New perspectives and approaches in social-ecological landscape evaluation

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Abstract

To face the challenge of sustainable development of human settlements, an effective interdisciplinary integration has to be achieved by embodying the complexities of societies and economies into landscape ecology analyses. Such integration is getting far more complex today as landscape ecology is expanding its scope to respond to the challenges of sustainable development of human–environmental systems. In this paper we point out the recent and novel approaches applied in landscape ecology to move beyond the traditional separation of social and ecological components in social-ecological landscapes (SELs), considering SELs as a whole co-evolving and historically interdependent systems of humans-in-nature. To meet the challenges of sustainability, landscape ecology needs to strengthen its capacity to develop spatially explicit problem solving related to landscape sustainability issues. In this respect, addressing SELs represents a more pragmatic basis for envisioning how the real world works and how we would like the world to be, as SELs represent the spatially explicit integration of social-political and ecological scales in the geographical world. However, there is still the need to go beyond the traditional views embraced by landscape and urban planning where

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sustainability has been envisioned as a durable, stable condition that, once achieved, could persist for generations.

Keywords

Ecosystem services, environmental security, landscape dynamics, ecological networks, multiscale assessment, sustainability.

Introduction

Landscape ecology offers new concepts, theories and methods that highlight the importance of spatial and temporal patterns on the dynamics of interacting social-ecological landscapes (SELs), which represent the context for the development of human settlements. Landscape ecology is considered to be a holistic and transdisciplinary science of landscape study, appraisal, history, planning and management, conservation, and restoration dealing with the interrelation between human society and its living space (Naveh, Lieberman, 1994). It combines abiotic, biotic, and anthropogenic interactions, therefore it represents a multidisciplinary research program and a practical approach (Petrosillo *et al.*, 2008). New emerging applied fields are represented by ecosystem services valuation and environmental security, namely socio-ecological landscape risk analysis (Petrosillo *et al.* 2009, 2010a, 2010b); multi-scales ecological network (Petrosillo *et al.*, 2010b; Zaccarelli *et al.*, 2008a); spatial and temporal dynamics of social-ecological landscapes (Petrosillo *et al.*, 2010a; Zaccarelli *et al.*, 2008a, 2008b; Zurlini *et al.*, 2006 a, 2006b; 2007), and analyses of tourism sustainability (Lacitignola *et al.*, 2007, 2010; Petrosillo *et al.*, 2006, 2007, 2010b). In the following paraghaphs there are some of the most recent insights about the contribution of the landscape ecology to the analysis of social-ecological landscapes.

Social-ecological landscape risk analysis

The natural and semi-natural systems provide, through ecological processes and functions, a wide range of goods and services essential to support human wellbeing and quality of life (Costanza *et al.,* 2007). However, human activities are altering the ability of ecosystems to provide these services (Vitousek *et al*., 1997), so it is necessary to identify and monitor ecosystem services both locally and worldwide, incorporate the economic value in the decision process and identify the complex relationships among mankind, environment and services, recognizing their dynamic character. In particular, a relevant role is played by the maintenance of Ecosystem Service Providers (ESPs) in a disturbed context given by the temporal and spatial patterns of human land-uses at different hierarchical levels in a panarchy of social–ecological landscapes (Petrosillo *et al*., 2010a). In this context, Petrosillo and colleagues (2010a) have proposed a measure of the functional importance of ESPs given by natural areas and permanent cultivations in providing ecosystem services. This study points out how natural areas and permanent cultivations (olive groves and vineyards) will act in the interplay of disturbance patterns within SELs, regulating landscape mosaic dynamics and compensating disturbances across scales.
In performing landscape risk analysis it is important to take into account the historical dynamics of SELs with an approach based on 'learning by doing' (Gunderson, Holling, 2002). Some studies address the recent historical dynamics of SELs considering the ecosystem services provided by natural protected areas and the risks that may emerge considering the economic, social and environmental conflicts, arising from multiple uses. These studies, dealing with environmental security, are carried out through the integration of objective and subjective assessments of risk (Petrosillo *et al*., 2008). In this context, the protected areas seem to have important practical implications, because they support effective management practices tested in the past and then implemented, providing indication on action priorities. Furthermore, human perception represents the subjective component of environmental security that is fundamental

