Unmanned Aerial Vehicle (UAV) Images for Coastal Erosion Monitoring.

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Unmanned aerial vehicle (UAV) images for coastal erosion monitoring.

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Abstract: *Unmanned aerial vehicles (UAVs) are increasingly utilized for various measurements and surveys, including coastal areas assessment studies. Key applications include coastal monitoring, mapping, geohazard identification, and forecasting. This paper examines the effectiveness of UAV imagery for monitoring coastal erosion at Regency Beach, Port Dickson, using Pix4DCapture, Pix4DMapper, and ArcGIS 10.3. The UAV imagery revealed visible improvements in the shoreline, potentially impacting the coastal region significantly. Accuracy was assessed using Root Mean Square Error (RMSE) computations, which confirmed that the data met the 7.95 cm RMSEx/RMSEy Horizontal Accuracy Class of the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014). The results showed an RMSEx of 4.26 cm and an RMSEy of 1.57 cm. Given the successful outcome of this study, UAVs are recommended as an effective tool for monitoring coastal changes.*

Keywords: UAV; Mapping; Coastal erosion; Coastal monitoring.

1. INTRODUCTION

The coastal zone is one of the most productive areas in the world and has a densely populated population. The beach is a coastal area significant for tourism, fishing, and port operations. During the monsoon season, coastal areas are prone to erosion [1-3], which causes harm to mangrove trees, trees near the coast, marine life, and people's lives. Coastal locations are also vulnerable to environmental risks such as erosion deposition processes, according to [4]. This could result in coastal land loss and damage to infrastructure and structures. Coastal erosion is a natural disaster that happens as a result of natural processes and systems interacting. Erosion is thought to happen constantly along the shore due to natural and human influences.

Tidal currents or sea level rise [5-10], wave currents [11], or climate change [12-13] are all examples of soil removal and coastal sand sediment removal. Changes in coastlines and human activities in the coastal zone are two aspects that contribute to the coastal environment's vulnerability and poor quality. Coastal erosion and overcrowding on beaches are two main challenges to coastal areas. Tourism considerably impacts coastal areas nowadays, necessitating sophisticated approaches for coastal monitoring and regulation. The phenomena of coastal erosion are caused by a combination of natural and human influences. Dealing with erosion becomes more challenging if the area is subjected to severe gusts and big waves. Sandy beaches always change, posing a hazard to buildings and transportation infrastructure. Rising sea levels will worsen coastal erosion in this ecosystem. This indicates that changes in sea level impact changes in coastlines.

Coastal erosion removes material from the coast due to an imbalance in the export and supply of materials under the influence of waves, tidal currents, and/or human activities, typically resulting in coastal retreat [14]. Furthermore, coastal erosion is a concern in many coastal locations as a result of both natural and human-caused factors [15]. Coastal erosion, according to [16], is a global issue that poses a threat to human settlement and development. It has far-reaching effects on the environment, the economy, and society. Coastal erosion will worsen as a result of human activity and natural processes, as well as climate change. Coastal mapping is thus one of the methods for monitoring coastline areas, with the map containing coastal data, soil conditions, coastal terrain, buildings, and residential areas. Figure 1 shows a conceptual diagram of erosion, accretion trends, and inferred net sediment in coastal regions.

Coastal maps are also meant to be regularly generated as reference information for parties such as developers, local governments, engineers, and researchers to aid decision-making [17]. Unmanned aerial vehicles (UAV) are commonly employed to acquire geospatial data in various applications. Recently, UAVs have been employed in various coastal and marine surveying, monitoring, and management applications. UAVs are an excellent platform for gathering comprehensive spatial information. Coastal monitoring necessitates collecting various temporal data, which can be obtained from satellite or UAV photos. According to [18], the high availability of the Digital Surface Model (DSM) and orthophoto has a significant impact on the monitoring that is carried out.

2. STUDY AREA

The research region is located at Port Dickson between 2° 29’ 7.63” N, 101° 50’ 43.42” E, and 2° 28’ 42.67” N, 101° 58’ 48.62” E, where the standard chart datum for Port Dickson is 5.36 m below the benchmark in concrete mooring lights, or 1.45 m below the ground survey datum. The coastal length of the research area is 850 m, while the projected length of erosion is 450 m. Several rocks constructed with erosion barrier constructions have collapsed as a visible impact of erosion. The study region has been eroded by wave impact on the structure. Since early 2002 till the present day, coastal erosion has occurred in this area [19]. Since 2004, numerous anti-erosion measures have been implemented in the study region, including the Beach Management System (BMS), sandbags and geotextiles, groynes, erosion barrier structures, and most recently, coastal reclamation. Despite the implementation of numerous strategies, coastal erosion has happened. The research area is located at Regency Beach in Port Dickson and has an estimated size of 174 m by 627 m. The region contains two 5-star hotels, The Grand Beach Resort and Tanjung Tuan Beach Resort Apartment, and is one of the most popular vacation destinations in Malaysia. Regency Beach is located approximately 5 miles north of Avillion Admiral Cove along the coast of Negeri Sembilan, about 5 miles from Port Dickson Marina Bay. The aerial perspective of Regency Beach is seen in Figure 2.

