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Original Article

Landslides Monitoring by Using Topographical Surveying and 3D Laser Scan

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Abstract

Landslides are usually triggered by natural hazards, but this incidence is increasing due to impropriate land use practices with visible social, environmental and economic consequences for medium and long term, and is also the most extensive form of degradation. Modern techniques facilitates delivering of monitoring results faster than classic methods, taking into account the specific natural conditions used in the planning and organization of degraded lands. Land degradation processes influence negatively agricultural lands, especially pastures which are the most dangerous outbreaks of soil degradation. This article shows the monitoring results regarding the digital terrain model of a landslide located in Lechinta Commune – Vermes Village (Cluj County).

Keywords: landslides, hazard maps, digital terrain model (DTM).

1. Introduction

Landslides have a negative and extensive impact on terrain, and the cost of landslides breaks down into the following proportions: damage (60%) and adjustment (40%) [1]. In landslides studies are used digital elevation models (DEM) or LIDAR techniques for monitoring and characterization of this phenomena [3].

Landslides are usually triggered by natural hazards, but this incidence is increasing due to impropriate land use practices [5]. Landslides processes influence negatively agricultural lands, especially pastures which are the most dangerous outbreaks of soil degradation [4].

According with geological maps (Fig. 2), the lithological layers are described by clay facies, fertile, and conglomerates, belonging to Pannonian, Sarmatian, present both on the tops and on the slopes of the hills. From these deposits were formed solification sediments, whether they directly or by reshuffling the slopes, as colluvial and colluviums.

The study area is localized in Lechinta Commune, Vermes Village, Bistrita-Nasaud County (Fig. 1). The studied site has a perimeter of 4,500 m and an area of 120 hectares.

The landform is exclusive hilly, including the highest hills of Transylvania Plain. The height of the hills is between 450-600 m and the hillsides are characterized by moderate to extreme slope (5º-25º). In the studied site were determined elevation differencies ranging between 0 and 185 m (353 RMN – 538 RMN). The climate is typically temperate, moderate continental; with sever winters and relative warm summers, followed by warm autumns.

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The landslides monitoring was done based on repeating measurements using classic and modern methods and techniques [10].

In field determinations were used to establish monitoring actions and algorithms which were used to create a Geographic Information System regarding landslides as natural hazard.

The geographic information systems compiled with GPS-GNSS-RTK techniques [2, 6, 7, 8, 11] could be used in preventing landslide negative aspects upon environment and settlements or farmer's livelihoods [9, 12].

Figure 1. The localization of the studied area – Lechinta Commune (Bistrita-Nasaud County) [13]

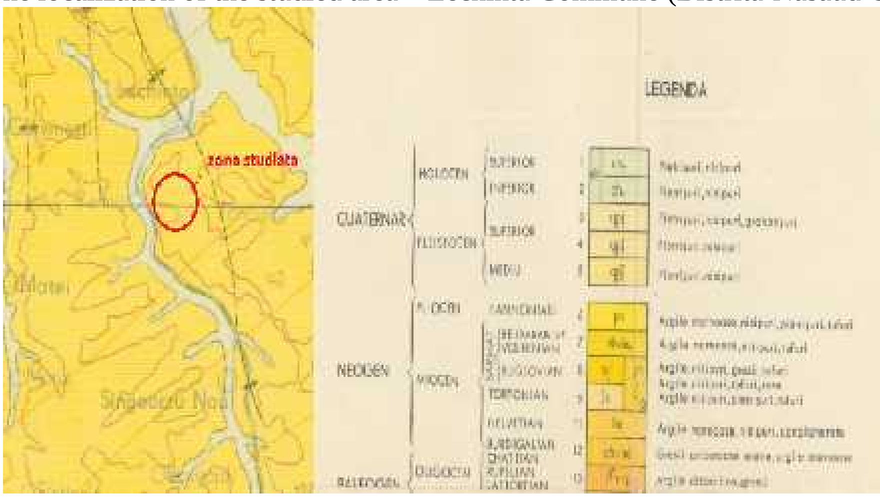

Figure 2. Geological map - L - 35 – VII [14]

2. Material and Method

In designing the landslides monitoring were considered: (1) identification of the study site; and (2) marking the site perimeter with concrete borne. In this landslide study were taken four repeating measurements: one classic method using total station with 2 second precision, and three modern methods using GPS-GNSS-RTK techniques – GPS by static and cinematic methods with double frequency L1/L2 - and 3D laser scan.

