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Land sparing versus land sharing: an economist's perspective

Jean-Michel Salles¹  · Félix Teillard^{2,3} · Muriel Tichit² · Maiko Zanella⁴

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Abstract The land sparing versus land sharing debate has already had a significant history and was particularly active during the last decade. Studies carried out mostly by ecologists and agronomists have clarified a number of issues related to best land use strategies in different landscapes, establishing that the best strategy depends first on the response of biodiversity to anthropogenic pressures, and can vary with the spatial scale of the analysis. We argue that the first contribution of an economist's perspective is to place the idea of social efficiency, i.e., the improvement in human welfare from limited resources, at the heart of discussions and models concerning the food/biodiversity nexus. The purpose and meaning of economic approaches, whether incorporated into biophysical analyses or based on their results, is to identify and understand the logic and behaviour of agents and their impact on land use.

We highlight some significant results derived from modelling work. In particular, it is shown that the assumption of fixed production target used in many works is unrealistic. We put into perspective recent work that analysed the effects of price changes and the impact of agricultural markets on land use. We conclude on the importance of integrating the economic mechanisms that guide individual and collective behaviours, in the design of local policy mix between land sparing and land sharing.

Keywords Agriculture · Conservation · Economic analysis · Land sharing · Land sparing

The land sparing versus land sharing debate

The concept of sparing land for biodiversity conservation was introduced by Waggoner (1996) to characterize zoning policies that set aside land from agricultural production for biodiversity conservation. This idea is sometimes referred to as “the Borlaug hypothesis”, after Norman Borlaug, father of the Green Revolution, who considered agricultural intensification good for the environment as it concentrated production on limited land (Borlaug 2007). The main alternative to this approach is to promote agricultural practices with lower ecosystem impacts and to increase within-field biodiversity (so-called wildlife-friendly farming). Green et al. (2005) introduced a debate on the advantages and disadvantages of wildlife-friendly farming in relation to a land sparing strategy, for conservation, which has been changed quickly into “land sparing versus land sharing” that sounds better.

One of the central elements of the debate concerns the effects of agricultural intensity (or yield) on biodiversity. This question takes into consideration the underlying

✉ Jean-Michel Salles
jean-michel.salles@supagro.inra.fr

Félix Teillard
Felix.Teillard@fao.org

Muriel Tichit
muriel.tichit@agroparistech.fr

Maiko Zanella
maikozanella@hotmail.com.br

¹ LAMETA, CNRS, INRA, Montpellier SupAgro, Univ. Montpellier, Univ. Paul Valéry, Montpellier, France

² UMR SADAPT, INRA, AgroParisTech, Université Paris-Saclay, 75005 Paris, France

³ Animal Production and Health Division, Food and Agriculture Organization of the United Nations (FAO), 00153 Rome, Italy

⁴ UMR 1135 LAMETA, Montpellier SupAgro, 2 place Viala, 34060 Montpellier, France

mechanisms of how ecosystems react to increasing agricultural pressure (Fig. 1). If the biodiversity/yield response follows a convex negative curve (Fig. 1a), meaning that the loss of either unfarmed or very extensively managed habitats is the most detrimental to biodiversity, the land sparing strategy is preferred. Part of a region would be spared at null or very low intensity to fulfil conservation objectives, while the remaining area would compensate for the loss of productive land with high yielding intensive farming. However, if the response is concave (Fig. 1a), meaning that biodiversity declines slowly, as intensity starts to increase, but becomes severely impacted at high-intensity levels, the land sharing strategy is the most efficient. The entire region would be farmed with moderate farming intensity, reconciling satisfying performance for both agricultural production and biodiversity conservation

criteria. Agricultural yield is not considered to influence biodiversity directly, but it does it indirectly. Higher yield correlates with certain management practices (e.g. higher input use intensity) that may negatively affect species and their habitats (Tilman et al. 2001). This correlation is not robust because yield also depends on soil and climatic conditions. Both yield (Phalan et al. 2011b, Hulme et al. 2013) and input intensity (Kleijn et al. 2009, Teillard et al. 2015) have been used to determine the biodiversity response curve (concave versus convex); however, only yield contains information that is required to assess trade-offs between production and biodiversity and to guide decisions on land sparing versus land sharing. Phalan et al. (2011b) argued that species density is the most appropriate metric for quantitative biodiversity information used to compute the biodiversity/yield curve. Information on

