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Smart spatial incentives for market-based conservation

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ABSTRACT

Market-based instruments such as payments, auctions or tradable permits have been proposed as flexible and cost-effective instruments for biodiversity conservation on private lands. Trading the service of conservation requires one to define a metric that determines the extent to which a conserved site adds to the regional conservation objective. Yet, while markets for conservation are widely discussed and increasingly applied, little research has been conducted on explicitly accounting for spatial ecological processes in the trading. In this paper, we use a coupled ecological–economic simulation model to examine how spatial connectivity may be considered in the financial incentives created by a market-based conservation scheme. Land use decisions, driven by changing conservation costs and the conservation market, are simulated by an agent-based model of land users. On top of that, a metapopulation model evaluates the conservational success of the market. We find that optimal spatial incentives for agents correlate with species characteristics such as the dispersal distance, but they also depend on the spatio-temporal distribution of conservation costs. We conclude that a combined analysis of ecological and socio-economic conditions should be applied when designing market instruments to protect biodiversity.

1. Introduction

Market-based instruments such as payments (Wunder, 2007; Drechsler et al., 2007), auctions (Latacz-Lohmann and Van der Hamsvoort, 1998) or biodiversity offset trading (Panayotou, 1994; Chomitz, 2004) have been suggested as a means to complement existing reserves by inducing biodiversity protection on private lands. Market-based instruments are currently being used or tested in many countries around the world. Some examples are conservation and wetland mitigation banking in the US (Salzman and Ruhl, 2000; Wilcove and Lee, 2004; Fox and Nino-Murcia, 2005) or market schemes in Australia (Coggan and Whitten, 2005; Latacz-Lohmann and Schilizzi, 2005). One of the reasons for the increasing popularity of these instruments is the realization that markets may achieve a more targeted and therefore more cost-efficient correction of a conservation problem, in particular because landowners have more information about their local costs and can choose the allocation of conservation measures accordingly (Jack et al., 2008). Another reason is that market-based instruments are well suited for targeting multiple ecosystem services, e.g. conservation and carbon sequestration (Nelson et al., 2008), a point which has been highlighted in a recent statement of the European Union (EU-Commission, 2007).

At the same time, however, there has been considerable concern over whether current implementations of conservation markets target the right entities. At present, market-based policies for conservation tend to use simple and indirect incentives, such as payments for certain farming practices (Ferraro and Kiss, 2002). But are those incentives efficient in protecting threatened species, or are we paying ”money for nothing” (Ferraro and Pattanayak, 2006)? Examin-

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ing the structure of the given incentives for landowners is the key to answering these questions. What defines a unit of conservation? What are we paying landowners for?

The overall goal of global conservation efforts is to ensure the persistence of biodiversity in our landscapes (Margules and Pressey, 2000). Therefore, it would be ideal to assess the market value of a conservation measure directly by assessing its effect on species survival (Williams and Araujo, 2000; Bruggeman and Jones, 2008). Unfortunately, applying this method to real-world situations is often not feasible because direct monitoring or detailed population models are too expensive or not available (Jack et al., 2008). Moreover, the efficiency of markets crucially depends on the information available to landowners. If landowners do not understand the evaluation criteria for their land, they may choose suboptimal land configurations, or they may decide not to participate in the market at all. Therefore, practically all existing market schemes use a metric, given by a number of indices, that relates measurable quantities of a site (e.g. size) to the site's market value.

Most of these existing schemes base their evaluation solely on the quality and size of the local site without considering its surroundings. This raises some concern because in many cases, the ecological value of a typical private property (e.g. an arable field or a forest lot) does in fact depend on neighboring properties. Populations or ecosystems may exhibit thresholds for the effectiveness of conservation measures, which implies that a local measure may be ineffective when it is not accompanied by other measures (Hanski et al., 1996; Scheffer et al., 2001). Furthermore, for many endangered species, not only the absolute loss of habitat area, but also habitat fragmentation is a major cause of population decline (compare e.g. Saunders et al., 1991; Fahrig, 2002). Therefore, metrics that only evaluate sites locally may set the wrong incentives because they do not correspond to the real conservational value of a site.

Spatial metrics that consider the surrounding of a site are available and are widely used for systematic reserve site selection (e.g. Moilanen, 2005; van Teeffelen et al., 2006). Yet, simply transferring spatial metrics from conservation planning into connectivity-dependent incentives for landowners (in the following we will call such incentives short "spatial incentives") would be short sighted. Conservation planning metrics have been developed for assessing and optimizing the ecological value of a habitat network from the viewpoint of a planner who considers the whole landscape. Landowners in conservation markets, on the other hand, react to the given incentives independently and with limited knowledge, striving for maximization of their individual utility rather than maximizing global welfare. The fact that the value of a site depends on neighboring sites implies that land use decisions may create costs or benefits for neighboring landowners. In economics, such costs or benefits are referred to as externalities. It is well known that markets may fail to deliver an optimal allocation of land use in the presence of such externalities (Mills, 1980). Another problem is that, unless we assume perfect information and unlimited intellectual capacities, we must take into account that landowners may fail to find the optimal adoption of their land use in the presence of complicated spatial evaluation rules (Hartig and Drechsler, 2008a). Thus, the need to consider human behavior in metrics for market-based instruments is characterized by a trade-off: Ecological accuracy calls for a metric that is complex enough to capture all details of the relevant ecological processes, but socio-economic reality may suggest compromises towards more practical and robust metrics.

In this paper, we combine a spatially explicit population model with an agent-based simulation model to assess the effect of connectivity-dependent incentives in a virtual conservation market. One key assumption is that landowners do not react optimally to the given incentives, but base their decisions only on the present land configuration and their estimated costs and benefits for the next period. Thus, we seek to optimize for ecological parameters such as dispersal as well as for economic parameters such as behavior of landowners. To simulate the reactions of landowners towards a given spatial metric, we use the conservation market model introduced in (Hartig and Drechsler, 2008a). A spatially explicit metapopulation model is placed on top of the emerging landscape structure to evaluate the conservation success for different species in terms of survival probability at a fixed time horizon.

2. Methods

2.1. Overview and purpose

The aim of this study is to design spatial incentives that result in cost-effective conservation when there are many landowners and the conservation outcome depends on the combination of decisions by landowners. Here, cost-effective means that we maximize the conservation effect at a given budget. The model used contains two submodels: An economic submodel that simulates the trading of conservation credits and an ecological submodel to assess the viability of several species in the dynamic landscape that emerges from the trading activity. The driver for trading and the subsequent change of the landscape configuration is economic change in the region, reflected by heterogeneously changing costs of maintaining a local site in a conserved state. We first describe the state variables of the model, followed by the economic and the ecological submodel and the coupling of the submodels. The coupled model is then used to find the cost-effective metric by comparing the forecasted species persistence across a range of different parameterizations of the metric. Fig. 1 shows a graphical representation of our model approach.

2.2. State variables and scales

The simulation is conducted on a rectangular 30×30 grid with periodic boundary conditions (i.e. the grid has the topology of a torus). The $n = 30^2$ grid cells represent both the economic (property) units and the ecological (habitat) units. Although the model may be applied to any spatial and temporal scale, we think of grid cells as being of the size of an average agricultural field in Europe (around 10 ha), and time steps being a year. Grid cells x_i occur in two states: They can be conserved at a cost c_i and thus provide habitat for the species, or