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Ecosystems resilience to drought: indicators derived from time-series of Earth Observation data

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Increasing our understanding of how ecosystems differ in their vulnerability to extreme climatic events such as drought is critical. Resilient ecosystems are capable to cope with climatic perturbations retaining the same essential function, structure and feedbacks. However, if the effect of a perturbation is amplified, abrupt shifts can occur such as in desertification processes. Empirical indicators of robustness and resilience to drought events could be developed from time series of Earth Observation (EO) data. So far, the information content of EO time series for monitoring ecosystem resilience has been underutilized, being mostly limited to detection of greening or rainfall use efficiency (RUE) trends at interannual time-scales. Detection of thresholds, shifts, extremes, and hysteresis processes is still in its infancy using EO data. Only recently some studies are starting to utilize this avenue of research using vegetation indices with some controversy due to the substitution of time by space.

In drylands, where ecosystem functioning is largely controlled by rainfall, a key variable for monitoring is evapotranspiration as it connects the energy, water and carbon cycles. It can be estimated using EO data using a surface energy balance approach.

In this work we propose the use of new empirical indicators of resilience to drought derived from EO time series. They are extracted from analyses of lagged cross-correlations between rainfall and evapotranspiration anomalies at several time-steps. This allows elucidating as well if an observed extreme ecological response can be attributed to a climate extreme. Additionally, increases in autocorrelation have been proposed to detect losses of resilience or changes in recovery capacity from a perturbation.

Our objective was to compare rates of recovery from drought of different ecosystems in the natural park of Doñana (Spain) composed of wetlands, pine forest, shrublands with and without access to groundwater. The recovery was characterized by (i) the duration of -effects (ii) resistance to change and (iii) autocorrelation of the time-series.

Time series of 2000-2008 from the satellite MODIS and meteorological stations were used. Evapotranspiration was estimated using a surface energy balance contextual or triangle approach using EO data. Analyses were performed at time-steps from 1 month up to 1 year.

Among the four ecosystems, wetlands were the most resilient with a faster rate of recovery from drought but at the same time greater transient responses. Perennial vegetation types showed more resistance to drought but higher persistence of effects into the following year, especially shrublands without access to groundwater. Drought effects in pine forests were minimum as they access groundwater during dry periods.

Our results suggest that in a future context of higher rainfall extremes, the long-term success in the case of vegetation types with access to the water table might depend on their capability to balance groundwater extractions and rainfall recharge. In the vegetation types without access to the water table their success will depend on their recovery potential after a drought sequence of several years.