60 Ecosystem Services: Understanding Drivers, Opportunities, and Risks to Move Towards Sustainable Land Management and Governance

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The *Atlas of Ecosystem Services* has collected knowledge on drivers, trade-offs, and synergies of ecosystem services and biodiversity, as well as societal responses. It presents case studies from various fields to demonstrate concepts of sustainable land management and governance. In this final chapter, we identify important open questions to sketch avenues for future research in the field (see also Grunewald and Bastian [1]).

60.1 Which Variables and Data Do We Need to Better Quantify, Assess, and Monitor Ecological and Societal Aspects of Ecosystem Services?

Several assessment approaches have been developed, starting with biological monitoring to measure the effects of stressors on biological systems [2], followed by the closely related Essential Biodiversity Variables [3] and indicators of ecological integrity [4]. Promising steps have been taken [5], but the task of linking biodiversity to ecological systems functioning is still a challenge. It is apparent, however, that the role of biodiversity underpinning multiple ecosystem functions and services is not fully understood. Many contributions to this volume hence employ proxies, such as land cover, to assess ecosystem services. Progress has been made to use remote sensing to assess different entities of ecosystem services [6]. The actual realisation of ecosystem services, however, often depends on the demand of different beneficiaries. Here, general measures identifying societal interest and demand as well as impacts on human well-being need to be further developed.

60.2 What Are the Main Driving Forces for Ecosystem Service Change?

This Atlas provides an overview of drivers and pressures on ecosystem services and demonstrates these with different case studies. The Driving-forces-Pressures-States-Impacts-Responses (DPSIR) framework developed by the European Environmental Agency, based on former UN and OECD approaches [7, 8], has been employed in many case studies. Such frameworks must be further developed and implemented in studies on ecosystem service risks [9, 10]. Drivers of ecosystem risk (first order) and ecosystem service risks (second order) can be manifold. Among the diverse drivers covered in this Atlas are the loss of genetic diversity, disturbance of ecological processes, invasions affecting the provision of services to society, pollution, land use, and climate change. The relationship between dynamic anthropogenic pressures and ecosystem functions needs to be better understood, and a process understanding needs to be integrated into ecosystem service valuation [11]. Furthermore, global commodity trade may affect and potentially displace pressures to ecosystems elsewhere. Rising societal demands triggered by, e.g., consumption patterns, demographic challenges and political agendas, may lead to inter-regionally coupled drivers for ecosystem service provision. These drivers may be exacerbated in the coming decades by climate change and associated socio-economic pressures. It is therefore important to not only assess current provision of ecosystem services, but also future changes.

60.3 What Are the Main Spatial and Temporal Patterns of Ecosystem Services?

Spatial scales and hierarchies must be differentiated in the analysis of ecosystem services. The chapters in this volume present a series of studies at different spatial scales and discuss the importance of spatial patterns including the amount and size of different ecosystems and their configuration within a landscape context for the provision of ecosystem services. Open questions relate to the co-appearance of ecosystem services in bundles across landscapes or administrative units. Ecosystem services depend strongly on a given time span with unique patterns of pressures and societal needs. Historically, ecosystems have been formed by a char-

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acteristic set of specific societal needs, cultural preferences, and technological abilities. Looking at the past can facilitate understanding of present situations, patterns of change, and future potentials. Scenario developments are needed to evaluate both the capacity of ecosystems to provide services and their actual use [12].

60.4 Which Trade-Offs and Synergies Occur Between Different Ecosystem Services?

Different types of relationships between ecosystem services have been studied: trade-offs (negative relationships) and synergies (positive relationships) among ecosystem services and with biodiversity and other societal goals [13]. Bundles, i.e., sets of services spatially co-appearing, may result from these relationships, or may develop owing to simple coincidence. There are knowledge gaps on how bundles of services can change over time, and how they differ across large regions. Contributions of the Atlas pointed out the crucial relevance of spatial analyses for analysing relationships between ecosystem services. These can help to identify hotspots, in which conflicts arise that need specific management solutions. To foster advances in this field, research needs to be based also on better regionalized data and on development of metrics and indicators that help to understand the underlying causes of ecosystem service relationships. Such indicators could be used to track changes in ecosystem service relationships over time. An important question in this context is how society can overcome the problem of singular and often competing interests of different land uses for different services, and those impacting on future opportunities. Hence, land use conflicts are a core subject of current and future research. To increase societal relevance of ecosystem service science, studies need to assess socio-ecological systems in an integrative fashion, bridge across scientific disciplines, and include different interest groups and decisionmakers in co-creating research questions.

60.5 What Is the Importance of Different Societal and Political Contexts?

Contributions to the Atlas have pointed to different societal response strategies, including the mitigation of drivers of ecosystem service change, adaptation to a changed ecosystem service provision, and consideration for proactive transformation of ecosystems through management approaches. Different policies and policy mixes need to be considered. When creating and implementing policy instruments, local contexts as well as different stakeholders need to be considered through, e.g., engagement in participatory research approaches. Overall, incentives need to be developed to foster more sustainable land use options. Within this endeavour it is necessary to take a comprehensive approach, i.e., addressing several drivers, to foster policy and management cross-coherence and avoid shifting pressures. There is a strong need to better understand ecological complexity to be able to create suitable policy instruments. Concerning the dynamics of ecosystem service provision, the equitable distribution of benefits derived from ecosystem services needs to be analysed in terms of distributive and procedural equity. There are differences between stakeholders with regard to needs and preferences of ecosystem services, and there are differences in power relationships, which has the potential to lead to inequitable distributions of these benefits. When making decisions, multiple values in society should be considered and a comprehensive understanding of human well-being is needed—one that embraces considerations on, e.g., shared social values and health.

60.6 How Can We Integrate Concepts, Methods, and Models from Different Disciplines for Future Studies of Ecosystem Services?

The study of ecosystem services needs contributions from different scientific fields [14] and the involvement of civil society. Many contributions to this Atlas point directly or indirectly to the need for interdisciplinary studies across natural and social sciences. Some of the studies in this volume analyse drivers of change but do not yet comprehensively address the societal response side, while others analyse societal responses but do not yet fully address the drivers of or relationships between ecosystem services. The challenge ahead for the field is to develop avenues for integrative studies to cover several elements of our framework (Schröter et al., Chap. 1, this volume). Overarching general approaches that could guide future research might be ecosystem integrity or resilience [15].

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