FEEDBACK BETWEEN EMERGING STRUCTURES AND HYDROLOGIC PROCESSES DURING THE INITIAL ECOSYSTEM DEVELOPMENT PHASE IN AN ARTIFICIAL WATER CATCHMENT

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Motivation

During the past three decades considerable progress has been made in hydrological research of catchments, including the development of a vast number of conceptual and physically based runoff models. However, little effort has been made to the implementation of feedback mechanisms between hydrological variables and the development of structures, such as erosion rills or vegetation patterns, into hydrological or ecosystem models. Therefore, there is still a lack of knowledge about how evolving structures in the initial phase of an ecosystem affect the hydrology in a catchment.

Project objectives

The work presented is realised as part of the interdisciplinary study performed by the Transregional Collaborative Research Centre SFB/TRR 38 of the German Research Foundation (DFG) (http://www-1.tu-cottbus.de/BTU/Innov/SFB)

This project aims to investigate relevant structures and processes of the initial ecosystem development phase and to answer the following questions:

– Is it possible to identify different ecosystem development phases on the basis of spatiotemporal change of water flows?
– How does the investigation of structures on different scales affect the catchment hydrology?
– Does a more detailed process description on the small scale lead to better model results for the entire catchment?

Experimental site

Within the framework of this study, an artificial catchment (ca. 6 ha), including a small lake was built near Cottbus (Germany) and left, as far as possible, to an undirected succession. The crucial benefits of an artificial catchment are the well documented structures and the well defined boundary conditions. The initial slope was 4% on average. A clay layer underlying the soil formes the lower boundary and assures that the underground is hydrologically seald. The mean soil depth above the clay layer is in the range of 2-3 m.

Measurements

After the construction phase, the catchment was instrumented intensively to gather validation information for the model results.

Weather data, serving as model input, is monitored at two standard meteo stations. Repeated aerial photographs and laserscanning campaigns give information about the topography, which is subjected to subsidence and erosional processes with ongoing time.

Soil properties (texture, saturated hydraulic conductivity, pH) are measured at specific locations across the catchment, whereas soil moisture, suction, soil temperature and groundwater level is measured in four soil pits. Ephemeral stream runoff in gullies is captured with runoff flumes at two locations in the catchment. A weir at the lake outlet measures the total runoff from the catchment. Together with lake level change measurements, an estimation of the water budget is possible.

Model approach

We investigate the interaction between the developing structures (e.g. erosion rills, vegetation patterns) and hydrological variables, such as surface and subsurface runoff, infiltration, permeability and soil moisture distribution. To model the emergence of these complex structures and to simulate the spatial and temporal water distribution, we develop a new three dimensional cellular automaton model. Cellular automata are used to model spatially discrete dynamic systems. They consist of a regular grid of cells, a number of states the cells can be in, a finite neighbourhood and a local transition rule. The state of a cell at time t is a function of the state of the cells in the neighbourhood at time t-1. The advantage of cellular automata is the application of simple loacl rules, while still providing the possibility to model complex spatiotemporal phenomena. Another benefit is the description of local processes, i.e. no numeric integration with global equations has to be used.

The results gained with the new model are compared with measurements for validation. In a second step, results from other hydrological models, such as COUP (Jansson and Karlberg, 2004) or WaSiM-ETH (Schulla and Jasper, 2007) will be considered as well.

References

Jansson P-E. Karlberg L., 2004: *Coupled heat and mass transfer model for soil-plant-atmosphere systems*. Royal Institute of Technology, Department of Civil and Environmental Engineering, Stockholm, 435 pp. (http://www.lwr.kth.se/vara%20datorprogram/CoupModel/index.htm).

Schulla, J., Jasper, K., 2007: *WaSiM-ETH – The hydrological model system*. (http://homepage.hispeed.ch/wasim/products/wasim_all.htm).