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Impact of topography at different scales on ponding and runoff in flat areas

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In flat well-drained agricultural terrain, surface runoff is a relatively rare phenomenon, yet an important driver of sediment and nutrient transport. In this environment, periods of intense rainfall, shallow groundwater dynamics and local combinations of meso- and microtopography are the factors that determine whether water in ponds will make it to streams and ditches. We have combined surface runoff measurements at agricultural fields and a new modeling approach to explore the following questions: (i) what rainfall conditions prevail during surface runoff events and (ii) how do flow routes develop during surface runoff events in various types of microtopography?

We have collected surface runoff data from two field sites in flat, lowland catchments in the sandy part of the Netherlands. In addition, we developed a dynamic model (FAST-runoff) that simulates redistribution of water over a heterogeneous surface with infiltration and 2-dimensional groundwater flow.

The field measurements showed that most surface runoff occurred as saturation excess runoff during long wet periods or during snow melt periods. For both fields, the contributing area during the saturation excess events was large and flow paths long, irrespective of the profoundly different microtopographies. We explored this behaviour with our FAST-Runoff model and found that under saturation excess conditions, meso-topographic features, such as natural depressions or those caused by tillage, gain importance at the expense of the spatial organization of microtopography. Mesotopography affects surface runoff development under saturation excess conditions by actually rerouting ponding water over longer distances. The infiltration of water in mesotopographic depressions can lead to a decrease of the gradient of the groundwater table over a large part of each field, which decreases groundwater flow. In our analyses, the storage and rerouting characteristics of the mesotopography increased the sensitivity of the fields to the specific structure of yearly rainfall series. It resulted in differences of the total volume of surface runoff generated per season of one order of magnitude for statistically identical rainfall timeseries, which is in agreement with the general variable occurrence of surface runoff events in flat, well-drained, wet catchments.