Ecological Economics 147 (2018) 189–196

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Effectiveness of Tradable Permits for the Conservation of Metacommunities With Two Competing Species

Clément Surun[1], Martin Drechsler*

UFZ – Helmholtz Centre for Environmental Research, Department of Ecological Modelling, Permoserstr. 15, 04318 Leipzig, Germany

ARTICLE INFO

Keywords:
Competition
Conservation
Ecological-economic model
Metacommunity
Tradable permits

ABSTRACT

Market-based instruments are gaining relevance for biodiversity conservation, since they promise higher cost-effectiveness than other instruments like planning. Previous studies have analysed the effectiveness of market-based instruments on single or multiple but independent species. On the example of tradable land-use permits we address an important issue for the first time: the conservation of interacting species (metacommunities). We consider two competing species where the superior competitor locally replaces the inferior competitor. Both species are structured as metapopulations, i.e. can go locally extinct while empty habitats can be recolonised by local populations on neighbouring habitats. Combining a spatially explicit and dynamic ecological-economic simulation model with cluster analysis we investigate how the coexistence of both species depends on the design of the tradable permit scheme, and how the effective scheme design (i.e. the scheme design that maximises coexistence) depends on the biological characteristics of the two species. We show that scheme designs that are effective for the conservation of single species may be ineffective for the conservation of two competing species and that the effectiveness of a scheme with regard to coexistence strongly depends on the relative performances of the two species with regard to their colonisation abilities and local extinction risks.

1. Introduction

The biodiversity in agricultural systems is continuing to decline worldwide (Barnosky et al., 2011; Pereira et al., 2012). Reasons include the intensification of agriculture such as increased use of machinery, fertilisers and pesticides, as well as synchronization and homogenization of land use (Drechsler et al., 2007; Pe'er et al., 2014), drainage of lands, expansion of monocultures and destruction of natural landscape elements like solitary trees and hedge rows. All these measures have contributed to reduce the abundance of many taxa like insects (Bourn and Thomas, 2002) and birds (Pe'er et al., 2014).

To counteract the loss of biodiversity in agricultural landscapes, agri-environmental schemes have been introduced e.g. to reduce the use of chemicals or to establish hedges (Primdahl et al., 2003). Such agri-environmental schemes are implemented mostly in the form of market-based instruments like compensation payments and tradable permit schemes (European Commission, 2005; OECD, 2012).

The introduction of agri-environmental schemes, however, has not lead to the expected results. Instead, their success has been mixed (e.g. Kleijn et al., 2006). There are many potential reasons why existing agri-environmental schemes are not effective (failing to reach desired biodiversity outcomes) nor cost-effective (failing to achieve outcomes at minimum costs). One issue that has been discussed in the recent past is spatial heterogeneity and spatial interactions. Both the costs and the effectiveness of conservation measures may vary in space which affects the cost-effectiveness of conservation policies (Mousset et al., 2014; Naidoo et al., 2006). Furthermore, the effectiveness of a conservation measure at a particular location may depend on conservation activities in the neighbourhood: For instance, agricultural land parcels are often too small to sustain a viable local species population, so many species can only survive in a region if such local populations can interact through dispersal of individuals (the so-called metapopulation theory: Hanski (1998)); since many species have limited dispersal abilities, the habitats of these local populations must be close enough to each other, which requires conservation measures to be spatially aggregated. Acknowledgement of this issue has lead, e.g., to the introduction of the agglomeration bonus approach that rewards spatial clustering of conservation measures (Parkhurst and Shogren, 2007; Parkhurst et al., 2002).

The agglomeration bonus concept can be employed in various types of conservation instruments, including payment schemes (where higher payments are offered to land users if they conserve land in the vicinity

* Corresponding author.
E-mail address: martin.drechsler@ufz.de (M. Drechsler).
[1] Present address: AgroParisTech, Campus de Nancy, 16 rue Girardet 54000 Nancy, France.

https://doi.org/10.1016/j.ecolecon.2018.01.016
Received 25 April 2017; Received in revised form 15 January 2018; Accepted 15 January 2018
Available online 03 February 2018
0921-8009/ © 2018 Elsevier B.V. All rights reserved.

of other conserved land) and tradable permit schemes (where the conservation of land close to other conserved land earns more land-use permits while the destruction of habitats close to other habitats requires more permits than that of isolated habitats (Drechsler and Wätzold, 2009). Both applications of the agglomeration bonus concept lead to a higher degree of spatial clustering of conserved land patches (habitats). The cost-effectiveness gains of the agglomeration bonus with regard to species conservation has been analysed in both settings (tradable permits and payment schemes) by Drechsler et al. (2010), Hartig and Drechsler (2009) and Wätzold and Drechsler (2014).

A shortcoming of the above-mentioned and other studies on the cost-effectiveness of conservation instruments is that only the conservation of single species (Drechsler et al., 2010; Hartig and Drechsler, 2009; Wätzold and Drechsler, 2014) or multiple but non-interacting species (Armsworth et al., 2012; Mouysset et al., 2014; Nelson et al., 2008) were considered. It has, however, been shown that the interaction between species can considerably affect the cost-effective allocation of conservation resources (Baumgärtner, 2004; Probert et al., 2011).

