might related to the extreme event such as Typhoon Haiyan that generate strong winds and waves around the island.

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