Assessing Da Nang coastline dynamics using the UAV data

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Abstract

Traditional methods for assessing coastal changes often rely on land surveying equipment, such as total station instruments, measuring the research area's topography. The coastal changes over time can be evaluated by comparing the results from multiple surveying. However, this approach is typically time-consuming and expensive, leading to relatively low efficiency. Currently, many researchers have used satellite imagery sequences to assess coastline dynamics. While this approach offers a more modern alternative, their accuracy is often hampered by the limited resolution of freely available data, typically with the resolution of more than 10 meters. This paper utilizes Unmanned Aerial Vehicle (UAV) aerial surveying technology to study a 4km stretch of coastline in Da Nang, Vietnam. After each aerial survey, captured images are processed to generate point clouds or Digital Elevation Models (DEMs) and are further refined using Ground Control Points (GCPs). This data then enables the extraction of coastline profiles, analysis of overlapping areas, and ultimately evaluate the coastline dynamics.

1. Introduction

Vietnam has 3,260 km of coastline, ranking 33rd out of 153 coastal countries, stretching from Quang Ninh to Kien Giang Province (Duy et al., 2022; Thao et al., 2014). Many beautiful beaches have been recognized and lauded by international organizations such as Nha Trang, Cua Dai, My Khe, etc. However, the past decade has witnessed a significant trend of coastal erosion. Many of these beautiful beaches are now threatened by landslides and the risk of complete disappearance (Dan & Viet, 2017; Tam, 2021).

Since the late 20th century, coastal erosion in Vietnam has intensified, likely associated with the rapid economic and societal changes following the Doi Moi economic reforms in 1986. The average erosion rate ranges from 5 to 10 m/year, but can reach to 50-100 m/year or more (Duy et al., 2022). This poses the significant threats where approximately 12 million people in coastal provinces are at risk of flooding, and over 35% of coastal settlement areas experience erosion. The coastal tourism sector heavily relies on attracting visitors with pristine beaches and ecosystems, but about 42% of resorts and hotels built along the coast face eroding beaches (Binh and Duong, 2018; Duy et al., 2022; Trang et al., 2023).

In Da Nang city, while experiencing accretion at an average rate of 1.01 m/year from 1965 to 1995, the accretion rate decreased to about 0.98 m/year between 1995 and 2005 (Trang et al., 2023). However, since 2005, the coastline has eroded at an alarming average rate of -0.65 m/year.

Recently, there are many methods for studying coastal evolution. Traditionally, topographic survey machines and echo sounders were employed to survey the study area and determine the shoreline, which is a highly accurate but time-consuming and expensive (May et al., 1983). Simpler methods involved analyzing past photographs or coastal maps (Boak & Turner, 2005). Aerial photos offered a more bird's-eye view for data analysis (Anders & Byrnes, 1991). A more recent innovative method employed kinematic differential GPS mounted on vehicles to map the shoreline (Morton et al., 1993).

Today, with the development of science and technology, many advanced methods have been applied to detect shorelines and evaluate beach developments. Many scientists around the world leverage remote sensing technology as an effective tool to detect sedimentation and erosion trends of beaches

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(Binh and Duong, 2018; Tinh et al., 2018; Tung & Graaff, 2006; Viet et al., 2022). Additionally, other researchers have developed shoreline interpretation technologies from video-camera data (Thuan et al., 2019). Each method has its own advantages and limitations.

With the rapid development of UAV production technology, these versatile drones have become valuable tools for various fields, including coastal studies. This paper will present the process of utilizing UAV technology to interpret beach topography, extract the shoreline, and ultimately, evaluate the coastal evolution.

2. Case study and data collection

2.1. Case study

Da Nang, located along the beautiful coast in Vietnam's Central region, attracts nearly 8 million tourists each year, both international and domestic (Van, 2023). One reason for this wonder lies in its stunning coastline, stretches of golden sand and clear blue waters.

