Beach Profile Assessment and Erosion Rate Estimation of Monsoonal Coastline Area in Pahang, Malaysia

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Abstract. Malaysia has a long coastline stretching over 4,809 km where more than 1,300 km of beaches are experiencing erosion. Coastal erosion is defined as the permanent loss of land and habitats along the coastline resulting in changes to the coast. Thus, it is important to detect and monitor coastline changes especially in Pahang, Malaysia. This study used temporal data and high spatial resolution imagery of SPOT 5. It also explored remote sensing and GIS techniques to monitor coastline changes along 10 identified locations, from Cherating to Pekan of the Pahang coast. Ten significant coastline locations namely Pantai Cherating, Pantai Air Balok, Sungai Ular, Pantai Batu Hitam, Pantai Beserah, Swiss Garden Kuantan, Taman Gelora, Pantai Sepat, Pantai Cherok Palok, and Pantai Tanjung Agas were identified to be vulnerable to coastline erosion. Two temporal remote sensed date of SPOT 5 for the year of 2006 and 2014 were used to quantify erosion or accretion rate using National Coastal Erosion Study (NCES) guidelines. The research found that eight area out of 196 or 39.7% locations were eroded and categorized into acceptable erosion category (K3), while 64 area or 32.7 % had significant erosion category (K2) where the coastline retreated more than one meter per year and the most critical eroded area was K1 at 54 or 27.6% sites. Cherating, Swiss Garden Resort, and Cherok Paloh were among the sites with the highest erosion rate between -5.692 and -6.919 m/yr. Meanwhile, the highest rate of accretion or sedimentation was indicated in Tanjung Agas at 7.391 m/yr. A qualitative relationship between the erosion rate and slope percentage for the entire Kuantan coast that stretch from Pantai Cherating to Tanjung Agas, Pekan indicated that the coastal slope percentage, the beach width, and the beach material that deposited on the sites were interrelated and had significant impacts on the erosion rate on several particular zones of the Kuantan coastlines. The findings from monitoring coastline changes and identifying vulnerable erosion areas might be useful in the policy and decision making for sustainable coastal management.
1. Introduction
The coastal zone is defined as a narrow area of land adjacent to the coastline where the sea and the land intersect. This area is a highly dynamic and complex environment characterized by a multitude of processes and activities. The low-water line of a coastal state is the starting point of the baseline. Straight baselines may be used when the coastline is deeply indented, has fringing islands or is highly unstable. Baseline is important because it is fundamental to maritime claims. Baseline is the starting point for claiming maritime zones. Every coastal state has jurisdiction over the oceans and seas, the limits of which are defined by international conventions and national regulations must confirm to international law. The severity of shoreline erosion was defined by several factors, including geomorphologic properties and land use (Pile et al., 2017).

Beaches are made up of eroded material that has been transported from elsewhere and deposited by the sea. The open sandy beach is a natural sediment buffer for coastal systems. Erosion and accretion of this buffer are correlated with high and low energy wave conditions. High energy waves erode sand from the beach, while low energy waves supply sedimentary material. The smallest material is deposited near the water and larger material is found nearer the cliffs at the back of the beach. Most waves break near the coastline, so sediment near the water is more effectively broken down by attrition. The processes outlined can present problems to unprotected coastal areas, such as the Kuala Terengganu lagoon. The National Coastal Erosion identified that 29% of the Malaysian coastline was in various stages of evacuation (Ghazali, 2006).

The east coast of Peninsular Malaysia is exposed to higher current speeds compared to the west coast. Pahang is one of the largest states which are located on the east coast of Peninsular Malaysia. Coastal areas in Pahang offer many beautiful beaches with fascinating landscape and scenery, which capture the attention of visitors and tourists. Cherating, Teluk Chempedak, Tanjung Lumpur, and Pantai Sepat are the most attractive beaches in Pahang, which attract people for recreational activities (Mohd et al., 2014). Pahang lays on the Eastern part of Peninsular Malaysia making it exposed to maximum current speeds of winds during two seasonal monsoons. Pahang coastline was identified as having been badly eroded with erosion rates ranging from -3 m/yr to -5m/yr and in some places it was more than -5m/yr (Mohamad et al. 2014). This condition would make people move inland and find other higher places that are suitable for agriculture and residential.

Since the 2010s, several strategies have been adapted to prevent further erosion and protect the eroded beaches in Pahang coast. These projects, consisting of the construction of a series of groins and breakwater, have been implemented along the Kuantan Port and Pantai Batu Hitam, Kuantan. Kuantan Port is one of the major maritime gateways to the east coast region of Peninsular Malaysia and contributes to Pahang economy. Fishery and aquaculture products are also a main source of income especially for the communities on the long coastline and large network of rivers of the state.

