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Exploring Panarchy in Alpine Grasslands: an Application of Adaptive Cycle Concepts to the Conservation of a Cultural Landscape

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ABSTRACT. This paper explores approaches of applying the panarchy perspective to a case study of natural resource management in the cultural landscape of upland alpine pastures in northern Italy. The close interaction within the cultural landscape between alpine pasture ecology and the management regimes offers a strong fit with the concept of social-ecological systems and provides insights to appropriate and adaptive management of sites of conservation interest. We examine the limited literature available that offers a resilience understanding of such landscapes and address apparent gaps in the application through our interpretation and use of adaptive cycles and panarchy. We draft conceptual models of adaptive cycles considering ecological and socioeconomic information as acting in separate but interacting domains. Notwithstanding the difficulties in defining and measuring quantitative state variables, we found that a panarchy model can offer a powerful metaphor with practical implications for the maintenance of such alpine cultural landscapes. In effect, our panarchy interpretation of interacting adaptive cycles provides new insights into the description of and the future options for land use in our case study area. Some issues are only partly developed. We hypothesized measurable parameters that could be related to system resilience, such as alternative states, shifting thresholds, and regime stability, which are all dependent on adaptive processes; but we found quantification difficult even at a conceptual level. Nevertheless, we found it helpful to use nature conservation evaluation as a useful surrogate for measures of capital in adaptive cycles of vegetation. However, care is needed to distinguish between the descriptive metaphor using selective surrogate measures and real ecological behavior. Additionally we recognize the need to integrate this ecological understanding with cycles in socioeconomic domains and consider that interactions between the loss of both social and ecological capital would be interesting issues to explore further in our case study.

We suggest that resilience theory, through its focus on adaptive cycles interacting at different speeds and across varying geographic scales, offers useful insights into resource management and in particular for nature conservation interest sites, by focusing more on dynamics than on an optimal state of species assemblages. This may help to define sites and to achieve the objectives of Natura 2000 through the European Habitats Directive, offering a basis to guide a conservation of processes, in which cultural tradition and local ecological knowledge are valued.

Key Words: *adaptive cycles; alpine pastures; cultural landscapes; Natura 2000; natural resource management; panarchy*

INTRODUCTION

Cultural landscapes, according to the UNESCO World Heritage Committee (Rossler 2006), are landscapes that have “organically evolved” by association with and in response to their natural environment. They thus offer good examples of the concept of social-ecological systems. Indeed, Folke et al. state that a social-ecological system (SES) is an “[i]ntegrated system of ecosystems and human society with reciprocal feedback and interdependence” (Table 1 in Folke et al. 2010). According to Farina (2000) there are many types of cultural landscapes, all are shaped by initial landscape conditions and their socioeconomic and cultural contexts. Their complexity can be expressed in three main domains: ecological, cultural (or social), and economic. The type of linkages among these domains determines the system identity and persistence.

The interconnections, reciprocal effects, and feedbacks among human and natural systems are the core issue of resilience and SES studies (Holling 2001). Since its introduction in 1973 by the ecologist Crawford (Buzz) Holling, the term “resilience” has diffused into several disciplines (Holling 1973; for a short review see Folke 2006). According to Holling’s seminal works (e.g., Gunderson and Holling 2002), resilience is related to: (a) the amount of change a system can undergo and still remain within the same state, or maintain identity; (b) the degree to which a system is capable of self-organization, compared to lack of organization or organization forced by external factors; and (c) the degree to which a system can build capacity to learn and adapt.

The recent speculative developments about an integrated theory on resilience of SES attempt to explain how and under what conditions ecological systems and communities adjust and adapt or dramatically change their self-organization in response to slow changing variables or shocks (Lebel et al. 2006, Olsson et al. 2006, Walker et al. 2006). The resilience concept was originally linked to the adaptive renewal cycle model (Holling 2001) and the more recent panarchy concept

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(Gunderson and Holling 2002). This adaptive cycle comprises a four-phase model of growth, conservation, release, or collapse and reorganization and was deduced from observations of ecosystem dynamics, but has been applied across SESs (Gunderson and Holling 2002). The concept of panarchy identifies the significance of cross-scale dynamics and interplay between a set or sets of such nested adaptive cycles. Such cross-scale connections are suggested as existing in different and interacting ecological, economic, and social domains and may be associated with regime shifts within regional social-ecological systems (Kinzig et al. 2006). Such models can be seen as useful conceptual constructions providing a way of thinking, helping to understand how complex adaptive systems, such as cultural landscapes, operate (Folke 2006).

Highland pastures in the Alps particularly fit with the description of a cultural landscape, being pastoral grassland ecosystems having coevolved with human practices over centuries. Their management has had historical continuity that shows distinctive cultural identities (Cole and Wolf 1999) in different parts of the Alps. Their location near the altitudinal limit of tree growth emphasizes the significance of human drivers. Being dependent upon edaphic and climatic mixes of variables they have an unstable equilibrium requiring constant human interventions to be maintained.

