Ecohydrological modelling of vegetation composition in semi-arid ecosystems with shallow saline groundwater systems

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Soil salinity management is becoming increasingly urgent in view of a growing world population, demand in food production and increasing drought risk. Semi-arid soils are prone to salinization due to interactions with saline groundwater which also interacts with the vegetation distribution. Plant communities in those regions create heterogeneous, self-reinforcing spatial structures consisting of densely vegetated and less vegetated or bare patches. Vegetation influences groundwater recharge and salt dynamics and vice versa [1], hence it is necessary to meet the challenge of understanding salinity-vegetation interactions and determining stable system states. As an analogy, different patterns have been associated with changes of system states, which were warning signs of desertification [2]. Understanding and predicting these system changes can aid in adjusting land management measures to prevent catastrophic shifts. Groundwater-salt dynamics and the resulting vegetation response are not fully understood, and the role of salinity in interaction with vegetation dynamics and a changing climate has to be assessed. We present a modelling tool to analyze the influence of environmental factors on vegetation pattern formation in semiarid ecosystems. This is an extension of an existing model [3] that bases pattern formation on increased infiltration under vegetated patches. Suitable parameterizations for the new extensions are demonstrated.

- Salinity effects on vegetation occur as osmotic effects lead to reduced water availability (virtual saturation) and toxicity effects lead to reduced plant growth, fertility, seed germination and increased mortality. These effects are linked to an ecosystem carrying capacity determined by salinity and plant sensitivity to salinity [4,1].
- Groundwater influence by capillary rise and thus salt transport into the root zone, vertical drainage and rise has been implemented with an analytical solution [5]
- Positive and negative plant interactions occur in terms of facilitation and competition as a function of distance [6]
- Stress-gradient-hypothesis [7] is implemented as a change in relative dominance of competition and facilitation corresponding with increasing stress, including salinity stress
- Species can have complementary traits (sensitivity to drought and salinity, spatial ranges of facilitation)
- Microtopography influences ecohydrological processes. Hence surface elevation heterogeneity has been included and an algorithm to account for ponding and surface water redistribution using DInfinity flow routing [8] is implemented

We discuss simulation results for different DEM, rainfall, groundwater table depth and salt concentrations in one- and multi-species scenarios aimed at assessing the influence of hillslope, seasonal rainfall times series and non-seasonal Poisson-distributed generated precipitation, groundwater depth and salinity levels and soil type. To interpret the results regarding their influence on vegetation patterns, patch geometry analysis such as shape indices as well as species composition (diversity) chosen. It is crucial to understand these interactions and assess salinity impacts separately before further irreversible soil fertility loss can occur. This study could hence contribute to sustainable land use practices, saline site restoration and invasive species management.
References