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Research Article

Beach Morphology Changes during the Northeast and Southwest Monsoons at Mantanani Besar Island, Sabah (Malaysia)

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Abstract

Mantanani Besar Island is a tourism and island that also has communities and is located in the west coast of Sabah. The island coastline is dominated by sandy beaches that tend to change due to direct exposure from natural phenomenon (waves, wind, current and periodic storm) and anthropogenic activities. The seasonal monsoon (NEM and SWM) is an important factor that intensifies the natural phenomenon leading to major beach changes in a short period of time. Therefore, this study aims to determine the beach morphology changes (profile, width, angle and volume) and to identify short-term beach changes trends at different seasonal monsoons. This study was conducted annually between 2013 and 2015. Beach profiling and field measurements were done in May and November 2013, March and September 2014 and January and May 2015 at 5 selected stations around Mantanani Besar Island. Further analysis of beach width, angle and volume were calculated based on beach profile data. The result of beach profile shows St. 1, St. 2 and St. 5 undergoing erosion while St. 3 and St. 4 are experiencing accretion. Averages of beach morphology were higher during the NEM than in SWM indicating more sediment accumulation on the beach of Mantanani Besar Island during the NEM and vice versa in SWM. The findings of this study are useful for local communities, tourist operators and the local government as a guide for any development and to produce shoreline management plans for Mantanani Besar Island.

Keywords: beach morphologies, beach changes, seasonal monsoons, Mantanani Besar Island

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Introduction

Shoreline changes have been documented by many researchers around the globe and it is dominated with erosion especially at coastal areas where at least 70 % of the world's sandy beaches are affected (Bird, 1985; Zhang et al., 2004). In Malaysia, almost 30 % of its coastline experienced critical coastal erosions (shore-based facilities or infrastructures are in danger of collapse/damage) especially in Sabah which experienced the longest coastal erosion compared to other states (DID, 2007). Major erosion in Sabah (significant to critical) occurred along the coastline in the west coast (Papar and Kimanis) and east coast (Sandakan).

Shoreline changes related to beach processes (accretion and erosion) happen along the shore. These can be classified into three parts which are long-term changes, short-term changes and episodic changes. These classifications provide a picture on how the shoreline has changed in a certain period of time and illustrate the most dynamic areas along the shoreline (Gibeaut et al., 2001). Long-term beach changes occur for between ten to thousands of years. It is caused by any activity that can significantly alter the sea level (rise or fall) and tectonic activities which lead to subsidence or emergence of coastal land (Prasetya, 2007). Short-term changes occur within 5 to 10 years or several seasons. The beach responds to smaller scale events such as winds, coastal waves, currents and tides. Episodic changes only occur in response to a single storm and it usually causes more beach changes compared to long-term and short-term changes (Gibeaut et al., 2001).

Mantanani Besar Island is an important island for both tourism and communities in the west coast of Sabah. Tourist arrivals has increased yearly (RCM, 2012) ande the island is also inhabited by local communities mainly from the Bajau Ubian ethnicity (Rosazman et al., 2015). The island coastline is dominated by sandy beaches and a small portion of cliff. The shape and size of the beach is constantly changing due to the continuous interaction of sandy beaches (loose granular sediments) with the natural phenomenon (wave action, tides and the wind) and human activities (boating, beach activities and clearance of beach vegetation). The beach change is further intensified by the presence of seasonal monsoons.

Malaysia is affected by yearly two major monsoon regimes which are the Northeast Monsoon (NEM) and the Southwest Monsoon (SWM). A different energy of waves, currents and winds occur at different directions depending on the type of monsoon. Coastal currents during NEM that occur from November to March flow southward and usually bring heavy rainfall contributing to a major rainy season and rough seas. The monsoon systems are developed in conjunction with cold air outbreaks from Siberia which produce heavy rains that often cause severe floods along the east coast states of Peninsular Malaysia (Kelantan, Terengganu, Pahang and East Johor) and in the state of Sarawak (Met Malaysia, 2015). Coastal currents during SWM (late May to September) flow northwards with calmer weather (Nakajima et al., 2015). Most states in Peninsular Malaysia experience minimum rainfall and dry conditions due to the rain shadow effect of the Sumatran Mountain range. In contrast, Sabah experiences wetter weather conditions during the SWM due to the tail effects of typhoons during their journey from islands in the Philippinesacross the South China Sea and beyond (Diman & Tahir, 2012; Met Malaysia, 2015).

