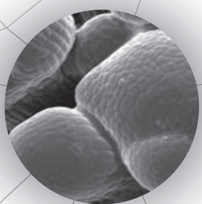
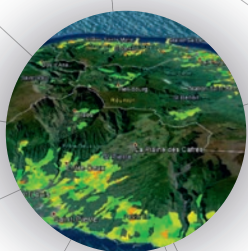
les dossiers d'AGROPOLIS INTERNATIONAL

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

COMPLEX SYSTEMS
From biology to landscapes





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Understanding and analysing complex systems

A complex system consists of many entities (single or more) whose interactions produce a general behaviour that cannot be easily explained solely via the individual properties of the constituents—this is called emergence. Interpersonal interactions overlap individual behaviours. In a social network, for instance, an individual may interact with a group that he/she belongs to and is influenced by—this is called system feedback. The essence is thus to gain insight into temporal and multilevel phenomena. As we have seen in the first chapter of this *Dossier*, the challenge is to collect data, with appropriate storage and calculation capacities, so as to enhance awareness on these different system levels. This, however, is not sufficient because feedback phenomena, or stochastic environmental impacts on the system, give rise to general behaviours with cascading phenomena, while bifurcations in the evolution of the system lead to sudden qualitative changes that are hard to analyse, understand and predict with conventional tools. Specific tools that enable effective use of data are thus needed to highlight the different dynamics of the underlying complex systems.

The research examples presented in this chapter shed light on the diversity of levels investigated and methods developed in the ecological and environmental fields. Questions are usually asked at a given level whereas the methodological approaches are mostly multiscale. The examples were therefore compiled depending on whether the dynamics addressed were situated at the intracellular, intraorganism, population, ecosystem or even territorial management level, while including human and social dynamics.

The first part deals with the dynamics of organisms, ranging from intracellular dynamics to plant genesis, multicellular dynamics (tumours) and phenotypic expression mechanisms. These aspects are approached by presenting network analysis tools (stochastic or not) that are used for modelling gene networks or tumour invasion development, by coupling partial differential equation models or, more generally, using statistical physics tools. These simulation models can be useful in predicting the effectiveness of current or future therapies. Different plant growth models are presented, often based on numerical simulation platforms that offer an alternative to strictly mathematical approaches.

The second part focuses on population dynamics, ranging from those of bacteria to humans, insects, fish and ruminants. Multiscale landscape models, including population-environment relationships or not, are also used to analyse the behaviour of populations (insects, voles, etc.) or the colonization or extinction dynamics of plant species (eelgrass in the Thau lagoon). These models are in the form of multiagent platforms (analysis of small African rodents and their parasites) or stochastic/deterministic hybrid models (biofilms in water purification systems). Several epidemic models (with threshold effects) concerning the transmission of epizootic diseases in Africa: mosquitoes in Vietnam, tiger mosquitoes in southern France and the role of humans and their transportation systems are presented. Anthropobiology studies assess environmental impacts on the biological heritage of individuals and populations.

The ecosystem modelling examples discussed (third part) range from African savanna fire modelling to agrosystem modelling in Morocco, Zambia, Guyana and Chile, as well as land surface biophysics and interactions between water, carbon and energy cycles. Heterogeneous data assimilation methods are used and often require extensive computational resources. The resilience of ecosystems to environmental or human disruptions and the ability to foresee transitional phenomena is a major concern in many studies.

Finally, in the fourth part, the land management models discussed focus on the range of stakeholders involved: the impact of roads and new forms of pollution in Brazil, assessment of the effects of pesticide reductions on vineyard grape production, the impact of seed exchanges on agrobiodiversity in Chile. Several epidemiological models presented are applied to Chagas disease in Brazil, malaria in Guyana and Chikugunya in Indonesia. Some research addresses the multiterritorial scope of primary forest management in Madagascar.

Several very high throughput data and computation centres or experimental platforms are set up in Occitanie region—they are essential for processing data on complex systems, as showcased in special inserts.

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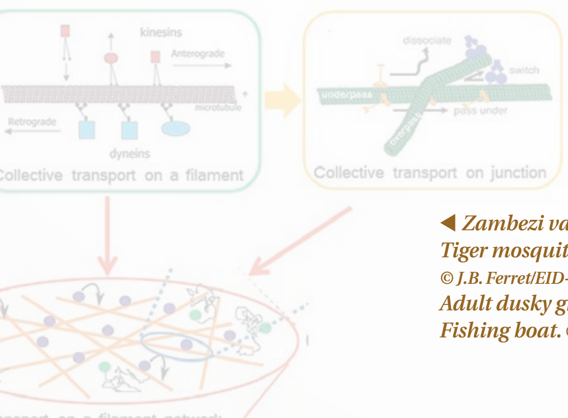

◀ *Zambezi valley (Zimbabwe).* © L. Guerrini/CIRAD
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