Da Nang includes two distinct coastlines (Figure 1), where Da Nang Bay is less developed in tourism, while the coast from Son Tra peninsula to Cua Dai estuary is spanning about 17 km. This stretch boasts some of the city's most beautiful beaches, including the renowned My Khe beach (Figure 2).

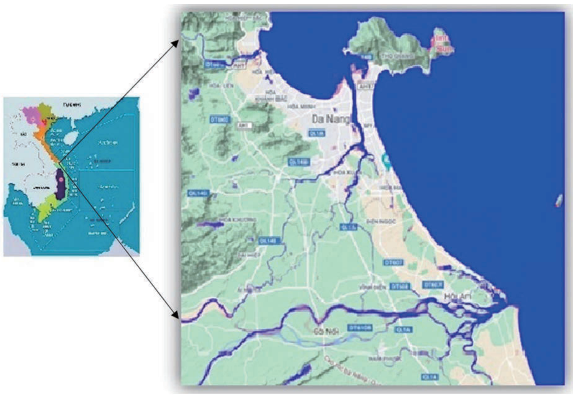


Figure 1. The location of Da Nang City

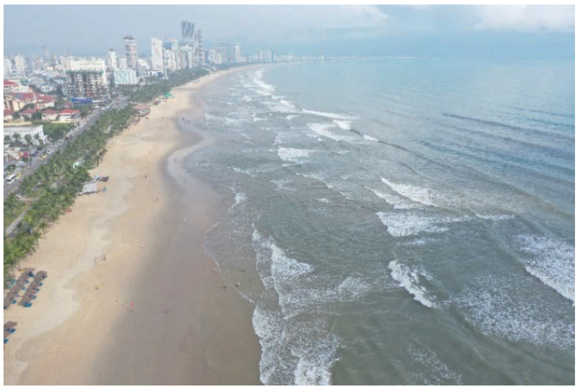


Figure 2. My Khe beach in Da Nang city

My Khe, a 4 km stretch, serves as the main and most beautiful beach of Da Nang. Prior to 2015, this area enjoyed a steady accretion trend (Tanaka et al., 2018; Tinh et al., 2018; Trang et al., 2023; Viet et al., 2018, 2022). However, from 2017 to 2021, powerful waves unleashed a series of erosion attacks, destroying many coastal structures and significantly narrowing the once-spacious beach (Figure 3, Figure 4).

Figure 3. A corner of the guard house and fence of a resort were destroyed by waves (January 28th, 2018)

Figure 4. Erosion of My Khe beach (February 21st, 2021)

2.2. Data collection

Since 2021, numerous UAV surveys have been conducted along My Khe beach, capturing data at different times and seasons. The popular DJI Mavic 2 Pro aircraft, capable of taking aerial photos with a 20-megapixels resolution were used. Its impressive technical specifications for in-depth coastal analysis are shown in Table 1 (DJI, 2018).

Table 1. DJI Mavic 2 pro specifications

No	Information
1	Sensor: 1” CMOS/ 20Mpx (Hasselblad camera)
2	Lens: 28mm f/2.8-11 fixed
3	ISO range: 100-6400
4	Maximum speed: 44.7mph
5	Advanced HDR photo with 14EV
6	Technology OcuSync 2.0 transmission
7	Flight time: 31 minutes
8	Video recording: 4K, 2.7K, Full HD
9	3-axis anti-shake gimbal
10	Weight 907g

During each survey, the aircraft adheres to strict parameters: flight altitude 70 m, front overlap 75%, side overlap 65%, ground resolution 1.6 cm/pixel. These consistent settings ensure high-quality, comparable data across our various surveys.

Moreover, in February 2023, the author further enriched the dataset by employing echo sounder equipment and an electronic total station to measure the study area's topography. This additional data will serve as a valuable verification tool for the terrain interpretation derived from the UAV surveys.

3. Methodology

The process of assessing shoreline developments with UAVs is carried out in 3 main steps: i) UAV survey; ii) generate topographic data of the study area; and iii) accuracy assessment (Figure 5).

