ANALYSIS OF HYDROLOGICAL REGIME OF PYROCLASTIC SOIL MANTLED SLOPES IN CAMPANIA (SOUTHERN ITALY) FOR ASSESSING DEBRIS FLOW HAZARD

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Ash-fall pyroclastic deposits erupted in the last 39 k-yrs by the Somma-Vesuvius and Phlegrean Fields volcanoes mantle mountain ranges that surround the Campanian plain (southern Italy), discontinuously and with variable thickness depending fundamentally on the total amount fallen locally and slope angle[1,2]. In this geomorphological framework, both sedimentary and volcanic bedrock were mantled by volcaniclastic soils which exert a very relevant hydrological and environmental behavior under the influence of thickness, stratigraphic settings and vegetation cover. One of the most important issues related to the hydrological response of these pyroclastic soil mantled slopes is the recurrence of deadly rainfall-induced debris flow, whose timing is controlled by the occurrence of critical combinations of rainfall intensity and duration as well as by antecedent soil hydrological status[3]. Consequently, several studies have tackled the hydrological monitoring of ash-fall pyroclastic deposits in test areas along peri-Vesuvian mountains aimed at the comprehension of hydrological dynamics leading to debris flow initiation[4,5,6].

In our research, since December 2010 we installed and maintained a soil hydrological monitoring station upslope of a representative debris flow source area in the southwestern slope of the Sarno Mountains[7], where ash-fall pyroclastic deposits mantle a carbonate bedrock reaching a total thickness of about 4 m. Locally, the volcaniclastic series is formed, from the topmost, by a topsoil horizon (A and B soil horizons) and two pumiceous lapilli horizons (C horizons) with an intercalated paleosol (Bb horizons), while at the contact with the bedrock interface a basal paleosol (Bb_{basal} horizon) was observed.

The monitoring station was assembled with a total of 39 devices comprising tensiometers and matric potential instruments, represented by Watermark (Irrometer Inc.) and MPS-2 (Decagon Inc.) sensors, which were installed in a number variable with depth, depending on the stratigraphic setting of the pyroclastic mantle and the expected damping of the hydrological response.

Monitoring results over about a seven-year span showed consistently pressure head values in unsaturated conditions, with strong seasonal and interannual variations, as well as delayed and damped dynamics at different depths. Among the most innovative findings[8] are those depicted in the following: a) the involvement of the whole thickness of the ash-fall pyroclastic soil cover in the annual and interannual hydrological dynamics; b) the exceedance of minimum pressure head values far beyond (down to -60.0 m) the functioning limit of tensiometers (about -7.0 m); c) from the late spring to late autumn, the abrupt decrease of pressure head values owing to the strong evapotranspiration demand of deciduous chestnut forest; d) from the late autumn to early winter, the approximate balance among rainfall, unsaturated drainage and reduced evapotranspiration which leads to pressure head values ranging around -2.0 m, but with peaks up to near-saturation conditions (-0.3 m) recorded during winter rainstorms; e) strongly delayed response among surficial and deeper soil horizons leading to opposite wetting/drying conditions during transition periods between wet and dry seasons.

Frequency analysis of recorded pressure head time series by the reconstruction of duration curves, allowed quantifying the seasonal hydrological regime of the whole ash-fall pyroclastic soil mantle and individual soil horizons as well. According to field measurements carried out during winter rainy periods, pressure head values higher than -1.0 m were identified as hydrological conditions predisposing to landsliding. Therefore, the pressure head value of -1.0 m was assumed as a reasonable threshold for landslide alert and then seasonal frequencies exceeding this value were assessed. The same analyses showed a strongly delayed hydrological response for individual soil horizons, determining in winter and summer opposite hydrological conditions between the shallowest and deepest soil horizons. In addition, thickness of the ash-fall pyroclastic soil mantle was supposed controlling its hydrological response because determining the soil water depth of moisture available for the evapotranspiration.

In conclusion, the proposed approach allowed to advance knowledge about temporal probability of antecedent hydrological conditions that predispose to landslide triggering[8]. Moreover, results obtained give new hints for the assessment of thresholds values of rainfall triggering debris flow, providing a consistent support for their estimation by a deterministic approach, which is based on a consistent engineering-geological reconstruction of the landslide source areas and a coupled hydrological/stability modelling that considers also antecedent hydrological conditions[3].

Keywords: Ash-fall pyroclastic soils, field hydrological monitoring, rainfall-triggered debris flow, peri-volcanic mountain areas.

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