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

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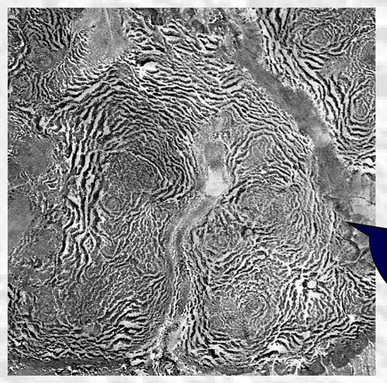
Vegetation patterns and their eco-hydrological role

Runoff production over a patched field is a complex phenomenon in which many variables are involved: slope, microtopography, vegetation density and arrangement, and soil properties affecting infiltration and runoff flow.

At the LANDSCAPE SCALE...

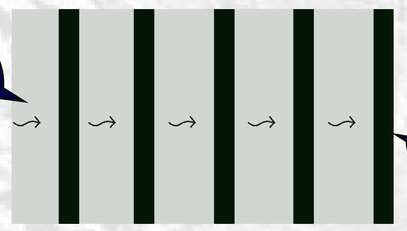


Tiger bush, Niger: no runoff is produced, because of the great infiltration efficiency of the transverse bands

CROSS-SCALE FEEDBACK

Periodic, self-organized vegetation patterns allow efficient water use

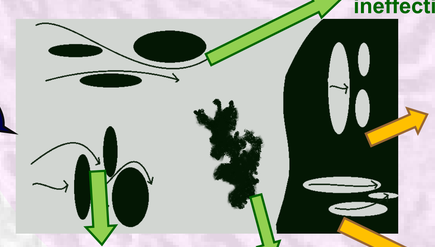
At the INTERMEDIATE SCALE...



Vegetation bands and bare soil act as a SOURCE-SINK system

Mediterranean vegetation also exhibits patterned configuration, although non periodic and often altered by disturbances such as fire.

At the PATCH SCALE...



VEGETATION PATCHES, PARALLEL TO FLOW: ineffective in retaining runoff

SOIL PATCHES: ineffective in producing runoff

VEGETATION PATCHES, TRANSVERSE TO FLOW: effective in retaining runoff

REALISTIC VEGETATION PATCHES

SOIL PATCHES: effective in producing runoff

Materials and methods

The experimental plots

Ramat Menashe site (Israel)

Recovery after a severe fire (2006)

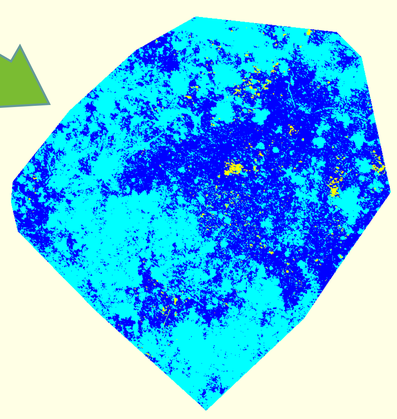
Two-years long monitoring (2006/2007 and 2007/2008)

The collected data

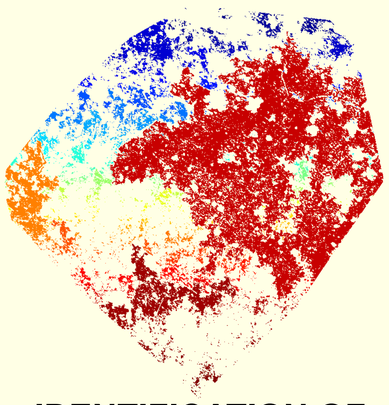
Digital photographs of vegetation growth

Measures of run-off and sediments

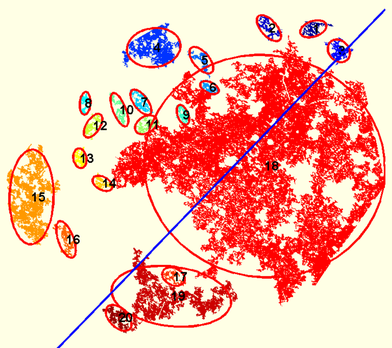
ACQUISITION OF DIGITAL IMAGES



CLASSIFICATION



IDENTIFICATION OF SOIL PATCHES



EVALUATION OF PATCH PROPERTIES

Indexing Connectivity

We investigated the correlation between the bare-soil-patches **shape** (departure from circularity) and **orientation** (with respect to the runoff direction) and runoff production, by defining **FlowShape** Index, which averages these properties over the plot.

$$FlowShape = \frac{\sum_i \left((1 - C_i) \cdot \cos \alpha_i \cdot A_i \right)}{A}$$

Scientific questions

Does the spatial vegetation distribution play a determinant role in infiltration (under similar soil, climate and vegetation cover conditions)?

What geometrical properties of soil and vegetation patches affect runoff?

Are surface and subsurface connected paths linked?

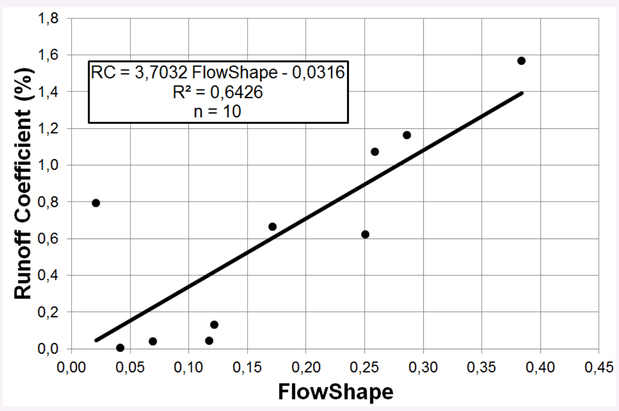
Results

*Correlation between **FlowShape** and Runoff Coefficient*

High coefficient of determination (R^2 = 64%)
when limiting the dataset to:

– high rainfall depth

– high levels of vegetation cover



Index Performance

We compared **FlowShape** to another Index described in literature (FlowLength, *Mayor et al., 2008*) and with simple soil cover proportion.

Neither of them was as able as **FlowShape** to explain the runoff coefficient variability and rank the aptitude to runoff production of the plots.

Conclusions

FlowShape Index (*Malkinson et al., 2016*) presents some advantages:

– **not** (or weakly) **grain sensitive**

– applicable also when **microtopography** is **not available**

– Accounts for the **degree of runoff connectivity**, with values ranging from 0 to 1

0 → ***degree of connectivity*** → **1**

the plot is completely vegetated, or the soil patches are oriented perfectly transverse to the runoff flow direction: thorough runoff paths **disconnectivity**

bare plot, no vegetation patches: full runoff paths **connectivity**

Mayor, Á.G., Bautista, S., Small, E.E., Dixon, M., and J. Bellot (2008), Measurement of the connectivity of runoff source areas as determined by vegetation pattern and topography: A tool for assessing potential water and soil losses in drylands, Water Resour. Res., 44, W10423, doi:10.1029/2007WR006367.

Malkinson, D., Callegaro, C., Ursino, N., and L. Wittenberg (2016), **FlowShape**: a runoff connectivity index for patched environments, based on shape and orientation of runoff sources, *manuscript in preparation*.