Effect of Erosion and Accretion on Beach Profile in Kuala Terengganu Coastal Areas

Rohayu Haron Narashid¹, Muhammad Arif Zakaria¹, Fazly Amri Mohd¹, Muhammad Faiz Pa’suya¹, Noorfatekah Talib¹ and Effi Helmy Ariffin²

¹ Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Perlis Branch, Arau Campus, 02600 Arau, Perlis, Malaysia
² Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

Email: rohayuharon@gmail.com

Abstract. Coastal erosion and accretion are long-term processes that may cause changes in shoreline and beach profiles. Due to erosion and accretion effects, most of the coastal areas in Malaysia are suffering from destruction of property especially at the coastal areas in east coast of Peninsular Malaysia. This study was conducted to determine the effects of erosion and accretion on beach profiles at four (4) coastal areas in Kuala Terengganu using remote sensing and GPS observation methods. The objectives include to derive the coastal erosion and accretion rate, to measure coastal elevation for beach slope angle calculation, and to determine the relationship between beach slope angle with coastal erosion and accretion. The erosion and accretion rate was derived from SPOT-5 satellite image and unmanned aerial vehicles (UAV). In order to obtain the beach profile, the elevation with 50m offset for every chainage, and 5m offset for each cross-section point were carried out using real-time kinetic (RTK) observation methods. It was found that the highest and lowest erosion and accretion rates were 170.29 m²/year and 57.53 m²/year, respectively. The beach profile became steeper with the beach slope values of 11.004° and 7.652° at high and low erosion areas, respectively. The relationships between beach slope angle and coastal erosion/accretion were found as 0.12 and 0.86 respectively. The findings showed that steeper beach profiles influenced the high rate values of erosion and accretion. For more accurate findings, further studies on the factors affecting the erosion and accretion such as monsoon seasonal changes and morphological impact are necessary to support the reliable decision-making process for sustainable coastal management.

1. Introduction
Erosion is always related to extreme weather events and sedimentation. The sediment scarcity is one of the common conditions threatening the development of buildings and infrastructure, beaches, ecosystems and valuable wetlands that may lead to the erosion phenomena[1]. Generally, erosion and accretion can affect the elevation of the beach profile, causing changes of the beach slope elevation either higher or lower depending on how extreme the phenomena.

As mentioned by [2]-[4] Malaysia has about 4,809 km of coastline consisting of two (2) clearly different physical formations, namely the mangrove-fringed mud flats and sandy beaches. Additionally, [5] found that the beach profile along the coastline in the Malaysian East Coast consists of sandy beaches. The erosion and accretion of the coastal area are correlated with the high and low energy wave conditions. High energy waves erode the beach sand, while the supplies of low energy waves increase.
The critical problem is the rate of erosion increases dramatically especially in the east coast region of Malaysia [6]. According to [7], strong waves in the monsoon season have resulted in erosion closer to the highway. Effects of the erosion include damage and loss of property as mentioned by [8] where the fishing boats placed at Kampung Tengah near Kuala Terengganu Coastal Area were swept away by a storm with losses estimated at RM10,000. The construction work of the Sultan Mahmud Airport’s extensions as well as several coastal protection structures along this coast were also some of the causes affecting erosion and accretion in Kuala Terengganu[6].

There are various techniques that can be utilized to determine erosion and accretion including the use of statistical approaches [9] aerial photography, and topographic surveys. The current technique used to estimate erosion and accretion from historical data was implemented by [10] using the Bruun Model and the Geographic Information System (GIS) Techniques.

The aim of this study is to determine the effect of coastal erosion and accretion derived from SPOT-5 image and unmanned aerial vehicles (UAV) image on the beach profile using real-time kinetic (RTK-GPS) method at Kuala Terengganu. The objectives are (i) to derive the coastal erosion and accretion rates, (ii) to measure coastal elevation for beach slope angle calculation and (iii) to determine the relationships between beach slope angle and coastal erosion and accretion.