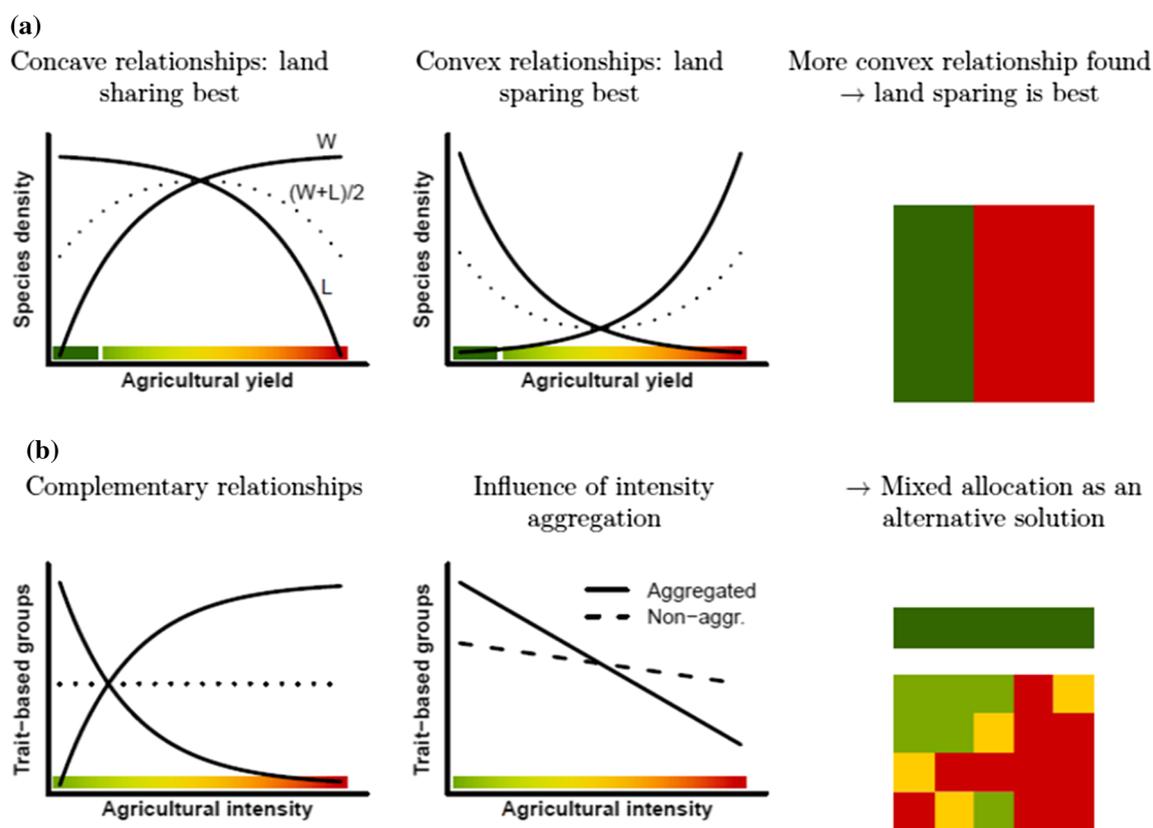


Fig. 1 Land sparing and sharing model applied to tropical and temperate ecosystems. **a** As originally formalized by Green et al. (2005) and further applied by Phalan et al. (2011b) on Ghana and India data. The agricultural intensity gradient includes unexploited land uses (*dark green*). Authors state that concave responses for both loser (*L*, negative response) and winner (*W*, positive response) species involve land sharing to be best. Convex responses show land sparing to be best. It implies that, within one strategy, the sum between loser and winner $[(W + L)/2]$, *dotted lines* is not constant along the intensity gradient. Since the authors find more convex negative responses, they suggest land sparing is the best strategy. **b** As formalized by Teillard (2012) and Teillard et al. (2012) in temperate

agroecosystems, based on a nationwide intensity gradient (France). Unexploited land uses are excluded from this intensity gradient. Authors showed complementary responses between loser and winners: convex and concave, respectively. Their summed abundance is, therefore, constant along the intensity gradient. They also show that the spatial aggregation of intensity strengthens its effect (Teillard et al. 2015). They suggest that a mixed strategy including the following would be the best: (1) separate consideration of unexploited land use because it has conservation issues that differ from farmland in Europe; (2) promotion of large clusters of homogeneous, extensive areas; and (3) of intensive areas that display more heterogeneity (colour figure online)

species richness and diversity also has been used, but it does not consider the higher conservation value of certain species (e.g. threatened or patrimonial species).