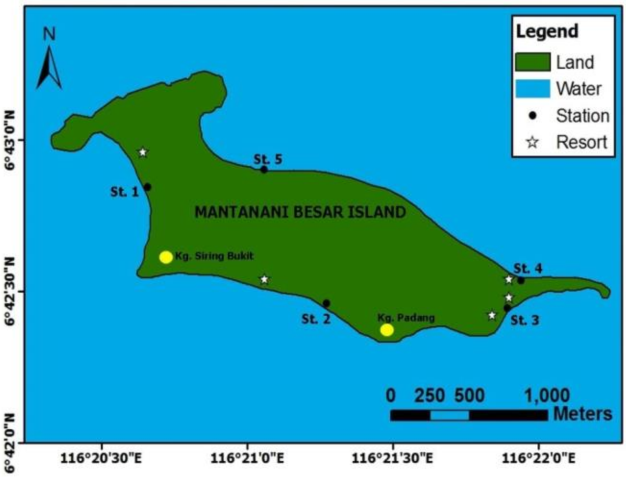
Effects of monsoons on shoreline changes vary locally (Mohd Lokman et al., 1995). Based on Wong (1981), erosion usually occurs during NEM and accretions during SWM. Mantanani Besar Island is also known to experience a major problem of beach erosion which affects communities and infrastructure along the coastline (Koiting et al., 2015). Limited baseline data especially physical data means there is less information on beach changes which lead to difficulties for communities and tourist operators in managing livelihoods as well as finding suitable places for houses/chalets construction. Further, continuous erosion may happen if the island is not protected which eventually could lead to the loss of island areas.

Therefore, this study aims to determine the beach morphology changes (profile, width, angle and volume) and to identify the short term trends of beach changes (erosion and accretion) at different seasonal monsoons in Mantanani Besar Island. Seasonal variation (short-term) of beach changes (erosion and accretion) and the evolution of beach profile provides useful information for coastal processes understanding and management (Andrade & Ferreira, 2006; Gujar et al., 2011; Dora et al., 2012).

Materials and Methods

Study Area

Mantanani Besar Island is one of the three islands (others are Mantanani Kecil and Linggisan) that make up the Mantanani Island cluster. It is located at the northwest of Sabah facing the South China Sea (Figure 1) within Kota Belud distrct. Mantanani Besar Island is the biggest and only inhabited island in this cluster. Most of the man-made infrastructure (villages and tourism infrastructures) are found along the eastern, southern and western parts of the coastline (Figure 1).



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′

Figure 1. Mantanani Besar Island and location of measurement stations

Methods and Measurements

Measurements of beach morphologies were done using beach profiling method at different seasonal monsoons (NEM and SWM) between 2013 and 2015 [2nd May 2013 (SWM), 13th November 2013 (NEM), 13th March 2014 (NEM), 12th September 2014 (SWM), 19th January 2015 (NEM) and 20th May 2015 (SWM)]. Five stations (St.) were selected for the beach profiling measurement (Figure 1). Locations of the stations were chosen by considering the presence of anthropogenic activities. St. 1 is located near Kg. Siring Bukit (KSB) with the presence of one resort, St. 2 is located near Kg. Padang (KP) with two resorts, St. 3 and St. 4 are located near four tourism resorts while St. 5 is located at an undeveloped area (north). The coordinates of each sampling station are shown in Figure 1.

Materials used for beach profiling are a tripod, auto level, staff, measuring tape and Global Positioning System (model: Garmin GPSmap 60CSx). A tripod was set up at the vegetation area that grows near the beach at all stations. Permanent solid structures that were selected as a control point in this study are tall trees, boulders and houses available at the vegetation area. Coordinates of each station were recorded by GPS to mark the location and as one of the precautions taken in case the control point was damaged by natural causes or human intervention. The auto level was placed onto the tripod to ensure its stability by adjusting the air bubbles to be positioned in the middle for better accuracy of reading. A measuring tape was pulled perpendicular from the tripod to the low water line. The staff was placed and held in an upright position and the measurement of the height differences between the auto level and the staff were taken at every 5m interval along the tape.

Data Analysis

Beach profiles were obtained by plotting the graph of beach elevation versus distance. The calculations of each beach width, angle and volume were based on the beach profile readings elaborated by Dora et al. (2012). Beach width was the distance of the beach from vegetation area to the low water line.