These cultural landscapes provide a series of ecosystem goods and services to a variety of resource users, and managers have had to respond to changing environmental conditions and societal demand. They, similar to many others in Europe (Vos and Meekes 1999), are threatened by changes in ecological processes, e.g., climate change; human practices, e.g., abandonment of agricultural activities and mass tourism; as well as by social-economic changes, including a globalized market economy and changes in cultural values. To appropriately respond to these various drivers and levels of uncertainty, under a range of different perceptions and values, adaptive management by stakeholders is required (Olsson et al. 2006).

Our analysis focuses on a pastoral system of an Italian alpine province, referred to as a Malga system. A Malga system comprises a community-owned highland grassland area, with pasture or meadow use, that is associated with a mountain hut, cheese production facilities, and cattle sheds. The land is traditionally managed by a cattle herder and/or dairyman under community rules on behalf of cattle owners. The land that includes the Malga system investigated in our study site has been designated as the “Monti Tremalzo e Tombea” Site of Community Importance under the terms of the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (European Commission 2010). It is part of the Natura 2000 network of sites protected for nature conservation. We subsequently refer to Natura 2000 as “shorthand” for habitats that qualify for this designation (European Commission 2007).

Our objective has been to verify whether application of resilience theory in the management of cultural landscapes, applied to our case study of the social-ecological Malga system, would give us new insights into ecological and social processes and possible future scenarios for cultural landscape research. In particular, we describe components of the selected Malga system in terms of adaptive cycles and interactions described as panarchy. Additionally, we wish to explore a link between conservation and resilience theory and to associate these to cultural landscape research.

The current literature appears to have rarely drafted adaptive cycles for cultural landscapes per se, but rather focuses on single ecosystems at a time, e.g., lakes, forests, coral reefs. Also, although vegetation shifts characterizing adaptive cycle phases have been described and studied, we did not find examples for alpine pastures. We consider that a resilience theory application may support adaptive management of Natura 2000 sites and would be particularly relevant within the cultural landscape of alpine pastures.

We explore the literature in search of an appropriate methodology to apply the above concepts to our particular cultural landscape. The application section comprises a characterization of the study site, an exploration of which parameters can be identified within adaptive cycles, and an interpretation of cross scale interactions between adaptive cycles. Our conclusion focuses on general application of an adaptive cycle for the evaluation and management of Natura 2000 sites and related cultural landscapes.

ASSESSMENT OF RESILIENCE IN CULTURAL LANDSCAPES

The study of cultural landscapes is a recent issue in the human-environment research tradition. In addition to UNESCO guidance (Rossler 2006, UNESCO World Heritage Centre 2008), the European Landscape Convention (Council of Europe 2000) also recognizes the value of cultural landscapes and highlights their coupled natural/human dimension. European regions, especially the Alps, have a long history of landscape use (Viazzo 1989), ranging from prehistoric to present times, in which humans have acted as one of the key factors influencing ecosystem states. In general, such cultural landscapes and their characteristic management regimes are highly sensitive to changes in agriculture, economy, and practices, caused by changes in regional and international economies (Vos and Meekes 1999). In the past, economic capital and natural capital were maintained by local cultural capital, e.g., traditional ecological knowledge and its rooting in the community’s actions and beliefs, that acted as a filter between the different processes (Deutsch et al. 2003). Today, the local economic capital usually relies more on dynamic and open systems, e.g., tourism industry, and this has been changing the inner structures of local communities and the relationships between these and their local natural resources.

We reviewed the literature by searching for papers mentioning “resilience” and “cultural landscape”, in the period 1974-2011 in the Science Direct database. According to this review, out of about 220 papers only 10 studies follow or refer to the paradigm suggested in the Resilience Alliance workbook (RA 2007), based on Walker’s works (e.g., Walker et al. 2006), and extended by Folke et al. (2010). Over the broad range of papers examined, a resilience assessment integrating social and ecological domains is often simply mentioned or is suggested as required support for effective landscape management (Piussi and Farrell 2000, Rescia et al. 2010).

Nevertheless, we did find examples of similar or complementary approaches. These include the concept of landscape sensitivity that recognizes different responses across time and space. Some studies deal with forests and mountain areas with cultural landscapes that may have similar issues relevant to our case study. These often included examination of community involvement using participatory techniques. Examples of loss of resilience included economic and socio-cultural constraints that compromised actions to restore degraded landscapes and public preference for unsustainable use of a cultural landscape. It is hard not to conclude that the root cause of problems for the sustainability of cultural landscapes is a lack of understanding of ecological dynamics and of its resilience by land managers or the general public. We show a useful application of the concept of linked social-ecological systems to demonstrate to land managers the value of including ecological dynamics in their land use and land use planning. Our application equally demonstrates the relevance of governance structures and the need for local actors/community to consider the resilience of the local resource system in the environmental policies and strategies for the future.