Coastal areas are categorized by high concentrations of human settlements where population density is usually three times the global mean. If the problem remains unsolved within five to ten years, the beaches in the area might be fully eroded. Akhir and Jawchuen (2011) noted that during the Northeast Monsoon season, the surface current runs southward along the east coast of Peninsular Malaysia. Strong waves are prevalent during the northeast monsoon when the winds are onshore, while during the southwest monsoon, the winds are offshore and low energy. Thus, this study utilized remote sensing data on coastal extraction to quantify the rate of erosion and accretion along selected Kuantan coastline. Association with coastal slope as estimated from active remote sensing data such as IFSAR and open-source data such as Google Earth images were also included to understand the relationship between erosion rate with beach morphology characteristics (i.e., beach width, sand types, beach slope).

2. Study Area and Methods

2.1. Study Area
The study area encompasses the coastal areas from Cherating to Pekan along the coast of Pahang state, which is located in the east coast of Peninsular Malaysia facing the South China Sea. The coastal areas
are low lying areas between the latitude 4° 07’ 38.39” and 3° 32’ 5.25” East and longitude 103° 23’ 44.68” and 103° 27’ 41.08” North. Coastal erosion is always accompanied with a shoreward recession of the coastline and the loss of land area which also largely depends on the nature of the waves. However, the study area covers approximately 83.91 km of the coastal length from Cherating to Pekan where sand materials make up the entire coastline. The geomorphology of coastal areas from Cherating to Pekan is a sandy type. The climate of Pahang is characterized by the Northeast monsoon which prevails between November and March. The annual temperature is between 25.6 °C and 27.8 °C (Malaysian Meteorological Department 2016). This study identified ten zones based on ten locations from Cherating to Pekan coastal areas namely Pantai Cherating, Kampung Sungai Ular, Pantai Rekreasi Air Balok, Pantai Batu Hitam, Pantai Kampung Beserah, Swiss Garden Resort, Taman Gelora, Pantai Sepat, Cherok Paloh and Tanjung Agas as shown in Figure 1.

2.2. Data Acquisition
The aim of this study is to determine beach profile and comparison with remotely sensed data while analyzing the relationship towards erosion event that happened. However, a traditional method which is beach profiling was still needed to perform to compare the results by checking the accuracy and precision. Thus, traverse, levelling, and GPS observation needs were established for acquiring the ground control points (GCPs). Three stages of data acquisition were done i.e., GPS observation, traversing and levelling; satellite imageries; and beach profiling. Data used in this study was obtained from different temporal resolutions covering the coastlines from Pantai Cherating to Tanjung Agas, Pekan. Temporal resolution refers to the data acquisition between the changes occurring between 2006 and 2014. Table 1 shows the data acquisition from different department and universities performed for this study.

Table 2 presents data acquisition regarding data types, date and time of acquisition and spatial resolution of SPOT data. In this study, the projection system used for image satellite is Geodetic Datum of Malaysia (GDM) 2000. The acquisition date relied on the availability of satellite operation while
capturing the images and at the same time, avoiding cloudy and bad weather conditions in this area. Commonly, in remote sensing principle, the coastline can be extracted from a single band image, since the reflectance of water is nearly equal to zero in the reflective infrared bands (Lillesand and Kiefer, 2004).

Table 1. Data acquisition from respected agencies.

| Raw Data                          | Acquisition Years | Department/Institute/Agency                                         |
|-----------------------------------|-------------------|---------------------------------------------------------------------|
| SPOT-5                            | 2006 and 2014     | Department of Survey and Mapping Malaysia (JUPEM) through Universiti Kebangsaan Malaysia (UKM) |
| IFSAR                             | 2010              |                                                                     |
| Elevation Profile (Google Earth)  | 2010              | Open-source data extracted from Google Earth Pro                   |
| GPS Survey (Slope)                | 2018              | National Hydraulic Research Institute of Malaysia (NAHRIM)         |
| Site Visit                        | 2018              | Universiti Teknologi MARA (UiTM) supervision by Universiti Kebangsaan Malaysia (UKM) |
| Geomorphology and geological studies | 2007              | Department of Irrigation and Drainage (DID)                       |
| Malaysian Tidal Harmonic constant | 2017              | JUPEM and National Hydrographic Centre (NHC)                       |

Table 2. Satellite image specification (SPOT-5).