The beach angle is known as the gradient of the beach that shows the potential of beach changes in different steepness of the beach. It was calculated based on the height and width of the measured beach by adopting the right angle triangle trigonometric formula as below (1):

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

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

Where,

H is the height (m) or elevation, W is the width (m) and θ is the degree of beach angle.

Volumes of sediment within the beach profile were calculated in each station to determine beach irregularities and total sediment gain and loss during the study period. The beach sediment volumes were calculated based on trapezoid formula as given below (2):

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

Where,

L1 and L2 are the length (m) of each beach profile base while H is the height (m) or elevation.

Results

Beach profile

The trend of beach profile patterns at the western (St. 1), southern (St. 2) and northern (St. 5) sections of Mantanani Besar Island were almost the same in all sampling periods (Figure 2abe). These three stations also show decreasing pattern of profile and beach width at the end of the sampling period. Only St. 2 displays a drop of beach elevation at the beginning of 2015 (January) (Figure 2b). Northern beach profile (St. 5) shows increase of sedimentation on the beach within the period of May 2013 and November 2013 and then gradually decreased until May 2015 (Figure 2e). The eastern beach profile (St. 3 and St. 4) are varied (Figure 2cd). Nonetheless, these stations displayed an increase of profile patterns and beach width from May 2013 to May 2015.

The average of beach profiles was higher during the NEM than in SWM at all stations except St. 5 (Figure 3). A small portion of beach profile for SWM was seen slightly higher at beach width 8-12 m for St. 1 (Figure 3a) and at the end of the beach width for both St. 3 and St. 5 (Figure 3ce). In contrast, the average profiles at St. 4 were lower during NEM than the SWM (Figure 3d). The SWM profile was almost the same with NEM profile at width 8-12 m.

Beach width, angle and volume

The volumes of sediment on the beach at all stations were higher during NEM than in SWM (Figure 4c). The highest and lowest beach sediment volumes were at St. 4 and St. 2 respectively. Width average at each station in Mantanani Besar Island were wider during the NEM than SWM except for St. 5 (Figure 4a). The longest beach width was at St. 4 during both NEM and SWM with an average of more than 25 m while shorter beach width (< 20 m) was found at St. 5 (NEM) and St. 2 (SWM). Total average for width is slightly higher in NEM than SWM (Figure 4a).

Beach angle was varied in the NEM and the SWM. St. 1 and St. 2 have higher beach angles during the NEM while other stations are vice versa. The NEM beach angle was ranged from 4^{o} to 10^{o} whereas the SWM from 3^{o} to 8^{o}. There were high differences of beach angles at St. 5 compared to the other stations. Overall, the total averages of beach angle were higher in NEM (Figure 4b).

