

LANDSLIDE MAPPING USING DRONE-BASED METHOD

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ABSTRACT. The article focuses on the possibilities of landslide mapping using photogrammetric and LiDAR measurements from a drone. The measurements are then evaluated and compared with conventional methods.

KEYWORDS: Territory mapping, landslides, photogrammetry, LiDAR, drone.

1. INTRODUCTION

In recent years, there has been an improvement in the availability of tools that can be used to map an area from a height. This is the case whether we are talking about drones or devices that are attached to them and then used for the actual measurement. In these cases, we usually mean special cameras or laser scanners (LiDARs). A few years ago there was relatively little choice among devices capable of performing high-quality height mapping. Moreover, their price reached very high amounts even in the order of millions of CZK (Czech Crowns). However, recently we have seen a significant improvement – a quality drone with a camera or LiDAR, which can easily map a large area, and which can be found at only tens of thousands of CZK. The quality of current cheaper devices is quite easily equal to that of the more expensive older drones. At the same time, there is also a growing supply of private companies that can carry out this territory mapping at a relatively low cost. One of the main advantages of height mapping is the rapid coverage of a large area. A site in the Elbe River valley on the eastern edge of Ústí nad Labem in the village of Neštětice was chosen as a pilot project to test the new possibilities of modern instruments. It is an active landslide area according to the landslide register in the ČGS – geofond (according to ČGS [1]), posing a potential risk of endangering a local road and with a gas pipeline running directly through the landslide area (Figure 1).

2. GEOMORPHOLOGICAL AND GEOLOGICAL DESCRIPTION OF THE AREA

The study area is situated on the southwest slopes of the Elbe River valley, where a deep and wide canyon was created during the Pleistocene period (e.g. Kalvoda a Zvebil 1983 [2]). The weathered surface layer of clay material which was developed from mainly cretaceous sediments, tertiary volcanoclastics, and quaternary eolic sediments, was disrupted due to unloading because of river incision and erosion.

The clay character of these sediments is the cause of additional slope movements. Considerable gravitational movements have taken place in the surface layer in the area of interest. Moreover, the high-pressure pipeline which goes more or less directly through the huge active landslide is affected by the recent gravitational movement activity. In wider areas, local people observed many local slope movements in the past, ranging from very fast movements to slow creeping movements. The latter is well documented and is just in front of the middle part of the local road from Neštětice to Skalka housing estate, which was built up in the area of active landslides. This locality was remediated a few decades ago, but the problems persist. According to data from the Czech geological survey, the active area of landslides is 221 000 m².

3. MAPPING OF THE TERRAIN

The survey of the area was carried out by a DJI Matrice 300 RTK drone equipped with a DJI Zenmuse P1 camera and a DJI Zenmuse L1 LiDAR (Figure 2). Similar results can be achieved in the case of photogrammetry currently with equipment costing about 80–100 thousand CZK.

To evaluate the individual data, it was necessary to take several measurements over time, process them, and then compare them. A total of four measurements were made, namely in July 2021, December 2021, April 2022, and February 2023. All measurements were made using photogrammetry, while the December 2021 measurement was also made using a laser scanner (LiDAR). The measurements result in so-called point clouds, which are very detailed and contain tens of millions of points (Figure 3).

Such detailed data needs to be further processed. First, points that are not representative of the terrain itself, be it buildings or vegetation (trees, bushes), must be eliminated. Next, the total number of points must be reduced to generate a digital terrain model on which individual comparisons can be made. The processing of the point clouds was carried out in the “GEO5 Point Cloud” software from the FINE company. The program contains special algorithms that allow

