MODERN METHODS OF MAPPING LANDSLIDES. CASE STUDY – THE IEZER-FEREDEU LANDSLIDE

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Abstract. The landslides from the mountainous area, which have generated natural dam lakes, have always attracted the interest of the researchers. In Romania, even if some of these landslides are very old, they have not yet been thoroughly investigated. In this respect, the aim of the current research is to present the results obtained by applying modern methods of mapping landslides on one of the oldest Romanian landslide, Iezer-Feredeu (Sadova village). The results are very interesting especially because there have been many discussion about using GPS in mountain forested areas. The area affected by the landslide of Iezer Feredeu is a major one, having approximately 62 hectares and a height difference of 337m, located in a less accessible area, mostly covered by coniferous forest with high tree density. In these conditions, mapping the entire body sliding was possible due to the use of the GPS, with which were taken approximately 1500 representative points from the field that were used to generate a cartographic background with an equidistance of 5 and 10 meters. The method that we used in researching the landslide from Sadova has proven to be a viable one and can be used furthermore in other similar conditions.

Keywords: *methods of mapping, landslides, Iezer-Feredeu landslide*

1. Introduction

Most of the Romanian natural dam lakes have been a permanent attraction for researchers of both hydrology and geomorphology fields. Geomorphology had a crucial role in unlocking and understanding the mechanisms that characterize the landslides that led to the formation of lakes. But there are still some areas that escaped from the attention of researches and Iezer Lake is one of them. Therefore, the aim of this article is to analyze the major landslide of Iezer-Feredeu by using modern methods and equipment. The research is more interesting as Iezer Lake from Obcina Feredeului (Feredeu Mountains) is one of the oldest natural lake in Romania, being mentioned in documents since 1594 and was formed after a massive landslide that occurred approximately 1100 years ago (Mândrescu et al., 2010).

The best known natural dam lakes of the Romanian Carpathians benefited of numerous scientific studies as is the case of the Red Lake from Hăghimaş Mountains (Schueller, 1838; Mihăilescu, 1940; Pandi & Buzilă, 2004; Romanescu & Stoleriu, 2010) and Cuejdel Lake from Stânişoarei Mountains (Ichim & Rădoane, 1996; Rusu et al. 2002; Rădoane, 2003).

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As the surface of Iezer Lake from Feredeu Mountains does not exceed 1.7 hectares it has remained outside the scientific attention until 2009, when an extensive program of research (Lesenciuc et al., 2010, Mândrescu et al., 2010) has started.

2. The study area

Iezer Lake is located in Feredeu Mountains, in Sadova catchment area, left tributary of Moldova River. The landslide that blocked Sadova brook, took place on the western slope of Feredeu Mountains, at an altitude of 900 meters up to 1237 meters and the lake maximum elevation is at 927 meters. The geographical location of the landslide is marked by the intersection of parallel 47º 36' 13" north latitude with the meridian 25º 27' 24" east longitude (Figure 1).

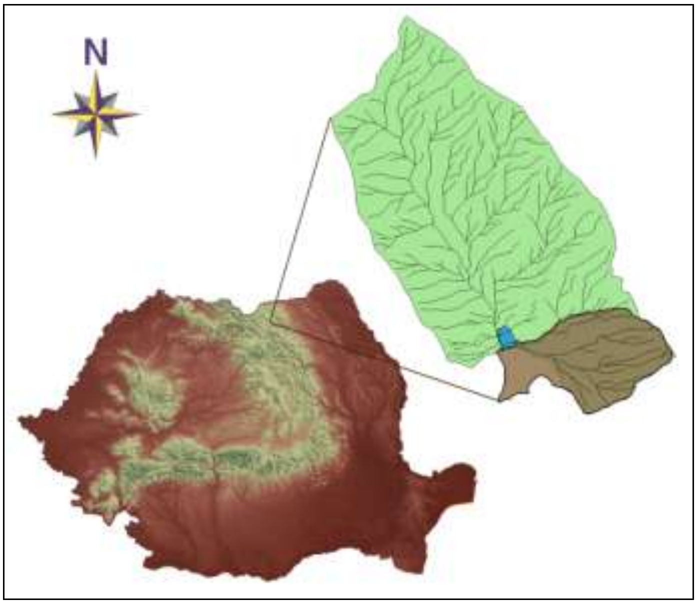

Figure 1: The Geographical location of Iezer-Feredeu landslide in the upper catchment of Sadova brook and Romania