2. Study Area
This study was conducted at the coastal area in Kuala Terengganu. The location of study was divided in four (4) zone areas namely Zone A, Zone B, Zone C, and Zone D. Zone A is located at Pantai Batu Buruk, Zone B at Pantai Mengabang Kapal, Zone C at Pantai Pengkalan Maras, and Zone D at Pantai University Malaysia Terengganu. Every zone covers about 200m of coastal area, each zone having five (5) chainages with offset for every chainage is 50m, and the offset of cross-section to observe their elevation point is 5m every point. This area was selected due to the erosion that was entering a critical stage, with works to prevent the erosion are still in the process of reviewing and planning.

![Figure 1. Location of study area](image)

3. Data Used and Methodology
3.1 Data Acquisition
There were two main data used for this project which were acquired from the Institute of Climate Change (ICC) in the National University Malaysia (UKM) and the National Hydraulic Resource Institute of Malaysia (NAHRIM). The first data was taken is georeferenced SPOT-5 satellite image captured in 2014 as well as UAV image acquired in 2018. This data were compulsory for this project in order to prepare the base map for digitizing the shoreline, and to compute the erosion and accretion rates from the digitized data.
The second data was the elevation of the beach profile collected using RTK-GPS method and observed in MRSO coordinate system. To perform this process, control points were needed to be established. There were four (4) control points with one point established for each study zone area. BM1347 was used as reference for height values, while GNSS Levelling method was employed for the levelling process. For RTK-GPS observation, the point of chainage was made along the shoreline with offset interval of 50m for every chainage. To generate the surface of beach profile, a cross-section of the beach profile was taken for every chainage point with offset interval of 5m. Thus, the surface of beach profile can be generated.

3.2 Data processing

A Image Data Processing

3.2.1 Resolution merge
The first stage of image data processing was to perform resolution merge between georeferenced SPOT-5 satellite and UAV images using Erdas Imagine Software. The purpose of resolution merge is to integrate the SPOT-5 satellite image (2.5m) with UAV +/- 15cm. Thus, a similar spatial resolution was obtained.

3.2.2 Shoreline digitizing and overlay
The second stage was to digitize the shoreline from both image data. The scale of the image was remained along the digitizing process to avoid errors and to achieve the best accuracy. The digitized data was overlaid onto each other to generate the polygon of the area for accretion or erosion calculation. To determine the area of accretion or erosion, the line position towards the sea was referred. If the digitized line of the older period was located towards the sea, the coastal line was having erosion and vice versa. The attributes of the polygons also needed to be updated based on the fields: erosion status, the area of the polygon, coastal width, range year and erosion rates.

The processed RTK point coordinates value were then added into the workspace. The coastal zone region shapefile was produced by tracing the point which refers to the maximum extent of the polygon of coastal area changes towards offshore and inland. The coastal region was then divided into 16 different areas by digitizing the RTK slope line.

The coastal area zone created was then used to extract the information of coastal area changes to the desired extent. Using the Intersect tool, coastal area changes of both temporal period and the coastal area zone were intersected to obtain the coastal area changes for the selective zones. The attributes were inspected to ensure the information regarding the erosion and accretion area was correctly displayed with no errors occurred during performing the analysis.

3.2.3 Calculation of erosion rate
The calculation of the erosion and accretion rates was done in the ArcGIS software. The information needed to calculate the rate of erosion and accretion includes the area of erosion and accretion, as well as the range year of data used i.e. 2014 until 2018. From the information obtained, the formula to compute the rate of erosion and accretion by [11] was as applied as follows:

$$Erosion and Accretion Rates = \frac{\text{Area (meter)}}{\text{Range year}}$$

B. In Situ Data Processing

Control Point Processing
The control point processing was done using the correction data from three (3) Continuously Operating Reference Stations (CORS) namely Kuala Terengganu, Setiu, and Teris. By applying the GNSS levelling method, four (4) control points were established.
Generate Beach Profile
The RTK data of beach elevation was then exported from the GPS controller into the Microsoft Excel software. Based on the data, the beach profile was generated for every chainage and the results were shown in line graph.

Beach Slope Angle Calculation
The beach slope angle from the elevation data at every chainage was calculated using the formula from David R. Maidment (2011):

\[
\tan (slope) = \frac{\text{rise}}{\text{run}}
\]

(2)

Where \(\text{rise} = y_2 - y_1\) and \(\text{run} = x_2 - x_1\).

