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Coastline Changes in Mantanani Besar Island, Sabah, Malaysia

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ABSTRACT
Coastline dominated by sandy beaches tends to change due to the processes of beach erosion and accretion. However, the coastline of an island is continuously changes due to direct exposure to physical forces from the sea and anthropogenic activities. At Mantanani Besar Island (west coast of Sabah), continuous beach erosion is among the major threats and a matter of concern by both islanders and tour operators. Therefore, this study aim at identifying the long-term coastline changes and the most dynamic coastline processes by detecting the pattern of beach modifications based on remote sensing images and photographs. The island was divided into four segments following the cardinal directions namely westward (seg 1), southward (seg 2), eastward (seg 3) and northward (seg 4). Aerial photos (1986, 1990, 2001 and 2013) and satellite image (2010) were analysed using ArcGIS Software Version 9.3. Results revealed that the island has undergone long-term coastline erosion (1986 to 2013) with the estimated total beach loss area of 168,113 m^2. All these segments experienced more beach erosion than accretion where seg 2 had the highest beach loss, approximately 71,590 m^2 followed by seg 4 (57,558 m^2), seg 1 (23,008 m^2) and seg 3 (15,957 m^2). The most dynamic areas were at seg 3 which had experienced more beach processes. Impacts from both natural phenomenon and anthropogenic activities lead to different rates of erosion at each segment. Further study on hydrodynamic forces (winds, waves and currents) at Mantanani Besar Island is recommended to better understand the coastal processes. Studies on hydrodynamics and beach changes would provide baseline data that might be helpful in planning measures for protecting the island from further erosion.

Introduction

Mantanani Besar Island is among a cluster of three islands (others are Mantanani Kecil Island and Linggisan Island). It is the biggest of these three islands located on the west coast of Sabah. The island is important for both tourism and indigenous communities. Tourism program in Mantanani Besar Island has increased the number of tourist arrival to fourfold in the last three years (RCM, 2012). Bajau Ubian is the dominant ethnic community on this island. They have been living historically and using the available resources for their livelihood (Rosazman *et al.*, 2015). The islanders have been experiencing beach erosion over the last few decades. This has affected both the community and the infrastructures that have been developed along the coastline.

Studies on long-term coastline changes are time-consuming and become apparent only after a significant lapse of period (Gibeaut *et al*., 2001). The comparison between past years' images is the best and quick method of detecting landscape changes over time (Rocchini & Rita, 2005). Objectives of this study were to detect coastline changes due to beach erosion and accretion using remote sensing time series data and to identify the most areas of the dynamic coastline at the Mantanani Besar Island.

Methodology

Study area

The coastline of Mantanani Besar Island is characterized by sandy beaches and small rocky cliff at northwest area of the island. The entire man-made infrastructures including the two villages (Kg Padang and Kg Siring Bukit) and tourism facilities can be found along the coastline except at northern region while sandy spit formation was visible at the eastern most area of the island (Figure 1).

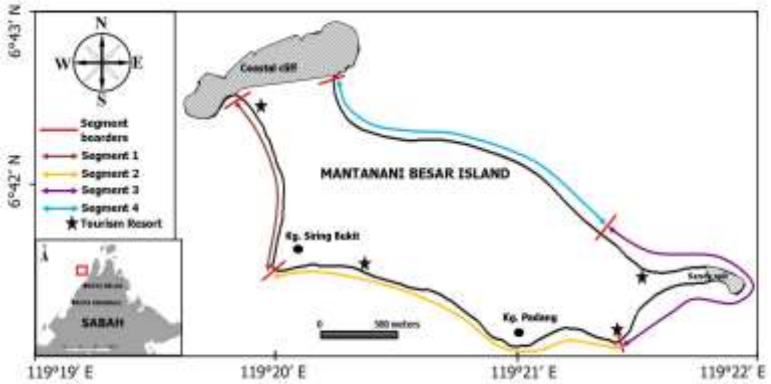

Figure 1. Map of study area (Mantanani Besar Island)

Method and measurement

Datasets (aerial photos and satellite image of Mantanani Besar Island) were acquired from various sources. Aerial photo 2013 was used as a base layer consistent with the stipulation of Department of Survey and Mapping Malaysia which it shows the existence of all features in the real world as well as the removal of the image displacement (Nielsen, 2004). Tidal readings indicate that all maps were taken during low tide with estimated tidal ranges (TR) were less than 1 m (Table 1).

