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Evaluation Coastal Volume Changes with UAV Photogrammetry: An Example in West Coast Malaysia

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ABSTRACT

Variations of beach volume changes have been put into place at the coastline to measure the changes in volume and analyse beach response using geometric and volumetric comparison of beach profile sets. This study examined the volume change of a beach in an eroded location in Batu Pahat. As Pantai Punggur was identified as an eroding area, it was chosen as the research area where identifying changes to the beach's volume is necessary to evaluate changes to the condition of the beach. There is a rather strong demand for both technologies and research methods since technology tends to advance quickly. Therefore, in order to satisfy demand, the process of identifying the volumetric of the shoreline area was carried out using an unmanned aerial vehicle with the assistance of Pix4D Mapper and Global Mapper as a medium to study the changes in beach volume. Pix4D Mapper was used to process the beach volume changes and to analyze the aerial image, while the Global Mapper software conducted an analysis of beach volume changes. This study demonstrates that there is a noticeable shift in the volume of the beach within a month. Overall, the data provided demonstrates that Zones A and E are more vulnerable to erosion than the other zones.

1. Introduction

The maritime nation of Malaysia is made up of 13 states of Peninsular Malaysia (referred to as West Malaysia), Sabah and Sarawak (referred to as East Malaysia), and the Federal Territories of landlocked Kuala Lumpur and the island of Labuan. Due to widespread developments, the coasts of Malaysia experience significant and numerous environmental and ecological problems. The extensive development of microcliffs and shelly beaches has resulted from coastal erosion, which has changed the coastal morphology. Wave climate, topography, and sediments are the main forcing factors that influence beach morphodynamics, and consequently, coastal erosion in Malaysia. The main government departments that have a sectoral interest in coastal issues are the Department of

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Irrigation and Drainage (DID), Department of Environment (DOE), Town and Country Planning Department (TCPD), and Department of Fisheries (DOF) [1-4].

Beach volume refers to the volume of sand above the originally defined vertical datum and seaward of a benchmark. In order to quantify the changes in volume and study the beach response, which can be done with geometric and volumetric comparison of beach profile sets, variations of beach volume changes have been implemented at the coastal area. The comparison is paramount to understand the beaches' response towards the coastal process [5]. In recent years, it has been essential to monitor beach volume changes as the coastal zone will experience changes due to environmental factors, which include wave speed, wind speed, and tidal height.

Furthermore, the demand of technologies and approach for research is now relatively high as the technologies tend to develop rapidly. As an example, Kaamin *et al.,* [6], demonstrated the utilization of UAVs for roof inspection, and the research conducted by Zaman *et al.,* [7], employed UAVs and YOLOv5 for human detection in search and rescue operations, exemplify the increasing adoption of innovative solutions and technologies in various fields, highlighting the continuous development and integration of UAVs for diverse applications. Another study by Mokhtar *et al.,* [8] and Siddiq *et al.,* [9] demonstrate the ongoing research efforts in utilizing UAV photogrammetry to assess and understand coastal erosion phenomena. The use of UAVs and aerial imaging techniques provides valuable insights into the dynamics of coastal environments, aiding in the development of effective strategies for coastal management and protection. Therefore, in order to meet the demand, the Unmanned Aerial Vehicle (UAV) can be used in the process of identifying the volumetric of coastal areas. This process will replace the conventional method that previous researchers used to collect data on changes in beach volume. Based on the preceding research, LULC (Land Use/Land Cover) and LIDAR (Light Detection and Ranging) are the methods used to identify anything related to coastal research [10]. The method that has been proposed to conduct this research involves using a UAV to capture aerial images of the beach profile. This is a more convenient method compared to the previous one as it can produce high-resolution aerial images. An orthomosaic model will be generated with the help of software, where it can be used in quantifying beach volume changes and determining how much sand has been lost or increased throughout the erosional and sedimentation process.

According to Alsebai *et al.,* [11], Malaysia possesses a lengthy coastline that provides panoramic views of the South China Sea as well as the Malacca Straits. This study is focused on the West Coast of Malaysia, at Pantai Punggur, Batu Pahat of Johor. Hassan *et al*., [12] stated that most of Batu Pahat's coastal area is eroding as a result of coastline changes. Wan Mohtar *et al.,* [13] reported that samples from the eroded and depositional regions at the eroded coastline of Batu Pahat, Malaysia, displayed no distinctive characteristics and exhibited similar profiles. Due to the high energy condition, the sediments were transported as suspension, mostly as pelagic, and were then deposited as shallow marine and agitated deposits.

2. Methodology

Data acquisition from photogrammetry works and image processing are the two primary processes that are involved before beach volume changes can be analyzed.