Several studies have concluded that increased efficiency and intensification of agricultural production could potentially help biodiversity conservation by sparing land from production (Trewavas 2001; Tilman et al. 2002; Green et al. 2005; Balmford et al. 2005). This conclusion is supported by empirical evidence of the biodiversity/yield curve, which is more convex than concave in developing and industrialized countries (Phalan et al. 2011a; Hulme et al. 2013; Kleijn et al. 2009; Teillard et al. 2015). However, high biodiversity levels can be found in extensive areas of farmland, in both developed and developing countries (Bignal and McCracken 1996; Ranganathan et al. 2008), which suggests that concave biodiversity/yield curve also exists. This observation has led several authors to argue that ignoring the role of agricultural landscapes for biodiversity conservation would be an unproductive strategy and that land sharing could be a better solution for biodiversity in a number of situations (Fischer et al. 2008; Perfecto and Vandermeer 2008a, Tschardt et al. 2012).

Land sparing strategies envision that biodiversity conservation should occur primarily in reserves and protected areas by spatially segregating conservation and production functions (Table 1). They require solutions for the negative influences that arise from the proximity of intensively cultivated areas to natural areas (e.g. soil and water pollution by nutrients and pesticides) or from global impacts (e.g. greenhouse gas emissions that cause climate change). These solutions could be facilitated by management practices and technology that increase yields while reducing negative externalities (Godfray et al. 2010).

Land sharing strategies consider a landscape perspective in which agricultural land provides resources to species and enables their migration between natural habitats; therefore, they envision that biodiversity conservation should be extended beyond reserves (Table 1). This vision is well recognized in Europe, e.g., through the concept of High Nature Value farmland (Paracchini et al. 2008), and can be found in tropical areas (Chazdon et al. 2009). By promoting biodiversity conservation in farmland, land sharing creates an opportunity for agricultural systems to benefit from ecological processes. This is the field of agroecology,

which investigates how agriculture can rely on ecosystem services to partially achieve functions that are currently fulfilled by chemical inputs (Altieri 2002).

Land sparing and land sharing cannot be considered equivalent at different scales (Fischer et al. 2008). In the land sparing strategy, areas of natural habitat should be sufficiently large to support viable populations (Phalan et al. 2011b). Land sparing results in a coarse grain landscape heterogeneity, with large areas of natural habitat within a matrix of intensively cultivated agricultural land, whereas land sharing results in fine scale landscape heterogeneity. Agri-environmental measures such as grassy strips, tree/shrub hedges, or those promoting a diversity of agricultural land uses could be considered as land sparing at a field or farm scale; however, they correspond to land sharing at a landscape scale, which is the relevant scale for conservation of most farmland species (e.g. butterflies, pollinators, and birds). These measures do not independently provide viable habitat, but they allow farmland species to access a variety of resources and migrate between habitats across the landscape.

Some key points

The land sparing versus land sharing debate did not emerge suddenly with Green's article. The concept that natural areas can and must be preserved within inhabited territories, and especially within farmlands, was proposed at the origin of the UNESCO Man and Biosphere programme in 1977. The founding document of the World Conservation Strategy (Allen 1980), which is one of the first documents to use the term "sustainable development", states that long-term conservation objectives could not be achieved only with nature reserves. Pimentel et al. (1992) argued that most biodiversity lives in human-managed ecosystems and that agricultural systems provided a landscape context that determined the effectiveness of protected areas. The importance of agricultural production intensification as a strategy to counter agricultural land demands was emphasized by ecologists (Kendall and Pimentel 1994; Goklany 1998; along with agricultural scientists concerned with criticisms of the mainstream agriculture, e.g., Waggoner) and agricultural economists conducting research in areas

Table 1 Characteristics of land sparing and land sharing strategies

Land sparing	Land sharing
Production and conservation in distinct areas	Conservation in agricultural areas
Production intensification	Agricultural production benefits from ecological systems
Less land allocated to production	More land allocated to agriculture
More inputs to agricultural production	Less input (self-sustained agriculture)
Mono-cropping	Diverse or associated crops

where new farmland was expanding (Griffon and Weber 1998; Angelsen and Kaimowitz 2001). Although the issues surrounding land sparing versus land sharing strategies have been debated for several decades, there is growing discord among proponents of the different approaches and a consensus opinion has not been reached. Published literature on land sparing and land sharing has increased exponentially; however, it remains very difficult to obtain empirical results that validate one of the approaches. Local parameters such as topography, soil type, and climate can strongly influence the efficacy of the best local solution. Perfecto and Vandermeer (2010) suggested an approach in terms of an agro-ecological matrix that integrates the spatial dimension of ecological processes to maximize the output from each spatial unit of farmland or natural area.

