Creation and Assessment of a Topographic Map from Unmanned Aerial Vehicle Data in Thanh Son District, Vietnam

Thanh, P. T.,[1] Elshewy, M. A.,[2]* and Long, N. B.[1]
[1]Vietnam National University of Forestry, Ha Noi, Viet Nam
E-mail: trungthanhphung@gmail.com, longnb@vnuf.edu.vn
[2]Department of Civil Engineer, Faculty of Engineering, Al-Azhar University, Cairo, Arab Republic of Egypt
E-mail: mimoelshewy@gmail.com
**Corresponding Author*

DOI: https://doi.org/10.52939/ijg.v19i3.2605

Abstract
In recent years, there has been a rapid advancement in the use of unmanned aerial vehicles (UAVs) in various aspects of life, especially in the area of automated data collection. These advancements have brought about numerous possibilities. The article describes the use of an unmanned aerial vehicle, specifically the PHANTOM 4 pro, to gather remote sensing data and create digital topographic plans at a scale of 1:2000 in Phu Tho province's Thanh Son district. A method was suggested for improving the current systems for obtaining remote sensing data for cartography using UAVs. The ease of controlling the UAVs and the quality and timeliness of the data they transmit to control points confirm the value of using them to create topographic maps. In addition to UAVs, fieldwork also involves the use of the GNSS brand CHCNAV I50. The high precision GNSS system enables the camera's 3D position to be detected within a few centimeters at the time of each capture. A digital topographic map was compiled of Thanh Son district, covering 165 hectares, and processed using software such as Agisoft and Global Mapper. The digital topographic map that was produced satisfies the documentation requirements of government organizations. The maximum error in height is 4.7 cm, the error of coordinates north and east are 1.8 cm and 1.4 cm respectively. This was achieved by using 590 raster images, which had a resolution of 2.3 cm and a size of 5472x3648 pixels. Based on the findings, the map's accuracy is within an acceptable range of less than 2 cm, which is suitable for a map scale of 1:2000.

Keywords: Digital Elevation Model, DJI Phantom 4, Real-Time Kinematic (RTK), Topographic Map, Unmanned Aerial Vehicles

1. Introduction

Today, the utilization of unmanned aerial vehicles (UAVs) has the potential to significantly decrease the cost of aerial photography [1] [2] and [3]. Diverse types of UAVs have demonstrated their precision in conducting topographic surveys across the globe [4] [5] [6] and [7]. According to [8] and [9], using UAVs is a cost-effective, ease of use, low-maintenance, and time-efficient monitoring tool that grants scientists and engineers access to high-resolution geospatial data [10]. UAVs offer numerous benefits such as rapid data acquisition, low cost, high accuracy, and the capability to gather data in unfavorable environmental conditions [11] and [12]. UAVs can be equipped with various digital devices, ranging from domestic cameras to orthopedic production machines. These cameras can capture images at fixed intervals, eliminating the risk of exhausting financial and physical resources (as digital memory is cheap and widely available). Modern software allows for the capture of geometrically edited images that conform to a single coordinate system. Moreover, advancements in digital methods of optical image processing have led to the development of software programs and systems capable of handling even low-quality aerial photography data with minimal operator involvement. One of the key applications of UAVs is cartography, where images from drones have emerged as the primary source for creating and updating topographic maps [13], providing significant advantages.

This technology has clear advantages and unique features when it comes to topographical and geodetic production that helps in planning and developing infrastructure projects [14], as well as increasing crop yields in agricultural areas [15]. It involves the use of UAV aerial photography to generate and maintain digital maps and plans of territories that would be impractical or uneconomical to study in detail and extract digital features from using traditional aerial or satellite imagery. For instance, it can be used for areas that are obscured by shadows or clouds in space or traditional aerial photographs, for terrain that undergoes mostly linear changes due to persistent objects, for topographical changes during alluvial development in settlements, and for terrain that requires operational analysis due to constant change.

The use of lightweight GNSS units on UAVs enables accurate spatial mapping. GNSS technology provides real-time positioning accuracy, improves waypoint navigation, supports autonomous landing, and require post-processing software for immediate use in challenging environments, whereby the accuracy of the on-board GNSS receiver is improved via a correction signal sent by a fixed base station. In theory, RTK systems make it possible to determine the precise location of the UAV with an accuracy of a few centimeters [16] and [17]. Such drones can be utilized locally for mapping purposes, reducing reliance on government mapping agencies. They complement traditional survey and satellite mapping techniques by filling in gaps in coverage [18].

