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Landslide shape modeling from field cartography

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Introduction
Madeira Island is located on the North Atlantic, about 520km from the African coast, and its geomorphology is characterized by an abrupt relief, with very deep 'V'-shaped valleys, almost vertical on harder volcanic rock strata. Madeira Island is a region extremely liable for the occurrence of landslides because of the combination of steep terrain, geological settings and occurrence of heavy rain episodes.

One of these heavy rain episodes occurred on 20th February 2010, with records of rain reaching twice the double of monthly average (between 6AM and 11AM were registered 108mm at Funchal and 146mm at Pico do Areeiro). Such extreme event triggered a number of landslides and alluvium floods mainly in two areas: Ribeira Brava and Funchal, with extensive and severe personal and material damages.

The gravity of the event generated the necessity for the improvement on the knowledge of this type of events in order to predict and minimize the damages. The studies concentrated on the evaluation of the event itself, with the characterization of the amount of precipitation, the computation of the volumetric amount of sediment dislocated during the landslides and the volumetric contribution by each sub hydrographic basin. The landslide assessment was made with remote sensing techniques and validated with field work.

Methods
In order to validate the classification results a topographic survey was conducted on 31 landslides covering the five principal hydrographic basins (HB) of the two main affected areas: five landslides at Tabua HB, ten at Ribeira Brava, five at S. João, four at Sta. Luzia and seven at João Gomes. The topographic survey used differential GPS positioning and a total station, acquiring two different sets of control points for each landslide scar. One set of points was acquired on the outline of the landslide scar and the other set inside the scar, trying as much as possible to represent the landslide surface.

The requirement of two different sets of control points is justified by the calculation of the landslide volumetric shape, which needs two reference surfaces. The pre landslide surface is represented by the control point sets of the outline of the landslide scar; the post landslide surface is built with both point sets, allowing the delineation of the landslide surface. The difference between both pre and post landslide surfaces will reveal the geometry of the volumetric sedimentary material dislocated downwards in each landslide. The pre landslide surface was modeled with the outline control points because the DTM available for the study area was insufficient to represent the detail of the landslide scars. The DTM available represented these structures by cells of 4x4m, which was clearly inadequate for the precision required.

Results
The modeling of the volumetric shape of 31 landslides was made with Matlab®, allowing the characterization of the landslides in terms of mean, maximum and minimum height, area and volume dislocated and the evaluation of the geometry of the volumetric shape. For the Ribeira Brava area, with two main hydrographic basins, the mean height was calculated in 0.86m; for the Funchal area, containing three hydrographic basins, the mean height was estimated in 0.77m. The maximum height was 2m and the maximum volume dislocated of 656m3.

Conclusion
The results indicate that these landslides are shallow, with a maximum height of 2m, but the area affected is quite large, which translates on a large sediment volume dislocated. This fact, by itself, justifies the availability of material capable at the hydrographic network that fed the alluviums generated on that day. Moreover, the field work results indicate that there is still a large amount of sediment available, with the potential to feed future alluvium events.