

Landslide Investigation Using UAV Photogrammetric Methods Within Marly Formations in Open Pit Lignite Mines in Northern Greece.

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Energy production in Greece greatly depends on lignite combustion, therefore exploitation of the indigenous deposits is of great importance. Lignite mainly comes from open pit mines, in whom marly formations are usually found overlaying the lignite accumulation. Due to poor geotechnical parameters, mine’s unique geometry (high temporary slopes in steep angles), combined with the pore water pressure from heavy rainfalls behaving as triggering mechanism, as a result landslide phenomenon often occur. The current research takes advantage of Unmanned Aerial Vehicles and their capabilities to detect, map and with the appropriate process, analyze and discover the basic engineering geological principles (type of failure, triggering mechanism, volume etc.) governing these failures.

Specifically, two mine areas have been examined, both of them have undergone rehabilitation (Marinos 2012). The first one is in Florina and the second in Kozani prefecture. These two districts according to the geotectonic units of Greece appertain to Pelagonian nappe and moreover belong in the upper and in the lower part of the elongated intermontaine Florina-Ptolemais-Kozani tectonic graben respectively (Pavlidis *et al.*, 1986).

Research was initiated with data collection from the in-situ investigation of the mining areas. The UAV, bearing a high-resolution camera with a GPS tracker, was set to fly in a pre-determined flight path to map the plain view of each mine. Meanwhile a thorough field survey to recognize and assess the basic geological and geometrical factors regulating the landslides like marl’s bed dip/dip direction, discontinuity surfaces, geometrical characteristics of landslides, faults, etc. was executed.

The Digital Surface Model, Point Cloud and finally Orthomosaic with the contribution of a photogrammetric software was created taking consideration of the desired Ground Sampling Distance (GSD). Methodology continued with the creation of topographic parameters such as Hillshade, Aspect, Slope. With an accurate manual mapping in GIS environment of the Orthomosaic obtained in each case, two individual landslides were identified at Florina’s mine in Amyntaio (Figure 1) and 147 in total at Kozani’s mine in Prosilio (Figure 2).

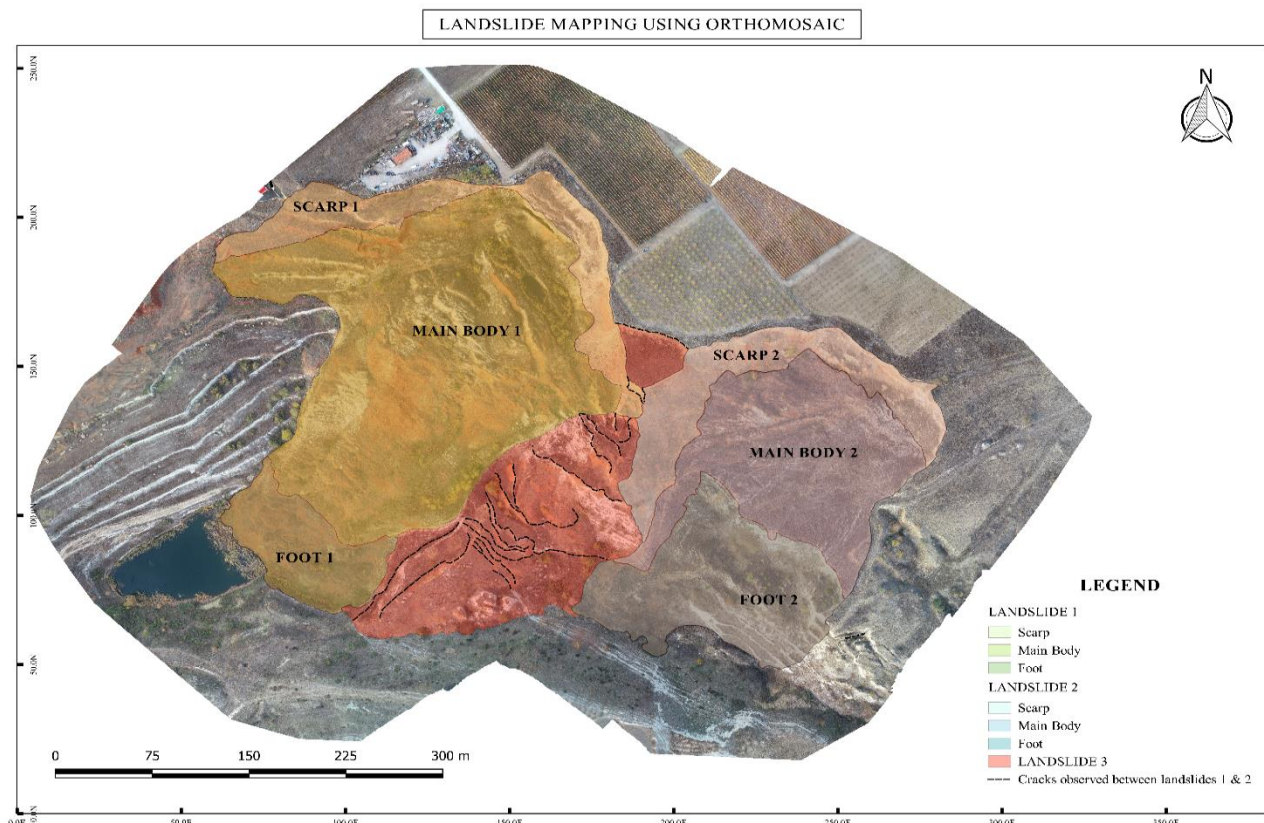


Figure 1. Map based on the Orthomosaic depicting two landslides within marly formations in Florina’s mine in Amyntaio area, each with its individual characteristics. The pink color corresponds to the possible union between landslide 1 & 2 into a massive one.

