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Debris Flow on a Fully Activated Intramontane Fan during the Flash Flood of Mandra. UAS-aided Field Mapping of Katsimidi Fan

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Post-flood investigations contribute greatly to the hazard assessment in areas where catastrophic sedimentary processes are associated with extreme floods, through the analysis of the dominant sedimentary processes of the fans (Crosta & Frattini, 2004; Gaume & Borga, 2008). Structure from Motion techniques, and the use of Unmanned Aircraft Systems (UAS) in general, have been increasingly proved useful to post flood surveys (Andreadakis, Kapourani, Diakakis, Papaspyropoulos, & Filis, 2017; Tamminga, Eaton, & Hugenholtz, 2015). During November 2017, an extremely intense rainfall took place in West Attica. The highest precipitation levels were recorded on the high altitude areas west of Mandra and Nea Peramos. This resulted in extreme floods in the region that reached the towns, bringing destruction and 24 fatalities. The huge volume of surface runoff that reached 170 m^3/s and 4 m in height above the ground surface in some spots (Diakakis et al., 2018), reactivated old landforms on which a large portion of Mandra was built, resulting in houses, factories and roads being seriously damaged. The present research focused on the intramontane alluvial fan of Katsimidi stream, a tributary of Agia Ekaterini stream that caused the disaster in Mandra settlement, and at a 4 km distance upstream (west). It can be considered a prime example of reactivation of a fan of Pleistocene origin, accompanied by a debris flow, in which boulders larger than 1 meter in diameter were detached and transported along the streambed and finally deposited over the fan surface (Figure 1). The aim of the study was mapping of the flood features on the fan in explicit detail, with the aid of photogrammetry mapping by an Unmanned Aircraft Vehicle. The procedure included a number of flights programmed and executed through the Pix4D capture software for 3D maps, and processing, firstly in the Pix4D mapper software, and then in the ArcMap software of ESRI. In the first phase of modeling, through processing of 591 images, producing more than 7000 matches per image and a final cloud of more than 41 million points, the 3d model of the fan was produced, along with the orthophotomosaic and Digital Surface Model of the area.

Figure 1. Flood deposits in the streambed, near the apex (left). Boulders on the fan surface downstream (right)

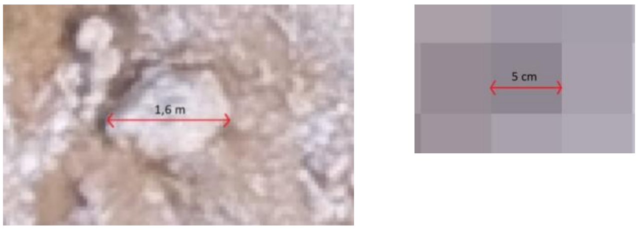

Figure 2. Left: Boulder characterizing extremely high energy flow. Right: Spatial resolution of UAV images

These products were introduced to the ArcMap environment, and a further processing producing the slope map of the area. Linear erosion was delineated with the aid of the orthomosaic and the slope map, followed by outlining of the flood deposits outcrops and areas of recently exposed bedrock. The outcome was a first map of erosion/deposition features. Further analysis taking into account the dominant visible clast size within the deposit polygons, lead to classification of deposition areas by dominant clast size (Figure 3). The resulting map (Figure 3), shows the following:

a) Larger diameter clasts (boulders larger than 50cm in diameter) were mainly deposited near the apex of the fan and along the main axis of flow of Katsimidi stream.

b) Bedrock exposure is located mainly along the local flood extent boundary
c) The size of clasts is reduced from the apex to the foot of the fan and from the axis of flow to the sides
d) Most of the coarse flood deposits are buffered by the forested area at the foot of the fan, permitting transportation only along corridors through the vegetation, and prevented from entering Agia Ekaterini stream.

