

Monitoring the resilience of patterned vegetation in the Sahel using Google Earth Engine

The Alan Turing Institute

Nick Barlow, Camila Rangel Smith, Sam Van Stroud, Tim Lenton, Chris Boulton



Introduction

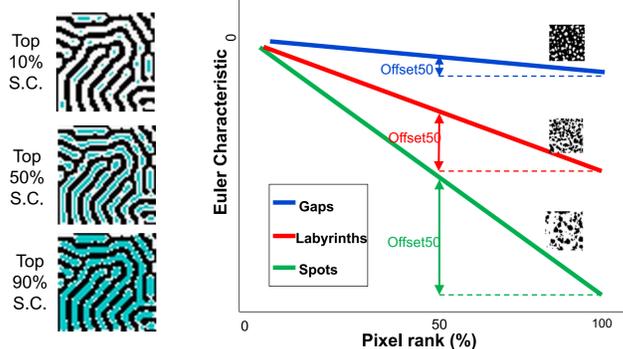
To preserve ecosystems, it is useful to identify early warning signs of “**tipping points**”, where the *resilience* (i.e. the ability to recover from adverse changes) reduces suddenly.

One ecosystem where we expect to be able to measure quantitative changes over time is the Tiger Bush in the Sahel region of Africa. Depending on rainfall and topography, vegetation here can form distinctive patterns: “*labyrinths*”, “*gaps*” or “*spots*” [1][2].



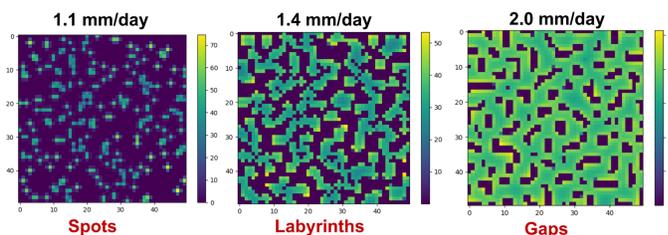
Network centrality

We measure the *connectedness* of vegetation in images by treating them as networks, with pixels containing significant vegetation as nodes. We order these pixels according to their *subgraph centrality* [3] and construct a feature vector by calculating the *Euler Characteristic* [4] for different quantiles. The slope of this feature vector gives a measure of how connected the vegetation is, hence how well it can hold water during drought periods.



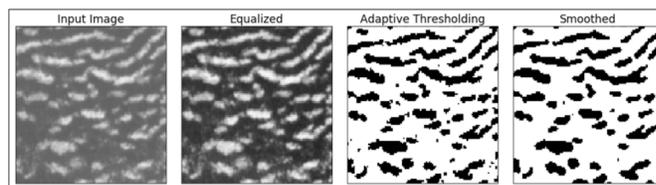
Simulating patterns

Using a simple model [2] that takes into account surface water, soil water, and plant biomass, and transfer between them (water uptake from plants, evaporation, diffusion), we can simulate the patterns observed in nature for different values of rainfall.



Satellite imagery

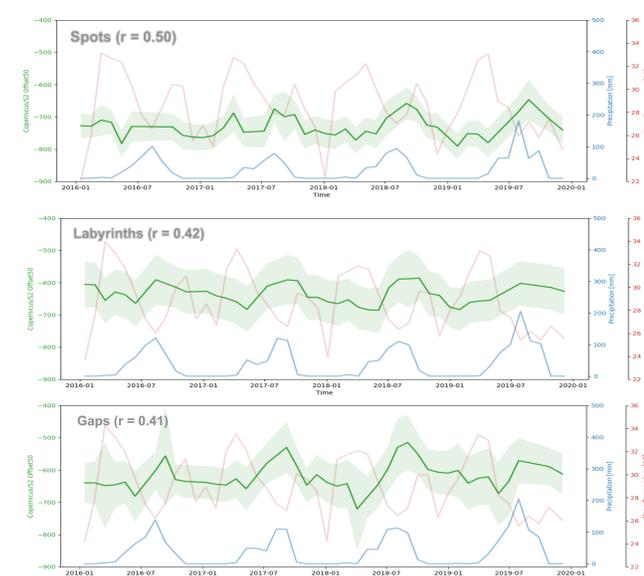
We use Google Earth Engine [5] to obtain images from the **Sentinel 2** and **Landsat 5** satellites. We look at *NDVI* (Normalized Difference Vegetation Index) [6], and divide each image into 50x50 pixel sub-images. We then use histogram equalization and adaptive thresholding to convert these into black-and-white (with vegetation in black) in order to perform the network analysis.



We also obtain weather information (total monthly precipitation, and average temperature) from the **ERA5** dataset, also available via Google Earth Engine.

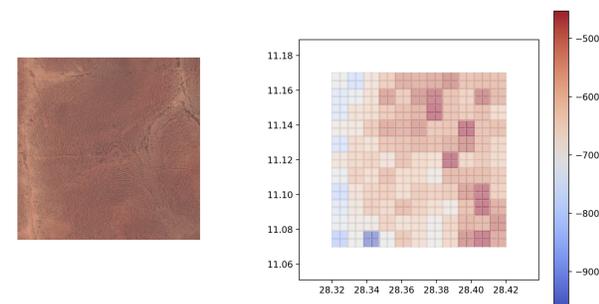
Results

We plot time-series of network centrality values from Sentinel 2 images, along with precipitation and temperature information, from December 2015 to early 2020, for three locations, representing the different types of pattern:

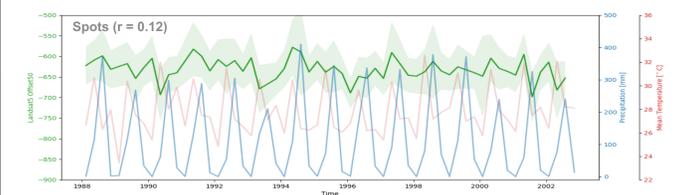


We can see a yearly cycle in vegetation connectedness, correlated with precipitation.

Comparing network centrality values with the original RGB image we can see it correctly picks up areas of vegetation or bare soil.



We also look at Landsat 5 data for the period from 1988 to 2003:



The correlation between precipitation and network centrality is less clear in the Landsat 5 data. One possible factor is the lower resolution in Landsat images. We are currently investigating this by comparing Landsat 8 images with the Sentinel images for the same periods and locations.

Next steps

We will analyse the time series to model seasonal and non-seasonal trends, exploring auto-regression variables [7] and Kendall Tau [8], that can be indicators of tipping points. We will also look at other parts of the world, and continue to develop the package in order to run at scale.

This is an open source project [9] aimed to be used by other researchers in this and similar fields.

Bibliography

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