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Research paper

Spatial correlation of agri-environmental measures with high levels of ecosystem services

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ABSTRACT

The maintenance of multifunctional landscapes is essential for halting biodiversity loss and maintaining a balanced supply of ecosystem services. Policies of the European Union aim at achieving these goals, e.g. by designating protected areas, supporting organic farming or establishing other agri-environmental measures. We analysed the extent to which the application of such regulatory and incentive schemes relates to the supply of ecosystem services at municipal level. Our study focussed on two neighbouring counties in Germany (Wetterau and Vogelsberg, Federal State of Hesse) with contrasting environmental and socioeconomic conditions. Based on indicators for six individual ecosystem services derived from a suite of spatially explicit models, we obtained estimates of total ecosystem service supply (Total Ecosystem Service Value, TESV) as well as indicators for the balance in supply of different ecosystem service categories (ecosystem service clusters). Indicators for total ecosystem service supply as well as for the balance in supply of different service categories showed significant correlations with indicators for efforts made to maintain high and balanced levels of ecosystem service supply. The mechanisms causing the matching spatial patterns of the indicators are likely to differ for regulatory and incentive schemes. Natura 2000 areas are designated where habitats and species of conservation concern occur, and these areas provide co-benefits for balanced ecosystem service supply. The low uptake in highly productive landscapes, by contrast, suggests that agri-environmental measures currently do not motivate farmers to provide a broader portfolio of ecosystem services. At municipal level, indicators for both ecosystem services and policy tools provide valuable insights into the structure of regional socio-ecological systems. Incentive schemes aiming at stimulating high and balanced provision of ecosystem services in productive landscapes need to integrate socio-economic information on the factors driving decision-making by farmers and land managers.

1. Introduction

Spatial and temporal heterogeneity of landscapes is essential for the conservation of biodiversity and the supply of ecosystem services (ES). Policy instruments have been established by the European Union to maintain or increase the diversity of land use types and landscape elements. It is a key question whether the policy instruments are being applied in locations where they can be expected to create the intended outcomes. In order to answer this question, suitable indicators are necessary to compare the spatial distribution of policy uptake with the distribution of biodiversity and ecosystem service supply. Within this context, multifunctionality is an important concept of EU policies for rural landscapes. It includes the notion that an optimal land allocation scheme may be developed for a given landscape to satisfy different societal demands concerning production, cultural or ecological functions (Jongeneel et al., 2008; Waldhardt et al., 2010). The Common Agricultural Policy (CAP) of the EU, for example, aims to promote multifunctional agriculture by rewarding farmers for producing commodities and simultaneously protecting farmland biodiversity (Wiggering et al., 2003; Plieninger et al., 2012).

The aim of this paper is to investigate the spatial correlation between incentive and regulatory policy schemes and levels of ecosystem

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service supply in order to identify the contribution of policy schemes to key ecosystem services. It focusses on the relationship between ecosystem service supply and indicators for the application of policy instruments. We selected three different policy instruments of the EU that all aim at maintaining or restoring multifunctionality of landscapes: agri-environmental measures (AEM), percentage of organic farming and the designation of protected areas under the Natura 2000 network. The uptake of AEM was measured by calculating payments per total utilized agricultural area at municipality level. AEM commitments can focus on a variety of management schemes such as the reduced application of agro-chemicals, biodiversity conservation, or the preservation of landscape features. AEM are the most prominent means of the CAP to increase multifunctionality and to mitigate the negative environmental effects of agricultural intensification (Ekroos et al., 2014; Batáry et al., 2015; Galler et al., 2015). They are intended to compensate for income losses caused by adopting environmentally friendly management practices (European Parliament and Council of the European Union, 2013; Hodge et al., 2015). The financial support for AEM within the CAP is justified by the additional provision of non-commodity outputs, i.e. ecosystem services, of a multifunctional agriculture (Galler et al., 2015). Since AEM are designed and implemented at national or subnational scales, measures represent priorities at these levels (Hodge et al., 2015). Therefore, the number of schemes as well as the share of agricultural land enrolled varies significantly among EU member states and regions (Zimmermann and Britz, 2016).

A high share of organically managed land has been proven to deliver significantly more environmental benefits than conventional agriculture by utilising and maintaining several ecosystem services, including soil fertility, plant protection and water regulation (Sandhu et al., 2010; Kremen and Miles, 2012). The number of organic farms relative to the total number of farms thus appropriately indicates diversified farming practices and hence reduced environmental externalities (Kremen and Miles, 2012). This farming practice, which initially was part of the AEM, now is supported by a separate measure of the European Agricultural Fund for Rural Development in the CAP programming period 2014–2020 (European Parliament and Council of the European Union, 2013).

