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A step-by step approach to build-up land management scenarios based on multiple viewpoints on multi-agent system simulations

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Abstract: A multi-agent system was developed to simulate strategies of natural resources management in the remarkable site of the Causse Méjan, a limestone plateau dominated by a rare pseudo-steppe endangered by pine encroachment. To stimulate the emergence of alternative long-term management strategies of the sheep farms and of the woodlands, contrasting dynamic viewpoints on land resources were designed at different space scales. In a first step, they were individually used to validate the model with each main stakeholder (foresters, farmers and the National Park of Cévennes rangers), to improve it and to propose individual scenarios of natural resources management. Once the model adapted to these scenarios, the set of viewpoints permitted to assess the impact of these basic management strategies on the main productive (sheep stocking rate, timber growth) and environmental (endangered species, landscape value) stakes on any spatial entity considered as relevant by any stakeholder. As the different points of view were collectively viewed and confronted, the need to agree to a compromise raised up and lead to new scenarios based on a more collective management of the pine woodlands. The results of these alternative scenarios were newly collectively evaluated and permitted to select a set of feasible scenarios according to the current actors' perceptions and practices and to suggest alternative sylvopastoral management based on innovative practices. The paper underlines the usefulness of viewpoints representations to allow for scenario description and impact assessment of the compared management strategies. It also points out how the step-by-step approach contributed to improve the decision making by the managers of the National Park.

Keywords: Natural resource management; Management scenarios; Multi-agent system; Viewpoints

1. INTRODUCTION

The integration of simulation models into collective decision-making in natural resource management (NRM) is one of the core points of adaptive management [Holling 1978]. However, few work has been done on stakeholders' participation in the successive modelling steps from conceptualisation to scenario simulation [Bousquet et al., 2002; Costanza and Ruth, 1998].

We analyse here the way multi-agent system (MAS) simulations can be integrated into a step-by step approach to build-up land management scenarios based on multiple viewpoints on NRM. A MAS was built with the Cormas toolkit [Bousquet et al., 1998]. Vegetation changes in terms of structure, composition and productivity were simulated by a cellular automata incorporating real data from 1990s surveys and topographic maps. The global landscape dynamics resulted from a combination of the natural

vegetation dynamics processes related to pine encroachment and the operations performed by three kind of agents : sheep farmers, foresters and National Park rangers [Etienne and Le Page., 2002].

The MAS was then used to simulate contrasting scenarios of behaviour in front of the pine encroachment process. The paper shows how contrasting dynamic viewpoints on land resources were designed at different stages of the step-by-step approach to enable the different categories of protagonists first to validate individually the representations provided by the MAS and then to exchange collectively their views on an ecological process over which they have little control.

2. THE STUDY AREA

Located in the South-eastern part of the Massif Central, the mountains of Central France, the Causse Méjan is an elevated (800 to 1250 m) limestone plateau cut off from the surrounding

plateaux by deep canyons. A long land-use history of cereal cropping and grazing, and the peculiar conditions of transition between mountain and Mediterranean climate lead to a natural ecosystem of high biological diversity [O'Rourke, 1999] linked with typical open landscapes [Lepart et al., 2000]. Recent changes in livestock production systems and a wide afforestation plan initialised in the 1970s are strongly modifying the landscape by enhancing pine encroachment by *Pinus sylvestris* and *P. nigra* at different temporal and spatial scales [Etienne, 2001].

Sheep farmers, foresters, and the National Park of Cévennes are interacting in this land but are differently concerned by this global biological process as it affects their management goals (sheep production, timber production, nature conservation) in very different ways.

3. THE APPROACH

The approach is based on four concepts : i/ the point of view, a specific way each stakeholder perceives its resources and identifies the entities to manage; ii/ the viewpoint, a spatial representation of a point of view; iii/ indicators, a set of markers selected by the stakeholders to monitor the dynamics of the system; iv/ scenarios, prospective management rules to tackle the pine encroachment problem.

As the Cormas toolkit permits to view land dynamics by means of a cellular automata, a basic viewpoint was designed in order to represent the physiognomic characteristics of the vegetation according to the modeller's point of view. As it had to be easily understood by any stakeholder or manager, it was based on a very simplistic rule : the basic colours were attributed to the basic plant types: trees are blue, shrubs are red and grasses are yellow. When different layers were overlapping in the same place, the corresponding colours were mixed. This "vegetation forms" point of view was considered as a compulsory key, imposed by the modeller, to read landscape dynamics (Figure 1).

