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Rock Mass Characterization Using Lidar Terrestrial Laser Scanner for Rockfall Susceptibility Assessment in Perissa Area (Santorini)

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Rockfalls consist one of the most dominant geological hazards in mountainous rocky regions with the potential to turn catastrophic if occurs in the anthropogenic environment. Due to that fact, the identification of the possible locations to produce the phenomenon is of high importance. Susceptibility is the parameter describes these locations and the qualitative and quantitative assessment of it is necessary for the timely treatment of a possible rockfall occurrence. However, this approach requires some critical rock mass characteristics to be known. These ones that govern the phenomenon and so the more detailed acquisition of them increases the calculations reliability. Such data acquisition can be achieved by implementing conventional mapping methods as well as remote sensing techniques like LiDAR (Light Detection and Ranging) scanners. The LiDAR technology is extremely preferred the last decades in the field of Geosciences, providing many advantages against the pre-existing methods (Abellán et al., 2009; Lato et al., 2009; Kromer et al., 2018).

In the current study, LiDAR technology was implemented to extract the appropriate parameters can be used for the rockfall susceptibility assessment. The study area was the limestone slopes in Perissa area at the southeastern part of Thera island at Santorini complex. After data processing, joint orientation parameters, joint spacing and block volumes were extracted. Parameters which are usually either statistically or at confined areas estimated considering homogeneous rock mass in them respect. The extra element this methodology provides is the creation of spatial distribution maps of the above-mentioned parameters, taking into account the fluctuation of their values along the slopes. Thus, the produced result can be used in the spatially-specific susceptibility assessment without considering each slope or formation as an entire susceptibility mapping unit. The data processing is extensively analyzed step by step providing the reader with the desirable view of the whole procedure. Finally, the results produced by the current methodology are validated and interpreted according to in-situ records and measurements as well as manually extracted measurements on the point clouds.

Study area

In particular, the study area is part of the internal Hellenic Volcanic Arc and geologically belongs to the Atticocyladian geotectonic zone's bedrock. Located on the southeastern part of Thera, represents one of the two pre-alpine bedrock exposures on the island, and specifically the indigenous unit, as the rest is covered by the later volcanic activity's products. Perissa's cliffs belong to the wider carbonate formation of Profitis Ilias that consists of Early Cretaceous recrystallized limestones which compose the semi-metamorphosed bedrock of the Atticocycladian zone and specifically the South Cyclades Unit. The landscape of the coastal Perissa area is in general very steep with dipping up to 70 degrees, heights up to 50 m and face towards the SW and SSW.

Data acquisition

The LiDAR data was obtained by using an Optech ILRIS-3D long-range terrestrial laser scanner and the survey planning aimed to acquire a dense and high-resolution dataset for the detailed mapping of all necessary parameters required in the direction of rockfall susceptibility. In specific, five predefined scan locations were used to cover the different slopes formed along the entire cliff with the most feasible overlapping, given the buildings that exist in a small distance from the slopes, in order to minimize the orientation bias and occlusion effect. The obtained point clouds were merged and geo-referenced by utilizing on-slope-placed targets and their absolute coordinates measurements taken from a total station as they were easily identified within the dataset due to the high resolution. The entire dataset consists of more than 15 million points.

Methodology

The proposed methodology initially aims to the orientation estimation of the individual slopes formed along the cliff as well as the discontinuity sets, following aproaches proposed by Riquelme et al., 2014. Sequentially, joint spacing values are extracted for each discontinuity set according to Riquelme et al., 2015 and based on these geometric parameters the block volume distribution is estimated. Furthermore, a spatial distribution map (Figure 1) for each of the above-mentioned parameters is created providing the desirable spatial information which a further analysis could be based on in order to produce a spatial-aimed result rather than a single susceptibility value for each individual slope. Current methodology's implementation was carried out by using CloudCompare and ArcGIS software as well as numerous Matlab algorithms on DSE software package.

Results

Principal discontinuity sets orientations extracted from the used semi-automated methodology are presented and compared with the conventional compass measurements taken in-situ. Furthermore, statistics, graphs and maps illustrate the distribution of each discontinuity set orientation, spacing value, as well as the block volume, are listed.

