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TOPOGRAPHIC MAPPING OF THE INTERTIDAL ZONE USING UNMANNED AERIAL VEHICLES

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ABSTRACT

Intertidal zone is not only an important marine ecosystem but also serves as a buffer zone to minimize the impact of natural disasters such as storms and coastal erosion on the interior land. To study the intertidal zone, the topographic map of the intertidal zone is of great importance. However, with the specific geographical location, the establishment of topographic maps of intertidal zone is very difficult if applying traditional surveying methods. Unmanned aerial vehicle with low flight altitude, flexible flight ability can overcome the limitations of traditional measurement methods in making the intertidal topographic map.

In this paper, we present the approach of using unmanned aerial vehicle in intertidal topographic mapping. Our method focuses on selecting the optimal timing for flight to determine the extent and topography of the intertidal zone. The orientation element of the image is determined by satellite positioning technology combined with the IMU system in order to overcome the limitation of the ground control arrangement in intertidal zone. We then evaluated the results of the intertidal topographic mapping using drone technology.

Keywords: Intertidal zone; unmanned aerial vehicle; Topographic map.

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1. INTRODUCTION

The intertidal zone is an important coastal ecosystem, characterized by high biodiversity and providing habitat for for both resident and migrating birds. The intertidal zone also protects the coast against erosion and protects coastal properties from extreme waves caused by storms [1, 2]. intertidal areas are under pressure from human socio-economic activities and climate change. These changes can all lead to changes in the topography of the intertidal zone [3].

With the importance of the intertidal zone, the determination of the extent and topography of the intertidal zone has been the attention of scientists. However, intertidal is an area with a very specific geographical location that is submerged with water during high tide and exposed to the air during low tide. With this particular geographical feature, mapping the intertidal zone is very difficult and expensive, if done by traditional surveying method [1]. Because it is often dominated by tides and waves, it is very expensive and dangerous to create a topographic map of the intertidal zone by field survey. Using the photogrammetry or lidar scanning methods to map the intertidal zone is also ineffective. With its shape being a narrow coastal strip of land, it is economically inefficient to collect data on the plane. The data collection from the aircraft became more difficult and ineffective because the intertidal zone only emerged from the sea water for a short period of the day [1].

Remote sensing data has long been used in intertidal zone study including shoreline change [1, 4-7]. The shoreline change is determined through comparison of water edge on remote sensing images at different imaging times [8-11]. The methods used to determine the water edge are quite diverse, including manual digitization [12] as well as automation in distinguishing adjacent pixels as images of water or land [9-11].

Recently, a number of studies are interested in determining the extent and topography of the intertidal zone using multi-temporal remote sensing images combined with the tidal level model. To determine the topography and extent of the intertidal zone, remote sensing data were acquired over a period of several decades [1, 13]. Thus, the results of determining the topography and extent of the intertidal zone are correct only when the intertidal zone is stable during the data acquisition time. However, the intertidal zone with a particular geographic location is affected by many factors including human and natural, so the extent and topography of the intertidal zone are often less stable [14, 15]. Human activities on coastal areas such as infrastructure construction, aquaculture ... seriously affect the landscape of intertidal areas. Even inland activities, such as dam construction for irrigation and hydropower purposes, obstruct the flow of silt that flows along rivers into the sea. This activity may negatively affect the erosion and accretion in the estuary area [16]. Furthermore, the intertidal zone is a place that is frequently affected by waves and currents. These effects also change the extent and topography of the intertidal zone. Thus, determining the extent and topography of the intertidal zone using multi-temporal remote sensing data has many factors affecting the accuracy.

Recently, unmanned aerial vehicles (UAV) are used more and more widely in daily life, including in topographic mapping activities. Numerous publications have shown that this technology provides topographic mapping with horizontal and vertical accuracy better than 5 cm and 10 cm accordingly [17, 18]. This technology proves many advantages in topographic mapping. Flying at low altitude limits the effects of weather conditions on flight performance.

Thus, drone photography can be done any time of the day and every day of the year. In addition, with a compact and lightweight equipment configuration, this system is extremely suitable for mapping in small areas [19]. In this article we introduce the approach and method of determining the topography and intertidal range using drones.