| Date of acquisition | Tidal Height | Event | Time of Acquisition | Spatial Resolution |
|---------------------|--------------|-------|---------------------|--------------------|
| 02/07/2006          | 2.5 m        | High Tide | 11.49 am          | 2.5 m              |
| 22/08/2014          | 2.2 m        | High Tide | 11.00 am          | 2.5 m              |
| 20/07/2006          | 1.9 m        | Low Tide  | 11.49 am          | 2.5 m              |
| 05/08/2014          | 1.8 m        | Low Tide  | 11.03 am          | 2.5 m              |

2.3. Methods

Figure 2 shows the flowchart of this research. The stages consist of identification of problem, reconnaissance, planning and design, data acquisition, data processing, and result and analysis. GPS observation was necessary because the GCP establishment can be done from traversing and levelling (Labuz, 2016; Andrade et al., 2006). However, this research focused on the accuracy of different methods for obtaining the GCP. Thus, GPS observation was conducted on every traverse station for checking the accuracy between traverse data and GPS data. All that was required was a GPS receiver, available in different models and at different accuracies. For this research, the GPS observation method used was the MyRTKnet method. MyRTKnet method is a very fast method with only one or two seconds of observation depending on the availability of satellite during the time of observation. The concept of MyRTKnet is that the data captured during one observation is approximately 300 data. Afterwards, the system calculates the mean and saves the mean data only.
2.3.1. Physical and Economic Factor Determination for Erosion Rate Calculation. The physical erosion rates of coastline analysed from historical satellite images were used as the physical parameters in determining the erosion categorisation. It was noted that the erosion rates might vary along a stretch of eroding coastline. The maximum retreat rate analysed was used for the purpose of erosion categorisation. The scoring of physical parameter based on the physical erosion rates are given in Table 3. Physical erosion is considered “High” for annual erosion rates greater than 4 m/year and “Low” for annual erosion rates less than 1 m/year. Erosion rates that ranged between 1 and 3.9 m/year are considered as “Medium”.

**Figure 2.** Flowchart of Beach Profiling and Erosion Rate.
Table 3. Scoring for physical parameter (NCES, 2015).

| Parameter                  | Description | Erosion Rate (m/year) | Physical Erosion Score |
|----------------------------|-------------|-----------------------|------------------------|
| Rate of coastline from      | Low         | ≤0.99                 | Actual erosion rate (m/year) |
| Medium                     | 1.00 to 1.99|                       | 2 points               |
| High                       | 2.00 to 2.99| 3 points              |
|                           | 3.00 to 3.99| 4 points              |
|                           | ≥4.00       | 5 points              |

An economic parameter is based on the economic significance of the stretch of eroding coastline. For the purpose of erosion categorization, the economic significance can be described by the following components such as land use, building and establishment, public utilities and amenities that exist in the area (NCES, 2015).

\[
\text{Total Score} = \text{Physical Parameter Score} \times \\
\left[ 0.1 \times \text{Land Use Rating} + 0.4 \times \text{Buildings and Establishments Rating} + 0.3 \times \text{Public Utilities and Infrastructure Rating} + 0.2 \times \text{Public Facilities and Amenities Rating} \right]
\]  

(Eq 1)

2.3.2. Slope Derivation. The main concerns and results for this study are slope profiles for the beach and the erosion rate tables with verification sensor-based remote data of IFSAR and Google Earth (high spatial resolution). Figure 3 shows the data processing flow chart for the slope profiles that were obtained from three different sources and techniques applied.

\[
\text{Slope Percentage} \ (\%) = \left( \frac{\text{Elevation}_{\text{maximum}} - \text{Elevation}_{\text{minimum}}}{\text{Cumulative Distance}} \right) \times 100\%
\]

Figure 3. Data Processing for Coastal Slope Derivation.

Thus, the survey and satellite data extraction needed to be accurate and proven to support the relationship of erosion phenomenon that occurred in Kuantan, Pahang. Therefore, the actual coastline was mapped and the eroded and accredited area were determined, especially on coastal habitable land where the baseline had been changing due to reclaiming activities. The formula (Eq.2) below was used for the calculation of slope percentage for both IFSAR and Google Earth data.
3. Result and analysis

High-resolution satellite imagery of SPOT-5 obtained from the Malaysia Remote Sensing Agency for the years of 2006 and 2014 were used to derive the coastline along Kuantan area. Accredited and eroded polygon area were determined through ArcGIS spatial analysis processing so that further categorization of erosion rate using the NCES categorization could be performed. The IFSAR measurement data that were obtained from Malaysia’s Department of Surveying and Mapping (JUPEM) and National Hydraulics Research Institute Malaysia (NAHRIM) were used for further erosion rate analysis, beach slope profiling and to figure out the relationship between these two outputs. The IFSAR data were compared to Google Earth and GPS survey to obtain the exact elevation of each selected beach slope for profiling. Moreover, to validate the accuracy of estimated beach slope from the IFSAR and Google Earth, physical site verification was conducted from 28 October 2018 until 30 October 2018 and comparison to the NAHRIM slope data was done.