Table 1. List of datasets

Dataset	Date	Time	Low tides	Scale/Resolution	Sources
Aerial Photo (scanned)	15/3/1986	08:22	07:11 (TR: 0.51 m)	1:40, 000	Sabah Forest Management
Aerial Photo (scanned)	7/12/1990	09:15	09:33 (TR: 1.66 m)	1:40, 000	Sabah Lands and Surveys Department
Aerial Photo (scanned)	6/4/2001	09:17	04:12 (TR: 0.94 m)	1:25, 000	Department of Survey and Mapping Malaysia
Satellite Image	27/2/2010	08:06	04:50 (TR: 0.94)	2.5 m	Malaysian Remote Sensing Agency
Aerial Photo (scanned)	8/2/2013	-	07:58	0.5 m	Department of Survey and Mapping Malaysia

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Coastline of Mantanani Besar Island was divided into 4 segments (seg) to identify the areas with the occurrence of most beach changes and dynamic beaches during the 28 years of time interval (1986 to 2013). These segments were chosen based on the cardinal directions where seg 1 was along the west coast, seg 2 was in the southern part of the island, seg 3 in eastern areas and seg 4 was located along the northern part of the island (see Figure 1).

Digital analysis of the coastline changes was carried out by ArcGIS Software Version 9.3. Ground Control Points (GCP) of each map were intermixed with hard and soft GCP and the coordinates were obtained from Google Earth. Scanned images were subjected to co-regristration that was achieved by georeferencing individual photos to the same base layer as followed by Hughes *et al*. (2006). The coastline was then digitized by creating polyline for each island. Layered colored polyline from different datasets enabled easy spotting on the difference coastline shapes. The beach changes (erosion and accretion) patterns and the changing values of each seg were revealed at each subtracting image overtime (1986 to 1990, 1990 to 2001, 2001 to 2010 and 2010 to 2013). Areas of changes, either erosion (E) or accretion (A), between the subtracting images were identified by creating a polygon at the changed areas and calculated by using the ArcGIS software. The projection systems used in ArcGIS Software was Timbalai 1948 RSO Borneo Meters. Negative (-) value of changes was considered as erosion while positive (+) value indicated accretion. The percentage of area changes (accretion minus erosion) in each segment were calculated based on the total area changes at all segments and the most dynamic area were based on the numbers of beach process occurrence (total numbers of erosion and accretion).

Results and discussion

Overlying remote sensing images shows that the coastline of Mantanani Besar Island is changing from 1986 to 2013. There is evidence of both beach erosion as well as accretion. Few noticeable changes occurred at the southwest and eastern part of the island especially at the spit area while no obvious changes were observed along the northwest (coastal cliff) of the island (Figure 2).

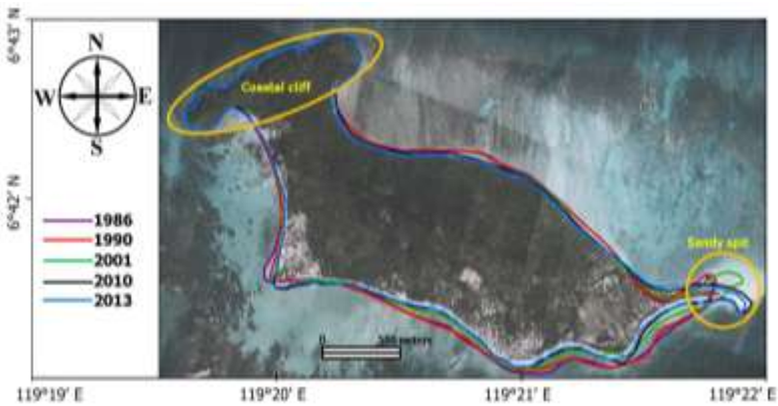

Figure 2. Difference in the shape of coastline trends at Mantanani Besar Island for various years

A total of 39 areas were identified that experienced beach changes throughout the 28 years. There were 22 eroded areas and 17 deposition areas. Total value of erosion exceeding accretion indicates that Mantanani Besar Island has been experiencing coastal erosion over the specific time period (Figure 3). According to Gibeaut *et al.*, (2001), if an area has been experiencing erosion for the previous decades, then the erosion process will eventually resume even though particular beach may have been advancing or stable over the last several years. The concept can be ruled out if there is a "permanent" increase or decrease in the sand supply that has changed the system. Therefore, Mantanani Besar Island will undergo erosion along its coastline with the exception of area A17 that had experienced deposition for the past decade (A7, A11 and A17) (see Figure 3).

The most dynamic seg with the highest occurrence of beach processes (erosion and accretion) were at seg 3 where 16 identified changes (eight erosion and eight accretion) were followed by seg 2 with 11 changes (five erosion and six accretion), seg 4 with 7 changes (six erosion and one accretion) and seg 1 with 6 changes (four erosion and two accretion) (see Figure 3).

