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STRUCTURAL DEFORMATION ANALYSIS BY LANDSLIDE IN REINA DEL CISNE SECTOR - PACCHA USING LIDAR SCANS AND CLOUDCOMPARE SOFTWARE

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Abstract: To know the stability of a land where it is desired to build is transcendental for the execution of the work and above all for the conservation of the same, for this reason information has been compiled on geology, geomorphology, geotechnics, climate, precipitation, soil stability, soil taxonomy and slope classification, in order to have a preliminary vision of the Reina del Cisne sector in the Paccha; in a field view, a soil sample was collected and tested in the laboratory; in addition, a three-dimensional scan of a house was performed on two different dates to determine the deformation of the house; with the help of the Scene and ReCap software, the point clouds of the scans were joined, and with the CloudCompare software, the deformation of the house could be distinguished using the previously joined point clouds. With the laboratory results and the deformation of the house structure, it is concluded that the terrain is in the process of potential landslide, so there may be human and economic losses.
Keywords: Ground stability, laboratory test, three-dimensional scanning, deformation, Scene, ReCap, CloudCompare, potential slip, LiDAR.

INTRODUCTION

Landslides are one of the most destructive geological processes that deform structures. Understanding how a structure behaves in the face of a disaster of this nature would help to take preventive measures for an event of this denomination. In this way, a three-dimensional analysis of a structure in areas of possible landslides is of utmost importance for the development of a city like Cuenca and its surroundings, since with the rapid growth of the city part of the population is living in mountainous or hillside areas, therefore, this type of study allows to avoid as a collective some kind of risk situation where economic and even human losses can occur. Therefore, before carrying out a construction, it is necessary to know the vulnerability of the area where we want to build, either by conducting soil studies or observing around us how the soil has been behaving in existing constructions.

The use of (TLS) for the study of deformations in structures is considered as a very effective method, since it is able to provide reliable results, since it satisfies the safety of analysis of different types of structures with various types of materials, resulting in the correct deformation monitoring of the analyzed structure (Yang et al., 2017). There have been researches related to the topic, where landslide scans have been analyzed (Travelletti et al., 2014), in addition to structures, such as: columns (Yang et al., 2016), roofs (Kajzar et al., 2017) and buildings (Mustafin et al., 2017). So, taking these previous analyses as a reference, it is achieved to analyze the deformation of a house using different tools. To achieve this objective, a soil study is performed, with a collected sample, with which classification and expansion tests can be performed; where a denomination was obtained for SM soil and silty sand.

The objective of this study is to partially determine the vulnerability of the soil; in addition to carrying out a comparative three-dimensional analysis of two dates of a house built in the area, using CloudCompare software to determine how the sliding of the soil deforms its structure.

EXPERIMENTAL

Some physical and mechanical properties of the two types of soils of the Azogues Formation present in the study area have been determined by means of laboratory geotechnical tests, specifically: density, humidity, granulometry, Atterberg limits, free and controlled expansion. Shear strength tests have not been carried out due to the impossibility of obtaining deep soil samples.

In order to know the morphology of the landslide and its kinetics in the past, the aerial photographs of the Military Geographic Institute of the years 1963, 1977, 1988 and 2008.

Regarding its current morphology and kinetics, two partial surveys of the landslide were carried out with terrestrial laser scanners in the months of May and June 2017. The massive clouds of points have been analyzed with the Scene, CloudCompare and AutoCAD Civil 3D software. For the comparison of point clouds from different dates, 3 control points located outside the slider area have been used.

RESULTS AND DISCUSSION

The geotechnical laboratory tests have provided the following results: The soil located in one of the secondary escarpments of the landslide (Figure 1), is residual, called SM Silty sand according to the SUCS classification, which has a natural humidity of 24%. The soil has an expansion percentage: 0.025% which is given a very low degree of expansion. Also, the soil has a swelling pressure of 14.27KPa.

