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Spatial and temporal variability of throughfall at the plot scale in the Italian pre-Alps

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The redistribution of rainfall in the forest canopy affects many hydrological and biogeochemical processes. Although many studies have focused on the quantification of throughfall, the controls on the spatial variability and temporal persistence of throughfall patterns are still poorly understood. This study therefore aims to: i) quantify throughfall at the plot scale for a pre-Alpine forested hillslope in Italy; ii) assess measurement differences between two different throughfall collectors; and iii) investigate the spatial and temporal variability of throughfall patterns and their relation to canopy characteristics.

Throughfall measurements were taken from April to November 2013 in a 500 m^2 experimental plot on the hillslope of a small and densely forested catchment (Ressi) in the Italian pre-Alps. 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). Two different rainfall collectors were used: buckets (collecting area: 556 cm^2; capacity: 162 mm) and rain gauges (collecting area: 47 cm^2; capacity: 80 mm). Fifty buckets were randomly distributed in the plot, while 40 rain gauges were installed on a regular grid (spacing 2.5x3 m). One bucket and one rain gauge collected rainfall in a nearby open area. A tipping bucket rain gauge was installed in the open area as well. Rainfall and throughfall were measured for 20 events by manually emptying the collectors and measuring the volume of water in the collectors. Canopy openness was determined by taking pictures with a 24 mm lens upward from each sampler and selecting thresholds between dark (canopy) and light (sky) areas.

For the measured events, rainfall in the open area ranged from 4 mm to 122 mm. Plot-average throughfall for these events ranged between 69%-94% and 68%-100% of precipitation for the buckets and rain gauges, respectively. Throughfall measured by the two types of samplers was statistically similar (Mann-Whitney rank sum test, $p>0.05$). However, despite the smaller number of rain gauges than the buckets, the standard deviation and the coefficient of variation were typically higher for the rain gauges, likely due to their smaller area. Measured throughfall in the plot ranged between 25%-178% and between 13%-379% of the precipitation in open area for the bucket and the rain gauge measurements, respectively. This suggests an important role of dripping points in shaping plot-scale variability in throughfall, especially during small rainfall events, and underlines the greater variability in throughfall measured by the rain gauges than by the larger buckets. Throughfall as a percentage of precipitation tended to increase with increasing rainfall depth and rainfall intensity. The spatial variability of throughfall, expressed by the coefficient of variation, decreased asymptotically with increasing total rainfall and rainfall intensity.

Canopy openness (quantified for buckets) was poorly correlated with the mean relative difference of throughfall and significantly correlated ($r=0.58$, $p<0.05$) with the standard deviation of the relative difference. This suggests that canopy density and its associate heterogeneity exert a weaker control on the spatial variability of throughfall than on the temporal persistence of throughfall patterns. In particular, areas with gaps showed a more variable behavior relative to the plot average than close canopy areas.

Keywords: throughfall, experimental plot, spatial and temporal variability, canopy openness.