



Modelling of spatial dynamics and biodiversity conservation on Lure mountain (France)

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ARTICLE INFO

Article history:

Received 29 January 2008

Received in revised form

7 July 2009

Accepted 3 September 2009

Keywords:

Multi-agent systems

Biodiversity

Forest dynamics

Shrub encroachment

Orsini viper

Genetic forest management

Pasture

ABSTRACT

Our study is part of a multi-disciplinary research project aimed at stimulating debate among researchers and local managers. The central question of this multi-disciplinary research project was to better understand and manage high biodiversity value open habitats threatened with shrub encroachment and landscape closure, a common problem throughout Europe. Here, we study shrub encroachment and its impact on biodiversity conservation in Mount Ventoux, a MAB Biosphere Reserve located at the southernmost tip of the French Alps. We show how using a multi-agent modelling approach provide a valuable framework to confront two potentially conflicting conservation efforts in this mountain Mediterranean landscape, that of the within-species diversity of a tree (*Abies alba*, the European silver fir) and that of an endangered species (*Vipera ursinii ursinii*, the Orsini viper). A companion modelling approach – approach which aims at transmitting and sharing knowledge, methods and tools that help understand and strengthen the collective decision making process of stakeholders sharing a common resource – was used in order to collectively represent the main activities underway on the mountain and to have a tool to address both open landscapes rehabilitation and restoration of forest environments. The co-construction of the model allowed us to build a shared representation of the territory under study and to develop and compare alternative management scenarios with local stakeholders, both to evaluate their impact on biodiversity and to provide information for forest and grazing management practice.

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1. Introduction

This study was completed within the frame of a program from the French Institute of Biodiversity entitled “Organization of access to resources and biodiversity applied to the French Biosphere reserves”. The project, which focuses on four French biosphere reserves (Iroise Sea, Northern Vosges, Ventoux – Lure, Luberon), used multi-agent systems to evaluate interactions between the closing of open landscapes and emergence of new social expectations as to the environmental value of these landscapes. Based on a multidisciplinary and companion modelling approach (Collectif ComMod, 2005) which is a type of participatory modelling, it

enabled a better understanding of relations between stakeholders, their management goals as well as biodiversity dynamics.

The objectives of the study were defined by a consortium of scientists from different disciplines (biology, ecology, social sciences, geography, ethnology). At the beginning of the project, these objectives were presented to stakeholders, who significantly modified them. A consensus was then reached by discussing each point, and the conceptual model was built. It was later modified during the course of the project whenever a specific objective could not be addressed (no data for example) or appeared to have no consequence on the main goal of the project, the modification of open landscapes by canopy closure.

Among major stakeholders in the project, the National Agency for Forest Management and protection of Special Areas of Conservation (sites designated under the EC Habitats Directive), managers of natural spaces in charge of the Biosphere Reserve, viper protection and ski resort tourism development (summer and winter). For other aspects (genetic resources conservation

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(fir tree), grazing), management issues were brought by researchers.

Multi-agent system modelling, within a participatory modelling process, is an effective tool for exploring complex systems in that it is prospective rather than purely predictive (Bousquet et al., 1999). Since it takes into account the different stakeholders concerned by the management of resources, it makes use of the experience and rules of stakeholders to help them in orienting and promoting discussions focused on the subject of landscape closure. Varying the rules of each agent helps evaluate the importance of all parameters taken into account in the model and increases understanding of the studied system. The model can then be used to explore social and landscape dynamics over a certain period of time and to bring extremely relevant knowledge on stakeholders' behaviour. Understanding these processes will provide managers and local authorities with a strong scientific background which will help them propose an organization for access to landscapes and resources that is reasonable and socially acceptable to all concerned. In this paper we present the Ventoux-Lure biosphere reserve ecological and social context and then we present the agent-based model that was built. We also give and discuss preliminary results for forest settlements, both as evidence of the landscape closure process and as tracers of floristic and faunistic homogenization. We finally discuss the lessons for the stakeholders.

