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Modeling structures and patterns controlling the hydrology of an artificial catchment

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Water flow in an artificially created catchment was found to be controlled by emerging surface structures. To simulate the hydrology of the system, the generation of these structures and the processes therein must be modeled adequately.
The catchment ('Chicken Creek') with a surface area of 6 ha and an average slope of approximately 2% was created near Cottbus, Germany, in 2005. The lower boundary of the system is a clay layer of 2-3 m thickness, assuring the hydrological sealing of the catchment. The overlying substrate stems from sandy accumulations of Pleistocene age. After construction the catchment was left to an undirected primary succession. A system of erosion rills was generated during rainfall events and vegetation started to grow and is expected to affect water infiltration. Further heterogeneities were found in the subsurface that were caused by the construction procedure. Due to these structures, the catchment cannot be described as a system with smoothly varying properties but is characterized by sharp contrast between different structures.
To take these structures into account we develop a new three-dimensional high-resolution model that mimics the emergence of various structures and the hydraulic processes therein. Statistical and deterministic models of drainage networks were tested and compared to the measured patterns of gully erosion. Elements of percolation theory and cellular automata were applied to characterize the outflow for different saturation conditions. The description of water flow was simplified by introducing a threshold separating between soil elements with 'mobile' and 'immobile' water. Compared to the time scale defined by rainfall and infiltration rate, the flow through elements with mobile water was instantaneous while the flow through cells with immobile water was slow and driven by water content differences.