Companion modelling: a tool for dialogue and concertation[1] in biosphere reserves

Michel ÉTIENNE

The integration of simulation models to assist in collective decision-making for the management of natural resources is one of the particular features of adaptive management (Holling, 1978; Walters, 1986). The utilization of such models to stimulate the participation of stakeholders in building land management scenarios is, however, much less common (Costanza and Ruth, 1998; Bousquet et al., 2004). A group of researchers belonging to the ComMod network (Etienne et al., 2005) decided to develop this approach and to test it in the management of natural areas (d'Aquino et al., 2003; Etienne et al., 2003) and forest management (Etienne, 2003; Purnomo and Vanclay, 2003). To do so, their approach emphasized the aspects of multi-functionality, concertation and monitoring (Subotsch-Lamande and Chauvin, 2002) and used multi-agent models and role-playing games as mediation tools based on a democratic model (Chauvin, 2002) stimulating the implementation of new ways to build and to share information.

Following a brief presentation of the foundations and possibilities for the utilization of companion modelling, the use of the approach in biosphere reserve implementation is described and discussed. Emphasis is placed, in particular, on three ways to use multi-agent models and role playing in biosphere reserves: as an educational tool to increase awareness of the interactions between stakeholders and resources, as a mediation tool among users of the biosphere reserve, and as a decision-making tool in the implementation of a concerted land management plan.

Three examples in France and West Africa illustrate the potential applications of this approach. The first was developed to help stakeholders involved in the creation or during the periodic review of a biosphere reserve to formalize the main interactions between ecological dynamics and social dynamics on their territory, and to spatialize the issues at stake. The main purpose of the second is to offer an original method to address use conflicts that arise between naturalists and local stakeholders, by working on representations and scales of value. The third aims to improve exchanges between researchers and reserve managers, and to develop a teaching tool that is able to stimulate the development of possible scenarios for the concerted territorial management of biosphere reserves.

1. The term 'dialogue' as used here refers to a means to foster improved mutual understanding with a view to decision making. The term 'concertation' is intended as a means to project into the future collectively.

Context

Companion modelling applied to the management of renewable natural resources is based on the principle that any land management document reflects a way to organize and manage interactions between ecological dynamics and social dynamics. Therefore, it must be based on an ability to visualize probable changes within a territory in terms of structure, composition, juxtaposition or overlapping usage. The biosphere reserve must then be considered as a combination of ecological processes (regeneration, growth, population dynamics) and social processes (usage, economic value, history), so that the products of this territory represent a range of resources coveted by one and all.

Multi-agent systems constitute a particularly powerful tool to represent such complex systems and to account for the various environmental components, relations among social groups, and interactions between the practices of the stakeholders in the system and the primary ecological dynamics. They will consider the biosphere reserve territory as a group of objects about which agents make decisions on the basis of their perceptions and exchanges with other categories of agents (Fig. 1). Multi-agent systems are also able to represent this range of perceptions by offering viewpoints on the system created by using a palette of indicators that the various stakeholders concerned by the land management project consider to be relevant.

Finally, the complexity of situations addressed in a biosphere reserve is such that the decision-making process is necessarily evolving, repeated and continuous, and should be built according to an approach that makes it possible to facilitate collective decision making. Companion modelling is designed to meet this challenge by providing tools that make it easier to understand different viewpoints and the subjective criteria to which various stakeholders refer implicitly, or even unconsciously

(Etienne et al., 2005). It goes farther than traditional participatory approaches and recent concertation support systems (Auvergne et al., 2001) insofar as the functional diagrams commonly used in such approaches are dynamic and interactive.

Approach

The first step in the companion modelling approach consists of collectively identifying the main stakeholders concerned by the existence of the biosphere reserve, their management entities and the main dynamics at play. To accomplish this first step, the group taking part in the co-construction of the model must answer the following four questions:

- What are the main resources on the territory and the essential information needed to guarantee their sustainable use?
- Who are the main stakeholders that seem to be able to or need to play a decisive role in managing this territory?
- What are the main ecological dynamics at stake, and how are such dynamics impacted by these stakeholders?
- How can each selected stakeholder use the desired resources?