Conservation issues differ among global regions. Pristine tropical forests are crucial biodiversity hot spots that are under severe threat by the rapid expansion to agricultural conversion. Protecting these habitats through land sparing can thus be a conservation priority. In Europe, unexploited natural areas are rarely threatened by the conversion to agriculture, since many of them already belong to reserves. Conversely, the abandonment of farming in traditional agricultural landscapes with low productivity leads to the loss of specifically adapted local species (Queiroz et al. 2014). Agricultural intensification is another important cause of the decline of farmland specialist species (Chiron et al. 2014), which suffer from higher rates of decline than other groups (e.g. woodland species). Therefore, promoting biodiversity conservation in farmland through land sharing represents a central conservation issue.

Overall, the manner in which land sparing and land sharing strategies are characterized depends on the type of ecosystem and species under consideration. In the tropical ecosystems, most of the endemic biodiversity lies in the pristine forest, an unexploited land cover which intensity can thereby be considered equal to zero. Transition from forest to exploited land uses even with moderate intensity leads to the loss of most species. However, in Europe, land use exploited with moderate intensity can show high biodiversity levels (e.g. permanent grasslands, Bignal and McCracken 1996). These two contrasted examples show that the type of ecosystem can influence what should be considered a reserve habitat in a land sparing strategy. Agricultural habitats represent a central conservation issue, and their farmland specialist species cannot live in the unexploited habitats. The definition of a spared habitat is thus unclear: grasslands could be considered land sharing because production and biodiversity objectives are jointly achieved or, alternatively, as land sparing because they also host unique biodiversity that should be preserved.

Green's canonical model assumes a monotonic relationship between agricultural yield and biodiversity. Further work (Phalan 2011a) analyzes this relationship species by species. The model thus remains very species-centered and neglects other levels (species vs. genes, landscape ecosystems) and other dimensions (composition of species vs. structure or function) of biodiversity. But depending on the type of ecosystem, the scale, the species considered, the results would change a lot. The land sparing versus land sharing debate can be repeated at various scales, for various taxa, with different results. The framework is not scale/species focus consistent due to the simplistic way to "represent" biodiversity. Therefore, a single land use strategy, whether land sparing or sharing, cannot ensure the conservation of all species. For example, species that are highly specialized for farmland habitats are more sensitive to intensification than generalist species (Ekroos et al. 2010). Among farmland specialists, there are differences between grassland and non-grassland species (Batory et al. 2007). At the moment when relationships were computed for different taxa, both convex and concave biodiversity relationships were observed (Perfecto et al. 2005), in addition to binomial ones (Steffan-Dewenter et al. 2007). A recent study reported the presence of both loser (negative functional response) and winner (positive functional response) species with respect to crop yield intensification (Phalan et al. 2011a, b). Finding a balance between loser and winner species and setting conservation priorities are questions that go beyond the land sparing versus land sharing debate.

Allocation strategies, as they are represented in the Green et al. (2005) model, include only yield levels and their relative proportions. The model does not account for spatial arrangement of different land uses and thus different yield levels. The model can thus be improved by considering the spatial arrangement of areas under intensive agricultural cultivation (Vandermeer and Perfecto 2005, Phalan et al. 2011b). From this perspective, land sparing corresponds to an aggregated arrangement because the two intensity extremes are segregated in space, whereas land sharing corresponds in most case¹ to fine scale landscape heterogeneity. In a given area, biodiversity can be affected by the intensity of the surrounding land uses; high-intensity agricultural land use in areas adjoining semi-natural habitats can limit dispersal abilities and lead to chemical drift from pesticides and fertilizers, whereas low-intensity land use in adjoining areas can provide complementary resources (Perfecto and Vandermeer 2008b). In this case, the biodiversity/yield curve helps to determine the optimal mix of land use intensity (land sparing versus land

¹ If the ecological conditions allow it in the long run, an openfield of organic production would fit the land sharing concept. In fact, the literature on agroecology is often artificially linked to the LS² debate (as well as the debate on ecological intensification).

sharing). It is thus necessary to account for the spatial arrangement of land use intensity which also influences biodiversity response (Teillard et al. 2015; Fig. 1b). Land productivity will affect the relative performance of either approach. The question “can organic farming feed the world?” (Badgley and Perfecto 2007; Badgley et al. 2007; Seufert et al. 2012) is closely related to the land sparing/land sharing debate. The green revolution promoted a high-input agricultural model that appears appropriate for the world hunger issue (Borlaug 2002), but has also imposed a self-reinforcing technical model which is challenged today, firstly because it is not suited to certain situations in which it led to substantial harmful effects or loss of agricultural land, but also in its very essence. Preferences for organic agriculture in affluent countries are not only derived from perceived higher taste or safety attributes of the products and also reflect a willingness-to-pay motivated by the desire to contribute to a public good related to the environment (Bougherara and Combris 2009). In a behavioural perspective, these authors point out the crucial role of the way information is conveyed to participants (in their experimental protocol) and also the importance of their prior beliefs.