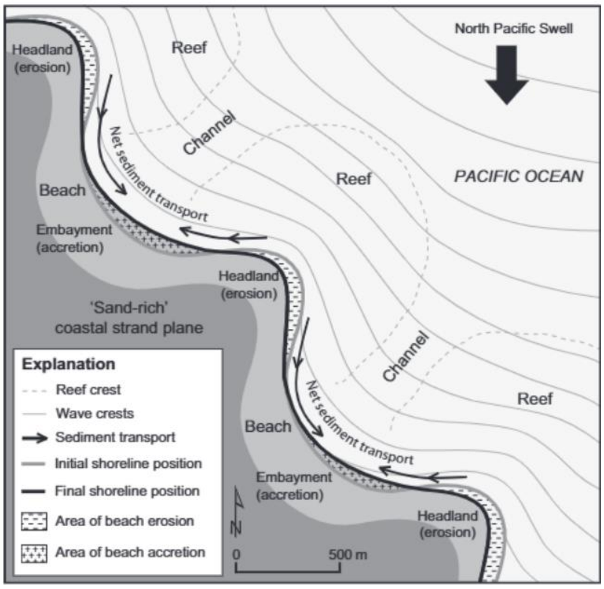

Fig. 1. Conceptual diagram of erosion and accretion trends and inferred net sediment.


Fig. 2. Aerial View of the regency beach (A red line marks the 800m study area).

3. USE OF UAV IN COASTAL EROSION

Some geo-information approaches for mapping or monitoring coastal erosion include manned aerial photogrammetry, remote sensing, light and range (LiDAR), and global positioning system (GPS). In addition to the suburbs, recreational theme parks, and resorts, the coastal regions are among the actively developed and expanding growth areas. Widespread applications of aerial photogrammetry include studies on highways, the environment, early design, and geographic information systems (GIS). The demand for aerial photogrammetry has increased, especially since the creation, research, and manufacturing of UAV platforms [20-21]. Integration of GIS with UAV is one approach that enables an accurate and thorough annual assessment of the information. UAVs, often known as drones and numerous other names, are human-controlled unmanned aircraft that have been utilized in various investigations, such as Antarctic moss beds [22] and high-resolution topographic constructs [23]. UAVs are low-altitude aerial imagery that has evolved for military reasons over the past decade and are now routinely deployed by the authorities [24]. UAVs have begun to replace traditional surveying techniques in the mining, construction, and agricultural industries [25] due to their usefulness and convenience. Drones are used to capture images from the air for a certain amount of time. Changes in coastal areas can be determined using images gathered on a number of dates. Malaysia should also do research on national coastline planning to conduct a comprehensive scientific investigation. According to [26], the priority of activities in photogrammetric systems is to evaluate digital images. The images acquired in the first stage will form an image pyramid. This method produces minimal coverage of the research area while also speeding up the system's functioning and making it easier to use. As reported by [27], the UAV can deliver more reliable data than previous methods as it can fly as low as 10 meters. Using UAV techniques, photogrammetric software, and GIS analytical tools, [28] reported that coastal mapping can provide novel estuarine and coastal morphologic concepts. UAVs are currently a viable tool for coastal surveying for both researchers and professional coastal engineers, according to [29]. This demonstrates that this method will enhance the mapping of coastal changes in Malaysia.

4. METHODOLOGY

Various types of UAVs have been used to monitor changes in the shoreline, according to previous studies on UAVs. The usage of UAV photogrammetry facilitates in the capturing of an image in the study location in order to estimate the positioning distance [30]. The coastal region has, as a matter of principle, utilized the traditional approach for control and inspection activities. As a result, unmanned aerial vehicles (UAV) were incorporated into this study in order to complete the tasks economically and effectively.

Smaller drones, such as the Dji Mavic 2 Pro, can take photos in tighter locations faster than larger drones. The aerial imagery in this research was captured using a DJI Mavic 2 Pro drone. A site visit to the research area is essential before beginning the study to assess the study location's circumstances and the optimal time to conduct flight planning. Weather conditions play a role in this inquiry because the UAV must be flown at the correct moment. If the UAV is flown on a rainy day, it will cause complications and damage. Pix4Dcapture and the DJI Go application were used to collect data, while Pix4Dmapper was used to analyze the images. Understanding how to operate an unmanned aerial vehicle (UAV) is critical in this study. Before undertaking research in the study area, the user must first learn how to control the UAV. Failure to control the UAV will disrupt the workflow, potentially altering the data obtained and endangering the UAV. Flight planning should also be available to assist with work by collecting data and information. Although the UAV images are usually not intrusive, the consent of the parties involved in the research is essential to avoid privacy concerns.