The analysis was carried out to determine the relationship between the beach slope with the rate of coastal erosion and accretion.

\[\tan (slope) = \frac{\text{rise}}{\text{run}}\]

(2)

Where \(\text{rise} = y_2 - y_1\) and \(\text{run} = x_2 - x_1\). Therefore, from the results, the analysis was carried out to determine the relationship between the beach slope and the coastal erosion and accretion rates.

The overall methodology flow chart can be seen in Figure 2.

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**Figure 2.** Research Methodology Flowchart
4. Results and discussion

4.1 Erosion and Accretion Rates

Shoreline images of SPOT-5 satellite image and UAV image data were digitized and overlapped in order to identify the erosion and accretion area at Zone A, Zone B, Zone C, and Zone D as shown in Figure 3(a), 3(b), 3(c), and 3(d) respectively.

Table 1 lists the rate of erosion and accretion for each zone. The average of erosion at Zone A from 2014 to 2018 was very high compared to other zones with 170.29 m²/year. The average of erosion was lower at Zone B with 164.79 m²/year. Zone C recorded the lowest rate of erosion and only has an accretion rate with 98.81 m²/year. These results were affected by the location of the study area from the development area.
Table 1. Erosion rates and accretion on year 2014 and 2018

| Zone | Area | Zone Area (m²) | Erosion Area (m²) | Erosion Rate (m²/year) | Average between erosion rates and accretion (m/year) |
|------|------|----------------|-------------------|------------------------|-----------------------------------------------|
| A    | A1   | 1617.26        | 679.67            | 135.93                 | 170.29                                        |
|      | A2   | 1810.22        | 1019.25           | 203.85                 |                                               |
|      | A3   | 1495.16        | 849.05            | 169.85                 |                                               |
|      | A4   | 1614.18        | 857.92            | 171.58                 |                                               |
| B    | B1   | 1111.71        | 636.704           | 127.34                 | 164.79                                        |
|      | B2   | 1134.13        | 711.616           | 142.32                 |                                               |
|      | B3   | 1155.79        | 872.252           | 174.45                 |                                               |
|      | B4   | 1377.35        | 1075.33           | 215.07                 |                                               |
| C    | C1   | 828.45         | 533.27            | 106.65                 | 98.81                                         |
|      | C2   | 623.23         | 498.24            | 99.65                  |                                               |
|      | C3   | 711.73         | 542.75            | 108.55                 |                                               |
|      | C4   | 794.07         | 401.90            | 80.38                  |                                               |
| D    | D1   | 1269.68        | 482.19            | 96.44                  | 57.53                                         |
|      | D2   | 1322.71        | 249.42            | 49.88                  |                                               |
|      | D3   | 1468.01        | 47.305            | 9.461                  |                                               |
|      | D4   | 2156.95        | 347.816           | 69.56                  |                                               |

4.2 Beach Profiles and Slope Angles

Figure 4 shows that the location of Zone A was the furthest zone between other zones with approximately 10 km from the development area, while the location of Zone D was the nearest zone with 4 km. This result was clearly affected by the erosion and accretion surrounding the development area, whereby the result of Zone A recorded the highest average for the rate of erosion due to its further location from the development area. The development area caused erosion at the neighbouring areas due to the sand reclamation project to form a runway platform for the Sultan Mahmud Airport in Kuala Terengganu. The expansion was built towards the sea with beach nourishment in order to accommodate the operation of 747-400 aircraft landing at the airport [13]. The engineering structure known as revetment was built to protect the nourishment area from erosion. The protection of the beach using hard structures caused erosion to the coastal surroundings since the protected beach will no longer contribute sediment to the local coastline [14].
Figure 5. Beach profile every zone