3.1. Physical Site Verification

Site visits for verification purposes were done from 28 October until 30 October 2018 and served as verification data for estimation of accretion and erosion rate derived from satellite SPOT 5 data. The data collected includes the coordinates (x, y) for each site, time, wind speed, temperature, types of tides, geomorphology of the beach and the types of nearby facilities. All of the data collected were used for the relationship quantification of coastal erosion and slope profile along the study area. Table 4 shows the information gathered from the site visit of each location along Kuantan coastline.
### Table 4. Site Verification along Kuantan coastline.

| Details | Zone |
|---------|------|
| **Easha Cheating** | ![Image](image1.jpg) |
| Date: 29/10/2018 |  |
| Time: 15:42:50 |  |
| Coordinates: N 4° 07.517’ | ![Image](image2.jpg) |
| E 103° 23.624’ |  |
| Wind Speed: 3.9 m/s | ![Image](image3.jpg) |
| Temperature: 34.5°C |  |
| Tide: Low tide | ![Image](image4.jpg) |
| Geomorphology: White fine sandy beach |  |
| Facility: Tourist Attraction |  |
| **Kampung Surgai Urii** | ![Image](image5.jpg) |
| Date: 29/10/2018 |  |
| Time: 16:23:20 |  |
| Coordinates: N 4° 03.233’ | ![Image](image6.jpg) |
| E 103° 23.817’ |  |
| Wind Speed: 6.0 m/s | ![Image](image7.jpg) |
| Temperature: 30.3°C |  |
| Tide: High tide wants to begin | ![Image](image8.jpg) |
| Geomorphology: Back (White fine sand) Front (Yellowish brown course and solid texture) |  |
| Facility: Residential |  |
| **Desa Laksamana Air Balok** | ![Image](image9.jpg) |
| Date: 29/10/2018 |  |
| Time: 16:58:10 |  |
| Coordinates: N 3° 55.126’ | ![Image](image10.jpg) |
| E 103° 22.423’ |  |
| Wind Speed: 5.2 m/s |  |
| Temperature: 29.8°C |  |
| Tide: High tide begins |  |
| Geomorphology: Course sand (Grey color) | ![Image](image11.jpg) |
| Facility: Recreational Area |  |
Some of the area were not accessible due to restrictions and that they were labeled as private properties which limited accessibility to the sites for site verification. The geomorphology and types of sands that existed served as an indicator of erosion with grain size and slope property (steep or slant).

3.2. Coastal Erosion and Accretion Analysis

Ten significant eroded spots were identified as shown in Figure 5, namely Pantai Cherating, Pantai Air Balok, Swiss Garden Resort Kuantan, Kampung Sungai Ular, Pantai Batu Hitam Beserah, Kampung Pantai Beserah, Taman Gelora, Pantai Sepat, Pantai Cherok Palok and Pantai Tanjung Agas. As shown in Table 5, there are 78 area out of 196, which means 39.7% locations were eroded and being categorized as K3 of acceptable erosion category (Table 3). The category was given based on the NCES 2015 guidelines which indicates that a total score of lower than or equal to 5 is considered as acceptable category. About 64 area or 32.7 % was of significant erosion category (K2) where the coastline had retreated more than 1 meter per year on a generally sparse populated area with some agricultural
activities. A significant value means the threat of erosion on that spot is imminent and if it is left untreated it can be worsened in upcoming years and preventive measures should be taken by the local authorities. The most critical eroded area was K1 which consisted of 54 sites or 27.6% of the sites with fast retreating coastline in fairly dense human settlement and significant public infrastructure. These critical areas are usually left by people and the soil is not suitable for vegetation. Beach nourishment or construction of sea walls could save the residential area along the coastline. People would lose their homes otherwise, and compensation would be high to be sustained by local authorities. There was a total of up to 205.66 hectares of area that had been eroded along 103 kilometers stretching from Cherating to Pekan indicating the needs for future preventive measures.