Some argue that further agricultural intensification would release pressure on land conversion and spare land for nature conservation (Borlaug 2002, 2007), but this argument is still subject to debate. Intensification tends to increase farm profit margins and could stimulate production and cropland expansion² (Ewers et al. 2009). Public subsidies for production could even accentuate this trend. Agricultural intensification within the land sparing strategy would have to be combined with strict limitations on agricultural expansion to ensure that land is actually spared for nature. This spared land would have to be appropriately managed to maximize biodiversity. Innovative management solutions would have to target the agricultural area to mitigate the biodiversity loss that further intensification inevitably causes (Phalan et al. 2014).

About the meaning of an economist's perspective

In a recent attempt to move beyond this debate, Grau et al. (2013) have tried to summarize the reason to prefer either land sparing or land sharing, according to spatial scales. Besides the ecological and agronomic aspects, their synthesis offers a significant place to economic considerations. Here we want to highlight that the most relevant economic arguments are of a totally different nature from technical or

ecological arguments and can result in changes in the hierarchy between the two strategies.

A central point in economic analysis is to consider the observed or expected situations as the result of choices made by rational agents. Although the metaphor of an omniscient and well-intentioned central planner is sometimes used as a baseline, changes at the landscape scale are considered as the result of choices made by a diversity of individuals (e.g. farmers, agro-industries, consumers, policy makers, environmental activists) pursuing specific interests. To analyse and forecast current and future land use trends or the impact of public policies, explicit assumptions have to be made about individual rationalities and how individual behaviours and strategies interact (e.g. competitive markets, monopolies, externalities, public policies).

Ecological approaches to conservation strategies are typically based on exogenous targets for agricultural production or on consumers “needs”. The food production target underlying Green's and Balmford framework (Green et al. 2005; Balmford et al. 2005) can be presented as an example. But, it is difficult, if not inappropriate, to characterize the “needs” in absolute terms. In most situations, consumption is more accurately characterized in terms of demand for goods and services that may adjust according to prices, and institutional, social or technological changes. From an economic perspective, land allocation depends on variables such as crop prices (relatively to other prices such as production factors or other consumption goods), labour productivity, and local cost/time benefits that may become endogenous to an economic model.

The rationale for a land sparing strategy is to intensify production on part of the land—where possible, the land with the best agronomic potential—this implies that agricultural production becomes technically more efficient. This option leads to lower prices of agricultural output, compared to land sharing. Thus, the consequence is an increase in demand of output which can result in an increase in the demand for resources, namely agricultural land, dedicated to their production, or at least a lower decrease than what is suggested by a simple arithmetic calculation based on an exogenous production targets. This is the so-called rebound effect that tends to hamper conservation strategies based solely on technological improvement. The price-elasticity of the demand for human food is usually low (it is a textbook example, for a recent survey see Andreyeva et al. 2010), but agricultural production also serves demands for animal feed, biofuels, and industrial raw materials. In economic terms, the increase in agricultural productivity makes it more competitive and, as demand for food is inelastic, supply is moving towards new markets.

The land sparing versus land sharing debate has mostly been investigated by ecologist and to a lesser extend agronomist. Economic analysis and modelling of land

² This effect is ambiguous and depends on the shape of the demand function for food. Intensification (assuming higher profit) increases the share of intensive agriculture, but may reduce more than proportionally the share of extensive farming if demand has a low price-elasticity. The overall result may depend on some type of rebound effect (see Lambin and Meyfroidt 2011).

allocation decisions have to integrate the complexity and dynamics of human behaviours that lead to these situations. The economic literature on the related issues is still rather limited, but some research results and perspectives can be presented in the following.

