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RAPID COMMUNICATION

Landscape multifunctionality: a powerful concept to identify effects of environmental change

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Abstract The interdisciplinary concept of landscape multifunctionality provides a suitable platform to combine or disentangle effects of multiple environmental stressors acting on the landscape. The concept allows mapping of trade-offs, synergies, and priority conflicts between individual landscape functions, thus providing easily accessible, hands-on means to communicate findings of environmental research to decision makers and society. This rapid communication provides an overview of current developments and potential future research avenues in landscape multifunctionality.

Keywords Environmental change assessments · Landscape multifunctionality · Regional environmental change

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Landscapes and ecosystems provide benefits (goods and services) to society which include both physical and cultural resources (e.g., environmental quality, food, esthetic qualities) which are of great societal value (de Groot 2006; MA 2005). These services are the annual flow of benefits provided by the "natural capital" (e.g., de Groot 2006) or "stock" (Kienast et al. 2009) of a landscape or ecosystem. These "stocks" are the capacity of a landscape to provide services. They are represented in the landscape either by landscape structures (e.g., vegetation, topographical constraints, land cover) or by ecosystem processes (e.g., net primary productivity). It has been suggested to use the term landscape functions (de Groot 2006; Haines-Young and Potschin 2009) to describe the composite nature of the landscape's capital stocks. The literature (Bolliger and Kienast 2010; Costanza et al. 1997; de Groot et al. 2002; Hein et al. 2006; Kienast et al. 2009; MA 2005) suggests that a wide range of landscape functions (stocks) and associated services (flows) can be identified belonging to four major groups: (1) production functions, (2) regulation functions, (3) habitat functions for maintaining ecological structures/processes, and (4) information functions. Overall, the topic of landscape functions currently seems to gain increasing attention across a broad range of communities dealing with environmental issues (e.g., http://www.eea.europa.eu/publications/briefing_2008_2).

Typically, landscapes are characterized by a variety of overlapping functions. Multifunctionality assessments of landscapes are therefore needed to allow identification of the potential benefits that a landscape can provide to society (Helming and Wiggering 2003; Brandt and Vejre 2004). In a given region, some landscape functions may be beneficial, some adverse, some may be synergetic, and some may be sources of conflicts. Some functions may be spatially and temporally segregated; others may become effective at the same location at the same time. Hence, landscape functions may be particularly useful for public policy making which often relies on efforts to negotiate trade-offs between potentially conflicting demands of various stakeholders (Gimona and van der Horst 2007).

Research needs

Analyzing trade-offs between landscape functions and related services

It has been recognized that multifunctionality assessments of landscapes may be a powerful tool to analyze trade-offs between landscape services (Brandt and Vejre 2004; Helming and Wiggering 2003; Kienast et al. 2009; Potschin and Haines-Young 2006; Zebisch et al. 2004). For example, trends in land-use change lead to an increase in forest coverage (Albert et al. 2008; Tasser and Tappeiner 2002) with largely negative consequences for open-land species (Bolliger et al. 2007). This is particularly true for marginal and mountainous European regions where economic development has resulted in abandonment of low-intensity agriculture (Bätzig 1996; Maurer et al. 2006; Meeus et al. 1991). As a consequence, land-use changes are generally considered to have a negative impact on grassland species (Bolliger et al. 2007; Dullinger et al. 2003; Laiolo et al. 2004). Contrarily to grassland species (representing habitat functions), the effects on C stocks in terrestrial ecosystems (representing regulation functions) are considered positive as forests are the most important C sink (Janssens et al. 2003). Thus, reforestation may cause severe concerns for conservation (representing habitat functions) while, at the same time, provide an important mitigation strategy for reducing the increase in atmospheric CO_2 concentrations (Bolliger et al. 2008).