The answers to these questions are represented in simple diagrams, which are structured to be readily translated into computer language. Four diagrams are thus drawn collectively and consecutively:

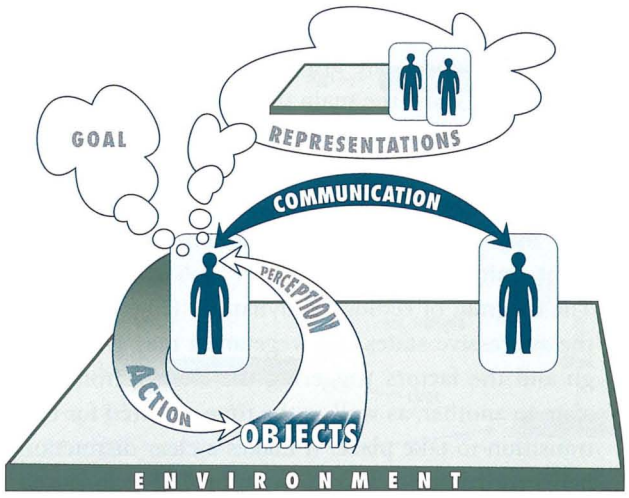
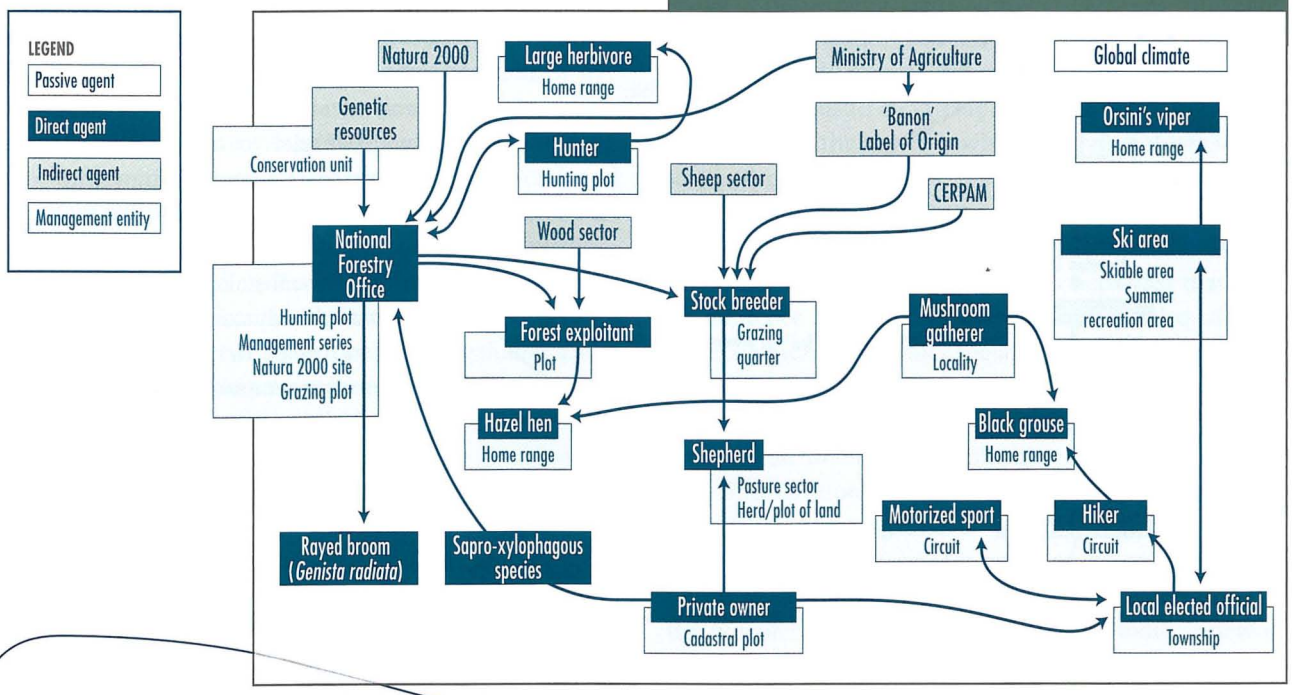


Fig. 1: Architecture of a multi-agent system (based on Ferber, 1995)

- The diagram of stakeholders and management entities (Fig. 2) makes it possible to list all the stakeholders who play a key role in the biosphere reserve, and to distinguish direct stakeholders (whose practices have a direct impact on the dynamics of certain resources) from indirect stakeholders (whose actions will encourage the direct stakeholders to change their practices). Each direct stakeholder is associated with one or more management entities that may be spatial (a plot of forest, a grazing area), or not (a herd). Predominant external variables such as

Fig. 2: Diagram of stakeholders (in this example, Ventoux Biosphere Reserve)



climate variations are also indicated. Lastly, arrows are used to show the main interactions between the various stakeholders represented in the diagram.

