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Analysis and modelling of the temporal stability of throughfall and near-surface soil moisture at the plot scale in the Italian pre-Alps

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Understanding the spatial and temporal variation in soil moisture at different scales is crucial for hydrological sciences. In forested areas, spatial patterns in throughfall and vegetation characteristics are expected to control soil moisture variability. However, few studies have focused on the influence of throughfall spatial patterns on near-surface soil moisture. Therefore, this study aimed to: i) investigate the relation between the spatial patterns of throughfall and near-surface soil moisture at the plot scale for a forested hillslope, ii) compare the temporal stability of throughfall and soil moisture with canopy characteristics, and iii) assess the controls on the correlation between throughfall and soil moisture temporal stability by means of a dynamic soil moisture model.

Throughfall and soil moisture measurements were taken in a 500 m^2 experimental plot on the hillslope of a densely forested catchment (Ressi) in the Italian pre-Alps between April 2013 and March 2014. The main tree species in the plot are beech and chestnut. The median diameter at breast height of the trees in the plot is 4 cm (range 1-61 cm). Fifty buckets (collecting area: 556 cm^2; capacity: 162 mm) were randomly distributed in the plot for throughfall measurements, while a bucket was also installed in a nearby open area (approximately 150 m from the experimental plot) to collect rainfall. Volumetric soil moisture content was measured at 50 points, about 30 cm upslope of each bucket, at two depths (0-7 and 0-12 cm) before and after 23 rainfall events (7.7 mm to 156 mm) using portable TDR (Time Domain Reflectivity) probes. Canopy openness and leaf area index (LAI) were determined from hemispherical pictures at each bucket.

For the measured events throughfall and soil moisture spatial patterns were not significantly or only weakly correlated, likely due to the lateral and vertical redistribution of water in the soil profile during the 2-36 hour period between the end of the rainfall event and the start of the soil moisture measurements. The temporal stability of soil moisture was larger than the temporal stability of throughfall and they were also not significantly correlated. The patterns of temporal stability were also not related to canopy openness or LAI, suggesting that the spatial variability in throughfall is probably linked to small scale characteristics of the canopy.

A soil moisture model was used to test which combination of soil properties and vegetation characteristics leads to uncorrelated patterns of temporal stability of throughfall and soil moisture. The application of the model revealed that a large spatial variability in saturated hydraulic conductivity that is correlated with the spatial variability in LAI and root fraction tends to strongly weaken the correlation between throughfall and soil moisture patterns. The analysis of field data combined with the model application suggests that in this specific forested hillslope the spatial organization of soil moisture is dominated by a combination of soil properties and vegetation characteristics, rather than by the throughfall spatial patterns.

Keywords: throughfall; near-surface soil moisture; temporal stability; plot scale; spatial variability; forested hillslope.