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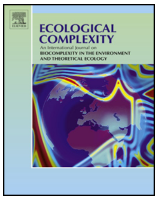

Short Note

The impact of cost feedbacks on the land-use dynamics induced by a tradable permit market

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ABSTRACT

The costs of conserving land for species generally vary in space and time. In addition, they are not exogenous to the land-use dynamics but develop endogenously. This gives rise to feedback loops because the costs determine the land use dynamics which in turn determine the costs. This cost feedback is likely to affect the effectiveness of biodiversity conservation instruments that target land use in a spatially explicit manner. In the present paper a model of a tradable permit market with agglomeration bonus is extended for the consideration of cost feedbacks such that the presence of conserved land in the neighborhood may increase or decrease the local cost. The model analysis demonstrates that the in the former case the level of spatial clustering of conserved land is reduced while in the latter case it is increased. Clustering of conserved land is important for many species and thus cost feedbacks will eventually affect the survival of species and need to be considered in the design of conservation instruments.

1. Introduction

Market-based instruments form an important constituent of global biodiversity conservation policy. Common types of conservation instruments are payment schemes and tradable land-use permits. Generally, these conservation instruments are spatially homogenous so that rewards received for a conservation measure are independent of the spatial location of the measure and the spatial location of other measures. This contrasts ecological theory which states that the value of a habitat for a species may depend on the habitat's proximity to other habitats (Hanski, 1999; McDonnell et al., 2002; Frank and Wissel, 2002; Gustafson et al., 2007; Schulte et al., 2008; Drechsler, 2011). Thus, the effectiveness of a conservation measure depends on its spatial context.

The ecological effectiveness of conservation instruments may be enhanced by so-called agglomeration boni (Parkhurst et al., 2002) that target not only the total amount but also the spatial connectivity of land on which conservation measures are applied. Agglomeration boni have been considered in the context of payment schemes (Parkhurst and Shogren, 2007, 2008; Drechsler et al., 2010; Lewis and Plantinga, 2007; Schulte et al., 2008; Juutinen et al., 2009; Lewis et al., 2011) with few examples in the field of tradable land-use permits (Drechsler and Wätzold, 2009; Hartig and Drechsler, 2009).

The conservation of habitats is usually costly, which implies that there exists a trade-off between the total amount and the spatial connectivity of habitats: To maximize the total amount of habitat available for given total cost requires conserving the least costly habitats which usually does not maximize the spatial connectivity of these habitats; vice versa, maximizing connectivity generally requires conserving some expensive habitats which implies that the total amount of habitat for given total cost is not maximised. Therefore, amount and spatial connectivity of habitats cannot be maximised at the same time.

A possibility to control the spatial connectivity of habitats are tradable permit schemes with an agglomeration bonus (Drechsler and Wätzold, 2009). In a tradable permit scheme, each land user is obliged to conserve some land or buy land-use permits on the market. Land users who conserve more land than they are obliged to earn permits and can sell them on the market. More permits are earned when habitat is created in the vicinity of other habitats (which is termed an agglomeration bonus). For the case of spatially uncorrelated conservation costs Drechsler and Wätzold (2009) found that if a large agglomeration bonus is offered, a clustered habitat configuration will emerge from the individual decisions of the land users, and a more scattered configuration otherwise. This general finding was confirmed by Hartig and Drechsler (2009) even for the case of spatially correlated conservation costs.

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If the costs of conserving land change in time, so does the land-use pattern, i.e. the spatial allocation of conserved and economically used land. The reason is that conserved land parcels with increasing conservation costs are likely to switch to economic use (after their owners have bought an appropriate amount of land-use permits) while economically used land parcels with decreasing conservation costs are likely to switch to conservation (so their owners can earn and sell land-use permits). This implies turnover of habitats, such that in each time step some land parcels switch from conservation to economic use and others from economic use to conservation. Habitat turnover is often harmful to species because not only habitats are destroyed but also the local populations inhabiting them (e.g., Drechsler and Johst, 2010). Drechsler and Wätzold showed that in a tradable permit market with agglomeration bonus there is a relationship between the degree of spatial clustering and the turnover of habitats.

The exact delineation between clustered and scattered habitat configurations depends on the spatial and temporal heterogeneity of conservation costs: the larger this heterogeneity the stronger the tendency for a scattered configuration because clustering of habitats becomes increasingly expensive. Hartig and Drechsler (2009) investigated the role of spatial and temporal correlations in the conservation costs and found that these correlations ceteris paribus tend to reduce the level of clustering of habitats.

