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Adopting a resilience lens to analyse adaptation to climate change on summer mountain pastures

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Abstract. Summer mountain pastures represent a key forage resource for many agropastoral farming systems, whose herds graze on these areas during summer. The extensive pastoral management of these areas enables to preserve both the forage value and the biodiversity of the vegetation. However, climate change threatens the fragile equilibrium of these complex socio-ecosystems, and existing analytical frameworks appear inadequate in this new context. In this paper we mobilise the concept of social ecological resilience in order to bring new keys to accompany adaptation to climate change on summer mountain pastures. Through this concept, we analyse the way diversity of vegetation is mobilized for adaptation at different management levels.

Keywords. Social-ecological resilience – Summer mountain pasture – Alpines pasture – Adaptation to climate change.

Adopter une grille de lecture « résilience » pour analyser l'adaptation des alpages au changement climatique

Résumé. *Les alpages sont une ressource estivale clé pour de nombreux systèmes agropastoraux. Leur gestion pastorale extensive permet de maintenir à la fois la qualité de la ressource et la biodiversité associée. Mais le changement climatique menace le fragile équilibre de ces socio-écosystèmes, et les cadres d'analyse existants ne permettent pas d'accompagner l'adaptation au changement climatique. Dans cet article nous mobilisons le concept de résilience pour apporter une nouvelle clé de lecture du fonctionnement des alpages. A travers ce concept, nous analysons la façon dont la diversité des végétations est mobilisée pour l'adaptation à différents niveaux de gestion.*

Mots-clés. *Résilience socio-écologique – Alpage – Estive – Adaptation au changement climatique.*

I – Introduction

Summer mountain pastures (SMP) can be defined as permanent grasslands used specifically for grazing in summer. They are used by many livestock farmers in the mountain regions and surrounding plains and cover a wide variety of spaces: different sizes and configurations, elevations and altitudinal zones. SMP are often used in a collective manner by several farmers. SMP are also multipurpose areas (tourism, hunting, logging, etc.) with a very rich biodiversity resulting from several thousand years of pastoral use. SMP are thus a good example of complex social-ecological systems (SES) with closely-linked human and ecological dimensions.

Climate change creates strong disturbances to SMP, which are highly exposed, and challenges the ability of these SESs to adapt (IPCC, 2014). Climate change causes two difficulties in two different timeframes. (1) In the short term of annual management, climate change results in an increase in inter-annual climate variability and extreme events, particularly summer droughts. (2) In the long term, climate change is expected to lead to a change in the type of vegetation, with major uncertainties as to future developments.

In response to climate change, adjustments have to be made at different management scales. The diversity of vegetation is said to be an important source of flexibility, but the current analytical framework and management-support tools (Savini *et al*., 1995) are not adequate to analyse adaptation to climate change. It is difficult to use them to understand the adjustments made on SMP or at SMP-farm interactions, in particular the way farmers and shepherds mobilise the diversity of vegetation, neither at an annual management scale nor at a multiannual scale. In this article we propose a new analytical framework based on the concept of social-ecological resilience, which is "the capacity of a social-ecological system to absorb disturbances and reorganize while undergoing change so as to continue to retain essentially the same function, structure, feedbacks and, therefore identity" (Folke *et al*., 2010). It is an increasingly widespread concept whose success depends on the promise of an operational character for management of SES. We propose to test the capacity of this framework to analyse the way diversity of vegetation is mobilised for adaptation to climate change.

II – Methods

We applied the method proposed by Walker and Salt (2012) to the case of SMP. We built a conceptual model of the functioning of SMP based on expert knowledge, through participatory modelling. We crossed this model with Walker and Salt's generic criteria conferring resilience to SES (diversity, openness, reserves, tightness of feedback (or detection and reaction capacity, reactivity), modularity, social capital) in order to build an analysis grid of criteria conferring resilience to SMP (Table 1). We illustrate the use of this grid through a focus on the way two contrasted study cases mobilise the diversity of vegetation.

