Using the concept of ecosystem services to foster social learning for concerted management of social ecological system: preliminary results from a case study in Mont Lozère, France

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Abstract: *Mountain areas in Europe are facing important land use changes, mainly land abandonment combined with agriculture intensification. Mountains are known as multifunctional areas, and land use changes imply management trade-offs because some functions are improved to the detriment of others. It has been proved that social learning can contribute to tackling trade-offs in social-ecological systems by increasing the awareness of interdependencies, especially in multi-stakeholder dialogue processes. How can we foster social learning to inform choices about management of mountain farming systems? In this study, we make the hypothesis that using the concept of ecosystem service in multi-stakeholder dialogue processes can improve awareness of interdependencies, and thus social learning. To test this hypothesis, we study the case of Mont Lozère, Cévennes region, France, that is facing important land use change. We studied trade-offs among ecosystem services due to two agricultural practices: rock removal and ploughing of meadows. We designed a role-playing game to reveal hidden interdependencies between stakeholders, and to open dialogue about the governance of trade-offs between ecosystem services. The analysis of the game sessions is still in progress, but we identified three kinds of learning which seem to be fostered by the game: learning on the issue at stake, learning about others, and organizational learning.*

Keywords*: social learning; multi-stakeholder dialogue processes; economic service; socio-ecological interdependencies; mountain farming system.*

1. Introduction

Mountain areas in Europe are facing important land use changes. The main trend is land abandonment: traditional labor intensive practices are declining, marginal land are being abandoned and this leads to encroachment and reforestation (MacDonald et al., 2000). At the same time, there is an agriculture intensification, mainly located on more accessible and higher quality lands (MacDonald et al., 2000). This double dynamics of land abandonment and intensification is deeply changing the landscapes and farming systems in the mountain areas in Europe.

Mountains are known as multifunctional ecosystems (Reed et al., 2009). By ecosystem, we mean "*dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit*" (Millennium Ecosystem Assessment, 2005b). Grasslands for example have a function of fodder production, but also many others functions like rare species conservation, habitat protection, agro-tourism, soil and water quality, resilience to environmental perturbations (Hopkins & Holz, 2006). Land use changes can affect the balance between these different functions, and their sustainable management remains a challenge for land users and managers (Mottet, Ladet, Coqué, & Gibon, 2006).

Land use changes imply trade-offs, which "*emerge when an action, for example, a management intervention, enhances one aspect to the detriment of another*" (Galafassi et al., 2017). Dealing

with trade-offs implies dealing with perceptions and representations, because trade-offs might be invisible, diversely perceived or intentionally hidden. Learning processes are thus necessary to enrich representations of trade-offs and inform choices. Learning is defined as "*the acquisition of knowledge for effective action in the domain of existence*" (Daré et al., 2014), and social learning refers both to the learning of individuals in a social environment and to the group processes that provide a basis for joint action (Pahl-Wostl et al., 2007). Multi-stakeholder dialogue processes are considered as an appropriate mean to foster social learning, i.e. learning through interactions with other people (Pahl-Wostl et al., 2007; Röling, 2002; Roux, Stirzaker, Breen, Lefroy, & Cresswell, 2010). Galafassi et al. (2017) suggest that social learning processes can support in particular the tackling of trade-offs by five means: developing systemic perspective, understanding how trade-offs impact people, supporting collaboration between stakeholders, supporting development of shared goals, stimulating new practices. Regarding the systemic perspective, learning process can play a role by increasing people's awareness of the multiple socio-ecological interdependencies involved in a complex socio-ecological system (Daré et al., 2014; Mathevet, Thompson, Folke, & Chapin, 2016).

How can we foster social learning to better address trade-offs and to inform choices about management of mountain farming systems? In this study, we make the hypothesis that using the concept of ecosystem services in multi-stakeholder dialogue processes can foster social learning by increasing the awareness of interdependencies.

By ecosystem services (ES), we mean the "*benefits people obtain from ecosystems"* (Millennium Ecosystem Assessment, 2005a). These include provisioning services such as food, water or timber; regulating services that affect, e.g., climate, floods or water quality; and cultural services that provide recreational, aesthetic, and spiritual benefits. Bennett and al (2009) show that there are trade-offs between ES (ES can be antagonist or in synergy) and that changes on ecosystem can have an impact on several ES.

