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Modeling spatial and seasonal soil moisture in a semi arid hillslope: The impact of integrating soil surface seal parameters

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Modeling hillslope hydrology and the complex and coupled reaction of runoff processes to rainfall, lies in the focus of a growing number of research studies. The ability to characterize and understand the mechanisms underlying the complex hillslope soil moisture patterns, which trigger spatially variable non linear runoff initiation, still remains a current hydrological challenge especially in ungauged catchments. In humid climates, connectivity of transient moisture patches was suggested as a unifying concept for studying thresholds for subsurface flow and redistribution of soil moisture at the hillslope scale. In semiarid areas, however, transient moisture patches control also the differentiation between evaporation and surface runoff and the ability to identify a unifying concept controlling the large variability of soil moisture at the hillslope scale remains an open research gap. At the LTER Lehavim site in the center of Israel (31^{0}20' N, 34^{0}45' E) a typical hillslope (0.115 km^2) was chosen offering different aspects and a classic geomorphologic banding. The annual rainfall is 290 mm, the soils are brown lithosols and arid brown loess and the dominant rock formations are Eocenean limestone and chalk with patches of calcrete. The vegetation is characterised by scattered dwarf shrubs (dominant species *Sarcopoterium spinosum*) and patches of herbaceous vegetation, mostly annuals, are spread between rocks and dwarf shrubs. An extensive spatial database of soil hydraulic and environmental parameters (e.g. slope, radiation, bulk density) was measured in the field and interpolated to continuous maps using geostatistical techniques and physically based modelling. To explore the effect of soil surface sealing, Mualem and Assouline (1989) equations describing the change in hydraulic parameters resulting from soil seal formation were applied. Two simple indices were developed to describe local evaporation values and contribution of water from rock outcrops to the soil down slope. This spatio-temporal database was used to characterise 1187 spatial cells serving as an input to a numeric model (Hydrus 1D) solving the flow equations to predict soil water content at the single storm and seasonal scales. The model was verified by sampling soil moisture at 63 random locations at the research site, during three consecutive storms in the 2008-09 rainy season. The results show that incorporating a seal layer in the model reduces significantly the variability of soil moisture and improves the correlation between simulated and observed values (R^2 = 0.84). The emerging soil moisture patterns have clear structural nature, shaped by the following factors as found by applying a stepwise regression analysis: 1) soil porosity; 2) profile depth; 3) radiation and 4) rock outcrops. We suggest that seal layers, as a cross scale phenomena, decrease the variability in the soil hydrological parameters and allow the variability in environmental factors to dominate spatial water content patterns. This approach allows investigations of the different factors affecting hillslope soil moisture patterns and functional role of different geomorphic units on water relocation at the hillslope scale.