We did not find applications of Holling’s four-phase adaptive cycle(s) in case studies of the cultural landscape, and we noted the difficulties of applying such a conceptual model to the complexities at a landscape scale. We overcame some of the difficulties by structuring our analysis of the Malga system using the approach to determine resilience surrogates proposed by Bennett et al. (2005). This method can be easily applied in our case study, by looking for operational definitions of phases and shifting variables in adaptive cycles, within the bigger picture across domains and scales.

APPLICATION OF RESILIENCE PERSPECTIVE TO THE CASE STUDY AREA

Our process was to examine application of the adaptive cycle model as a metaphor; to consider what parameters might be used to describe ecological structure and processes, and in particular to verify whether particular types of vegetation units could be described in terms of adaptive cycles. We then searched for indications of system resilience or vulnerability. We followed the Bennett et al. (2005) approach. This consisted of key questions in a four-step process. These comprised:

1. Assessment and problem definition, e.g., what aspect of the system should be resilient?
2. Identifying feedback processes: What variables are changing? What processes and drivers are producing these changes?
3. Designing a qualitative system model: What are key elements and how are they connected?
4. Using the system model to identify resilience surrogates: What moves the system from being controlled by one feedback loop to another? What is the threshold value of the state variable, i.e., a key variable that allows description of the future behavior of the system?

In our analysis, we addressed the above questions within Gunderson and Holling’s (2002) model of adaptive cycle and panarchy. In this paper, we concentrate on the ecological domain and its management objectives.

We draw on two years of field work and research in the alpine valley of Ledro, focusing on a selected Malga system. The research comprised examination of the grey literature for past uses, semistructured interviews, and some shadowing to identify land use practices and to understand current governance. The main interviews involved all the 12 farmers in the valley employed in full-time farming, and the one nonowner herdsman; other interviews involved local authority administration and local associations. We drew on available botanical data supplemented with some quadrat surveys to check species occurrence under different grazing practices and to deduce vegetation phases within the same pasture.

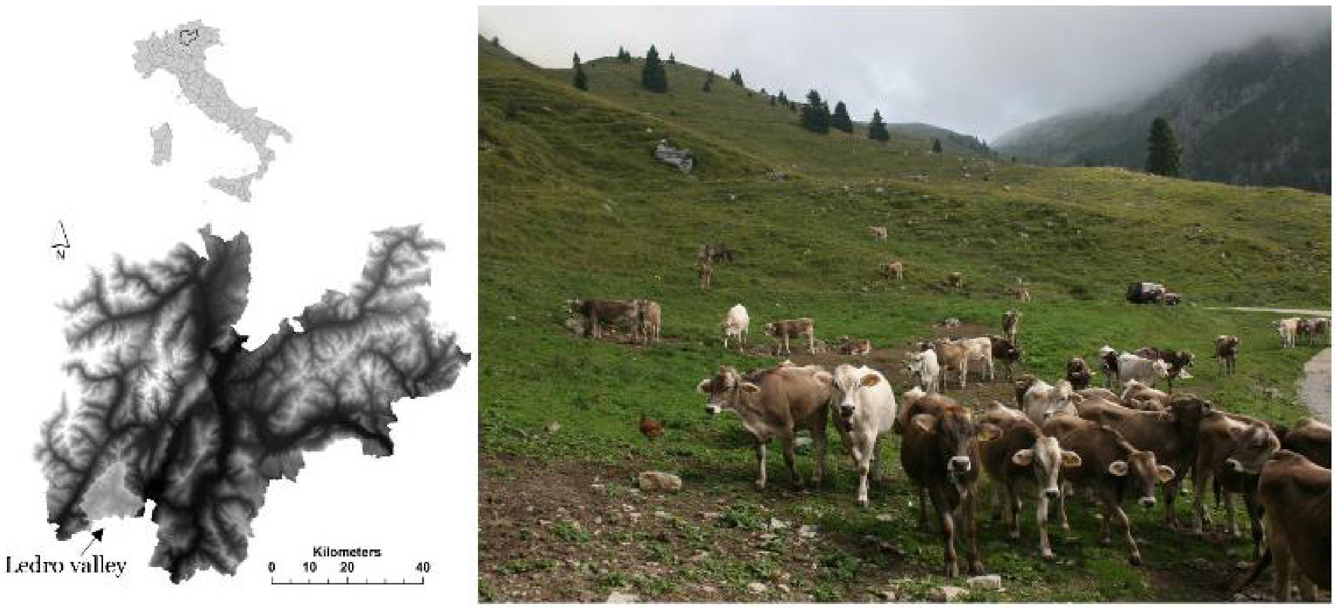
Finally, we identified and described adaptive cycles at the scale of stands of vegetation communities, and additionally considered natural capital at several scales in the selected cultural landscape. Natural capital is shown to be dependent upon management by farmers, and influenced by multiple-level governance, from interventions of local stakeholders and local markets to regional institutions.

