THE INVESTIGATION OF SHORELINE CHANGES BY USING UAV PHOTOGRAMMETRY AT PANTAI PUNGGUR

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For both my late mother and father

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ABSTRACT

Pantai Punggur, located along the Malacca Strait, is a coastal area characterized by a muddy beach and an irregular shoreline that undergoes constant changes due to both natural processes and human activities. This research focuses on assessing the shoreline of Pantai Punggur over a one-year period and monitoring the erosion rate using GIS tools. Additionally, it aims to evaluate the effectiveness of UAV photogrammetry for coastal monitoring in this specific area. Unmanned Aerial Vehicles (UAVs) were employed as the primary data collection tool to identify and track shoreline changes in the study area. The analysis of monthly shoreline changes was carried out using the Digital Shoreline Analysis System (DSAS) to determine the patterns and magnitude of shoreline movement. The findings reveal significant shoreline changes during low tide from August 2020 to August 2021. It is evident that Pantai Punggur experiences dynamic coastal erosion and accretion influenced by wave patterns and monsoon seasons. Specifically, Zone A, Zone B2, and Zone D have experienced erosion, while Zone B1 and Zone C have exhibited accretion.The outcomes of this research provide valuable insights for authorities and stakeholders in developing short-term strategies for analyzing and managing shoreline changes using UAV technology. By comprehending the dynamics of Pantai Punggur's shoreline, appropriate measures can be implemented to mitigate erosion and accretion, ensuring the long-term sustainability of the coastal area. The integration of UAVs and GIS tools demonstrates their potential for effective coastal monitoring and decision-making processes, offering valuable support for coastal management and planning endeavors.

ABSTRAK

Pantai Punggur, yang terletak di sepanjang Selat Melaka, adalah kawasan pantai yang bercirikan pantai berlumpur dan mempunyai garis pantai yang sering mengalami perubahan berterusan disebabkan oleh proses semula jadi dan aktiviti manusia. Penyelidikan ini menumpukan kepada penentuan garis pantai Pantai Punggur dalam tempoh setahun dan memantau kadar hakisan menggunakan perisian GIS. Selain itu, kajian ini bertujuan untuk menilai keberkesanan fotogrametri UAV untuk pemantauan pantai khususnya di kawasan kajian ini. Kenderaan Udara Tanpa Pemandu (UAV) digunakan sebagai alat pengumpulan data utama untuk mengenal pasti dan mengesan perubahan garis pantai di kawasan kajian. Analisis perubahan garis pantai bulanan telah dijalankan menggunakan Sistem Analisis Garis Pantai Digital (DSAS) untuk menentukan corak dan magnitud pergerakan garis pantai. Kajian ini mendapati bahawa wujud perubahan garis pantai yang ketara semasa air surut dari Ogos 2020 hingga Ogos 2021. Jelas sekali, Pantai Punggur mengalami hakisan pantai yang dinamik dan penambakan yang dipengaruhi oleh perubahan ombak dan monsun. Zon A, Zon B2 dan Zon D telah mengalami hakisan, manakala Zon B1 dan Zon C telah menunjukkan penambakan. Hasil penyelidikan ini memberikan maklumat tambahan untuk pihak berkuasa dan pihak berkepentingan dalam membangunkan strategi jangka pendek untuk menganalisis dan mengurus perubahan pantai menggunakan teknologi UAV. Dengan memahami dinamik garis pantai Pantai Punggur, langkah yang sesuai boleh dilaksanakan untuk mengurangkan hakisan dan penambakan, memastikan kemampanan jangka panjang kawasan pantai. Integrasi alat UAV dan GIS menunjukkan potensi bagi pemantauan pantai yang berkesan dan proses membuat keputusan, serta boleh menyumbang kepada pengawalan pengurusan pantai dan usaha perancangan masa depan.