Table 2. Result of slope angle, erosion and accretion rates

| Zone | Area | Erosion Area (m³) | Slope Angle (°) | Rate of Acc (m²/year) | Rate Ero (m²/year) |
|------|------|------------------|----------------|---------------------|-------------------|
| A    | A1   | 679.67           | 6.34           | -                   | 135.93            |
|      | A2   | 1019.25          | 6.12           | -                   | 203.85            |
|      | A3   | 849.05           | 5.94           | -                   | 169.81            |
|      | A4   | 857.92           | 5.56           | -                   | 171.58            |
| B    | B1   | 636.70           | 8.27           | -                   | 127.34            |
|      | B2   | 711.62           | 9.55           | -                   | 142.32            |
|      | B3   | 872.25           | 13.01          | -                   | 174.45            |
|      | B4   | 1075.33          | 13.19          | -                   | 215.07            |
| C    | C1   | 533.27           | 8.01           | -                   | 106.65            |
|      | C2   | 498.24           | 8.24           | -                   | 99.65             |
|      | C3   | 542.75           | 8.47           | -                   | 108.55            |
|      | C4   | 401.90           | 8.07           | -                   | 80.38             |
| D    | D1   | 482.19           | 8.77           | -                   | 96.44             |
|      | D2   | 249.42           | 6.90           | -                   | 49.88             |
|      | D3   | 471.11           | 5.97           | 9.46                | 4.77              |
|      | D4   | 347.82           | 7.46           | 69.56               | -                 |
Table 3. Slope Angle Average

| Zone | Slope Angle Average (°) |
|------|-------------------------|
| A    | 6.34                    |
| B    | 11.00                   |
| C    | 8.13                    |
| D    | 7.65                    |

Figure 5 shows the plotted graph of beach profiles for Zones A, B, C, and D. The profiles for each zone were plotted based on the elevations observed at five (5) chainages ranging between 0.5m to 4.5m at distances of 0 to 25m. Based on the profiles, the slopes were computed (refer to Table 2). Table 3 shows the average slopes angles for each zone. The average slope at Zone A was 6.14° since this area has natural breakwater located about 300m from the coastal area, thus affecting the result of the slope angle at Zone A that was lower than other zones. The breakwater functions as wave barriers to prevent high waves from reaching the coastal directly. Meanwhile, Zone B (11.004°) was the highest average beach slope compared to other zones. The number then decreased as Zone C was 8.133° and Zone D was 7.652°. Generally, the slope angle was decreased due to the site’s location nearer to the construction area of the airport. The beach nourishment occurred at the airport construction, thus affecting the nearby coastal area. Therefore, the further the coastal area from the construction site, the beach slope angle increases and the beach profile becomes more steep [15].

4.3 Relationship Between Slope Angle and Coastal Erosion

Figure 6 (a) shows the relationship between slopes with the rate of erosion and accretion for all zones A, B, C, and D, where the $R^2$ is 0.1231. The beach slope angle value for Zone A was low, but the rate of erosion and accretion was high. Thus, Zone A affected the $R^2$ value to become low due to the natural breakwater located about 300m from the coastline of this area. In Figure 6 (b), the $R^2$ is 0.8625 with the relationship between slopes with the rate of erosion and accretion for Zones B, C, and D. The results showed that the coastal erosion and accretion at Zones B, C, and D really affected the beach slope angles. Overall, the beach slope angles will increase as the rate of erosion and accretion increases.

![Figure 6 (a). The relationship between erosion and accretion rates and slope angles.](image-url)
5.0 Conclusions
The Coastal erosion and accretion are phenomena that can cause bad effects to the surroundings. The findings showed that the rate of erosion and accretion can really affect the beach profile directly which increased starting from Zone D with the lowest rate erosion and accretion at 57.5271 m²/year that affected the beach profile with 7.652°. The results showed an increase in Zone B with the rate of erosion and accretion at 164.79 m²/year and the value of beach slope angle at 11.004°. The results were different for Zone A with a high rate of erosion and accretion at 170.29 m²/year, but the beach slope angle value was the lowest at 6.14°. This was due to the natural breakwater located about 300m from the coastal area of Zone A. The breakwater functions as wave barriers to prevent high waves from reaching the coastal area directly. For future research, the factors affecting the erosion such as change of seasons at the study area and related morphology data can be considered to obtain better the accuracy and best result. The results can help in decision-making process for sustainable coastal management.

Acknowledgements
The authors wish to thank of all members from Centre of Studies Surveying Science and Geomatics, UiTM Cawangan Perlis, Universiti Malaysia Terengganu, Universiti Kebangsaan Malaysia and NAHRIM for suggestions and comments on the improvement of the research. The study was funded by UiTM internal LESTARI SDG-Triangle (600-RMC/LESTARI SDG-T 5/3 (103/2019)).

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