APPLICATION OF UNMANNED AERIAL VEHICLES TO OBTAIN MORPHOMETRIC CHARACTERISTICS OF LANDSLIDES

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Abstract

The article deals with the use of DJI Phantom 4 RTK unmanned aerial vehicle to obtain morphometric characteristics of the landslide that occurred on May 15 in Tekeli town. A 5-year-old child died as a result of the landslide. During the survey, the site was surveyed using a DJI Phantom 4 RTK quadcopter. On the basis of the obtained aerial photographs, the following were built: a 3D digital elevation model, an orthophoto of the terrain, longitudinal and transverse profiles of the landslide area and the adjacent slope using special software Agisoft Metashape Professional.

Keywords: landslide, drones, DJI Phantom 4 RTK, DEM, orthophoto, 3D surface models, Agisoft Metashape

I. Introduction

The modern world cannot do without new technologies, innovations. One of the methods to obtain data quickly and accurately is the use of unmanned aerial vehicles (UAVs). The advantage of UAVs is that they can be easily deployed and directed to hard-to-reach areas. The resulting imagery data has a high spatial resolution, which minimizes errors in identifying or measuring objects.

The territory of the Republic of Kazakhstan is subject to almost all types of natural disasters. Landslide phenomena occurring on the territory of the Republic are mainly related to human activity and moisture saturation of earth rocks due to abundant precipitation.

We used unmanned aerial vehicles (UAVs) to survey landslide-prone areas in Tekeli town and created digital elevation models (DEMs) based on the obtained aerial photographs. Various morphometric parameters were extracted from the DEMs. The study demonstrated how remote sensing using UAV-derived DEMs complements the results of traditional approaches. And also during the survey of landslide-prone areas the intensity of manifestations and prevalence of landslide and subsidence processes were determined, objects exposed to their impact were identified, the nature of damage, the probability of destruction of objects, as well as material and social damage from such impacts were assessed.

II. Methodology

2.1 Study Area

The city of Tekeli with a population of over 30,000 people is located in the western part of the Zhetysu Alatau range at the confluence of the Kora, Chazha and Tekelinka rivers, which form the Karatal River. Most of the city is located at the bottom of the wide valley of the Karatal River below the confluence of the Kora and Chazha Rivers. At the exit of the mountains, at an altitude of 980 meters above sea level, the width of the valley floor is 1500 meters. To the east, the valley narrows and after 5 km, at the confluence of the Kora and Chazha rivers, at an altitude of 1030, the valley floor is 200 m wide. The height of watersheds of the Zhetysu Alatau spurs bounding the valley of the Karatal River is 1700-1900 m for the southern spur and up to 2000 m for the northern spur. Under the northern slope of the southern spur, which is the left side of the Karatal River, there is a foothill step up to 500 m wide, descending to the bed of the Karatal River with a slope of 4 to 15 degrees, cut through by logs descending from the mountain slope. The step is composed of loess-like loams up to 30 m thick and is built up with private one-storey residential houses with homestead plots.

According to the State Institution "Kazselezaschita", the landslide occurred at 12 hours 03 minutes on May 15, 2022. The landslide occurred on the territory of the abandoned house No. 6 on Chekhov Street. The formed breakaway niche (landslide formation zone) occupies almost the entire territory of the site. As a result of the landslide on Chekhova Street, house No. 4 was damaged and the area of house No. 6 was completely destroyed. On Konaeva Street, house No. 350 was completely destroyed, house No. 348 was completely covered with mud mass, and house No. 255 was partially blocked. A 5-year-old child died in house #350.

