Multi-level spatial simulation

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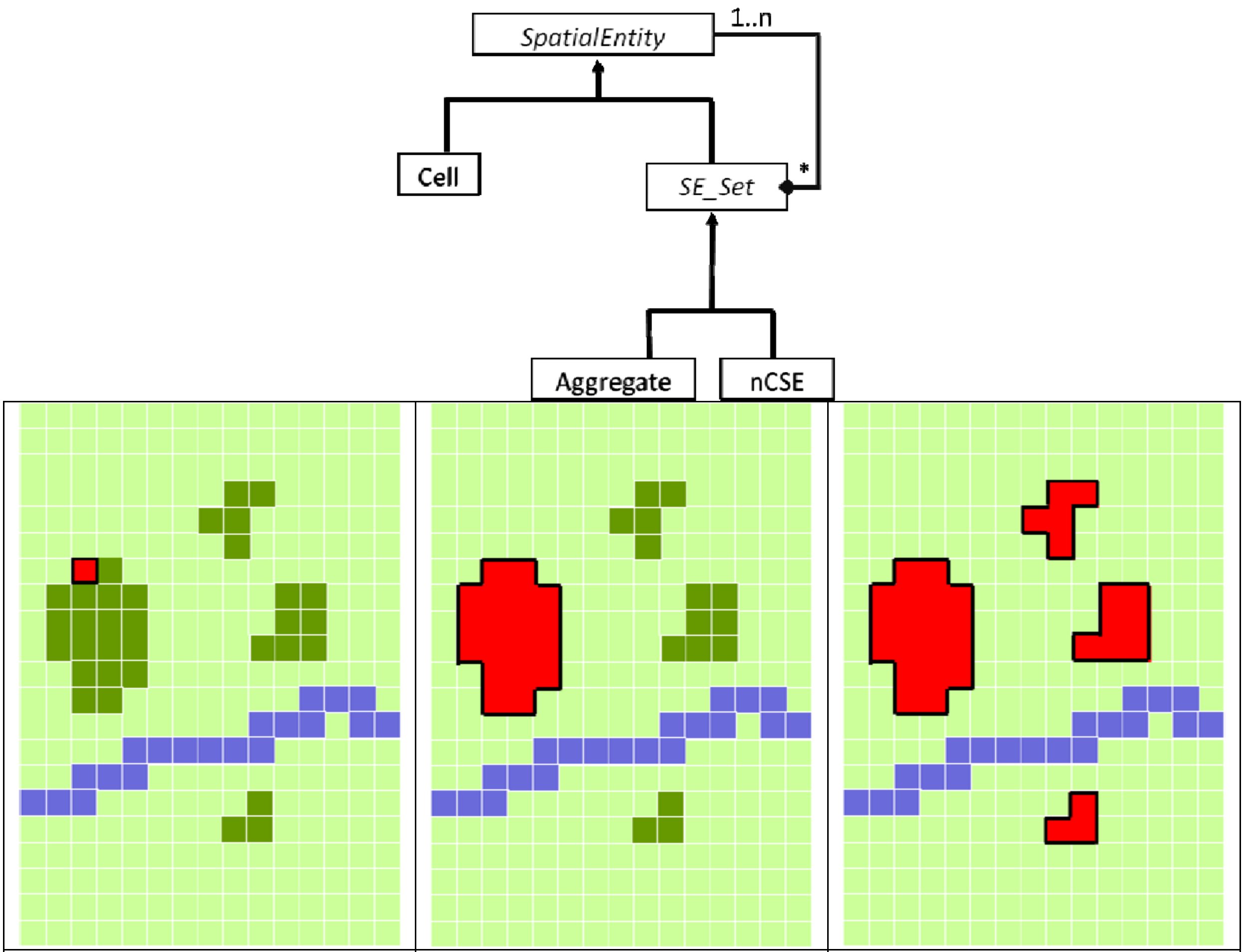
1. Introduction

This paper presents a spatial model of natural resource management which models space at two levels: the lower level as cellular automata (traditional modelling of resource dynamics within MAS) and an aggregated level. The aggregated level is used to model ecological patches which control the dynamics of the resources. The renewal of the resource depends on the spatial properties of the aggregate. The resource users' agents have their own representation of the aggregates and how they should be managed. The collective decision is applied at the level of the aggregates.
Thus, in the model, we consider four elements that interact dynamically: ecological spatial dynamics, individuals' spatial practices, individual representations of space and collective spatial representation. These four elements interact as time goes by and the individual practices and representations simultaneously ensue from the collective representation and influence it.

In this paper we focus first on the description of the implementation of the spatial entities. Then we describe the structure of the model and simulation scenarios. We conduct a sensitivity analysis on different spatial parameters: the initial resource configuration, the spatial foraging behaviour of the agents, the collective regulation rule which is based on the size of the aggregates. In the last part we discuss the simulation results.