- The diagram of resources (Fig. 3) shows the main types of resources used, which are often divided into five major categories (construction, water, stone, plant, animal).
- The diagram of ecological dynamics (Fig. 4) shows the successive states that vegetation may go through and the factors triggering the change from one state to another, as well as the time required for this transition to take place. It makes a clear distinction between dynamics linked to anthropic actions and natural dynamics (when usage is abandoned). When issues related to fauna are clearly shown, there are as many diagrams of population dynamics as there are issues.
- Lastly, the diagram of interactions (Fig. 5) summarizes the previous diagrams by highlighting the relations between users and resources. The arrows symbolize the interactions between stakeholders and resources or interactions among stakeholders about resources. They are associated with verbs that specify the type of action that results in interaction and the indicators that correspond to information used by the stakeholders in making decisions. This phase is often the most informative and the most interesting in the modelling process.

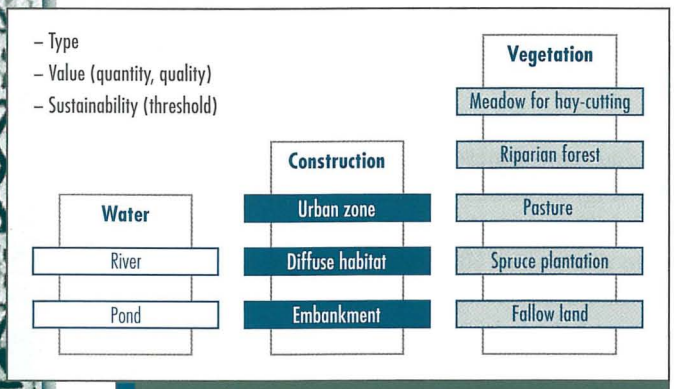
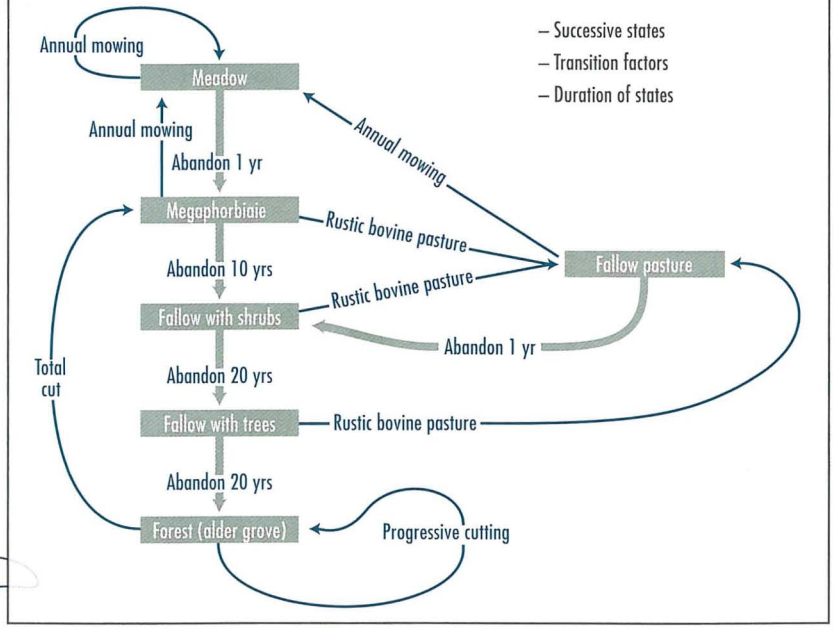


Fig. 3: Diagram of resources (in this example, Vosges du Nord Biosphere Reserve)

Fig. 4: Diagram of ecological dynamics (in this example, Vosges du Nord Biosphere Reserve)



Once the ecological process, the territory and the main management entities have been properly represented and 'implemented' in the computer model, it is possible to use the resulting companion tool in two ways. If the objective is mediation[2], it is preferable for the modelling of how user interactions function to be easily accessible, in order to facilitate the rapid sharing of representations of one or more processes at work in land use planning, while leaving the participants free to invent an action or negotiation strategy (d'Aquino et al., 2001). The mediator will then organize the simulation by having them take part in a role-playing game that reproduces the context of the territory subject to land management (Bousquet et al., 2002). If the objective is conciliation, it is preferable to represent the interactions between stakeholders and resources as accurately as possible and to facilitate the visualization of the impact of such interactions, based on a range of viewpoints that is as broad as possible. The conciliator will then suggest that they react to a series of simulations developed on the basis of their individual opinions and encourage them to use the multi-agent model to build and compare alternative scenarios, drawn up and assessed collectively.