Then, the first step of the simulation approach was to validate the way the ecological process and the stakeholders behaviour were integrated into the MAS. For this, a scenario corresponding to the current situation was built up and discussed individually with each type of agent. A set of individual points of view raised up from these discussions and pointed out how specific to each stakeholder and specialised was the perception of the resources and the entities to manage.

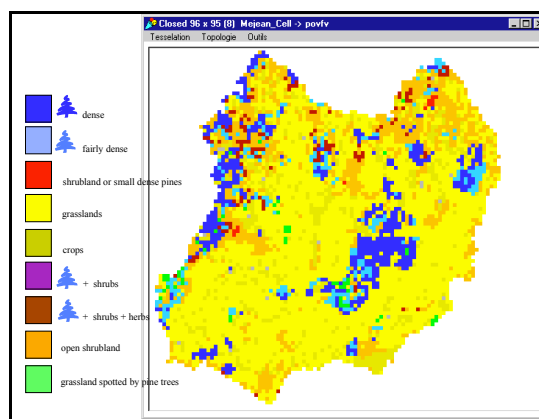


Figure 1 : The vegetation forms viewpoint

In a second step, the indicators mentioned by the main stakeholders (foresters, farmers and the National Park rangers) as essential to them to plan their activities and understand the dynamics of their resources were listed. Accordingly, a set of viewpoints were designed with the stakeholders and they were individually used to validate the model with each of them. After running the simulation, the most common reaction was to propose minor modifications to some indicators and alternative individual scenarios improving the management of each own resources.

The third step consisted in adapting the MAS to these scenarios, by creating new spatial entities according to specific rules of aggregation [Etienne and Le Page, 2002] and by coding new behaviours and new ways to react to environmental changes. A new set of viewpoints was designed to permit to assess easily the impact of these basic management strategies on the main productive (sheep stocking rate, timber growth) and environmental (endangered species, landscape value) stakes on any spatial entity considered as relevant by any stakeholder.

The goal of the following step was to view and confront collectively the different scenarios through each of the available viewpoints. At this step, the need to agree to a compromise raised up and lead to new scenarios based on a more collective management of pine encroachment.

In the last step, the results of these alternative scenarios were newly collectively evaluated and permitted to select a set of feasible scenarios according to the current actors' perceptions and practices and to suggest alternative sylvopastoral management based on innovative practices .

4. THE INDIVIDUAL SCENARIOS

4.1 Foresters (scenario 1)

Foresters considered that pine encroachment is a natural process moving early seral succession stages towards late seral succession stages. They also pointed out that the intensity of the process

demonstrated the incapability of the sheep farmers to manage correctly their rangelands. So they propose a scenario called “let nature work” where landscape dynamics depend only on natural succession according to the current tree seed bearers. They made the hypothesis that grazing management was too extensive to control pine seedlings on rangelands and considered that any new land unit colonised by pines major than 20 years old would go under their management rules.

4.2 Conservationists (scenario 3)

Conservationists decided that the natural spread of conifers had to be stopped on all the territory because they wanted to maintain one of the two remaining pseudo-steppic landscape of Western Europe. They even asked to testing a scenario called “Let recreate the steppe” where Scots pine stands and Austrian black pine afforestations were eliminated and replaced by native grasslands new devoted to grazing. They assume that the current ecological process of pine encroachment was too strong and widely distributed to be controlled without a drastic decision such as the complete eradication of adult pine stands.

4.3 Sheep farmers (scenario 2)

Farmers were ready to control pine encroachment only in places where it competes with farm production. These places were determined according to the current land tenure pattern and the requirements of the sheep production system. They made the hypothesis that pine encroachment was totally controlled in cultivated areas and partly reduced in grazed areas according to current grazing practices. They did not scheduled any intervention on their planted pine stands but they supposed the other forests to be managed as usually by means of a basic sylviculture.

5. THE VIEWPOINTS

The MAS demonstrated to be a good support to help the stakeholders to determine the range of possible strategies through which they may adapt to a process with which they had not yet been confronted. Two aspects were particularly effective: sharing dynamic processes and comparing contrasting scenarios.

