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Analysis

# Conjunctive Implementation of Land Sparing and Land Sharing for Environmental Preservation☆

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ABSTRACT

In this paper, we investigate the concept of land sharing and land sparing management options for environmental preservation. We propose a general framework for the analysis of the conjunctive implementation of both land management options. This general framework provides an empirical rule of selection that can easily be implemented by a land-planner without specific knowledge of optimization procedures. Our main finding is that both the environmental benefit to cost ratio and the benefit difference (between a sharing and a sparing management option) to cost difference ratio matter for selection of parcels. We then develop an empirical application of this framework for the Seine-Ource river catchment in Burgundy, France. We look for the best land management option to implement for water quality preservation. We show that it is more cost-effective to implement land sharing and land sparing management options conjunctively than separately.



## 1. Introduction

Land conservation has attracted considerable resources from the private and public sectors. In the United States, around USD32 billion was spent between 1992 and 2001 on land conservation efforts, both short-term (rentals, cost-share programs) and permanent (fee simple, easements) (Lerner et al., 2007). This amount of effort still lays well below the estimated necessary funds to secure a strategic habitat network in the United States (USD250 to USD500 billion, according to Shaffer et al., 2002). Furthermore, current conservation programs are usually far from being cost-effective.[1]

In an effort to achieve more cost-effective conservation programs, various selection strategies have been analysed. In the field of conservation biology, Margules et al. (1988), for instance, produced a methodology for selecting land to preserve that consists of maximising biological diversity. Extensions of this work proposed switching from a maximisation of the number of species preserved to a strategy that also considers the cost of land purchase. For instance, Ando et al. (1998) compared both methods and showed that the hierarchy of lands to preserve can be very different between methods. A rich body of economic literature has developed since then. It broadens the understanding of the implications of different issues for the cost-effectiveness of policies.[2]

In this paper, we raise the question of the optimal selection procedure when more than one option can be applied by a unique agency or land-planner to achieve a given environmental outcome, and that these options have different costs and benefits. Typically, land easement or land purchase from land-owners and payments for environmental

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[1] See for instance Babcock et al. (1996), Ferraro (2003a), Messer and Allen (2010), Duke et al. (2014) or Messer et al. (2016).

[2] Issues such as threshold effects in the provision of the environmental good (Wu and Boggess, 1999; Wu et al., 2000; Wu and Skelton-Groth, 2002; Ferraro, 2003b), the joint distribution of costs and benefits (Babcock et al., 1997; Ferraro, 2004), the consideration of multiple environmental objectives (Coiner et al., 2001; Newburn et al., 2006) or the multiplication of funding sources (Messer et al., 2016) are adressed.

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services constitute 2 types of options to secure land conservation that do not exhibit the same costs and benefits. Such options can be revisited through a typology that has received a lot of attention in the ecology literature, the land sharing versus land sparing distinction. The concepts of land sharing and land sparing were originally defined in the case of biodiversity conservation (Green et al., 2005). In the land sharing approach, wildlife-friendly farming is spread over the landscape to improve the wildlife population without decreasing agricultural production. In the land sparing approach, demand for farmland is reduced through an increase in yields, leaving more room for natural land uses. The literature that followed aimed at finding the best way to reconcile food production and biodiversity (see for instance Phalan et al., 2011 or Godfray, 2011).

To the best of our knowledge, economic analysis of this debate is fairly absent from the literature (see Martinet, 2014). In this paper, we propose to fill this gap by taking this debate as a point of departure to improve environmental conservation. Unlike the existing ecology literature, we implicitly assume that agricultural yields cannot be improved and that fixed yields do not have an impact on commodity prices. The consequence is that we look for the best land management option to improve environmental preservation while keeping agricultural incomes constant, rather than keeping agricultural production constant.[3]

Quantitative comparisons of land sharing and land sparing options from an economic point of view are scarce (Hanley et al., 2012), with the recent exception of Curran et al. (2016). In this study, they prospectively compare the cost-effectiveness of payments for ecosystem services and land purchases or easements in Central Kenya and show that under different scenarios the purchase approach dominates the payment approach, with respect to different measures of environmental benefits and costs. We adopt a different approach in this paper. We consider that both options can be applied in conjunction, so that the agency in charge of land conservation has to select both the parcels to conserve and the conservation option to apply to each parcel. In this respect, our analysis is an ex ante one, since it aims at defining the best selection procedure before its implementation.