When UAVs take aerial photographs, they capture spatial distribution data of terrain objects which can be processed to produce digital topographic maps (DTMs) and digital topographic plans (DTPs). Thus, UAVs are a highly advanced land mapping technique.

This study has looked at using UAVs to take aerial photos and incorporating real-time kinematic (RTK) measurements to make detailed maps of a residential area in Thanh Son district from Phu Tho. The region experiences heavy rainfall during monsoon season in the Northwest of Vietnam. The wet climate makes the soil slippery and difficult to go through, prohibiting access. It has been researched if it is possible to do a topographic survey by combining RTK-GPS and UAV devices in a difficult to reach area in Phu Tho.

2. Methodology for performing work

The study was conducted using a model of utilizing unmanned aerial vehicles (UAVs) in topographical survey of 1:2000 scale to locate a specific area in Thanh Son district, Phu Tho province. The main data source for this research was images obtained from UAVs, which were then integrated with RTK measurements in the region. **Figure 1** illustrates the procedure employed to devise a strategy for producing a digital topographic map at a 1:2000 scale.

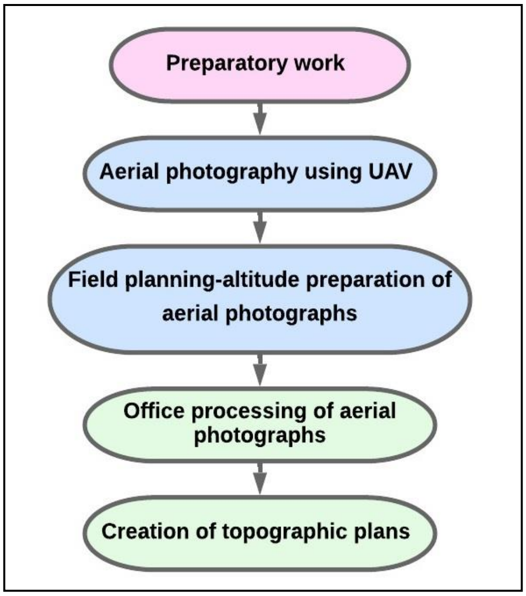

Figure 1: The method utilized to generate digital topographic plans

The aerial work was carried out by an area survey complex (ASC), which includes:

- ground reference station mounted in the area of the UAV launch;
- unmanned aerial vehicle (UAV).

The main technical characteristics of the area survey complex and the main technical characteristics of the UAV are given in **Tables 1 and 2**. **Figure 2** shows the Phantom 4 Pro that was used in the fieldwork.

2.1 The Initial Steps of the Work Involve

- Examining the available materials and gathering or creating requirements for necessary materials based on the survey results. This includes determining the map type and scale, survey object boundaries, and technical requirements for shooting materials such as resolution, contour coordinates of the survey site, overlapping images, accuracy of determining the coordinates of the centers of photography, and ground reference network requirements.

- Creating a flight task for the unmanned aerial vehicle (UAV). This is done using a program called the flight planner, which is part of the system. The operator selects the appropriate UAV and photographic equipment configuration (if the program allows for multiple configurations), sets the shooting area's boundary and approximate launch site position on the map, specifies the required resolution and overlap, and the program calculates the flight plan and checks its feasibility.

The UAV uses the 1-inch CMOS sensor to capture video (up to 4096x2160p at 24fps or 4K at up to 30 fps with the Phantom 4 Pro and 12 megapixels. The scheme of the ground survey complex is shown in **Figure 3** [20]. The project of work and the calculation of the parameters of aerial photography from a flight altitude of 300 meters.