The Malga system of Ledro valley

The valley is about 155 km², mainly covered by woodland, and lies between 65-2250 m altitude in the northern part of Italy, specifically in the Autonomous Province of Trento, situated in the southern part of the Alps (Fig. 1). The natural woodland shows an altitudinal zonation from broadleaved to conifers. The forest line appears to be around 1800-2000 m in this area with scattered “krumholz” woodland, that is, subalpine stunted woodland typically dominated by *Pinus mugo*, above and below this altitude.

In this territory, the calcareous Monte Tremalzo massif (1974 m) is particularly interesting. It is characterized by extensive

Fig. 1. Ledro valley, northern Italy, and a characteristic view.



woodlands, managed communal pastures, and hay meadows with the ecological potential to become woodland. These pastures consist of species-rich calcareous grasslands and also include several endemics, e.g., *Silene elisabethae*, often associated with chasmophytic communities, i.e., plants that colonize the cracks and fissures of rock faces. The common alpine pasture of the Tremalzo area has been historically open to grazing stock from four ancient parishes. Since the 15th century summer grazing was carried out by sheep and goats, but by the end of 18th century, under Austrian dominion a switch to cow grazing occurred. Large cowsheds within the alpine pasture as part of the Malga system, to protect against bad weather, are a 20th century innovation.

Since the late 1960s this self-contained production system has begun to fragment with abandonment of grazing, by switching to beef production and/or by linking any remaining dairy production with valley farms and dairies or by managing several Malga pastures as one commercial activity within pluriactivity. The number of families involved in cattle management has abruptly decreased and today the largest part of the local working population is employed in manufacturing or the tourism sector.

Relevant variables, states, and dynamics

The Malga system of managed mountain/alpine grassland provides a cultural landscape of high nature conservation interest combined with pasture that supports agricultural production. The environmental value in nature conservation terms is based on the criteria used to justify the inclusion of Tremalzo massif in notified Natura 2000 sites. In practice, conservation evaluation of Natura 2000 sites is done by reference to the interpretation manuals of the Habitats Directive (European Commission 2010). These provide lists of habitats, as vegetation types and species, and identify priority conservation interest for certain assemblages of plant species. In the grazed Malga ecosystem of Tremalzo the following vegetation assemblages were identified:

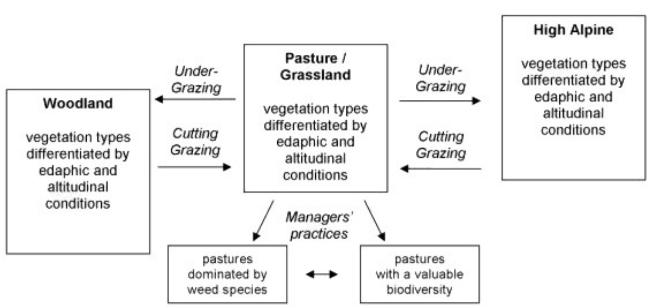
- Alpine and subalpine calcareous grasslands (type 6170, according to Natura 2000 lists);
- Seminatural dry grasslands and scrubland facies on calcareous substrates and important orchid sites (type 6210);
- Species rich *Nardus* grasslands on mountain siliceous substrates (type 6230);
- Calcareous rocky slopes with chasmophytic vegetation (type 8210), in the upslope areas often including the high alpine zone;
- Ungrazed or only intermittently grazed areas include bushes with *Pinus mugo* and *Rhododendron hirsute* (type 4070).

These vegetation types have a high nature conservation value and this value is associated with a stability of occurrence of desired indicator species at a required threshold. Thus, for nature conservation, specific occurrences of certain species may be considered as key system variables in adaptive cycles that include desired species vegetation composition and structure. These values are contingent upon a particular nature conservation objective, that of maintenance of desired Natura 2000 phytosociological types, but this may or may not be coincident with farmers' objectives.

The farmers' agricultural objective is to maintain or improve production of forage species. Each farmer can have different practices in pasture use, mainly in terms of timing of grazing and control of overgrazing. From this perspective, the agricultural issue is to identify and maintain the optimal grass/herb production and palatable species mixture. The species mixture appears highly sensitive to farmers' practice; subtle differences in daily practice of summer grazing result in visible differentiation at vegetation stands, confirmed by our rapid botanical examination. We identified nature conservation and agricultural objectives and associated variables to define those aspects of the system that should be resilient, and conform to step 1 of the Bennett et al. approach (2005).

In Figure 2 we present a simplified interpretation of possible system states as habitat types to help identify possible significant drivers of change and to provide context for indicators relevant to the conservation objectives of the Habitats Directive. This diagram is a first step to describe the dynamics in terms of adaptive cycles; this highlights that different management regimes may involve interactive and cumulative effects on the maintenance of species coexistence in grasslands (see a short review in Barbaro et al. 2004). Figure 2 helped our preliminary structuring of information to identify which system variables are changing and what processes reproduce these changes (see Bennett et al. 2005, step 2). Subsequent steps described below consider socioeconomic, cultural, and ecological drivers.

Fig. 2. Different vegetation compositions as system states and drivers of change between them.