Table 5. Summary of erosion categories in Kuantan, Pahang coastal area.

|          | Coastline Length (m) | Area (Hectare) | Area (Acre) | Area (Sq. Meter) | Condition | Coastline Width (m) |
|----------|----------------------|----------------|-------------|------------------|-----------|---------------------|
| Total K3 | 15928.923            | 5.560          | 13.738      | 55596.979        | Acceptable| 746.431             |
| Total K2 | 42604.100            | 46.414         | 114.691     | 464136.652       | Significant| 1682.398           |
| Total K1 | 97815.691            | 205.659        | 508.194     | 2056586.006      | Critical  | 2910.123            |

Based on Table 5 and Figure 4, Cherating, Swiss Garden Resort and Cherok Paloh were among those with the highest erosion rates, between -5.692 and -6.919 m/yr. Comparing beach profiles in this study, no significant changes of accretion were found in two locations, Cherating and Balok. Meanwhile, the highest rate of accretion value was indicated in Tanjung Agas at 7.391 m/year. Based on the location of the coastline that was facing the South China Sea, this result is also supported by Mohd et al. (2018) which stated that beach erosion occurring along the coastline of the east coast states of Peninsular Malaysia is mainly due to large waves activity during the northeast monsoon seasons (Husain et al., 1998, Ariffin et al., 2016).

Other areas such as Kampung Sungai Ular, Pantai Rekreasi Air Balok, Pantai Batu Hitam Beserah and Pantai Sepat had erosion rates ranging from -3.369 to 4.373 m/yr. The accretion rates at these four locations were slightly increasing due to erosion at about 20% per year. Beach materials for the study area were made of flat white sandy beach with minimum development in the surrounding area. Most activities were agriculture and coastal residential with fisheries industry booming along the coastline. Taman Gelora, which is situated near Pekan, also had a moderate erosion rate of -4.550 m/yr and accretion rate of about 2.479 m/yr. Some mitigation structures were built along its shore, such as a breakwater of about one kilometer in length.

Figure 4. The rate of erosion and accretion at ten locations in the study area (m/yr).
3.3. Beach Profile and Coastal Slope Derivation

The digital elevation model (DEM) created from an IFSAR system is essentially a first-surface DEM, also known as digital surface model (DSM). The digital terrain model (DTM), representative of the earth’s terrain, is obtained by editing the DSM using a semi-automated process during which all man-made and vegetation features are removed. The distribution of beach profiles was along the ten locations facing the South China Sea. The findings of in-situ measurements showed that the study area mainly consisted of sandy beach, while the Cherating area had rocky shores and sandy beaches except at the mouth of the river where the sandspit had been formed. Apart from that, Sungai Ular, Balok and Tanjung Agas consisted of fine sand and medium sand.

Figure 5 shows the topographic profile section of Pahang coast. From the ten area, Pantai Cherating and Tanjung Agas had steeper slopes with values ranging between 1.5-3.6%. Meanwhile, Sungai Ular, Pantai Balok, Pantai Sepat, and Cherok Paloh were represented by flatten and wider areas. These areas are known for the most fascinating beaches in Pahang, which attract many tourists for recreational activities. Meanwhile, Kampung Sungai Ular and Kampung Pantai Beserah had the least elevated beach with elevation height ranging from 0.192 to 16.775 meters from the mean sea level. The most elevated beach in Kuantan was Pusat Rekreasi Air Balok with a range of 2.265 and 20.556 meter. These data were further verified with in-situ data by NAHRIM and site verification survey. The profile for Air Balok beach consisted of small dunes along the vegetation line. Many bushes and sparse vegetation along the shore and wide beaches were also spotted and they were very suitable for social activities.
There are many ways to determine coastal slope, subjected to the specific region. In this study, IFSAR data and Google Earth were utilized to derive elevation (Z value) and position (X and Y value) for each point of the ten locations along the coastline. GPS survey conducted by NAHRIM was considered as observed data and the accuracy was higher than the estimated slope from IFSAR and Google Earth. Table 6 shows the slope estimation from IFSAR, Google Earth and NAHRIM, represented as slope percentage value.

Table 6. Coastal slope percentage for ten eroded zones taken from IFSAR (2010), Google Earth (2010) and NAHRIM (2018).