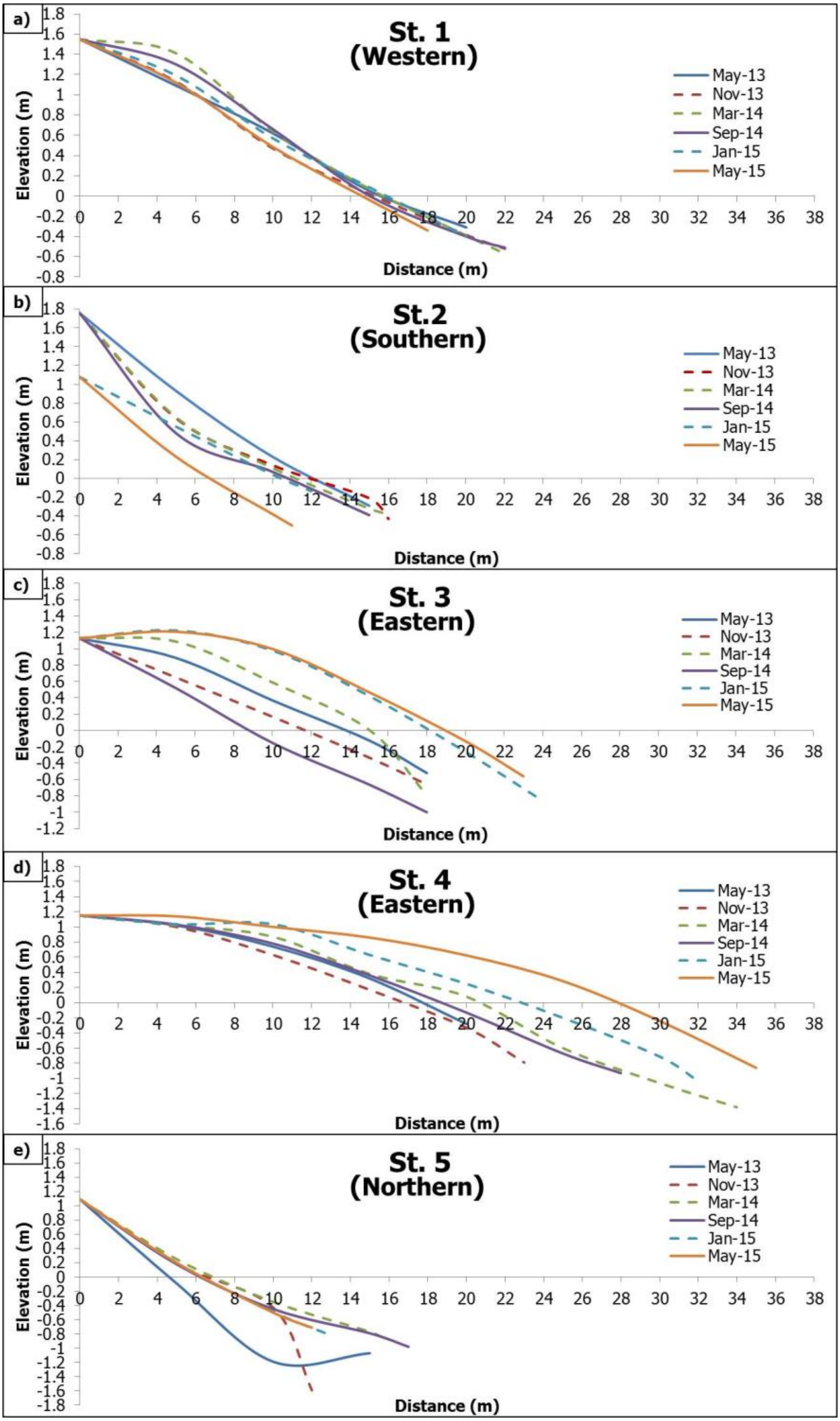


Figure 2. Seasonal of beach profiles at Mantanani Besar Island with five stations (a) St. 1; (b) St. 2; (c) St. 3; (d) St. 4 and; (e) St. 5.

