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The role of stable and unstable vegetation boundaries in the propagation of desertification in the American southwest: A modelling approach

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Desertification and land degradation in the south-western part of the United States have led to a significant vegetation change from productive grassland to desert shrubland within the last 150 years. Overland flow generated by short, high-intensity rainstorm events has been suggested as having an important role in these land-degradation processes through the redistribution of water and soil resources. To assess the impact of these water and nutrient fluxes on the degradation processes, an event- and process-based, spatially distributed modelling approach was employed in this study. The model implementation was carried out with specific consideration of parameter and process scaling issues at the landscape scale. The modelling studies enabled the quantification of the percentage change of water and nutrient fluxes across vegetation boundaries between shrubland and grassland associations. The modelling results suggest that landscape linkages through the redistribution of water and soil resources across vegetation-transition zones at the landscape scale and feedback dynamics of overland flow processes play a significant role in the persistent land degradation. It is hypothesised that a vegetation boundary is stable when two conditions prevail that balance the lower resistance of grassland towards the existing environmental setting with the higher resistance of shrubland. First, the soil depletion of nutrients by the action of overland flow in the grassland zone close to the boundary is in balance with the replenishment rates of grassland by nutrient cycling. Second, the grassland gains enough water resources from the upslope shrublands. On the contrary, a vegetation boundary potentially becomes unstable when the grassland acquires a competitive disadvantage

towards shrubland regarding water benefit and nutrient depletion due to the combined effects of overland flow dynamics and some external stresses. With reference to the ecosystem stability and resilience theory, the modelling results provided important insights in the potential stability of the grassland-shrubland boundaries as a function of soil-nutrient depletion and water-resource enrichment for the grassland. On the basis of the modelling results, it is hypothesised that external forces such as overgrazing or climatic variations might potentially disturb this boundary-stability scenario, which consequently leads to a unstable vegetation boundary conditions and thus to the invasion of shrubs into the grassland.