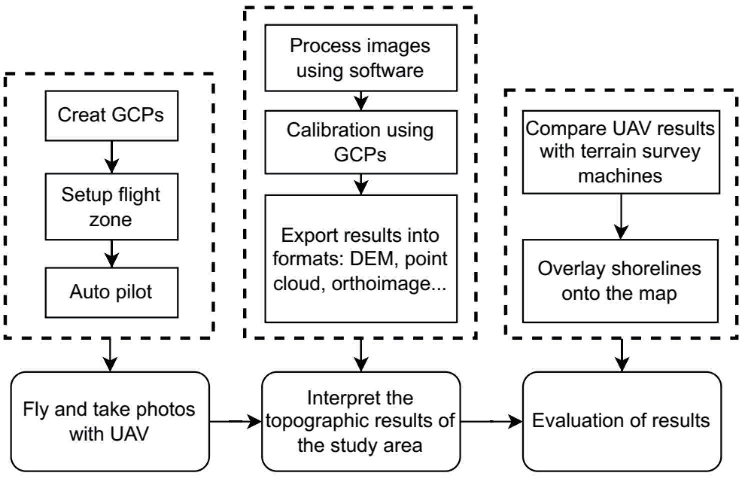


Figure 5. Process for determining shoreline developments

During each flight, consistent parameters as described previously are maintained to ensure data uniformity. Then, Trimble Business Center software was leveraged to interpret the captured images into a detailed topographic analysis of the beach. 24 GCPs were used to (*Figure 6*) evenly spread across the flight range, serve as anchors for calibrating and rectifying the images. Finally, the deviation between point clouds was assessed to evaluate the accuracy of the interpretation process. By comparing the elevation values of the measured GCPs and the results after interpretation on February 7^{th}, 2023, the Average Error (AE) and Root Mean Square Error (RMSE) were calculated. Table 2 reveals that the average error (AE) is 0.02 m and the root mean error (RMSE) is 0.026. This remarkable accuracy confirms the effectiveness of the UAV-based methodology for interpreting beach terrain and assessing shoreline developments

Table 2. GCPs calibration results

Name	Elevation value of GCPs (m)	Mavic 2 Pro			
		Check point elevation (m)	Actual error (m)	Absolute value (m)	Square of the real error
MK1	4.620	4.5689	-0.051	0.051	0.00261
MK1a	4.693	4.7081	0.015	0.015	0.00023
MK2	4.648	4.5998	-0.048	0.048	0.00232
MK2a	4.650	4.6559	0.006	0.006	0.00003
MK3a	4.235	4.2294	-0.006	0.006	0.00003
MK5	5.036	5.0203	-0.016	0.016	0.00025
MK5a	5.003	5.0027	0.000	0.000	0.00000
MK6	4.257	4.2394	-0.018	0.018	0.00031
MK7	4.181	4.1583	-0.023	0.023	0.00052
MK14a	3.466	3.4397	-0.026	0.026	0.00069
MK15	3.733	3.7428	0.010	0.010	0.00010
MK19	4.505	4.5206	0.016	0.016	0.00024
MK20	4.505	4.5223	0.017	0.017	0.00030
T1	4.490	4.4893	-0.001	0.001	0.00000
T2	4.424	4.4174	-0.007	0.007	0.00004
T3	4.370	4.3797	0.010	0.010	0.00009
T4	4.909	4.9036	-0.005	0.005	0.00003
T5	4.082	4.0722	-0.010	0.010	0.00010
T6	4.137	4.1283	-0.009	0.009	0.00008
T7	4.134	4.0960	-0.038	0.038	0.00144
T8	4.189	4.1484	-0.041	0.041	0.00165
T10	4.023	3.9746	-0.048	0.048	0.00234
T11	3.948	3.9234	-0.025	0.025	0.00061
T12	3.848	3.8045	-0.043	0.043	0.00189