The economics of the food versus biodiversity issue

The economic aspects are mentioned in a few papers related to land sharing versus land sparing or to the spatial dimension of the food versus biodiversity question. Without claiming to be exhaustive, mention should be made of the early work done by Thomas Tomich, Meine van Noordwijk and their colleagues at ICRAF (Indonesia). Their general objective was to find economically viable alternatives to slash-and-burn practices that threatened the forests of Southeast Asia and other regions. The idea that agricultural intensification could result in land sparing was at the core of the economic model they elaborated to study the trade-offs and synergies between agricultural production, economic development and the environment (Tomich et al. 2001). Their perspective was to bring material support for negotiations on integrated natural resource management in tropical forest margins. On the basis of fieldwork in Indonesia and elsewhere, they developed the idea of an “integration” versus “segregation” dilemma in landscape management for biodiversity and agricultural production (Van Noordwijk et al. 2003).

More recently, Hertel et al. (2014) aim to assess the assertion that agricultural innovation tends to spare land. Considering that numerous case studies and global empirical studies have found little evidence of higher yields being accompanied by reduced area, they introduce a theoretical framework for analysing the impacts of regional and global innovation on long run crop output, prices, land rents, land use, and associated CO₂ emissions too. A first important point of their study is to validate the Borlaug Hypothesis that the Green Revolution in Asia, Latin America, and the Middle East was unambiguously land and emissions sparing, compared with a counterfactual world without these innovations. But the environmental impacts of a prospective African Green Revolution appear potentially ambiguous. They explain these divergent results by the relative differences between the innovating region and the rest of the world in terms of yields, cropland supply response, and intensification potential. However, according to their model, if it were sustained for several decades, an African Green Revolution might end up becoming land sparing.

In a more specific framework, Hart et al. (2014) compared uniform and spatially differentiated conditions to produce food and preserve wildlife in a northern European landscape. They argue that trying to boost wildlife on

agricultural land through a general reduction in intensity may not be optimal, since cost functions for provision of wildlife on agricultural land may be non-convex, due to fixed costs associated with such provision. To test this hypothesis, they built a model based on the theoretical situation of identical farmers managing mown grasslands in southern Sweden, where the two products are silage and successful reproduction of ground-nesting birds, and the farmer can choose the date of the first mowing. They showed that the optimal solutions consist of some farmers maintain profit-maximizing practices while other—identical—farmers delay their first mowing.

The economics of the land sparing versus land sharing debate

As Fischer et al. (2014) points out: “These strategies are not mutually exclusive, and many conservationists believe that a combination of reserve and off reserve strategies is needed for effective biodiversity conservation” (see Fischer et al. 2008; Scariot 2013). And the central issue, for both current conservation strategies and food security, is to identify efficient trade-offs. In order to explicitly study these trade-offs, ecological and agronomic knowledge is indispensable and is logically at the heart of existing analyses. But “the framework on land sparing versus land sharing is essentially an economic one because it is interested in the efficient allocation of a scarce resource, namely land” (Fischer et al. 2014).

Fischer et al. (2014) argue (after Butsic et al. 2012) that, rather than talking about food production, the debate should be framed around the notion of land scarcity. They justify the choice of this approach by three observations: “(1) land use is effectively the object of choices, (2) much of what is grown on land is not actually used to feed people (e.g. energy crops or fibre), or (3) serves to satisfy economic demand far above what is strictly ‘needed’ (e.g. overconsumption that leads to ill health; coffee and cocoa; or soy fed to livestock)”. Their analysis highlights the importance of what they call “partial trade-offs”, i.e., solutions combining the two land-saving and land sharing strategies. To analyse the choice options, they identify the issues related to how biodiversity should be quantified and a series of scale effects that may not be adequately addressed.

From an economic perspective, a central question in the land sparing versus land sharing debate can be formulated as follows: since land allocation results from rational choices of various agents, what would be the most socially beneficial situation resulting from distinct policy options? To explore this issue, Barraquand and Martinet (2011) developed a dynamic ecological economic model of agricultural land use and spatially explicit population

dynamics. Then, they introduced policies (subsidies to meadows, taxation of agricultural intensity) and analysed the related ecological impact. Exhibiting the trade-offs between the probability of persistence of a species of interest and agricultural production, they studied the effectiveness of agri-environmental programmes for biological conservation. They showed that improving conservation does not require reducing the agricultural output too heavily and that input taxation to reduce intensity appears as a substitute for subsidy to favourable habitat.