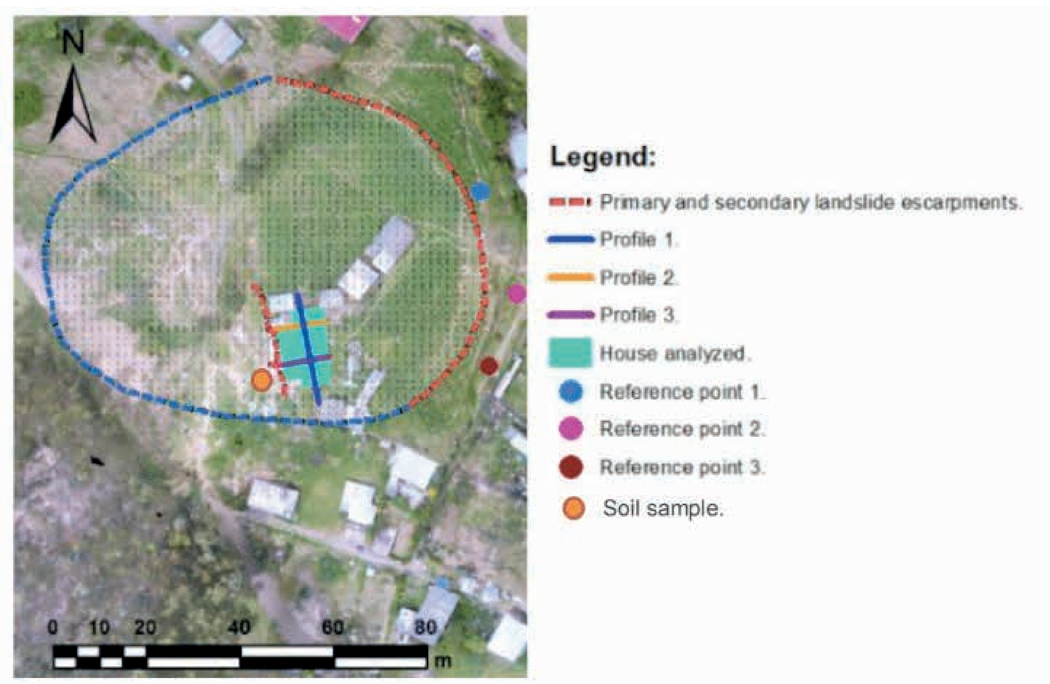

Figure 1. Study area (Cuenca – Ecuador) with information about the landslide and distribution of the profiles studied.

The merging of scans to form each of the two-point clouds was satisfactory. Figure 2 shows the average clustering errors in each point cloud. The very low error was due to the fact that the software recognized the 3 mandatory references that it must have between scans in order for them to be correctly coupled. Scan to scan so that they are correctly coupled, which can be checked more intuitively with the green traffic lights. The clinometer error between scan and scan was 0%.

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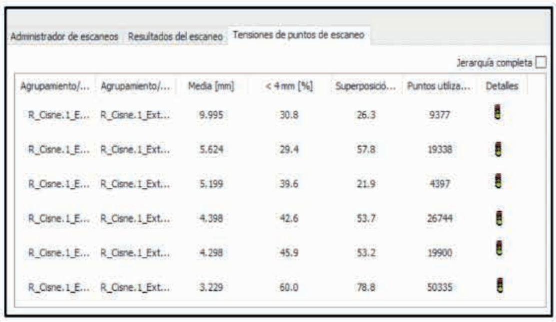
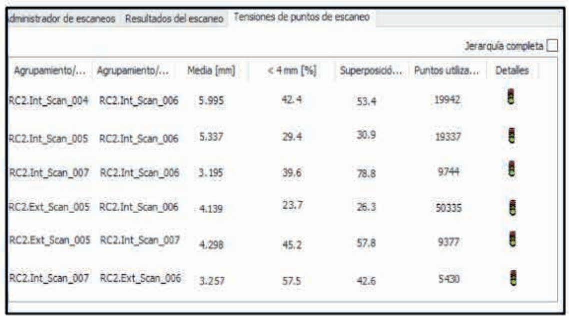


Agrupamiento/...	Agrupamiento/...	Media [mm]	< 4 mm [%]	Superposició...	Puntos utiliza...	Detalles
R_Cisne.1_E...	R_Cisne.1_Ext...	9.995	30.8	26.3	9377	
R_Cisne.1_E...	R_Cisne.1_Ext...	5.624	29.4	57.8	19338	
R_Cisne.1_E...	R_Cisne.1_Ext...	5.199	39.6	21.9	4397	
R_Cisne.1_E...	R_Cisne.1_Ext...	4.398	42.6	53.7	26744	
R_Cisne.1_E...	R_Cisne.1_Ext...	4.298	45.9	53.2	19900	
R_Cisne.1_E...	R_Cisne.1_Ext...	3.229	60.0	78.8	50335	



Agrupamiento/...	Agrupamiento/...	Media [mm]	< 4 mm [%]	Superposició...	Puntos utiliza...	Detalles
RC2.Int_Scan_004	RC2.Int_Scan_006	5.995	42.4	53.4	19942	
RC2.Int_Scan_005	RC2.Int_Scan_006	5.337	29.4	30.9	19337	
RC2.Int_Scan_007	RC2.Int_Scan_006	3.195	39.6	78.8	9744	
RC2.Ext_Scan_005	RC2.Int_Scan_006	4.139	23.7	26.3	50335	
RC2.Ext_Scan_005	RC2.Int_Scan_007	4.298	45.2	57.8	9377	
RC2.Int_Scan_007	RC2.Ext_Scan_006	3.257	57.5	42.6	5430	

Figure 2. Mean errors in mm when merging May (left) and June (right) scans.