III – Results

1. Summer mountain pasture management model and analysis grid

The model comprises a management sub-model and a biophysical sub-model. In this paper we only present shortly the management sub-model. This model comprises 5 interlinked spatial and time scales and makes it possible to define the functions expected from the vegetation in the SMP at different management scales. The first three of these five scales (day and "grazing route", pastoral season and "allotment", SMP season) correspond to the scales previously proposed by Savini *et al*. (1995). There are also two higher scales: the first encompasses the entire year to consider the interactions between the SMP and the associated farms; the second is the long-term scale that is essential to consider the lasting dynamics of the system with respect to the different spatial scales (changes in climate, vegetation, system managers, characteristics of the associated farms and their objectives for the SMP, etc.).

From this five management scales, we built an analysis grid of generic criteria conferring resilience to SMP, according to the "Men-Herd-Resources" triptych of the livestock farming systems approach (Gibon *et al*., 1999) (Table 1).

2. Analysis of two study cases

We present here how our model enables us to understand the way the diversity of vegetation is mobilized on two different study cases (DAR and CRO: Table 2), and conclusions on resilience on these two SMP. For DAR study case, due to multiple constraints, the usage of vegetation diversity at different management scales is vital for system resilience. That's why shepherds take care to maintain this diversity on long-term. Nevertheless uncertain property rights threaten the maintenance of vegetation diversity at the annual scale, which is the main adjustment level (less constraints). For

CRO resilience is permitted by altitudinal zonation and a reserve of very flexible vegetation in the undergrowth. Forestry management maintains balance in the habitat. The main risk stems from the arrival of wolves on the SMP, which would prohibit access to the undergrowth (today the main adjustment resource).

Table 1. List of generic criteria conferring resilience to SMP. Generic criteria identified by Walker and Salt (2012) are indicated in square brackets

Spatial and temporal management scale	People	Herd	Resource
Day and grazing route	Herders, with their know-how and knowledge [tightness of feedback], technics of shepherding [diversity].	Behaviour of livestock regarding its capacity to use the vegetation [diversity, tightness of feedback]	Functional diversity of the vegetation, diversity of sector configuration [diversity]. Configuration of the allotment: position of equipment, ease of herd movement [diversity, modularity]
Allotment and pastoral season	Herder (as above) [tightness of feedback]. Livestock farmers, depending on their involvement with the SMP (as above) [tightness of feedback], and on their collective motivation [social capital (leadership)]. Herder-farmer relations [tightness of feedback, social capital (trust)]. Availability of farmers (labour) [reserves, modularity].	Buffering capacity (genetic, health status and zootechnical objectives) [reserves]. Level of livestock needs (w.r.t. production cycle) [diversity].	Vegetation response diversity: supports availability of grass regardless of climatic hazards [diversity, modularity]. Preservation of supplementary resource in management [reserves]
SMP and SMP season			Diversity of soil and climate conditions (aspect, elevation, slope, soil types) to not suffer from the same events everywhere [diversity, modularity]. Existence of a supplementary resource to be used at any time in the season [reserves].
Year and SMP-farms system	Relationships between farmers, functioning rules [diversity, social capital, tightness of feedback]. Relationships with extension officers, sources of information [openness, tightness of feedback, social capital (social network)]. Hiring of herders, requiring the support of professional networks [openness, social capital].	Selection criteria for dates, summer pasturing livestock numbers and needs [tightness of feedback] Health status [reserves]. Genetic and behavioural differences between herds (breeds, selection criteria, previous learning) [diversity]. Ability to buy/sell livestock to adjust to resources [openness].	Bridging resource between farms and SMP to be able to adapt carrying capacity [reserves] or off farms: purchased fodder, pasturing outside farm land [openness]. Resources that can be grazed at different times on the farms [diversity]. Use of other summering areas [modularity, diversity]. Diversity of farming systems (location, functioning, weather experienced and weather sensitivity) [diversity]. Number of farms [modularity].
Long term	Change in pastoral association members, in farm selection criteria [diversity, modularity]. Learning [tightness of feedback].	Livestock selection criteria [reserves]. Diversity of selection criteria between farms [diversity]. Changes in the size of the herd [reserves]. Herd learning ability [diversity]. Changes in the herds and in selection criteria across farms [diversity].	Changes to spatial organisation and equipment: change in available land, in access to parcels, [reserves], in vegetation diversity at different scales [diversity]. SMP practices (grazing, maintenance): change in the quality of vegetation types (cf. state and transition model in appendix 1) [reserves] and in the diversity of vegetation [diversity]. Shift in the forage systems and choice of farms during their replacement [diversity, modularity].