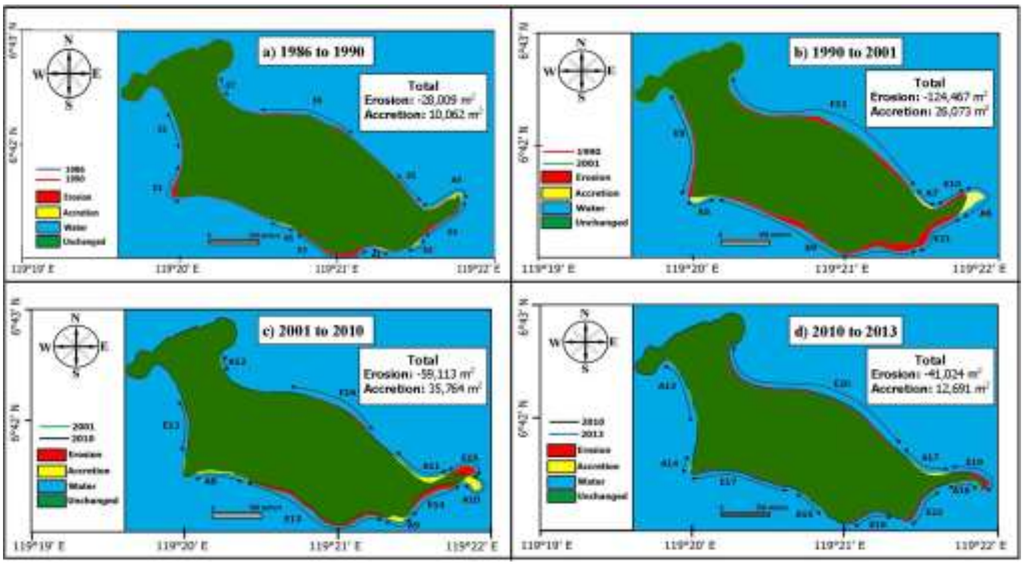

Figure 3. Identified areas with erosion (E) and accretion (A) trends at a) 1986 to 1990, b) 1990 to 2001, c) 2001 to 2010 and d) 2010 to 2013

The total erosion areas throughout the 28 years were estimated to be 168,113 m^2 (Table 2). Seg 2 has the highest beach loss estimated at 71,590 m^2 (43%) followed by seg 4 with 57,558 m^2 (34%), seg 1 with 23,008 m^2 (14%) and seg 3 with 15,957 m^2 (9%).

Table 2. Erosion and accretion at each segment

Segments	Accretion (m^2)	Erosion (m^2)	Total area changes (m^2)	Percentage of loss (%)
1	3,166	-26,174	-23,008 (Erosion)	14
2	21,084	-92,674	-71,590 (Erosion)	43
3	59,484	-75,441	-15,957 (Erosion)	9
4	766	-58,324	-57,558 (Erosion)	34
Total	**84,500**	**-252,613**	**-168,113 (Erosion)**	**100%**

The percentage of erosion was different at each segment might be due to the different levels of energy impacts either from natural processes or anthropogenic activities along the shore. The presences of most of the residents both locals (Kg Padang with a portion of Kg Siring Bukit) and tourists (three resorts) with no barrier in front of the beach lead both anthropogenic activities and natural factors to be high in seg 2. In contrast seg 4, with no developments along the shoreline has minimal impact from anthropogenic activities but the exposure of open ocean forces is high due to absence of barrier. The two islands (Linggisan and Mantanani Kecil Island) located adjacent to seg 1 might reduce the impact from natural phenomenon to the beach and the presence of only one resort and village (portion of Kampung Siring Bukit) keep the anthropogenic factors low in seg 1. Seg 3 have experienced substantial erosion of >10 m^2 (E14, E15 and E21) while high sediment gain (>10 m^2) also occurred mainly at the spit (A4, A6, A10 and A16) (Figure 3).

Conclusion

Mantanani Besar Island is experiencing a long-term erosion which is expected to continue in the future. Beach erosion prominently occurs along most of the island with few areas of accretions that have been identified. The greatest beach loss occurred at seg 2 followed by seg 4, seg 1 and seg 3. Different levels of energy from natural phenomenon and anthropogenic activities lead to different rates of erosion at each segment. The most dynamic beach is at seg 3 (eight erosions and eight accretions) followed by seg 2 (five erosions and six accretions), segment 4 (six erosions and one accretion) and segment 1 (four erosions and two accretions). Studies on detailed hydrodynamic forces (winds, waves and currents) of Mantanani Besar Island should be done to get a better understanding of the environmental forces acting around the island. studies on the combined hydrodynamic and beach changes would be useful in providing a scientific basis for taking measures aimed at protecting the island from further erosion.

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