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Special Issue Editorial

Landscape indicators – Monitoring of biodiversity and ecosystem services at landscape level

1. The challenge

A global increase in the anthropogenic load on ecosystems has resulted in the loss of near-natural habitats, species and structural landscape elements as well as aesthetically attractive scenery. This perceptible decline in biological diversity is undesirable for society. People generally appreciate biological diversity (or, in short, biodiversity) as a valued natural resource, while politicians have meanwhile come to recognize their responsibility to preserve it worldwide. Furthermore, it is becoming increasingly clear that the loss of biodiversity is causing a reduction or even loss of important ecosystem services. For these reasons, there is an urgent and growing need to control the various pressures on ecosystems and to ensure sustainable land use. In order to meet the goals of the Convention on Biological Diversity (United Nations, 1993), scientists as well as the general public require a clear understanding of biodiversity. The CBD provides a formal definition of biological diversity as 'variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' (United Nations, 1993, Art. 2). According to Haber (2008), however, this three-tiered concept of diversity has to be expanded to include 'diversity of structures, forms, colours, of physiology and interactions of organisms, and also the landscape level.' Currently, there is no generally accepted understanding of the term biological diversity in the context of ecological stability and equilibrium. The terms ecology and biodiversity are in fact used very broadly within societal and political discussions, whereby the meaning becomes blurred. At present, we lack any comprehensive and consistent scientific conceptual framework that could provide a stable scientific basis for analyses, monitoring and decision-making to safeguard biodiversity.

Rather, the relevant disciplines of biology, landscape ecology, landscape planning and several other academic disciplines are still competing to identify which components of biodiversity must be considered and explain how these components are related to one another. Progress has been achieved in some fields, thereby contributing to a more rational approach to the conservation of threatened natural resources and the associated quality of life. In this issue we highlight some promising developments along with conceptual contributions, quantitative measurable indicators, structural features and ecosystem services.

The research community in landscape ecology can make a useful contribution by quantifying particular features of ecosystems and determining their role and significance within a consistent concept of biodiversity. Current tasks are the mapping and visualization of ecosystems, biodiversity and their services in order to convince ordinary citizens, politicians and private investors to place greater value on biodiversity and to reflect this in their decision-making. For this purpose, we need solid scientific indicators to reveal general trends as well as spatially-explicit results for regional and local measures. While unable in this Special Issue to draw up a comprehensive theoretical concept, we do intend to give insights into recent research on indicators at the landscape level in the field of biodiversity and ecosystem services.

According to the Convention on Biological Diversity (CBD), biodiversity should be considered at the level of species, between species and ecosystems. As mentioned above, this focus should be expanded to include the level of landscapes. In public perception and in many studies, biodiversity is simply equated with the number of species or specific groups of species, i.e., one level only. Yet species cannot exist without the context of required habitats. Therefore, habitats and the entire landscape pattern must be taken into account at a second level. Two core interests of landscape ecology are the quantification of landscape structure by means of landscape metrics and analysis of how this structure is related to species diversity. The current Special Issue also shows how research in this field is a strong driver of indicator development at the landscape level. The genetic level of diversity – as a third, or better *underlying* level – was long neglected, perhaps due to the challenges of genetic analysis and measurement but also the difficulty of integrating this information into a more general approach involving taxonomic and structural indicators. Aspects of intra-population diversity also relate to the level of genetic diversity. Therefore, this Special Issue offers a new theoretical concept to address intra-population diversity and to integrate this with the other aspects of biodiversity (Bukvareva, 2018, in this issue).

2. The status of ecosystems and indicators for ecosystem services

The concept of ecosystem services (ES), which is currently shaping the debate on sustainable land use and management, is closely related to the preservation of biodiversity (Millennium Ecosystem Assessment, 2005; Haines-Young and Potschin, 2009; European Commission, 2014). Although humankind exploits the services of ecosystems and landscapes, and experts are becoming increasingly aware of the value of natural processes in ecosystems, there is still no widespread acceptance of these facts or of the need to take action to safeguard these services.

Clearly, we require indicators for biodiversity and ecosystem

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services that can be regionally quantified. For example, the EU asked its member states to report regularly on the state of ecosystems and ecosystem services in such a way as to enable comparison between countries (European Commission, 2011). The underlying motivation for such mapping and assessment is the preservation of biodiversity, which encompasses diversity in land use, landscape structure and ecological connectivity. Indicators should be selected and calculated in a way that allows regular monitoring using nationwide public data. The contributions within this Special Issue give an overview of indicators on landscape diversity, landscape heterogeneity and associated ecosystem services. In particular, methods for mapping, cartographic analysis and evaluation are explained below. They show that while biodiversity partly forms the basis for the provision of ecosystem services (although not to the same degree in each case), it is also a service in itself, providing habitat functions and ethical values. Uncovering the complex interrelations between biodiversity, landscape structure, ecosystem services and their impact on human well-being offers interesting scientific insights as well as useful practical findings for landscape design and management (Albert et al., 2016).

In this issue, Nowak and Grunewald (2018) investigate how to characterize the sustainable use of landscapes in terms of landscape services (LS). They use landscape metrics, e.g., to investigate the significance of landscape diversity and connectivity, whereby composition metrics (proportion of forest and arable land) allow the identification of landscapes dominated by regulating and provisioning LS, and configuration metrics (especially Shannon's Diversity Index and Contagion Index) detect landscapes with high cultural LS.