Table 1: The main technical characteristics of the aerial survey

Deployment time	**2 hours**
UAV range:	2 km
The maximum stay of the UAV in the air is	28 minutes
Working time	8 hours
Shutter speed	7-9m/s
Altitude	300m
Percentage of side lap and overlap	90%
Staff	3 persons

Table 2: The main technical characteristics of the UAV [19]

Weight (Battery & Propellers Included)	**1380 g**
Max Speed	20 m/s (Sport mode)
Max Flight Time	Approx. 30 minutes
Satellite Systems	GPS/GLONASS
Velocity Range	≤10 m/s (2 m above ground)
Flight control	manual and automatic modes
Camera Control	Automatic
Lens	FOC 84O,8.8 mm (35 mm format equivalen: 24 mm, f/2.8-f/11, auto focus at 1m - ∞
Electronic Shutter Speed	8 s to 1/8000 s
Max Image Size	5742 x 3648 (pixels)
Capacity	5350 mAh
Energy	81.3 Wh
Max. Charging Power	100 W

Figure 2: Research area and Phantom 4 Pro

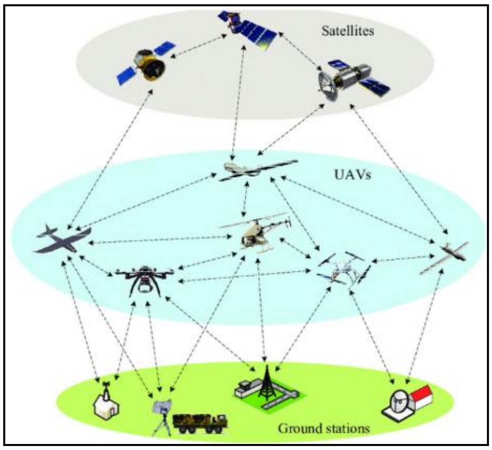

Figure 3: Functional scheme of the ground survey complex

2.2 Aerial Photography Using UAV

When shooting, the camera aligns itself with the path it's on. At a drone speed of 30 km/h, the camera takes pictures with an interval of 1/800 seconds. Based on the survey site's configuration and the calculated parameters of the aerial image on the 1:20,000 scale satellite image, 70 routes were planned, and the coordinates of the start and end points for each route were collected using a GPS receiver. The UAV flight program uses coordinates in the WGS-84 spatial coordinate system. The altitude of UAV always depends on the required accuracy, **Table 3** provides the requirements for planning-altitude substantiation (PVO) for UAV aerial photography. **Figure 4** shows the scheme of flight routes for the unmanned aerial vehicle. The preliminary stage of the project involves conducting area reconnaissance to identify the launch and landing sites as well as the location of the ground control station. Satellite imagery with detailed information was used to conduct an initial survey of objects for aerial photography. The DJI Flight software program was used to calculate the parameters of aerial photography and to design its flight routes. Based on the cartographic requirements, topographic parameters such as height, area, and route number were calculated after analyzing the results of aerial photography: height 300 m above the elliptical plane, area of the object is 160 ha, and 70 routes.

2.3 Field Planning-Altitude Preparation of Aerial Photographs

The meteorological conditions were evaluated one hour prior to the group's scheduled departure (preliminary assessment) and again upon their arrival at the work area just before the deployment of the survey equipment (preliminary appraisal, quantification, evaluation). The drone is controlled in automatic mode, and telemetry information, including direction, speed, altitude, wind, drift angle, ambient temperature, current consumption, GPS location accuracy, and radio control signal strength, is continuously monitored on a laptop screen. After reaching the required altitude of 300 m, the drone is leveled and brought to the starting point of the aerial photography mission, where it begins to rotate. The average flight time required to complete the aerial photography routes, ascent, and descent is approximately 65 minutes. During the flight mission, technicians continuously monitor the drone using binoculars while also monitoring the air and weather conditions in the flight area.

Once the aerial photography and drone landing were complete, the photos were transferred from the digital camera's memory card to a geodatabase on the laptop. Then, the digital photographs were arranged into a block composition. During the block layout creation process, an electronic map displays each frame's location based on the coordinates of the center point, azimuth, and altitude captured by the onboard GPS receiver at the time of capture.

Table 3: Requirements for planning and altitude justification for aerial photography using UAVs

Requirement	**Aerial survey**			
Map scale	1:5000	1:2000	1:500	1:500+
Number of points per 1 km^2	0,5	2	6	10
Accuracy of determining the coordinates	20 см	10 см	5 см	3 см

Figure 4: Scheme of flight

2.4 Setting Up Benchmarks and GCP

Thirteen points of the third-class geodetic network, according to the Department of Natural Resources and National Benchmarks of Vietnam, were used to establish twenty Ground Control Points (GCPs) in the study area. At the intersections, the twenty GCPs were established using the static GPS survey technique (~ 30 minutes), each measuring 60x60 cm with a stroke width of 10 cm, as shown in **Figure 5**. The 20 GCPs were divided into two groups, the first group containing 16 points used for calculation, and the second group containing 4 control points utilized for validation purposes.