In the role-playing game, in order to build local stakeholders' awareness of natural dynamics, both current and future, participants are subject to rules of vegetation dynamics that are simple but precise enough to accurately take into account the impact of management methods. They are also obliged to spatialize their activities and devote a specific amount of time to discussion and exchange about

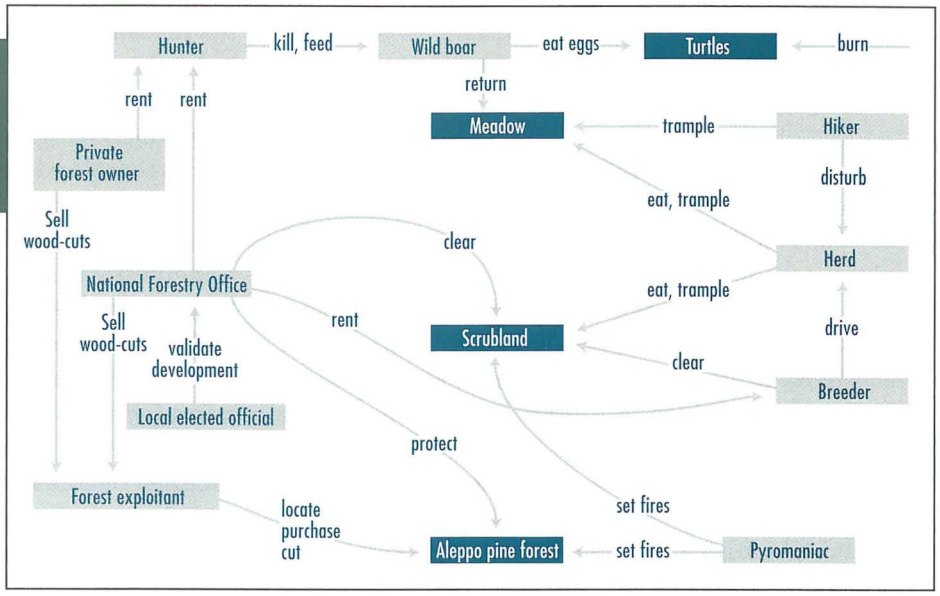


Fig. 5: Diagram of interactions (in this example, Luberon Biosphere Reserve)

both similar and antagonistic roles (multiple negotiation). Lastly, they are projected into the future using role-playing. The model for this simulates landscape dynamics resulting from actions that are chosen individually or collectively by the stakeholders.

During simulations, participants can visualize landscape dynamics, action dynamics or production dynamics, using animated maps or dynamic graphs. These viewpoints translate what each person is used to seeing or wants to see on the territory he or she manages or administers, or where they have a regular activity. This enables an individual to understand what the other person sees, and measure the impact of each one's own practices on indicators he or she is not used to employing.

Applications

Becoming aware of interactions

This aspect is part of the approach currently applied in France within the framework of the periodic review of biosphere reserves, or to support preparatory considerations for the creation of a new biosphere reserve. The main initiators in the creation or periodic review project are invited to take part in the exercise over four or five half-day sessions. The first day is devoted to discussion among the participants about the components that make up the biosphere reserve (stakeholders, resources) and the main natural dynamics at play, giving each person an opportunity to express his or her opinion. The purpose is to create a shared vision of the future biosphere reserve territory, to stimulate the creativity of participants and to reveal potential usage conflicts. Particular effort is focused on clarifying the terms that are used, defining described entities, and establishing the concerned time step.

The second day is devoted to identifying the major biosphere reserve issues and drawing up interaction diagrams concerning these issues. This phase requires participants to describe the actions that have a decisive impact on territorial dynamics or make it possible to strengthen a particular social link. If there are not too many issues and participants, it may be carried out collectively; otherwise it is preferable to divide the participants into groups of five or six people and, at the end of the session, to discuss and compare the diagrams created by each group.

The last half-day addresses the scales of time and space that are relevant for the representation of the management entities used by the selected stakeholders. For each of the stakeholders, it is necessary to specify the scope of his or her activity (number of stakeholders and portion of the concerned territory), its economic, social and ecological impact, and the current state of knowledge. This leads to an attempt to spatialize the issues on those parts of the territory where all stakeholders identified in the interaction diagrams are present, and where it is possible to make biodiversity conservation compatible with the sustainable development of economic activities. This involves quantifying the main activities that have an influence on the territorial dynamics and qualifying the ecological, economic, social and cultural viability of the current development model on this territory.