because security is meaningless unless there is somebody perceiving it as such (Petrosillo *et al.*, 2009). In this perspective, Petrosillo and colleagues (2009) assessed the temporal dynamics of land-use and land-cover mosaics, and indirectly of the natural capital they support, using the economic valuation of ecosystem goods and services as surrogate of the natural capital flow. The results of this research highlighted that not all environmental conservation policies have played an equal role in fostering the security of natural capital.

Multi-scale ecological networks

Several research attempts have been carried out to enhance the conservation of biodiversity through the development of ecological networks models to foster landscape sustainability. The conceptual patch-corridor-matrix model (Forman, 1995) considers each conservation area as a connected component of a regional network capable of sustaining metapopulations and biodiversity. This conceptual model is useful for the assessment of the matrix surrounding conservation areas for effective planning choices. The analysis of landscape context at different spatial scales is particularly relevant in highly developed regions where protected areas are geographically scattered and relatively small, and where ongoing human activities and new land-covers can be juxtaposed within increasingly fragmented native land-covers and habitats. In addition, human activities inside and outside protected areas take place at multiple spatial scales ranging from the regional differentiation of tourism (Petrosillo *et al.*, 2006) and agricultural areas (Zurlini *et al.*, 2006a), to the landscape decisions made by individual farmers within small agricultural fields. In this context, Zaccarelli and colleagues (2008a) have quantified the spatial pattern of disturbance at multiple scales and have investigated how the environmental conditions of differently spatial contexts may affect conservation networks in facing human disturbance. Their research represents a novel approach for describing the landscape context of protected areas, by assessing disturbance, measured by NDVI

(Normalized Difference Vegetation Index) changes. Often, strategies geared to sustaining human well-being like good production, do not guarantee the maintenance of biodiversity in terms of specific-diversity, but would foster the persistence of structures and functions that support ecosystem services, by preserving the natural disturbance regime and the adaptive capacity of the biotic component. Several researches have shown that the recognition of the natural value of a site according to the European Directives (Habitat and Bird Directives) is not sufficiently effective for the conservation of the natural capital, while the presence of a local management authority setting some limits on human activities that cause landscape changes, can increase the security of natural capital (Petrosillo *et al.*, 2009; 2010b).

Spatial and temporal dynamics of social-ecological landscapes

Through the application of tools like Geographic Information Systems (GIS), Remote Sensing and moving windows algorithm to landscape analyses, it is possible to assess the spatial and temporal dynamics of the recent history of SELs. Zurlini and colleagues (2006a) investigated the spatial patterns of human disturbances at multiple scales in SELs, and described an operational framework to identify multi-scale profiles of short-term anthropogenic disturbances to measure the amount and configuration of disturbance, by applying moving window algorithm to satellite imageries. Results allowed identifying scale intervals where disturbance has been most likely and clumped – i.e. fragility highest and resilience lowest, as retrospectively observed by past exposure to external pressures. In addition, Zurlini and colleagues (2006b) argue that the type, magnitude, length and timing of external pressure, its predictability, the exposure of habitats, and the habitat's inherent resistance have important interactive relationships that determine resilience at multiple scales. Therefore, they provided an operational framework to derive operational indices of short-term