In this study, we focus on trade-offs between ES, which we consider a good way to reveal socio-ecological trade-offs: "*trade-offs can be translated as land-use or management choices that increase the delivery of one (or more) ecosystem service(s) at the expense of the delivery of other ecosystem services"* (Turkelboom et al., 2017). The author argue that the concept of ES is a good manner to capture the socio ecological trade-offs, because it can help to predict the time and place of trade-off, encourage dialogue and learning between stakeholders, lead to more effective decision and help social justice (Turkelboom et al., 2017).

In this paper, we propose to use the concept of ES into multi-stakeholder processes to foster social learning so as to inform trade-offs about land use changes in mountain areas. This paper is a work in progress and present preliminary results.

2. Case study, methods and concepts

Two kinds of methods are combined in this study: in a first phase, individual interviews for trade-offs and stakeholder analysis, and, in a second phase, participatory workshops to foster social learning about trade-offs. Following a brief description of the case study, we will present in this section the methods and concepts involved in these two phases.

a. Case study

To test the hypothesis that the concept of ES can foster social learning to better address trade-offs due to land use changes, we study the case of the Mont Lozère. This area of 400 km² is located in the South of France. It has mountainous climate and landscape, with the highest point at 1699 m, with granite chaos. The main economic activities are bovine and ovine livestock farming, wood exploitation, and tourism. This area is protected as a National Park since 1970, a

Man and Biosphere Reserve since 1985 and the UNESCO World Heritage since 2011 (PNC, 2013).

A major land use change in this area in the last century is the spontaneous reforestation, which results from land abandonment and decline of pastoral livestock farming activity, i.e. the extensive use of grasslands for grazing. This land abandonment on marginal lands co-exists with the intensification of farming practices on the areas that are suitable for mechanization: drainage; conversions from permanent to temporary meadows; rock removal to facilitate mechanization; increasing use of barbed wires, etc. These changes enflame debates and controversies among stakeholders (i.e. naturalists, farmers, tourism operators, etc.) with conflicting interests and perspectives. We focused on two practices – the rock removals and ploughing of the meadows – because there are controversial and because they are good examples of trade-offs among ES.

b. Context and stakeholder analysis: concepts and methods

For the context and stakeholder analysis of these two issues (rock removal and meadows' ploughing), we use the key concept of trade-offs between ES. In this article, we follow the hypothesis that trade-offs between ES also create social interactions, presented in Fig. 1. Indeed, when two (or more) ES are antagonist, this creates conflicts of interests between beneficiaries of these ES. Trade-offs between ES imply social choices, which can be explicit or implicit, discussed collectively or not (Barnaud et al., 2018).

To drive our stakeholder analysis, we use the conceptual framework proposed by Barnaud and al. (2018) which uses an ES lens to uncover hidden social interdependencies among people so as to reflect on existing or potential collective actions among them. We analyzed in particular the social interdependencies related to trade-offs among ES, referring to the "3i" framework: interests, institutions, ideas (Hall, 1986; Heclo, 1994).

