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The cost-effective length of contracts for payments to compensate land owners for biodiversity conservation measures

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ABSTRACT

Payments to compensate land owners for land use measures which are beneficial to biodiversity conservation but costly to them have become a prominent policy instrument. A key question in the design of such payment schemes is for how long the land owners shall commit themselves to carry out biodiversity-enhancing land use measures, i.e. the length of contracts. From an ecological perspective, longer contracts seem better as they ensure that an area stays a suitable habitat for a longer time. However, with longer contracts land owners are likely to demand a higher annual compensation payment if they give up for a longer time their right to manage their land in a way they prefer. We analyse with a conceptual ecological-economic model how the cost-effectiveness of short versus long contract lengths depends on different ecological and economic parameters. We demonstrate the practical relevance of the model by applying it to the case of butterfly conservation in a region in Germany. Our results suggest that for the case study a 5-year contract is more cost-effective than a 10-year contract. Overall, we find that when deciding about the contract length economic parameters (for example the budget size where high budgets favour long contract lengths) and ecological parameters (for example species colonisation rates where high rates favour short contract lengths) need to be considered.

1. Introduction

One of the key drivers of biodiversity loss is land use in agriculture and forestry which is profit-maximising for land owners but harmful to biodiversity (Sala et al., 2000). Payments to compensate land owners for land use measures which are more beneficial to biodiversity but costly to land owners have become a prominent policy instrument to mitigate biodiversity loss and conserve endangered species and habitats (Engel et al., 2008; TEEB, 2010). In a developing country context these payments are often subsumed under the broader category of payments for environmental services (PES, cf. Engel et al., 2008) and in the context of agricultural policy in developed countries they are referred to as agri-environment schemes (AES, cf. Kleijn et al., 2011). In the US and the member states of the EU together more than USD$8.9B is spent each year on AES (Armsworth et al., 2012) and numerous PES schemes exist in developing countries throughout the world (Ezzine-de-Blas et al., 2016).

Participation in such payment schemes is typically voluntary. Land owners willing to participate sign a contract in which they commit themselves to carry out a biodiversity-enhancing land use measures for a certain period of time. Afterwards, they may renew the contract or return to the profit-maximising land use which, however, is harmful to biodiversity.

An important question in the design of payment schemes is for how many years shall the land owners commit themselves to carry out biodiversity-enhancing land use measures, i.e. the length of contracts (Ando and Chen, 2011; Hanley et al., 2012; Engel, 2015). In surveying contract lengths in AES and PES schemes around the world Lennox and Armsworth (2011) found that contract lengths range between 5 and 30 years. Contract durations differ even within the same policy context. For example, the contract length for English AES in the Entry Level Stewardship progamme is 5 years whereas it is 10 years in the somewhat more demanding Higher Level Stewardship programme (DEFRA, 2008). Another example is Costa Rica's forest conservation programme where, depending on the specific measure, the contract length is 5, 10 or 15 years (Zbinden and Lee, 2005).

The length of contracts in AES and PES schemes is also discussed controversially in the literature. For example, studies that evaluate German AES, provide different recommendations regarding contract length. Reiter et al. (2005) recommend a shorter length of contracts to increase the acceptance of AES among farmers. This suggestion is supported by survey results of Danish farmers who prefer shorter over longer contract lengths (Christensen et al., 2011). In contrast, Niens and Marggraf (2010) and Institut für ländliche Strukturforschung (2015) point out that longer contracts have the advantage of providing

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environmental services generated from AES for a longer time, an issue that in the PES literature is often referred to as enhancing 'permanence' (Engel, 2015). These controversies and the differences in contract lengths of existing policies call for a more in-depth analysis of the ecological and economic circumstances that make shorter or longer contracts preferable.

From an ecological perspective, longer contracts are advantageous as they ensure that an area stays a suitable habitat for a longer time. Shorter contracts allow land owners to earlier reconsider their decision to participate in the scheme and switch back to the profit-maximising land use. Although they may be replaced by other land owners who join the scheme such that the whole area conserved with the programme remains constant, species are negatively affected. The move of land owners from participation to non-participation and vice versa results in habitat turnover (existing habitat is destroyed and new habitat is created) which tends to be damaging for a species population even at overall constant number of habitat patches (Johst et al., 2011; Van Teeffelen et al., 2012). This holds even if the dispersal range of the species is very large because the destruction of a habitat destroys not only the habitat but also the local species population on it, increasing the natural local extinction rate of the species (DeWoody et al., 2005; Drechsler and Johst, 2010). Individual land owners may change their decision to participate in a scheme because, for example, they intend to sell their land and it may have a negative impact on the price if the new land owner is restricted by a contract to a certain type of land use (Van Herzele et al., 2011). The preferences of land owners regarding biodiversity conservation and hence programme participation may also change over time. Moreover, land may be bequeathed and the heir may have other preferences regarding scheme participation than the old land owner (Ando and Chen, 2011). A further reason for a change in the landowners' decisions may be that prior to scheme participation land owners have only rough ideas about the costs and benefits of participation and only after participation they know the actual values. By this, they may find out that their expectations were wrong and, consequently, change their decision regarding scheme participation (Frondel et al., 2012).

