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Drought resilience of dryland ecosystems under spatial periodic forcing

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We investigate the drought resilience of a dryland ecosystem by modeling the coupled dynamics of water and vegetation. For low annual precipitation rates P, the ecosystem is stabilized by a water-harvesting intervention, consisting of a 1d periodic removal of soil crust. Besides a stable bare-soil solution, there are two stable patterned states: a) a striped pattern, where vegetation stripes are found along every soil crust intervention (a 1:1 wavenumber locking); and b) a rhombic pattern, where the pattern of vegetation patches repeats itself every other intervention period (a 2:1 wavenumber locking). Due to the nonlinearities in the water-vegetation system — primarily the infiltration feedback — there are regions in P of multiple stable solutions, where the striped pattern and rhombic pattern undergo subcritical bifurcations. We found a mechanism that could cause a collapse of a vegetated state (the striped pattern) towards a bare soil solution for precipitation values where there is another viable vegetated stable solution (the rhombic pattern). This phenomenon is due to the influence of usually relegated unstable solutions, that divide the "solution space" into basins of attraction associated with the rhombic solution and with the bare soil solution. This indicates that under these circumstances, planting vegetation in a rhombic pattern (or turning a striped pattern into a rhombic pattern by vegetation removal) makes the system more resilient to environmental changes (droughts). A more general conclusion is that the identification of unstable states (not accessible by direct observation) is of paramount importance in determining the resilience of patterned solutions to changes or fluctuations in the system parameters, in the context of dryland ecosystem management and otherwise.