retrospective resilience of real grasslands in a northern Italy watershed, and to find scale domains for habitat edges where change is most likely. The results suggested that the effects of external pressure are significantly related to habitat scale domains, resulting from the interactions among ecological, physical, and social controls shaping the systems. To interpret the spatial patterns of disturbances at multiple scales in SELs Zurlini and colleagues (2007) suggested that, within the socio-ecological framework, management of disturbances depend less on local drivers of disturbance and more on broader-scale drivers. Since disturbances may be imposed at multiple scales, species could be affected in different ways by disturbance in the same place, and a potentially way to appreciate these differences is to look at how disturbances are patterned in space at multiple scales (Zurlini *et al.* 2006a, 2006b). Therefore, taking into account the scales and patterns of human land-uses as source/sink disturbance systems, Zaccarelli and colleagues (2008b) described a framework to characterize and interpret the spatial patterns of disturbances along a continuum of scales in a panarchy of nested jurisdictional SELs like region, provinces, and counties. By using moving windows they identified multiscale disturbance source/sink trajectories in the pattern metric space defined by composition and configuration of disturbance. This study clarified the potential roles of natural areas and permanent cultivations in buffering landscape dynamics and disturbances across scales. In addition, they highlighted that in the real geographic world spatial scale mismatches of disturbance can occur at particular scale ranges because of cross-scale disparities in land-uses for the amount of disturbance and/or the lag distance of disturbance configuration, leading to more or less exacerbation of contrasting source/sink systems along certain scale domains.

Analysis of tourism sustainability

Tourism is the cause of numerous environmental pressures but, at the same time, it represents a source of income being one of

the main productive sectors of SELs. In light of this, Petrosillo and colleagues (2006) addressed the risk assessment of tourism environmental pressures for 10 SELs. They combined two models to perform the assessment: the Holling's conceptual sustainability model (Gunderson, Holling, 2002) and a fragility model (Zurlini *et al.*, 2006b). The results suggested that the environmental pressure due to tourism could not be adequately represented by the official tourist presences in areas characterized by mass-tourism. In this context, Lacitignola and colleagues (2007, 2010) focused on the interplay between tourism and ecosystem quality in marine protected areas, developing a model of SELs based on tourism. In particular, by distinguishing two main tourist typologies – mass and eco-tourists, they focused on the interplay among tourists, quality of ecosystem goods and services and economic capital, to provide a tool for scenario building useful for effective sustainable management of tourist destination. Under this line of research the period-doubling route to chaos has occupied a prominent position and it is still object of great interest among the different complex phenomena observed in nonlinear dynamical systems. This aspect is of relevance in the context of adaptive management of tourism-based SELs, since these period-doubling reversals could in fact be used to control chaos, since they potentially can act in suppressing possibly dangerous fluctuations.

Finally, the management of recreational ecosystem services depends on how they are perceived by people, so that to improve their management it is necessary to consider the perception of their users (Daily, 1997). Research carried out by Petrosillo and colleagues (2007) addressed the general problem of tourist perception in a marine protected area, detecting a different perception mainly related to visitors' place of residence.

Conclusions

To face the challenge of sustainable development of human settlements, an effective interdisciplinary integration has to be

achieved by embodying the complexities of societies and economies into landscape ecology analyses. Landscape sustainability can be considered in terms of order and disorder of SELs, where order implies causality, well-defined boundaries and predictable outcomes, while disorder implies uncertain causality, shifting boundaries and often-unpredictable outcomes. Recently, Zurlini and colleagues (2012) and Zaccarelli and colleagues (2012) addressed the interplay of order and disorder in SELs using spatiotemporal analysis of entropy-related indices of NDVI time-series. The aim of these researches is to help interpret what an increase of order/disorder means with regards to SELs, and the underlying drivers and causes of conditions in SELs. The approach can be used to increase spatially explicit anticipatory capability in environmental science and natural resource management based on how the system has responded to stress in the past. These advancements should greatly contribute to the application of spatial resilience strategies in general, and to sustainable landscape planning in particular, and for the spatially explicit adaptive co-management of ecosystem services. In conclusion, there is the need to go beyond the traditional views embraced by landscape and urban planning where sustainability has been envisioned as a durable, stable condition that, once achieved, could persist for generations.

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