According to Kazgidromet data at the gauging station "R. Tekeli" for the previous day fell 15.6 mm of liquid precipitation. The total amount of precipitation since the beginning of May this year amounted to 31.8 mm. At the meteorological station "Tekeli" the sum of precipitation on May 15 this year amounted to 18.3 mm, and from May 1 to 15 this year - 31.2 mm. The sum of precipitation for April amounted to 35.8 mm. Daily maximum precipitation of 10% probability (once in 10 years) was 58.5 mm. The average precipitation in April for the multiyear period is 77 mm. Analysis of meteorological data shows that daily precipitation on May 15, 2022 is repeated more often than once in 10 years, and the sum of precipitation for April of the current year was 45% of the norm. Thus, the meteorological situation in Tekeli during the period preceding the landslide is not abnormal.

Fig. 1: *General view of the landslide on 15.05.2022 in Tekeli*

2.2 Unmanned Aerial Vehicle (UAV).

For the study we used a DJI Phantom 4 RTK drone designed for geographic data collection. The model is equipped with an RTK module and a 20-megapixel camera. The updated RTK module provides positioning data with centimeter accuracy in real time to improve the absolute accuracy of image metadata.

Fig. 2: *DJI Phantom 4 pro RTK*

Table 1: *UAV Specification*

Equipment type	Quadcopter
User level	for professionals
Equipment	DJI Phantom 4 RTK drone Drone body Remote control 4 x Pair of propellers 2 x Smart Flight Battery AC power cable Smart Remote Control Battery AC Power Adapter Charging Hub for Smart Battery Charging Hub for Smart Flight Battery Mobile station Tripod for mobile station Manuals and instructions
Product Weight	1.391 kg (Battery & Propellers Included)
Battery capacity	5870 mAh
Battery life	30 min
Maximum speed	50 km/h (P-mode), 58 km/h (A-mode)
Maximum uphill - downhill speed (up to)	6 m/s - 5 m/s
Maximum wind resistance	10 m/s
GPS mode	GNSS: GPS+BeiDou+Galileo Asia)+RTK; GNSS: GPS+GLONASS+Galileo other regions)+RTK
Sensors / Sensors	Dual IMU; Dual GNSS
Maximum distance	Up to 7 km (FCC) and 5 km (CE)
Maximum altitude	6000 м
Obstacle detection	Front/back (binocular optical sensors): 0.7-30 m; Side (infrared): 0.2-7 m; Down (VPS): 0.7-30 m.
Programs	DJI GS RTK (Android); DJI FlightHub (Browser)

Table 2: *Camera Specification*

Number of megapixels	20
Image size:	4864×3648 (4:3), 5472×3648 (3:2)
Sensor	1" CMOS
Lens: Angle of view	84°: 8.8mm / 24mm (35mm equivalent), f/2.8-f11, focus from 1m to ∞
Video modes	H.264, 4K: 3840×2160 (30p)
Supported file formats	FAT32 (≤ 32GB) or exFAT (> 32GB), JPEG, MOV

2.3. Data used

JPEG images with georeferencing and coordinate system were acquired from the UAV. The area of the processed area was 945.1 m², the estimated flight time was 7 minutes and 47 seconds, the number of images received was 113 images. The flight height was 50 meters, speed was 2.0 m/s, vertical and horizontal overlap coefficient was 80%. The images were processed using Agisoft Metashape Professional software. In the first step of the process, the images are loaded and the coordinate system is set, the next step is to align the photos. In the second step Metashape creates a dense point cloud based on the camera positions calculated in the first processing step and the photos used. The next step is to build a digital terrain model based on the dense point cloud. DEM is a surface model in the form of a regular grid of elevation values.