The exercise then combines these various components to facilitate the identification of research, education and continuous monitoring needs, as well as to identify the local stakeholders who should be involved, and for which interfaces it is necessary to consider them. These elements then enable the collective definition of the biosphere reserve project or the periodic review of

2. In negotiation, two stakeholders try to come to an agreement directly. In the event they wish to involve a third party, conciliation consists of the third party suggesting solutions, while mediation involves helping the stakeholders reach an agreement, without suggesting solutions.

the biosphere reserve file, and consideration of the types of policies that will ensure sustainable development of the territory (Fig. 6).

Addressing use conflicts

This aspect was addressed during a workshop in May 2003 in Benin focusing on six West African biosphere reserves[3]. The first part of the workshop allowed participants to consider the different elements that make up a biosphere reserve (stakeholders, resources) and the main dynamics at play (ecological and social). The participants were divided into three homogenous groups according to their professional status (MAB National Committees, reserve managers, local representatives) and including a representative from each country (Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal). In order to ensure that all participants would have the same level of understanding about the territory under discussion, the groups tried to outline the functioning of a fictional biosphere reserve deliberately located in a country that was 'exotic' to them (Chile), with the goal of protecting ecosystems that were, however, similar to their own (savannas and dry forests, herbivores and wild cats) in a rural context modelled by agricultural activities that are common in their home country (breeding, hunting, gathering firewood).

This exercise took two days. The first day was spent collecting and organizing the information that the three groups considered essential, while during the second day participants worked together to sketch out a functional diagram of the biosphere reserve and a proposal for zonation and actions aiming to reduce potential sources of conflict. During the first day, each group answered the four questions outlined at the beginning of the paper, based on the same core information: a general presentation (written) of the context of the virtual biosphere reserve, illustrations (photos and block diagrams), and additional information to be consulted upon request, provided by two resource persons trained beforehand by the workshop trainers.

The comparison and collective discussion of each group's proposals revealed that the choices concerning the representations of methods, viewpoints, and ranking of objectives differed greatly according to each group's origins. Figure 7 summarizes the main points highlighted by each group concerning the principal resources, main stakeholders, decisive ecological processes and human activities that could threaten these processes. A comparative analysis of each group's proposals showed that perceptions are expressed on different scales, in terms of both stakeholders and resources, with highly contrasted hierarchical criteria.

Next, by sharing the representations it was possible to draw up a list including all the stakeholders concerned by the biosphere reserve, the resources, and the ways they were used. This step revealed the importance of reaching an agreement about the definition of terms and the functions attributed to these words during collective debate. The collective construction (imposed by giving the floor to each individual three times maximum) of interaction diagrams among these

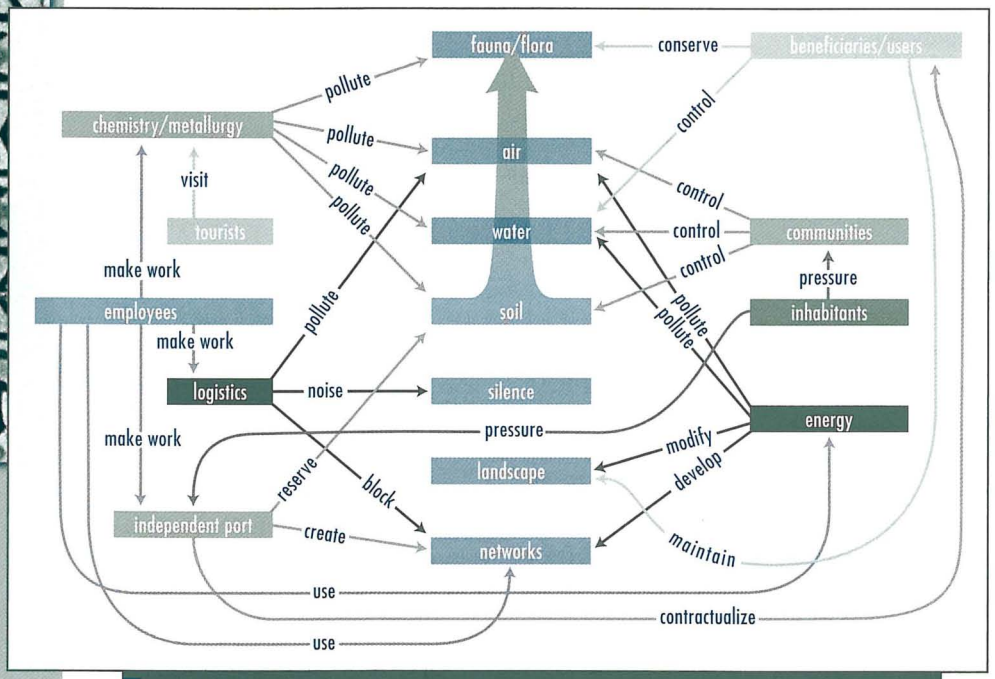


Fig. 6 : Diagram of the interactions around the industrial zone/natural zone interface (example of the periodic review of Camargue Biosphere Reserve)

