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Landslide Change Detection Based on Multi-Temporal Digital Elevation Models of Ropoto, Central Greece

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Introduction

A landslide constitutes a significant natural hazard that includes mass movement of soil, rocks and/or mud due to the pull of gravity, most of them occurring gradually, but some may be abrupt. It is a phenomenon which most of the times it is not predictable and unfortunately unavoidable and can cause significant casualties and immeasurable economic losses, effecting many aspects of human life. Extensive rainfall, earthquakes, unfavorable geology and human intervention are some potential triggering factors that can induce a landslide event. According the aforementioned, it is necessary to mitigate the landslide hazard to ensure optimum security. As a result, new methodologies are required to develop a better perception of landslide hazards. With the recent advances of technology, various remote sensing methods have been developed providing useful topographic data. In the current study, detailed imagery data has been obtained by using Unmanned Aerial Vehicles (UAV). The UAVs, also known as drones, are aircrafts where are capable of taking high-resolution images and producing via photogrammetric software, precise 3D point cloud, Digital Surface Models and respective Orthophoto. Valuable data source with extended applications on surveillance, inspection, mapping and 3D imaging are now available. The purpose of this study is to investigate and detect potential topographic changes of a mega-landslide by using multi-temporal UAV data. The landslide is induced at the community of Ropoto and constitutes a great risk while a large part of the village has been affected (approximately 280m wide and 750m long) (Figure 1). Ropoto village, belongs to the Municipality of Trikala in the Central part of Greece and according to the geological map (1:50.000), with the title “Mouzakion”, belongs to the geotectonic zone of Pindos (Mountrakis, 1985). The geology of the area of interest consists of the following formations: Paleocene-Eocene flysch formations (transition flysch units in this case) that present a high heterogeneity (sandstones, conglomerates, limestones, siltstones, shales, marls), transition beds consisted of thick-bedded limestones with sandstone and shale (M. Maastrichtian-L. Paleocene) and the thin-bedded limestone formation (Turonian-M. Maastrichtian). The tectonic development of the Ropoto area affected all of the formations and mainly the newer ones (flysch and transition formations), thus isoclinal folds and thrust faults were created. Flysch has thus suffered from compressional forces being highly deformed. Shear zones and smaller faults are also present in the site specific area due to this tectonic disturbance. These geological characteristics produced very weak rock masses which presented the landslide. Brittle rock formations, such as limestones here, created very permeable zones, so very high pore water pressure is often developed triggering the landslide. The latter, explains the water presence between the flysch and thick-bedded limestone formations covered by scree. Consequently, the landslide occurred after 12 hours of intense rainfall within the weathered mantle of flysch depth of the transition beds. As a result, the greater part of the central village infrastructure massively collapsed.

Methodology

For the detection of surface deformation due to landsliding, field investigation is requisite and typically involve field mapping to characterize the geomorphological conditions. Additionally, there is a number of factors that need to be continuously assessed: the extent of the landslide, detection of fissure structures, topography of the land and the rate of displacements that could be related to the fracture (Niethammer et al. 2010). The latter, depending on the scale of the problem, can take valuable time while rough terrain can constitute access restrictions, therefore the assessment of the landslide is deficient. In order to understand the mechanism of the landslide, horizontal and vertical displacements should be measured. A number of remote sensing methods are valuable tools towards this assessment. Therefore, except the visual interpretation, high resolution images were captured by the UAV while it provides ultra-high spatial resolution and accuracy that is needed to monitor temporal changes. At the community of Ropoto, several movements have been recorded during the last decades. First movement occurred in 1963, while the last episodic large landslide happened in 2012. Ever since the landslide is evolving gradually without perceivable movements. In this survey, in order to detect these changes multi-temporal digital elevation models of the area we quantified and compared.