The coordinates were compute in the national networks: (1) 1970 Stereographic Projection System used for planimetrics measurements and 1975 Marea Neagră Elevation System (Fig. 3).

The devices used for terrain measurements are: (1) GPS South 82T with TransData implemented system; (2) Sense Scanner 3D with 1 mm resolution and TopCon 3002N total station.The software used to compute the topographic data of the terrain are: (1) Topo Lt (topographic data process); (2) Sense 3D (scanner data process); (3) Cinema 4D (digital terrain model process); (4) Cadian (CAD information process); (5) Prof Lt (terrain longitudinal and transversal profiles); and (6) ArcMap and ArcGIS (process of GIS data).

The 3D model of the terrain was proceeding with main level curves generated with 50 m equidistant and 5 m equidistant for the secondary level curves (Fig. 4, Fig. 5 and Fig. 6).

Also, for monitoring and analyzing the landslides elevation data were done four transversal profiles and one longitudinal profile (Fig. 7).

Coordonate stereografice 1970
Data : 10.01.2015

nr. pct.	X (Nord)	Y (Est)	Z (cota)
52	610603,5738	448861,433	326,3508
53	610604,8469	448861,4149	326,1284
54	610608,0849	448860,6312	326,0905
55	610608,1476	448861,7122	326,3176
56	610608,3958	448863,5795	326,6872
57	610608,7977	448864,8572	327,123
58	610607,6057	448866,1996	327,4365
59	610606,6403	448866,0485	326,9706
60	610605,8875	448865,7109	327,0427
61	610604,9819	448864,2958	326,6344
62	610617,1846	448860,3577	326,7868
63	610620,2919	448861,4425	327,309
64	610625,4771	448862,3473	327,9908
65	610635,3462	448862,9587	329,3811
66	610638,9103	448863,0563	329,7886
67	610643,2082	448861,6353	329,9487
68	610649,8388	448857,8475	329,7743
69	610653,3559	448856,7495	329,6661
70	610675,5576	448844,3454	326,1136
71	610686,3953	448834,7933	323,7067
72	610697,9755	448833,3406	324,7449
73	610721,3655	448831,9968	326,8945
74	610741,5961	448837,3025	330,2682
75	610755,0006	448833,8887	331,418
76	610767,5013	448830,3947	331,9164

Coordonate stereografice 1970
Data : 28.04.2015

nr. pct.	X (Nord)	Y (Est)	Z (cota)
52	610603,5996	448861,4588	326,3766
53	610604,8705	448861,4385	326,152
54	610608,1209	448860,6672	326,1265
55	610608,1656	448861,7302	326,3356
56	610608,4208	448863,6045	326,7122
57	610608,8337	448864,8932	327,159
58	610607,6467	448866,2406	327,4775
59	610606,6653	448866,0735	326,9956
60	610605,9235	448865,7469	327,0067
61	610605,0199	448864,3338	326,5964
62	610617,2026	448860,3757	326,7688
63	610620,3149	448861,4655	327,286
64	610625,5101	448862,3803	327,9578
65	610635,3752	448862,9877	329,3521
66	610638,9463	448863,0923	329,8246
67	610643,2322	448861,6593	329,9727
68	610649,8738	448857,8825	329,8093
69	610653,3989	448856,7925	329,7091
70	610675,5846	448844,3724	326,1406
71	610686,4133	448834,8113	323,7247
72	610698,0085	448833,3736	324,7779
73	610721,3975	448832,0288	326,8625
74	610741,6211	448837,3275	330,2432
75	610755,0376	448833,9257	331,381
76	610767,5203	448830,4137	331,8974

Figure 3. The coordinates computed in 1970 Stereographic Projection System and 1975 Marea Neagră Elevation System

