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Convergent biomass, divergent patterns: Can initial conditions govern vegetation self-organisation?

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Vegetation self-organisation in water-limited ecosystems in semi-arid climates has been extensively studied by means of numerical simulation using a set of different reaction-diffusion-equations. Most of such models and studies have been concerned with the long-term steady ecohydrological states on domains with periodic boundaries and forced by steady rainfall, whilst little interest has been given to the transient states which lead to them as well as the spatiotemporal multiscale nature of the feedback processes.

It is generally accepted that alternative random initial biomass distributions do not significantly affect the resulting steady state vegetation patterns. However, the role of the initial hydrological conditions –initial surface and subsurface water– has not been explored, mainly due to the interest in the long-term steady state. Nonetheless, vegetation patterns are directly linked to the water distribution occurring at much shorter time scales than vegetation growth, and because they have been shown to be sensitive to annual rainfall, it is reasonable that the initially available water will also play a role. We therefore hypothesize that the initially available water will play a role in the transient process leading to a steady ecohydrological state, and that the steady vegetation patterns will differ in response to the water availability in time during the entire process.

In this contribution we explore the role of initial hydrological conditions on both the transient and long-term steady ecohydrological state. A simulation study was performed using the HilleRisLambers-Rietkerk ecohydrological model on a flatland varying the initial available water whilst also spanning the rainfall gradient (90 – 360 mm/year) . The results were assessed in terms of the evolution and steady state of total biomass yield and hydrological water balance, as well as a quantitative assessment of both transient and steady vegetation patterns. The results show that the initially available water does play a role, not only in the early transient state, but in the long-term steady state, and indeed in the geometry of the converged vegetation pattern. Furthermore, although the steady state biomass yield may be the same for varying initial conditions, the final patterns still differ, e.g., a reduction to one-fourth initial water availability results in more but smaller vegetation patches, while a reduction to one-eigth initial water results in less, but larger patches, and a reduction to one-sixteenth results in a completely new pattern, although total biomass is the same for all. This suggests that long-term average rainfall may govern the total biomass but the initial conditions may play a relevant shaping role in the long term spatial distributions of steady ecohydrological states of water-limited ecohydrosystems. This is relevant, among other reasons, because the resilience of the system is associated to the vegetation patterns. It also suggests that neither the temporal distribution of rainfall nor the system's evolution cannot be neglected to understand the environmental factors which lead to a steady ecohydrological state, since multiple paths may be possible. This warrants further developments from the ecohydrological modelling community and further study of transient states through process-based models.