The alignment of the two massive point clouds from the scans performed in the months of May and June 2017, has revealed that the landslide has moved significantly during this period of time, as it has significantly affected structures that are close to it, which can be seen in Figures 3, 4 and 5. Unlike structures not so close to it, where the movement is much less, as shown in Figures 6 and 7. Figure 8 shows the location of the profiles made with respect to the sliding mass and Figures 9, 10 and 11 show these profiles in May, June and the superposition between them. In the three profiles, significant ground displacements can be seen, where it can be appreciated that the house tends to follow the direction of the landslide, which we can verify with the results cited above. In the profile of Figure 9 it can be noted that the landslide has tilted the house to the left side, creating a certain convexity in its structure, which has its maximum point between the abscissa of 13.00 m to 13.5 m, which causes the structure of the house to suffer from internal cracking, which will worsen as the sliding mass increases.

On the other hand, the profile in Figure 10 shows the inclination that the house now presents, since it has lost support due to the landslide. The house has lost support due to the landslide that has removed material, so that the house has tended to follow the direction of the landslide.

In the same way, the profile in Figure 11 shows how the house is leaning towards the direction of the landslide, causing the house to lean in the direction of the landslide. This can be interpreted by comparing one scan with another, where the slab together with the ground tends to move more and more, in the same way it can be seen in the house.

Deformation monitoring of the structure of interest should be carried out by selecting the most relevant profiles, where the analysis is fruitful, in order to determine more clearly the problems caused by the deformation (Yang et al., 2001). caused by such deformation (Yang et al., 2017)

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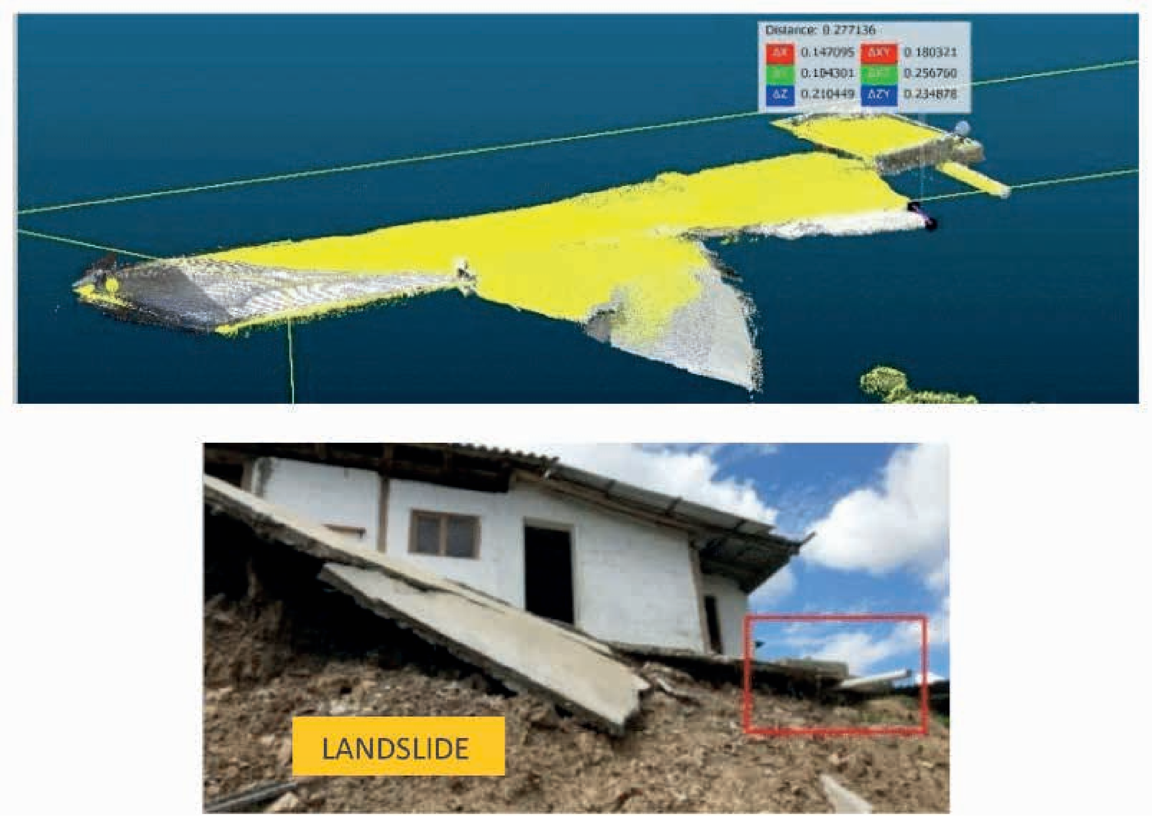

Figure 3. (Top) Slab near the landslide, in yellow: May scan and in RGB: June scan, (bottom) slab in field.

