

FORUM

Managing ecosystem services and biodiversity conservation in agricultural landscapes: are the solutions the same?

Sarina Macfadyen^{1*}, Saul A. Cunningham¹, Alejandro C. Costamagna^{2†} and Nancy A. Schellhorn²

¹CSIRO Ecosystem Sciences and Sustainable Agriculture Flagship, Clunies Ross St., Canberra ACT 2601, Australia; and ²CSIRO Ecosystem Sciences and Sustainable Agriculture Flagship, Dutton Park, Brisbane QLD 4001, Australia

Summary

1. Biodiversity conservation and agricultural production have traditionally been viewed as substantially in conflict and recent declines in biodiversity have been linked to intensive agricultural production. An increased use of ecosystem services to benefit agricultural production has been proposed as one strategy to enhance conservation of biodiversity in agricultural landscapes and attenuate this conflict.
2. We use examples from the literature to examine the relationship between management of agricultural landscapes for the provision of ecosystem services and management for biodiversity conservation.
3. We argue that although there is a relationship between biodiversity conservation and management for ecosystem services, it does not follow that focusing solely on one or the other will provide reciprocal benefits of the kind we should be seeking in land-use decision-making.
4. We identify a number of asymmetries in the relationship between management for maximizing ecosystem services and biodiversity conservation. Actions that increase or protect biodiversity in an agricultural landscape will often indirectly help preserve ecosystem services, but actions that focus on enhancing ecosystem services will not necessarily provide good outcomes for biodiversity.
5. *Synthesis and applications.* Synergies between agricultural productivity and biodiversity conservation can only be achieved if an understanding of ecosystem services leads to a change in management practice that supports greater biodiversity.

Key-words: ecosystem function, land-use change, production

Introduction

Biodiversity conservation and agricultural production have traditionally been viewed as substantially in conflict and recent declines in biodiversity across a range of taxa have been linked to intensive agricultural production (Biesmeijer *et al.* 2006; Conrad *et al.* 2006; Butler, Vickery & Norris 2007). We know that biodiversity supports many ecosystem functions that may ultimately provide ecosystem services crucial to human well-being and survival (e.g. carbon sequestration, decomposition,

pest control). Rands *et al.* (2010) and Thompson *et al.* (2011) similarly suggest that loss of ecosystem services is one of the imminent threats flowing from biodiversity loss. At least superficially, incorporating ecosystem services into agricultural landscapes opens the possibility of management approaches that support efficient production through the conservation of biodiversity – suggesting a synergy or win-win situation (Fig. 1c). Even though the use of ecosystem services is often criticized as promoting only utilitarian biodiversity values, it nonetheless provides an impetus for conservation that some find attractive (Odling-Smee 2005). We suggest, however, that there are a number of important asymmetries between management for biodiversity conservation and management for ecosystem services which make these synergies hard to attain

*Correspondence author. E-mail: sarina.macfadyen@csiro.au

†Present address: Department of Entomology, University of Manitoba, Winnipeg, MB R3T 2N2, Canada.

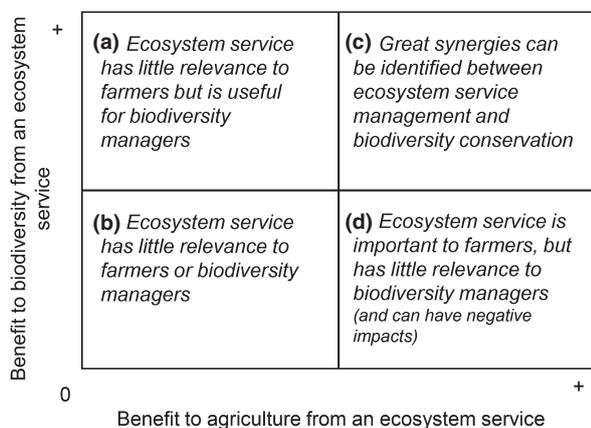


Fig. 1. Possible outcomes when ecosystem services are used to support biodiversity conservation in agricultural landscapes. We have simplified the conceptual space into four distinct outcomes, but in reality there will be a continuum between these areas and circumstances which have multiple outcomes depending on the stakeholder.