2. Geographical context

2.1. Closure of Mediterranean mountain landscapes

Mediterranean mountains shelter an exceptional biodiversity, including animal and vegetation species of oromediterranean origin as well as alpine affinity. This heritage is the fruit of natural and human history. These species are currently threatened by the closing of landscapes following the withdrawal of agriculture. This is particularly true of supraforest ecosystems from peaks, which are important mountain biodiversity tanks and which are undergoing an inexorable extension of woodland (Barbero and Quezel, 1988; Pech, 2001). This phenomenon has been qualified as "Landscape closure" by some rural stakeholders (Deuffic, 2005). Indeed, almost completely degraded by pastoral activities and logging (heating, construction, etc) during the 19th century, the forest now occupies a considerable surface area following restoration forestry works undertaken in the mountain areas since the end of the 19th century and with natural seedlings now growing under this man-planted forest. Today, forest represents one of the major attractions of the Mediterranean mountains. The fir stands of Lure and Ventoux are thus registered in the national network for management and conservation of genetic resources of the silver fir (*Abies alba* Mill.), both for their ecological value and their intra-specific biodiversity (http://www.brg.prd.fr/brg/pages/les_rg_en_france/rgv_arbresFor estiers.php). This forest is currently spreading at the expense of open landscapes, but it could begin to recede quite significantly under the effect of climatic change. Indeed, forest reconquest often starts from isolated individuals, which can lead to a strongly consanguineous or even self-fertilization descent presenting low genetic diversity (Charlesworth, 2003). This phenomenon may arguably prevent it from adapting to strong ecological fluctuations (Garcia-Ramos and Kirkpatrick, 1997).

The Mediterranean mountains are easily accessible from large regional cities by means of roads and motorways and even from the rest of Europe by using high-speed transport. They are currently subject to a renewed interest and higher stakes emanating from many actors (ski resort management, hikers, mountain bike or four-wheel drive vehicle, hunters, mushroom gatherers, etc). All these actors are adapted and/or managed in very different ways (Pech

et al., 1997). Winter tourism decline as a consequence of global warming has led public organizations and local managers to consider new tourism attractions that would be available all year-round (Tabeaud et al., 2005, 2003). Thus, some upland resorts are seeking to convert their assets towards summer activities considered attractive for the urban citizens who have strong feelings for natural environments. The changes underway are not always appreciated by defenders of natural resources and nature preservation. The mountains of the Pre-Alps are also attracting new inhabitants – second homes, permanent retired residents, permanent residents working on the site or in surrounding areas – being pushed by exurbanisation processes in progress (Simon, 1997). These different processes constitute a threat to the natural and cultural heritage conservation of these Mediterranean mountains. Indeed, excessive utilization during the summer months and increase in high-impact activities such as motorized sports, could cause the destruction of already weakened mountain ecosystems (Simon et al., 1994). Wild establishments sometimes lead to a urban scattering detrimental to landscape heritage conservation of these environments. On a wider scale, the decision to keep or not the mosaic structure resulting from the juxtaposition of these activities requires a collective reflection as to the most harmonious way to share space and resources between stakeholders whose objectives and time management are clearly very different.

2.2. Lure mountain, a natural continuation of Mount Ventoux

Mount Ventoux is a MAB Biosphere Reserve located at the southernmost tip of the French Alps. It extends towards the east as the Lure mountain. The two rural areas share the same land-use history and present identical ecological and social conditions. Due to the lack of sufficiently precise geographical data on Ventoux, we decided to develop our multi-agent system on the Lure mountain. This Mediterranean mountain is characterized by a high biodiversity, particularly the summit grassland landscapes which are affected by closing and the old fir tree forest settlements which are currently expanding. It has been studied regularly for over ten years. The knowledge obtained on the Lure mountain concerning landscape dynamics, in particular the spatio-temporal dynamics of fir stands and supraforest ecosystems, was based on a cartographic approach by means of GIS. Thanks to this technique, an inventory was drawn up at a given time in order to quantify dynamics as well as to integrate factors involved within landscape closure processes. It was used as a spatial support for our model.

The Lure mountain is an area of upland mountains. It is located in the southern Alps and reaches an altitude of 1826 m (Fig. 1). It is characterized by a uneven topography with an East-West oriented ridge, separating a steep northern slope from a relatively gradual south-facing slope. The northern slope is mostly planted with fir stands, whereas the south-facing slope presents largely open landscapes, in particular on summit areas where morphological and climatic constraints (frost, cryoclasty) reduce the spread of vegetation and only enable the conservation of lawns (meadows), juniper shrubs (*Juniperus communis nana*) and scree slopes – broken fragments of rock, usually formed by freeze-thaw activity – (Simon and Tamru, 1998). Whereas, due to a very high rural population and extensive agro – sylvo – pastoral development, rural landscapes were largely open at the beginning of the 19th century, nowadays the Lure mountain has become an area of low human total number where forest formations are dominant in the landscape. Forest succession that began in the middle of the 19th century following the withdrawal of agriculture, was subsequently strengthened in the first half of the 20th century as a result of the intensive (Mountain Terrain Restoration) and primary protective reforestation policy (Pech et al., 1997). Sheep breeding still takes

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