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MINI REVIEW

Land Sparing Versus Land Sharing: Moving Forward

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Abstract

To address the challenges of biodiversity conservation and commodity production, a framework has been proposed that distinguishes between the integration ("land sharing") and separation ("land sparing") of conservation and production. Controversy has arisen around this framework partly because many scholars have focused specifically on food production rather than more encompassing notions such as land scarcity or food security. Controversy further surrounds the practical value of partial trade-off analyses, the ways in which biodiversity should be quantified, and a series of scale effects that are not readily accounted for. We see key priorities for the future in (1) addressing these issues when using the existing framework, and (2) developing alternative, holistic ways to conceptualise challenges related to food, biodiversity, and land scarcity.

Introduction

Scientific debate is at the heart of knowledge creation. A healthy scientific community should test, confirm, and perhaps even argue about ideas, conceptual frameworks and theories. However, at times, scientific debates can become polarised and unproductive. Two classic examples in conservation science are past debates about the design of protected areas (the "SLOSS" debate; Higgs & Usher 1980; Murphy 1989) and about the role of corridors (e.g., Simberloff *et al.* 1992; Noss & Beier 2000).

Today, conservation scientists (along with scholars from other disciplines) are once again engaged in heated discussions—this time about the notion of "land sparing" versus "land sharing" (also termed wildlife-friendly farming; Green *et al.* 2005). In a land sparing strategy, some land is set aside for conservation while other land is used intensively to produce agricultural commodities; in a land sharing strategy, less land is set aside specifically for conservation, but less intensive production techniques are used to maintain some biodiversity throughout agricultural land (Green *et al.* 2005). 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 (Fischer *et al.* 2008; Scariot 2013). Throughout this article, we refer to the explicit analysis of trade-offs

between commodity production and biodiversity conservation, as originally proposed by Green *et al.* (2005), as the "land sparing versus sharing framework."

Notably, debate about how to harmonize agricultural activities with biodiversity conservation is not new (e.g., Waggoner 1996). Over 20 years ago, Pimentel *et al.* (1992) argued that most biodiversity existed in human-managed ecosystems. According to them, agricultural systems were important for biodiversity conservation in their own right, and because they provided the landscape context that would determine the effectiveness of protected areas. Similarly, ecologists were analysing how to meet rising global demand for food at minimal cost to biodiversity long before 2005. For example, both Kendall & Pimentel (1994) and Goklany (1998) flagged the intensification of agricultural land use as a potentially important strategy because they considered it preferable to the further expansion of agricultural land.

Despite a long history of ecologists discussing how to harmonise biodiversity conservation and human land use, the most recent framing of two alternative strategies—land sparing versus land sharing—has sparked lively new debate on the issue. Literature on land sparing and land sharing is now exponentially increasing (Table S1), and strong opinions are being expressed, both in scientific journals (e.g., Vandermeer & Perfecto 2005; Fischer *et al.* 2008, 2011; Chappell *et al.* 2009; Phalan *et al.* 2011b, 2012; Tscharntke *et al.* 2012; Wright *et al.* 2012; Scariot 2013), and in a variety of blogs (Table S1). Why is there so much controversy around this issue? And, more importantly, what would need to happen for this controversy to be resolved? Here, we highlight five points of friction that appear to lead to controversy. For each point, we discuss apparent problems and suggest possible ways forward. We conclude by summarizing what the existing framework on land sparing versus land sharing can and cannot do, and suggest future research priorities.

Five points of friction

Different but overlapping discourses on food

Much of the work on land sparing versus sharing has been concerned with producing food in a way that minimizes harm to biodiversity (Green *et al.* 2005; Phalan *et al.* 2011a, b). "Food" is of interest to a very wide range of scholars with different backgrounds, and so papers on the land sparing versus sharing framework have attracted attention in many scholarly communities—including those interested in ecology, biodiversity conservation, economics, and land use science, but also poverty reduction and sustainability. While these communities share an interest in food, they emphasize different facets. Specifically, disagreements have arisen because the focus on production in the land sparing versus sharing framework has been met with criticism by some scholars (Chappell & LaValle 2011; Fischer *et al.* 2011).