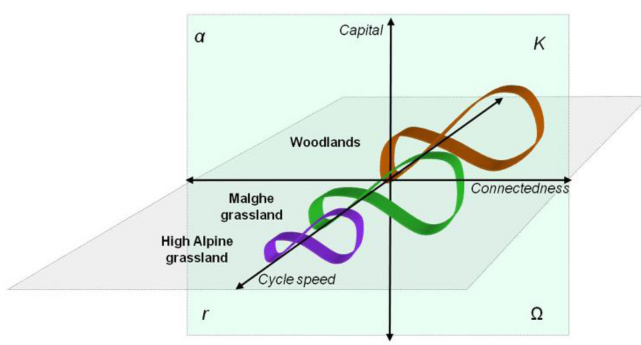
ADAPTIVE CYCLE MODEL – A PRELIMINARY APPLICATION TO THE MALGA SYSTEM

The conceptual model

According to Gunderson and Holling (2002), ecological and social systems tend to move, in their dynamics, through four recurring phases forming the adaptive cycles. The sequence generally goes from a rapid growth phase to a conservation phase in which resources are increasingly unavailable because they are locked up in existing structures, followed by a release phase that quickly moves into a phase of reorganization, and thence into another growth phase. The amount of resources accumulated in biomass and nutrients is regarded as "system potential," setting "the number of alternative options for the future" and as ecosystem "capital" (Holling 2001:394). Furthermore, the adaptive cycle model includes the concept of connectedness as "internal controllability," related to the degree to which the system can control its own destiny against external forces.

In our interpretative model of the Malga ecosystem, the vegetation dynamics are represented as three adaptive cycles (Fig. 3). Here, the capital (vertical axis) can be measured in respect to the objectives for a desired ecological state and conservation value. More precisely, the notion of capital is associated with conservation evaluation including aspects of biological diversity and functioning of the system, while the connectedness concept (horizontal axis) embraces the number of relationships between the system components. In this diagram, following Gunderson and Holling (2002), we have added a third axis of speed of cycle to highlight differences.

Fig. 3. Three adaptive cycles at the Malga system (based on Gunderson and Holling 2002).



Capital and connectedness

We have arbitrarily assigned the intersections of each cycle to the intersection of these two axes. The growth of capital, covering two phases, corresponds to an increase in "valued species" and related attributes (according to Natura 2000 criteria) occurrence, through the exploitation phase into a conservation phase. Connectedness is regarded as proportional to the amount of interactions and would rise with species number. The capital measure could eventually reach a maximum value beyond which a breakdown in the equilibrium between the drivers of plant succession and grazing pressure would be likely to cause a negative change, e.g., loss, in the species composition with a high capital value.

The triggers for this could be management interventions, i.e., farmers' practices, abandonment, or natural events. With loss of the capital value and of connectedness a release phase takes place. Beyond a certain change in vegetation, in terms of composition and pasture coverage, a return to the previous status quo through succession could be difficult, and a different suite of species could appear, corresponding to a reorganization of the system. However, if sufficient key species remain or conditions favor their re-establishment, the exploitation phase would lead to a recommencing of the cycle.

Cycle speed

In Figure 3, the z-axis represents the speed of cycles, increasing from the right to the left. In detail, the first cycle represents a component of the alpine grasslands, the chasmophytic calcareous grassland around the alpine zone. This contains species whose valued conservation attributes can show a quick response to the frequent fluctuations in climate or edaphic condition changes that occur at microscale (or stand scale) in this zone. The second cycle represents the Malga grassland with relatively longer lived species associated with high species diversity and with a comparatively higher resistance to microscale changes. The third cycle represents alpine woodland with longer lived woodland species and slow successional processes.

Each of the three conceptual cycles has its own characteristic relative speeds and drivers: faster for short-life grassland species and slower for long-life woodland species. These also vary depending on local edaphic and altitudinal conditions (seasonal). On a longer time-scale, i.e., years and decades, these adaptive cycles may be linked by possible cross-scale dynamics and shifts, i.e., panarchy, influenced by land management regimes (Fig. 2) in addition to the ecological drivers.

Calibrating the capital axis

Within the description above of qualitative changes in four different phases it is possible to link a capital gradient to species composition and richness as defined within Natura 2000 criteria. For the Malga grassland vegetation types the capital level can be defined in terms of desired vegetation types for nature conservation. This is of course only a partial representation of capital as envisaged by Gunderson and Holling but it does have the practical value of allowing scoring against objectives. The model should be interpreted with caution because the scaling and the apparent system behavior illustrated by the model adaptive cycle could vary with different selection of species attributes used to measure connectedness or natural capital. Thus, the shapes of cycles (in Fig. 3) would vary accordingly in all three dimensions. For example, our representation of the "rapid" alpine cycle, using selected chasmophytic species, may be modified by considering that most plant species in the true alpine zone are relatively long-lived with consequent effects on changes in aboveground cover and frequency within plant associations.