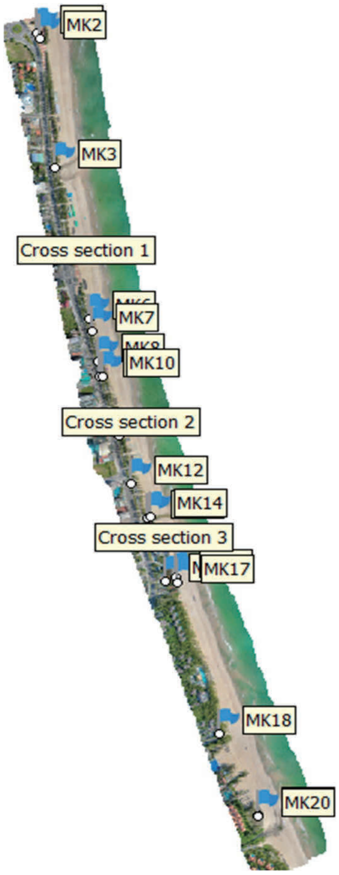
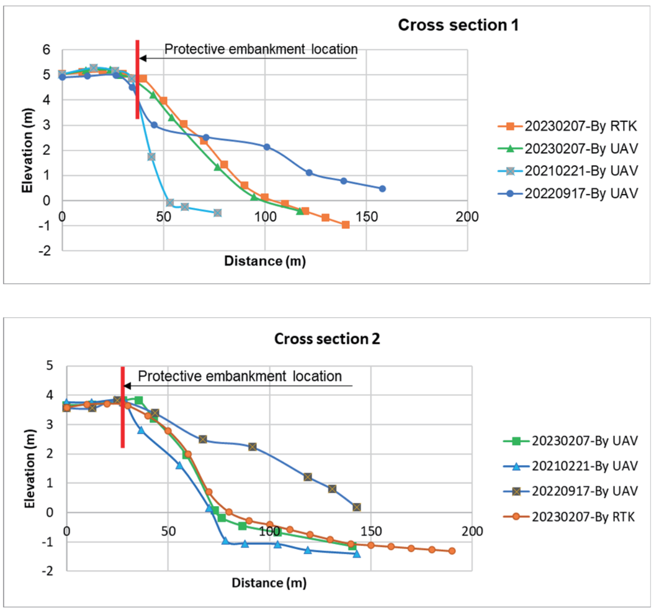


Figure 6. Arrange GCPs on the ground

4. Results and discussion

4.1. UAVs: validated for coastal terrain analysis

To verify the accuracy of UAV data, traditional surveying methods to collect beach cross section data using both total station and echo sounder (RTK) technology alongside the UAV flight were conducted on February 7th, 2023. Three strategically chosen cross-sections spanning the study area were analyzed (*Figure 6*). By superimposing the cross-sections obtained through both methods, a remarkable similarity between the UAV and RTK data for February 7th, 2023, was observed (*Figure 7*). This strong agreement validates the accuracy of mentioned UAV-based terrain interpretation, demonstrating its suitability for coastal research and development assessment.



In addition, by analyzing data from

different time periods, the dynamic story of My Khe beach was obtained. The cross section from February 21st, 2021 (northeast monsoon season) reveals significant erosion, completely aligning with the visual evidence shown in Figure 4 and highlights the erosive impacts of the season. In contrast, the cross section from September 17th, 2022 (end of the southwest monsoon season) paints a different phenomenon with the evidence of substantial accretion, demonstrating the coastline's dynamic response to different seasonal conditions.