2. MATERIALS AND METHODS

2.1. Study site

Nam Dinh ($19^0$54 '- 20^{0-}40' N, $105^0$55 '- 106^0 45 E) is a province in the Red River Delta of northern Vietnam. This province has a coastline of 72 km in the Gulf of Tonkin. The coastal topography of Nam Dinh province is very flat with an average elevation of 1 m above sea level. The coast of Nam Dinh province is home to many estuaries including Red River, Ninh Co River, and Day River. Like other areas of the Gulf of Tonkin, the Tidal regime in Nam Dinh coast is diurnal [20]. According to measurement data of Hon Dau station, the tidal fluctuating amplitude is 0.2 m to 3.8 m.

2.2. Unmanned aerial vehicles used

To take photograph of the study area, we use unmanned aerial vehicles (UAV) capable of taking off vertically. The parameters of the unmanned aerial vehicles are shown in Table 1.

Table 1 Specifications of the UAV used

No	Specifications	Parameters
1	Wingspan	2.6 m
2	Fuselage length	1.6 m
3	Weight	7 kg
4	Cruise speed	72 km/h
5	Maximum flight time	1.5 h
6	Wind resistance	10 m/s

2.3. Map making process

The topographic map of the intertidal zone was produced following the procedure depicted in figure 1.

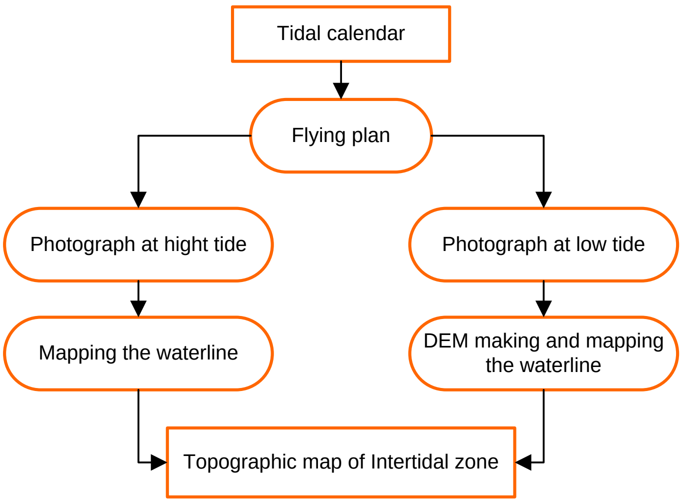

Figure 1 The topographic map making process of intertidal zone using unmanned aerial vehicles

The tidal calendar is collected at a hydrological monitoring station near the study area or calculated by tidal models. Based on the tidal calendar, photo taking plan is developed so that the images of intertidal zone can be taken during the highest and lowest tides. During photo capture, image orientation elements are determined directly using satellite positioning technology and inertion measurment unit (IMU) to minimize the use of ground control points.

Images taken during high tide were rectified and then mosaicked to make orthophoto of the study area. This ortho-photo was used to draw the edge of the water at high tide. Images taken during low tide were used to generate digital elevation model of the study site. These images are also rectified to make the orthophoto of the coastal at low tide. The features on the intertidal zone and the water edge at low tide were digitized on the orthophoto. The intertidal zone extent is determined based on the water line at high and low tide.

3. RESULTS

3.1. Photograph the study site

Figure 2 shows the December tide chart in the study area from 6:00 am to 6:00 pm. The figure shows that, from the 14th to the 17th and the 27th to 30th, the tidal amplitude fluctuates greatly. The highest tide is on December 16th and lowest on December 27th. Based on the tidal calendar, the photos of the study site can be taken from 4:00 pm to 6:00 pm on December 27 during low tide. To record the image of the study area during the high tide, aerial photo of the study site can be taken from 6:00 a.m. to 8:00 am on December 16th.