Some difficulties in constructing a realistic ecological model may arise from giving too much weight to Natura 2000 criteria, which could be too narrow to capture the extent of changes of species in different phases, e.g., for woodland dynamics. The same point may be considered as an issue that could be used to provide improvement of Natura 2000 criteria, which could be better oriented to consider ecological processes in addition to a single desired state of vegetation structure and composition. The model draws attention to the importance of considering the differential dynamics of vegetation components and highlights that interaction between cycles may have different effects at different stages of the cycles.

Relating the model to the grazed ecosystem of Tremalzo

Natura 2000 criteria do not necessarily reflect the real ecological relationships among the species involved in the scoring system, thus we need to verify whether vegetation types, used in evaluation of Natura 2000 sites, can be associated with adaptive cycle phases. We investigated this for a number of different habitat types occurring in the Malga ecosystem. We present in Table 1 a selection of habitats in which the four phases can be recognized and whose ecosystem capital can be described in terms of evaluation against nature conservation objectives used for Natura 2000. We identified some of the likely factors driving each phase and more generally the processes that might drive the system toward critical thresholds or affect phases of the adaptive cycle. Besides the ecological processes, we considered the management practices as further drivers affecting the phases of adaptive cycles.

The information in Table 1 was gathered on the basis of our ecological interpretation of information provided by interviews with pasture keepers and observation of grazing plots under different grazing practices. To simplify the argument we have not included the slow woodland cycle, although this further level of complexity exists, as presented in Figure 2. Including the woodland cycle would offer a further level of complexity in describing interactions between adaptive cycles, and to be realistic, a further objective for woodland management would need to be introduced.

Possible different shapes of the adaptive cycle: using the model to compare processes

In Figure 4 we present two different shapes of the adaptive cycle to speculatively explore how different objectives of agricultural management (black) and nature conservation (brown) can be considered and compared in the construction of an adaptive cycle model. We particularly focus here on the problem of different possible methods of measuring capital. In Figure 4 we are solely considering an ecological domain whose capital is measured through the proxy measure of nature conservation value according to the Natura 2000. The grass-rich vegetation community, considered as the outcome of agricultural management, is tracked (black) in terms of the scoring given by nature conservation criteria. Because of the

Table 1. Adaptive cycles in vegetation types (recognized within Natura 2000) of the Tremalzo case study.

	Adaptive cycle phases				
	K - conservation Measure of capital	Ω - release or collapse Factors decreasing capital and connectedness	α – reorganization Factors contributing to reorganization (resilience or transformation)	r – growth Factors involved in re-establishment of capital and connectedness	Driving forces toward system shifting
Fast cycle - High Alpine vegetation (Tremalzo example: 8210†)	• Maximum number of desired vegetation attributes for conservation objectives, e.g., Max no. of valued species for conservation objectives (described in Natura 2000) • Minimum number of undesirable vegetation attributes for conservation objectives	• Loss of valued attributes, e.g., key species, due to: erosion, nutrient addition, overgrazing	• Lack of weed species • Protection key species • Establishment of Malga rules or their application	• (Factors as in α – phase) • High level of ecological knowledge	• Natural and man-made erosion and debris • Long-term climate changes
Medium speed cycle – Malga grassland (Tremalzo example: 6170‡, 6210§, 6230ǀ)	• Max no. of desired vegetation attributes • Desired vegetation structure for both conservation and agricultural objectives • Minimum number of undesirable vegetation attributes	• Loss of valued attributes, e.g., key species through: over/ under grazing • weed species colonization • abandonment of Malga pastures • breakdown of land use rules, loss of skills in applying the rules • lack/loss of ecological knowledge in pasture use	• Protection/survival of palatable species and key Natura 2000 species through appropriate grazing • Socioeconomic supports to Malga managers	• Re-establish Malga regime • Community agreement on resource utilization proportionate to natural productivity	• Management regimes: low grazing, abandonment, or high intensity grazing

† (Natura 2000 codes) Calcareous rocky slopes with chasmophytic vegetation.
‡ Alpine and subalpine calcareous grasslands.
§ Seminatural dry grasslands and scrubland facies on calcareous substrates (important orchid sites).
ǀ Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas in Continental Europe).

prevalence of productive grass species its relatively stable K phase has a lower natural capital (than nature conservation management, by this evaluation) and the reorganization phase following any disturbed release phase would have lower capital value and connectedness because of lower biodiversity. In contrast, lightly grazed pasture (brown), termed as "conservation grazing," prevents the pasture reverting to scrub or woodland as well as limiting grazing pressure, and would tend to lead to a peak of valued species (for Natura 2000 criteria), corresponding to a higher capital value and to higher connectedness. However, this peak in production of valued rare species might be less stable and lead to a potentially faster decline.

From a whole system perspective, an integration of the two different objectives of pasture productivity and nature conservation would require different types of knowledge. We might hypothesize that the pasture manager, beyond the

Fig. 4. Two adaptive cycles for different grazing regimes and objectives (based on Gunderson and Holling 2002).