Although there is an understanding of the effect of distribution and heterogeneity of conservation costs on the performance of conservation policies, a short-coming of all above-mentioned studies is that the conservation costs are set exogenously, and the question arises what happens if these costs evolve endogenously within the land-use dynamics. The reason to consider endogenous costs is that land prices often depend on the land-use pattern in the vicinity of the focal land parcel. Effects can go in various directions so that the land price may, e.g., increase, with increasing share of conserved land in the vicinity or with increasing share of cultivated land (Sander and Polasky 2009; Waltert and Schläpfer, 2010; Ma and Swinton 2011; Abelairas-Etxebarria and Astorkiza, 2012; Gibbons et al., 2014). This price change is likely to affect the land use in the focal land parcel so that altogether the land-use change in a region depends on the current land-use pattern – leading to a feedback loop in land use and land prices (Armsworth et al., 2006; Tóth et al., 2011).

The presence of feed backs in land prices (conservation costs) is likely to affect the performance of conservation policies, but the question is, how? To investigate the effect of cost feedbacks I use the model of Drechsler and Wätzold (2009) which exhibited the above-described behavior that at large agglomeration boni and/or small heterogeneity in conservation costs lead to spatial clustering of habitats while low agglomeration boni and/or high cost heterogeneity lead to scattering of habitats. To introduce feedback loops in conservation costs into this model I consider that the conservation cost in a focal land parcel may increase or decrease when more land parcels in the neighborhood are conserved. An increase may be due to an increased amenity value of the land, a decrease may be due to reduced access or due to prospects that the land will become imposed to stricter conservation regulations in the future.

I will analyze this extended model with regard to the question of how the size of the agglomeration bonus and the heterogeneity in the conservation costs affect the land-use dynamics – in particular the conditions under which clustered respectively scattered habitats can be expected. In the following Section 2 I will present the model and describe the way in which it is analyzed. Section 3 contains the results of the model analysis and Section 4 concludes with a discussion.

2. Methods

The model is an extension of the simulation model by Drechsler and Wätzold (2009) which considers only exogenous conservation costs. First I briefly outline that model and then describe the extension to introduce the cost feedbacks.

The basis of the model is a landscape structured as a square grid of land parcels each of which can be used for conservation or for economic purposes, such as agriculture or forestry. Conservation of a land parcel *i* incurs an opportunity, or conservation cost c_i. The c_i are uniform random numbers drawn from the interval $[1-\sigma, 1+\sigma]$, where σ denotes the cost variation. To model economic change the conservation costs c_i are randomly re-drawn in each time step (year).

If a land parcel is under conservation land-use permits of magnitude $v_i = 1 + wm_i$ are produced, where *mi* is the proportion of conserved land parcels in the Moore neighborhood around land parcel *i*. The Moore neighborhood consists of the eight land parcels adjacent to land parcel *i*. Parameter *w* is the *connectivity weight* attached to the presence of other habitats in the Moore neighborhood. A large (small) *w* implies that the presence of conserved land parcels in the neighborhood strongly (weakly) increases the amount of permits earned from conservation.

Each land user is obliged to produce $\lambda(1+w)$ permits on his or her land parcel where λ controls the proportion of land parcels that have to be conserved in the model region altogether. However, it is up to the land users to decide whether they wish to conserve their land parcel and earn permits, or buy permits from conserving land users and use their own land parcel for economic purposes. Profit-maximizing land users associated with high conservation costs will wish to buy permits and use their land for economic purposes while land users with low costs will produce and sell permits. This exchange of permits allows for a cost-effective spatial allocation of conservation efforts on the less costly land parcels.

The two policy parameters λ and *w* allow inducing a large rage of land-use patterns and dynamics. While λ controls the total number of conserved land parcels in the region *w* acts like an agglomeration bonus (Parkhurst et al., 2002) that induces spatial clustering of conserved land parcels. As Drechsler and Wätzold (2009) showed, if *w* is large compared to the cost variation σ, the conserved land parcels tend to be clustered while for smaller *w* they are spatially dispersed. The transition between clustered and dispersed is rather discontinuous, i.e. occurs rapidly as *w* crosses a certain threshold. The size of the threshold depends on σ.

To introduce endogenous conservation costs I extend the model in the following manner. Based on the random cost c_i generated as described above I add a correction term and calculate

$$c_i \rightarrow c_i' = c_i + sm_i/8 \quad (1)$$

where $m_i/8$ is the proportion of conserved land parcels in the Moore neighborhood as introduced above and $s \geq 0$ the strength of the feedback. If *s* is positive the presence of conserved land parcels increases the conservation cost c_i of the focal land parcel *i*. This influence increases with increasing *s*.

To model an inverse influence of m_i on c_i I use

$$c_i \rightarrow c_i' = c_i + s(1 - m_i/8) \quad (2)$$

instead of Eq. (1). Here the conservation cost of focal patch *i* decreases with increasing proportion of conserved land parcels in the Moore neighborhood, and the magnitude of this decrease increases with increasing *s*.

I am interested on the influences of these two types of feedback on the land-use dynamics in the model region, in particular the level of spatial clustering, measured by the average number of conserved land parcels around a conserved land parcel. For this I