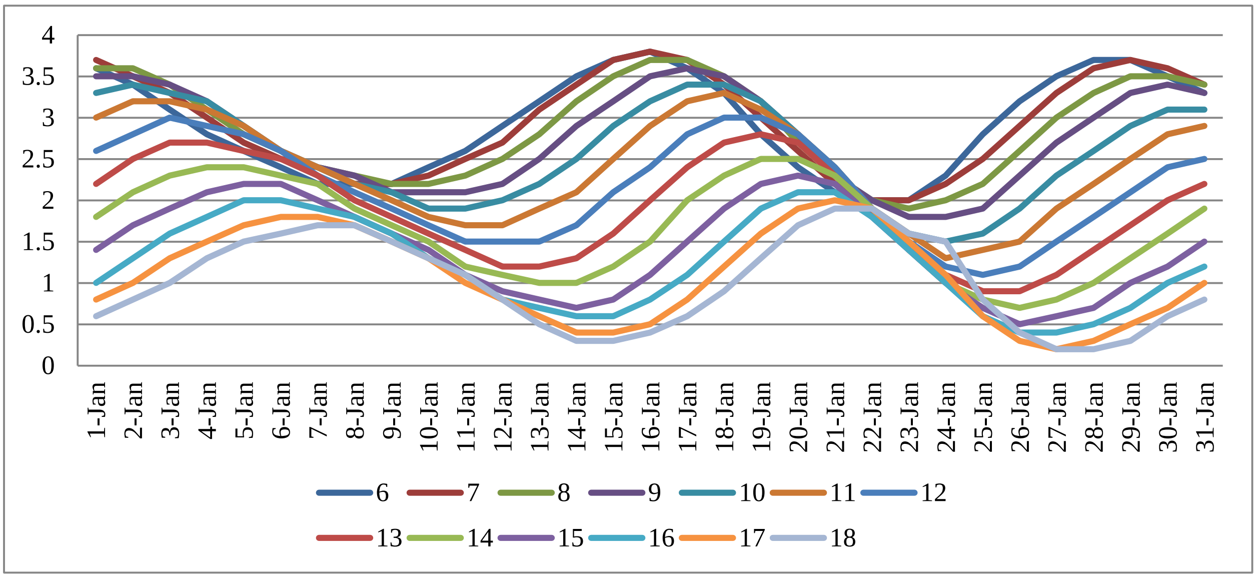

Figure 2 Tidal calendar of December 2019

On December 16th, we took photos of the study area from 7:00 am to 8:00 am during the high tide. Photographing of the study area during low tide was conducted at 4 to 5 pm on December 27th. The flight altitude is 350 m. The image resolution is about 5 cm. Figure 3 shows the center coordinates of the images captured during high tide.

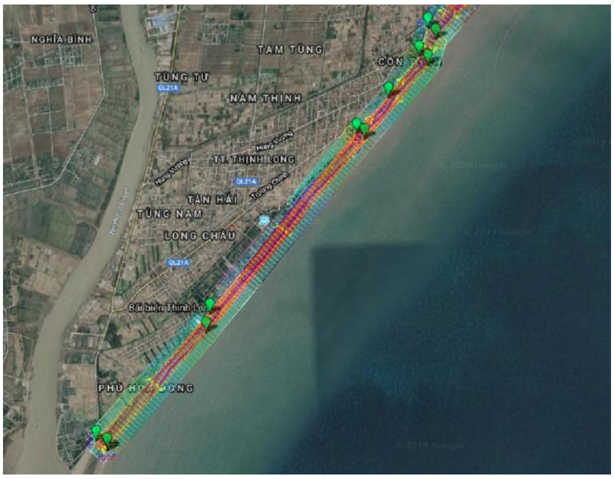

Figure 3 Center coordinates of the images captured during high tide

3.2. Intertidal zone topographic mapping

Agisoft Metashape software is used to process drone images for topographic map making. Photos taken at high tide were rectified and mosaicked to create orthophoto of the study area. The water edge is digitized in the image to determine the extent of the intertidal zone at high tide (figure 4).