2.5 Increased Image Control Points (GPS-RTK Survey)

The accuracy of geographic data at easily accessible locations was enhanced through RTK-GPS surveys that were conducted using either the stop-and-go or semi-kinetic modes. **Figure 6** shows that 1545 control points were measured during the surveys. These points are developed from the 20 GCPs measured by Trimble's GPS measuring device R3 by the RTK method.

Figure 5: Control points painted on the road surface (size 60x60 cm)

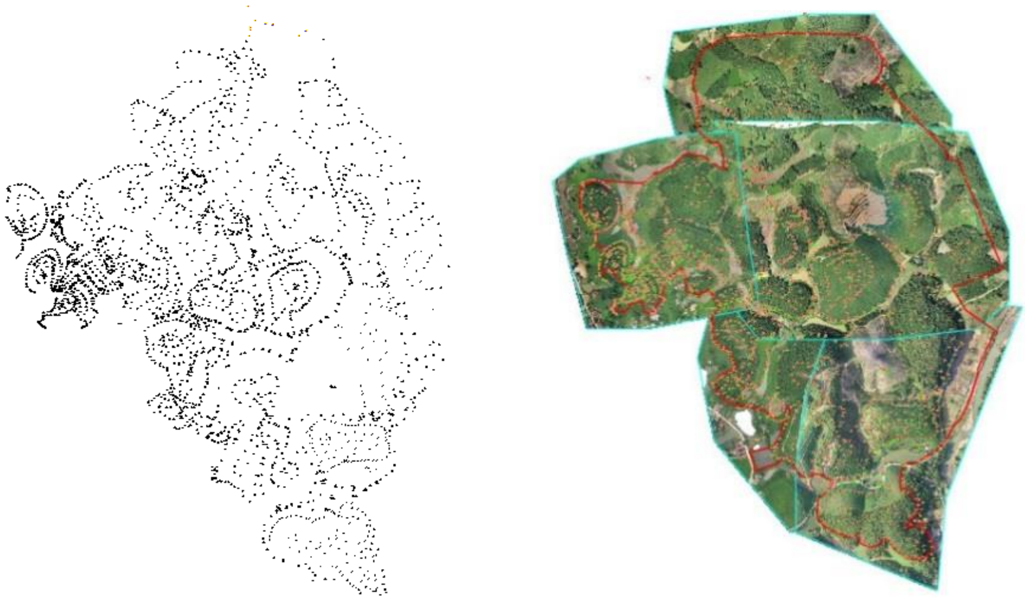

Figure 6: The 1545 control points measured by the RTK method

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2.6 Data Processing

The Agisoft software was used to download and process the RTK-GPS and UAV data. To obtain high-quality images, it is necessary to determine the lens distortion value, and this information will be entered in the camera declaration to enable the software to eliminate any lens errors during image processing. The ground control points coordinates were imported into the software to geo-reference the orthophotos. From the dense, mesh-textured tiled model, the DTM was created. Points were chosen on the orthographic image for comparison with the GPS-RTK validation points. The aligned images are shown in **Figure 7**.

3. Results and Analysis

The images obtained after constructing a DTM of the survey area are depicted in **Figure 8**. The 20 GCPs coordinates utilized for geo-referencing the othophoto are presented in **Table 3** and **Figure 9** shows their distribution of them in the study area. **Table 5** displays the verification results of GPS-RTK points against chosen points on the processed orthographic image. The maximum deviation recorded in **Table 5** was 4.7 cm in height, and 1.8 cm in the Easting and 1.4 cm in Northing.