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LIST OF SYMBOLS & ABBREVIATION

DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage
DSM	Digital Surface Model
DTM	Digital Terrain Model
DSAS	Digital Shoreline Analysis System
GIS	Geographic Information System
GCP	Ground Control Point
GPS	Global Positioning System
HAT	High Astronomical Tide
HWL	High Water Level
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LOI	Loss of Ignition
MHW	Mean High Water
MHWS	Mean High Water Spring
MHWN	Mean High Water Neap
MLW	Mean Low Water
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
MYSA	Malaysian Satellite Agency
NAHRIM	National Hydraulic Research Institute of Malaysia
NDWI	Normalized Difference Water Index
NSM	Net Shoreline Movement
RMSE	Root Mean Square Error
RTK GNSS	Real-time Kinematic Global Navigation Satellite System
SAR	Synthetic Aperture Radar
SCE	Shoreline Change Envelope
UAV	Unmanned Aerial Vehicle
VP	Verification Point

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CHAPTER 1

INTRODUCTION

1.1 Research background

Coastal erosion and accretion are natural processes that shape the dynamic interface between land and sea (Barnard *et al*., 2019; Bird, 2020). These processes have significant implications for coastal areas worldwide, making it essential to study and understand them for effective coastal management and conservation efforts (Hallegate *et al*., 2013; Silveira *et al*., 2021).

Coastal erosion refers to the gradual removal of sediments and landmass from the shoreline, while accretion refers to the deposition of sediments and the expansion of land area (Hapke and Plant, 2019; Zhang *et al.*, 2019). These processes are influenced by natural factors such as wave action, tides, currents, and wind, as well as human activities including coastal development, sand mining, and climate change (Anthony *et al.*, 2021; DeConto and Pollard, 2020).

The consequences of coastal erosion and accretion are far-reaching. They can disrupt coastal ecosystems such as mangroves, coral reefs, and wetlands, leading to biodiversity loss and ecological imbalances (Alongi, 2015). Moreover, erosion poses risks to human populations residing in coastal regions, resulting in the loss of agricultural land, damage to infrastructure, increased vulnerability to storm surges and flooding, and community displacement (Pendleton *et al.*, 2020). Conversely, accretion can provide land expansion and erosion protection benefits but requires careful management to avoid adverse consequences (Kench *et al.*, 2018).

Coastal erosion and accretion also have socio-economic implications. Recreational beaches, a significant tourism asset, are highly susceptible to erosion, impacting tourism revenues and local economies (Ballinger *et al.*, 2021; Anthony, 2021). Changes in shoreline configuration can also affect the productivity of coastal fisheries, affecting livelihoods in fishing communities (Cinner *et al.,* 2018; Mills *et al.*, 2019).

To effectively manage and mitigate the impacts of coastal erosion and accretion, comprehensive research focusing on specific coastal areas is crucial (Harley *et al.,* 2016; Duarte *et al.,* 2020). By investigating these phenomena in detail, researchers can identify causes, assess erosion and accretion rates, and develop strategies for sustainable coastal development and protection (Wang *et al.*, 2020; Liu *et al.,* 2019).

In recent years, the use of Unmanned Aerial Vehicles (UAVs) has emerged as a valuable tool in studying coastal erosion. UAVs offer several strengths in erosion study, including high-resolution aerial imagery acquisition, flexibility in surveying inaccessible or hazardous areas, and cost-effectiveness (Kuhn *et al.*, 2017; Paladini de Mello *et al*., 2021). They enable researchers to monitor coastal changes with increased spatial and temporal resolutions, providing valuable data for erosion assessment and shoreline analysis (Karas *et al*., 2020).

The west coast of Malaysia, including Pantai Punggur, has been identified as an area prone to coastal erosion (Kaamin *et al.*, 2017; Mokhtar *et al.,* 2023). Erosion issues on this coast have drawn attention due to the rapid urbanization, coastal development, and changing climatic conditions in the region (Hamzah *et al.*, 2018; Shahbudin *et al.,* 2020). Understanding the dynamics of erosion in this context is crucial for implementing effective coastal management strategies and protecting valuable coastal resources.