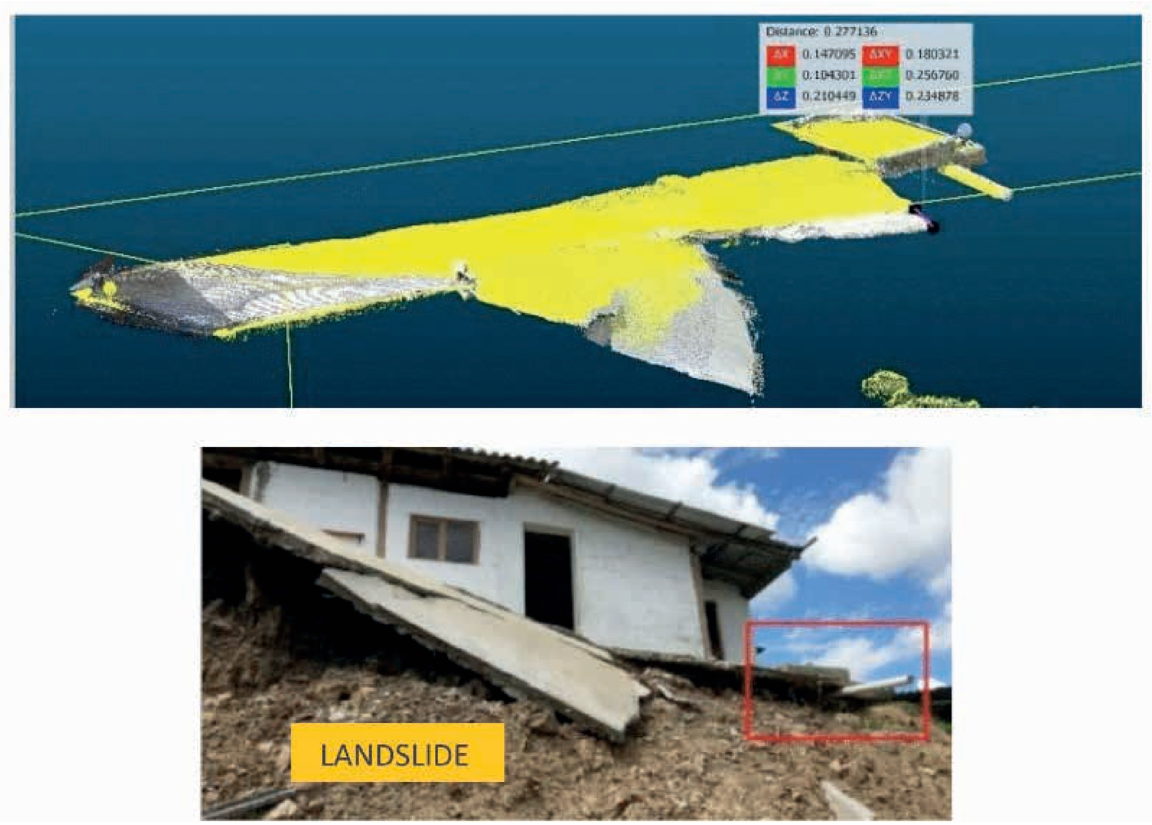

Figure 4. (Left) Slab near the landslide, in yellow: May scan and in RGB: June scan, (right) slab in field.

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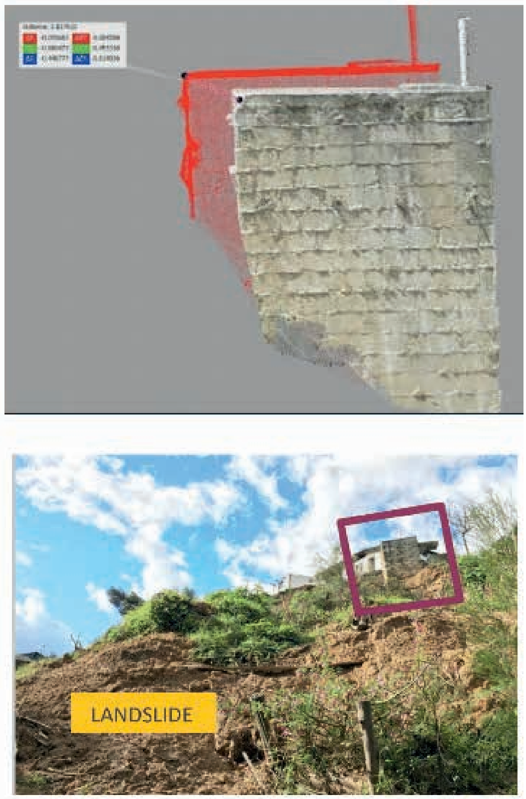


Figure 5. (Top) Tank near the landslide, in red: May scan and in RGB: June scan, (bottom) tank in the field.

Figure 6. (Top) Wall slightly away from the slide, in red: May scan and in yellow: June scan, (bottom) wall in field.