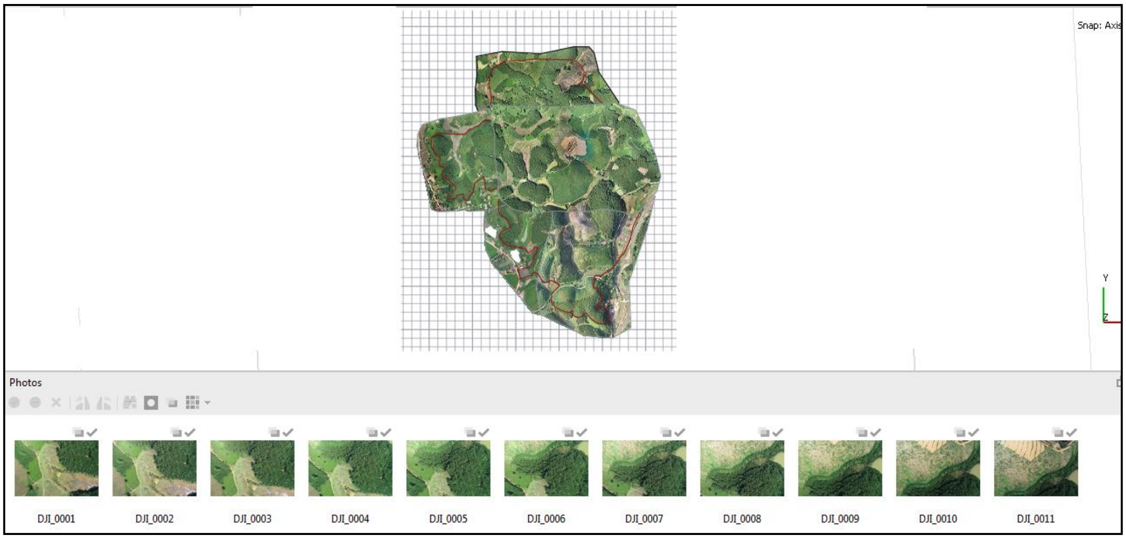

Figure 7: The images after building dense cloud

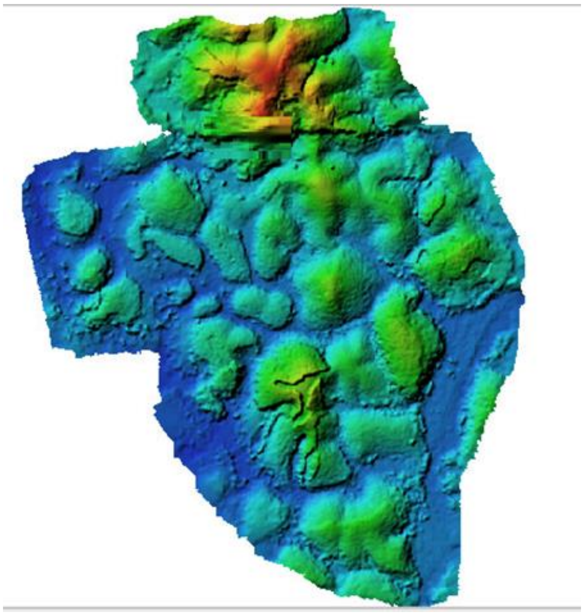

Figure 8: DTM at the survey area

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Table 4: Coordinates of ground control points

No	Eastings(m)	Northings(m)	Height(m)	Name	No	Eastings(m)	Northings(m)	Height(m)	Name
1	2334080.509	538577.785	75.547	VP01	11	2333476.853	539242.745	59.724	VP11
2	2334247.248	538720.300	71.369	VP02	12	2333419.007	538974.059	67.211	VP12
3	2334483.490	538916.510	95.23	VP03	13	2333534.836	538735.925	72.592	VP13
4	2334419.817	538717.528	92.997	VP04	14	2333733.703	538862.870	91.304	VP14
5	2334219.786	539313.745	64.744	VO05	15	2334243.821	538402.062	77.733	VP15
6	2334043.973	539245.485	72.476	VP06	16	2334360.554	538297.474	71.993	VP16
7	2334115.841	539586.780	62.863	VP07	17	2334501.458	538372.439	70.885	VP17
8	2335212.788	539191.653	66.258	VP08	18	2334662.102	538508.355	77.773	VP18
9	2335048.781	539205.052	73.883	VP09	19	2334804.684	538674.768	84.29	VP19
10	2333595.023	539468.082	56.193	VP10	20	2334910.429	538388.565	74.855	VP20