The data were collected on 18th November 2020 inclusively. Before a flight can even get off the ground, the flight plan needs to be carefully planned out to ensure the best potential outcome. Before performing UAV data observations, a control point is a physically fixed spot on the earth's surface. It should be clearly marked at a well-balanced and easily visible place from the air and conveniently accessible. Control points were utilized to apply local coordinate corrections to fix the observed aerial picture data. Aside from that, it's used to convert UAV data into the correct scale for three-dimensional measurements. In image processing, ground control points (GCP) improve data accuracy by detecting where the data is located. GCPs are physically specified sites with fixed placements that have been precisely established and labeled. Figures 3 and 4 show the GCP position detected by the UAV camera and the position of the camera on the UAV during the flight to take data.

Fig 3: The process of matching coordinates and images of control points.

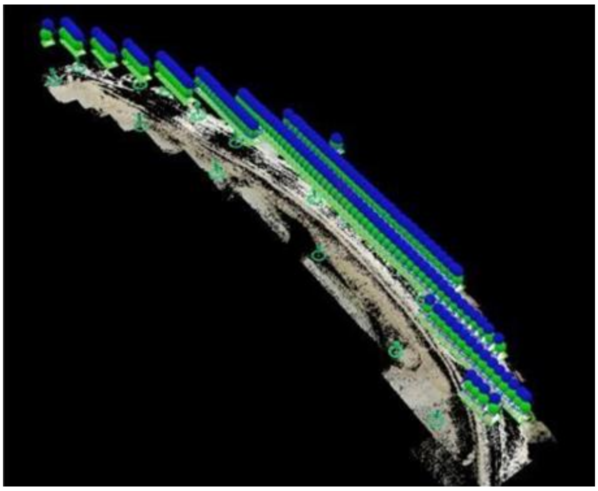

Fig 4: Camera position during flight.

The control points for UAV observations are movable in shape and placed above the control points marked with a marker. The information was gathered when the tide was low since it was easier to access the shoreline during that period. The information regarding the tides was collected from Malaysia's Department of Survey and Mapping.

5. RESULTS AND DISCUSSION

The method of developing a beach mapping consists of various parts. The measures include selection of study instruments, acquisition of aerial images, establishment of Ground Control Point (GCP) and Check Point (CP), and aerial image processing. The UAV was set up at 50 meters for aerial images of the research region. UAVs flying at those heights are ideal for image processing with Pix4Dmapper software. The number of images reflects the percentage of significant image processing such as orthomosaic, Digital Surface Model (DSM), and Digital Terrain Model (DTM) that has been performed. The front overlap between the runways was captured at 80%, while the side overlap between the runways was captured at 72%. This is to ensure that high-resolution and accurate 3D images can be generated. When utilizing Pix4Dmapper software, a decisive step is matching control point coordinates and images.

To get the best aerial images, image capture is a critical phase that must be done. To take aerial images, flight planning must be completed ahead of time. An autonomous UAV for image acquisition was used for the flight mission and landing. In autonomous mode, the UAV received commands from a remote controller and flew from the starting waypoints to the end of the waypoints. The UAV has gathered 149 images in each flight plan and processed them using Pix4Dmapper software. All images must be converted to a three-dimensional (3D) model as part of the project's workflow. The processing of the images took two days for each flight. After Pix4Dmapper has processed all of the images, they will be sent to ArcGIS 10.3 in .tiff format. All images were overlaid with ArcGIS 10.3 so that manual modifications to the shoreline could be made while the real images were visible.

Based on the UAV data, 9 Ground Control Points (GCP) and 5 Check Points (CP) were selected for each UAV flight show at figure 5 below. Root Mean Square Error (RMSE) computations were used to determine the accuracy of the data collected by the UAV. The RMSE number was calculated using the criteria of the American Society for Photogrammetry and Remote Sensing (ASPRS). The RMSE computed for GCP data only shows the data processing quality with Pix4Dmapper software. However, the RMSE calculated for the checkpoint represents the quality of the data processed by UAV. As an example, Tables 1 and 2 present data for November 2020.

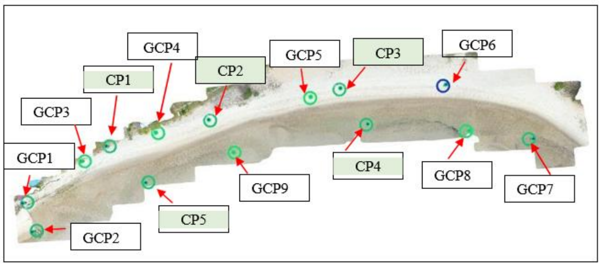

Fig 5: Position of the control points.