2.1 Data Acquisition Process

The introduction of the UAV DJI Phantom 4 (Figure 1) allowed work related to aerial photogrammetry in the coastal area to be conducted. The use of UAVs is in high demand in business, research institutions, and industries as it is comparatively less expensive and easier to manage compared to other data collection equipment. In order to analyze changes in beach volume, UAVs were one of the instruments utilized in this study to capture aerial images of the coastal region. One of the criteria that influenced the selection of this technology was the UAV's ability to fly at low latitude while delivering high resolution images [10]. The UAV aircraft can fly at a height of 50 m over an area of 1000 m x 300 m.

The aerial photogrammetric method was utilized as the primary method to collect data on coastal changes, particularly in Pantai Punggur. When determining the flight planning schedule, several aspects were taken into consideration, such as tidal periods, weather, and wind speed. Tidal times need to be considered to ensure that beach coastline changes may be observed during low tide, and for this research, the low tide ranged from 0.2 to 0.25 m. The UAV images were taken at several points throughout the flight to ensure that the entire research area was covered. Each image had 80% of overlapping images because the photographs were taken in such a way that they could be used in tandem.

Fig. 1. UAV DJI Phantom 4

Ground control points (GCPs) are used to georeference unmanned aerial systems (UAS) photographs indirectly [14]. Several Ground Control Points (GCPs) were established in suitable locations throughout the coastal area for accuracy of the assessment data collected with the UAV, i.e., calculate scale, orientation, and absolute position of the photos. These points were marked before the UAV took off to ensure that they could be easily seen in the photographs. A majority of the GCPs are black and white due to the high contrast patterns which are easier to notice [15]. The GCPs utilized in this investigation are shown in Figure 2.

A total of 15 GCPs had been installed along the shoreline of Pantai Punggur. The GCPs were used to improve the coastline's accuracy as provided by the program and to ensure that the orthomosaic map generated by the software is correctly geolocated. The route mean square error (RMSE) was found to be in the range of 0.009 m to 0.022 m after rectifying the GCP, which indicated that the images were geometrically well-matched. Several researchers had successfully detected shoreline changes with RMSE in the range of 0.012 m [16] to 0.023 m [17].

Fig. 2. Ground control point (GCP)

The images captured by the UAV were processed using Pix4D and Global Mapper software. According to Burnham [18], Pix4D Mapper is presently owned by the Parrot group and is the company's core product. This is yet another comprehensive end-to-end photogrammetry tool that can handle photographic inputs from UAVs and other camera rigs, video, fish eye, or 360° photos, as well as spectral images, including thermal imaging. As a result, Pix4D claims that any image can be used as a starting point, as long as it is a JPEG or TIFF. The Pix4D mapper, a professional drone photogrammetry tool, is able to generate maps from all of the UAV's images. This program is relatively easy to use. Data from the Pix4D capture are used by the program to create a map. The accuracy of the aerial image processing performed by this software depends on the input of Ground Control Points (GCP) into this program.

The Pantai Punggur aerial map was then created by combining and processing all of the overlapping aerial photos using the Pix4D Mapper program. The Pix4D Mapper is divided into three primary stages. The first step is to have all of the photos sorted and calibrated using Aerial Triangulation and Bundle Block Adjustment. This is followed by creating a densified point cloud in the second step, as seen in Figure 3, which provides the model with a 3D textured mesh. In the third step, an orthomosaic map and Digital Surface Model are created. Subsequently, the coastline determination procedure is completed when the orthomosaic map is analyzed with the Global Mapper.

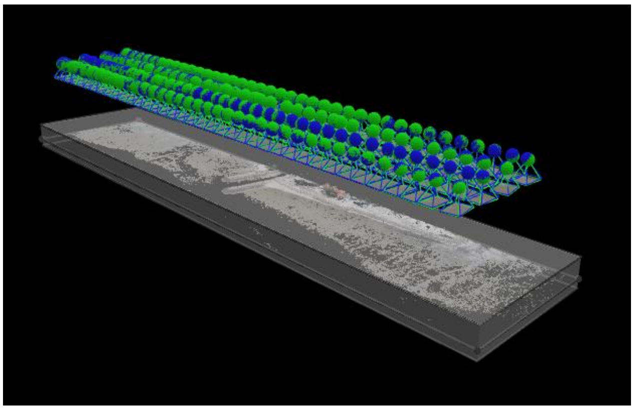

Fig. 3. Pix4D Mapper Software densified point cloud of Pantai Punggur

Once the Pix4D mapper software has completely finished the process of overlapping the images, the Global Mapper software will then begin the process of analyzing the beach volume changes. This program was used to analyze every photo captured by the DJI Phantom 4 in Pantai Punggur. There are a few steps that must be followed carefully to ensure that the analysis of beach volume changes can be done using this software. The Global Mapper is used once the Pix4D Mapper has completed the overlapping images. The Global Mapper was used in this research to obtain the beach volume changes by referring to the related parameter. Besides following the abovementioned steps, the selection and modification when using this software should be taken into consideration.