Food production is of central interest in the context of rapidly increasing demand for food and looming land scarcity (Lambin & Meyfroidt 2011; Tilman *et al.* 2011). Because food production potentially competes with other, more biodiversity-friendly land uses (Foley *et al.* 2005), the question how a given amount of food can be produced with least harm to biodiversity is of interest. However, food production also plays a role in the discourse on *food security*. Within the food security discourse, food production is considered as just one of several potential means to alleviate food insecurity (Godfray *et al.* 2010; Foley *et al.* 2011; Garnett & Godfray 2012). Food production is controversial in the food security discourse because it has often been emphasized ahead of other means to alleviate food insecurity, such as reducing poverty and ensuring equitable access to the food already available globally (Chappell & LaValle 2011; Tscharntke *et al.* 2012). Finally, the discourse on *food sovereignty* values people's rights to decide without undue outside pressure which foods they would like to market and consume (Wittman 2010). In this context, a production focus has a particularly negative connotation because it can easily be seen (rightly or wrongly) to embody the interests of "big business" (Box 1).

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. Misunderstandings about the framework therefore might be least likely among economists and land use scientists. To many, though certainly not all, scholars working in these fields, it might seem reasonable to focus on food production as a useful entity in its own right. Yet, it is important to recognize that a focus on production is itself a choice of analytical frame, whose value invites being questioned by others, who may find this focus too narrow.

To avoid misunderstandings in the future, we believe it would be more useful to frame the discussion around the notion of "land scarcity" rather than food production (Butsic *et al.* 2012). This would be appropriate because (i) effectively, land use if the object of choice, (ii) much of what is grown on land is not actually used to feed people (e.g., energy crops or fiber), or (iii) 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). Moreover, similar conceptions of the relationships between land use intensity and biodiversity exist for housing development (Pejchar *et al.*

Box 1: Three overlapping discourses on food

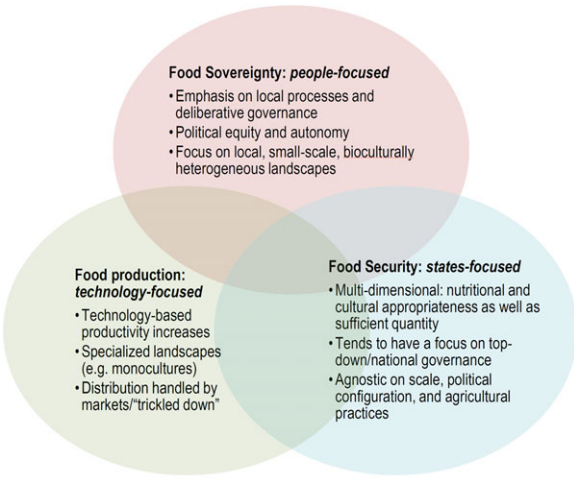

Figure (inset). Summary of key themes addressed in different discourses on food. Note that dominant themes in the different discourses are highlighted to draw out key differences. Themes other than those listed also may be addressed within a given discourse.

Food production: technology-focused. Much literature on the written history of hunger has come at it from the perspective of "too many people, too little food," and thus has looked at remedying famine and chronic hunger through increasing food production. Gains in productivity from the Green Revolution are widely thought to have prevented millions of people from starving (Evenson & Gollin 2003), and to have "benefited virtually all consumers in the world" (Pingali 2012). Reduced prices due to higher food supplies are thought to particularly help the poor, because they spend relatively more of their income on food (Pingali 2007).

Food security: states-focused. Food security can be defined as physical and economic access by all people in a society at all times to enough culturally and nutritionally appropriate food for a healthy and active lifestyle (e.g., Food and Agriculture Organization of the United Nations [FAO] 1996). This multidimensional definition was developed in response to research showing that "starvation is the characteristic of some people not having enough food to eat. It is not the characteristic of there not being enough food to eat. While the latter can be a cause of the former, it is but one of many possible causes" (Sen 1981). Further, lower prices from higher food productivity can even cause increased hunger, because they can reduce profits and wages for poor farmers (Stone *et al.* 2002; Aksoy & Isik-Dikmelik 2008).