and difficult to generalize. Figure 1 conceptualizes the range of possible outcomes when ecosystem services are associated with biodiversity conservation in agricultural landscapes. Here we argue that actions that increase or protect biodiversity in a landscape will often indirectly help preserve ecosystem services to the remaining agriculture, but actions that focus on enhancing ecosystem services will not necessarily provide good outcomes for biodiversity (Fig. 1b,d). Even in circumstances where there is a strong benefit to biodiversity that flows from management for a particular ecosystem service, that service is not necessarily valued by all farmers in a landscape (e.g. insect pollination services are of little value to wheat growers, Fig. 1a). Key to achieving win-win situations for biodiversity and ecosystem services is identifying potential asymmetries and then understanding how management practices that are implemented for the provision of ecosystem services will impact biodiversity conservation. We assume that agriculturalists have some responsibility to conserve biodiversity, even where there is no proven utilitarian value; however, if farmers can value biodiversity in a practical way, we are more likely to achieve good conservation outcomes.

Why is this issue important to think about now?

We have recently observed an increased tendency to link the conservation of biodiversity with the provision of ecosystem services both in ecological studies (Rey Benayas *et al.* 2009; Rhymer *et al.* 2010; Tejada-Cruz *et al.* 2010) and in national and international initiatives designed to conserve biodiversity (see Bullock *et al.* 2011). For example, agri-environment schemes are starting to explore incorporating ecosystem services into initiatives previously aimed solely at biodiversity conservation (see references in Whittingham 2011). If policies for agricultural production and biodiversity conservation are to work sympathetically, it is essential that we identify real threats and opportunities when managing for both. Misunder-

standing can lead to less than satisfactory outcomes, or in some cases negative outcomes (e.g. Dunn 2010; Power 2010 discuss ecosystem disservices from agriculture). In the following sections, we examine three notable asymmetries between ecosystem services and biodiversity that challenge the assumption that planning for one (ecosystem services) will provide obvious benefits for the other (biodiversity). These asymmetries help to explain why much of the outcome space is not, unfortunately, in the win-win territory we desire. We provide examples from the literature to support our arguments but do not attempt a complete review.

Asymmetry in the types of organisms involved

Many ecosystem services are provided by organisms not normally considered during biodiversity conservation planning. For example, soil biota, which are directly linked to ecosystem services related to food production, have been largely ignored in biodiversity conservation management plans (despite evidence in the literature that soils have high levels of diversity, Menta *et al.* 2011; Parker 2010; Smith *et al.* 2008). Native species are rightly the focus of biodiversity conservation, but important ecosystem services will often be provided by species that are non-native, or so common as to be an inappropriate target for conservation management. An obvious example is the European honeybee *Apis mellifera* which provides economically significant crop pollination services in many parts of the world where they are not native (Ricketts 2004; Ricketts *et al.* 2004). In Australia, introduced dung beetles bury and consume cattle dung, hence break down and recycle organic matter. This function can result in improved nutrient cycling and soil structure, and reduce pests and diseases of livestock (daCruz *et al.* 2002). Many biological control agents are exotic or relatively common arthropods. For example, a number of exotic pest aphid species in Australia are attacked by parasitoids that have been imported as biological control agents (Carver 1984). Management to maintain the services of these exotic species for pest control and pollination may not relate to management to maintain the native species providing similar services, or biodiversity conservation more generally.

In some cases, the problem goes beyond an asymmetry to an actual conflict, because some species providing ecosystem services negatively affect biodiversity. For example, two exotic ladybeetle species, *Harmonia axyridis* and *Coccinella septempunctata*, provide important ecosystem services controlling *Aphis glycines*, a soybean pest, but have been shown to decrease dramatically the diversity of native ladybeetles (Costamagna & Landis 2006; Snyder & Evans 2006). Feral honeybees can threaten native biota both through their use of hollows that come at the expense of native fauna and through competition for food (Paini & Roberts 2005).

The level of diversity necessary to provide an ecosystem service is often low compared to the full complement of local biodiversity, and so managing for ecosystem services does not necessarily imply management for diversity. In some cases, a monoculture of exotic species can provide specific ecosystem services as well (or even better) than a diverse community of

native species (examples in Bullock *et al.* 2011). For example, biocontrol ecosystem services are often provided by a few species within assemblages of multiple natural enemy species, with species identity effects being more important than the complement among multiple species (Straub & Snyder 2006). Complementary impacts of species on agricultural pests are more likely to occur when there is resource partitioning by the different species, rather than by diversity *per se* (Finke & Snyder 2008). Even if the service benefits from a diversity of species (Cardinale *et al.* 2003; Crowder *et al.* 2010; Macfadyen *et al.* 2011), those species still reflect a fraction of the broader biodiversity of the area. In cases where the biodiversity benefit is not gained by protecting the service providers *per se*, then benefits will only occur coincidentally if the management action provides a general biodiversity benefit (e.g. Arthur *et al.* 2010).