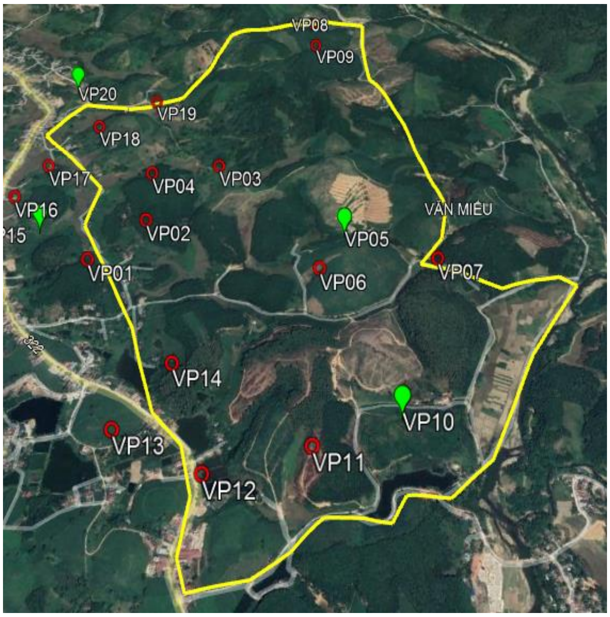

Figure 9: The distribution of the 20 GCPs (red color: 16 points GCPS, green color: 4 validation points)

Table 5: Validation of GPS-RTK points against Orthophoto points

Description	Coordinates (m)		Difference (m)	Description	Coordinates (m)		Difference (m)
	VP5	VP05-1			VP10	VP10-1	
Easting	539313.745	539313.762	0.017	Easting	539468.082	539468.100	0.018
Northing	2334219.786	2334219.776	0.010	Northing	2333595.023	2333595.037	0.014
Height	64.744	64.699	0.045	Height	56.193	56.153	0.040
	VP15	VP15-1			VP20	VP20-1	
Easting	538402.062	538402.076	0.014	Easting	538388.565	538388.554	0.011
Northing	2334243.821	2334243.809	0.012	Northing	2334910.429	2334910.416	0.013
Height	77.733	77.780	0.047	Height	74.855	74.889	0.034

3.1 Digitize the Objects on the Image

To view the process of creating a topographic map at a 1:2000 scale in Thanh Son district of Phu Tho province, refer to **Figure 10**. The features shown in the image, such as water systems, transportation, population centers, vegetation, and boundaries, have been digitized. We have measured and included all types of buildings in residential areas on the map, with buildings and structures larger than 5mm^2 (~ 20 m^2 the real area on the earth surface) being drawn according to the house model and foundation. For structures with an area less than 5mm^2, they are represented by a dot in the center. Material storage and landfill areas are depicted along the boundary.