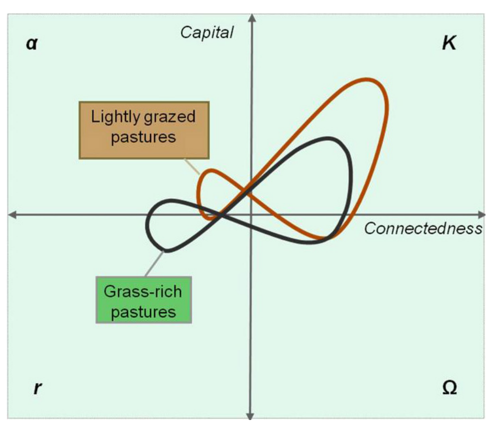


Table 2. Peaks of capital, drivers, shifting states, and evidence of resilience across scales in the Malga ecosystem.

	Stand	Field	Malga	Landscape
Peak of Capital Measure (within adaptive cycle described by changes in evaluation of vegetation characteristics)	1) Maximum sustainable grass production 2) Maximum score of desired Natura 2000 species attributes (See Table 1)	1) As at stand including control of weed species 2) Optimal vegetation mosaic dynamics through maintenance of conservation grazing	1) Maximum sustainable use of land 2) Maximum sustainable score for the site	1) Local community targets for Malga delivery of nature conservation and agricultural objectives 2) Natura 2000 experts' targets
Drivers of ecological adaptive cycles Note: Manager knowledge (part of knowledge capital in a socioeconomic domain) is pivotal driver across all scales of the ecological domain	1) Grazing practices and other agricultural interventions (normally defined at higher scale) 2) Natural succession (influenced by management interventions)	1) management intervention (e.g., weed control, manure practices) 2) manager intervention (e. g., clearing scrub)	1) definition of agricultural potential (influenced by economic drivers and community cultural contexts, which might elsewhere be described in separate socioeconomic domains) 2) definition of conservation values and resource availability for conservation management	1) As for Malga level but influenced by a wider range of actors and economic drivers (e.g., dairy production) 2) As for Malga level but influenced by a wider range of actors (e.g., tourism) and upper scale processes (e.g., provincial funding strategy)
Conditions for shifting of cycle state	1) Loss of production 2) Loss of Natura 2000 key species and/or vegetation stand attributes	1) Weed invasion and loss of hay production 2) Loss of Natura 2000 score through changed balance of mosaics	1) Loss of high quality grazing land 2) Loss of Natura 2000 priority habitats	1) Loss of profitability for local farmers 2) Loss of valuable species in the landscape
Evidence of adaptive management (likely outcome of resilience)	1) Stability of desired grass/herb mixture 2) Stability of phytosociological unit	1) As per stand 2) Balance between natural succession and desired vegetation types	Balance of land-use forms of production delivering a variety of ecosystem services to different sectors of users, through coordinated interventions (e.g., grazing policy, use of hay, land rotation, balances with forestry regulations)	

traditional knowledge needed to maintain pasture productivity, also requires additional knowledge on grazing and vegetation dynamics to achieve Natura 2000, and thus biodiversity, objectives.

In our case study, the farmers do have some ecological understanding of their pasture and this is mainly derived from guidelines and rules to obtain subsidies, e.g., in terms of maximum number of animals per hectare. However, only one farmer seems to have certain awareness about pasture carrying capacity inherited from his grandfather. We did not systematically explore the linkage between social networks and ecological traditional knowledge, but such anecdotal evidence suggests that today such linkage is weaker than in the past. Accordingly, in our case study as in the hypothesis above, the "conservation grazing" regime may require a higher level of social capital, including both traditional ecological knowledge plus expert knowledge shared through social networks. Hence, to achieve Natura 2000 goals, social capital seems to be required and would involve a set of conditions favorable for knowledge sharing and activation of adaptive management.

Thus, using social information and ecologically based evaluations we have demonstrated alternative ways of constructing adaptive cycle models that could help to design and understand the key parameters for linked social and ecological systems; this corresponds to step 3 in the Bennett et al. (2005) methodology.

UNDERSTANDING ADAPTIVE CYCLES ACROSS SCALES WITH A PANARCHY PERSPECTIVE

We have used the above analysis to refine our preliminary adaptive cycle description to attempt to include governance issues related to the pastures. In effect, pasture governance within our case study entails nested spatial scales, each related to a group of social actors such as farmers, officers of regional agencies for agriculture development, and the European Commission, each acting at different scales and hierarchical levels through different rules or institutions (sensu Ostrom 1990). In Table 2 we have largely confined our analysis to the ecological domain, neglecting for the moment the economic and social ones except in as much as they affect the ecological outcome, and considered the vegetation attributes relevant to two different objectives at four different scales. The scales refer to stand, i.e., the level of homogenous vegetation unit in terms of phytosociological class; to field, meaning a subunit of management including several species assemblages; to the Malga level, i.e., a management unit with numerous fields, which may consist of different mountain sides or grasslands; and to the whole cultural landscape, formed by local villages and farmers within a Malga system, specifically, a whole valley. Certainly, larger scales exist, hence, the considered nesting scales may only approximate to the differential feedback between domains and scales. Nevertheless, this exercise is a useful way to identify indicators of capital, drivers of possible adaptive cycles, and adaptation processes to be defined with the stakeholders, who themselves are located in various distances from the valley dependent on their specific interests to the SES in question, for example urban consumers of milk products or tourists. The possibilities of cross-scale and cross-domain interaction might result in “cascading” effects, as described in Kinzig et al. (2006), in which collapse at one scale or domain may trigger a collapse elsewhere and any inbuilt resistance to this represents a measure of the resilience of the system as a whole. Thus this approach of investigation through constructing a conceptual adaptive cycle model fulfills step 4 of the Bennett et al. (2005) methodology.