Food sovereignty: people-focused. Food sovereignty defines "the rights of local peoples to determine their own agricultural and food policy, organize production and consumption to meet local needs, and secure access to land, water, and seed" (Wittman 2010). It is viewed by proponents as a corrective to the inadequacies of "food security," which "avoided discussing the social control of the food system. As far as the terms of food security go, it is entirely possible for people to be food secure in prison or under a dictatorship" (Patel 2009). Food sovereignty is based on the idea(l)s of political agency and autonomy. It insists that the optimal configuration of a food system should not be taken for granted and left purely to markets or possibly unrepresentative governments, and instead must involve deliberative action by citizens at local and regional, as well as national levels (Chappell 2013).

2007; Gagne & Fahrig 2010) and forestry (Cote *et al.* 2010). By focusing on the broader notion of land scarcity, rather than the specific notion of food production, the land sparing versus sharing framework would be less likely to attract criticism from scholars interested in food security and food sovereignty.

The benefits and limits of analyzing trade-offs

Trade-off analysis is at the core of the land sparing versus sharing framework. We believe it is useful to consider what the explicit analysis of trade-offs can and cannot do. This is because trade-off analysis has clear intellectual value, but also has some important practical limitations.

The explicit analysis of trade-offs can identify where the current allocation of land is inefficient in terms of the provision of multiple goods or services, such as biodiversity and agricultural production. It can therefore identify situations where agricultural production or biodiversity can be increased without any, or with only minimal, negative effects on the other good. Moreover, trade-off analysis can help to identify multiple efficient allocations of land between these two potentially desirable goods by delineating a "production possibility frontier" (Figure 1). There will always be different possible efficient allocations at which it is not possible to increase the provision of one good without reducing the provision of the other. However, a partial trade-off analysis, on its own, provides insufficient information to judge which of the many possible efficient allocations is socially preferable. Do we want an efficient allocation with high biodiversity and low yields, or vice versa? To judge which is better it is necessary to ascribe values to the two different uses. In any given landscape, depending on societal goals, there is no a priori reason to assume that yields should increase, decrease, or remain constant.

Moreover, land provides more valued goods than the two variables considered in the sparing versus sharing

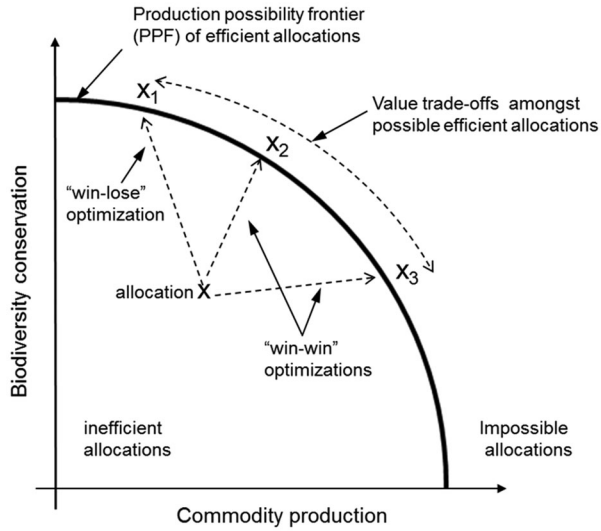

Figure 1 Schematic illustration of the concept of a production possibility frontier. The frontier shows all efficient allocations of land to the provision of two goods (using current technology), namely biodiversity and agricultural production. Trade-off analysis can help distinguish between inefficient allocations of land (within the frontier) and a multitude of efficient allocations (on the frontier). Without an analysis of societal preferences, however, trade-off analysis cannot say anything about which of various efficient allocations should be implemented.

framework. Especially in multifunctional landscapes with rich cultures and histories, reducing land use decisions to two variables (commodity production and biodiversity) is likely to be of limited practical use. Theoretically more than two goods could be considered (Polasky *et al.* 2008; Nelson *et al.* 2009). Increasing the use of multiple trade-off models could help to provide a richer picture of the trade-offs between alternative land uses, but still could not answer which efficient points are best for society. Indeed, many sustainability problems that involve both social and environmental considerations are "wicked" problems—in such problems there is no "right" solution, but "only trade-offs that appear more or less favorable depending on your perspective" (Game *et al.* 2014).