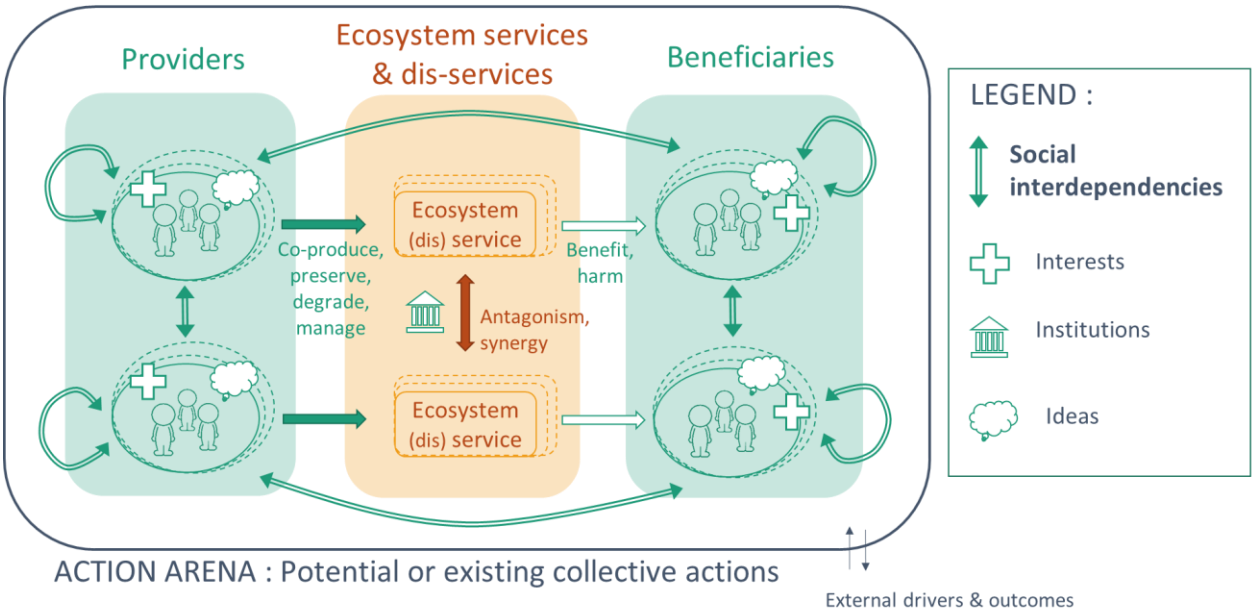

Figure 1. Conceptual framework used for context and stakeholder analysis (adapted from Barnaud and al., 2018)

By interest, we mean not only *"the level of utility or welfare perceived by stakeholders"* (Grimble & Wellard, 1997), but also their "*wants and concerns"* (Wollenberg, Anderson, & Edmunds, 2001) and "*aspirations*" (Carnevale, 2006). Because of its subjective dimension, the concept of ES is useful to reveal interests of the stakeholders. Some authors use this concept to analyze

power relations and social interactions (Berbés-Blázquez, González, & Pascual, 2016; Hein, van Koppen, de Groot, & van Ierland, 2006; Vallet, Locatelli, Levret, & Dendoncker, 2016). In this study, we use it to reveal interests and conflict of interests (Barnaud et al., 2018; Chevassus-Au-Louis, Salles, & Pujol, 2009).

By institutions, we mean *"the sets of working rules that are used to determine who is eligible to make decision in some action arenas"* (Ostrom, 1990), which can be formal or informal. Some studies combine Ostrom's approach and ES framework (Gomez-Baggethun, 2015; Muradian & Rival, 2012; Partelow & Winkler, 2016). In this paper, we use the Ostrom's framework to understand how trade-offs between ES are regulated, and if the social choices related to trade-offs between ES are concerted and collectively discussed.

Concerning ideas, we focus on the diversity of relations that people have with nature. Indeed, the ES concept suggests that the relation between human and nature is normative, anthropocentric and utilitarian (Maris, 2014). Some authors argue that people have also other kinds of relation with nature, for example a relation of stewardship or web of life (Mathevet, Bousquet, & Raymond, 2018; Raymond, 2015). In this study, we characterize the relations that different people have with nature, including the ES relation.

In terms of methods, the context and stakeholder analysis is based on semi-structured interviews, conducted by the first author of this paper from July 2016 to August 2017 with 46 people. The purpose of these interviews was to gather a diversity of perceptions about landscape dynamics. A panel was first established, including people from the sectors of farming, forest, environment, tourism, hunting, and territorial management. An interview grid was designed before the interviews, with 4 main themes: life trajectory, management practices, perceptions of landscape dynamics and benefits obtained from nature. The interviews were integrally transcribed then analyzed with N'Vivo software (Welsh, 2002).

c. Companion modelling: concepts and methods

The second phase of our study follows the companion modelling method, which is a participatory approach based on the co-construction and use of models. Models are used to facilitate the conceptualization of issues and encourage discussions among participants (Barreteau et al., 2003; Étienne, 2013). These models can have different forms: mental models, computer-based simulation, role playing game, etc. Role-playing games are considered as powerful tools to convey systemic thinking and increase people's awareness of the multiple interdependencies of the social ecological system (Mathevet et al., 2007).

We designed a role playing game representing the trade-offs among ES underlying the debates over the issues of rock removal and ploughing of meadows. This game was designed by the authors of this paper with regular exchanges with local stakeholders (especially agents from National Park) and scientists. We focused on 6 ES: grass production, hay production, drinking water, heritage landscape of grazing lands, cultural value of rocks and tourism and existence value of biodiversity (two birds species: Whinchat - *Saxicola rubetra* and Hen harrier - *Circus cyaneus*). The objectives of this game are to encourage collective discussion about the links between farming practices and ES, the trade-offs between ES, the management of the trade-offs and the social interdependencies underlying these trade-offs.