3. Methodology

In 2009 this area began to be properly researched as it was made the first topographic measurements of the lake using the Leica TCR 1201 total station. In 2011, the research continued, using this time the Leica GPS 1200 (figure 2), generating an accurate topographic measurement of the entire body slide. It was preferred to use the GPS due to the hard work field conditions (difficult access, high tree density) and also because this method is much faster than the use of the total station (3-4 days compared to 2-3 weeks). Even if the accuracy of using the total station is superior to GPS, considering the scale and size of the landslide it was preferred the GPS as our research did not required millimeter precision measurements. In addition to the topographic research method was also very important the cartographic method as there were also used the 1:25.000 scale topographical maps and the 1:5.000 scale orthophotoplans made during the 2005 flights. In processing the cartographic materials there have been used several software such as: Leica Geo Office, Global Mapper 11, AutoCAD 2009, Surfer 9, Microsoft Excel, Photoshop CS5. Global Positioning System (GPS) is a system based on the communication between a number of satellites and their receiving stations on Earth. The basic principle is to use the GPS satellites as reference points to determine position by triangulation points on the ground.

Figure 2: Leica GPS 1200 System

To achieve a high accuracy in recording measurements it is necessary to pay attention to the area of study. Frequent loss of signal is found in and near buildings or in the woods while the open fields are the ideal locations as the signals are very strong. In this case, considering the large area of the landslide (61.63 ha) and also the strong fragmentation of the landscape, the measurements were carried out under very good conditions as the precision needed for this kind of research did not have to be very high. Thus, this modern method of researching a geomorphological process even under conditions similar to those from Iezer Lake is welcomed because errors are easily removed and the processing software brings fantastic contribution in achieving the final mapping product.

Therefore, there were measured about 1500 representative points (which GPS transcribed directly into the mapping project of Romania, STEREO 70) that were eventually imported into Global Mapper and overlaid on the 1:5.000 scale orthophotoplan (aerial photograph), resulting the correct slide limits (Figure 3).

Figure 3: The slide limits and the measured points overlaid on the orthophotoplan

The program also allows verifying the accuracy of the data collected from the field by measuring, besides the points from the body slide, some checkpoints, in order to be able to verify later if there were made any mistakes during the process of data translation or if the coordinates reversed during their introduction into the GPS. Therefore, on the orthophotoplans there are some elements that do not change (significantly) over the time and so they can be taken as mark points, such as a road or the electricity network. In this case, the checkpoints measured on the road limits were overlaid on the orthophotoplan, thus proving that no errors have been made (Figure 4).

Figure 4: The checkpoints measured on the road limits

In order to use the data derived from measurements also on other 3D modeling programs, the measured points were centralized in a chart of coordinates and altitude rates (Table. 1).

Table 1: The points measured in STEREO 70 system

Point No.	X (Latitude)	Y (Longitude)	Z (Altitude)
1	533764.350	678244.789	937.858
2	533765.650	678237.601	935.772
3	533771.553	678230.007	943.831
4	533773.130	678226.805	946.545
...	...	...	...
1549	534698.491	678507.256	1120.033
1550	534697.218	678515.535	1116.141
1551	534683.850	678528.432	1097.927
1552	534681.773	678549.065	1114.793
1553	534683.595	678564.894	1115.828

Like the Global Mapper software, other programs also use the same form of data but operate with different interpolation algorithms that offer different results of course, but transmit the same information.

4.Results and conclusions

A great advantage of using the GPS is that is very useful when it comes to forest areas and the accuracy required does not have to be as great as in the measurement and marking of points for a road project or for an urban area, where errors that exceed a few centimeters are not allowed.

As GPS measurement methods are used: the static and the dynamic methods. These two methods are subdivided into: static, static - fast, pseudo - static and kinematic. Compared to static GPS measurements, the kinematic measurement involves the antenna stationing in some points for a few minutes in order to retrieve data from satellites, and data acquisition is performed in real time.

This was the procedure in this case and the errors arising are of centimeters, or even meters in areas with higher slope where the GPS signal was not strong enough, for example, under the separation cornice, the signal was very poor due to high slope and the antenna did not received signals from the satellites located in the east (Figure 5).

