
Ecosystems are developing! Qualitative modeling of complex interaction networks

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Abstract

Several concepts have been proposed to understand ecosystem dynamics over the long term. Among them, basins of attraction capturing the system resilience and tipping points capturing sharp changes in the ecosystem dynamics are everyday more used in ecology (Scheffer et al. 2001, Brook et al. 2013). Yet, to identify and to quantify such behaviours remain a challenge, whatever the ecosystem types and dynamics.

In this study, I propose a family of models aiming at exhaustively characterizing ecosystem dynamics, once the ecosystem functioning has been clearly defined. Such models are based on discrete systems borrowed to theoretical computer sciences and are already applied in biology (Pommereau 2010, Reisig 2013), but not yet in ecology. Hence, we have developed a qualitative model based on Petri nets representing a complex interaction network, then rigorously handled through its long term changes.

Conversely to traditional (equation based-) models, the functional rules used in our qualitative model strongly modify the network structure (i.e. the ecosystem components and processes present). I illustrate this model in a theoretical ecosystem chosen as an insect (termite) colony as well as in more realistic ecosystems (Gaucherel and Pommereau 2017, Gaucherel et al. 2017). Every ecosystem modeled here combines trophic, non-trophic, abiotic and anthropogenic processes (and components), and allows exhaustively exploring its trajectories.

Some specific "ecosystem developments" (more or less stable dynamic types) are easily detected and quantified, such as some stable behaviours (i.e. strongly connected states), tipping points (critical processes along trajectories), and various kinds of collapses (functioning system, yet with a frozen structure). Some of these qualitative developments have been validated on observed trajectories. In addition to theoretical abilities, qualitative Petri nets already proved useful to capture ecosystem developments in long time and to recommend some sustainable trajectories to stakeholders.

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