Two further issues complicate the real-world application of the sparing versus sharing framework. First, the two variables considered (commodity production and biodiversity) are not fully independent. The ultimate good "biodiversity" partly upholds the other good ("production") via ecosystem services such as pollination and pest control (see the following section on measuring biodiversity; Bommarco *et al.* 2012; Tscharntke *et al.* 2012). Second, there are few reliable mechanisms that can guarantee that more intensive production in one place does in fact lead to more land spared for biodiversity elsewhere (but see Chandler *et al.* 2013; also see the section on scale issues below). In fact, the opposite may be the case with intensification in an area inviting more intensification because of economies of scale (Matson & Vitousek 2006; Perfecto & Vandermeer 2010). Given inherent and unavoidable limitations of trade-off analysis, the land sparing versus sharing framework is of intellectual value, but cannot easily inform real-world decisions.

Measuring biodiversity

Assuming that a trade-off analysis of agricultural production versus biodiversity is deemed useful, misunderstandings can arise due to contrasting ways of defining or measuring biodiversity. Because aggregate diversity measures such as species richness are scale-dependent and nonadditive, recent analyses on sparing versus sharing instead have focused on the abundance of species (Green *et al.* 2005; Hodgson *et al.* 2010; Phalan *et al.* 2011b; Gabriel *et al.* 2013). Accounting for abundance has advantages because richness on its own says nothing about population viability. However, abundance is not without problems, either—accurate abundance estimates can be difficult to obtain and are not necessarily translatable into population viability (Pulliam 1988). The relationship between population size and its long-term viability is typically nonlinear (Boyce 1992). Moreover, population dynamics will depend not only on habitat area but also on landscape composition, for example, due to source-sink dynamics (Pulliam 1988) or landscape complementation (where species use different parts of a landscape to satisfy different needs; Dunning *et al.* 1992).

Value judgments cannot be avoided when defining appropriate proxies for "biodiversity". The outcome of a particular trade-off analysis will at least partly depend on how biodiversity is measured, and which species are of interest. For example, ecologists might differentiate between generalists and specialists; between common and rare species; or attribute special value to functionally important species such as large, long-lived trees. In tropical areas endemic forest species and species with small geographic ranges are often deemed particularly important (Green *et al.* 2005; Clough *et al.* 2011; Phalan *et al.* 2011b), whereas in European cultural landscapes many species of conservation concern are associated with traditionally managed seminatural grasslands (van Swaay *et al.* 2012), and therefore depend on regular human management (Poschlod & WallisDeVries 2002). This raises a semantic issue that can cause confusion and disagreement—should traditionally managed grasslands and other environments associated with cultural landscapes be classified as examples of land sharing or as critical habitat to be spared (Hodgson *et al.* 2010)?

No matter how biodiversity is defined, by focusing on one part of biodiversity, the consequences of any given land use strategy on other parts of biodiversity might be glossed over or underestimated. Management might favor, for example, species that are rare or those that provide particular ecosystem functions. While many rare species cannot survive in farmland, many species that provide important ecosystem functions can. Some of these species, in turn, provide ecosystem services that positively influence yields (Bommarco *et al.* 2012).

In summary, there is no objective answer as to which aspects of biodiversity ought to be optimized, and all choices are inevitably driven by value judgments. To avoid undue confusion and disagreement, internal consistency and explicit recognition of the limitations of any given approach are important.

Scale effects

Further misunderstandings in discussions about land sparing versus sharing can arise because many studies are not explicit about which spatial and temporal scales are addressed. Moreover, some important scale issues are inherently difficult to address within the sparing versus sharing framework.

First, the spatial grain (i.e., resolution) and extent (i.e., total area) addressed by sparing versus sharing strategies is often unclear. Sparing is often assumed to imply a large geographic extent and a coarse spatial grain (i.e., large blocks of internally homogenous land), whereas land sharing typically refers to integrating agriculture and biodiversity conservation at a fine grain (Fischer *et al.* 2008). However, land sparing also has been used to refer to conservation measures only visible at fine spatial grain, including field margins (Egan & Mortensen 2012; Gabriel *et al.* 2013), land set aside (Quinn *et al.* 2012), or systematically restored parts of small family farms (Chandler *et al.* 2013). Particularly if they are implemented throughout entire landscapes, these strategies are very likely to create what some authors would refer to as landscapes dominated by "land sharing," not sparing (Fischer *et al.* 2008; Rey Benayas & Bullock 2012). Clearly, confusion arises because neither sparing nor sharing strategies are conceptually tied to a particular scale. As a consequence, it is often unclear when sharing becomes sparing, and a landscape considered an example of "land sparing" by some can be considered an example of "land sharing" by others.