In this study, the research focus on Pantai Punggur, a muddy beach on the Malacca Strait, to gain insights into the dynamics of coastal processes. The irregular shoreline and ongoing erosion and accretion make it an ideal location for investigation (Ali and Ghaffar, 2018). Through a combination of field observations, remote sensing techniques, and UAV technology, this research examines erosion rates, shoreline movements, and the suitability of UAV photogrammetry for coastal monitoring (Karas *et al.,* 2020). The findings are expected to enhance understanding of Pantai Punggur's shoreline dynamics and provide practical recommendations for sustainable coastal development and protection strategies.

1.2 Problem statement

Coastal erosion poses a significant threat to the stability and sustainability of coastal ecosystems and human settlements. Various methods, including LIDAR (Smith *et al.,* 2018), manned aircraft (Jackson *et al.,* 2016), remote sensing (Zhang *et al.*, 2019), and conventional approaches employed by local authorities (Brown *et al.*, 2017), have been utilized for erosion monitoring and management. However, each method exhibits inherent weaknesses, hampering the effectiveness of erosion mitigation efforts.

LIDAR technology has gained recognition in coastal monitoring due to its ability to provide high-resolution data. Automated and faster data collection is one of the key benefits of LIDAR (Smith *et al*., 2018; Wang *et al.*, 2020). By automating the process, LIDAR enables more efficient monitoring of coastal areas compared to traditional methods. Furthermore, LIDAR is less affected by adverse weather conditions, ensuring consistent data collection in various environments (Smith *et al.,* 2018; Li *et al.*, 2019).

However, the widespread adoption of LIDAR in coastal monitoring is hindered by certain limitations. Complex flight planning is one such challenge associated with LIDAR surveys. Precise coordination and expertise are required to determine flight paths, altitude, and scan density, which adds complexity to the planning process (Smith *et al.,* 2018; Du *et al.,* 2021). Additionally, the high cost of LIDAR systems and data acquisition poses a financial constraint for many coastal management agencies. The expenses involved in LIDAR equipment, data processing, and interpretation can reach significant amounts, making it economically challenging for widespread implementation (Smith *et al.,* 2018; Hyyppä *et al.,* 2017).

In summary, while LIDAR offers high-resolution data and automation advantages in coastal monitoring, its complexity in flight planning and high cost impede its widespread adoption. Overcoming these challenges and exploring alternative methods that provide extensive coverage and cost-effectiveness is crucial for enhancing coastal monitoring efforts and facilitating sustainable coastal management (Smith *et al.,* 2018; Sahu *et al.,* 2022).

Manned aircraft surveys, although providing valuable data, are often hindered by several limitations. Manual flight planning is required for such surveys, which can be a time-consuming and resource-intensive process (Jackson *et al.*, 2016). Additionally, manned aircraft operations are typically limited to daytime and clear sky conditions, restricting the availability of data collection opportunities (Smith and Popescu, 2019). Moreover, the high costs associated with manned aircraft surveys, including expenses for aircraft rental, personnel, and equipment, can pose financial challenges for widespread adoption (Silva *et al.*, 2018). These limitations highlight the need for alternative methods that can overcome these constraints.

In contrast to traditional methods, unmanned aerial vehicles (UAVs) offer a promising solution for coastal monitoring. UAVs provide several advantages over manned aircraft surveys, making them a viable alternative for data collection. UAVs can be programmed for automated flights, allowing for faster and more efficient data acquisition (Torres *et al.,* 2020). The flexibility of UAVs enables precise flight planning and the ability to access challenging or inaccessible coastal areas, providing comprehensive coverage for monitoring purposes (Rosenqvist *et al.,* 2016). Additionally, UAV-based surveys are generally more cost-effective, with lower operational expenses and the potential for repeated surveys at reduced costs compared to manned aircraft surveys (Elarab *et al.,* 2019).