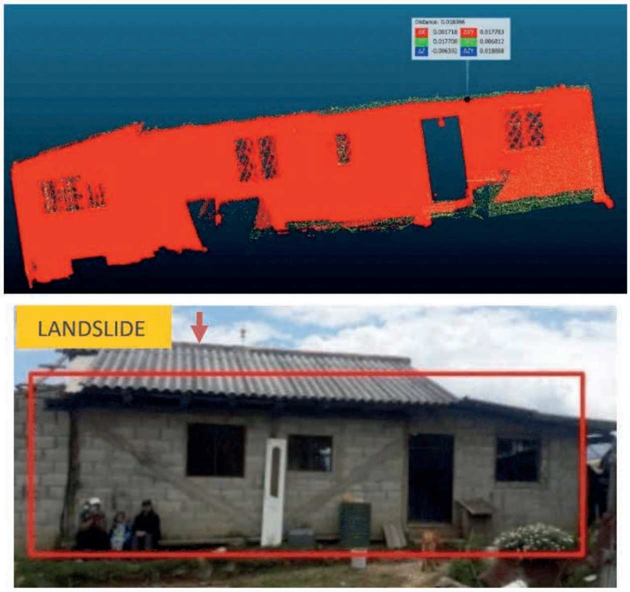


Figure 7. (Top) Wall away from the landslide, in red: May scan and in yellow: June scan, (bottom) wall in the field.

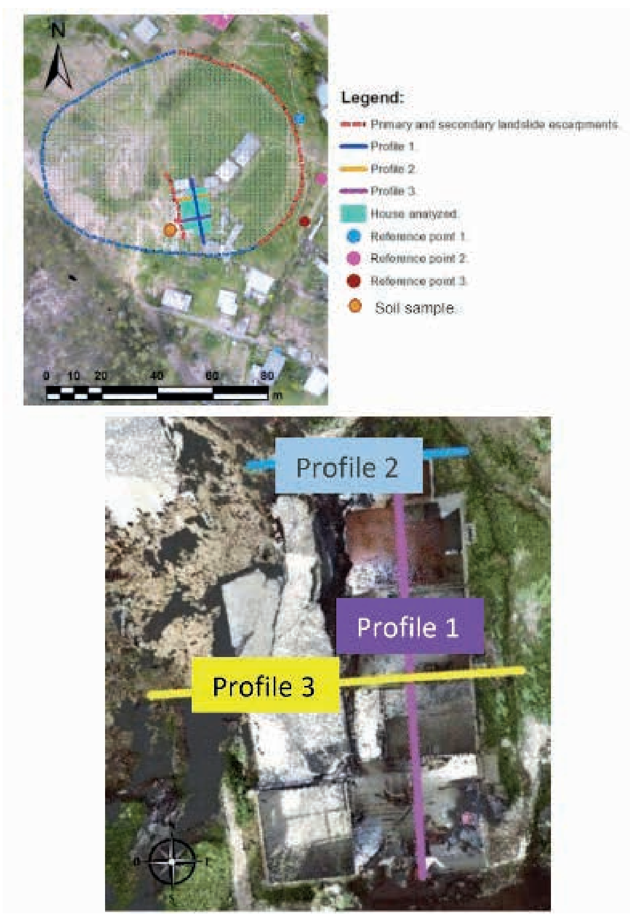
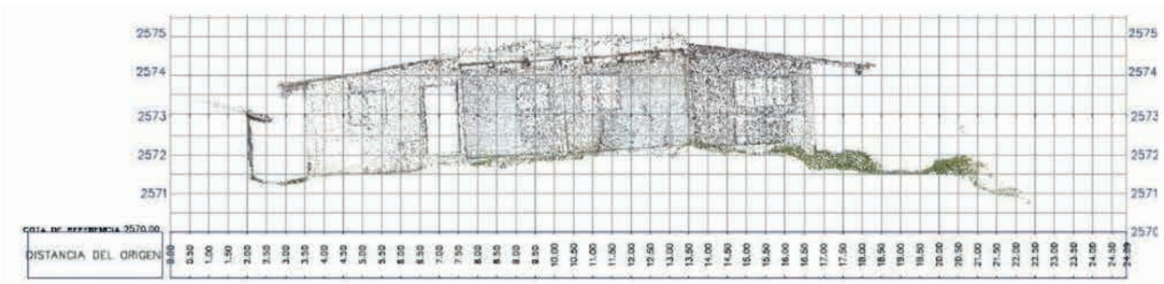


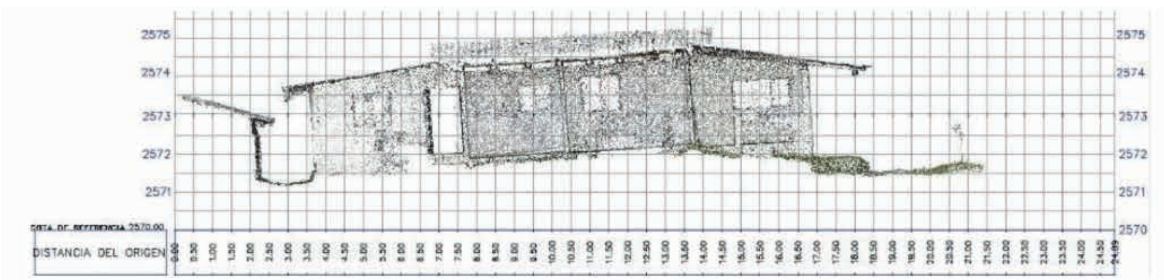
Figure 8. (Top) Longitudinal (1) and transverse (2 and 3) profiles in general plane of the scanned slip area, (bottom) selection of profiles in CloudCompare software.

