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Hortonian surface runoff in flat areas due to microtopography and spatially varying infiltration characteristics

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In flat groundwater-dominated areas surface runoff is a commonly neglected phenomenon despite its frequent occurrence and the relevance this fast flow route can have for water quality issues. When the regional surface gradient is weak, the routing of runoff is mainly determined by microtopography. Local depressions fill, full depressions merge and eventually connect with the field boundary. Rainfall rate and duration, soil hydraulic properties and groundwater levels determine the speed with which these depressions fill and whether or not they connect to ditches or channels. We investigate the relative contributions of microtopography and soil hydraulic properties in runoff generation in these flat areas.

The topographies of the system were simulated with a Gaussian distribution of which we varied the standard deviation and the correlation length. Non-Gaussian topographies with the same first-order statistics were also included in the analysis. Saturated hydraulic conductivity and sorptivity were appointed to every cell of the elevation grid. For the distribution of these parameters different spatial correlation distances were used. Surface runoff was allowed at all boundaries of the topographies, simulating a system surrounded by ditches. We developed an algorithm that explicitly deals with the filling, merging, and connecting of depressions in a field. The routine has a successive steady-state setup: in every time step the excess water in each cell is routed to its ultimate sink, either in the field or in the surrounding surface water, under the assumption of instantaneous water transfer. When the capacity of a depression is exceeded, water is routed to a neighbouring depression, or depressions are merged to form a new, larger depression. We coupled Philip's Two-Term infiltration model to this algorithm.

The volumes of water involved in ponding and surface runoff are scale-dependent: the larger a topography or the standard deviation of the elevation distribution, the larger the amounts of water that can be stored in the surface topography. When studying surface runoff rates in a dimensionless setting the development of surface runoff does not depend on these characteristics. The correlation length of the elevation distribution does change the development when it is relatively large compared to field size. When microchannels are present in the topography these dominate the surface runoff development. Including infiltration in the analysis delays the onset of surface runoff and decreases the quantity of surface runoff. The ponding in the depressions levels most of the differences in infiltration behaviour. Spatial variation of infiltration characteristics affects the dimensionless development of surface runoff in the same order of magnitude as do coincidental variations of microtopography. When the correlation length of the distribution of infiltration characteristics is much larger than that of the distribution of elevation, the changes in development of surface runoff increase.