This data set was tested to fulfill the 7.95 cm RMSEx / RMSEy Horizontal Accuracy Class of the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014). RMSEx = 4.26 cm and RMSEy = 1.57 cm were found to be the actual positional accuracy. Based on this data, UAVs are capable of producing aerial images with excellent quality. Low altitude is also helpful for aerial images DJI Mavic 2 Pro as it provides clear photos of existing cloud cover. Figure 6 shows an example of the photo image captured by the UAV in the research area for 2020 and 2021. Local authorities, government organizations, and commercial companies can utilize UAV technology for mapping and risk assessment with this technology.

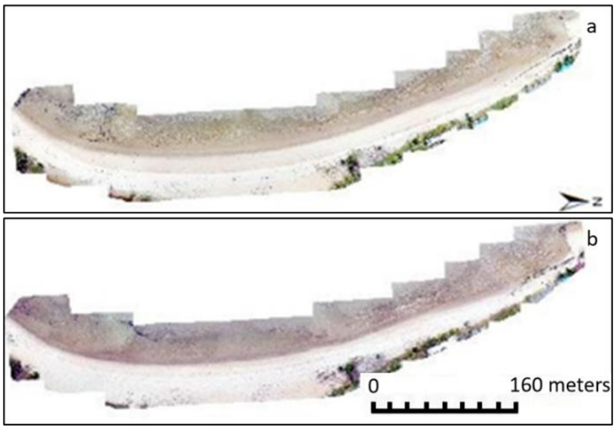

Fig 6: Image captured by the UAV in the research area for 2020 and 2021.

6. CONCLUSION

The accuracy of an unmanned aerial vehicle system for a coastal landscape was effectively evaluated in this study. The Root Mean Square Error (RMSE) represents the correctness of the study area's evaluation. Coastal terrain sceneries impacted the best large-scale mapping for coastal regions. As a result, with the proper method and procedure for image collecting and processing, this micro-UAV may give accuracy up to a centimeter-level for large-scale coastline mapping. This study will broaden its analysis in the future by employing historical remote-sensing photos as a platform to compare historical and current data from the study area. The coastal map will be compared to establish the level of differences.

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Appendix:

Table 1. GCP accuracy statistics

Point ID	Map-derived values			Survey check points values			Residual (Errors)		
	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)
	m	m	m	m	m	m	m	m	m
GCPI	427609.362	274961.524	1.637	427609.362	274961.524	1.637	0.000	0.000	0.000
GCP2	427575.915	274958.615	0.891	427575.903	274958.619	0.857	0.011	-0.004	0.033
GCP3	427673.318	274871.797	2.905	427673.368	274871.814	2.843	-0.050	-0.018	0.061
GCP4	427698.252	274761.740	1.058	427698.252	274761.740	1.058	0.000	0.000	0.000
GCP5	427733.832	274619.586	1.071	427733.832	274619.586	1.071	0.000	0.000	0.000
GCP6	427736.934	274506.182	1.531	427736.934	274506.182	1.531	0.000	0.000	0.000
GCP7	427678.924	274411.293	0.127	427678.924	274411.293	0.127	0.000	0.000	0.000
GCPS	427691.352	274593.586	-0.668	427691.381	274593.590	-0.632	-0.029	-0.005	-0.036
GCP9	427627.141	274834.568	-6.786	427627.116	274834.553	-6.830	0.024	0.015	0.044
Number of GCP							9	9	9
Mean error (m)							-0.005	-0.001	0.011
Standard deviation (m)							0.022	0.008	0.030
RMSE (m)							0.022	0.008	0.030
3D RMSE (m)							0.038		

Table 2. CP accuracy statistics

Point ID	Map-derived values			Survey check points values			Residual (Errors)		
	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)
	m	m	m	m	m	m	m	m	m
CPI	427654.561	274898.479	1.531	427654.633	274898.488	1.417	-0.072	-0.009	0.114
CP2	427682.821	274816.656	-2.562	427682.760	274816.690	-2.471	0.061	-0.034	-0.091
CP3	427722.888	274654.239	0.500	427722.874	274654.236	0.506	0.014	0.003	-0.006
CP4	427689.375	274476.198	-0.572	427689.375	274476.198	-0.572	0.000	0.000	0.000
CP5	427663.008	274733.325	-1.292	427663.008	274733.325	-1.292	0.000	0.000	0.000
Number of GCP							5.000	5.000	5.000
Mean error (m)							0.001	-0.008	0.003
Standard deviation (m)							0.043	0.015	0.064
RMSE (m)							0.043	0.016	0.065
3D RMSE (m)							0.071		