Profile 1, June 2017. 100% RGB point cloud. CloudCompare.

Profile 1, May 2017. Reduced RGB point cloud. AutoCAD Civil 3D.



Profile 1, June 2017. Reduced RGB point cloud. AutoCAD Civil 3D.



Profile 1, May (yellow) and June (red) point clouds reduced. AutoCAD Civil 3D.

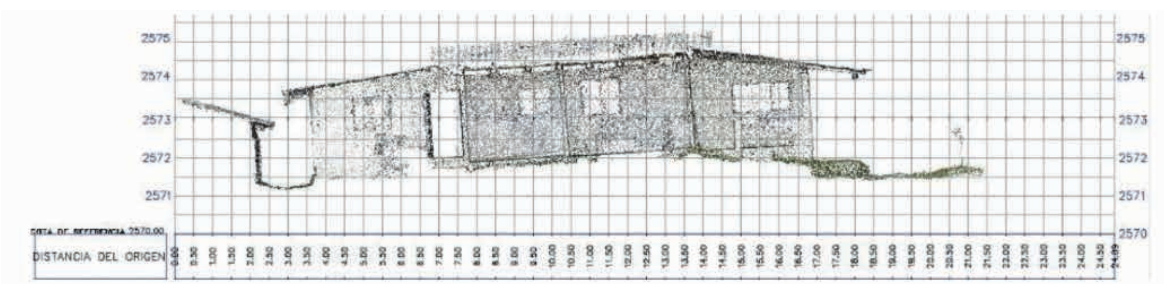
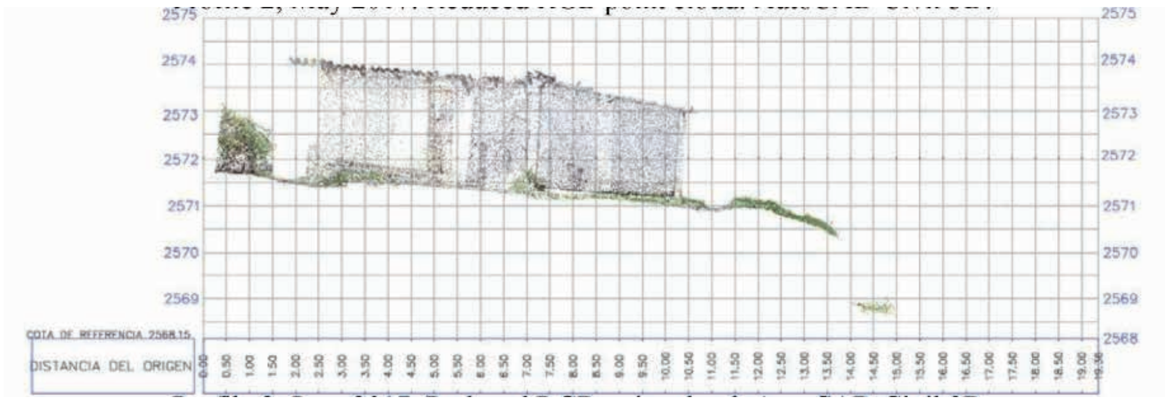


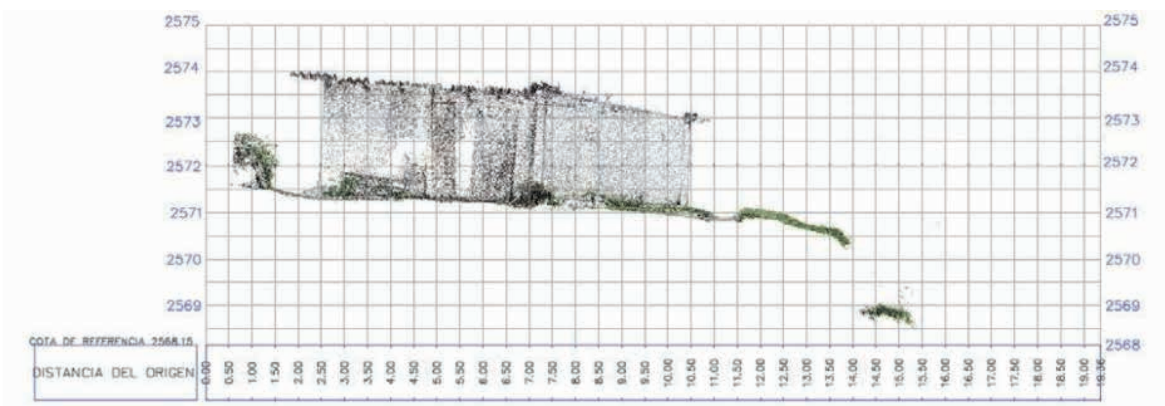
Figure 9. Profile 1 (longitudinal) in May, June and comparison of both.

Profile 2, May 2017. 100% RGB point cloud. CloudCompare

Profile 2, May 2017. Reduced RGB point cloud. AutoCAD Civil 3D.