The game board represents a virtual site in the Mont Lozère, with 4 kinds of plots: temporary meadow and permanent meadow, which produce hay and which are not grazed; grazing land, which is grazed and produces pasture grass; and shrubby area, which is a former grazing land that turned into shrubs and cannot be grazed anymore. There is also a granite chaos which is a touristic spot and a natural spring for drinking water. There are 7 roles: 4 livestock farmers (2 suckler-cow farmers and 2 dairy farmers), whose objective is to maintain or increase their herds. There are 3 National Park agents: one is from the Agriculture department, his objective is to

maintain agricultural activity and heritage landscape (grazing lands); one is from Tourism department, his objective is to maintain granite rocks and heritage landscape (grazing lands); one is from Conservation department, his objective is to protect two emblematic birds.

Figure 2. Photo of the board game during a game session, Mont Lozère, March 2018

The game board evolves due to the ecological dynamics of shrub encroachment and due to farming practices (i.e. rock removal, ploughing of meadow, re-opening grazing land and natural evolution from temporary to permanent meadows). For some of these practices they need to ask for a permission given by the agents of the Park. The agents of the Park can also give agri-environmental measures (AEM) to farmers. This game counts 3 to 5 turns, each turn representing a year. At the end of each year, there is a collective overview of the level of each ecosystem service.

This game was organized twice on the Mont Lozère during spring 2018. The game sessions lasted 4h00, including a briefing, questionnaires, the game itself (3 and 4 turns) and a debriefing. In total, 13 stakeholders came: 7 farmers, 5 agents of the National Park and one municipal councilor. During the game, we asked the players to exchange their roles (farmers played agents of National Park and *vice versa*).

The analysis will include an examination of the session dynamics (evolution of each ES during the game) and dialogues that occur between players. This analysis is not finish yet, but we present thereafter some preliminary results.

3. Results

a. Trade-offs and stakeholder analysis on rock removal and ploughing of meadow

In the core zone of the National Park, farmers have to obtain permissions from the Park to do these practices. These permissions are causes of controversies. Demands from farmers are increasing because of the constraints on land and the influence of the Common Agriculture Policy (CAP). The National Park answers case-by-case, but there is a lack of perspective about the long-term impacts on landscape. More particularly, cumulative impacts and threshold impacts are uncertain. These issues are very important for farmers, in a context in which land

access is difficult, but also for the National Park, which is mandated to preserve landscapes and the "character" of the Park.

(i) Rock removal: trade-offs among ES and action arena

Rock removal refers to the fact that farmers displace big granite rocks, in the center, coin of the plot, or out of the plot. This practice is very old, but with modern means (for example powerful excavator) the impact on landscape is more important.