| Station                  | Chainage | IFSAR (Estimated slope) | Google Earth (Estimated slope) | NAHRIM (Observed slope) |
|--------------------------|----------|-------------------------|-------------------------------|-------------------------|
| Pantai Cherating         | CH1:     | 4.818                   | 4.237                         | 4.504                   |
|                          | CH 2:    | 5.154                   | 5.952                         | 1.265                   |
|                          | CH 3:    | 5.348                   | 10.460                        | 3.103                   |
| Kampung Sungai Ular      | CH1:     | 1.542                   | 1.379                         | 1.665                   |
|                          | CH 2:    | 3.973                   | 5.072                         | 2.641                   |
|                          | CH 3:    | 4.721                   | 5.147                         | 1.900                   |
| Pantai Rekreasi Air Balok| CH1:     | 2.211                   | 2.242                         | 2.374                   |
|                          | CH 2:    | 2.951                   | 3.703                         | 1.180                   |
|                          | CH 3:    | 3.951                   | 4.048                         | 1.135                   |
| Swiss Garden Resort      | CH1:     | 6.332                   | 6.482                         | 3.165                   |
| Kuantan                  | CH 2:    | 6.914                   | 6.723                         | 6.400                   |
|                          | CH 3:    | 9.336                   | 8.605                         | 2.852                   |
| Pantai Batu Hitam Berserah| CH1:    | 3.234                   | 3.824                         | 3.464                   |
|                          | CH 2:    | 2.059                   | 4.662                         | 7.837                   |
|                          | CH 3:    | 6.982                   | 9.174                         | 4.496                   |
| Kampung Pantai Beserah   | CH1:     | 3.023                   | 5.780                         | 5.181                   |
|                          | CH 2:    | 4.693                   | 7.650                         | 6.104                   |
|                          | CH 3:    | 10.259                  | 3.363                         | 4.320                   |
Table 7 shows the quantification of difference between observed slope (NAHRIM) and estimated slope (IFSAR and Google Earth). The equation below is used to determine the accuracy of the observed value compared to the estimated value from satellite (IFSAR and Google Earth). The equation below is used to calculate the difference as stated above.

\[
\text{Difference in Slope} \% = \frac{\text{Observed Slope} (a) - \text{Observed Slope} (b)}{\text{Observed Slope} (a)} \times 100 \\
\text{(Eq.3)}
\]

| Station                      | Chainage | Slope (%)                  |
|------------------------------|----------|----------------------------|
|                              |          | IFSAR (Estimated slope)    |
|                              |          | Google Earth (Estimated slope) | |
|                              |          | NAHRIM (Observed slope)    |
| Taman Gelora                 | CH1:     | 3.894                      |
|                              |          | 3.351                      |
|                              |          | 3.651                      |
|                              | CH 2:    | 8.261                      |
|                              |          | 4.070                      |
|                              |          | 15.236                     |
|                              | CH 3:    | 7.595                      |
|                              |          | 3.012                      |
|                              |          | 13.447                     |
| Pantai Sepat                 | CH1:     | 3.457                      |
|                              |          | 6.390                      |
|                              |          | 4.542                      |
|                              | CH 2:    | 3.987                      |
|                              |          | 6.202                      |
|                              |          | 5.067                      |
|                              | CH 3:    | 5.553                      |
|                              |          | 3.200                      |
|                              |          | 3.241                      |
| Cherok Paloh, Pekan          | CH1:     | 2.910                      |
|                              |          | 3.478                      |
|                              |          | 9.212                      |
|                              | CH 2:    | 8.587                      |
|                              |          | 6.202                      |
|                              |          | 5.067                      |
|                              | CH 3:    | 11.441                     |
|                              |          | 10.626                     |
|                              |          | 5.660                      |
| Tanjung Agas, Pekan          | CH1:     | 3.972                      |
|                              |          | 5.000                      |
|                              |          | 6.141                      |
|                              | CH 2:    | 7.522                      |
|                              |          | 5.502                      |
|                              |          | 7.776                      |
|                              | CH 3:    | 5.360                      |
|                              |          | 4.918                      |
|                              |          | 6.190                      |

Kampung Sungai Ular, Pantai Rekreasi Air Balok, and Swiss Garden Resort Kuantan indicated a small % difference in slope, between -8.04% to 17.16%, compared to the other locations in the study area. The wave that hits the shore loses its energy with not enough to cover a long and large surface area of the beach.

The highest difference was found in Kampung Pantai Beserah and Pantai Sepat with more than 20% of slope difference between those data. Human activities such as mining, construction, and development activities along the coast might have caused the higher erosion rate and coastal slope modification. In addition, the difference in years of data acquisition period might have resulted in significantly different
readings in those years (2010 and 2018). Based on Table 7, the difference in values of slope percentage was slightly small with less than one percent of difference for each reading. It can be deduced that the measurement using Google Earth can be used to determine the elevation height estimation apart from the site data observation. The accuracy of data obtained from Google Earth was comparable and can be used for further study.