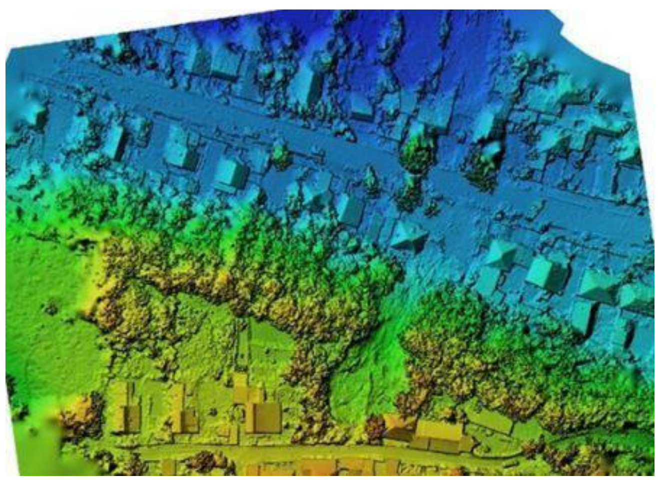

Fig. 3: *Digital elevation model*

At the fourth stage orthophoto plan is created, the initial data is the DEM.

Fig. 4: *Orthophotoplane*

The final step in Agisoft Metashape Professional is to build a 3D terrain model.

III. Results

The landslide occurred on the ledge of a gentle foothill terrace of the north oriented slope of the left side of the Tekeli River valley. The terrace edge is located at 1050 m abs. and the footwall at 1022 m abs. Geographic coordinates of the landslide top: 44º 51' 17.6" N, 76º 47' 31.38" E. The upper part of the profile (landslide formation zone) has a steepness of 20º for 40 m, the lower part (transit zone) - 30 m long, has a steepness of about 30º (Fig. - profile from copter).