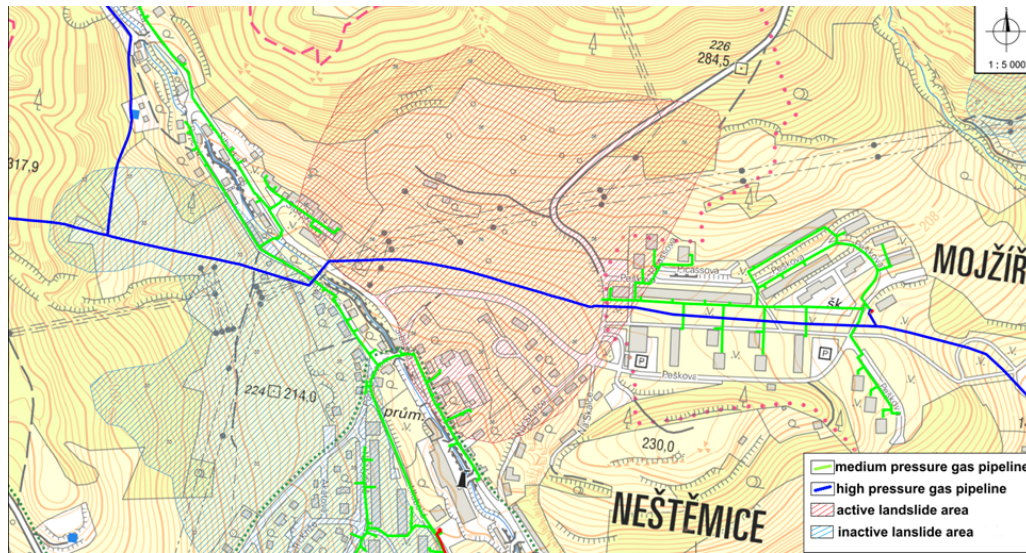


FIGURE 1. The studied area with the marked landslides near the gas pipeline.



FIGURE 2. DJI M300 RTK drone with camera for photogrammetric measurements.

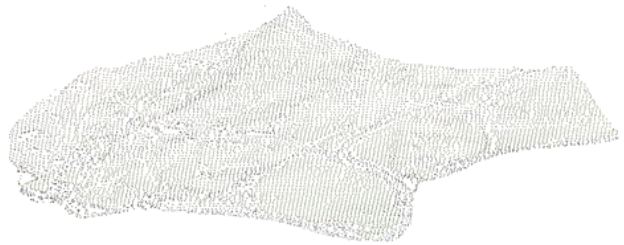


FIGURE 4. Reduced point cloud (approx. 7 000 points).

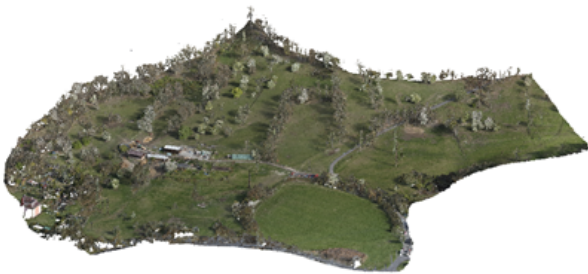


FIGURE 3. Original point cloud (approx. 90 million points).



FIGURE 5. Studied area.

for the simple removal of vegetation, while the entire cloud can be arbitrarily reduced. The clouds were processed to contain about 7 000 points – this number already allowed for the creation of a digital terrain model including the subsoil (Figure 4).

Based on the data from each measurement, four digital terrain models were created. The “GEO5 Stratigraphy” software was used to create them, which allows us to calculate the volumetric changes between the models and also to track the differences of the focused points in detail. In order to eliminate inaccuracies

at the edges of the plume, we decided to “trim” the study area to a size of approximately 60.000 m², where potential changes were most likely to occur (Figure 5).

4. EVALUATION OF MEASUREMENTS

The original idea was to track volume changes across the entire area – if there was a part of the model

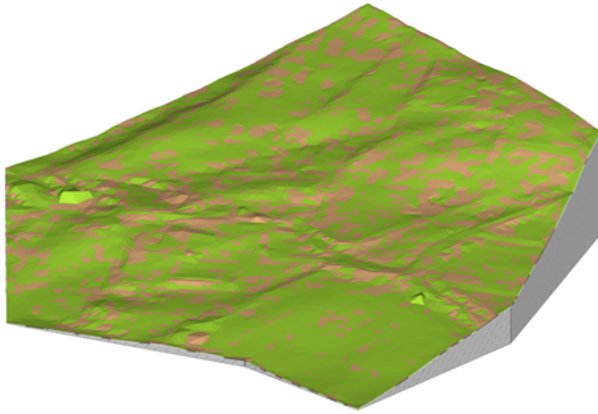


FIGURE 6. Comparison of terrain from 12/2021 and 4/2022 (original terrain brown, new terrain green).

