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Regime shifts in spatially extended ecosystems: fairy circles as a case model

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Ecosystem regime shifts are regarded as abrupt global transitions from one stable state to an alternative stable state, induced by slow environmental changes or by global disturbances. Spatially extended ecosystems, however, can also respond to local disturbances by forming small domains of the alternative state. Such a response can lead to gradual regime shifts, involving the expansion of alternative-state domains by front propagation and domain coalescence [1]. When one of the states is spatially patterned, a multitude of stable hybrid states can appear [1,2]. Hybrid states involve stable confined domains of one state in a system otherwise occupied by the other state. Their appearance can be attributed to the pinning of the fronts that separate the two alternative states in a range of the control parameter. This behavior, often referred to as “homoclinic snaking”, is unlike the case of two stable uniform states, where isolated fronts generally propagate, and are stationary only at a single parameter value - the so-called Maxwell point. The presence of hybrid states can lead to incipient shifts, i.e. shifts that terminate at hybrid states, or, in the presence of environmental fluctuations (e.g. a series of droughts) to a unidirectional cascade of small shifts from one hybrid state to another that culminates in a global transition to the alternative state.
In this presentation I will review a few relevant results of pattern formation theory related to front dynamics, discuss applications of these results to gradual regime shifts in dryland vegetation [3], focusing on bistability of uniform vegetation and periodic gap patterns, and conclude by comparing theoretical predictions with empirical observations of Fairy-Circles dynamics in Namibia.

References
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