Second, land use in any given region is increasingly influenced by distant drivers (e.g., global markets, diffusion of technology), and many commodities are traded globally. The trade-offs between agriculture and biodiversity therefore play out in separate locations, posing difficulties in identifying and mitigating the consequences. For example, both implementing a land sparing system (e.g., through forest protection) or maintaining a land sharing system (e.g., by foregoing maximum yields) in one region can cause leakage effects in which agriculture is displaced to another region through trade (Seto *et al.* 2012; Grau *et al.* 2013). Considering such distant linkages or "teleconnections" between regions when analyzing the trade-offs between agriculture and biodiversity can lead to very different efficient solutions than when regions are assessed in isolation (Polasky *et al.* 2004; Box 2). Existing formulations of the trade-off between land sparing and land sharing have not considered these important spatial interdependencies.

Box 2: Teleconnections, trade, and displacement

The term "*land use teleconnections*" describes the connectedness of different land uses across space, often involving distant actors. *Trade* refers to exchanges between communities or countries and therefore is most appropriately thought of at the regional or global scale (Polasky *et al.* 2004). Both teleconnections and trade allow for land uses in one area to impact and be impacted by land uses in other areas. This can lead to *displacement* of land use (Meyfroidt *et al.* 2010). For example, local forest regrowth may occur because agricultural use has been displaced to another country, as has been the case in parts of Bhutan, China, and Peru (Meyfroidt *et al.* 2010). Likewise, displacement can take place within a country such as the clearing of forest in the central Amazon in Brazil, which has been linked to sugar cane expansion in Sao Palo (Andrade de Sá *et al.* 2013). Because the placement of agricultural activities impacts biodiversity, and because biodiversity varies spatially, teleconnections and displacement of land use via trade, can have distant but large impacts on biodiversity. Currently most of the debate on land sparing land versus land sharing focuses on single locations. The integration of trade and displacement dynamics into the land sparing versus sharing framework could make it more applicable to a connected world (Grau *et al.* 2013).

Finally, the sparing versus sharing framework is a snapshot in time, which fails to consider temporal variation in agricultural land use patterns. Current biodiversity partly reflects historic land uses (Dullinger *et al.* 2013)—for example, grassland communities in Sweden have been found to reflect past patterns of landscape connectivity, rather than current patterns (Lindborg & Eriksson 2004). Hence, it cannot be assumed that systems with the same current land use, but different histories, support the same biodiversity. Similarly, snapshots of current yields

cannot capture annual fluctuations or long-term trends in agricultural productivity or profitability. For example, organic maize production has produced higher yields during droughts, but performed less well than conventional maize production at times of higher precipitation (Lotter *et al.* 2003); and more diverse agricultural landscapes have returned more stable profits for farmers (Abson *et al.* 2013).

In conclusion, a key priority in the future is to be explicit about the spatial and temporal scales at which a given analysis is deemed to be useful. Although improvements are possible in this regard, it is important to recognize the inherent limitations of the land sparing versus sharing framework for dealing with scale effects.

Different conceptions of a viable human-nature balance

Beyond the technical and conceptual issues outlined above, the usefulness attributed to the land sparing versus sharing framework is shaped and limited by deeply held worldviews as to what constitutes a viable human-nature balance. The original framing of land sparing versus land sharing attributed no particular sociocultural significance to either solution (Green *et al.* 2005). According to that framing, as long as both human activities and nature persist, it does not matter whether they do so in the same location (land sharing) or in different locations (land sparing). Yet, this apparently value-neutral framing still chose to focus on "wild nature" versus "production," thereby implicitly embodying a certain world view by shedding light on some things and not others. The debate about land sparing versus sharing thus risks being circular: our worldviews shape the conceptual models we deem useful and interesting, and those models in turn are likely to reinforce our worldviews when populated with data (see also http://johnvandermeer.blogspot.de/2011/09/ideology-and-landsparing-versus.html).

Many scientists argue that the disconnection of people from nature is a root cause of biodiversity decline, and that reconnecting people and nature therefore should be an important societal goal (Miller 2005; Folke *et al.* 2011). Those who accept that reconnecting people and nature is important may either see opportunities for this in land sharing systems, or may see opportunities for experiencing wilderness in land sparing systems. Most likely, an inherent preference for either option by a given scholar will be influenced by the context in which she or he has been socialized as well as the land use histories of the systems deemed most interesting (see previous sections). Moreover, there is no single "correct" way in which to think about the relationship between people and nature (Raymond *et al.* 2013), or about pristine nature (Sheil & Meijaard 2010)—as with the measurement of biodiversity, the choice of analytical frame is inherently subjective.