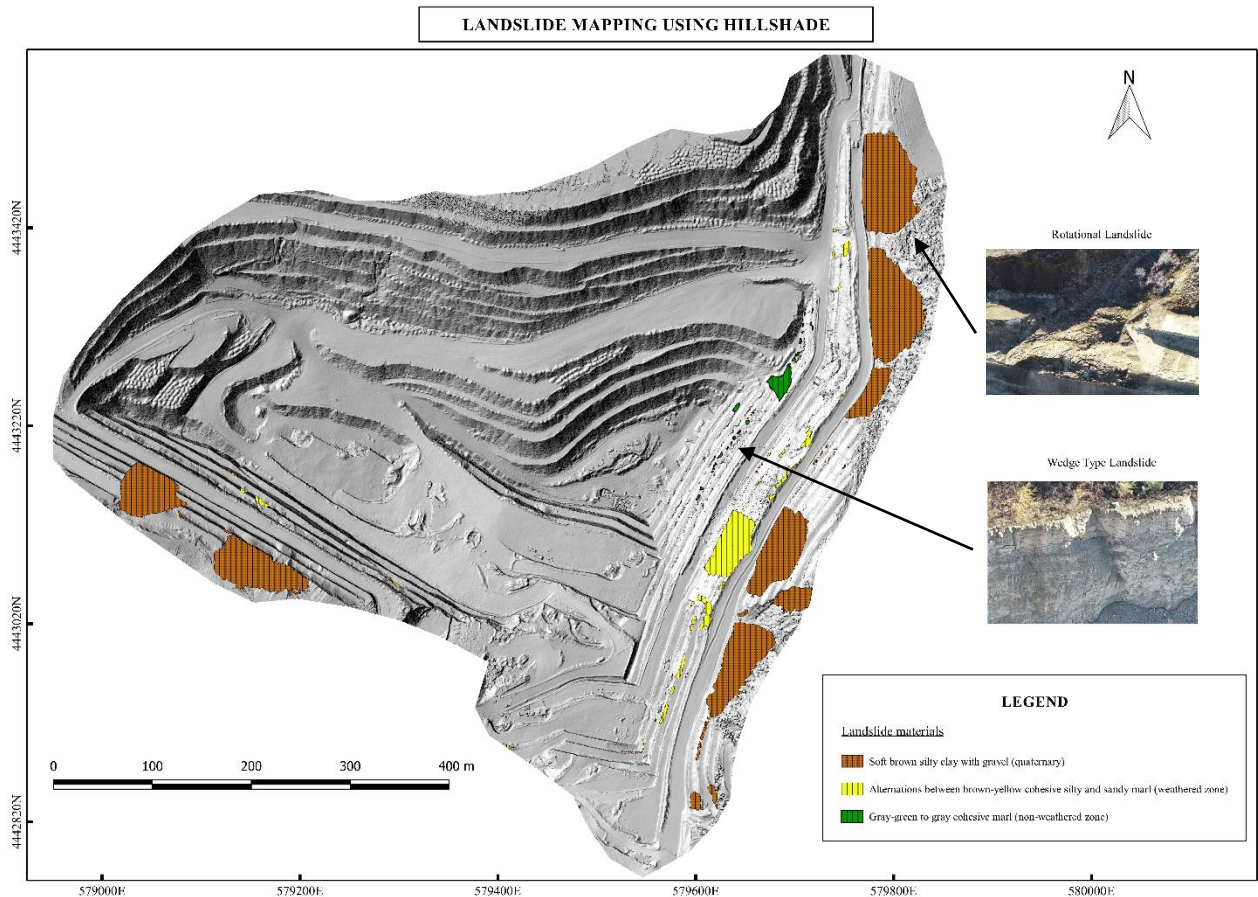


Figure 2. Map based on the Hillshade which depicts the 147 different landslides found in the upper parts of the mine within almost exclusively marly formations in Kozani's mine, in Prosilio area.

Furthermore, taking into account information derived from the interpretation of the aforementioned topographic tools it was made possible to calculate the fundamental data for each landslide such as slope orientation and dip, discontinuities orientation and dip and finally propose a failure mechanism matching those given by the in-situ investigation. Last but not least, through the application of the prementioned photogrammetric program it was made able to identify and export the volume of each slide with a very good correlation to reality as it was verified by actual data.

Finally, for the Amintaio open pit the responsible failure mechanism is the rotational one for both slides. In the Prosilio open pit from the 147 known landslides 109 were identified as rotational and 38 as wedge type failures. Volumetric analysis showed materials movements ranging from $0.28\text{m}^3 \pm 30.00\%$ to $531.71\text{m}^3 \pm 0.74\%$ for the mapped landslides in the area of interest.

Concluding, the aim of the research is to designate an effective and simultaneously low-cost method of detecting, monitoring and assessing landslide phenomena. This attribute comes to absolute need regarding open pit mines, where a 24/7 surveillance is essential because of marl's highly susceptibility to failures. UAV usage checks all the above criteria when it comes in conjunction with proper geological knowledge can truly provide remarkable results.

References

- Marinos, P., 2012. Autopsy report in slope stability in METE corporation mine located in Prosilio in Kozani area.
- Pavlidis, S.B., Mountrakis, D.M., 1986. Neotectonics of the Florina – Vegoritis – Ptolemais Neogene Basin (NW Greece): an example of extensional tectonics of the greater Aegean area. *Ann. Geol. Pays Hell.* 33 (1), 311 – 327.