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A systematic approach for assessing spatially and temporally differentiated opportunity costs of biodiversity conservation measures in grasslands

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ABSTRACT

Biodiversity loss in Europe is caused to a large extent by agricultural intensification. To halt this loss, agri-environment schemes have been introduced to compensate farmers for (costly) biodiversity conservation measures. Current agri-environment schemes often consider only a few conservation measures which is insufficient to conserve all endangered biodiversity in an agricultural region. This problem is particularly pertinent in grasslands where many different mowing and grazing dates are required to protect the variety of species breeding in the grassland at different times. A key requirement to design agri-environment schemes for grassland conservation is therefore to offer specific compensation for more measures based on a systematic approach that calculates farmers' opportunity costs in relation to the timing of grassland use which is still lacking. This will at best attract more farmers and offer compensation calculated in line with EU requirements for co-financed measures through the Rural Development Programme. We fill this gap by developing a systematic approach to assess the costs of different mowing and grazing dates. Our approach is general enough to be applicable on a large spatial scale but can still sensitively differentiate among different timings. Moreover it is straightforward and time-saving enough to be suitable for implementation in regional scale optimisation procedures. We demonstrate this by applying the systematic cost assessment in the decision support software *DSS-Ecopay* using the example of grassland biodiversity conservation measures in the German federal state of Saxony.

1. Introduction

Biodiversity loss in Europe is caused to a large extent by agricultural intensification (Benton et al., 2002; Kleijn et al., 2009). To halt this loss and to support species and habitat types in agricultural areas agri-environment schemes have been introduced in Europe (Buller et al., 2000; Cooper et al., 2009; Plieninger et al., 2012). Most schemes are implemented according to the EU Council Regulation EC/1698/05 but many other national and regional schemes exist independently of this EU regulation. Under such schemes farmers are financially compensated for carrying out biodiversity-enhancing land-use measures[1] (Finn and Ó hUallacháin, 2012). However, according to research studies (Kleijn and Sutherland, 2003; Kleijn et al., 2011; Marggraf, 2003) and farmland biodiversity indicators (Statistisches Bundesamt, 2010), the success of existing agri-environment schemes in terms of conservation is mixed at best. One of the reasons for this failure is, to our knowledge, the lack of approaches which systematically assess the costs of a large set of potential land-use measures on a national or regional scale and their effects on species of conservation concern, despite the growing body of research in this field (Drechsler et al., 2007; Johst et al., 2002; Primdahl et al., 2010; for integrated modelling approaches see also Rossing et al., 2007; Schipanski et al., 2014).

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[1] In this paper we refer to a single grassland measure such as for example "mowing takes place only once a year at the beginning of July" as a "biodiversity-enhancing land use measure" or "measure". We refer to a policy programme which consists of one or several measures and payments for each measure which land users receive if they conduct it as an agri-environment scheme.

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This lack of approaches is particularly pertinent in the context of designing agri-environment schemes in grasslands as a large number of different mowing and grazing regimes exists (Johst et al., 2015). However, current agri-environment schemes in grasslands frequently consider only very few measures with a fixed date (e.g. a typical mowing measure is mowing after June 15th, cf. Reiter et al., 2004).

As different species and habitats have different habitat requirements and survival probabilities depending on the timing of measures (cf. Johst et al. 2015), this is likely to be insufficient to cover all species and grassland habitats of conservation concern. To improve agri-environment schemes all potential grassland use timings should be screened by systematically analysing their impact on species and habitats and their costs. This provides the ecological and economic information which needs to be combined to identify cost-effective agri-environment schemes which maximise conservation outcomes for given financial resources (Drechsler et al., 2007; Johst et al., 2002). While an ecological model was recently developed to assess the impacts of grassland use timings on species and habitats (Johst et al., 2015), a systematic cost assessment for calculating a farmer's income loss is still missing. To fill this gap, this paper presents an approach which can be used to assess a large range of spatially and temporally differentiated opportunity costs of farmers for mowing and grazing regimes in a systematic manner and which is in concordance to the Principles of EU Rural development Programme schemes relying on income forgone (EU, 2013).

The development of such an approach is not straightforward. We are confronted with the same challenges identified by Johst et al. (2015) when they developed a new modelling approach for assessing the ecological impact of grassland measures on species and habitats. These key challenges, which are outlined below, have to be addressed in the development of a systematic approach for cost assessment.