Initially, for change the detection assessment, pre-disaster data is required. The reference data is provided by the Land Registry of Greece where Digital Elevation Models (DEM) - LSO (Large Scale Orthophotos) were created with the use of aircrafts equipped with high-end optical sensors between 2007 and 2009 with pixel resolution of 5 m. Those digital elevation models are specialized database that represents the topographic relief of a surface between points of known elevation. By interpolating known elevation data from sources such as ground surveys and photogrammetric data capture, a rectangular digital elevation model grid can be created. By setting these multi-temporal photogrammetric products under two different procedures, two similar results were given, while according to the visual interpretation they displayed the same volume of movement. In the first procedure the value of the second one has being subtracted from the value of the first one on a cell-by-cell basis and the second one calculates the area and the volume of the region between a surface and a reference plane. As a result, we have two DEM’s of difference involving quantifying volumetric change between these multi-temporal photogrammetric products showing parts with gain or loss material (Figure 2). Especially the crown and the foot of the landslide demonstrate major amount of material removal. On the other hand, several other parts of the landslide reveal an unexpected increment.

Concluding, Ropoto landslide constitute an active landslide that shows gradually evolving movements through the years. As so, the continuous monitoring of the landslide in 6 months’ period, it is required to determine the extent, magnitude and style of landslide movement, for risk and even emergency risk management assessments. Last but not least, the need of implementing Unmanned Aerial Vehicles (UAV) in landslide risk assessments is constantly increasing while they provide a safe, quick and potentially more accurate way of inspecting large scale and difficult to access areas, requiring minimal human resources. However, in order to process these results, the contribution and critical evaluation of an expert is obligatory.

Figure 1: Aspect of Ropoto landslide: a) 2016-Google earth, b) 2018-Image.

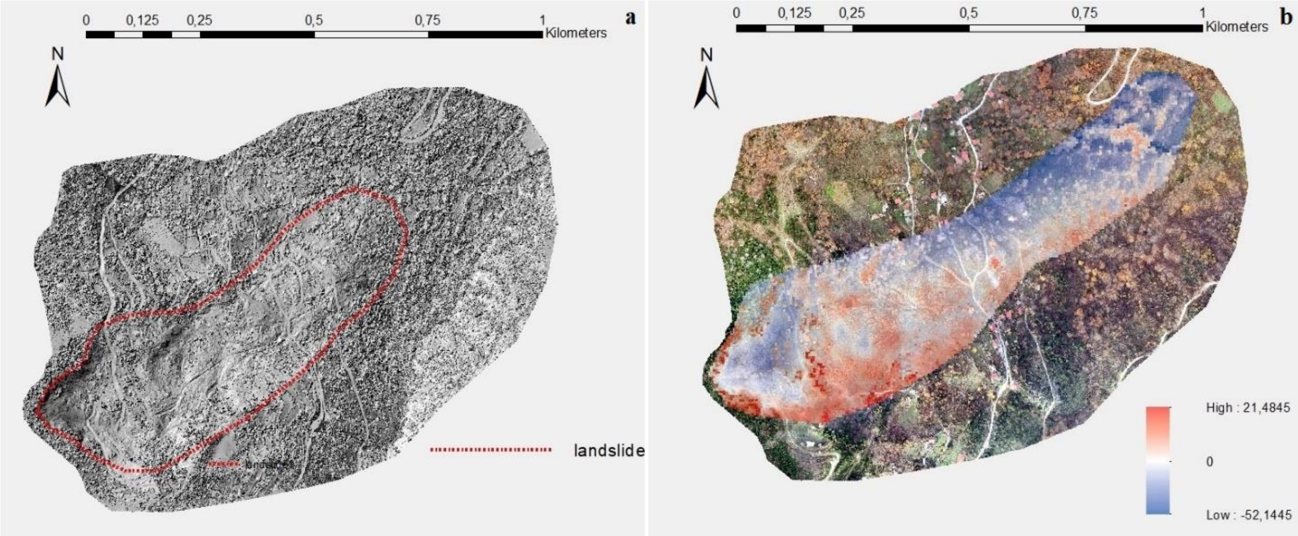

Figure 2: a) DEM of Ropoto-Hillshade , b) DEM of Difference of Ropoto

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