5.1 The ecologist viewpoint

On the first aspect, specific viewpoints were required to permit to the scientists to explain and share issues that arise on different temporal and spatial scales. A particular effort was made to design viewpoints that help the participants to exchange their perception on the process of pine encroachment. The best criteria to express the ongoing process was the age of the trees. Each time a cell was encroached by pine trees it became

pink, then, meanwhile pine trees were growing up without being easily visible, the colour of the cell moves from green to yellow. When pine trees became part of the landscape (age ranging from 10 to 30 years old), the colour of the cell got darker and darker red tints. Over 30 years old, pine trees were supposed to be part of manageable stands and the cell got blue tints (Figure 2).

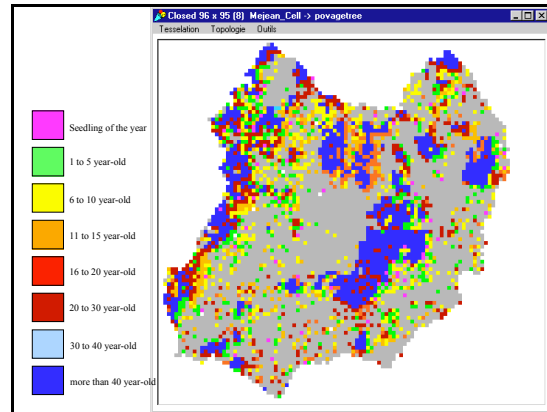


Figure 2 : The tree age viewpoint

5.2 The forester viewpoint

But the previous viewpoint provided too detailed information on tree age and was not precise enough on tree species to help foresters to monitor the dynamics of their resources. They asked for a point of view locating clearly all the pine woodlands ready to be managed. As the age of management and the size of the management units differed according to the pine dominant species and tree density, a crossed typology was proposed.

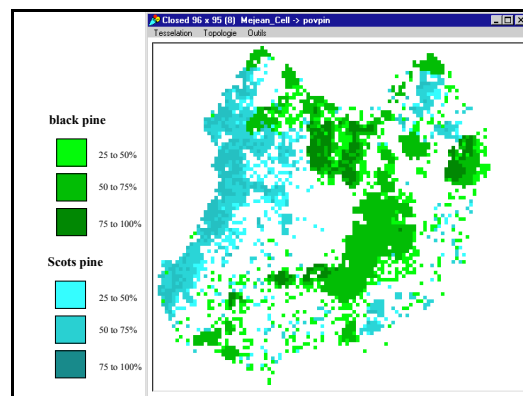


Figure 3 : The tree stands viewpoint

The colour was used to express the tree dominant species and the dominant production objective: blue for Scots pine (*Pinus sylvestris*) that are exclusively devoted to firewood or pulp production, green for Austrian black pine (*Pinus nigra*) that were established for timber production. The tint informed on tree density (Figure 3). This viewpoint was generally compared with the

distribution of pine stands according to age classes.

5.3 The conservationist viewpoints

Conservationists had a completely different look on the Mejan land. They both asked for a view on patches defined by a certain level of heritage value and for a way to monitor the maintenance of open landscapes. The first look was based on an index summing up flora, fauna and landscape stakes, and was supposed to permit to detect rapidly patches which size was large enough to warranty a sustainable conservation of valuable habitats [Etienne and Le Page, 2002]. The second look was based on an index of landscape quality calculated on specific spatial entities called landscape units that corresponded to portions of land with a specific scenic view (Figure 4).

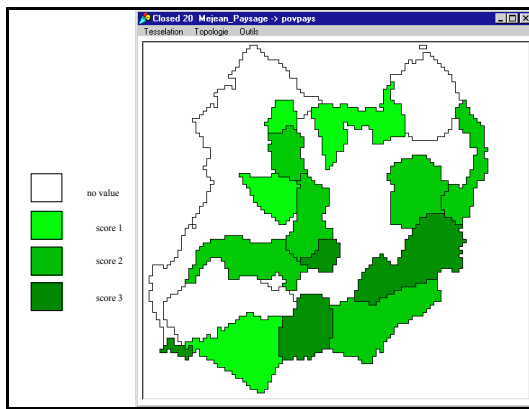


Figure 4 : The landscape units viewpoint

6. THE COLLECTIVE SCENARIOS

Two main types of scenarios were elaborated during the collective sessions. One fitted with an agreement on the emergency to conserve the essential of the endangered habitats and so to establish a global strategy of pine encroachment control. The other was based on an agreement to promote a sustainable development of agricultural and forestry practices aiming at a progressive decrease of pine woodlands.