First, a systematic cost assessment approach has to capture a wide variety of spatial differentiations in local conditions like, for example, soil quality and grassland measures potentially available for species and habitats protection, in a common way but also detailed enough to sufficiently consider the differences among them. The latter is particularly important because, in general, agri-environment scheme payments are planned at regional scale where significant spatial variations may exist. In Germany, for example, the schemes are generally designed at the federal state level (cf. Osterburg, 2006).

Second, not only *where* but also *when* a grassland measure is applied is of great importance. A temporal differentiation is important as the timing of grassland use determines the quantity and quality of the harvested grassland yield and its digestibility. For example, late use of grassland in the vegetation period often leads to a lower yield and quality of the grassland compared to earlier land use (e.g. Voigtländer and Jacob, 1987) and thus to an income loss to farmers, if they are not compensated (e.g. Bahner, 2005). Therefore, assessment of the grassland yield at varying dates in the year is relevant for agri-environment schemes. In contrast to the spatial differentiation of costs of grassland measures, their temporal differentiation has received very little attention.

Finally, if a cost assessment approach is to be implemented in a decision support tool for decision makers, e.g. conservation agencies, it has to be straightforward without losing too much differentiation and detail by assessing the effects of timing of grassland use on farmers' income. This implies that it should not require too much computing time (Ball et al., 2009) and is therefore suitable for optimisation procedures at large spatial scales.

The paper presents a systematic cost assessment solution that meets these challenges. The cost assessment approach is introduced in section 2. Section 2.1 explains the basic framework for assessing the costs of measures followed by a detailed explanation of how our systematic cost assessment approach can differentiate between different locations and timings of grassland uses in section 2.2. We demonstrate how the systematic approach works by inserting data from the German federal state of Saxony using the decision support software *DSS-Ecopay* in which the approach is implemented in section 3. There, we also assess the spatially and temporally differentiated costs of selected mowing and grazing regimes. Section 4 briefly discusses our approach.

2. Approach

2.1. Basic cost assessment framework

The purpose of the cost assessment is to estimate opportunity costs of specific land-use measures in the context of an agri-environment scheme and by this evaluate whether farmers are willing to implement them. The assessment is based on the assumption that a farmer will take part in an agri-environment scheme if he receives a compensation payment p that covers his opportunity costs[2] c for realising the measure m and his transaction costs tc for implementing it (see eq. 1):

$$c_m + tc_m \leq p_m \qquad \text{(eq. 1)}$$

The opportunity costs c reflect the foregone profits of a farmer if he does not use his land in a profit-maximising way but implements a biodiversity-enhancing land-use measure (e.g. in grassland a postponement of the first mowing to protect the nests of meadow birds). We assume that opportunity costs are calculated relative to, and farmers are compensated on the basis of, a specific reference situation, which in grassland is the farmer's profit maximising mowing or grazing regime in that landscape. Participation in an agri-environment scheme may also lead to transaction costs for the farmer (acquiring information about the scheme, administrative work to fill out forms, etc.) for which he needs to be compensated as well. In this paper we focus on the opportunity costs c of land use and refer the reader interested in transaction costs to the literature (e.g. Mettepenningen et al., 2009).

In more detail, the farmer's costs c for realising a grassland measure m are:

$$c_m = c_f - c_v - c_l = \left[\left(y_{ref} - y_m\right)\cdot p_f\right] - \left(c_{v,ref} - c_{v,m}\right) - \left[\left(l_{ref} - l_m\right)\cdot p_l\right] \qquad \text{(eq. 2)}$$

The three different terms of equation 2 have the following meanings.

(1) Yield revenue proxy, $c_f = \left(y_{ref} - y_m\right)\cdot p_f$ (eq. 2a)

The first term in equation 2 refers to the cost of concentrated feed c_f as a yield revenue proxy and is derived as follows. First, a change in the revenue from the market product of the field has to be considered. While on arable land, e.g., the harvested wheat or rape can be sold directly on the market, this usually does not hold for grassland with its grass yield. Instead, the market revenue here is an indirect one, as it is generated by the feeding of the grass to livestock (fresh, as silage or hay). Thus the market revenue depends on the type and structure of the farm, i.e. whether the farmer increases his revenues by e.g. dairy farming, suckler cow husbandry or fattening. The data needed for the assessment of the grassland market revenue is farm specific and requires complex calculations. In line with common practice of how compensation payments for agri-environment measures are calculated by responsible authorities in Germany (BMEL, 2012), we therefore apply a simplified calculation shown by the first term in equation 2, $\left(y_{ref} - y_m\right)\cdot p_f$.

[2] Readers which are not familiar with basic economic terms may consult an appropriate textbook such as, for example, Boardman et al. (2010).