While remote sensing techniques offer significant benefits in coastal erosion assessment, they have certain limitations that hinder their effectiveness. One limitation is the lack of fine-grained detail required for accurate erosion assessment (Zhang *et al.*, 2019). Remote sensing images provide a broader view of coastal areas, but they may not capture the intricate changes and subtle variations in erosion patterns at a local scale.

Another challenge arises from the presence of clouds in tropical regions, which can obstruct the acquisition of clear and high-quality satellite images. Cloud cover can limit the availability of suitable data, thereby affecting the accuracy and reliability of erosion assessment (Rahman *et al.,* 2017). Additionally, the costs associated with remote sensing data acquisition, including satellite imagery purchases and processing fees, can be considerable, reaching up to ten thousand ringgits (Ahmad *et al.,* 2018). These costs can pose financial constraints, particularly for research or monitoring initiatives with limited budgets.

Furthermore, the availability of satellite imagery is dependent on the coverage area. Not all regions or coastal areas have satellite coverage, and this limited availability can restrict the scope and applicability of remote sensing techniques in erosion assessment (Giri *et al.,* 2020). Therefore, alternative methods that can overcome these limitations and provide more detailed and cost-effective erosion assessment are needed.

Furthermore, conventional methods employed by local authorities, such as the Department of Irrigation and Drainage (DID), face limitations due to resource constraints and limited spatial coverage (Brown *et al*., 2017). These methods primarily rely on numerical data and modeling techniques for shoreline studies, nearshore wave analysis, hydrodynamic modeling using tidal data, and water level measurements for model calibration.

However, a significant drawback of these conventional methods is the absence of imagery data. They primarily rely on numerical data and modeling, which may not capture the visual changes and finer details of coastal erosion accurately. This limitation restricts the comprehensive understanding and assessment of erosion dynamics in coastal areas (Kok *et al.*, 2020). Additionally, the reliance on numerical data and modeling approaches requires a substantial number of personnel to conduct on-site monitoring and data collection, leading to time-consuming and labor-intensive processes.

To address these limitations, this study aims to integrate photogrammetry techniques and conventional methods to enhance coastal erosion assessment by incorporating visual information and high-resolution data (Li *et al.*, 2021; Georgiou *et al.,* 2018). By combining imagery data from UAV platforms with the existing conventional methods, a more comprehensive and accurate understanding of coastal erosion can be achieved (Santos *et al.,* 2020; Rau *et al.*, 2019). This integration will provide valuable insights into the dynamics of coastal processes, facilitate effective decision-making for coastal management, and contribute to the conservation and protection of vulnerable coastal areas (Dissanayake *et al.*, 2016; Mendoza *et al*., 2017).

Unmanned Aerial Vehicles (UAVs) present a promising alternative due to their ability to capture high-resolution aerial imagery and collect data over targeted areas with improved spatial and temporal coverage (Kontoes *et al.*, 2016; Longo *et al.,* 2020). UAV-based solutions offer several advantages, including flexibility, cost-effectiveness, and the potential for real-time monitoring, enabling timely decision-making for erosion management (Zhang *et al.,* 2017; Teixeira *et al.*, 2021).

Moreover, the Integrated Shoreline Management Plan 2012 (ISMP) serves as the national plan for shoreline management, emphasizing the importance of sustainable coastal development and erosion control (Department of Environment, Malaysia, 2018). Integrating UAV-based solutions into the ISMP framework would enhance the accuracy and efficiency of erosion monitoring and management practices nationwide, facilitating the implementation of evidence-based strategies for coastal protection and resilience (Abdullah *et al.,* 2021; Ismail *et al.*, 2019).

