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FlowShape: a runoff connectivity index for patched environments, based on shape and orientation of runoff sources

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The properties of vegetation cover are recognized to be a key factor in determining runoff processes and yield over natural areas. Still, how the actual vegetation spatial distribution affects these processes is not completely understood. In Mediterranean semi-arid regions, patched landscapes are often found, with clumped vegetation, grass or shrubs, surrounded by bare soil patches. These two phases produce a sink-source system for runoff, as precipitation falling over bare areas barely infiltrates and rather flows downslope. In contrast, vegetated patches have high infiltrability and can partially retain the runon water.
We hypothesize that, at a relatively small scale, the shape and orientation of bare soil patches with respect to the runoff flow direction is a significant for the connectivity of the runoff flow paths, and consequently for runoff values. We derive an index, FlowShape, which is candidate to be a good proxy for runoff connectivity and thus runoff production in patched environments. FlowShape is an area-weighted average of the geometrical properties of each bare soil patch.
Eight experimental plots in northern Israel were monitored during 2 years after a wildfire which occurred in 2006. Runoff was collected and measured – along with rainfall depth - after each rainfall event, at different levels of vegetation cover corresponding to post-fire recovery of vegetation and seasonality.
We obtained a good correlation between FlowShape and the runoff coefficient, at two conditions: a minimal percentage of vegetation cover over the plot, and minimal rainfall depth. Our results support the hypothesis that the spatial distribution of the two phases (vegetation and bare soil) in patched landscapes dictates, at least partially, runoff yield. The correlation between the runoff coefficient and FlowShape, which accounts for shape and orientation of soil patches, is higher than the correlation between the runoff coefficient and the bare soil percentage alone. Besides that, the existence of a vegetation cover threshold under which FlowShape loses correlation with runoff yield, suggests that different processes occur at different levels of vegetation cover. On bare or almost bare plots, runoff flows as a sheet, and small isolated plants do not impose a directionality to the flow or interrupt runoff connectivity. On the other hand, rainfall depth – and possibly rainfall intensity – also affect the hydrological processes of infiltration and runoff production, and thus the applicability of any purely geometrical index.
We compared the correlation to runoff coefficient with the FlowShape and FlowLength, a well-known index for runoff connectivity (Mayor et al., 2008) which is defined as the average of runoff flow paths over the plot. As microtopography was not available, our plots were idealized as planar hillslopes. We found that FlowShape is a better predictor than FlowLength for runoff yield over our experimental plots.