



Ecosystem assessment and management as key tools for sustainable landscape development: A case study of the Ore Mountains region in Central Europe



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ARTICLE INFO

Article history:

Available online 4 September 2014

Keywords:

DPSIR
Ecological concepts
Ecological integrity
Ecosystem services
Environmental crisis
Indicators

ABSTRACT

Principles of sustainability were mentioned for the very first time in the Ore Mountains in Central Europe some 300 years ago, triggered by the shortage of timber. Always new problems and challenges occurred throughout history caused by changes in ecosystems, which influenced sustainability aspects. This region was marked by drastic environmental impacts, particularly strong SO₂ immissions in the second half of the 20th century. Since the political transformation of 1989, both air quality and the functioning and integrity of ecosystems have improved and the rehabilitation of the destroyed forests and degraded peatbogs has begun. The ups and downs of landscape development, in particular the crises in the human–environment relationship in the region, were not only associated with changes in the ecosystem, but also with a process of gaining and structuring knowledge, concept development, and communications. In this paper, we provide a framework for assessing sustainable land use management, and to demonstrate it by way of examples of successful implementation in the Ore Mountains region. In this context we will focus on such important ecological approaches as the concepts of ecosystem research, ecological indicators, ecological integrity, and ecosystem services. Thus, we describe the demand for integrating available knowledge into conceptual approaches, and moving into implementation procedures by means of integrated land management.

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1. Introduction

The goal of sustainable landscape development is the creation, maintenance and restoration of multifunctional landscapes. Concepts for sustainable land use are necessarily based on a careful, in-depth assessment of the state of the environment and the ecosystems concerned. Such assessments should include various proven ecological concepts, approaches, tools and models.

Such terms as ‘sustainability’, ‘environmentally friendly development’ or ‘green economy’ have attained great political popularity since the early 1990s. ‘*Nachhaltigkeit*’ (sustainability) is first documented as a term of general usage in the 19th century in the German dictionary of the Brothers Grimm. In the previous century however, the Saxon *Berghauptmann* (mining administrator) Hans Carl von Carlowitz had already secured the honour of having first put the principles of sustainability into writing. In his book on the economics of forest culture, *Silvicultura oeconomica*, published

300 years ago, he shaped the principle of “... continuous, stable and sustainable utilization” (von Carlowitz, 1713). The roots of sustainability should, he said, be sought in the forest for two reasons: first, the finite nature of the resource wood, revealed by the experience of the shortage of timber was the main driving factor for Carlowitz; the second factor was the long duration of tree growth. Sustainability is thus the child of a scarcity crisis. The establishment of a well-maintained and well-managed forestry system was a response to this experience.

Forestry can thus claim to be the first form of land use which intentionally postulated sustainability as a management concept. Sustainability was defined as the continuous removal of biomass at a steady rate, without the destruction of the ecosystem, and especially, without damage to the soil. It was the beginning of the end of centuries of looting of the forests. Other aspects of sustainability, such as the issues of biodiversity, landscape conservation, and the assurance of natural dynamics, initially played a minor role (Broggi, 1995).

Not until 1992 did the world community elevate the concept of ‘sustainable development’ to a guiding principle. Currently, the idea of sustainability is based on environmentally appropriate,

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sustainable production processes. It describes a world that shares its goods and services fairly, and ensures at least the same degree of freedom to future generations. Sustainable development means the unity of economic, social and ecological development, and thus the integration of the processes of civilization into its supporting network (Rio Report, 1992).

In this context, the study area of the Ore Mountains in the German state of Saxony, a typical low Central European mountain range, plays a crucial role. This model region was the area where von Carlowitz worked, and also where Heinrich Cotta founded the Tharandt Forest College in 1811 and 1816, and thus laid the foundation for the scientifically based restoration of the looted forests with spruce.

Later, the Ore Mountains were subjected to aggravating landscape changes and environmental damage during the second half of the 20th century. Forest death (German: *Waldsterben*) was caused mainly by SO₂ immissions originating from coal-fired power plants in the surrounding area. Such problems were a trigger for the establishment of a new research field, scientific ecosystem research, in Germany (Ellenberg, 1973; Fränze et al., 1997; Joergensen and Müller, 2000). Other essential changes and disturbances of ecosystems in this region are related to eutrophication, acidification, loss of biodiversity, and peat degradation (e.g. Scheithauer, 2006; Scheithauer and Grunewald, 2007).