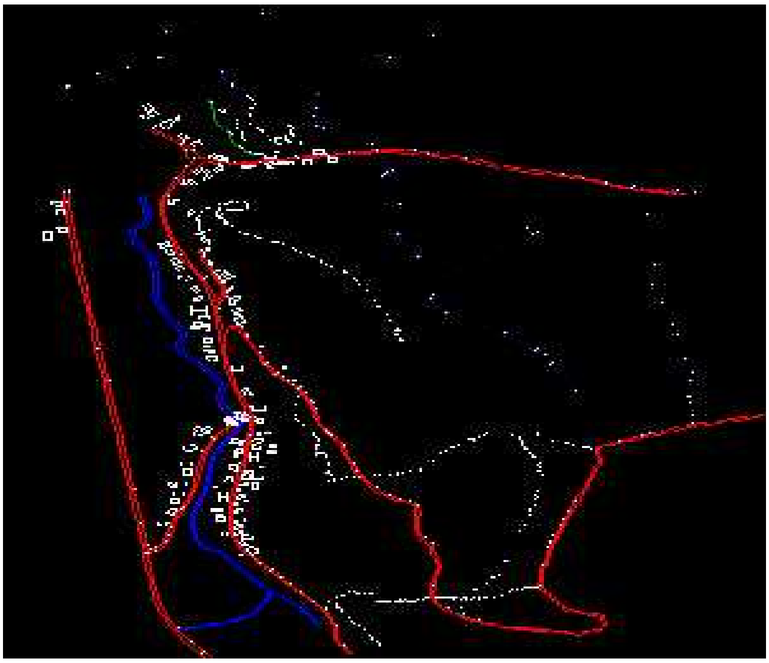

Figure 4. Representation of topographic plan using Cadian 2011 software

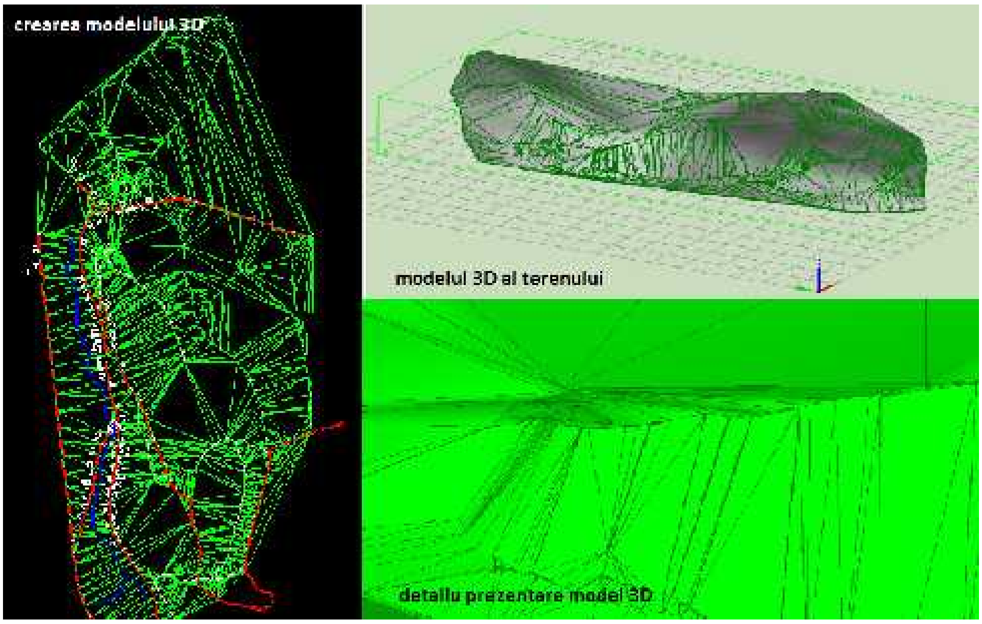

Figure 5. 3D model representation of landslide using Cadian 2011 software

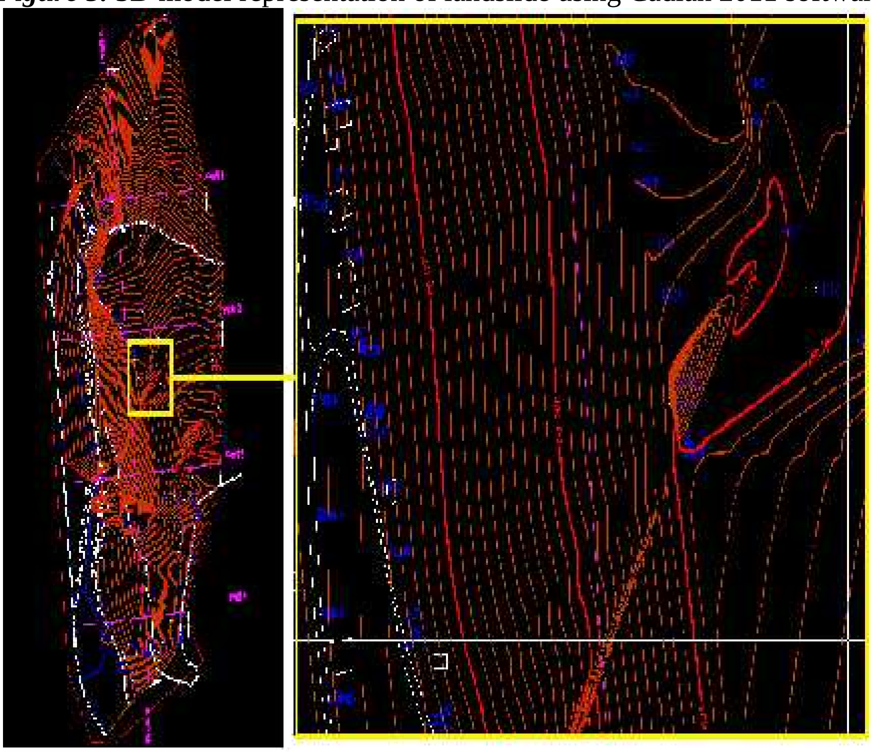

Figure 6. Main level curves generated with 50 m equidistant and 5 m equidistant for the secondary level curves using Cadian 2011 software and elevation profile paths

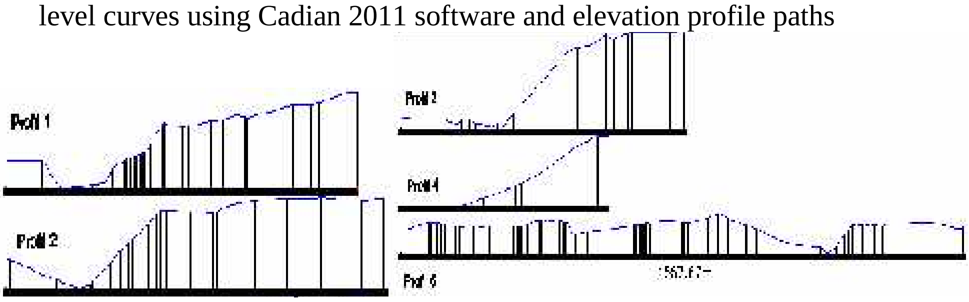

Figure 7. Transversal profiles (profile 1, profile 2, profile 3 and profile 4) and longitudinal profile (profile 5) of studied site

3. Results and Discussions

The differences recorded chronologically fits between 1.09 cm and 4.03 cm, tolerances which could be caused by errors of RTK-GNSS determination mode of the coordinates of main points. Due to difference mentioned before, it was necessary to take a detailed measurement of a zone by using 3D laser scan (Fig. 8).

Using the 3D laser scan was created panoramic views, point clouds, and analyzes of the scanned geometry.

Fig. 8. Image of the zone scanned with 3D laser scan technology

