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Bridging structural and functional hydrological connectivity in dryland ecosystems

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On dryland hillslopes, vegetation water availability is often subsidized by the redistribution of rainfall runoff from bare soil (sources) to vegetation patches (sinks). In regions where rainfall volumes are too low to support spatially continuous plant growth, such functional connectivity between bare soil and vegetated areas enables the establishment and persistence of dryland ecosystems. Increasing the connectivity within bare soil areas can intensify runoff and increase water losses from hillslopes, disrupting this redistribution and reducing the water available to sustain ecosystem function. Inferring functional connectivity (from bare to vegetated, or within bare areas) from structural landscape features is an attractive approach to enable rapid, scalable characterization of dryland ecosystem function from remote observations. Such inference, however, would rely on metrics of structural connectivity, which describe the contiguity of bare soil areas. Several studies have observed non-stationarity in the relations between functional and structural connectivity metrics as rainfall conditions vary. Consequently, the suitability of using structural connectivity to provide a reliable proxy for functional connectivity remains uncertain and motivates the work here.

Rainfall-runoff simulations across a wide range of dryland hillslopes, under varying soil and rainfall conditions, are used to establish relations between structural and functional connectivity metrics. The model results identify that the relations vary between two hydrologic limits -- a `local' limit, in which functional connectivity is related to structural connectivity, and a 'global' limit, in which functional connectivity is most related to the hillslope vegetation fraction regardless of the structural connectivity of bare soil areas. The transition between these limits within the simulations depends on rainfall intensity and duration, and soil permeability. While the local limit may strengthen positive feedbacks between vegetation and water availability, the implications of these limits for dryland functioning need further exploration, particularly considering the timescale separation between storm runoff production and vegetation growth.