Today, especially thanks to better air pollution control after the political transformation of 1989 in Eastern Germany, the worst forest damages have been overcome. Large parts of the upper Ore Mountains are currently under forest conversion – they are being planted with climate-appropriate native tree species. Tackling these ecological problems has engendered scientific progress, but it has also required major political and financial efforts.

In the first part of this paper, we will briefly address important steps of some basic ecological concepts which should be considered in the investigation of sustainable land use in general. In the second part, we will show the application of these concepts to solutions for serious land use problems and the maintenance of such typical Ore Mountains ecosystems as forests, raised bogs and mountain meadows, with special regard for the conditions of these ecosystems, which have largely been caused by human impacts, and the services they deliver. Finally we will discuss how these scientifically based concepts might be used to develop management strategies to achieve sustainable land use and landscape maintenance in regions like the Ore Mountains.

2. Methods

Starting from the term and concept of sustainability, scientific approaches are identified from the literature which can contribute to the analysis of the state of ecosystems and the operationalization of the sustainability concept. These include ecosystem research and long-term observation, the concepts of environmental indicators, ecological modelling and ecosystem services (ES), to which Felix Müller (see Section 3) has provided essential scientific contributions. We also address the in some cases very serious changes of ecosystems and landscapes, caused by various external influences and driving forces (Fig. 1), particularly such human impacts as climate change, scarcity of resources, loss of biodiversity, and pollution of the soil, the air and the water. The emergence of the concepts mentioned above will be related to some of these crucial or even creeping and finally cumulative environmental changes (events and disasters).

Our analytical approach can be considered as a modified DPSIR (drivers, pressures, state, impacts, responses) framework (Fig. 1). This concept scheme describes an adapted landscape management cycle, interactively obtained from the actors and natural

components in a causal sequence of analysis and decision-making steps (Müller, 2013). The DPSIR approach structures issues to a coherent framework, enabling an analytical separation of different dimensions of linked socio-ecological systems. It helps to identify what factors to assess, with indicators to answer the question as to how these factors are to be assessed. Finally, also current ES approaches are integrated in the model scheme. The innovative aspects of the framework presented in Fig. 1 relate to focusing on the integrity of ecosystems and the combining of various concepts for managing land use sustainably.

As a model region for the investigation and assessment of human–environment relations, the Ore Mountains of Central Europe was chosen because it has been well studied (e.g. geology, cultural landscape history), it has had to tackle typical human environmental crises and tasks, such as mining and the use of wood, and it still faces such issues as the increase of humic substances in surface waters, the rehabilitation of peat bogs, and the maintenance of mountain meadows (Figs. 2 and 3).

The case studies include results obtained from extensive studies of the environmental situation in the region (Figs. 4 and 6). They are based on our own surveys as well as data, models and results of public authorities and institutions such as the Ministry of Environment and Agriculture of Saxony (SMUL) or the Saxon State Reservoir Dam Authority (LTV). These studies always began with the development of target and indicator concepts (Fig. 5), were oriented interdisciplinary and focussed on the integrated management of ecosystem functioning and ecosystem services (Section 3.4).

The discussion will be guided by the question of whether the concepts presented here can be used to ensure sustainable land use, and what future challenges can be identified. It is the intention to show the usefulness of a conceptual research heuristics by formulating of theses on the future development for the model region under the influence of long-term changes, including such new drivers as climate change, with the ecosystem services concept playing an increasingly important role.

3. Theoretical fundamentals: important ecological concepts

3.1. Ecosystem research

The term and concept of the ecosystem originates with Tansley, who introduced it to ecology as a basic principle (Tansley, 1935). An ecosystem contains the structure of the interrelationships of living beings to one another, and to their inorganic environment. In the less abstract sense, an ecosystem is characterized by its long-term relationship (biocenosis) and its habitat (biotope) (Ellenberg, 1973).

Since Tansley, an international interdisciplinary and transdisciplinary ecosystem research community has emerged which has attempted to develop and apply holistic and systemic concepts. Ecosystem research is a conceptual approach with which particularly natural scientists identify, since analytical models of the structure and dynamics of spatial segments can be processed (ecosystem modelling).

An important basis for the ecosystem concept was developed in the context of a major research project in West Germany in the 1960s – even under the influence of a crisis, the forest dieback in the Central German mountain ranges. The ‘Solling Project’ carried out in Lower Saxony under the leadership of Ellenberg (1973) examined the structures, functions and processes of a Central European beech forest (Tavares et al., 2010).

What is significant in the Solling project and similar projects (e.g. Bornhöved project in Schleswig-Holstein) is the long-term perspective of the investigation. Such ‘Long Term Ecological Research’ (LTER) has become increasingly important in recent years. As

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