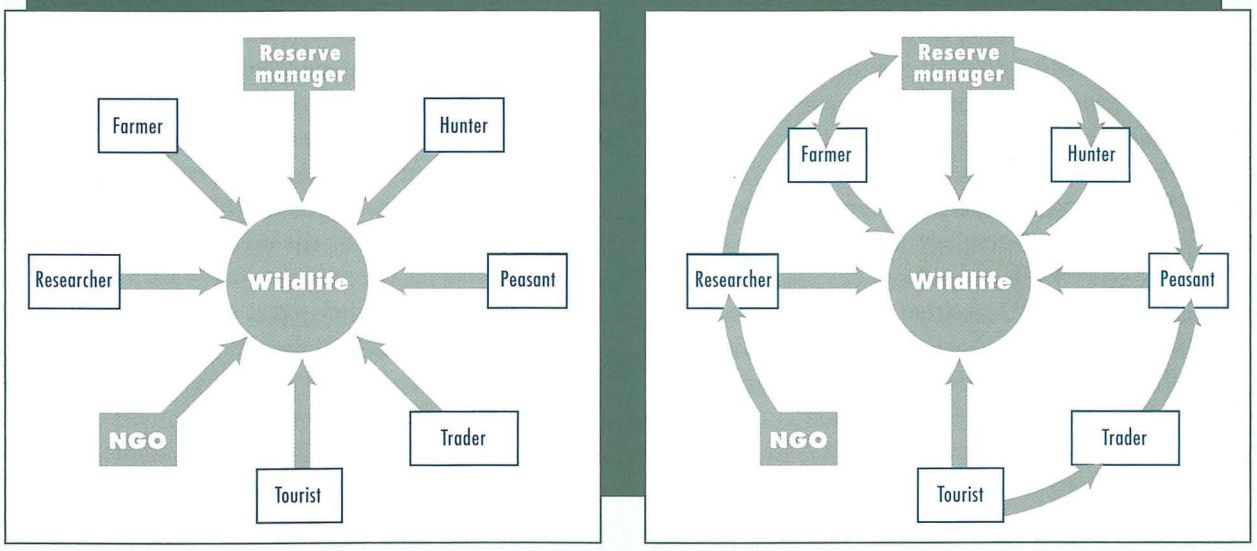
3. UNESCO. 2003. UNESCO-MAB/UNEP-GEF regional project. Final Report. Training Workshop on dialogue and concertation in Six Biosphere Reserves in West Africa. 11-17 May 2003. Pendjari Biosphere Reserve, Benin.– 13 pp + appendices.

stakeholders and the main resources then made it possible to identify the primary potential sources of stakeholder conflicts. Comparing the diagrams in fact made it possible to determine either those that have the greatest impact on the area or those that have the highest probability of conflict.

The group focused more closely on three of these by attempting to agree about the ways the stakeholders should act with respect to the type of resource, based on three aspects of their behaviour. Participants were asked to name a verb that expressed the action accomplished, a word to explain the goal they were aiming for, and a value to quantify the satisfaction rate for the objective. This exercise illustrated the direct and indirect pressure on resources and the actions associated with survival or pleasure, or the location of interactions where conflicts may appear. It also gave participants an opportunity to measure the difficulty of establishing objective criteria to determine rules of management that guarantee the sustainable conservation of resources. Discussion of the indicators required for the implementation and enforcement of such regulations revealed that a great deal of knowledge and monitoring are necessary to create and manage a biosphere reserve.

The example below (Fig. 7) concerning the resource 'wildlife' clearly shows the direct action of those who hunt or observe and the indirect action of those who sell the gains of the hunt. It also provides a clear illustration of the differing perceptions of those who see wildlife as the heritage of future generations (NGO, reserve manager), a source of pleasure (tourist, farmer, hunter), a source of food (hunter, peasant), and a source of profit (trader, peasant, reserve manager).