From a theoretical point of view, Duke et al. (2013) propose to divide the techniques behind cost-effective conservation planning between 2 main sets. The first group of techniques is based on iterative procedure of ranking and the second one on optimization algorithms. They explain that optimization algorithms help achieve cost-effectiveness in more complex situations. In this work, we propose to derive the corresponding ranking procedure that can occur in a quite complex situation, i.e. when 2 land management options (land sharing and land sparing) can be implemented conjunctively, from mathematical optimizations problems. By doing so, we extend the theoretical framework developed in Babcock et al. (1997) to accommodate targeting tools when 2 management options, with different costs and benefits, can be implemented. We compare selection strategies based on economic costs only, environmental benefits only or both. Our main contribution relies on the latter: we show that both the environmental benefit to cost ratio and the benefit difference to cost difference ratio (between management options) matter in a ranking procedure aiming at achieving cost-effectiveness through the conjunctive implementation of land sharing and land sparing management options.

We apply our theoretical analysis to the case of site selection to manage water quality in the Seine-Ource water catchment in Burgundy, France, by examining a sample of 4315 candidate parcels. Water pollution from agricultural sources, and in particular from pesticides use, is a crucial matter in Europe, and policies, such as the European Water Framework Directive or the Directive 2009/128/EC, on the sustainable use of pesticides have been implemented to regulate their use. Within this context, local decision makers typically implement 2 broad types of land management options. The land sharing option consists of using economic incentives, such as taxes or subsidies, to guide farmers toward sustainable pest management practices (see for instance Sexton et al., 2007 for more details). The land sparing option relies on direct intervention in the land market, to purchase and exclude the parcels with the highest risk of pesticide contamination from agricultural production. Our empirical application makes a second important contribution. It demonstrates that in situations where a policy-maker has multiple options with different costs and benefits, allowing for conjunctive implementation of these options increases the cost-effectiveness of policy intervention. In this respect, it allows the 'land sharing versus land sparing' debate to move forward by proposing to combine these options, rather than regarding them as opposing points of view.

## 2. General Framework

We analyse the situation where an environmental planner intervenes in the agricultural land market, which consists of I parcels. Let $1 \le i \le I$ be an indicator for each individual parcel of area $a_i$. Two types of land management options are available: the land sharing one (denoted by subscript h) and the land sparing one (denoted by subscript p). We focus on the case where these options are combined, that is when the land planner has the possibility to implement land purchase and agricultural subsidies in conjunction; hence, these options may coexist at the land planner's jurisdiction scale, but also within each parcel. This means that land sharing and land sparing management options can occur only on a portion of a parcel. In the land sparing option, parcels can be divided before being sold (see McPherson, 1983, for a treatment of land fragmentation). Concerning the subdivision in the land sharing case, riparian buffer strips constitute an example (see for instance Stutter et al., 2012).

Each parcel preservation generates per hectare costs $c_{hi}$ (or $c_{pi}$) and environmental gains $b_{hi}$ (or $b_{pi}$), depending on which option is implemented on this unit of land. $c_{pi}$ can be interpreted as the opportunity cost of agricultural production, which we take to be the minimum amount per hectare that the planner has to spend in order to take this land out of production. $c_{hi}$ is the minimum amount the planner has to offer in order to induce farmers to adopt new practices. The environmental gains are a measure of the increase in the provision of the ecosystem service per hectare when a land management option is implemented, as compared to the status quo agricultural land use. No a priori assumption is made on the ranking of these costs and gains.

Public intervention entails costs that depend on the amount of land under each type of land management option. Let $x_{hi}$ denote the area subsidized for land sharing and $x_{pi}$ the area purchased by the land planner in each land unit. Land on a parcel which is not shared or spared stays as the status quo agricultural land use. Consequently, this analysis goes beyond 'piece-meal' land preservation because we allow for only parts of parcels to be enrolled in a management option: $x_{hi} + x_{pi} \le a_i$.

We consider the cost-effective strategy, denoted as S, under which the regulator maximises the environmental gains under an economic cost constraint:

$$\max_{x_{hi},x_{pi}} \sum_{i=1}^{I} x_{hi}.b_{hi} + \sum_{i=1}^{I} x_{pi}.b_{pi}$$
$$\text{s.t.} \begin{cases} \sum_{i=1}^{I} x_{hi}.c_{hi} + \sum_{i=1}^{I} x_{pi}.c_{pi} \le B \\ x_{hi} + x_{pi} \le a_i \end{cases}$$

Let the values of the optimal solution be given by $x_{hi}^{\otimes}$, $x_{pi}^{\otimes}$ and $\pi^{\otimes}$ denote the optimal shadow price of the budget constraint. This shadow

[3] The difference between focusing on income and on production is that we will look for a cost-effective land management option instead of a yield-effective management option.