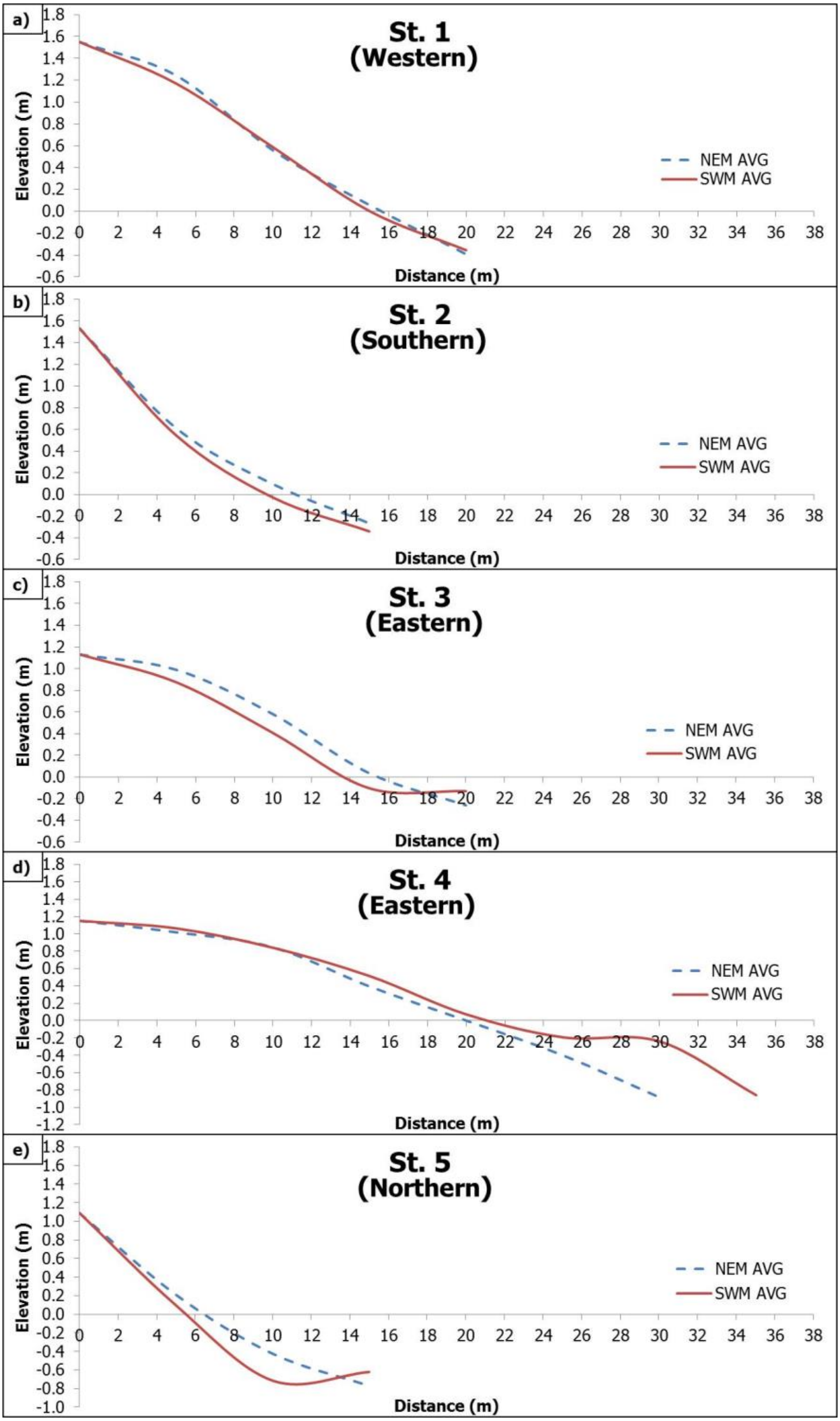


Figure 3. Seasonal average of beach profiles at Mantanani Besar Island during NEM and SWM with five stations (a) St. 1; (b) St. 2; (c) St. 3; (d) St. 4 and; (e) St. 5.

