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Modelling the effects of plant facilitation-competition mechanisms on semiarid landscape co-evolution

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Semiarid landscapes function as tightly coupled systems with strong biogeomorphic feedbacks. Worldwide, a vast portion of these areas are covered by patchy vegetation consisting of mixed herbaceous and woody plant species that interact exhibiting both competition and facilitation effects. Though the role of facilitative interactions in plant communities has received considerable attention in the last two decades, their effects on the coevolution of landscapes are still not clearly understood.

Here a modelling framework is used to investigate the effects of facilitative interactions among vegetation species, as well as their role on the coevolution of water redistribution, vegetation patterns, and landforms. The model simulates the dynamics of and interactions between coexisting grasses and shrubs under varying competition-facilitation conditions. We explore facilitation effects associated with changes in micro environmental conditions for water availability in dry environments focussing on the role of infiltration enhancement and shading effects. Field experiments have shown that in many semiarid environments vegetation enhances infiltration. However, herbaceous and woody plants seem to have varying hydrologic traits in different areas and it is therefore not clear which species has the greatest contribution to infiltration enhancement. This study tests alternative hypothesis, varying the relative contributions to total infiltration of both species, through a sensitivity analysis of the key parameters affecting infiltration.

We analyze the results by examining the simulated spatial patterns of biomass density, soil moisture and erosion. Results indicate that final vegetation cover structure and hydrologic connectivity strongly depend on the facilitation mechanisms included in the model. We find that the removal of woody species can lead to alternative steady states, including an increase on herbaceous cover, which is the expected outcome of these management practices. However, it can also result in a decrease on herbaceous cover, and under more extreme conditions to the desertification of the system with disastrous erosion consequences. The study suggests that the nonlinear character of the competition-facilitation interactions has a critical role on shaping coevolving landforms and for prescribing their response to environmental drivers such as anthropogenic activities and climate change. These results are relevant for the development of tools for ecosystem management and restoration.