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Optimizing environmental measures for landscape multifunctionality: Effectiveness, efficiency and recommendations for agri-environmental programs

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A B S T R A C T

Agri-environmental measures differ in their capacity to simultaneously enhance the provision of multiple ecosystem services. Multifunctional approaches are hampered by funding schemes that are usually administered by individual administrative sectors that each predominantly focus on one single environmental objective. Developing integrative management strategies that exploit synergies from implementing multifunctional measures is challenged by the need to quantify expected management effects on different ecosystem services.

The objective of this paper is to compare uncoordinated versus coordinated management strategies in their contribution to multiple environmental objectives. We developed and applied a method for quantifying effectiveness, as well as spatial and cost efficiency with respect to four key landscape functions: erosion prevention, water quality conservation, climate change mitigation and safeguarding biodiversity. The case study area was the county of Verden, Germany.

The following findings can be drawn: Measures for safeguarding biodiversity and climate change mitigation have generally high multifunctional effects, which makes them suitable for integrative management strategies. To make use of the added value of potential multifunctional measures, a spatially targeted allocation of agri-environmental measures is necessary. Compared to uncoordinated strategies, coordinated integrative management strategies either allow the optimization of the ratio of costs to environmental effects or an increase in the effects that can be achieved within an area unit. This is however, usually not simultaneous. Future research should seek to refine the assessment and valuation indicators.

1. Introduction

In environmental science and policy the concept of multifunctionality has gained importance. Numerous publications deal with multifunctionality in general (e.g. Bennett et al., 2009; Dijst et al., 2005; Mander et al., 2007; OECD, 2001; Wiggering et al., 2003; Willemen et al., 2008) or provide multifunctional assessment approaches (Bateman et al., 2013; Fürst et al., 2013; Nelson et al., 2009; Waldhardt et al., 2010). The term multifunctionality expresses the range of multiple (beneficial) landscape functions provided by the landscape (Lovell and Taylor, 2013), ranging from a specific site or within neighboring sites (local scale) or a region (regional scale). Multifunctionality may include different sets of (landscape) functions with respect to production, cultural or ecological dimensions (Lovell und Taylor, 2013). The regarded functions also reflect the different perspectives of various disciplines (Hagedorn, 2007). Landscape functions, as used within German landscape planning, are the potential (capacities) of a landscape to sustainably fulfill basic, lasting and socially legitimized material or immaterial human demands (Bastian et al., 2012; von Haaren and Albert, 2011). Hence, in this context, functions do not describe ecosystem processes, but are closely related to societal demands on the landscape, similarly to ecosystem services (ES) (von Haaren et al., 2014; Jax, 2000).

Multifunctionality has been recognized as a condition for sustainability (de Groot, 2006; Selman, 2009). Especially against the background of climate change, multifunctional landscapes are

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understood as an adaptive strategy for unknown future conditions (Lovell and Taylor, 2013). Within the ES concept multifunctional approaches are emphasized as being important for handling ES trade-offs (Rodríguez-Loinaz et al., 2015; Rodriguez et al., 2006). Current European Union policies reflect this insight, for example, the Common Agricultural Policy (CAP) follows the concept of multifunctional agriculture (Haaland et al., 2011; Zander et al., 2007; Wiggering et al., 2006). Furthermore, the Green Infrastructure strategy (European Commission, 2013) considers multifunctionality as a core element (Hansen and Pauleit, 2014; Kambites and Owen, 2006). Similarly in the US, the concept of multifunctional agriculture has gained importance (Jordan and Warner, 2010). Brandt et al. (2014) identify the connection that exists between multiple ES provision and biodiversity in temperate rainforests in the Pacific Northwest, USA.

Even though multifunctionality is widely recognized as important, it is typically seldom considered in decision-making at the implementation level. Effects of land use and land use changes on various ecosystem services and their values are often ignored (Bateman et al., 2013). Additionally, decisions on trade-offs are mainly based on assumptions rather than facts (Carpenter et al., 2009). Although the European directives emphasize potential synergies with other environmental objectives (for example, the European Water Framework Directive (WFD) refers to Natura 2000/Habitats Directive), implementation concepts and measures are not well coordinated between the individual regional administrations and they insufficiently consider synergies and trade-offs between environmental objectives (e.g. for water resource management: Borchardt et al., 2011; Evers, 2008; Grett, 2011; for multifunctional agriculture: Haaland et al., 2011).