6.1 Agreement on the conservation target

Two options were considered to reach the conservation target. Scenario 4 was initiated by a potential agreement between conservationists and foresters to define and give priority to operate on strategic ridges. These ridges were defined as key management entities where the felling of adult trees would stop pine seeds overspreading on catchments of high heritage value, for a long period. Even if this scenario required a delicate compromise between foresters and conservationists, it was tested to see how many

farmers would share the deal, by maintaining a sustained grazing pressure on the rangelands of the selected catchments. To monitor easily the number of cells to be treated a ridge viewpoint was designed. Each ridge located on the eastern edge of a pine afforestation was painted according to the age of the dominant tree : green for less than 20 year-old pine trees, light blue for 20 to 30 year-old pine trees, dark blue for more than 30 year-old pine trees (Figure 5).

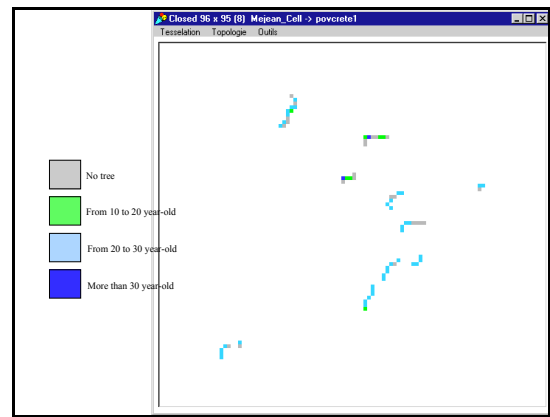


Figure 5 : The ridge viewpoint

Scenario 5 raised up from the wish of the National Park to support the farmers with environmental awareness and ecological practices. Once rated the farmers according to the quality of their practices in terms of ecological impact, the conservationists shared with the best-ranked farmers the work or cost of eradication of the pines. Both partners asked for a viewpoint on the work effort for pine cutting or mowing to have an idea of the intensity and frequency of work they would have to put in the field. Farmers or Park rangers could control pine encroachment by either chain mowing (blue tints), or by hand clearing (red tints). The darker the tint, the higher the frequency of intervention for getting rid of the pine trees. The first cut were painted with green in order to figure out easily, at the end of the simulation, the stands exploited for timber (Figure 6).

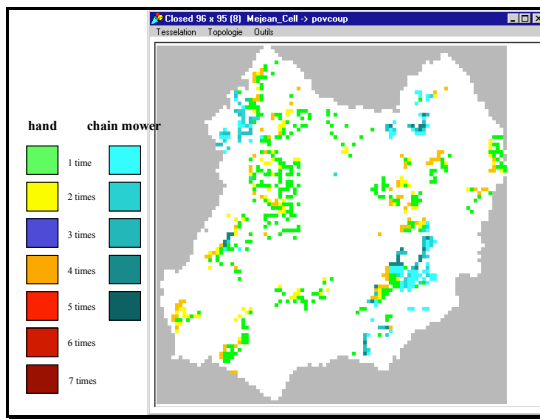


Figure 6 : The work effort viewpoint

6.2 Agreement on a sustainable development

The representative of the farmers and the forest owners preferred to test long-term scenarios based on more pragmatic and realistic operations. The long-term goal remained to restore or at least to extend partly the current steppic landscape. But the mean proposed was a progressive transformation of agricultural and forestry practices through the development of sylvopastoral management plans.

Two options were proposed. The foresters argued for a sylvopastoral management focused on timber production meanwhile the “Chambre d’Agriculture” supported a sylvopastoral management focused on forage production. Both options lead to the restoration of native pastures after the final exploitation of the sylvopastoral plots. Scenario 6 intensified the management of Scots pine woodlands through a strong thinning of stands over 40 years old on 20 ha plots in order to set up rapidly a rational grazing. Scenario 7 was, for farmers who suffer from a lack of forage, to operate on encroached cells as early as the pines were over 20 years old, in order to maintain the presence of a dense grass layer and to avoid to pay the woodland tax.

In order to follow the impact of the management strategies underlying each scenario, practical viewpoints were designed. One monitored the successive steps of wood-lots management It permitted to view the basic silviculture when applied to black pine afforestations : light green for the first thinning, green for the second thinning, dark green for the final cut. It allowed also to identify the exploitation of Scots pine woodlands for firewood (dark blue cells). And it gave particular emphasis on sylvopastoral management when applied on both pine species : from yellow to orange for black pine, blue tints for Scots pine. Final cuts were painted with flash colours (red for black pine and pink for Scots pine) to be easily located (Figure 7).