A key point is that different conceptions of what constitutes a viable human-nature balance are likely to play into scientists' value judgments about land sparing versus land sharing. A preference for either type of system by any given individual does not only result from the answers to a specific trade-off analysis, but very likely relates to much more deeply held views of the world. Importantly, this influences what type of analysis is being undertaken in the first place (using conceptual or quantitative models), and in which study system. This further underlines the first point raised in this article, on addressing food production, food security, or food sovereignty. Depending on their applied goals, scientists need to ask whether a sparing versus sharing framing can actually answer what they perceive to be a useful question—or whether their value judgments lead them to a different framing and therefore to a different analytical approach. We believe that certain ideological positions or inherent preferences cannot be avoided in this debate, but we encourage that such positions be openly discussed, rather than hidden behind an untouchable veil of (unattainable) "objectivity."

Moving forward

The land sparing versus sharing debate has been highly successful in generating much needed discussion about two of the most pressing problems of our time—feeding a growing human population and conserving biodiversity. As the debate matures, and as more people engage with the framework, we believe it is important to reflect on what the framework on land sparing versus sharing can and cannot do. In a nutshell, the framework fits into discourses on food production and land scarcity, but says nothing about food security or food sovereignty. It can help to identify trade-offs, but cannot tell us which of these trade-offs are socially desired. Its answers on biodiversity are only as good as the ways in which biodiversity is defined and measured. The framework distinguishes between two hypothetical conservation mechanisms (sparing versus sharing) but is not well-designed to address scale issues or globalization effects. Finally, the viable coexistence of humans and nature hinges on many additional variables that defy quantification.

No analytical framework is perfect, and there are clear strengths in the framework originally proposed by Green *et al.* (2005). Some scholars will continue to use this original framing, while others would welcome its

advancement or the development of fundamentally different ways to analyze the nexus of food and biodiversity. Recognizing that this choice is, in part, subjective, we make four recommendations to move forward—that is, to generate new insights on the nexus of food and biodiversity without further fuelling what is already a highly polarized debate.

Recommendation 1. When using the existing framework, focus on land scarcity and commodity production, but not specifically on food. Human land-use does not only contribute to well-being through food production, and not all food production contributes to food security (Box 1). A specific focus on food production, particularly when implicitly linked to notions of hunger or food security, is therefore open to criticism. By contrast, a focus on land scarcity is a less controversial, but equally valid frame for trade-off analyses.

Recommendation 2. When using the existing framework, recognize its intellectual value but also its limitations with respect to real-world application. A key reason for the success of the existing framework is that it is analytically elegant. However, partial-trade off analyses cannot directly inform real-world decisions without knowledge on social preferences; because of trade-offs with goods not considered in the analysis; and because of potentially unforeseen flow-on effects of land use choices in any given area (e.g., intensification attracting further intensification). These practical limitations do not deny the intellectual value of partial trade-off analyses, but suggest it is important to explicitly distinguish between intellectual and practical value.

Recommendation 3. The existing framework should be refined to more explicitly address scale issues. Scale issues associated with spatial resolution, temporal extent and teleconnections pose challenges for ecologists and land use scientists not only in the context of the debate on land sparing versus land sharing. While the poor treatment of scale issues is not unique to the existing analytical framework, there is a general need to more carefully consider scale issues when attempting to harmonize human land use with biodiversity conservation.

Recommendation 4. Alternative, more holistic analytical frameworks need to be developed to analyze the nexus of food and biodiversity. While criticism of the existing framework is rife, suggestions of alternative analytical approaches have been scarce. Scientists seeing fundamental problems with the framework on land sparing versus land sharing should develop alternative frameworks. A potentially promising approach could be to assess agricultural landscapes as social–ecological systems, and analyze whether there are properties of such systems that benefit at the same time both food security and biodiversity. A broadly similar systems-oriented approach was used by Ostrom (1990) to analyze the sustainability of common property resource systems.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Table S1. Examples of material dealing with the land sparing versus land sharing framework.

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