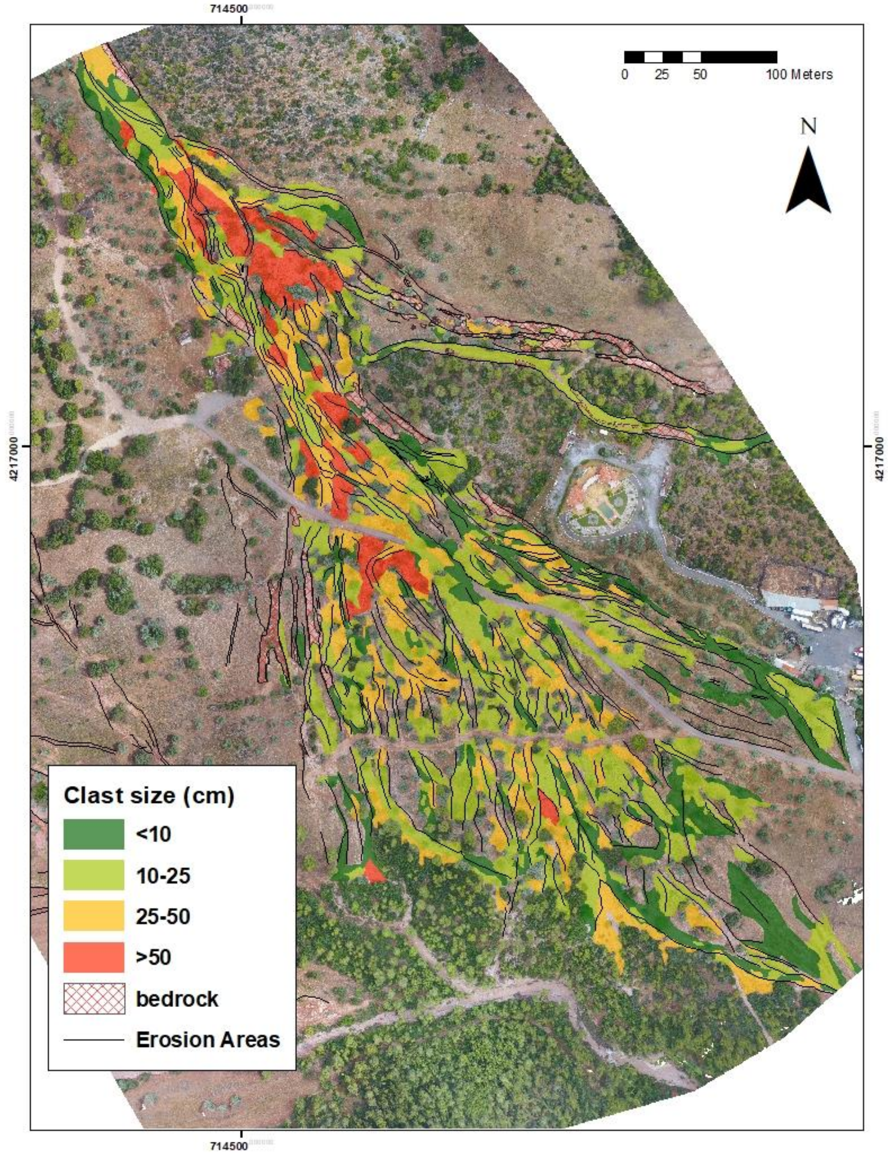

Figure 3. Linear erosion, bedrock exposure and flood deposition areas classified by clast size in Katsimidi fan.

This work demonstrates the applicability and value of imagery from small Unmanned Aircraft Systems in post flood surveys, as far as geomorphological impact and detailed mapping of small areas is concerned. Imagery should be collected with flights immediately after the disaster, and thus they help preserve all mapping data, which are usually soonafter altered or vanished, especially where restoration works are urgently needed, or when a following event should occur. In this way, research buys time to examine thoroughly and revisit virtually the disaster scene without leaving the lab, and more importantly, without missing any information from the field, not to mention the potential for explicitly detaild mapping, depending only on the initial ground sampling distance, which is adjusted through flight altitude.

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