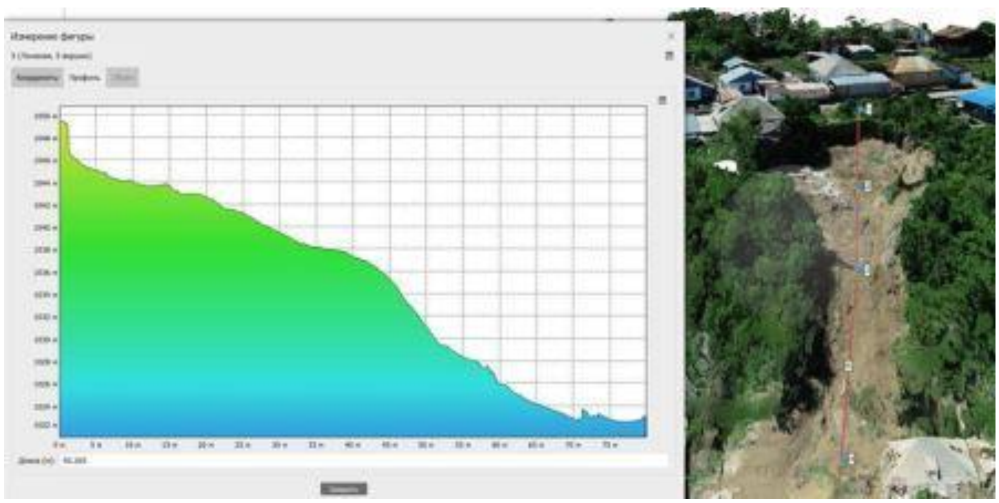

Fig. 5: *Longitudinal profile along the landslide path*

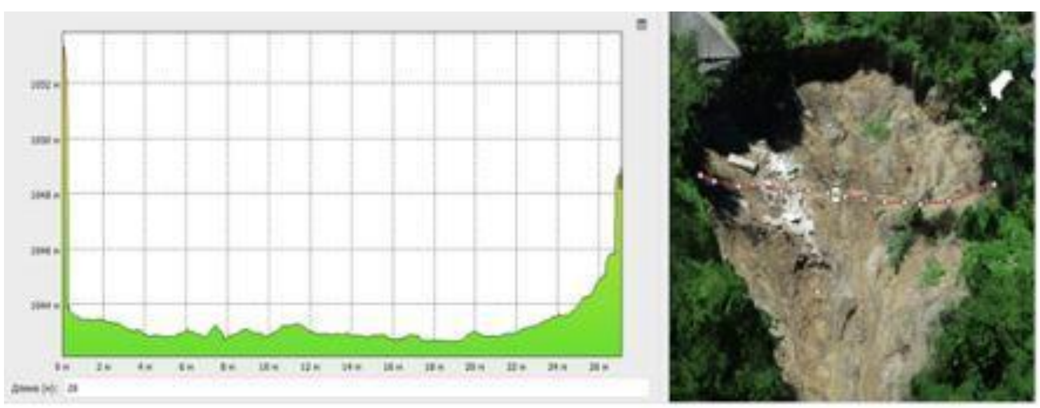

Fig. 6: *Transverse profile of the landslide detachment niche*

The slope is composed of dense clay of light brown color, overlaid with developed soil cover (thickness of humus layer 30-50 cm) with dense woody, shrub and herbaceous vegetation. Konaeva Street runs along the foot of the slope along the wide overflow terrace of the Tekeli River, and Chekhov Street runs along the edge of the terrace at the upper part of the slope.

The landslide was formed as a result of localized overwatering of the soil mass at the top of the upland terrace ledge. The landslide breakout niche is located along the lower side of Chekhov Street between houses No. 4 and 8. The line of detachment runs at a distance of 3 m from the road. The breakaway niche has an oval shape. Its length is 40 meters and width is 28 meters. The walls of the trench are almost vertical. The height of the walls at the top of the gap is 4-5 m (Fig.... - photo screenshot from the copter survey). The height of the side walls decreases along the landslide fall line and is 0.5-1 m in the lower part of the detachment niche. The area of the detachment niche (landslide formation zone) is 770 m2, average depth is 4.2 m. According to the survey data, the volume of the ground mass in motion amounted to 3234 m3.

From the rear wall of the landslide breakaway niche, a bare, buried by 1 m water pipe with a diameter of 20 mm, about 3 m long, protrudes for 3 meters. According to the testimony of the State Institution "Kazselezaschita", after the landslide occurred, water flowed from this pipe until water supply to Chekhov Street was stopped by the local municipal water supply company.

The bottom of the trench has a steepness of about 12º. It is covered with debris from the final stage of the landslide, as well as debris from the foundation and terrace of House No. 4. In some places, a "polished" slip plane is exposed at the bottom of the niche, along which the primary displacement of the landslide body took place.

The strongly overmoistened soil mass in the detachment niche, once in motion, quickly turned into a liquid mass and swiftly swept down the steep lower part of the slope in the form of a splash. Therefore, there are no large blocks of rock in the sediment zone, typical for slow-moving landslides. The width of the landslide transit zone is 14 m, length - 30 m, area - 400 m2. (Fig.7. - photo from copter).

Fig. 7: *Landslide transit zone*

The flow of liquid mud spread along an almost horizontal surface from the foot of the slope to a distance of 75 m, covering Konaeva Street. The landslide deposition zone is mainly represented by a homogeneous mud mass. It was 50 m wide and covered an area of 2,500 m2. The thickness of sediments on the road is 0.5-1 m, on the line of houses it reached 3 and more meters (Fig.8. - copter photo).

At present, there is no threat of recurrence of dangerous landslides, as the main mass of overwatered soil that formed the landslide body has been discharged down the slope profile. However, after heavy rains it is possible that clay sediments at the bottom of the detachment niche and in the area of landslide deposits will be eroded and small mud flows will be formed, which will drift down the road along Konaeva Street. It is also very possible that soil collapses on the walls of the breakaway niche with a volume of several m3 will stop at the hollow bottom of the breakaway niche without reaching the foot of the slope. This process may lead to the growth of the breakaway niche and destruction of house No. 4 on Chekhova Street and the road in front of house No. 9.

Fig. 8: *Landslide deposition zone*

IV. Conclusion

The use of UAVs is a new method of data acquisition, but has proven to be a fast and safe method of obtaining accurate morphometric characteristics.

In this study, the UAV technology provides an orthophoto and digital surface model (DSM) with a spatial resolution of 1 cm.

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