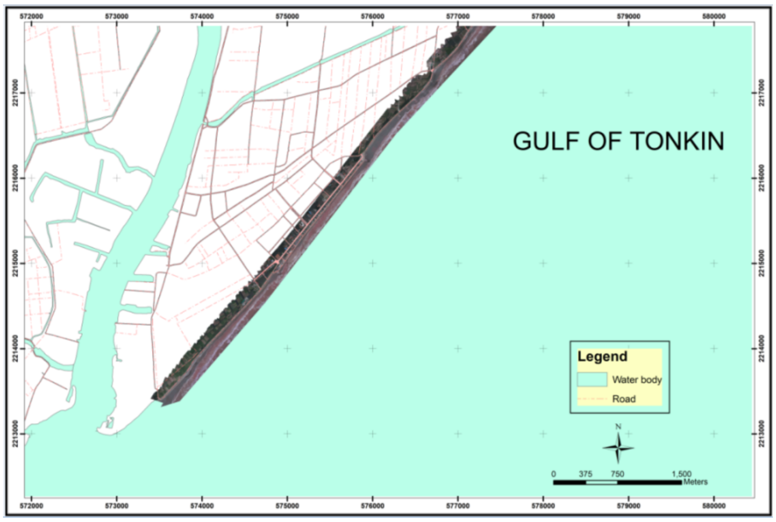

Figure 4 Orthophoto of the study site at

Images taken at low tide were used to establish the digital elevation model of the study area. These images were also used to create a orthophoto of the study area. The water edge was digitized on the orthophoto (figure 5).

Figure 5 Orthophoto at low tide

Figure 6 shows the topography and extent of the intertidal zone.

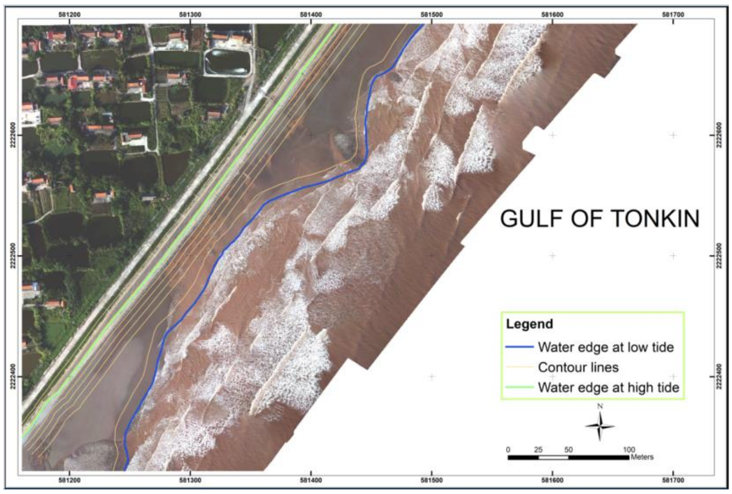

Figure 6 Topography and extent of the intertidal zone

3.3. Map accuracy assessment

To assess the accuracy of the intertidal topographic map making by drone aerial photo, 10 ground control points measured by Global Satellite Navigation System (GNSS) technology was used. Table 2 shows the difference in the coordinates of the control points determined by the GNSS technology and their positions on the map. The results of this assessment show that the accuracy of the map making by drone photo is 3.580 cm and 5.768 cm in plane and height respectively.

Table 2 Map accuracy assessment

No	Name	X_{Error} (cm)	Y_{Error} (cm)	H_{Error} (cm)
1	BM1	3.794	-2.82764	-5.606
2	BM2	-4.212	1.704	4.969
3	BM3	2.843	-1.339	-8.085
4	BM4	1.406	3.573	7.052
5	BM5	-2.911	1.715	-3.087
6	BM6	0.996	-1.238	3.055

No	Name	X_{Error} (cm)	Y_{Error} (cm)	H_{Error} (cm)
7	BM7	3.344	0.755	-6.041
8	BM8	2.622	1.882	5.076
9	BM9	-1.51	-3.051	5.795
10	BM10	1.104	-3.408	6.843
		RMS_{xy}= 3.580		RMS_H = 5.768

4. DISCUSSION

In this article we introduce the approach of creating a topographic map of intertidal zone using unmanned aerial vehicles. We described the process to make intertidal topographic maps using unmanned aerial vehicle images. Choosing the right time to take pictures is very important, which determines the mapping accuracy of the intertidal zone extent. The orientation elements of the images were directly determined during flight capture to overcome the difficulty of ground control arrangement in intertidal zones. The accuracy of the established map is 3.5 cm in terms of plane and 5.8 cm in height. Experimental results show that drone photogrammetry is potential method for mapping the topography and extent of intertidal zone.

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