Reasons for these deficits are twofold. Firstly, there is a lack of information regarding interactions among ES (Bennett et al., 2009). The tools and guiding principles do not simultaneously consider bundles of landscape functions and their respective ES (Lovell and Taylor, 2013). Moreover, quantitative assessment is crucial when considering multifunctional effects of environmental implementation measures in cost-benefit ratios. Although multifunctional effects of implementation measures have been quantitatively assessed in several studies (Chan et al., 2006; von Haaren et al., 2011; Kleijn et al., 2006; Primdahl et al., 2003; Rabotyagov and Feng, 2009; Rüter, 2008) there is still little empirical evidence regarding methods for systematically increasing spatial and cost efficiency by allocating and shaping multifunctional environmental measures.

A second reason for this deficit is that environmental planning and administration is sectorally organized in many countries along different environmental components (water, biodiversity, soil). Consequently, various funding programs and payment schemes in the European Union (EU) and its Member states focus on single environmental objectives. While this inhibits the implementation of multifunctional measures, measures targeting only one ES may additionally have unwanted side effects on other environmental objectives. This may cause a net loss of ES and their related benefits and values (e.g. Bateman et al., 2013). The funding of renewable energy in Germany (e.g. of energy crop cultivation) is a prominent example of public funding targeting only one ES which causes negative effects on other environmental objectives (Greiff et al., 2010). Furthermore, trade-offs between policy fields occur because public financial resources are limited and the different sectoral planning authorities (sector administrations) compete for funding.

It is of common societal interest to generate maximum environmental improvements with funds earmarked by the EU. This requires a broad environmental perspective (i.e. integrative planning) which enables the identification of synergies and trade-offs between the different environmental objectives (Bateman et al., 2013). However, it is still doubtful that integrative strategies can be implemented efficiently, because they usually require cost intensive data management and coordination of different sectoral planning authorities (cross-sector coordination) (Fährmann and Grajewski, 2011; Uthes et al., 2010). Furthermore, different administration sectors might be concerned that cooperation compromises the implementation of their own primary objectives (von Haaren and Galler, 2011). By assessing the multifunctional effects of implementation measures it is possible to then objectivize the beneficial effects of integrative strategies, compared to those which pursue a single environmental objective.

Given the high amount of public spending involved, a particularly important area for the application of such multifunctional assessments is agri-environmental programs, within the European Union's Common Agricultural Policy (CAP). These, and other payment schemes supporting rural development, are funded by Pillar 2 of the European Agricultural Fund for Rural Development (EAFRD), which provides about 95.6 billion € for the ongoing period from 2014 to 2020 (European Commission, 2013). For Germany this means an EU co-financing of 8.2 billion € (1.2 billion € per year), plus national funding (German Federal Ministry of Food and Agriculture (2014)). Increasingly, the provision of non-commodity outputs of multifunctional agriculture (Vatn, 2002; Vejre et al., 2007) is referred to as a justification for the financial support within the CAP (Marsden and Sonnino, 2008; Rodrigues et al., 2004; Wiggering et al., 2006). Hence, the scope of agri-environmental programs includes different environmental objectives and even socio-economic objectives, in the EU as well as in the US (Jordan et al., 2011; Jordan and Warner, 2010; Uthes et al., 2010). However, single agri-environmental measures usually target a single environmental objective.

The objective of this paper is to investigate the added value of integrative vs. non-integrative implementation scenarios of agri-environmental programs. In a case study, and by considering synergies and trade-offs, we contrast sectoral and integrative (i.e. cross-sectorally coordinated) strategies in order to examine their potential for optimizing effectiveness. Cost efficiency of management strategies was estimated by comparing implementation costs and the environmental benefits of measures. In this way, we respond to the argument that integrative strategies, which usually require cross-sectoral coordination, are more expensive than sectoral ones, mainly because of more ambitious measures and higher transaction costs (Uthes et al., 2010). Furthermore, we assessed the ratio of environmental benefits and the land that is claimed for implementation measures. We therefore take into account that a high competition for land use in many regions requires for maximizing environmental effects in a confined area.

We address the following three key questions:

- Which strategy is more efficient in terms of the average total environmental benefits achieved per hectare (spatial efficiency)?
- Which strategy is more efficient in terms of the environmental benefits achieved for a given amount of funding (cost efficiency)?
- Which trade-offs for a single environmental objective may occur?

With multifunctionality analysis, we consider four landscape functions: water quality, soil erosion, climate change mitigation and biodiversity. They represent the objectives of different sectoral planning and of agri-environmental programs within the EAFRD.

In Section 2 the respective methodology is presented. Section 3 summarizes the results of the case study analysis. In Section 4 the