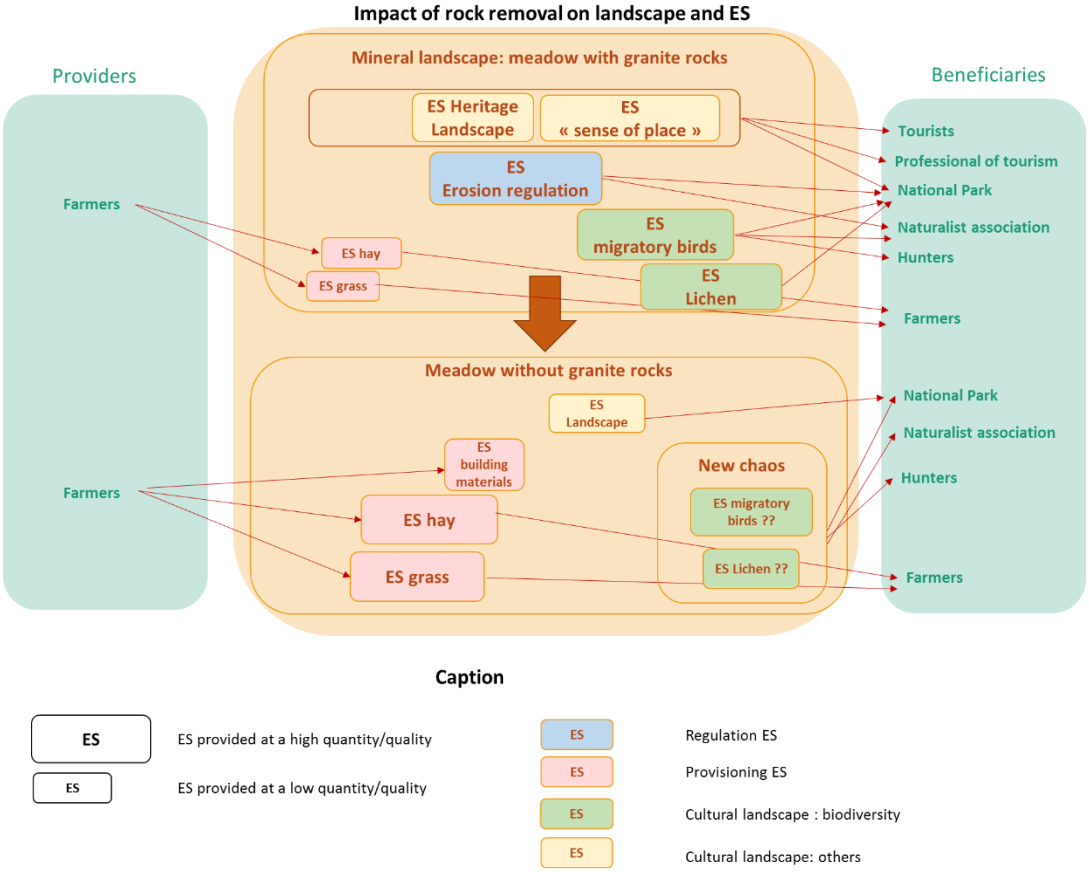

Figure 2. Impact of rock removal on landscape and ES

Rock removal impacts various ES simultaneously:

- It improves provisioning ES of hay production because it enables mechanization. Farmers are both providers and beneficiaries of these ES.
- It can degrade cultural ES of heritage landscape, historic heritage and "sense of place", because granite rocks have an important aesthetic, historic and even spiritual value for inhabitants and tourists. These ES were co-provided by nature and the previous generation. The beneficiaries of these ES belong to tourism sector (tourists, operators) and the "Welcome and Awareness" department of the National Park.
- It can impact the regulation ES and ES of biodiversity, by increasing erosion, disturbing migratory birds' habitat, and destroying some rare lichens. The beneficiaries of these ES are "Intelligence and Knowledge" department of the National Park, naturalist NGOs and hunters.

In conclusion, rock removal tends to improve provisioning ES in detriment of cultural and regulation ES, as it can be seen on Fig. 2.