Main types of species interaction include “predator–prey” (one species feeds on the other), “competition” (species compete for the same environmental resources) and “mutualism” (species positively influence each other) (Begon et al., 2006). Growing ecological research deals with the interaction of interacting species in a spatially structured environment. The most popular paradigm in this context is the metacommunity concept (Leibold et al., 2004). It is an extension of metapopulation theory (Hanski, 1998) and considers an ecosystem as an ensemble of interacting local communities. Each local community consists of a number of interacting local populations. Local communities interact with each other through the dispersal of individuals and the colonisation of neighbouring habitat patches. Species within a local community can go extinct either due to harming influences of other species in the habitat patch or adverse environmental conditions such as too high or too low temperature or too much or too little precipitation.

To improve instruments such as agri-environmental schemes for the conservation of biodiversity it is important to understand the circumstances under which species can co-exist, and how these circumstances are shaped by these schemes. To encompass the spectrum of species competition, in the one extreme, species occupy different ecological niches (i.e. have different requirements regarding temperature, precipitation, food resources, etc.), so the presence of one species in a local habitat has no or only a small influence on the other species and both species can co-exist locally. Here the species can be treated independently, as done in the studies mentioned above. In the other extreme both species occupy the same ecological niche. Here coexistence of both species is impossible (an effect termed the competitive exclusion principle (Begon et al., 2006)), but the superior competitor which utilises resources more efficiently, e.g., to transform given resources into a higher population growth rate, locally outcompetes the inferior competitor (Begon et al., 2006; Giller, 1984), with an empirical example by Mackie et al. (1978). Various mechanisms that facilitate the co-existence of competing species have been identified, one of them being spatial heterogeneity and spatial structure. Spatial structure implies that the superior species generally cannot occupy the entire landscape, which leaves space for the inferior species to survive. Of particular relevance here is the so-called competition-colonisation trade-off, which states that in a disturbed environment an inferior competitor can coexist together with a superior competitor if it has a higher ability to colonise empty habitat patches (Tilman et al., 1994; Cadotte, 2007). The higher colonisation ability allows the inferior competitor to continuously escape from becoming outcompeted in the entire landscape – even though locally (i.e. on individual habitat patches) it is always outcompeted by the superior species.

Species communities subject to the competition-colonisation trade-off are likely to be affected by the spatial land-use pattern, which in turn is affected by the existing (economic) constraints of the land use and conservation instruments. Conversely, species communities subject to the colonisation-extinction trade-off are likely to respond to conservation instruments differently from single or independent species. While the response of single species by conservation instruments is quite well understood (see references above) the response of interacting species still needs to be analysed.

The present study for the first time links an economic model with a metacommunity model to investigate which policy designs facilitate the survival and coexistence of two competing species in a region. For the economic model we choose the above-mentioned tradable permit model by Drechsler and Wätzold (2009). The land-use pattern induced by the permit market affects the survival of two competing species where the presence of one species (the superior competitor) locally inhibits the presence of the other (the inferior competitor). Both species are spatially structured as metapopulations, i.e. each habitat patch may be occupied by a local population, local populations can go extinct by chance and empty habitat patches can be recolonised by neighbouring local populations.

The ecological-economic model and the way in which it is analysed are presented in the next section which is followed by the Results section. The paper concludes with a discussion of the results in Section 4.

2. Methods

The following section describes the economic module and the integration of the ecological module into the economic module. The section concludes with a description of the way in which the combined model is analysed.

2.1. Economic Module

The economic module simulates a market for tradable land-use permits where a conservation agency imposes on each land user the obligation to conserve some of his or her land. If a land user conserves more land than required the excess conservation effort can be sold to other land user in the region through land-use permits. In turn, a land user who wishes to conserve less land than required can buy some of these land-use permits on the market to compensate for his or her shortfall of conservation effort. The module has been described in detail by Drechsler and Wätzold (2009). Below we provide a brief outline.

We consider a region of land parcels arranged in a square grid. Each land parcel i is owned by a land user and can be managed in two ways: conservation (i.e. generation of habitat for endangered species) or economic use, such as (intensive) agriculture or forestry. Conserving a land parcel i reduces agricultural or forestry profits on the land parcel, which reflects in conservation (opportunity) costs of magnitude z_i. The z_i are assumed to be uncorrelated uniform random numbers drawn from the interval $[1 - \sigma, 1 + \sigma]$, where σ denotes the cost variation. To model economic change the conservation costs z_i are randomly re-drawn in each time step (year).

Conservation of a land parcel i generates an amount of land-use permits of

$$v_i = 1 + wm_i$$

where m_i is the proportion of conserved land parcels in the Moore neighbourhood around land parcel i. The Moore neighbourhood consists of the eight land parcels adjacent to land parcel i. Parameter w is the weight attached to the presence of other habitats in the Moore neighbourhood. It is chosen by the policy maker and can take any non-negative value. A zero value implies that conserving a land parcel adjacent to other conserved land parcels generates as many land-use permits as the conservation of an isolated land parcel. An isolated land parcel generates land-use permits of an amount $v_i = 1$; if $w > 0$ conserving a land parcel adjacent to other conserved land parcels increases

Download English Version:

https://daneshyari.com/en/article/7344349

Download Persian Version:

https://daneshyari.com/article/7344349

Daneshyari.com