How will increases in rainfall intensity affect bistable patterned arid ecosystems?

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In arid ecosystems plants can improve soil structure, which on sloped terrains can result in the formation of spatially periodic vegetation bands perpendicular to the hillslope gradient. The formation of these bands allows plants to survive under harsher conditions, as during intense rain events surface water is 'harvested' from the bare interbands uphill. These banded arid ecosystems are however vulnerable: changing climatic conditions may push the system to a degraded state in which vegetation is absent. As a result of global warming, rain events are projected to become more intense in the coming decades. This could lead to increased runoff losses and decreased productivity of arid ecosystems, which may trigger a critical transition to a degraded bare state. Current conceptual models that describe vegetation pattern formation often only implicitly capture rainfall partitioning into infiltration and runoff. Therefore, these models cannot be used to study the role of rainfall intensity in these systems. In this paper we introduce a model in which rainwater partitioning is captured using simple conditional rules. From analysis of the model we conclude that increasing rainfall intensity, as projected for the coming decades, can induce and enhance bistability of arid ecosystems. The model predicts that periodic patterns resulting from surface water redistribution cannot exist in climatic regions with low mean rainfall intensity and that ecosystems in these areas are less likely to be bistable. An increase in rainfall intensity does not only affect the bistability of arid ecosystems, it can also push these ecosystems to a desert state, even if aggregated rainfall rates remain unchanged. Such a critical

transition is not necessarily preceded by the formation of vegetation patterns. If the system is in a patterned state, desertification resulting from increasing rainfall intensity can only occur if the mean rainfall intensity exceeds the infiltration capacity of bare soil and is more likely to take place if the impact of plants on soil structure is low. A decline in mean rainfall intensity may as well result in a critical transition to the desert state. However, this can only occur if the system is in a patterned state. Finally, decreasing rainfall intensity can result in revegetation. This recovery process is facilitated by the water harvesting mechanism responsible for vegetation patterning. In future studies spatially explicit stochastic models in combination with realistic infiltration models could be used to verify the obtained results. ■