3.4. Relationship Between Coastal Slope and Erosion Rate

A qualitative relationship between the erosion rate and slope percentage for the entire Kuantan coast that stretches from Pantai Cherating to Tanjung Agas, Pekan was established. Table 8 shows the coastal slope in percentage, the beach width and the beach material that was deposited on the sites. These three factors are interrelated and have significant impacts on the erosion rate at several particular zones. The first zone of Pantai Cherating has a short width of beach yet a steeper slope was observed compared to Kampung Sungai Ular. From site observation, the shorter width of beach combined with the steep slope might have resulted in higher erosion rate as the waves would hit more of the beach surface (Gracia, 2017). The energy from waves would directly wash the small surface area of the beach and carry away the white fine sand thus making the zone eroded faster than Kampung Sungai Ular.

The physical characteristics of the beach or geomorphology play an important role in analysing beach erosion. Kampung Sungai Ular zone had lesser erosion per year as most of the beach was represented by a flat beach with longer beach width. Kampung Sungai Ular also had a coarse and solid yellowish sand beach in the front but white fine sand in the backshore area. This coarse sand present in the front part of the beach made the waves dispersed more and the grains were heavy enough not to be carried away when the waves had lost their energy. The waves would dissipate more to cover larger surface area and the waves’ size depends on the wind speed (Mirzaei, Tangang and Juneng, 2014). Higher wind speed would result in stronger waves hitting the shore. The physical profile of the beach helps to spread the energy from the waves. White sandy beach in the backshore area was the result of erosion of coastal dunes that were present in Kampung Sungai Ular. This area is a residential area and most of the activities are fisheries which are considered to be less vulnerable to coastal erosion.

In contrast, Pantai Rekreasi Air Balok had a coarse sand and the same goes to Pantai Batu Hitam with gravel-like beach. For Pantai Rekreasi Air Balok, the width of the beach stretched for about 100 to 250 meter that made it suitable for recreational purposes. Based on the physical site visit, Pantai Air Balok comprised flat and coarse sandy beach. Some geological feature such as large rock lied on the front of the beach which helped to disperse and break the waves. Larger surface area of beach might help to reduce coastal erosion and the beach slope of the area had not been significantly changed for a long period of time. Meanwhile, Pantai Batu Hitam had a unique feature as there were multiple strips of upward rocks that were present on the beach. The sand that was deposited on the beach was coarse sand and the slope was also flat. Several mitigation features were constructed along three kilometers of the beach to prevent the developed area, such as buildings, from sinking to the sea and also to protect a recreational facility nearby.

In addition, Taman Gelora zones were recorded to have a muddy beach in front and sandy beach in the backshore zone. This area was also covered from direct wave and wind through the geographical feature of Bukit Pelindung on the north side. The sediment that was carried from other higher zones was deposited here making it nourished with the coarse sand. Some of the areas were covered with mangrove but a major part of Taman Gelora was also critically eroded. A breakwater being constructed along the coastline and some coastal walls to protect the residential area were observed. Taman Gelora had a shorter beach width and steeper slope compared with Pantai Sepat. The shorter width of beach made the erosion more aggressive instead of weak waves hitting the shore. However, rapid development of recreational facility and resorts along Taman Gelora and Swiss Garden Resort might result in higher erosion score in the upcoming years.
Table 8. Qualitative assessment of erosion rate with slope and beach geomorphology (beach width, beach slope and beach materials) along ten study locations.