(ii) Ploughing of meadow: trade-offs among ES and action arena

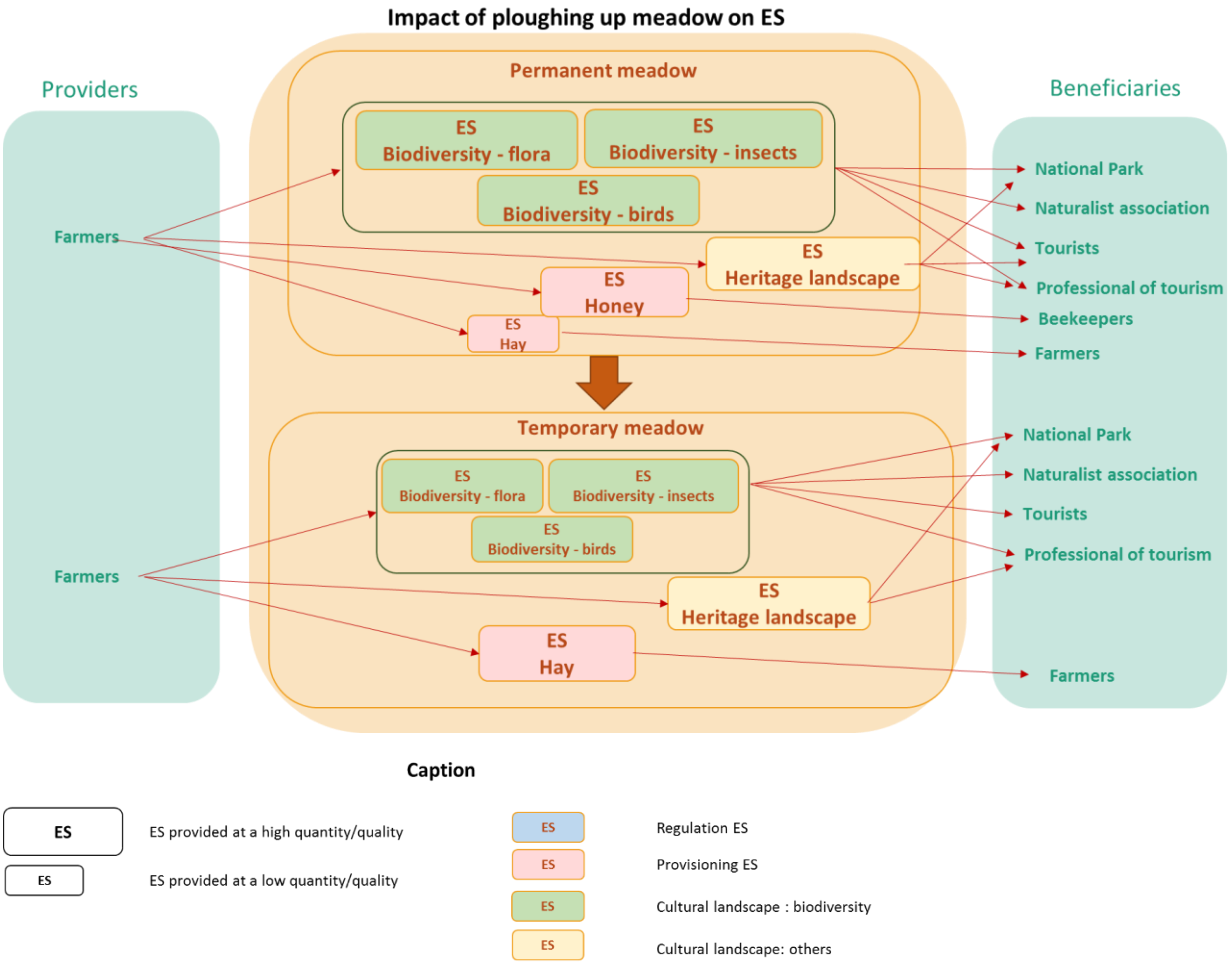

Figure 3. Impact of ploughing of meadows on landscape and ES

Ploughing meadows refers to the transition from permanent meadow to temporary meadow.

Ploughing the meadows impacts various ES simultaneously:

- It improves provisioning ES of hay because temporary meadows are more productive (quantitatively and qualitatively) than permanent meadows. Farmers are both providers and beneficiaries of these ES.
- It can degrade ES of biodiversity and provisioning ES of honey, because the temporary meadow is not as favorable as permanent meadow for flora, insects, birds and bees. The “Watch and Knowledge” department of the National Park, Naturalist NGOs and beekeepers are the beneficiaries of these ES.
- The impact of ploughing up meadow on aesthetic ES of open landscapes is controversial: some stakeholders (for example, naturalist NGO) consider that it degrades aesthetic value of open landscape, while others (for example tourists) don’t.

In conclusion, ploughing the meadows improves provisioning ES of hay in detriment to cultural ES (biodiversity and for some stakeholders, aesthetic value), as it can be seen on Fig. 3.

(iii) "3i" analysis: interest, institutions and ideas

Interests. There are, schematically, three kinds of interests, which reveal manners to consider the issue of rock removal and ploughing of the meadows.

- *Agriculture interests*: The objective of farmers is to improve provisioning ES of hay production and pasture grass production, in order to be autonomous in fodder. Ploughing meadow and rock removal are combined to transform meadows in mechanized and more productive plots. Three factors are encouraging these practices: a high constraint on access to land that leads to intensification; the new rules of CAP that deduce granite rocks from the calculation of eligible areas for subsidies, and the conversion to organic production that encourages autonomy in fodder. The agriculture interests is supported by farmers, but also agriculture councilors (Chamber of Agriculture) and Agriculture Department of the Park.

- *Environment interests***:** These interests focus on regulation ES and cultural ES of biodiversity, in order to preserve habitats and natural species. Ploughing the meadows is considered as a degradation of biodiversity because permanent meadows support many species of flora, insects or birds which are not present in temporary meadows. Rock removal has also to be avoided because granite rocks present a high ecological value, with lichen or migratory birds. The environmental approach is supported by some citizens, naturalist NGOs, hunter associations and "Watch and Knowledge" department of the National Park.

- *Heritage interests***:** These interests focus on cultural ES ("sense of place", historic heritage, landscapes). Granite rocks and permanent meadows are two elements that contribute to the image of a natural and preserved land and are integrated into commercial strategy of tourism operators. The recent labelling by UNESCO of the Mediterranean agro-pastoralism landscape as a World Heritage site in 2011 is a recognition of the heritage interest. The heritage interests are supported by tourism operators, tourists, public services dedicated to tourism, "Welcoming and Awareness" Department of the Park.

In conclusion, the recent changes concerning agriculture (new rules of CAP, transition to organic production) and concerning the heritage approach (UNESCO labels) leads to contradictory trends, leading on one hand to intensification, on another hand to maintain an extensive system. The debate on rock removal and ploughing of meadows (seen for some people as a brake on economic development of rangelands, for others as a lever) is the crystallization of the discrepancy related to these two trends.

Institutions.