The ES concept was developed to demonstrate the value of nature and to provide motivation for its careful and sustainable use. In view of the fact that most services directly benefit humans, the measurement, mapping and assessment of ES are not ends in themselves, but rather help us to place sufficient value on nature. Since the concept is rooted in biodiversity, each indicator must be assessed regarding its significance for the use and preservation of biodiversity. While some goods, processes and potentials are essential for human survival and well-being (Bastian et al., 2014), from an economic point of view, services only exist if there is demand for them. Therefore, we must distinguish – at the very least – between the supply of and demand for services (Syrbe et al., 2017). Indicators can express either qualitative or quantitative values. In the latter case, they may also serve as a basis for monetary valuation. In order to provide information on how to improve the state of the environment and to maintain biodiversity, appropriate indicator maps can help uncover risks for ecosystem health, the unsustainable use of resources, harmful impacts on landscapes, vulnerable assets and impaired flows of ecosystem services (Bagstad et al., 2013). They can also be used to identify mismatches between the supply of ecosystem services and demand from the socio-economic system. Additionally, interdependencies between trade-offs (mutually exclusive services) and synergies (mutually supportive services) can be better identified using maps and indicators (Nelson et al., 2009).

The ecosystem network and socio-economic system must be placed within a consistent framework that takes into account the mutual impacts and intrinsic subsystems, and which is amenable to different academic perspectives. Fig. 1 brings together the above-mentioned subjects, highlighting those that can be used for indicator generation (boxes with white borders). The ecosystem on the left can be characterized by indicators of condition and health (top), which are closely interlinked with structural features such as bio- and geodiversity. These components form the basis for ecosystem potentials, i.e., the capacity to deliver ecosystem services in a sustainable way. The supply of ecosystem services (bottom) depends not only on the (more or less natural) potential but also on human impacts. These impacts to the ecosystem can serve to worsen both the ecosystem condition and supply or, conversely, act to maintain or even co-produce services, i.e., the active contribution of people to enhance particular ecosystem services. On the right we see possible indicators of the socio-economic system regarding the ES approach, in particular the benefits to humans from a flow of services as well as the demand for services depending on various needs and preferences (see Fig. 1).

The following articles of this Special Issue explain various topics in detail and give examples of possible indicators as applied within local or regional case studies.

The second aim of Action 5 of the EU Biodiversity Strategy is for EU member states to conduct a nationwide assessment of ecosystem services by the year 2020 (European Commission, 2011). Basically the indicators should represent the condition of ecosystems as well as their services (Fig. 1). Most countries have recently begun developing their own indicator systems, which, however, in most cases are incomplete or (such as the systems of the UK, Finland or Flanders) fully adapted. Germany is developing a set of indicators for selected ecosystem services, including supply and demand indicators for ecosystem services for several classes of the Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin, 2017). A selection of indicators for provisioning, regulating and cultural ecosystem services are currently under development and discussion. Syrbe et al. (2018, in this issue) present the selection process and assessment results for one class, namely soil erosion.

Walz and Stein (2018, this issue) show how diverse landscapes fulfill two aims: as attractive landscapes for nature-based recreation while simultaneously preserving biological diversity. They propose an indicator derived from eight equivalent parameters for the determination of human use (s. Fig. 1) and landscape structure. The data provides an initial overview, e.g., for the planning of major powerlines as part of Germany's *Energiewende* (i.e., the shift to renewable sources of energy) or as a measure of the importance and potential of a region for nature-based tourism. This enables an evaluation of the provision of cultural ecosystem services for landscape-oriented recreation (Grunewald et al., 2016).

Of course, the aesthetic quality of a landscape is hardly measurable without asking the opinion of local residents. Here desires can be expressed through social media (s. Fig. 1). Photographs, in particular, can be used to assess and map the value of a landscape's cultural ecosystem services, which in turn supports landscape planning. The identification and perception of landscape services can clarify the emotional response of people to several landscape types. Oteros-Rozas et al. (2018, in this issue) have conducted a content analysis of photos uploaded to social media platforms, positing that such images represent the demand (s. Fig. 1) for cultural ecosystem services. As a result, the researchers are able to show how cultural heritage, social and spiritual values are particularly linked to landscapes with pasture and grasslands, as well as urban features and infrastructures, i.e., more strongly anthropogenic areas. The results are of interest both methodologically in the face of the increasing use of geo-tagged photos in ecosystem services research as well as for the identification and comparison of landscape values in Europe's cultural landscapes.

Sutherland et al. (2018, in this issue) argue that more value should be placed on regulating ecosystem services, which are fundamental to biosphere integrity, human welfare and the provision of most other ES. Lack of attention towards regulating ES can lead to unintended management trade-offs that create risk for human well-being and can cause immediate or delayed impacts on cultural and provisioning ES. Sutherland et al. (2018, in this issue) show how ES assessment frameworks can be improved by including indicators for regulating ES that differentiate between the capacity to provide a regulating ES, the demand for this, and the actual service conveyed (s. Fig. 1). The last of these is influenced to an equal degree by the underlying capacity and the ecological pressure on the ecosystem. Such indicators should also be spatially and temporally explicit to take full account of the dynamic influence of temporal variability, spatial scale and landscape configuration on regulating ES and their associated benefits (Fisher et al., 2009).