Mapping multifunctionality

Visualizing landscape functions as spatially explicit entities adds an important component to research conducted in the context of landscape multifunctionality. With maps, policy makers and planners are able to fully assess the set of landscape capacities at specific locations in an intuitively and comprehensive way. An increasing number of authors try to map landscape functions and trade-offs across large areas (Egoh et al. 2008; Eigenbrod et al. 2010; Kienast et al. 2009; Naidoo et al. 2008; Nelson et al. 2009; Swetnam et al. 2010). This attempt is challenging since landscape functions are rarely a direct outcome of one precisely measured variable in space and time. They rather relate to a blend of different drivers with a high spatial and temporal data heterogeneity (e.g., resolutions, time windows). Thus, data interpolation is an important prerequisite of landscape function mapping. Often, spatial data are used in combination with decision rules (look-up tables) for mapping landscape functions (e.g., Gimona and van der Horst 2007; Kienast et al. 2009). Decision rules rely on available expert knowledge and usually express assumptions that cannot be related spatially explicitly to sites. To overcome this drawback, promising approaches have recently been presented which explicitly consider the spatial heterogeneity and complexity of landscape characteristics (e.g., Willemen et al. 2008). Given the large spatial GIS databases that are currently available, future methodological progress will hopefully allow to use a broad range of the currently available spatial GIS datasets for multifunctionality assessments.

Fighting mono-causality

Current assessments often provide mono-causal information on individual functions or individual stressors, and it remains largely unknown how the different processes interact. For example, many studies deal with effects of climate change (Beniston 2007; Beniston and Garcia-Herrera 2008; Bonnard et al. 2008; IPCC 2007; Lopez-Moreno et al. 2008; Metzger et al. 2006) and land-use change separately (Bolliger et al. 2007, 2008; Laiolo et al. 2004; Lütolf et al. 2009; Menzel 2000; Steck et al. 2007; Verburg et al. 2006, 2009; Verburg and Overmars 2009). Promising approaches for integrated effects of both climate and land-use change are presented by e.g., Metzger et al. (2008) or by Bradley (2010) who separate impacts caused by land use from impacts caused by climate change.

Emphasizing the temporal dimension of multifunctionality

It has been shown that climate change leads to changes in habitat functions, e.g., the distribution range of communities/species (Thomas et al. 2004; Thuiller et al. 2005). Thus, it may well be that currently protected species (e.g., in dry grasslands) may be driven out of their current reserves in the future (Araujo et al. 2004; Kienast et al. 1998). Additionally, invasive species may affect current species compositions (Bohren et al. 2008; Scharfy et al. 2009), may become problematic for public health (Ackermann-Liebrich et al. 2009), or species and populations may face extinction (Thomas et al. 2004; Thuiller et al. 2005). Promising examples of dynamic multifunctionality assessments are given by e.g., Hasselmann et al. (2010), Hersperger and Bürgi (2009), Houet et al. (2010), or Verburg et al. (2010).

Emphasizing the anthropogenic dimension

Production, regulation, and habitat functions appear to dominate the literature dealing with environmental issues. However, the anthropogenic dimension requires increasing consideration in scientific environmental change studies, since land management and policies may overrule landscape-scale effects of environmental change to a considerable extent (Willemen et al. 2008). For example, if former fields and pastures are increasingly covered by shrubs and eventually by forest, scenic beauty, an important landscape resource, may be at risk (Buijs et al. 2006). Previous studies show that a low to medium degree of spontaneous reforestation (patches or bosques of forest cover dispersed throughout a matrix of open space) is often found particularly attractive (Hunziker 1995; Hunziker and Kienast 1999), but see Gehring (2006). It has also been shown that conflicts may arise when the visual appearance of landscapes opposes public preferences (De la Fuente de Val et al. 2006). Thus, increasing attention should be given to the anthropogenic dimension of landscape-change assessments by addressing and developing the yet limited availability of information functions such as esthetic, recreation, cultural and artistic, or historic information.

Landscape multifunctionality is a challenging field to explore in current and future landscapes subject to a changing environment. Landscape multifunctionality can only be addressed if larger, interdisciplinary research consortia are willing to collaborate, merge current knowledge, and conduct new or supplementary research. No doubt, however, that the current manifold environmental issues are pressing and that scientific results are not easily communicated to land managers, politicians, and other decision makers. Visualization of landscape multifunctionality through maps of landscape function (changes) may provide helpful baseline information for discussions with stakeholders if tackling (future) requirements to support a dynamic environment is a priority for environmental research.

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