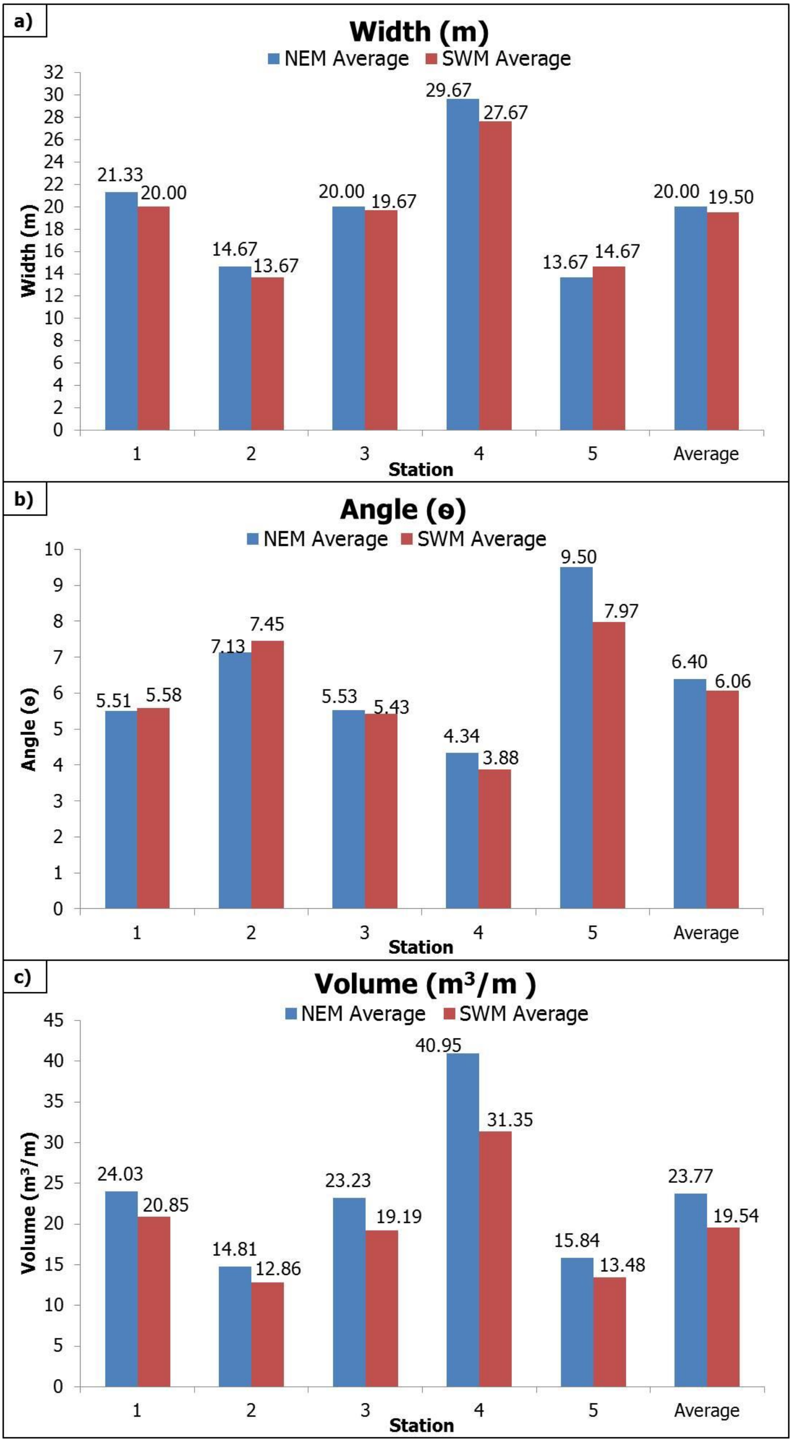


Figure 4. Seasonal average of beach morphology at Mantanani Besar Island during NEM and SWM with (a) beach width; (b) beach angle and; (c) beach sediment volume.

Discussion

Beach profiles of Mantanani Besar Island (2013 to 2015) showed that St. 1, St. 2 and St. 5 were undergoing erosion while St. 3 and St. 4 experienced accretion (Figure 2). High sedimentation increased on St. 5 beach within the period of May 2013 and November 2013 is an example of episodic beach changes where the beach experienced massive changes (high sediment deposition) due to the tail effect of Typhoon Haiyan that hit the Philippines (3-11 November 2013). Based on Gibeaut et al. (2001), extreme events have the tendency to change the shoreline by more than 30 m. The averages of beach morphologies were higher during the NEM than the SWM indicating that most sediment accumulated on the beach at the end of the year while sediment washed out after the first quarter of the year (Figure 3 and Figure 4).

Beach profiles can be related to the changes in beach width and beach sediment volume. The increase in beach width will cause sediment volume to increase as well. Therefore, beach profiles will rise if beach width and volume increases. The beach angles depend on the beach elevation and width. Based on Dora et al. (2011), the difference of beach angles are associated with beach erosion and accretion processes that happen along the beach. Deposition in both elevation and width leads to a small increase of angle while the increase of only elevation (or erosion on low tidal area) causes the beach to have a major increase in its angle (Koiting et al., 2015). Furthermore, studies done by Maryam et al. (2011) shows that smaller beach angle causes more land loss than a bigger beach angle. This is due to the bigger coverage of the area during wave breaks or tidal process at flat slopes rather than at steep ones.

Studies on short-term coastline changes (<10 years) is difficult to understand and predict. It is probably because one part of the beach may experience erosion while otherparts are accreting, or vice versa throughout the year. Apart from that, if a particular beach shows advancing or stablity for a few years but has a history of erosion in the previous decade, and then the erosion will eventually continue (Gibeaut et al., 2001).

Conclusion

Mantanani Besar Island has experienced erosion especially at the western (St. 1), southern (St. 2) and northern (St. 5) areas and accretion at the eastern part of the island (St. 3 and St. 4). The occurrence of beach erosion at western and southern Mantanani Besar Island has affected local community houses, jetties and also tourist facilities. The average of beach profile, width and sediment volume are higher during the NEM indicating that the island undergoes deposition during the NEM and then erosion takes place during the SWM while the varieties of beach angles within the monsoons are due to the process of beach erosion and accretion occuring at the different tidal areas. Studies on hydrodynamic forces (waves, winds and current) around Mantanani Besar Island are recommended to identify the influence of environmental forces on the beach. Both hydrodynamic forces and beach morphology changes would be very useful to get a better understanding of the beach processes of the island. Nonetheless, this study is still very useful as a guide for local communities and tourist operators for any development on the island. Considerable knowledge is also provided for the local government to produce relevant and effective shoreline management plans for Mantanani Besar Island.

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