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Competing feedbacks drive state transitions during initial catchment evolution: Examples from post-mining landscape and ecosystems evolution

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Within the context of severely disturbed landscapes with little or no ecological memory, such as post-mining landscapes, we propose a simple framework that explains the catchment evolution as a result of competing feedbacks influenced by the initial conditions and the atmospheric drivers such as rainfall intermittency and intensity. The first stage of the evolution is dominated by abiotic feedbacks triggered by rainfall and subsequent fluid flow causing particle mobilisation on the surface and in the subsurface leading to flow concentration or in some instances to densification of surface and subsurface substrates. Subsequently, abiotic-biotic feedbacks start to compete in the sense that biological activity generally stabilizes substrate by preventing particle mobilisation and hence contribute to converting the substrate to a habitat. We suggest that these competing feedbacks may generate alternative stable states in particular under semi-arid and arid climatic conditions, while in temperate often energy limited environments biological process "outcompete" abiotic processes leading to a stable state, in particular from the water balance point of view for comparable geomorphic situations.

To illustrate this framework, we provide examples from post-mining landscapes, in which soil, water and vegetation was monitored. In case of arid regions in Australia, we provide evidence that the initial conditions of a mine waste disposal "locked" the system into a state that was limited by water and nutrient storage capacity while at the same time it was stable from a geomorphic point of view for the observation period. The cause of the system to be locked in, is the very high hydraulic conductivity of the substrate, that has not undergone any changes during the first years. In contrast to this case study, we illustrate how this framework explains the evolution of an artificial catchment (Hühnerwasser Catchment) in Lusatia (150 km southeast of Berlin, Germany). During the initial phase of development the catchment changed very rapidly due to sediment transport, drainage network formation, and soil crusting very similar to geomorphic processes observed in arid and semi-arid landscapes void of dense vegetation. Hydraulic properties changed rapidly after few wet and dry cycles, indicative of particle mobilisation and trapping in the subsurface. Accordingly, the hydrological regime was controlled by rapid surface runoff enhanced through crust formation and at the same time a shallow ground water system developed. This surface runoff regime peeked about two years initialisation as shown by a maximum area of drainage channels. A major, fairly rapid transition occurred between three and five years after placement, in which the sediment transport ceased and vegetation coverage of the drainage channel exceeded 90%. The transition represents the onset of a transpiration dominated regime that is further enhanced by change of the plant composition of the vegetation with tree recruitment from the surrounding forming significant clusters in the catchment. This transition in the third year was also seen in a significant increase in soil fauna and plant diversity.