The next step, after the field measurements, is to upload the data in the software (Global Mapper) in order to create the curve lines level maps at various equidistance, as needed (Figure 6 and Figure 7). The higher density of the measured points the higher the accuracy of the maps using the curve lines. If one would like to highlight certain areas such as sectors or microforms of relief founded on the slide surface, it would be very easy using the GPS, by measuring them thoroughly and then overlay the data on the curve lines generated by the vectorization process on the 1:5000 scale plans. Unfortunately, this method will never be able to reflect the territory as well as the maps realized with topographic measurements, which are more precise and accurate.

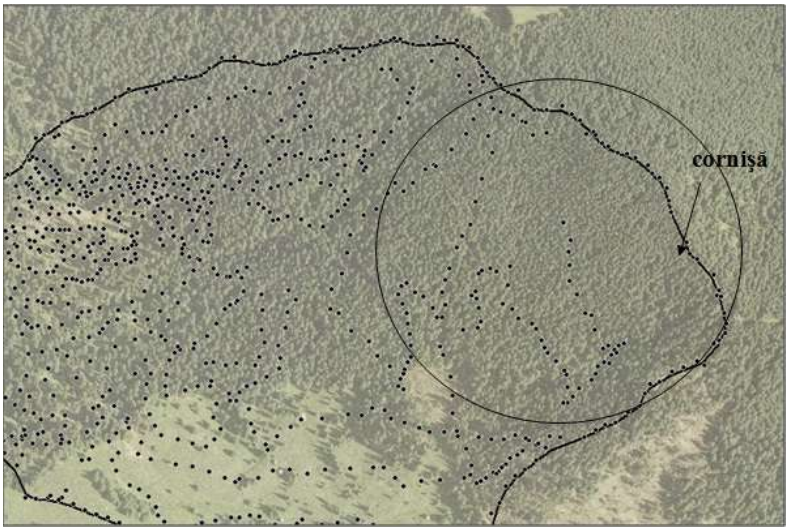

Figure 5: The lack of the measured points at the upper part of the landslide

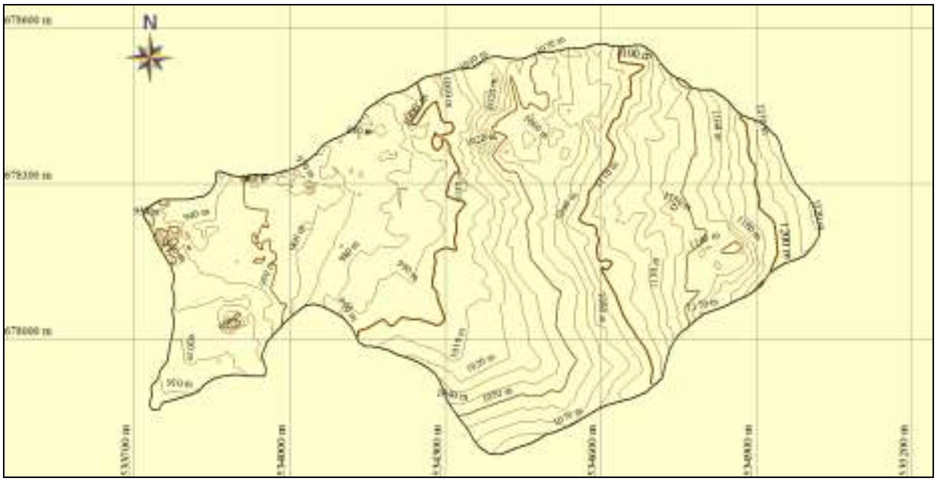

Figure 6: The curve line level map (10 meters equidistance)

