16th International Congress of the Geological Society of Greece

17-19 October, 2022 - Patras, Greece

Bulletin of the Geological Society of Greece, Sp. Publ. 10

Ext. Abs. GSG2022-059

Mapping the spatial distribution of detached boulders with the use of ultra-high resolution remote sensing data and simulation of rockfall events. The case of Kalymnos Island.

E. Vassilakis[1], A. Konsolaki[1], S. Laskari[1], I. Lialiaris[2], K. Soukis[1], E. Kotsi[1], E. Lekkas[1]

(1) Department of Geology and Geoenvironment, University of Athens, Greece, evasilak@geol.uoa.gr (2) Geodesign P.C., Athens, Greece.

We present a state-of-the-art multidisciplinary study of the Kalymnos rockfall risk, based on (i) classical geological mapping, (ii) interpretation of high-resolution satellite data, (iii) spatial distribution of rockfalls in GIS, (iv) close range remote sensing campaigns with Unmanned Aerial Systems (UAS), and (v) integrated simulation of rockfall events.

Kalymnos Island is located in SE Aegean (Greece) and is part of the northern Dodecanese. The geology of the island consists of the following groups from bottom to top (Franz *et al.*, 2005): i) the lowermost Kefala Unit comprising late Paleozoic interlayered phyllites, metapelites, and fossiliferous low-grade marble, overlain by a wild flysch with marble and ultramafic blocks, ii) the tectonically overlying Marina Basement Unit with Variscan higher grade rocks such as amphibolites, garnet mica schists, and quartzite, iii) the Marina Cover Unit, which includes Verrucano-type late Triassic, yellow to violet shales and a non-metamorphic Mesozoic sequence, with alternating neritic and pelagic facies of carbonate rocks. The contact between the Marina Basement Unit and the non-metamorphic Marina Cover Unit is a post-orogenic low-angle detachment fault, exposed at the western and central part of the island, marked by thick cataclasites with top to SSW sense of shear (Grasemann *et al.,* 2022). Due to differential weathering between the footwall and hanging wall units, this contact is spatially associated with an extended network of vertical to sub-vertical cliffs.

Detached boulders are observed throughout the entire island, making it one of the ideal places for studying rockfall events worldwide. The absence of vegetation, the existence of large vertical cliffs, and the relatively uniform geological basement, consisting of limestones (Fig. 1a-c), are the main reasons for this. The use of contemporary techniques and tools such as UAS image photogrammetric processing and high spectral and spatial resolution satellite data within GIS platform, allows the implementation of a detailed terrain model and the detection of the spatial distribution of boulders scattered on the downslope areas of steep carbonate cliffs (Gallo *et al.*, 2021).

The interpretation of WorldView-3 satellite images (8-band, 0.3m) allowed the identification of the high rockfall risk areas, related to the potential harm to human life, infrastructure, and property. Due to the very high spatial resolution, rock blocks with diameter greater than 3 meters were clearly identified. The footprint information was integrated into a geodatabase and more calculations and spatial analyses were created and stored in additional fields. More than 7,700 boulders were detected (Fig. 1d) and for each one of these entities an "identity” tab, was created with the incorporation of useful data. The next step of the methodology included new layers generation in the context of taking advantage of the rockfalls’ spatial ‘density’ (Fig. 1e), leading to additional processing for defining high-risk rock-concentration groups, either per altitude zone or per distance from several types of infrastructures. The latter led to the definition of high importance areas at which UAS campaigns were carried out, for aerial image acquisition that were used within structurefrom-motion data processing for 3D models (Fig. 1f) construction (high resolution DSMs, Ortho-photo-mosaics, point clouds) (Vassilakis *et al.,* 2021).

A DJI Phantom 4 pro RTK drone, equipped with an FC6310R camera and a focal length of 8.8mm was used, capturing 13 areas all around Kalymnos, which according to the processing and spatial analysis within the GIS, were characterized as the most critical ones. In total, 5,700 aerial photographs were acquired, covering a total of 6,02km^2. The photogrammetric procedure was accomplished within a Network-based RTK (NRTK) module, which allows the reconstruction of highly detailed photogrammetric products without using Ground Control Points.

The processing results represent the contemporary geomorphological regime that has emerged through geological times as a result of thousands of rockfalls from specific areas. As such, the simulation of the rockfalls based on this methodology provides an inherent and significant advantage over methods based on the results of intentionally induced rockfalls along specific areas of a smaller geographical extent (e.g. quarries or isolated slopes).

The rockfalls simulation was achieved using specialized software packages providing the investigation of several different scenarios which resulted in the reliable assessment of the input parameters (Rn & Rt coefficients, friction angle, slope roughness etc.). The validation of the observed data through back-analysis approach provided the opportunity to draw valuable conclusions regarding differentiations that may arise due to either subtle changes in lithology or topographical peculiarities, which should be considered by earth scientists. The proposed design parameter ranges could enrich the “software library” and can be used in the future at geologically similar areas, leading to reliable conclusions regarding the safe design of protection measures such as rockfall barriers.

