Current research related to agent-based modeling of land-use/land cover change

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My research in this area mainly focuses on methodological aspects on how to model the interactions between people and nature. These methodology studies are not restricted to LUCC but cover ecosystem management in general. A common element in the ecosystems of interest is the possibility of abrupt shifts among a multiplicity of very different stable domains. Multiple states have been observed in fresh water systems, forests, fisheries, semi-arid grasslands, and interacting populations in nature. Whether and when an ecosystem suddenly flip from a productive and sustainable state to an unproductive state depends on ecosystem management. Ideally resource managers strive to maintain the resilience of the system, that is they minimize the probability that the system flips to another state due to a perturbation (for example, fires and weather extremes). Most of the research is inspired by my participation in the Resilience Alliance (http://www.resalliance.org). I will briefly discuss three topics. For publications on the various topics I refer to my website.

Management of Ecosystems

Within the context of the Resilience Alliance I developed with others various stylized models on the interactions between resource managers and ecosystems like lakes and rangelands. The questions is how resource managers can learn to maintain the resilience of the system, or which type of resource managers are most likely to maintain resilience. One of the key-papers was a study where a number of properties (100) of rangelands were managed by particular types of pastoralists. The ecosystem characteristics were equal for all properties as well as the rainfall and the wool prices. But the characteristics of the pastoralists differ (lifestyle, knowledge, management style). When pastoralists do not earn enough income, they leave the system and one of the other pastoralists or a random new pastoralist starts to use that property. The question was what type of pastoralists would evolve for different types of governmental regulations (drought relief/conservation).

In current experiments we use genetic algorithms to find robust management strategies for rangelands, and explore the impact of spatial heterogeneity (leaving the mean-field assumption behind by simulating moving sheep) on the resilience of the system.

Cognitive strategies

Together with Wander Jager, social psychologist from the University of Groningen in the Netherlands, the consumat approach is developed (http://go.to/consumats). This is a multi-agent approach of individual decision-making based on a multi-theoretical framework of psychology. One of the main points is the distinction of different types of cognitive processes based on whether the agent is satisfied or not and whether the agent feels uncertain or not. We distinguish four types of cognitive processes: repetition, deliberation, imitation and social comparison. One of the current activities

is the development of a simple artificial world where agents with different cognitive strategies can live, die and reproduce. The question is to understand in which conditions agents use different types of cognitive strategies. Since cognition is limited, we can not deliberate for each decision, so it is economically rational from a cognition point of view to use other cognitive strategies like imitation and repetition. But differences in cognitive strategies can have important consequences for the type of resource use. In various papers we analyzed the different consequences of assuming Homo Economicus (only deliberation) and Homo Psychologicus (four different strategies).
In a recent study we use data from laboratory experiments on common pool resources from Indiana University. The predicted Nash equilibrium was not found in the experiments with real people, but economic models can not explain the experimental data. We use the consumats to understand what assumptions do we have to make to replicate the statistics of the experimental findings. The assumptions relate to the importance of the cognitive strategies, social orientation (cooperative and competitive attitudes) and the need for experimentation.

Institutions
A recent interest is the development of rules between people. I had for a long time problems to capture this topic, but I came across with the research on artificial immune systems and came to the conclusion that an immune system perspective might be a helpful metaphor. Together with PhD student Daniel Stow a conceptual model is developed to study the evolution of rules. How are they coded, created, get selected and be remembered. The next step will be the developments of a stylized model to study self-organization of rules. This might be based on the model I am developing with Elinor Ostrom from Indiana University. This model simulates a population that build up mutual trust relationships and may accept the implementation of a candidate set of rules. Furthermore, once the rule is implemented the agents can break rules, monitor and sanction. This model version only looks at the selection of a candidate rule set, and we want to understand the critical factors that foster self-governance of common pool resources. Maybe we will do an implementation of this model for the Pacific islands Mangaia and Tikopia, who have an interesting archeological record.

As one recognized my works is very methodological. I think that we need still to do a lot of work on the development of simple models of agents that are acceptable for behavioral scientists. Most of the agents in multi-agent models are rather simplistic and not very well based on theories in social science. The challenge will be to develop simple stylized models, to test hypothesis with them in the laboratory and to test the consequences of different assumptions with real field data.

What phenomenon can be addressed by agent-based models that cannot easily be addressed in other LUCC modeling frameworks?

Heterogeneity of the agent population leads to very different types of dynamics compared with the representative agent model. Sometimes we can mimic observed patterns by the representative agent, but we often have to make strict assumptions related to homogeneity and mean field equations. But, when agents differ, imitate each other, interact, have complex social relationships by social networks than the results of social processes can be very different than ordinary models.

How can cellular automata and agent-based models be combined to explicitly represent the complex dynamics of landscape systems?

Some, not all, models are developed in Cormas (http://cormas.cirad.fr). The cells represent the environment, often based on differential equations. The agents are the topic of research, and are represented as mobile agents. Agents can move and eat. How and when they move and eat relates to the decision process implemented for the agents, and to which rules affect the behavior of the agents.
The interaction between agents and the environment related with the energy/nutrition agents derive from the ecosystem.

How might we parameterize models and understand model behavior?

Since my models are often very stylized, I tend to define a default case and perform a lot of sensitivity tests. The default case can be, for example, lead to cooperation of the agents, and with sensitivity tests we want to understand for which parameter changes the agents will not be willing to cooperate anymore. Obviously, each experiment contains many runs due to stochastic elements of the model. It is also helpful to use an analytical version of the model using a representative agent to put the results in context with traditional models.

Validating model outcomes – How can we construct and carry out empirical tests of model hypothesis?

One of the items high on my wish list is to use agent models to formulate a number of hypotheses and test these in the laboratory. A problem with human agents is that there are no general well-accepted agent models. So, tuning an agent model to data is not enough. But, like classical laboratory experiments try to falsify theories, we may try to falsify the agent models. Of course, when the agent model pass the test it is not valid, but at least not falsified.

Infrastructure development – What is available in terms of research tools, infrastructure for sharing scripts, techniques, and learning resources, and opportunities for collaboration? What enhancements are needed?

Currently I use the Cormas software (based on Smalltalk). Cormas is very easy to use for little models with CA and MAS. But it is slow when you want to do many experiments. Probably I will explore Java too, especially since the new version of Java is not purely an interpreter anymore.

I can not discuss opportunities for cooperation since I do not know all the other participants by now. But I hope that I can benefit from the empirical information available in the different projects in other to test some of the methodologies.