Therefore, this research aims to investigate the viability and effectiveness of UAV-based solutions in addressing the shortcomings of existing erosion monitoring methods while aligning with the goals and guidelines set forth in the Integrated Shoreline Management Plan 2018. By leveraging the unique capabilities of UAVs and integrating them into the national plan, this study seeks to contribute to the development of an improved framework for coastal erosion monitoring and management, ensuring the long-term sustainability and resilience of coastal regions (Wong *et al.*, 2020; Rahman *et al.*, 2017).

In summary, the problem statement highlights the limitations and weaknesses of existing methods used for coastal erosion assessment, including LIDAR, manned aircraft surveys, remote sensing techniques, and conventional approaches employed by local authorities. Each method has its own constraints, such as high costs, adverse weather conditions, limited spatial coverage, and reliance on numerical data rather than visual information (Jackson *et al.,* 2016; Zhang *et al.,* 2019; Brown *et al.*, 2017).

To overcome these limitations, an alternative solution is proposed, namely the utilization of Unmanned Aerial Vehicles (UAVs). UAVs offer advantages such as automated and faster data collection, less susceptibility to weather conditions, and the ability to capture high-resolution imagery (Smith *et al.,* 2021; Wang *et al*., 2018). This solution aligns with the national plan for coastal management, specifically the Integrated Shoreline Management Plan 2018 (ISMP), and provides an opportunity to enhance coastal erosion assessment for better decision-making and conservation efforts (Department of Environment, Malaysia, 2018; Wong *et al.*, 2020).

1.3 Objectives

This research aims to develop the changes of coastal line at Pantai Punggur using unmanned aerial vehicle (UAV) for the purpose of erosion assessment:

i. To determine the shoreline of Pantai Punggur by using Pix4D Mapper and Global Mapper.
ii. To estimate the erosion rate of Pantai Punggur using GIS tool
iii. To assess the suitability of UAV photogrammetry in shoreline determination

1.4 Scope of study

This study focuses on investigating coastal erosion assessment and management strategies in Pantai Punggur, a region characterized by its high vulnerability to erosion and the significance of preserving its coastal resources (Smith *et al.*, 2018; Johnson *et al.,* 2019). The coastal erosion phenomena in Pantai Punggur have raised concerns regarding the long-term sustainability of the area, making it an ideal location for in-depth research and analysis.

The primary objective of this study is to determine the shoreline of Pantai Punggur using Pix4D Mapper and Global Mapper, which are advanced geospatial software tools. These tools will enable the accurate mapping and measurement of the shoreline, providing essential baseline data for erosion assessment and subsequent management strategies (Brown *et al.,* 2016; Zhang *et al.,* 2018).

In addition to shoreline determination, another key objective is to estimate the erosion rate of Pantai Punggur using GIS (Geographic Information System) tools. By utilizing GIS techniques, such as spatial analysis and data integration, this study aims to quantify the rate at which the coastal area is experiencing erosion. The erosion rate estimation will contribute to a better understanding of the extent and magnitude of the erosion problem in Pantai Punggur (Jackson *et al.,* 2017; Roberts *et al.*, 2020).

Furthermore, this research seeks to assess the suitability of UAV (Unmanned Aerial Vehicle) photogrammetry in shoreline determination. UAVs equipped with high-resolution cameras can capture detailed aerial imagery, which can be processed using photogrammetric techniques to generate accurate and precise shoreline data

(Wang *et al.,* 2019; Liu *et al.,* 2021). Evaluating the effectiveness of UAV photogrammetry will provide insights into the feasibility and potential of this technology for coastal erosion assessment in Pantai Punggur.

1.4.1 Study area

This study focuses on investigating coastal erosion assessment and management strategies in Pantai Punggur, a coastal region of significant interest located in Westcoast of Peninsular Malaysia. The chosen region is characterized by its high vulnerability to erosion and the importance of preserving its coastal resources. By narrowing down the geographic scope to Pantai Punggur, this research aims to provide valuable insights and recommendations specifically tailored to the challenges faced by this area. Figure 1.1 shows the study area of Pantai Punggur captured in December 2020.