3. Results

According to previous research, Pantai Punggur has been identified as one of the eroded areas in Batu Pahat where the rate of coastal erosion has gotten worse over time [8]. Coastal erosion is a natural process that results in sediment loss as a consequence of continuous stream and wave activity. Therefore, it is crucial to analyze the shoreline sediment properties in order to identify the erosion that beaches experience, and thus, assign a few implementations to inhibit the erosion process. Figure 4 shows an aerial image of Pantai Punggur.

Fig. 4. Aerial Image of Pantai Punggur

Beach volume changes are a result of the beach experiencing the process of coastal erosion and accretion over time. Beach erosion is described in the context of coastal zones as the long-term loss of sediment caused by hydrodynamic pattern changes, such as wind, wave, and current. In the natural coastal cycle, these hydrodynamic forces carry and disperse sediments along the coast, supplying material for dunes, beaches, and marshes. Even though anthropogenic activities are the primary cause of erosion, climate change has made its effects worse. The East Asian monsoon system causes waves, currents, winds, and a high rainfall frequency that heavily impact the coastal processes in Malaysia; all of which have a direct effect on the cycle of beach erosion and accretion in Malaysia [19].

In this research, analysis of the beach volume changes was conducted using the images that were processed by the Pix4D Mapper and imported into the Global Mapper. The feature in the Global Mapper was used to draw the location of sampling and the area of each zone. By setting the volume feature, the software generated data of the total enclosed area, volume of each zone, and each sampling point, mainly at High Tide and Mid Tide. The analysis of beach volume changes was carried out at all zones in relation with the analysis of sediment properties. The analysis of the beach volume changes in the Global Mapper is shown in Figure 5.

Fig. 5. Analyzation of beach volume changes in Global Mapper

Table 1 indicates the beach volume changes for each zone over a one month period (November-December). Although the volume was analyzed in November and December at the same enclosed area, different values of volume were obtained. This proves that even after only a month of observation, there was a rapid change in volume. This occurred as a result of the rapid accretion and erosion experienced at the beach. The analyzation of each tide was only focused on the High Tide (HT) and Mid Tide (LT) at each zone. The beach volume on a small scale, such as during each tide, also showed changes below 0.5 cm^3. The analysis of volume changes for each tide showed that the likelihood of sediment loss occurring is higher compared to accretion. The volume only increased during High Tide at Zones B, C, and D. On the other hand, the other zones portrayed a decrement of volume during Mid Tide.

Table 1
Beach volume changes in one month interval of each tide

Zone	Tide	Total enclosed area (sq km)	Total volume cm^3 (November)	Total volume cm^3 (December)	Volume changes cm^3
A	HT	0.000013	0.4464	0.0173	-0.4291
	MT	0.000013	0.4464	0.0050	-0.4414
B	HT	0.000013	0.3058	0.6395	0.3337
	MT	0.000013	0.3058	0.0146	-0.2912
C	HT	0.000013	0.1965	0.2308	0.0343
	MT	0.000013	0.1258	0.0187	-0.1071
D	HT	0.000013	0.1458	0.1461	0.0004
	MT	0.000013	0.0616	0.0095	-0.0521
E	HT	0.000013	0.1431	0.0070	-0.1361
	MT	0.000013	0.1068	0.0081	-0.0987

Figures 6 and 7 show the volume changes at High Tide (HT) and Mid Tide (MT) areas, respectively. At the HT area, accretion happened at these three zones, Zones B, C, and D, while Zones A and E showed a decreased amount which indicated erosion. However, in the MT area, erosion happened at all zones except Zone B, with the highest changes at Zone A. From this, it can be concluded that in a month-to-month comparison, Zone A experienced the most sediment loss compared to other zones. According to the analysis on sediment properties conducted by Mokhtar *et al.,* [20], sand and gravel predominates at HT locations in all zones. At the MT points, Zone A contains silty clay, Zone B contains sandy silt, and both Zones C and D contain clayey silt. The presence of sand and gravel at the HT area explains why accretion happened there as opposed to the MT area where all zones have silty soil, which is very fine sediment.