2 Spatial entities

Different levels of spatial entities have been implemented in the Cormas platform. At the lowest spatial level, the "elementary" entities represent homogeneous portions of space (determining the spatial resolution of the model). In Cormas, there are two types of compound spatial entities. The generic term "aggregate" stands for a compound spatial entity which constitutive elements are verifying a constraint of contiguity. There is another category of compound spatial entity without this contiguity constraint. The hierarchical pattern of Cormas spatial classes is shown in figure 1.



a. Elementary spatial entity (landscape metrics)	b. Aggregate (patch metrics)	c. Compound spatial entity (class metrics)

Figure 1: Cormas spatial entities

With Cormas, three main operations allow creating compound spatial entities: (i) conditional selection of contiguous components (this is the example shown in figure 1; aggregates produced by this operation cannot have contact points, otherwise they would merge); (ii) selection of components sharing the same value for one or more attributes; (iii) recursive expansion from « seeds » (a pre-defined number of components may be assigned to each aggregate), which is an algorithm to create Voronoï tesselations.
Cormas also provides some standard landscape ecology metrics to characterize both the composition and the configuration of the space. These indexes are defined at specific levels. For instance, to assess the diversity of land cover types at the level of the whole spatial grid, the Shannon index is based on a formula involving all the cells, each aggregate (call a “patch” in landscape ecology) can be characterized by specific metrics like compactness, whereas for each type of aggregates (call a “class” in landscape ecology), interspersion metrics like fractal dimension are defined.

3 The model

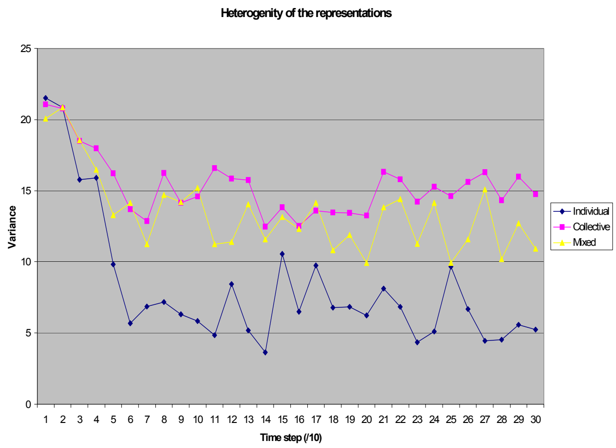
A virtual forest landscape is set as a squared lattice made of 50 by 50 hexagonal land units (the elementary spatial entities of the model). Each land unit may be covered by forest or not. At initialization a given proportion of land units are forested. Several initial spatial grids have been created with increasing degrees of patchiness (from random to the aggregation of all

forested cells). Forest units are aggregates of contiguous land units covered by forest. The forest growth is implemented at two levels: each bared land unit has a low but constant probability to be colonized by the forest (to account for dispersal of seeds by vectors like animals). At the same time, the established forest units are spreading from their edge at a rate proportional to their size.
Farmer agents are moving from a land unit to a neighboring one at each time step. Two foraging models are tested: random versus max-of-resource oriented. Farmer agents use a (limited) memory in order to record how many forested land units they have encountered.
At a regular interval, a forest department agent is in charge of organizing a census of the forest resource by identifying, sizing, and marking (for regulating the access) forest units. If the size of a forest unit is below the authorized minimum size, it will be marked "protected." To determine the authorized minimum size, the forest department requests all the farmers individually to report their perception on the minimum authorized size based on their memory. The average value is the authorized minimum size.
Two individual attitudes are introduced: "conformist" farmers will indefectibly follow the regulation set by the forest department; whereas "nonconformist" farmers will only refer to their own perception to decide whether or not to use a forest unit (not caring about the marks set by the forest department).

4. Discussion

The simulation model is implemented. We will conduct a sensitivity analysis on different spatial parameters: the initial resource configuration, the spatial foraging behaviour of the agents, the collective regulation rule which is based on the size of the aggregates. Through this archetypical model we will discuss the linked effects of resource configuration and dynamics, individual and collective decisions. Each of these factors is based on multiple spatial levels.
The sensitivity analysis has still to be performed. Preliminary simulations show meaningful results. We simulated three scenarios: the conformist strategy, the non conformist strategy, and a mixed strategy (in case of conflict between the individual and the collective representation, the agent will compute a mean threshold).
One can observe the individual strategy gives the worse results both in terms of resource preservation (the forested cells indicator is the worse) and in terms of agent satisfaction. The threshold gives a good measure of the agents' satisfaction. The less the agents finds resource the highest its threshold is. The individual strategy leads to larger forests and the collective norm leads to more fragmented landscapes with more resources. Figure 2 shows that the scenario with collective decisions shows the greatest heterogeneity of the representations. It means that a collective decision can go along with individual heterogeneity. The interpretation is that the distribution of the resources leads to diverse local histories of the agents. While foraging some succeed and some fail. The individual scenario is more homogenous, probably because of the lack of resource. There are minor differences between the collective strategy and the mixed strategy. By repeating the simulations, we observe that the mixed strategy gives more variability in the results.

Figure 2: Heterogeneity of the representations.
The values represent the inter-individual variability of threshold value



Our plan is to perform a comprehensive exploration of the model to elaborate more on the mutual influence of spatial aspects at various levels, including agents' representations.