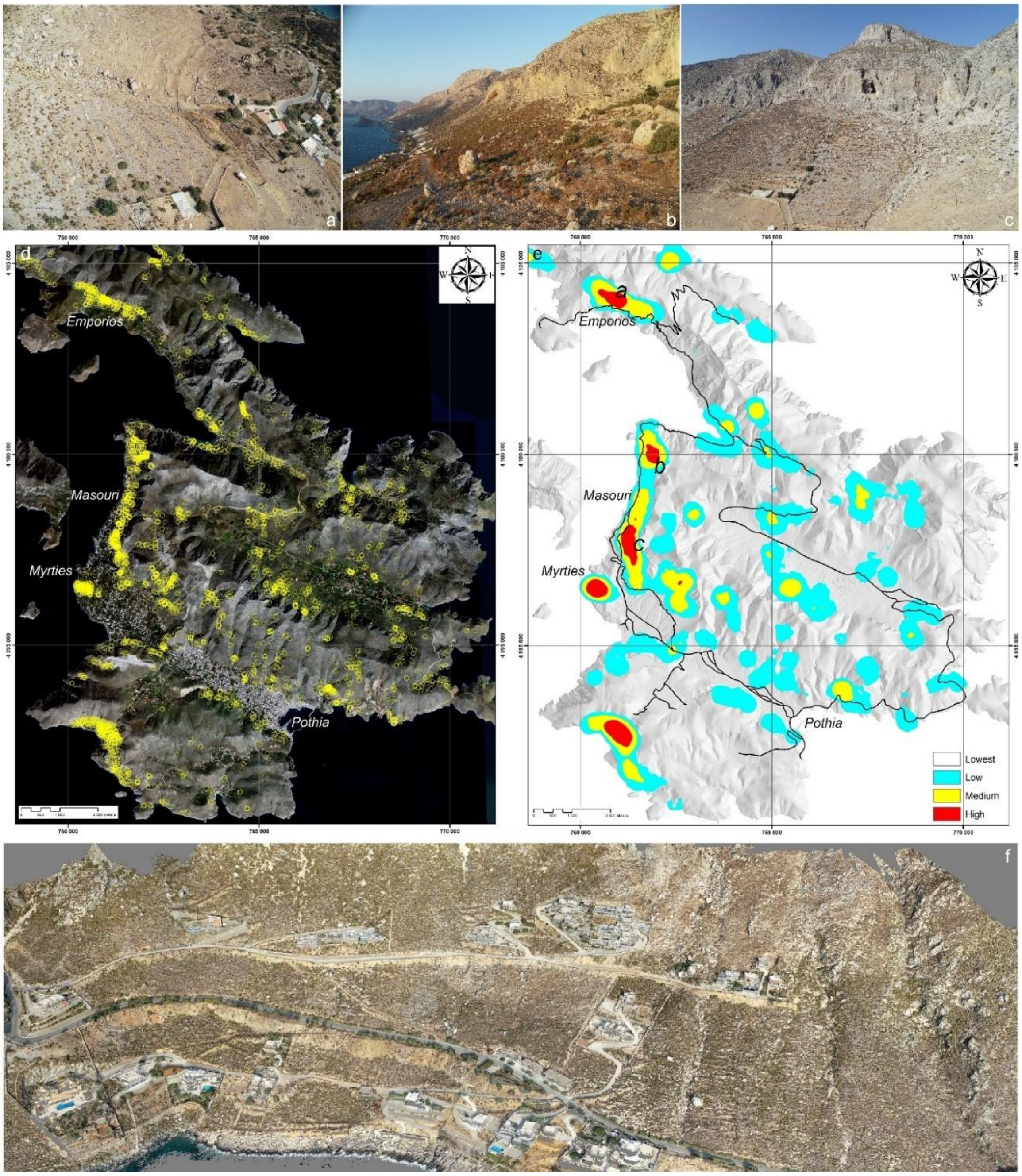

Figure 1. High risk areas due to big boulders downhill rolling towards the island infrastructure (a-c). A WorldView-3 satellite natural color image (acq. 4.3.2021) was used as a basemap for boulder detection (d). Boulder density map (e). Example of a point cloud extracted from photogrammetry processing (f).

Acknowledgements

This research was funded by the municipality of Kalymnos through the research grant "Reduction of landslide risk in areas of special geodynamic and seismotectonic regime. The island of Kalymnos".

References

Franz, L., Okrusch, M., Seidel, E., and Kreuzer, H., 2005, Polymetamorphic evolution of pre-Alpidic basement relics in the external Hellenides, Greece: Neues Jahrbuch für Mineralogie. Abhandlungen, v. 181, no. 2, p. 147–172, https://doi .org/10.1127/0077-7757/2005/0013.

Gallo, I. G., Martínez-Corbella, M., Sarro, R., Iovine, G., López-Vinielles, J., Hérnandez, M., Robustelli, G., Mateos, R. M., and García-Davalillo, J. C., 2021, An Integration of UAV-Based Photogrammetry and 3D Modelling for Rockfall Hazard Assessment: The Cárcavos Case in 2018 (Spain): Remote Sensing, v. 13, no. 17, p. 3450.

Grasemann, B., Schneider, D.A., Soukis, K., Roche, V. and Hubmann, B., 2022. Paleogeographic position of the central Dodecanese Islands, southeastern Greece: The push-pull of Pelagonia. Bulletin, 134(5-6), pp.1506-1528.

Vassilakis, E., Foumelis, M., Erkeki, A., Kotsi, E., and Lekkas, E., 2021, Post-event surface deformation of Amyntaio slide (Greece) by complementary analysis of Remotely Piloted Airborne System imagery and SAR interferometry: Applied Geomatics, v. 13, no. 1, p. 65-75.