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Coevolution of Semiarid Hillslopes: Ecogeomorphologic Patterns for Varying Biotic and Abiotic Conditions

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Ecogeomorphologic systems exhibit highly nonlinear interactions between physical and biological factors that give rise to the emergence of remarkable and intriguing landform-vegetation patterns. These self-organizing patterns result from the non-linear coevolution of landforms and biota, which makes the understanding and/or prediction of landscape responses to change highly challenging. The growing concern over ecosystem resilience to climate and land use perturbations that could result in irreversible degradation imposes a pressing need for research aiming at elucidating the processes, feedbacks and dynamics leading to these coevolving patterns. For arid and semiarid regions, causes for concern have increased at a rapid pace during the last few decades, due to growing anthropic and climatic pressures that have resulted in the degradation of numerous areas worldwide.

This work aims at improving our understanding of the ecogeomorphic evolution of landscape patterns in semiarid areas with a sparse biomass cover, through a modeling approach. A coupled vegetation-pattern formation and landform evolution model is used to study the coevolution of vegetation and topography over centennial time scales. The analysis shows that self-organized vegetation patterns strongly depend on feedbacks with coevolving landforms. The resulting patterns change depending on the prevailing erosion rates and mechanisms (prescribed by slopes and dominance or either fluvial or diffusive processes), which in term are affected by biotic factors related to vegetation cover protection. Moreover, results from simulations show that ecohydrologic processes leading to banded pattern formation, represented in the models currently used in the literature, when coupled with landform processes, can also lead to completely different patterns (stripes of vegetation along drainage lines) that are equally common in semiarid areas. Though banded patterns in high relief areas are possible, our results show that it is more likely to find concentrated flow leading to vegetation stripes, that is, plant growth along drainage lines (an extremely common pattern in semiarid areas). Moreover, we showed that small variations in slope and/or abiotic (soil erodibility or diffusivity) and biotic (plant species with varying protective effects on erodibility) factors can give rise to changes from banded to striped patterns.These findings reinforce the importance of analyzing the coevolution of landforms and vegetation to improve our understanding of the patterns and structures found in nature, and particularly in semi-arid regions.