To investigate the importance of spatial patterns, Martinet and Barraquand (2012) suggested an original approach extending Green's simple model to account for a number of usual economic assumptions: heterogeneous land and declining agricultural productivity with respect to land use (following the classical Ricardian hypothesis that the best land is put into cultivation first); private ownership of land, which implies decentralized optimization of land use and agricultural intensity; and declining returns with respect to scale in the agricultural sector. These authors reported the following conclusions: while land sparing is always dominating when the biodiversity/yield response is convex, when this relationship is concave, the benefit of land sharing is limited. Land sharing is a desirable option, but should not become a norm for all farmland; it may be more efficient for biodiversity conservation to increase production by agricultural intensification on the best quality land rather than expanding the area of land sharing on lower quality and less productive land. Teillard et al. (2015) also concluded that reconciling food production and biodiversity conservation requires mixed strategies combining sharing and sparing because farmland biodiversity includes both intensity "loser" (with concave response) and "winner" species (with convex response).

Martinet (2014) extended the analysis further to other economic aspects. Considering these outcomes, the author examined how policy instruments can be implemented to balance the social benefits of natural reserves, intensive agriculture on high-quality land, and low-intensity farming on low-quality land. Typically, these instruments (policy mix) may combine taxes on inputs and public subsidies for natural or semi-natural areas like grasslands (e.g. Mouysset et al. 2014). The model outcomes show that social welfare can be improved by this approach. However, it is not possible to define a public policy that is both market-neutral (i.e. that does not modify food production when modifying land use) and budget-balanced (i.e. intensity tax revenues offset the cost of natural reserve subsidies). It can be argued that it is not fruitful for economic analysis to set the debate in terms of food versus biodiversity. From a welfare economics perspective, the trade-offs are balanced between biodiversity conservation, as a source of amenities and production factors, and agricultural added-value if one considers a local-scale conservation problem, whereas the trade-offs must

involve food, biodiversity, and the rest of the economy—the other things that contribute to social welfare—if one considers a global conservation problem. In this perspective, an important part of the relationship with the rest of the economy is regulated by markets and prices.

How agricultural markets can make the difference

A whole body of literature related to land use has established that, in many situations, markets mechanisms contribute to worsen the pressure of agriculture or cattle husbandry on natural ecosystems. For example in cattle ranching in Latin America, variability in land (but also beef) prices fuels land speculation, inflated rates of investment in land, larger (and less intensively managed) farms and, thus, higher rates of deforestation in agrarian frontier areas (see Kaimowitz 1996, or more recently Roebeling and Hendrix 2010). But markets incentives can also have useful effects for conservation.

Desquilbet et al. (2013, 2016) explicitly studied the impacts of agricultural markets on land allocation by introducing prices as an adjustment mechanism between supply and demand for agricultural products. This study design enables testing the implicit but strong assumption that the market equilibrium reaches the same production target in the two production systems (land sparing and land sharing). Instead, their model considered prices and production levels as endogenous outcomes of the supply and demand equilibrium. The effect on global welfare then depends on the relative weights linked to producer and consumer surplus and on better biodiversity conservation in the short and medium term.

The authors reported that, even with a convex biodiversity/yield curve, extensive farming may increase biodiversity compared with intensive farming. The lower efficiency of extensive farming leads to higher market price, lower demand, and lower production output than that of intensive farming. Consequently, the land area used for production will increase less if the level of production is kept constant and may even decrease in some situations. A shift to extensive farming appears favourable for biodiversity in many cases. However, this shift to extensive farming has a negative effect on the sum of consumers' and producers' surplus,³ with a decline in consumers' surplus and either an increase or decline in producers' surplus. Agricultural production serves not only food production,

³ The consumers' surplus is the gain obtained by consumers when they can purchase a product for a price that is less than the highest price that they would be willing to pay it. The producers' surplus is the gain obtained by producers when they sell their product at a price higher than the least that they would be willing to sell for, or what it cost to produce it. The total surplus (consumers' and producers' surplus) is equivalent to the net economic value.

but also animal feed, biofuels, and industrial applications. The authors consider that the main effects observed in their model are not related to the price of food, which would increase food insecurity, but are related to the price of less essential or lower value crops.

Land sparing (intensive farming) thus appears less beneficial to biodiversity than extensive farming (land sharing) can be, “except when there is a high degree of convexity between biodiversity and yield” (Desquilbet et al. 2016). In this extended version of their paper, they explicitly studied the impact of the lower productivity related to a land sharing strategy on the markets of two products differentiated by the demand elasticity (low for human food, high for animal feed). They observe that the main effect of the higher prices associated with extensive farming is indeed a reduction in animal feed production, while they have a limited impact on plant-based food production.

