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Modelling the initial structure dynamics of soil and sediment exemplified for a constructed hydrological catchment

Thomas Maurer (1), Anna Schneider (2), and Horst H. Gerke (3)

(1) Chair Hydrology and Water Resources Management, Brandenburg University of Technology, Cottbus, Germany, (2) Chair Geopedology and Landscape Development, Brandenburg University of Technology Cottbus-Senftenberg, Germany , (3) Institute for Soil Landscape Research, Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany

The structure of a hydrological catchment is determined by the geometry of the boundaries and the spatial distribution of soil and sediment properties. Models of the 3D subsurface structure and the soil heterogeneity have often been built based on geostatistical approaches and conditional simulations for spatial interpolation between measurements. Here, an alternative model was proposed that generated 3D subsurface structures by imitating basic structures resulting from mass distribution processes. Instead of directly assuming stochastic variations of the subsurface structure, the present approach assumed stochastic variations in parameters of the process-based algorithms of the generator models.

The constructed hydrological catchment "Hühnerwasser" located in the Lower Lusatia region of Brandenburg, Germany, was used as an example for the development of such a 3D structure generator model. Boundary geometries and changes in the surface topography due to erosion and sedimentation processes were quantified on the basis of digital elevation models (DEMs) derived from aerial photographs and terrestrial laser scanning information. Basic sediment properties came i) from a geological model of the parent material at the outcrop site, ii) from actual soil sample measurements on-site, and iii) based on stochastic texture variations. Sediment distributions were generated according to construction processes such as sediment dumping, particle segregation, and soil compaction.

The resulting internal structures reflect the formation of spoil cones and surface compaction by machinery. The simulated 3D model scenarios of soil texture and bulk density distributions were incorporated in a gridded 3D volume model using the 3D software tool GoCAD (Paradigm Ltd.). This 3D distributed solid phase structure of the catchment allowed for a more direct comparison with observations using minimal invasive methods. By including structural changes over time (e.g., derived from DEM's), spatially-distributed solid mass balances can be inferred based on the comparison of 3D structure models for subsequent time steps, which is a basic information for studying soil development. The 3D structure model as spatial database of the solid phase allows an integrative analysis, a periodical mass balance, and a mechanistic process-based generation of complex realizations of distributed hydraulic model parameters for the exemplary catchment.