Fig. 7: Wildlife resource. Figure on the left is the result of the exercise. Figure on the right is the version as corrected after discussion on direct and indirect stakeholders



	Objective	Action	Criterion
Trader	Trade	Sell trophy, skins	Positive supply
Farmer	Trophy	Hunt	Handsome trophy
Peasant	Income + food	Hunt	Meeting needs
Hunter	Meat + trophy	Hunt	Pleasure
Reserve manager	Conservation	Enforce the law	Population density
Tourist	Pleasure	Observe	Maximum n° of species
Researcher	Knowledge	Observe	Sample size
NGO	Conservation	Provide funding	

The following example (Fig. 8) concerning the resource 'grazing areas' made it possible to include the spatial dimension as a potential source of conflict. In addition, it enabled participants to realize that wild herbivores can legitimately be considered 'predators' of fodder resources. It also revealed two ways to resolve potential conflicts between domestic and wild herbivores. Regulations can be used by the reserve manager to reduce access rights to grazing areas for peasants, in order to encourage wild herbivores to feed there. Negotiations can be used by the reserve manager to ask researchers to find ways to render 'double' use compatible, so that both domestic and wild herbivores could graze in the area. The results of this research would be communicated to breeders through the agricultural education services.

Encouraging exchange among researchers and reserve managers

This aspect was developed within the scope of a research-development project funded by the French Institute for Biodiversity (IFB) following a call for tender entitled 'Biodiversity dynamics and means of access to habitats and resources'. The project objective was to test the application of the companion modelling approach to facilitate exchanges between scientists and reserve managers on an issue of common interest. The main question they addressed had to do with the interaction between closing open habitats and the development of new social expectations concerning the environmental value of these habitats. The question was submitted to researchers from different backgrounds in the humanities and social sciences (geography, sociology, ethnology, economics) and natural sciences (ecology, biology, genetics) in four biosphere reserves in France that were selected for their contrasted ecological and socio-economic conditions.

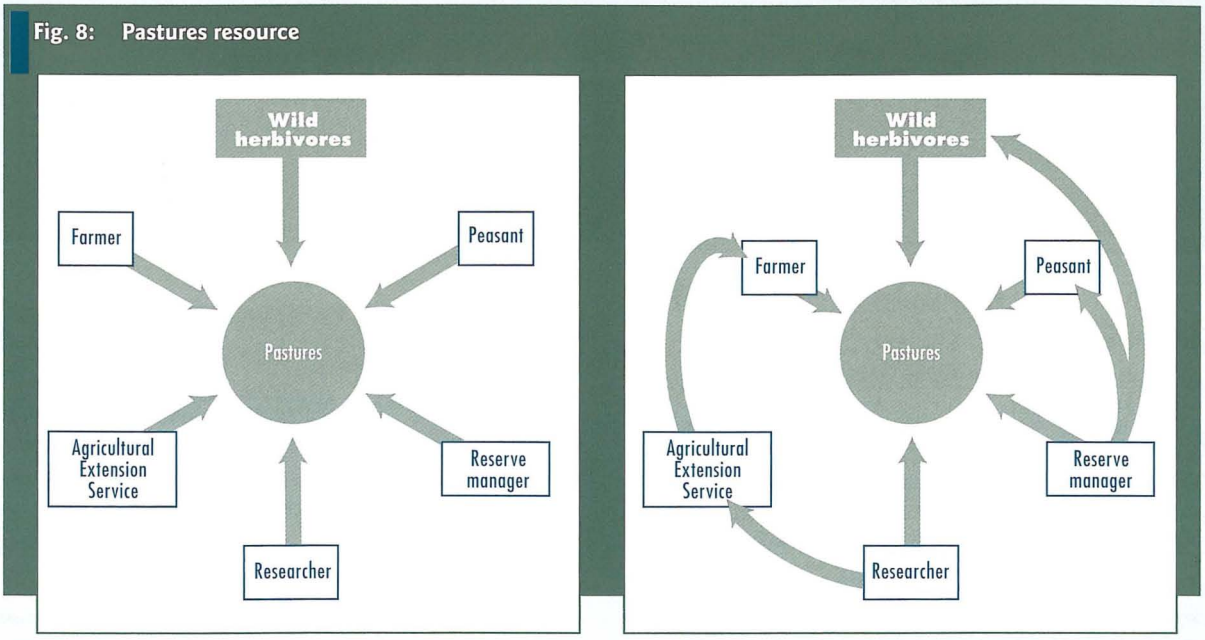
All these biosphere reserves have undergone similar experiences in terms of the utilization of the surface they cover: intense use during the 19th century, widespread abandon between the two world wars, decline of traditional breeding systems, appearance of the 'biodiversity conservation' issue in the 1980s, development over the last 50 years of woody plant species, causing profound modifications to biodiversity (genetic, specific, and landscape), and, lastly, the arrival of new categories of inhabitants. These points in common concerning the history of society–nature interactions and questions about shrub encroachment and its impact on biodiversity are nonetheless part of very diverse social and ecological contexts:

- In the Mer d'Iroise Biosphere Reserve, created in 1988, an oceanic island is subject to widespread proliferation of scrub and overgrowth. It is home to an original population of red-billed choughs that are very sensitive to the development of tourism activities.
- Vosges du Nord, a biosphere reserve created in 1989, is an immense forest interspersed with narrow, grassy valleys with original wetland meadows where the disappearance of traditional management through hay-cutting has created a threat to the diversity of flora and fauna.
- Mont Ventoux, a biosphere reserve created in 1990, is a mountain in the midst of scrubland. Home to exceptional flora and fauna, it is undergoing a spectacular expansion of cedar and pine forests with an impact on the genetic quality of populations settling here.
- In the Luberon, a biosphere reserve created in 1997, scrubland is shrinking, giving way to forests of cedar and Aleppo pine trees, thereby reducing the mosaic of Mediterranean landscapes and increasing the risk of fires.

This was an original approach because it focused on formalizing the interactions between natural dynamics and social dynamics, and collectively comparing the visions of researchers and reserve managers concerning natural resources and their dynamics, based on their own objectives and specific criteria. This co-construction approach, between researchers and reserve managers, successively addressed the four questions mentioned at the beginning of this contribution, which form the basis of the conceptual model.

The conceptual model implementation phase then forced the reserve managers to explicate the rules underlying decisions made by the main stakeholders concerned by the management of renewable natural resources. They had to specify the spatial entities on which such decisions were based, and the time step for updating the indicators at the source of decisions. The formalization of these management rules using a multi-agent model greatly facilitated the comparison of the time step of the natural systems under study and the economic and social rythms of the users of such systems. It will now make it possible to simulate scenarios for the management of these systems and to evaluate their impact on biodiversity on several scales (genetic, species, and landscape). The utilization of the model as an intermediary object during role-playing sessions scheduled with local stakeholders in 2006 should help measure the social acceptance level of the proposed scenarios and develop new options for the control of access to resources.

Fig. 8: Pastures resource



Discussion and prospects

With companion modelling, the model plays the role of a friendly and dynamic intermediary model. It is both a tool for sharing representations and a tool for scenario evaluations. The fact that it is the outcome of co-construction between researchers and reserve managers guarantees the ready appropriation of its content, direct validation of the representations it contains, and the clear identification of the limits of utilization. Insofar as it helps individuals understand others' viewpoints, it ensures good visibility of the role of each modelled agent, and stimulates the synergy between practical knowledge and technical expertise, between the layperson's know-how and the scientist's understanding.

Implementation, however, requires a large body of available knowledge in many different disciplines and, very often, the use of a computer platform. The success of this approach also depends to a large extent on the aptitudes of one or more leaders who will participate, one after another, in the conception-validation-utilization process, and on their ability to prove their legitimacy and guarantee their independence. The phase during which decisions are made about choice of partners, venue for sessions, and methods of invitation is, in particular, a very difficult exercise because the representativeness of the participants, and thus the agents who will play a key role in the model, depends on this phase.

According to the experience gained thus far, although the innovative aspect is relatively destabilizing for the participants, it is especially appreciated and is often mentioned as a critical feature of the approach. This exercise involves building something from nothing. Comparing the knowledge of stakeholders from different backgrounds, in addition to the careful argumentation imposed by this approach, ensures that the final outcome is fully pertinent and legitimate. The primary obstacle remains the often necessary reliance on computers, and what this implies in terms of dependency on specialized computer technicians. Yet is it truly possible to stimulate a collective discussion on the management of natural resources without being able to accurately represent the underlying dynamic processes?

Another aspect often mentioned as a handicap in feedback about ongoing experiments concerns the approach being complicated and time-consuming to implement. If one measures these aspects on a standard application that includes the co-construction of the model, development of the model, design of a role-playing game, utilization of the role-playing game and comparison of scenarios, it indeed takes one to two years, depending on the complexity of the issue being addressed and the scope of the territory in question. And during these one to two years, it must be possible to mobilize a number of stakeholders simultaneously, in working sessions that often last all day. This is the price to pay, but it is likely that such an investment is well worth it when one considers the time saved subsequently, during implementation of development or land management projects that result from this approach.

The companion modelling approach may be mobilized at three points in the life of a biosphere reserve: when it is created, as an educational tool to build awareness of the processes at play (landscape dynamics, biodiversity, awareness about fires); during periods of usage

conflicts, as a tool for mediation between partners (role-playing); and lastly, during periodic review as a decision-making tool for the implementation of concerted land management.

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