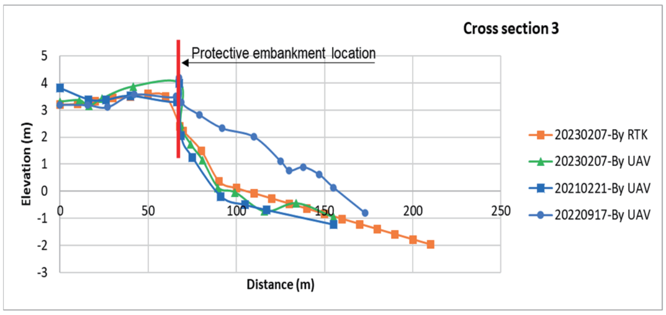


Figure 7. Compare the cross-sections evolution at a fixed location on the beach

In the future, the research aims to delve deeper into the quantitative analysis of My Khe's sediment dynamics. By superimposing cross-sections from various flights, we will calculate the precise volume of sediment and sand changes over time. Based on that, the sedimentation-erosion trend of the beach as well as the source of sand and mud supply of My Khe beach can be identified. This comprehensive data analysis will be an important basis of understanding the origin of sediment supply and is essential for addressing the root causes of beach erosion and developing effective solutions for stabilization.

4.2. Results of shoreline interpretation

The comprehensive UAV surveys, spanning 18 flights from January 2021 to December 2023, captured the dynamic coastline of My Khe beach. The results of shoreline interpretation were superimposed on the map dated September 26th, 2022, allowing for clear comparisons across time (Figure 8).

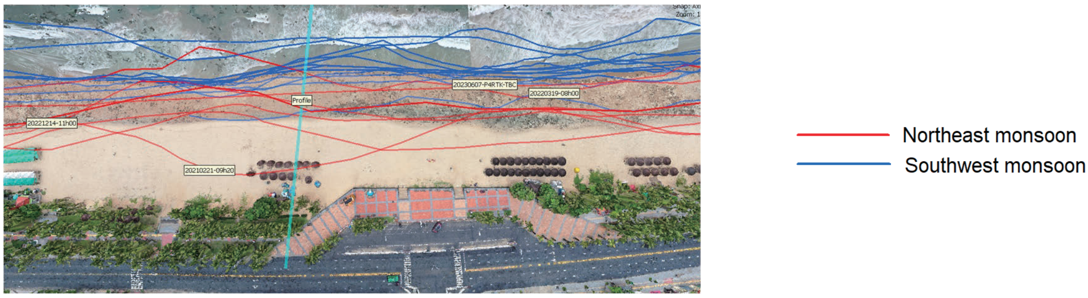


Figure 8. Extracted shorelines from UAV data

From the above results, it can be seen that in the southwest monsoon season (from May to September), the coastline has a width from 55.1 m to 93.2 m. However, during the Northeast monsoon season (from October to April next year), the coastline undergoes a dramatic transformation. The beach retreats with widths shrinking to a mere 27.9 m to 76.2 m. In extreme cases, erosion can reach the foot of the concrete embankment. Thus, the seasonal fluctuation in beach width can be staggering, ranging in between 17 m and 27.2 m depending on the time.

The primary results show that the coast is most strongly eroded around the period of December to January of the following year. This is also the time when the area is most strongly influenced by the northeast monsoon, causing wave towering from 1.0 m to 1.5 m, and occasionally reaching 2.0 m (Binh et al., 2022).

5. Conclusion

This study has successfully explored the potential of UAV technology as an advanced tool to analyze beach changes and its evolution. UAV data were used to extract the detailed topographic map of the area in DEM or point cloud form. Accurate pictures of the beach profiles were generated, including the shorelines, beach terrain and cross sections. The cross-section analysis from UAV interpretation gives good agreement with traditional ground measurements, validating its effectiveness for assessing sediment deficiencies. The collection of 18 shorelines from 18 surveys clearly shows the impact of the monsoon on the erosion and sedimentation process of My Khe coast. In the northeast monsoon season, the beach is rather narrow with averaging 52 m, while in the southwest monsoon season the beach will be increased into 74 m. In conclusion, UAVs can be used effectively as a versatile and cost-effective tool for studying coastal developments. By employing advanced technologies like

UAVs, a deeper understanding of the dynamic coastal processes could be obtained and utilized for future development.

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