Matson and Vitousek (2006) pointed out that the actual efficiency of the land sparing strategy was hindered by the fact that fertilizers and pesticides used for intensive farming have significant impacts on the surrounding ecosystems. They also considered that intensive production area tends to create a demand for a variety of products and services and to in-migration, population growth and associated land use outside intensive agricultural lands. Their conclusion was that land sparing remained both necessary and potentially beneficial for the natural environment, but the increase in production had to be implemented with a better precision than the standard intensive agriculture.

Desquilbet et al. (2016) does not return analytically to these points, but they highlight that with a zoning of land for nature conservation in the land sparing strategy, the relative effects remain, with a pressure of farmers to extend agriculture on protected areas and almost no effect on biofuel production if there are mandatory blending policies. Ewers et al. (2009) or Godfray (2011) pointed out that the effectiveness of the land sparing strategy could be challenged as farmers try to exploit protected areas.

A direct but unaddressed consequence of the lower productivity of wildlife-friendly farming is that a land sharing strategy would imply more agricultural work and thus would tend to create more agricultural jobs. A complete analysis should, however, consider that the creation of jobs in the agricultural production sector could be partially or fully offset by losses due to macroeconomic impact on other sectors. Creating agricultural jobs remains an important issue, since it is recognized that in certain situations, especially in rural areas,⁴ food security depends

less on global food production than on the ability of the poor to earn income to buy food (Godfray et al. 2010; Loos et al. 2014). For these populations, contrary to the view that high food prices are a cause of malnutrition—which is certainly true in urban areas, particularly in developing economies—higher prices for agricultural productions can mean higher incomes and therefore better access to food. Although AK Sen (1981) has already pointed out that hunger is not necessarily a problem of food availability, but above all a problem of people who do not have the purchasing power to obtain the food they need, this point is still considered a research question.

Concluding remarks

The land sparing versus land sharing debate is essentially a new way to deal with an old issue in agricultural production and in conservation: is it better to concentrate conservation efforts on hot spots, or to preserve as much as possible ecological dynamics and regulations everywhere? This issue has often been studied from an ecological point of view, which discusses whether protecting biodiversity hot spots is the best conservation policy. The economists’ perspective considers conservation and agricultural production symmetrically. The opportunity cost of conservation, i.e. the cost of the conservation strategy in terms of production and welfare losses, spatially differentiated following the productivity of land, thus become a central variable here. Several studies have shown that putting this opportunity cost at the heart of the analysis allows to identify more efficient and adaptive conservation strategies (Costello and Polasky 2004; Polasky et al. 2004, 2008; Naidoo et al. 2006). The land sparing versus land sharing debate is in fact a reflexion on future trade-offs and synergies between agricultural and conservation policies (just as the notion of ecosystem services has become a new framework for thinking about the dependence of human societies on ecological processes and ecosystem functions).

Considering these trade-offs, the economic point of view can be useful for analysing how societies or specific social groups react to new contexts, including for analysing the impact of new policy frameworks. Recent literature suggests that, alongside public policies, prices, especially those of agricultural commodities and land, are signals that help to coordinate the choices and behaviours of heterogeneous agents. In this perspective, the fixed production objective used in many models as a reference for comparing strategies is an artefact with limited realism. This target is neither convincing at the local level where agents’ strategies aim to maximize their income or welfare, nor at more global levels where agricultural production is only one dimension of the choices that impact land use patterns.

⁴ It is perhaps not superfluous to remind that a large part of the populations suffering from hunger are poor peasants: “Today, nearly two-thirds of the world’s hungry people are farmers and pastoralists who live in marginal lands in Asia and Africa” (Borlaug 2007).

Market prices and other mechanism that can indicate social importance and scarcities have to be taken into account in order to develop a useful modelling of the real effects of land strategies on biodiversity and food production.

However, economic analysis will not usefully enlighten the debate unless it is based on sound agricultural and ecological expertise. The land sparing versus land sharing debate is a complex issue that needs to explicitly integrate relevant information on ecosystem science, agricultural techniques and detailed analysis of individual behaviours and social choices. On the basis of an in-depth literature review, Kremen (2015) suggested that “the dichotomy of the land-sparing/land-sharing framework limits the realm of future possibilities to two, largely undesirable, options for conservation. Both large, protected regions and favorable surrounding matrices are needed to promote biodiversity conservation; they work synergistically and are not mutually exclusive.” Thus, the aim of this debate is not only to better understand, assess, or value existing situations, but mainly to formulate effective actions and policies to improve biodiversity conservation and food security. In a heterogeneous world, these choices must take into account circumstances depending on spatial characteristics, time horizon, actors' rationalities, and socioeconomic dynamics.

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