It is commonly accepted that the block volumes formed along a slope are the very critical parameter for the rockfall susceptibility assessment. Moreover, further space-resolved stability analyses for the susceptible-defined areas can be carried out utilizing the spatial distribution maps produced by this methodology. The authors also utilized the extracted orientation data in order to create the corresponding stereoplot to each slope and detect the governing failure mechanism on each of them. The parameters being extracted from the proposed LiDAR data processing methodology are spatially independent and display fluctuations along the cliffs. Thus, the main aftermath earned here is the fact that the rock masses are not represented realistically when being treated as homogenous and isotropic in respect of parameters such as joint spacing and/or block volumes. Sequentially, susceptibility is not represented any more by a specific value for an entire slope or a formation considered as a united mapping unit. Contrariwise, it can be changing defining the more and the less susceptible areas along the slopes. That fact leads the focus of interest, for additional analysis, only to certain areas and prevents the consumption of unnecessary funds and time in the entire united unit investigation.

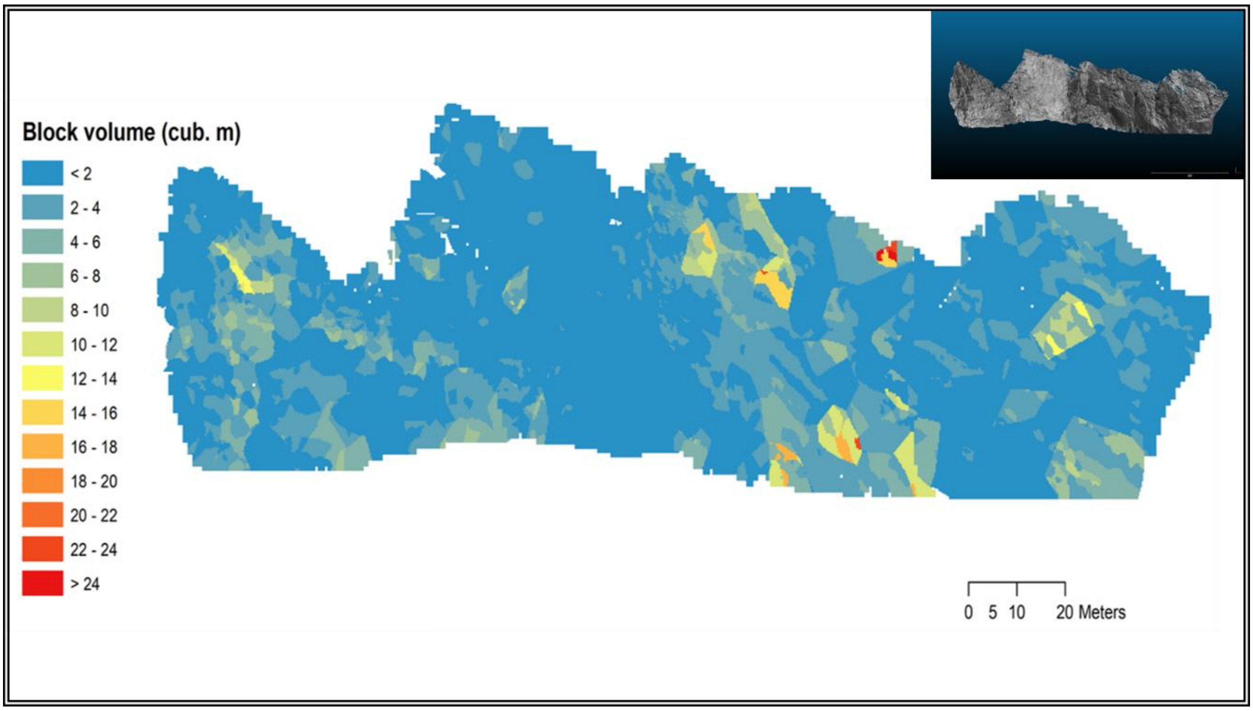

Figure 1. Potential block volume spatial distribution map.

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