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Topographical controls on soil moisture distribution and runoff response in a first order alpine catchment

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Hydrological processes driving runoff generation in mountain basins depend on a wide number of factors which are often strictly interconnected. Among them, topography is widely recognized as one of the dominant controls influencing soil moisture distribution in the root zone, depth to water table and location and extent of saturated areas possibly prone to runoff production. Morphological properties of catchments are responsible for the alternation between steep slopes and relatively flat areas which have the potentials to control the storage/release of water and hence the hydrological response of the whole watershed.

This work aims to: i) identify the role of topography as the main factor controlling the spatial distribution of near-surface soil moisture; ii) evaluate the possible switch in soil moisture spatial organization between wet and relatively dry periods and the stability of patterns during triggering of surface/subsurface runoff; iii) assess the possible connection between the develop of an ephemeral river network and the groundwater variations, examining the influence of the catchment topographical properties on the hydrological response.

Hydro-meteorological data were collected in a small subcatchment (Larch Creek Catchment, 0.033 km^2) of Rio Vauz basin (1.9 km^2), in the eastern Italian Alps. Precipitation, discharge, water table level over a net of 14 piezometric wells and volumetric soil moisture at 0-30 cm depth were monitored continuously during the late spring-early autumn months in 2007 and 2008. Soil water content at 0-6 and 0-20 cm depth was measured manually during 22 field surveys in summer 2007 over a 44-sampling point experimental plot (approximately 3000 m^2). In summer 2008 the sampling grid was extended to 64 points (approximately 4500 m^2) and 28 field surveys were carried out. The length of the ephemeral stream network developed during rainfall events was assessed by a net of 24 Overland Flow Detectors (OFDs), which are able to detect the presence/absence of surface runoff.

Results show a significant correlation between plot-averaged soil moisture at 0-20 cm depth, local slope and local curvature, while poor correlations were found with aspect and solar radiation: this suggests a sharp control of the catchment topological architecture (likely coupled with soil properties) on soil moisture distribution. This was also confirmed by the visual inspection of interpolated maps which reveal the persistence of high values of soil moisture in hollow areas and, conversely, of low values over the hillslopes. Moreover, a strong correlation between plot-averaged soil moisture patterns over time, with no decline after rainfall events, indicates a good temporal stability of water content distribution and its independence from the triggering of surface flow and transient lateral subsurface flow during wet conditions. The analysis of the time lag between storm centroid and piezometric peak shows an increasing delay of water table reaction with increasing distance from the stream, revealing different groundwater dynamics between the near-stream and the hillslope zone. Furthermore, the significant correlation between groundwater time lag monitored for the net of piezometers and the local slope suggests a topographical influence on the temporal and spatial variability of subsurface runoff. Finally, the extent of the ephemeral stream network was clearly dependent on the amount of precipitation but a different percentage of active OFDs and piezometers for the same rainfall event suggests a decoupling between patterns of surface and subsurface flows in the study area.

Key words: topographical controls, soil moisture patterns, groundwater level, overland flow.