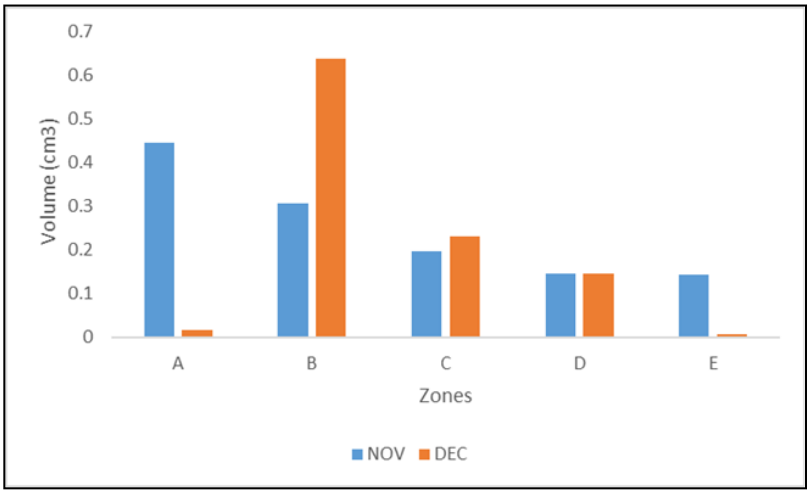

Fig. 6. Volume change at High Tide (HT) area

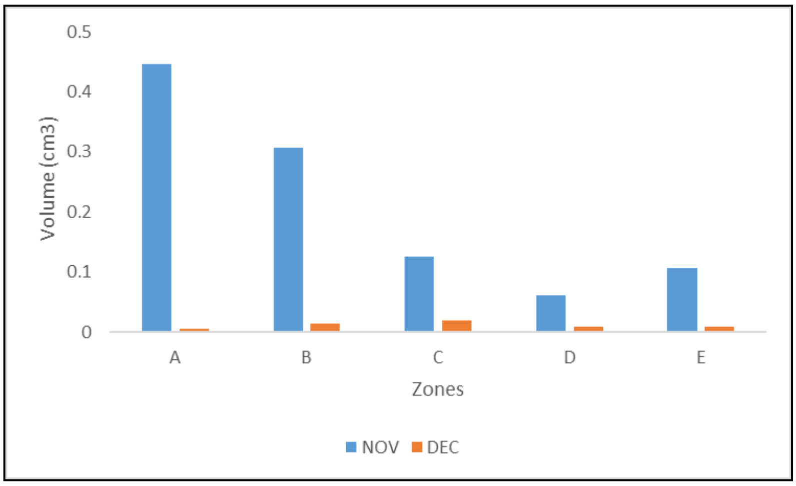

Fig. 7. Volume change at Mid Tide (MT) area

Based on the total volume change (HT and MT) as shows in Figure 8, Zone A had the highest volume decrease, followed by Zone E. It should be noted that there was an absence of any revetment protection in both zones, which explains why the projections were as they were. Zones B, C and D are located in the revetment zone. This shows how the presence of revetment areas will help in erosion control.

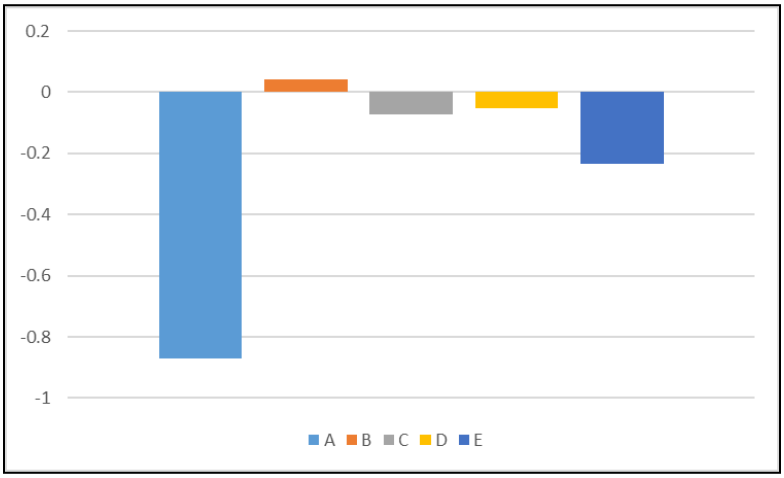

Fig. 8. Total volume change for all zones

4. Conclusion

Over a one month period, the beach volume variations exhibited a changing pattern at each tide and zone. At Pantai Punggur, the erosion rate is more critical in the coastal region, which inhibits the accretion process from occurring in the area. From the data gathered in the previous chapter, Zones A and E were shown to be more prone to erosion than the other zones. Zone A had the highest volume change at Mid Tide with a 0.4414cm^3 loss. The highest increment volume was at Zone B at High Tide with a 0.3337 cm^3 increase. The objective of this research, which was to identify volumetric changes in coastal areas using an Unmanned Aerial Vehicle (UAV) with Global Mapper and Pix4D Mapper software, was successfully achieved based on the research output. Therefore, the results of the data acquired from this study should be taken into consideration by the authorities as a warning to implement coastal structures or any other method suitable for nourishing the beaches. The revetment in this region helps reduce erosion; thus, it is important and needs more attention.

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