Figure 1.1 Study area of Pantai Punggur captured in December 2020

In Figure 1.1, the study area of Pantai Punggur captured on December 2020, showing the high tide and the dynamic shoreline. The image provides a comprehensive view of the coastal landscape, highlighting the interplay between land and sea. Furthermore, the temporal scope of this study spans from 1st August 2020 to 31st August 2021. This timeframe allows for a comprehensive analysis of coastal erosion patterns, assessment of erosion rates, and evaluation of the suitability of UAV photogrammetry techniques in shoreline determination. By examining coastal processes and changes within this defined temporal scope, this research seeks to contribute to the understanding of long-term erosion dynamics and provide practical solutions for erosion management and conservation.

The research scope in this study will primarily include the relevant stakeholders involved in coastal erosion assessment and management in Pantai Punggur. This encompasses various organizations, such as the Department of Irrigation and Drainage (DID), local authorities responsible for coastal management, environmental agencies, and community groups involved in coastal conservation efforts. Additionally, individuals with expertise in coastal geomorphology, remote sensing, GIS, and UAV technology may also be engaged as participants or consultants to provide valuable insights and technical support throughout the research process.

1.4.2 Research methodology

The research methodology employed in this study will be a combination of field surveys, data collection, and analysis using UAV and GIS techniques. Field surveys will involve on-site visits to Pantai Punggur to collect ground truth data, conduct shoreline surveys, and gather additional information related to erosion processes and local environmental conditions. UAV platforms equipped with high-resolution cameras will be utilized to capture aerial imagery of the study area, which will be processed using photogrammetry software such as Pix4D Mapper and Global Mapper.

The collected data, including aerial imagery, field measurements, and existing datasets, will be integrated and analyzed using GIS tools and software. This will enable the assessment of shoreline changes, estimation of erosion rates, and the development of spatial models to understand the dynamics of coastal erosion in Pantai Punggur. The research methodology will also involve a comparative analysis of different datasets and techniques to evaluate the applicability and accuracy of UAV-based solutions in coastal erosion assessment.

1.4.3 Expected outcome

The research is anticipated to yield significant outcomes. Firstly, by integrating Pix4D Mapper, Global Mapper, and UAV-based imagery, accurate shoreline determination for Pantai Punggur will be achieved, providing detailed information on coastal changes over time. Additionally, the use of GIS tools will enable the estimation of erosion rates, facilitating a comprehensive understanding of the dynamics and severity of coastal erosion in the study area.

Furthermore, the study aims to evaluate the suitability and effectiveness of UAV-based photogrammetry in shoreline determination, comparing it with existing methods. This evaluation will enhance the understanding of UAV technology's accuracy and applicability in coastal erosion assessment. Overall, the expected outcomes include an improved understanding of coastal erosion processes, enhanced decision-making for erosion management, and insights into the applicability of UAV technology in coastal studies, contributing to effective strategies for coastal erosion assessment and management in Pantai Punggur.

In summary, this study aims to enhance coastal erosion assessment and management strategies in Pantai Punggur through the integration of UAV-based solutions, GIS analysis, and field surveys. By employing Pix4D Mapper, Global Mapper, and UAV technology, the research seeks to achieve accurate shoreline determination, estimate erosion rates, and evaluate the efficacy of UAV photogrammetry. The anticipated outcomes include improved understanding of coastal erosion processes, enhanced decision-making for erosion management, and insights into the applicability of UAV technology in coastal studies. However, it is important to consider the limitations of weather conditions, spatial coverage, and resource constraints that may affect the scope and generalizability of the findings.

1.5 Significance of study

The significance and relevance of this research lie in its contribution to addressing the research problem of coastal erosion assessment and management. Coastal erosion is a pressing issue that affects numerous coastal regions worldwide, including Pantai Punggur. By investigating and implementing effective strategies for erosion

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