In the core zone of the Park, rock removal and ploughing of meadows are managed by permissions given to farmers by the National Park. Farmers fill a permit application explaining their project, with the help of National Park specialists. The lasts make an important upstream work, studying with farmers the feasibility and constraints of this project. Then, the project is submitted to the Scientific Council of the Park, composed by experts from many different disciplines (agronomy, geology, ecology, architecture…). The Council gives an advice to the Director of the Park, who gives the final permission. In practice, few projects are rejected, but National Park specialists may advise farmers not to apply if the project seems not acceptable.

The system of permission now shows its limits. Indeed, the National Park is mandated to preserve "the character" of the Park. The issue of the impacts of these two practices – ploughing the meadows and rock removal – on the "character of the territory" is crucial for the National Park. Now, demands are processed case by case. This governance does not allow to apprehend the cumulative and threshold effects of these practices. At last, there can be misunderstanding between farmers and National Park, because they have difficulty to understand the long term strategy of each other.

Ideas. We have, schematically, three ideas of the human/nature relationships:

- *The agricultural referential:* the human/nature relationships are dominated by an anthropocentric and utilitarian perspective of the landscape. Landscape should be managed, to be under control to secure some specific provisioning ES. In this perspective, conservationists are seen as holder of opposite value system. Any conservation plan should integrate development issues and economic or market constraints.

- *The naturalist referential*: the human/nature relationships are based on stewardship and tend to preserve nature from human negative impacts. Human activities are mostly considered as both biodiversity and landscape conservation constraints, and farmers or hunters as hopeless anthropocentrists. Any development project should integrate biodiversity conservation dimensions.

- *The heritage approach:* the human/nature relationships are based on stewardships in order to preserve harmonious human/nature relationships and existing landscapes. The landscape should be managed to secure cultural ES. Any conservation or development project should integrate local knowledge, sense of place and secular landscape dynamics.

b. A role playing game to foster social learning

We designed a role playing game representing the trade-offs among ES underlying the debates over the issues of rock removal and the ploughing up of meadow.

(i) Objectives of the role-playing game

The first objective of this game is to increase the awareness of socio-ecological interdependencies. In the game, socio-ecological interdependencies are represented by three means. First, all the players depend from nature to reach their goals, and their actions have impacts on nature. This represents *the retroaction between society and nature*. Secondly, a single action can impact positively or negatively various ES at the same time, which is an illustration of *the trade-offs between ES*. At last, the objective of each player is to optimize one or two specific ES, which can be in synergy or antagonist with other ES. This can lead to various interactions between players: competition, conflicts, cooperation, negotiation… These behaviors reveals *the social interdependencies.*

The second objective of the game is to open debate on the governance of trade-offs between ES. The game simulates the actual governance (permits) and its limits: social tensions, difficulty to deal with cumulative effect and threshold effect. During the debriefing, we will create debate among participants on alternative modalities of governance.

Increasing awareness of interdependencies and exploring alternative governance are two aspects of social learning, which is the global objective of this role playing game.

(ii) Results of the game on social learning

The analysis of the two game sessions is still ongoing. At the time of writing the paper, we can only give preliminary results. For now, 6 aspects of social learning seem to be fostered by the game: increasing awareness of the links between farming practices and ES, increasing awareness of trade-offs between ES, better understanding of the ES dynamics, increasing awareness of social interdependencies, exploring the different ways to manage ES and increasing empathy between players.

The game increases awareness of the links between farming practices and ES. In the game, farmers can implement several practices: sending their cows in grazing lands, removing rocks, re-opening shrubby areas, ploughing up meadows to establish temporary meadows, or letting the meadows evolve naturally into permanent meadows. These practices aim to improve two provisioning ES (hay and pasture grass), but they also impact other ES: for example, rock

removal degrades the cultural ES of tourism and heritage, while re-opening shrubby areas improves simultaneously provisioning ES of pasture grass and cultural ES of heritage landscape of grazing lands. Farmers can choose between several practices to reach their goals, and then having a different impact on ES. For example, they can produce hay with a temporary meadow (that produce more hay but does not provide biodiversity) or with permanent meadow (that produce less hay but provides habitats for whinchats). That is why we can assume that the game makes visible how farming practices impact simultaneously various ES, but also that adapting farming practices is a way to encourage synergy between ES.