Profile 2, June 2017. Reduced RGB point cloud. AutoCAD Civil 3D.



Profile 2, May (yellow) and June (red) point clouds reduced. AutoCAD Civil 3D.

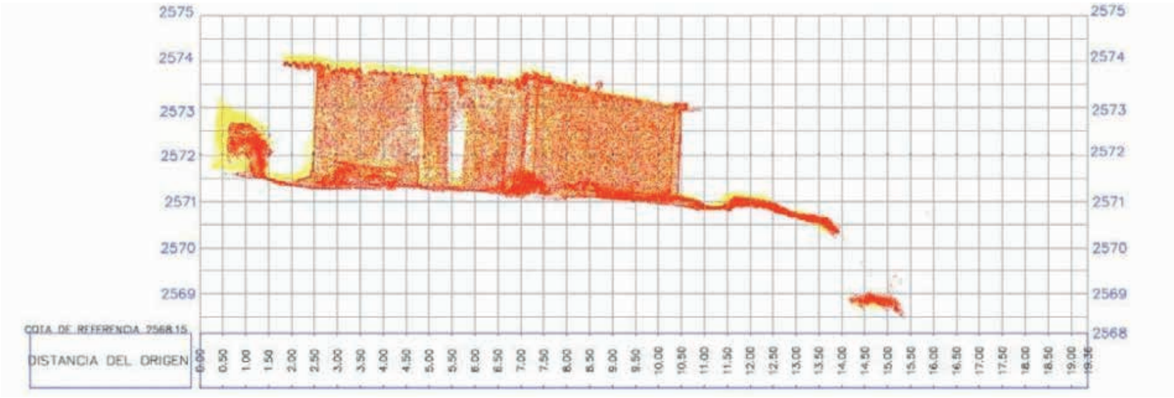
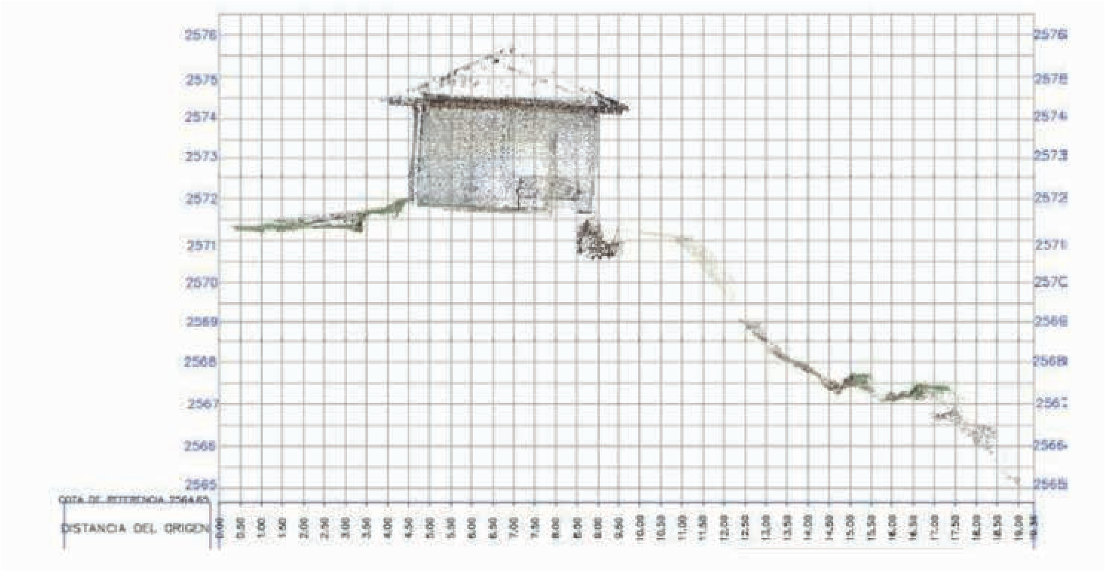