DISCUSSION AND CONCLUSIONS: PANARCHY, NATURE CONSERVATION, AND CULTURAL LANDSCAPES

Adaptive management to secure desired ecosystem services (e.g., Stringer et al. 2006) is not a new concept. Its application seems particularly prone to disciplinary misunderstandings concerning different interpretations of basic terminology, for example, about system resilience, shifting thresholds, and renewal cycles. We attempted to confront some of these difficulties by providing a system interpretation of the cultural landscape of alpine pastures. Our research question and hypothesis was that this approach may support landscape management for specified (divergent) objectives.

Within the ecological domain, field observation and ecological knowledge of plant communities allowed us subjective allocation of different vegetation types to different phases of Holling’s adaptive cycles. Here capital can be measured with respect to the objectives for a desired ecological state and conservation value. Evaluation systems within nature conservation, such as Natura 2000 criteria, provide ready-made references for proxy measures of natural capital. This means that the scaling of the adaptive cycle is socially derived and the shape this gives to the adaptive cycle is dependent upon the species used in evaluation and their ecological behavior. Nevertheless, the construction of an adaptive cycle model can inspire ecological insights, help assessments of social-ecological systems, and support decision making for their conservation. Ultimately, the adaptive cycle model is not intended as a predictive or quantitative model, rather as a conceptual tool and approach focusing on system behavior.

The construction of an adaptive cycle model for a SES involves describing the system under study in terms of adaptive cycle phases and panarchy interactions. Our approach in Tables 1 and 2 is conceptually capable of being drawn up for a range of social and economic objectives beyond the ecological one. Further refinement of the application may entail identification of quantitative indicators of capital (against the qualitative characterization of capital in Tables 1 and 2) and of value thresholds expected to rule the shifting of cycle states (see provisional designation of conditions for shifting in Table 2). Such identification should be developed in collaboration with relevant stakeholders, i.e., the actors involved in or affected by management interventions, because definition of such interventions, and criteria for success, will require agreement among relevant social actors.

An issue that then arises is how to align management objectives in a way that improves system stability and functioning. This may be addressed through social learning in the local community about the system resilience and related socioeconomic drivers at the different scales of individual Malga managers, their families, local communities, and wider communities. Our indicators of capital, shifting thresholds, adaptation, and drivers set out in Tables 1 and 2 are derived from consideration of the ecological domain, but they also include the different scales of interaction from Malga managers, community governance, and Natura 2000 regulations.

Currently the formerly strong link between the Malga system and the local community appears weakened; all the interviewed farmers expressed concern about nature conservation, but mostly with little awareness about ecological dynamic processes in their pastures and the possible impacts of their activity. A participative integration of objectives set for Natura 2000 into management planning at the community level might help to maintain a stable social-ecological system of pasture and pasture managers and other stakeholder groups. This requires, on one hand, merging local knowledge, e.g., older farmers’ familiarity of sustainable grazing, with expert knowledge, e.g., of key species in Natura 2000, and on the other hand, examining the importance of valued ecosystems for the entire social-ecological system that provides a shared reference for defining environmental values, and agreement on acceptable functions and services at landscape scale.

Although Malga managers are an essential component of the Malga system, the profitability of their activity today relies on public subsidies because of the competition of larger dairy firms in the open market. We agree with Vos and Meekes (1999) that a sustainable future for historic cultural landscapes requires multifunctionality that meets the demands of society and the farmers’ need of economically beneficial activity. This requires support from national and local authorities, and the public, for ecologically sound management and local solutions. Those responsible for landscape governance need both local knowledge and expert interpretation of management proposals against key ecological processes. Local dialogue is needed to verify to what extent ecological knowledge fits with the local system. This highlights the need to build social learning to enable governance that allows adaptive management of local and regional ecosystems.

In conclusion, our analysis has made more "tangible" the interactions between ecological and socioeconomic drivers at a variety of scales for the studied Malga system (Tables 1 and 2). This is particularly important for Natura 2000 sites where those responsible for higher level conservation decisions need to be more aware of the dynamics among ecosystems and local communities. The implications for Natura 2000 sites and cultural landscapes are that a shift in mental models is required from a focus on conservation of the status quo, involving existing values and species attributes, toward adaptive governance of social-ecological systems in times of accelerating economic and environmental change.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol17/iss3/art18/responses/

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