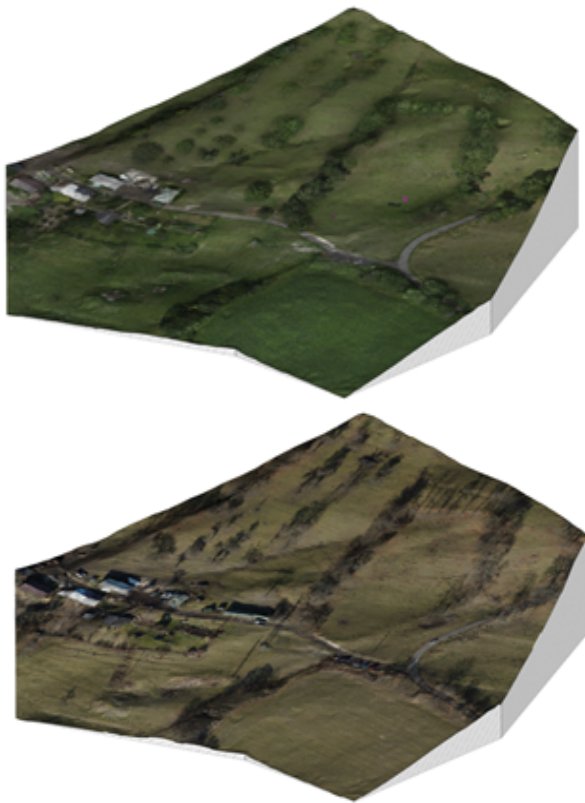


FIGURE 7. Vegetation change between the first and second measurement (July -> December 2021).

where there was an increase in ground volume at the bottom and a loss at the top, this could be a potential sign of surface mass movement. Thus, calculations of ground changes were made between each measurement (Figures 6 and 7).

After calculations of the changes in volumes between the models, the main disadvantage of this method became apparent. The vegetation cover changed between measurements. If grass grows even a few centimeters over such a large area, the total volume change is huge – in the order of thousands of m^3 .

This effect cannot be simply eliminated. Partly, it could help to keep the exact timing of the measure-

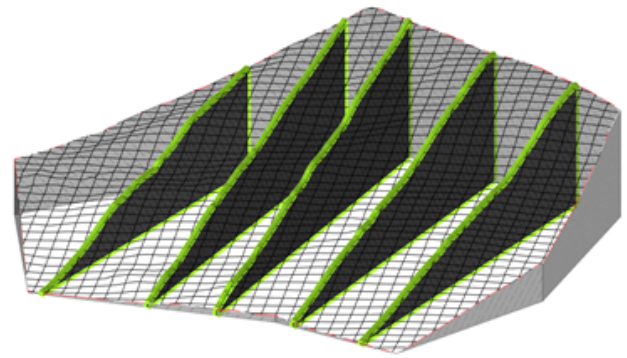


FIGURE 8. Output sections in the 3D model.

ments at annual intervals, but the amount of vegetation would still vary depending on climatic conditions. Larger vegetation such as trees and bushes can usually be removed relatively effectively with point cloud modification in various programs. However, there is no simple method when dealing with continuous grass vegetation. A laser scanner, called LiDAR, can deal with this to a certain level (unlike photogrammetry) as the rays can penetrate even thinner vegetation. But in the case of heavy vegetation, even this approach has limited results. In general, we can safely say that this is the kind of risk that the vegetation problem brings. The conversion of real terrain into digital representation is also addressed in e.g. [3]. However, a computational raster would suffer from the same shortcomings as in the case of photogrammetry or laser scanners. The information about the vegetation layer implicitly carries a financial risk that cannot be transferred to the assessor of the studied area. The conclusions of the assessment are the basis for deciding on future investments in the rehabilitation of the area, the amount of which cannot be estimated at this stage of the assessment.

