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Moment Analysis Characterizing Water Flow in Repellent Soils from On- and Sub-Surface Point Sources

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Water repellency has a significant impact on water flow patterns in the soil profile. Flow tends to become unstable in such soils, which affects the water availability to plants and subsurface hydrology. In this paper, water flow in repellent soils was experimentally studied using the light reflection method. The transient 2D moisture profiles were monitored by CCD camera for tested soils packed in a transparent flow chamber. Water infiltration experiments and subsequent redistribution from on-surface and subsurface point sources with different flow rates were conducted for two soils of different repellency degrees as well as for wettable soil. We used spatio-statistical analysis (moments) to characterize the flow patterns. The zeroth moment is related to the total volume of water inside the moisture plume, and the first and second moments are affinitive to the center of mass and spatial variances of the moisture plume, respectively.

The experimental results demonstrate that both the general shape and size of the wetting plume and the moisture distribution within the plume for the repellent soils are significantly different from that for the wettable soil. The wetting plume of the repellent soils is smaller, narrower, and longer (finger-like) than that of the wettable soil compared with that for the wettable soil that tended to roundness. Compared to the wettable soil, where the soil water content decreases radially from the source, moisture content for the water-repellent soils is higher, relatively uniform horizontally and gradually increases with depth (saturation overshoot), indicating that flow tends to become unstable. Ellipses, defined around the mass center and whose semi-axes represented a particular number of spatial variances, were successfully used to simulate the spatial and temporal variation of the moisture distribution in the soil profiles. Cumulative probability functions were defined for the water enclosed in these ellipses. Practically identical cumulative probability functions (beta distribution) were obtained for all soils, all source types, and flow rates. Further, same distributions were obtained for the infiltration and redistribution processes. This attractive result demonstrates the competence and advantage of the moment analysis method.