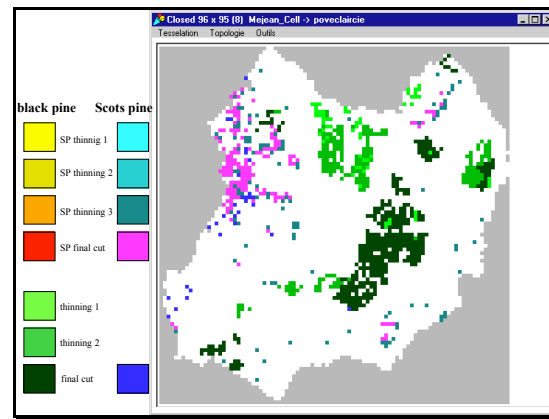


Figure 7 : The silviculture viewpoint

6.3 Results

At the Causse Méjan scale, the collective scenarios were much more effective than the individual ones for any of the indicators used. Among them, the development of sylvopastoral plots for timber appeared to be a promissory way to reverse, on a mid-term perspective, the current trend of pine encroachment and landscape closing (Figure 8).

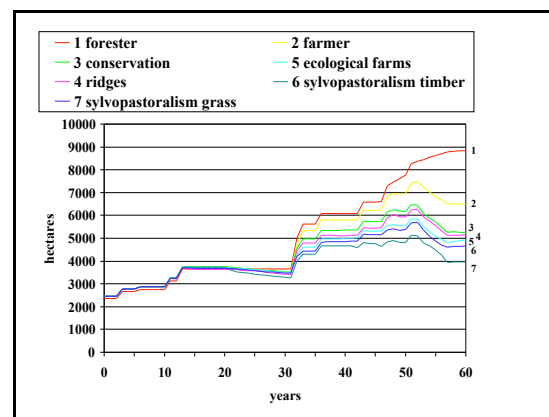


Figure 8 : Impact of the seven scenarios on pine forests area

At the farm scale, the results were more diverse, because all the farms were not similarly concerned by the encroachment process and by the actions of pine control. The first factor was mainly related to the location of the farm according to the wind direction and the distance from a mature pine stand. The second factor was strongly related to the type of agreement simulated by the model. For instance, the association between the National Park and the farmers with good environmental awareness permitted to maintain rangeland productivity on 30% of the farms but was not effective enough to sustain the current production system of 10% of the farms which overcome the maximum potential of their rangelands (Figure 9).

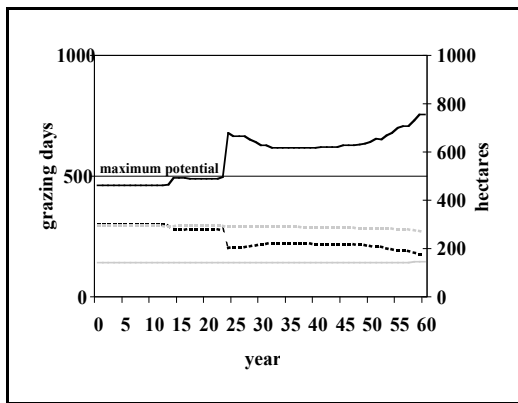


Figure 9 : Rangeland area (dotted line) and grazing pressure required (solid line) on sheep farms correctly (grey) and badly (black) protected from pine encroachment

7. CONCLUSIONS

The construction of contrasting viewpoints was essential to represent the different perceptions on natural resources and dynamic processes. The utilisation of these viewpoints during the simulation process permitted to inform widely the main stakeholders of the issues that divide them and of their common dependence upon any solution to the pine encroachment problem. The progressive elaboration of this set of perceptions, all along the step-by-step approach, helped the participants to understand that their views were all legitimate but also subjective and partial. The opportunity to use this set to build up scenarios and to assess their impact on the natural resources made much more easy the discussion on the acceptability of possible trends.

The step-by-step approach encouraged the participants to face in a collective way the environmental issue of pine encroachment and to plan co-operative actions for the coming years. This improvement of the decision making process is currently permitting to move from a set of isolated management plans to the collective planning of a concerted local development plan by the National Park, the Forest Service and the Chambre d'Agriculture.

8. ACKNOWLEDGEMENTS

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