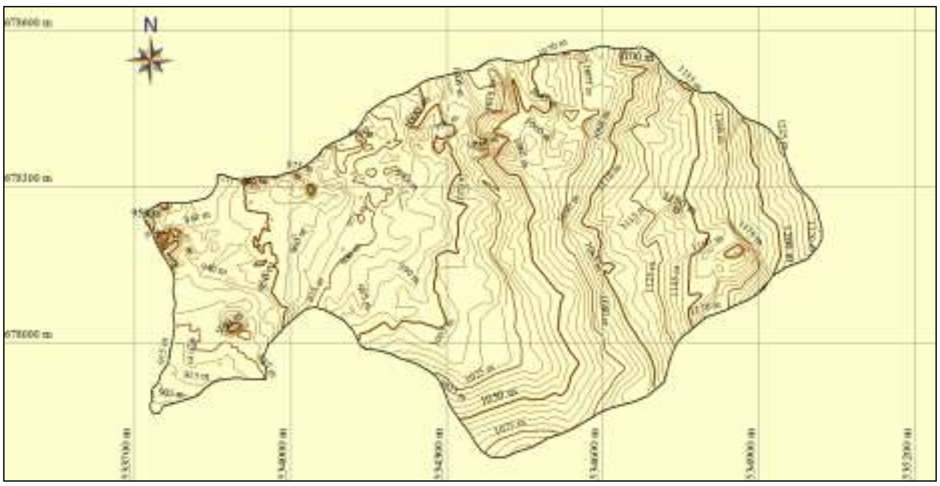

Figure 7: The curve line level map (5 meters equidistance)

Therefore, when studying a landslide, the confrontation of maps at different scales, obtained by different methods and different types, is a very important step, in order to better understand the morphology of the actual slide.

The data was also transferred in Excel and then introduced in Surfer software creating a series of 3D relief modeling using different methods of interpolation, resulting terrain models (figures 8 and 9).

A series of statistical data resulted from using these software: the landslide area totaling 61.63 hectares, the landslide perimeter summing 3851 meters, the maximum elevation of 1237.4 meters, the minimum elevation of 900.1 meters and the height difference of 337 meters (figure 10).

