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Tracers in rainfall simulation experiments to study the onset of the wet season in Eastern Mediterranean limestone environments

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The eastern Mediterranean rainfall regime is characterized by dry and hot summers and rainy cold winters. In this climate rocky limestone environments are regarded as major recharge zones due to (a) intensively enlarged fissures by solution weathering and (b) sparse vegetation and shallow soils which limit evapotranspiration losses. However, relatively little is known on hydrological processes during high magnitude rainstorms, which, at the beginning of the rainy season, may occur on both dry and wet soils. These conditions were investigated by a series of sprinkling experiments during two successive days. Rainfall was applied on large plots (143 and 180 m2) to include the variety of different terrain elements (rocky outcrops, bare soil, different vegetation). Sprinkling units were located at each corner of the plot and supplemented by additional ones to balance wind drift. This sprinkling set-up did not guarantee a uniform distribution of applied rainfall, as overlap of sprinkling areas could not be prevented. To assess the spatial rainfall distribution, a large number of totalizers was necessary. During two days of sprinkling these totalizers were regularly measured and spatially interpolated across the plot. The temporal rainfall distribution, a series of two high intensity storms on dry and wet soil, was observed by a tipping bucket raingauge. Tracers were added to the sprinkling water to obtain additional process insights. By end member mixing analysis the contribution of different water types (pre-sprinkling, first day, second day) could be quantified.

The first plot was located on a steep rocky hillslope. Significantly different concentration of chloride, nitrate and sulfate in the sprinkling waters helped to identify first day's water in second day's runoff. Surface runoff was a combination of infiltration excess runoff from rocky portions of the plot and saturation excess runoff from areas covered by soil. Soil saturation was accelerated by lateral runoff from adjacent rocky areas. Once the plot was saturated, 80-90% of the applied rainfall became surface runoff. About 14% of the flow collected during the second day originated from water applied during the first day. Both water sources obviously mixed in saturated soil reservoirs and contributed in variable percentages to surface flow. The second plot was located above a karstic cave. Additionally to soil moisture and surface runoff, the drip response of cave stalactites was measured. This time electrical conductivity and bromide were used to study recharge processes, water origin and mixing inside a 28 m vadose zone. Bromide tracing allowed identification of quick direct flow paths. Under dry preconditions, 80 mm of artificial rainfall applied in less than seven hours was not enough to initiate significant downward water percolation. Most water was required to fill uppermost soil and rock storages. During the second day of sprinkling, higher water contents in soils and karst cavities facilitated piston flow effects and a more intense response of the cave drips.

Both experiments yielded point estimates for seasonal thresholds of runoff generation and groundwater recharge. The filling of the unsaturated zone, including soil and rock storages, was found to be an important precondition for the onset of surface runoff and groundwater recharge. By mixing analysis, continuously applied tracers identified the dominating processes: saturation excess overland flow for runoff generation and piston flow for water percolation. Overall, a higher seasonal threshold for water percolation than for the generation of surface runoff was found.