Table 2. Comparison of the way in which vegetation diversity is used at different management levels on two individual SMP used for sheep grazing

SMP:	DAR	CRO
Configuration and types of dominant vegetation	Dry plateau (1300 m a.s.l.): intermediate subalpine grassland (high intra-type diversity); grazing woodland Crest (1900 m a.s.l.): Intermediate subalpine grassland of mediocre quality; no water	North side slope (1500-2500 m a.s.l.): Grazing woodland; productive facies; intermediate alpine meadows
Day and grazing	Usage of the functional diversity route of vegetation to balance the dailyrations (between rich and fibrous vegetation) and to adjust for weather conditions (between open spaces for nice days and woody spaces for rain and heatwaves).	
Pastoral season	Usage of the diversity of vegetation responses to droughts, the main hazard impacting grazing on this SMP with superficial soil (increased usage of undergrowth that is less drought-sensitive).	Usage of response diversity to early seasons (increased usage of early productive facies, during late springs and conversely).
Season and SMP	Due to the shortage of water in the Crest area, the capacity to use altitudinal layering is limited. Functional vegetation diversity is used to compensate: shepherds will use the different capacities to be standing stock to ensure sufficiently rich resources throughout the SMP season.	Essentially usage of the diversity of conditions allowed by altitudinal zonation to dispose of sufficiently rich resources throughout the SMP season.
Year and SMP – farm interaction	Wide variety of vegetation on the farm used in a different way each year to adjust to hazards; high capacity to shift SMP climb/descend dates (to compensate for the absence of early vegetation and variations in productivity).	Many constraints on the farm limiting the capacity to adjust SMP climb/descend dates. Hence, adjustments will be made on the SMP.
Long-term	Drop in quantity and diversity of resources available on the SMP: appearance of predators (wolf) that reduces the possibilities of grazing in the undergrowth. Progressive reduction in time spent on the SMP thanks to the usage of new areas at an intermediate elevation between the farm and the SMP but with a low level of control over the property. Improvement to the equipment (water reserves) to better use the existing resources on the SMP. Management of grazing pressure to preserve the functional diversity of the vegetation.	Grazing pressure adapted to the exact renewal of the resources on the open spaces and insufficient on the closed-off spaces, where it is the forestry activities that ensure that the habitat does not become overrun with brush.

III – Discussion – Conclusion

Social-ecological resilience theories are meaningful for SMP management. Among the concepts linked to social-ecological resilience is the concept of Panarchy (Gunderson and Holling, 2002) that we can summarize in two principles. (1) SES constantly evolve over time and according to the disturbances that cause them to adapt or transform. Sometimes they become more resilient and develop

their adaptive capacities, sometimes they become less resilient. There will always come a time when a very strong disturbance occurs and adaptability will be insufficient to cope. The system then exceeds a threshold and will transform itself to change functions, structures, feedbacks, and identity. This transformation may be forced, but it may also be desired to obtain a situation with improved resilience. (2) SES are made up of sub-systems at lower organisational levels and they are included in systems at a higher scale. These different levels of system organisation are not independent and a change in resilience at one level will have repercussions on resilience at the other levels. Developing adaptability at one level could necessitate a transformation at another level. The model that we built is in line with this understanding of the functioning of social-ecological systems. Different management scales have corresponding semi-autonomous systems: sectors, allotments, SMP, SMP-farm systems (Nettier *et al*., 2015). The challenge is to preserve or develop the adaptability of the SMP system and avoid reaching a threshold that would lead to the transformation of the SMP (abandonment for example). The different organisational levels interact and it is possible to make transformations at higher or lower levels to preserve the functions of the SMP (such as an allotment being abandoned or a disruption in farm functioning).

The Walker and Salt method that we implemented proved to be promising in terms of analysing the resilience of pastoral systems with a view to improving their management. The team of experts mobilised for modelling were already very close to resilience thinking. The construction of this model enabled us to put forward a vision of SMP as dynamic systems in a dynamic environment.

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