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Shrub invasion of desert grassland increases the strength of system feedbacks through enhanced flow-path connectivity

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The invasion of desert grasslands by shrubs is a process that is associated with strong ecohydrological feedbacks. As shrubs invade into grasslands, runoff-generating areas become more connected, due to changes in vegetation cover and distribution. Previous field-based experimentation has demonstrated that runoff-generating areas over grassland can become highly connected, but only under extremely large rainfall events that tend to occur infrequently. In contrast, on shrub-dominated hillslopes, it has been observed that bare areas become connected even under relatively small rainfall events. In this study we carry out a scenario-based modelling analysis, using Model for Assessing Hillslope to Landscape Erosion, Runofff, And Nutrients (MAHLERAN), to investigate changes in hydrological connectivity at over a trajectory of shrub invasion, from a grassland end member to a shrubland end member under different rainfall and antecedent soil-moisture conditions. We hypothesize that (i) as shrubs invade into grasslands the connectivity of flow paths will increase, transporting water, sediment and nutrients over greater distances leading to an increased loss of essential resources from hillslopes and (ii) the extent to which flow paths become connected will be sensitive to antecedent soil-moisture conditions, and therefore that the timing as well as magnitude of runoff events will be important, but less so with increasing levels of shrub encroachment.

We quantify hydrological connectivity by using a metric to calculate the maximum length of runoff-generating cells contributing flow to a point, to quantify the connectivity of runoff and entrained sediment. The metric is normalized relative to the maximum potential flow-path length to enable standardized comparisons between plots of different types. Results show that there are critical thresholds for large flow- and sediment-production events, which are a function of both rainfall type and antecedent moisture. The implication is that the pattern of rainfall events throughout a monsoon season in the US Southwest can be critical in reinforcing feedbacks that lead to desertification by producing enhanced connectivity of flow and erosion processes.