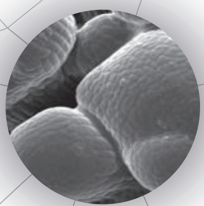
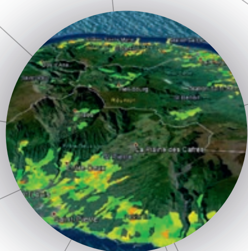
les dossiers d'AGROPOLIS INTERNATIONAL

Expertise of the scientific community in the Occitanie area (France)

COMPLEX SYSTEMS

From biology to landscapes





Number 23
February 2019

Catastrophic shifts in ecosystems

Predicting ecosystem responses to disturbances is a major challenge in the current global change context. It is therefore essential to identify the mechanisms underlying ecosystem resilience to changes in the environment. Some ecosystems respond in a predictable and gradual way to steady changes in environmental conditions (e.g. climate change), while others respond suddenly, unexpectedly and often irreversibly ('catastrophic shift'). These sudden transitions—with the desertification of dryland ecosystems being a classic example (*see figure below*)—can have dramatic ecological and economic consequences. At ISEM, we are developing mathematical models to study ecological mechanisms that shape ecosystem resilience. In dryland ecosystems, for instance, some plants facilitate the recruitment and growth of other plants under their canopy. This facilitation creates a feedback loop between the ecosystem's biotic and abiotic components, thus increasing the likelihood of catastrophic transitions to desertification. Modelling these mechanisms provides essential information for implementing ecosystem management and restoration strategies. These models also help in identifying degradation indicators that could be used as early warning signals. Does an ecosystem that is nearing an undesirable transition show any distinctive symptoms? We are developing, for example, indicators of Mediterranean ecosystem degradation in the European CASCADE project, in which we design statistical tools to help anticipate any potential irreversible degradation of these ecosystems and loss of the ecosystem services they provide. Our research on ecosystem resilience contributes to improving the overall understanding of ecosystem stability. Our aim is to develop tools to anticipate and manage ecosystem responses to current and future environmental change.

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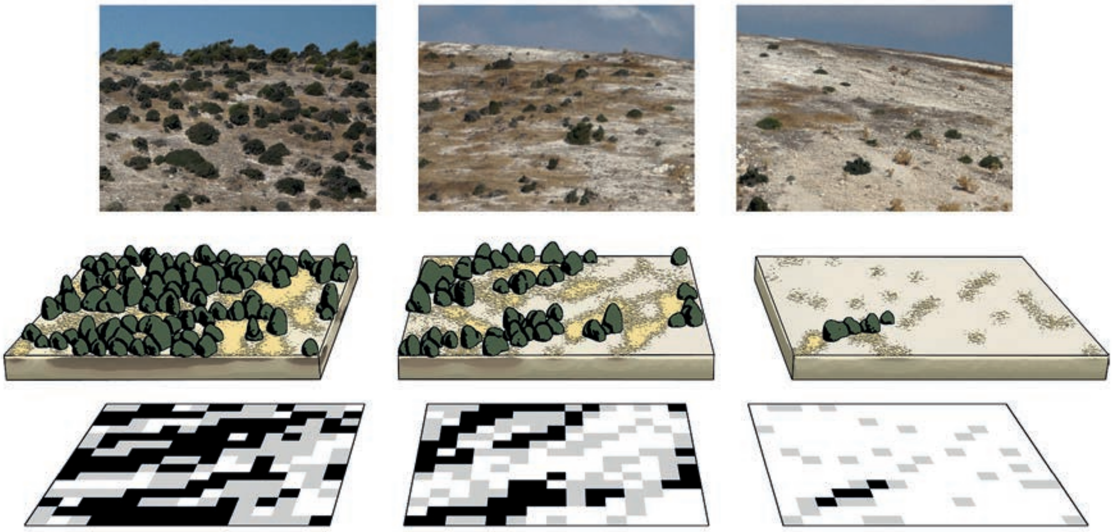
For further information on the CASCADE project:
www.cascadis-project.eu



◄ *Formalization of an arid ecosystem (top) into a cellular automaton (bottom).*
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Impulsive modelling of woody-herbaceous species interactions during fires – impacts on forest-savanna dynamics

Savanna biomes are composed of a variety of vegetation features that can be observed along tropical forest-to-desert climate gradients. The underlying dynamics are the result of direct and indirect interactions between woody and herbaceous plants when fires or other disturbances occur. Empirical observations indicate that different and sometimes highly contrasting features can coexist under similar precipitation regimes, suggesting that stable alternative states or very long transitions may prevail. These fascinating issues are the focus of many modelling studies, but none of them have led to an integrated system of predictions of vegetation conditions and their possible transitions in response to climate and human-induced change. To be useful, such a system must be applicable to fractions of continents, including territories without long-term monitoring sites, which is the case throughout most of Africa.

Our research is focused on defining, studying and testing parsimonious models able to capture essential processes, while being limited to a few parameters and enabling a thorough mathematical analysis of expected trends. The savanna system was modelled using a small number of state variables expressing the biomass of the main vegetation components, i.e. grasses, woody plants, while eventually differentiating their fire-susceptible and fire-nonsusceptible fractions. Impulsive differential equations can be used to account for the sporadic nature of fires. Spatial dynamics are accounted for by using diffusion operators and/or nodes that reflect the scope of the facilitating or inhibiting forces of vegetation. This makes it possible to assess the direction in which forest-savanna edges could evolve as a function of forcing parameters, such as the fire frequency (*see figure. below*).

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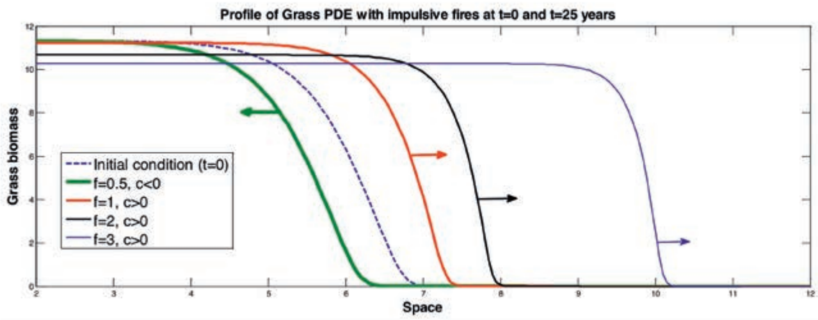
▲ *A. Variations in vegetation cover in a forest-savanna mosaic (central Cameroon, Google Earth®). Note the fringe of small woody areas around mature forest complexes, indicating a gradual extension of the latter stands.*



▲ *B. Predictions on the progression or retreat of the herbaceous plant component in the mosaic as a function of the fire frequency (modelled in impulsive form). In subequatorial environments, only a frequency of more than one fire a year seems to be able to curb the current forest expansion trend. From Yatat et al., 2017. Ecological Complexity.*