| Zone | Location | Title | IFSAR Slope (%) | Google Earth Slope (%) | Erosion Rate (m/year) |
|------|----------|-------|------------------|------------------------|----------------------|
| 1    | Pantai Cherating | Beach Slope (%) | 4.81 - 5.348 | 4.237 - 5.952 | 5.692 |
|      |          | Beach Width (m) | 50 - 100 | 40 - 60 |
|      |          | Beach Material | White fine sandy beach |
| 2    | Kampung Sungai Ular | Beach Slope (%) | 3.973 - 4.720 | 4.379 - 5.147 | 3.369 |
|      |          | Beach Width (m) | 50 - 140 | 65 - 135 |
|      |          | Beach Material | Back (White fine sand) Front (Yellowish brown course and solid texture) |
| 3    | Pantai Rekreasi Air Balok | Beach Slope (%) | 2.211 - 3.951 | 2.242 - 4.048 | 3.624 |
|      |          | Beach Width (m) | 50 - 75 | 40 - 60 |
|      |          | Beach Material | Coarse sand (Grey-color) |
| 4    | Swiss Garden Resort Kuantan | Beach Slope (%) | 6.332 - 9.336 | 6.482 - 8.605 | 6.270 |
|      |          | Beach Width (m) | 45 - 75 | 50 - 65 |
|      |          | Beach Material | White fine sandy beach |
| 5    | Pantai Batu Hitam Berserah | Beach Slope (%) | 3.234 - 6.982 | 3.824 - 6.174 | 3.841 |
|      |          | Beach Width (m) | 55 - 135 | 50 - 90 |
|      |          | Beach Material | Muddy and Gravel /Coarse Sand (Black color) |
| 6    | Kampung Pantai Beserah | Beach Slope (%) | 3.023 - 7.693 | 3.363 - 7.650 | 3.973 |
|      |          | Beach Width (m) | 65 - 100 | 80 - 95 |
|      |          | Beach Material | Yellow fine sand (Back) Black muddy sand (Front) |
| 7    | Taman Gelora | Beach Slope (%) | 3.894 - 7.595 | 3.894 - 7.595 | 4.550 |
|      |          | Beach Width (m) | 45 - 115 | 50 - 80 |
|      |          | Beach Material | Yellow fine sand (Back) Black muddy sand (Front) |
| 8    | Pantai Sepat | Beach Slope (%) | 3.457 - 5.553 | 3.202 - 6.201 | 4.372 |
|      |          | Beach Width (m) | 40 - 90 | 55 - 75 |
|      |          | Beach Material | White fine sandy beach |
| 9    | Cherok Paloh, Pekan | Beach Slope (%) | 2.910 - 11.441 | 3.478 - 10.626 | 6.919 |
|      |          | Beach Width (m) | 75 - 120 | 90 - 115 |
|      |          | Beach Material | White sandy beach (Back) and Muddy sand (Front) |
| 10   | Tanjung Agas, Pekan | Beach Slope (%) | 3.972 - 5.360 | 4.918 - 5.501 | 3.454 |
|      |          | Beach Width (m) | 70 - 125 | 80 - 100 |
|      |          | Beach Material | White sandy beach |

Cherok Paloh had the highest erosion score because of natural factors such as winds and currents that were present there. Most of the beach was white sandy beach with protection from a river delta that existed there. The river mouth kept changing and strong waves would hit them thus dragging the sand away from its place. Strong waves and direct winds that hit the shore might have resulted in dynamic coastal slope and critical erosion around the area.
It is generally known that the greatest beach profile changes occur along the ocean side. Therefore, many studies have focused on open coast beaches in high-energy environments. Wave energy and sediment transport rates on sandy beaches in very sheltered locations are much smaller than those on ocean side beaches. Such a beach is termed a “low-energy beach”, characterized by calm conditions and minimal non-storm wave heights (less than 0.25 m). Larger wave heights (less than 0.5 m) occur during storms that drive onshore winds. Some studies of low-energy beaches point out the differences in the characteristics and nature of beach profile compared with high energy beaches. Nonetheless, low-energy beaches have generally been subsumed within existing policies that manage high-energy beaches. Therefore, a prediction method for beach profile changes and sediment grain size distributions of low-energy beaches is necessary.

4. Conclusion

Coastal areas are mostly important resources for most countries in the world for the purpose of physical resources, wildlife, and protection against flooding, safety, and recreation. The changes of beach profile characteristics along Pahang coastline were caused by the northeast monsoon and human activities (Husain et al.). The beach profile measurement is an easy way to measure a beach cross-section, the simplest expression of beach morphology. The output of this study so far provided additional information about the geomorphology and rate of erosion and accretion characteristics of Pahang coast. The total length of coastline changes is about 14 km (14035.10 m) with totaling up to 205.66 hectares that had been eroded along 103 kilometers stretching from Cherating to Pekan. The research found that eight area out of 196 or 39.7% locations were eroded and being categorized as acceptable erosion category (K3), 64 area or 32.7 % had significant erosion category (K2) where the coastline retreated more than 1 meter per year, and the most critical eroded area, K1, were 54 sites or 27.6% of the sites. Cherating, Swiss Garden Resort, and Cherok Paloh were among those with the highest erosion rates from -5.692 to -6.919 m/year. Meanwhile, the highest rate of accretion value was indicated in Tanjung Agas at 7.391 m/year. A qualitative study of relationship between the erosion rate and slope percentage for the entire Kuantan coast stretching from Pantai Cherating to Tanjung Agas, Pekan indicated that the coastal slope percentage, the beach width, and the beach material deposited on the sites were interrelated and provided significant impacts to the erosion or accretion rates on several particular zones in Kuantan coastlines. Further study can be done to increase an understanding of the hydrodynamic parameters and numerical modeling effects towards the coastal area and coastal community. The findings from monitoring coastline changes and identifying vulnerable erosion areas might be useful in the policy and decision making for sustainable coastal management.

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