The response of shrubland patterns' properties to rainfall changes and to the catastrophic removal of plants in semi-arid regions predicted by Reaction–Diffusion simulations

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Extended areas of the Mediterranean and semi-arid ecosystems are predicted to face decreased water availability, alongside increased human disturbances owing to an increase in population during this century. The use of geosimulations is instrumental for studying the expected ecosystem's response to predicted changes in habitat conditions due to the lack of field data at appropriate spatial and temporal resolutions overwide regional extents throughout sufficient time spans. Computational simulations, based on reaction-diffusion equations (RDE),were performed in order to quantitatively assess the form of shrubland pattern changes in response to decreasing and increasing rainfall regimes and during recovery following catastrophic removal of plants, which would result from fires or droughts. Patch pattern properties were analyzed using the Shannon–Wiener fragmentation (SW) metric (=Σ Si Ln Si, where Si is the area fraction of patch i of n patches) and the edge ratio (ER) metric (=sum of edge area/sum of patches' area). The SW fragmentation change during pattern formation is characterized by 3 phases, where in the first phase there is decreased fragmentation, and the third phase represents the evolution of equilibrium. The second phase is the most interesting one, where we have observed pattern regularization obtained by rearranging the shrubs' patches while increasing the fragmentation of the shrub patches. Such regularization phases seem to be a primary characteristic of self-organized behavior in these ecosystems.

The general form of pattern properties change with decreasing or increasing rainfall according to SW fragmentation levels reached at equilibrium, which revealed a non-linear configuration with three divergence points. At these divergence points, the pattern evolution trajectories diverge according to the rainfall change rates. The most important divergence point occurs when rainfall drops below the critical desertification level. Whereas a slow reduction in rainfall would allow the shrub patches to be maintained below this critical rainfall level, rapid changes would cause immediate desertification. Edge ratios are closely linked to rainfall levels, and thus, they may provide early warnings and allow changes in the habitat conditions to be monitored due to climate changes.