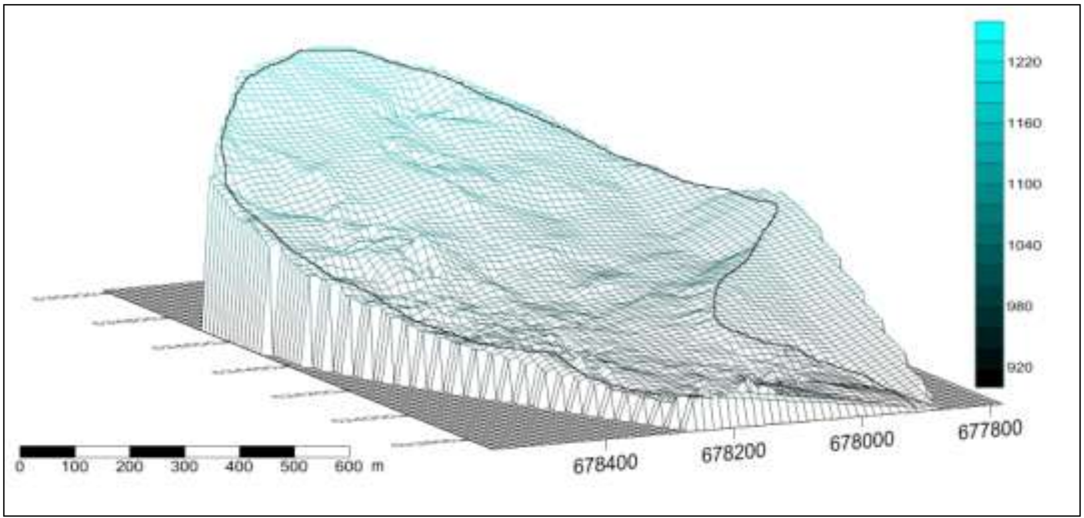

Figure 8: Three-dimensional modeling of the slide body

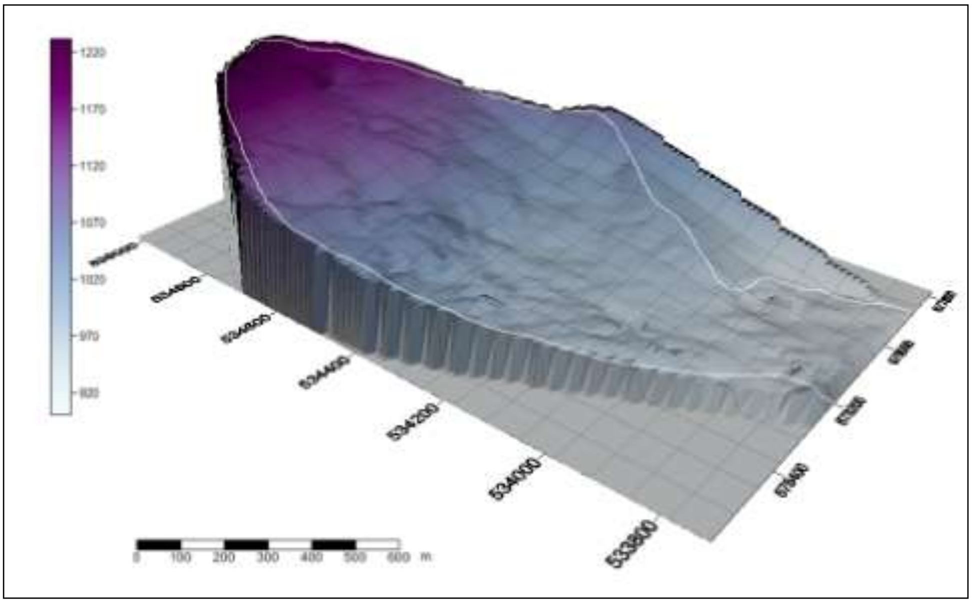

Figure 9: Three-dimensional modeling of the slide body

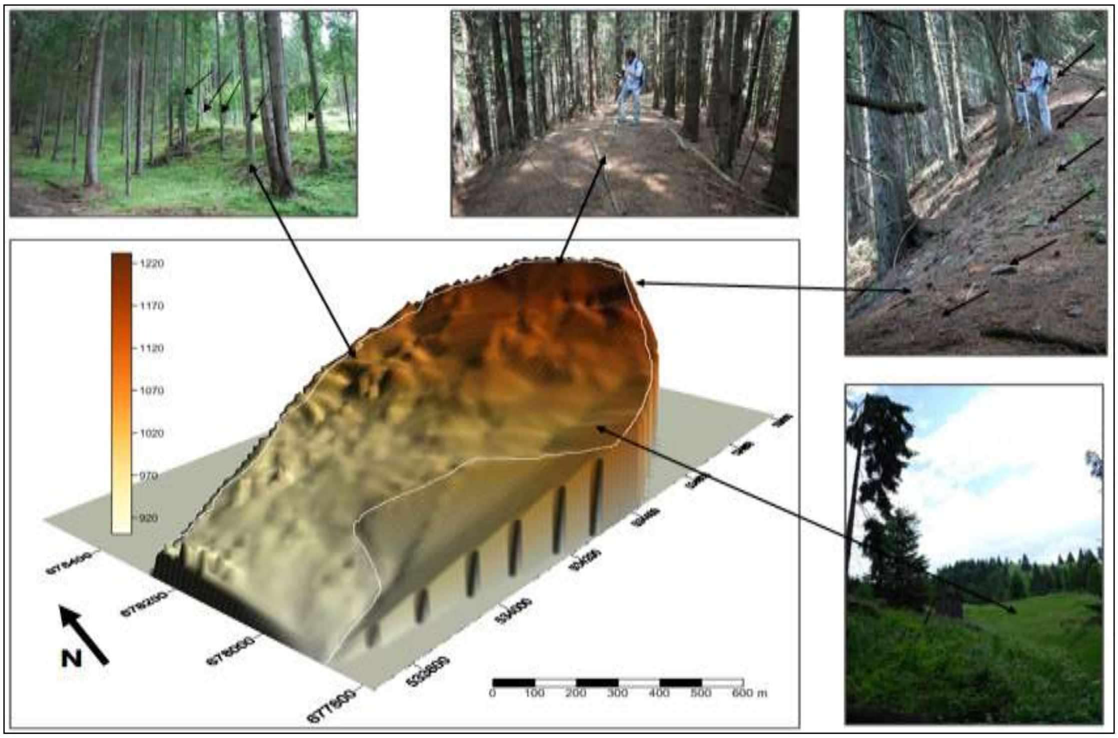

Figure 10: The measurements of the landslide limits

In conclusion, the use of GPS for mapping landslides in forested mountain areas is possible with the acceptance of some errors which does not affect fundamentally the final results. The method is especially useful in creating three-dimensional modeling of the study area.

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