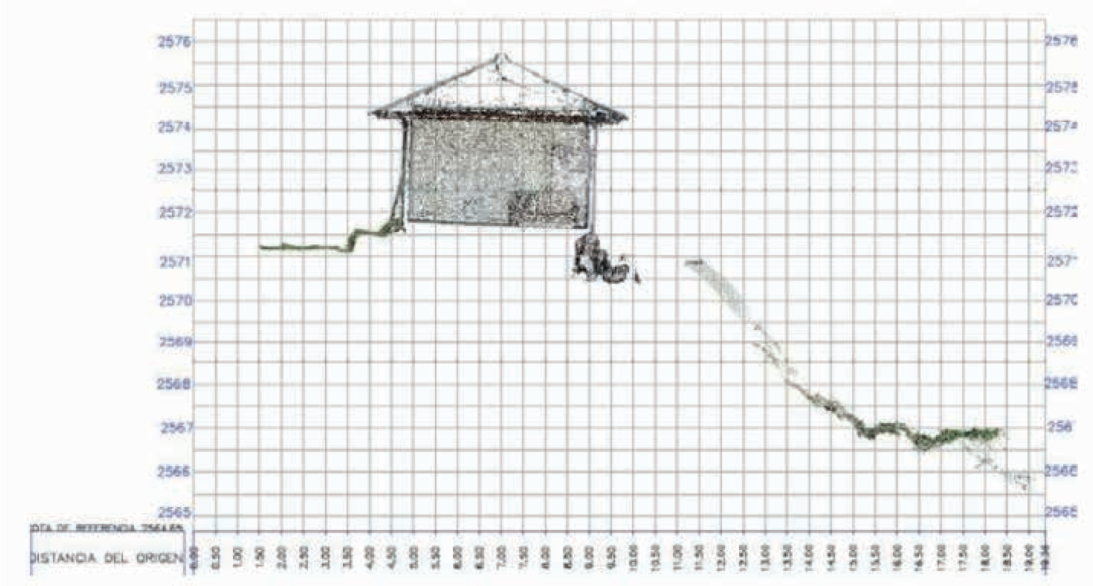
Figure 10. Profile 2 (cross-sectional) in May, June and comparison of both.

Profile 3, May 2017. 100% RGB point cloud. CloudCompare

Profile 3, May 2017. Reduced RGB point cloud. AutoCAD Civil 3D.



Profile 3, June 2017. Reduced RGB point cloud. AutoCAD Civil 3D.



Profile 3, May (yellow) and June (red) point clouds reduced. AutoCAD Civil 3D.

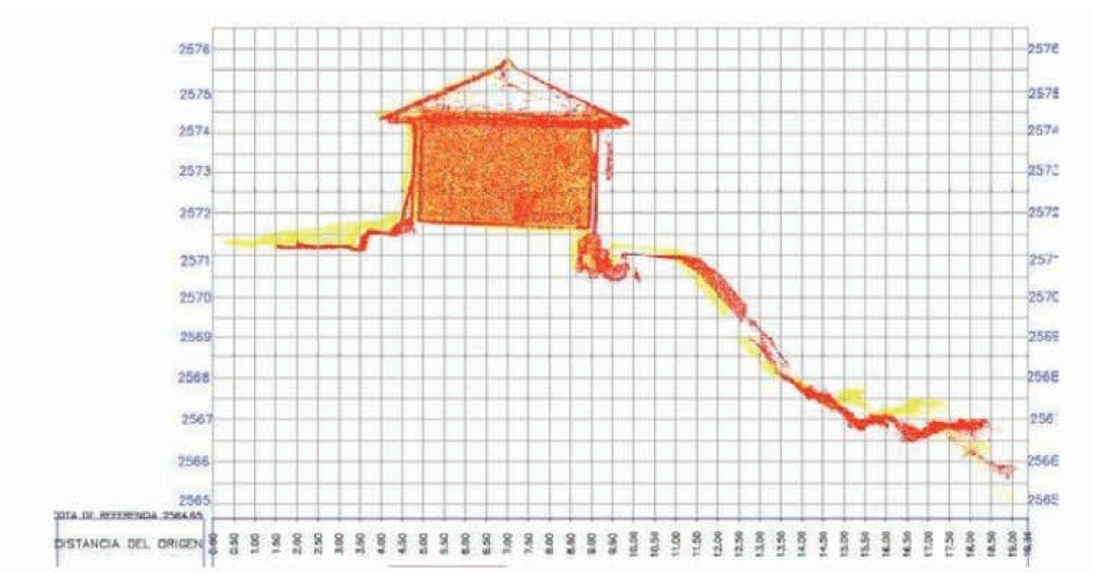


Figure 11. Profile 2 (cross-sectional) in May, June and comparison of both.

CONCLUSIONS

The landslide has moved significantly in the monitored period of time (May and June 2017). This is due to the fact that the landslide is in an active state, since it is a phenomenon that has been affecting the inhabitants of the sector for a short time, in addition this can be verified with the analyzed results, where in a short period of time the landslide has caused serious deformations in the studied house; as far as it is known, when a landslide is current its ravages are usually detected more easily unlike when the landslide is already a problem of years where the same one usually stabilizes (Rib, T. Liang., 1978), in the study area the landslide was provoked because a resident of the sector made a cut in the land which caused it to destabilize, which is why it is advisable to carry out a previous soil study before taking action on it; therefore, a landslide can not only be produced by the lithology of the land, but can also be provoked by bad practices in the same.

The morphological analysis of the ground surface, the spatial distribution of the damage in the study area, as well as the results of the geotechnical laboratory tests have been used to estimate the shape of the rupture surface in the study area. The shape of the rupture surface without the need for expensive geophysical surveys and/or drilling.

In fact, the house studied helped to determine that the landslide is rotational, and we were able to appreciate in the area typical problems that this kind of landslide presents, which are: escarpments (Figure 8, above), cracks, alterations at the foot of the landslide, vegetation removal (Figure 5, below), fissures, tree movements and landslide activity (Parkhurst, 2000).

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