The game increases awareness of trade-offs between ES. We selected 6 ES in the game: hay production, pasture grass production, heritage landscape, tourism, water quality and existence value of biodiversity. In the game, the players identified antagonism between ES: for example, pasture grass production and the existence of biodiversity with Hen harriers are antagonist because this bird of prey nests in shrubby areas which produce no grass. Players also identified synergy, for example, between pasture grass and heritage landscape because grazing lands provide both provisioning ES of pasture grass and cultural ES of heritage landscape. Thus, the game makes visible the complex trade-offs between ES. It proves that it is difficult to optimize one ES without impacting (positively or negatively) others, but also that the trade-offs between ES can vary according to the type of practice and spatial configuration.

The game increases awareness of the dynamic of ES. The management of ES is difficult because they can hardly be predicted. In the game, we reproduced these effects (cumulative effect, irreversibility, threshold effect and uncertainties). The players identified these effects. For example, the uncertainties lead players to make hypothesis on the drivers of water quality. They wanted to preserve water quality but they didn't know how. In both session, the quality decreased but the players rapidly reacted to prevent it. The game sessions showed that uncertainties about ES dynamics is a major brake to management of trade-offs between ES and to dialogue between stakeholders.

The game increases awareness of social interdependencies. In the game, there are 7 players, who have an interest in one or several ES. Because there are trade-offs between these ES, the players are highly interdependent. For example, farmers are interdependent because they are collectively responsible of the evolution of ES (for example breeding birds or water quality). Agents of the National Park are interdependent since they have antagonist objectives but they have to take a common decision. Farmers and National Park agents are also interdependent: farmers depend on agents of National Park's decision for permission, but agents of National Park depend on farmers to reach their goal (maintaining some ES like existence of biodiversity or heritage landscape).

The game allows players to explore the different ways of management of trade-offs between ES. In the game, the trade-offs between ES are regulated by different means: by law, since agents of the National Park give or not permission to farmers and because agents of the National Park can give AEM to farmers, and by concerted management, because the agents of the National Park and the farmers negotiate to find a compromise . In practice, we have a combination of these two ways of management of trade-offs between ES.

The game increases empathy between players. During the game, we asked the players to exchange their roles (farmers played agents of National Park and *vice versa*), in order to foster empathy. During the sessions, we observed that farmers understand National Park agents' point of view, for example they realize that it is hard to allocate AEM with the objective of equity, with a limited budget. National Park agents also understand farmers' point of views. For example, they realize that the economic constraints can lead farmers to make choices that are against

their principles. According to the stakeholders themselves, the game sessions was an opportunity to better understand others' interests, strategies and constraints.

4. Conclusion and perspectives

To conclude, we come back to the expected impacts of collective workshops on social learning, and the potential added-value of the ES concept.

Expected impacts of this game on social learning

Daré and al. (2013) identified five kinds of social learning that can be expected from participatory processes: learning related to the issue under consideration, learning knowledge and techniques, learning about others, communicational learning, organizational learning. In this game, three kinds of social learning can be expected: learning about others, learning related to the issue at stake, organizational learning.

This game fosters *learning about others*: during the game, participants play the role of another stakeholder, which is an opportunity to understand others' objectives and constraints. This aspect was appreciated by players, especially because they have the feeling that they could be better understood by others father the game session.

By proposing a simulation of the social ecological system dynamics, this game encourages *learning related to the issue at stake.* The game represents the natural and anthropic dynamics by showing that ES are in interactions. It also make visible uncertainties, cumulative and threshold effects. The game also shows that stakeholders are interdependent. At last, the game can foster co-production of knowledge, by integrating various kind of knowledges: lay/scientific, local/global… The exchange of knowledge can improve the participants' understanding of the social ecological system.

This game gives an opportunity to improve *organizational learning*. In the game, the management of trade-offs between ES is really close to reality (permissions). The purpose of this game is to show the limits of this management, particularly the difficulty to deal with cumulative effects and threshold effects. This step can lead to open debate on alternative modalities of management of trade-offs between ES.

Added-value of the concept of ES

The design of the game is based on the conceptual framework of ES. We can identify three aspects of the added-value of the ES concept for designing the game. The first aspect relates to the systemic dimension of the concept. Indeed, revealing the trade-offs between ES enables to understand the functioning of the social ecological system and the interdependencies between different elements. The second aspects refers to retroaction between society and nature. The ES notion reveals that human society depends on nature to develop or maintain its activities; but we also show that society has an impact on nature by providing, improving, degrading or managing ES. The last dimension is the interdependency between providers and/or beneficiaries of ES.

During the gaming session, we make the hypothesis that using the concept of ES can foster collective action, as Barnaud and al. (2018) suggest. With a deeper analysis of these results and the ongoing social processes, the final version of this paper should be able to explore this hypothesis.

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