Therefore, as another option for the comparison of terrains, the method of tracking the so-called output sections was used. In the Stratigraphy program, it is possible to create any number of such sections in the model, which can include terrains from all measurements simultaneously. These sections can then be compared in detail in CAD programs or directly exported to other calculation programs, e.g. for slope stability calculations (Figure 8).

In order to be able to compare individual sections, we first had to know the possible accuracy of the measurements. Therefore, we focused on the part of the model where we did not expect any changes – in our case, we selected the roof ridges of each building. As a result, the accuracy of the points between measurements was within approximately 5 centimeters, which is about the same as a standard GPS geodetic measurement.

We could then proceed to compare the individual sections (Figure 9).

A total of 30 resulting sections were created and compared, which were guided by the model in different

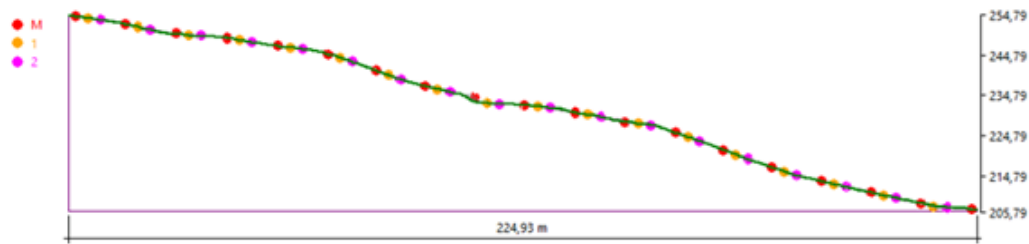


FIGURE 9. Detail of terrain comparison using the output section.



FIGURE 10. Hay store – location with volume change between measurements.

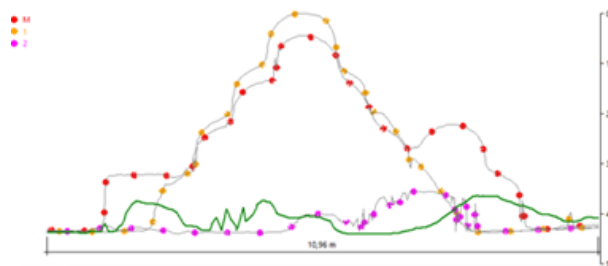


FIGURE 11. Hay store – output section.

directions and lengths. None of the sections examined showed potential signs of sliding during the period under study. Differences between points were at most in the order of sub-centimeters, and which could have been caused by vegetation changes or by the accuracy of the measurements themselves.

In order to be able to verify the possibility of comparison, we selected a location in the area where material movement was certain to have occurred – our choice was a hay store next to an agricultural building (Figure 10).

With simple steps, it was possible to calculate the changed volumes between the different time periods and also to compare the changes in terrain using the resulting sections (Figure 11).

5. CONCLUSION

Although no new significant slope movement occurred in the studied area during the nearly two years of monitoring and slow movements of a few centimeters per year were below the resolution capabilities of our instruments, we were able to test and learn new approaches in the use of photogrammetry and LiDAR. Mapping of the site did not lead to any results indicating potential landslide sites, leading to a simple

conclusion – no changes have occurred during the year and a half under study. The aim of this paper is therefore to bring the possibilities of aerial mapping closer to the needs of other researchers interested in slope movements, terrain morphology, and land surface change in general. It is an effective method that allows the monitoring of a large area in a short time. The approach described above can detect sudden morphological changes, even small landslides and changes in terrain volume in the order of tens of cm to the first few meters, and at a very low cost. The measurement accuracy is then comparable to geodetic point tracking using GPS. However, it is unsuitable for short-term monitoring of slow creep-type terrain changes.

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