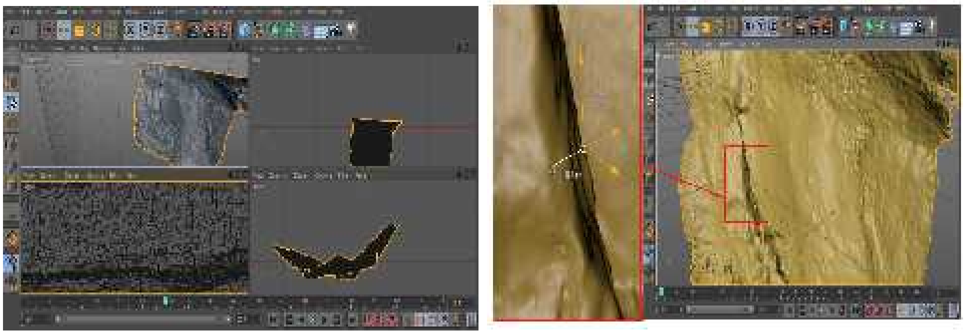

Fig. 9. Digital terrain model process with Cinema 4D software

The proceeding of infield measurements and determinations with Cadian 2011, SurfeCE, South GPS Procesor 4.0, TransLT, TopoLT, Cinema 4D, Sense scanner 3D softwear, established chronological and methodology accuracy for future monitoring of landslides.

The results of the 3D model showed insignificant chronological differences (up to 4.03 m) between RTK and GNSS coordinates determination mode at 3 months period between 1^{st} and 2^{nd} measurement phase (January to April 2015). By analyzing the 3D laser scan data was a 133.40 mm distance between stable layer and unstable clay layer.

4. Conclusions

The zones with a potential triggering landslides process could be identify by monitoring at least once in three months using 3D laser scan, with 1 mm scan accuracy. Time to make measurements with scanning systems is reduced, which leads to cost decreasing. Number of points determined in a short time is very large which leads to very precise interpretation of scanned items.

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