The European protected area network Natura 2000 is the main tool of the EU for reaching the goal of slowing the decline of biodiversity by 2020 (European Union, 2011). It is also considered to be the core component of European 'Green Infrastructure' providing ecosystem services (European Commission, 2013; Liquete et al., 2015). It is based on the 'Birds and the Habitats Directives' and complements the rather general approach of both AEM and support for organic farming by defining areas designated for valuable species and habitats of European conservation concern (Ostermann, 1998). In 2006, the concept of ecosystem services was included in the Natura 2000 strategy. Since many valuable habitats and species depend on traditional farming practices, it also promotes low-intensity agricultural management (Olmeda et al., 2014).

The effectiveness of these policy instruments is debated, since implementation is not always spatially targeted and does not consider synergies and trade-offs among their objectives (Kleijn and Sutherland, 2003; Batáry et al., 2015; Galler et al., 2015). Moreover, although European directives on nature conservation are committed to complement each other, implementation strategies and measures tend to be poorly coordinated among the different regional administrations and also do not adequately consider feedbacks (Galler et al., 2015). Several studies suggest that conservation measures are more effective in structurally simple than in complex landscapes (Tscharntke et al., 2005; Scheper et al., 2013). Similarly, the impact of conservation measures seems to increase with the size of ecological contrast created by the measure (Östman et al., 2001; Diekötter et al., 2010; Kleijn et al., 2011; Winqvist et al., 2012; Tuck et al., 2014). Thus, semi-natural habitats that strongly differ from the surrounding should have particularly strong effects on ecological processes and biodiversity in intensively managed areas of low multifunctionality (Tscharntke et al., 2005). Several authors have evaluated the effect of environmental policies on biodiversity and ecosystem services (Kleijn and Sutherland, 2003; Ekroos et al., 2014; Pe'er et al., 2014; Batáry et al., 2015). However, studies on the actual allocation and effectiveness of these policies are rare (Galler et al., 2015). One of the few studies that have attempted to quantify the impact of agricultural and nature conservation policies on ecosystem service provision reviewed the effect of Environmental Stewardship in England (Natural England, 2012). This study suggested to design management options specifically with the purpose of ecosystem service enhancement and to improve the understanding of the optimal location and arrangement of options within the landscape in order to improve ecosystem service delivery from Environmental Stewardship.

For the study presented here, we analysed the correlation between indicators of overall ecosystem service status and three policy schemes at the municipality level: (1) payments for AEM per total utilized agricultural area, (2) number of organic farms relative to the total number of farms, and (3) proportion of Natura 2000 areas. Based on a previous ecosystem service assessment of six ecosystem services (water provision, timber supply, food production, carbon storage, erosion control and outdoor recreation), we applied the Total Ecosystem Service Value (TESV) as an indicator for the capacity to provide multiple services (Maes et al., 2012). Furthermore, we conducted a cluster analysis to identify groups of municipalities with similar sets of ecosystem service supply. This study represents the first attempt to analyse the distribution of AEM payments on municipality level in Germany.

Based on the objectives of the policies and on the findings published concerning the effectiveness and efficiency of measures, we hypothesized that AEM should mainly be implemented in simple landscapes with low levels of ecosystem service provision to generate maximum environmental improvement. Natura 2000 protected areas, on the other hand, should be located primarily in areas of high total as well as balanced ecosystem service supply, because habitats and species of conservation concern are more likely to occur in more diverse landscapes. From these two hypotheses it follows that AEM implementation should not be correlated positively with Natura 2000 areas or regions with high proportions of organic farms in a municipality.

2. Methods

2.1. Study area

Our study was designed as a case study, in which the neighbouring counties Wetterau and Vogelsberg (Hesse, Germany) served as surrogates for regions strongly differing in environmental and socioeconomic conditions. The two counties jointly cover an area of 2557 km^2 (Table 1). Elevation ranges from 93 m a.s.l. in the Wetter valley to 771 m a.s.l. in the low mountain range Vogelsberg. Climatic conditions and land use characteristics vary accordingly (annual precipitation 1307 mm, annual mean temperature 5.6 °C at Hoherodskopf 743 m a.s.l., to annual precipitation 635 mm, annual average mean temperature 8.9 °C at Bad Nauheim 148 m a.s.l., period 1961–1990; Deutscher Wetterdienst, 2015). Land in the fertile loess-rich soil of the Wetterau is predominantly used for intensive crop production, whereas grassland used for livestock production and forests dominate the Vogelsberg area. The two counties are typical examples of Central European cultural landscapes, representing much of the land use gradient in this region. The counties encompass 44 municipalities with varying population densities ranging from 72 inhabitants per km^2 in the mountainous regions of the Vogelsberg to 271 inhabitants per km^2 in the Wetterau close to the metropolitan area of Frankfurt (Hessisches Statistisches Landesamt, 2016).

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