While longer contracts are beneficial to biodiversity they are generally more expensive for the conservation agency than shorter contracts. Surveys (Ruto and Garrod, 2009; Christensen et al., 2011; Yeboah et al., 2015) suggest that land owners will demand a higher (annual) compensation payment if they give up their right to manage their land as they prefer for a longer time as this reduces their flexibility to change land use (Engel, 2015). This implies that for a given budget the conservation agency can conserve less area with longer contracts than with shorter contracts. However, with shorter contracts habitat turnover is likely to happen more frequently than with longer contracts. Hence, a trade-off exists between maximising area and minimising habitat turnover and the issue of cost-effectiveness arises, namely, the question which contract length maximises the conservation output of a payment scheme for a given budget (Ando and Chen, 2011; Hanley et al., 2012).

In this paper we aim to contribute answering this question by analysing on a conceptual level the impact of different ecological and economic parameters when comparing the cost-effectiveness of longer and shorter contracts. For this purpose, we develop a conceptual model which integrates ecological and economic knowledge and information (cf. Cooke et al., 2009 for general considerations about ecological-economic modelling and Mouysset et al., 2015 for a recent example). The model is equation-based but solved numerically. It is deterministic and considers spatial variation among the landowners as well as temporal dynamics in an implicit manner.

The cost-effectiveness of payment schemes has been mostly analysed in terms of how to incentivise a cost-effective spatial allocation of conservation measures. This includes research about the cost-effective spatial differentiation of payment schemes (Armsworth et al., 2012; Hart et al., 2014) and the cost-effectiveness of different incentives to generate an agglomeration of conservation measures (Drechsler et al., 2010; Wätzold and Drechsler, 2014) as well as a spatially even allocation of measures (Bamière et al., 2011; Cong et al., 2014).

In contrast to spatial issues, the issue of the cost-effective lengths of contracts for conservation measures has been somewhat neglected (but see Gulati and Vercammen, 2005 as an example of research in the related field of contracts for carbon sequestration). Notable exceptions include Lennox and Armsworth (2011), who examine how uncertainty over future patch availability and over future patch ecological conditions affects the choice of contract duration, and Ando and Chen (2011) whose work is closest to ours. Ando and Chen (2011) investigate how the choice of the optimal length of contracts is affected by the type of environmental benefit, the turnover rate of patches participating in the conservation program, and the average income from land management. Moreover, Juutinen et al. (2014) investigate the optimal length of forest conservation contracts considering the effects of transaction costs and budget availability over time. Finally, also in a forestry context Juutinen et al. (2012) analyse how stand characteristics and species habitat requirements influence the optimal contract length.

We go beyond the existing work in several ways: We include metapopulation dynamics (species colonisation rate, species local extinction rate) in our model which enables us to relate the results regarding the length of contracts to species with specific characteristics. We further consider the size of the landscape, i.e. the total number of land patches available for conservation, which has not yet been investigated with respect to contract length. Moreover, we explicitly analyse the influence of the extra payment (inflexibility premium) that land owners demand for longer contracts compared to shorter contracts. These additions allow us to derive more differentiated results for the influence of ecological and economic conditions on the relative suitability of long versus short contracts. Our model also provides a conceptual framework for empirical studies as it is possible to collect data and information for the ecological and economic model parameters. We demonstrate this by applying the model to the case of butterfly conservation in a region in Germany and compare the cost-effectiveness of a 5-year contract and a 10-year contract.

2. The model

2.1. Landscape, basic cost structure and budget function

We consider a landscape with N_0 patches. Managing patch n ($n \in \{1, \ldots, N_0\}$) for conservation incurs an annual cost c_n. The costs c_n vary among patches and, for analytical tractability (cf., Eq. (4)), are assumed to be uniformly distributed in the interval $[1-\sigma, 1+\sigma]$ (cf. Wätzold and Drechsler, 2014). The corresponding marginal cost function is

$$c(n) = 1 - \sigma + 2\frac{n}{N_0}\sigma, \tag{1}$$

which gives the cost of the n-th patch if all patches are ordered according to their costs from lowest to highest (cf. Drechsler, 2011). The conservation agency offers a homogeneous annual payment z to all land owners who manage their patch for conservation (for notational simplicity each land owner is assumed to own one patch). All land owners whose costs are below the payment accept the agency's offer. As outlined in the Introduction land owners generally prefer shorter contracts because they increase their flexibility to react to changing circumstances (Christensen et al., 2011). We model this by assuming that the land owners demand an annual inflexibility premium $\pi > 0$ if they commit themselves for long-term contracts:

$$z \geq c + \pi \tag{2}$$

To induce n land owners to manage their patch for conservation, the payment z has to equal $c(n) + \pi$ and the required budget for the agency