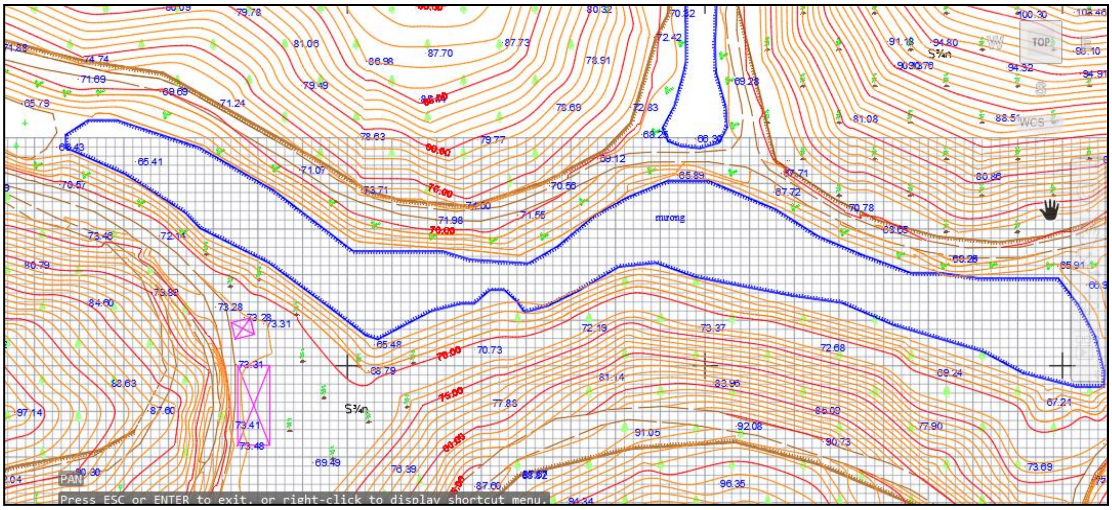

Figure 10: The topographic map of the province Phu Tho, Thanh Son district

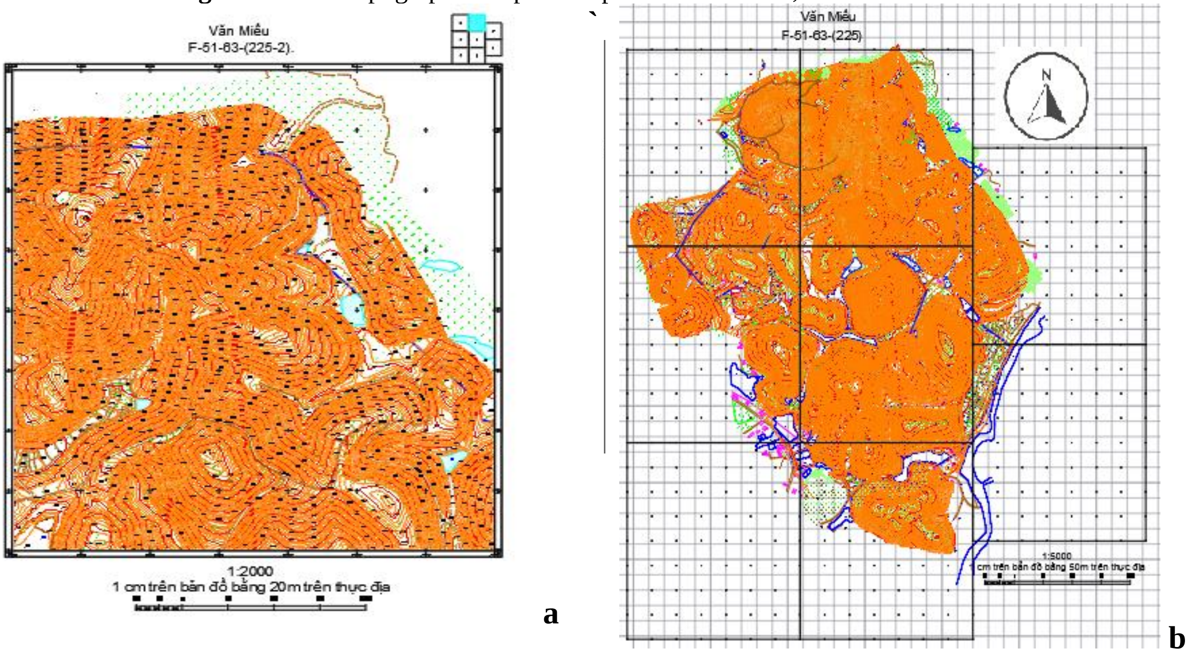

Figure 11: a) Digital map of the area on a scale of 1:2000, b) Digital map of the area before fragmentation

3.2 Map Editor

After digitizing the content elements on the map, we edit these content elements according to the rules of making topographic maps at the scale of 1:2000 in CAD software. The digital layout of Phu Tho province's Thanh Son district at a 1:2000 scale is depicted in **Figure 11**.

4. Conclusion

The experience of using UAVs to obtain Earth's remote sensing materials has shown that the possibilities of using aircraft to create maps exist where there are serious changes in the land use of built-up areas of urban areas. Thanh Son is a mountainous area with complex terrain, the application of UAV technology combined with RTK in building topographic maps has solved many economic and technical problems. The digital topographic map complies with the requirements of the documentation of state departmental organizations since 590 raster images with a resolution of 2.3 cm with a size of 5472x3648 pixels were used for compilation, which was obtained as a result of aerial photography. According to the findings, the largest difference observed was in the height measurement, which reached 4.7 cm. In terms of the Easting and Northing coordinates, the highest deviations recorded were 1.8 cm and 1.4 cm, respectively. According to the results, the accuracy of the map is less than 2 cm which is acceptable for 1:2000 map scale. As a result of processing remote sensing images, more than 15-million-point data with coordinates were obtained, which is enough to compile an orthophoto and a digital terrain model.

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