Asymmetry in the spatial scale of management

Biodiversity conservation planning must occur at a large spatial scale to encompass complementarities among locations in species composition (Margules & Pressey 2000). In contrast, many ecosystem services are managed at very local (e.g. Parker 2010) or relatively local scales (e.g. mobile ecosystem services that flow from remnant vegetation to fields, Bianchi, Booij & Tscharnke 2006; Ricketts *et al.* 2008). In this context, small patches of isolated remnant vegetation could be useful for providing ecosystem services, but have relatively little value in terms of biodiversity conservation (Wilcox & Murphy 1985). If these small patches were to be systematically linked by habitat corridors, or the surrounding agricultural matrix 'softened' in some way, such that species could utilize resources in these small patches more easily, their relevance to species conservation may be improved (Vandermeer, Perfecto & Schellhorn 2010). However, improving the connectivity of remnant vegetation patches is not necessarily linked to better provision of ecosystem services.

Asymmetry of the beneficiaries

In its broadest definition, ecosystem services include all those benefits that people obtain from ecosystems (Millennium Ecosystem Assessment 2005) regardless of whether people perceive or value these benefits (Costanza 2008). However, the ecosystem services that are most likely to encourage widespread change of practice in agricultural landscapes are those where the beneficiaries are local e.g. individual landholders (or a collection of landholders) who gain benefits directly from their management actions (e.g. area-wide pest management, Schellhorn *et al.* 2008). In contrast, the establishment of nature reserves, one of the main tools for biodiversity conservation, is created in the spirit of serving society more broadly, sometimes even to the resentment of the immediate neighbours. Many ecosystem services benefit the wider community (e.g. Costanza 2008; climate regulation, flood mitigation); however, it is rare that farmers are directly rewarded for these widely shared services (although carbon sequestration schemes provide an

example of how this divide can be crossed, Cole 2010). Farmers in some parts of the world are paid directly for conservation outcomes (e.g. agri-environment schemes in Europe, Fuentes-Montemayor, Goulson & Park 2011), but there are many practices that support ecosystem services where the costs and benefits are borne directly by the farmer (e.g. reduced tillage, maintaining remnant vegetation). Even if some of these activities also have biodiversity conservation benefits, the willingness of farmers to adopt them will still depend upon the direct benefit that the farmer receives (e.g. increased crop yield, decreased inputs, ability to access new markets). A unique feature of many ecosystem services in agricultural landscapes is that there is a direct private cost to the farmer, but a mixture of private and public benefits that create a new challenge when we try to value management actions (Balmford *et al.* 2011). Being explicit about whether private or public benefits (or both) flow from a management action implemented by a farmer is crucial when we think about who pays for the implementation costs.

How can synergies be achieved?

Currently, most synergies that exist between ecosystem services provision and biodiversity conservation are co-incident, rather than the result of optimized management. Naidoo *et al.* (2008) illustrate this point by mapping global proxies for four ecosystem services and targets for biodiversity conservation. The regions selected to maximize biodiversity provide no more ecosystem services than regions chosen at random. In fact, there is often lack of spatial concordance between biodiversity and ecosystem services: Chan *et al.* (2006) found that targeting ecosystem services directly (in a conservation planning framework) allowed a biodiversity loss of 44% relative to targeting biodiversity conservation alone. Real synergies can only be achieved if an understanding of ecosystem services leads to a change in land management that supports greater biodiversity (Eigenbrod *et al.* 2009). Here we outline some critical knowledge gaps, and how to address them in the future.

Biodiversity conservation has made great gains by understanding the habitat requirements and management needs of species of interest (Benton 2007). Similar approaches to understand the provision of ecosystem services across space and time are underway (Macfadyen *et al.* 2011). Greater crossover between the fields of conservation biology and production ecology may provide the data we need to achieve win-win outcomes (Fig. 1d). It is clear that we need some biodiversity to support ecosystem services that are integral to agricultural production, and if we erode biodiversity, we will start to see losses of ecosystem services. However, we do not know when we are crossing a critical threshold. For example, Garibaldi *et al.* (2011) used historical record of global crop yield to show that constraints on pollination ecosystem services have limited yield growth. To implement better ecosystem services management, we must first have the information required to quantify if and when a threshold has been reached.

There are still considerable knowledge gaps relating to ecosystem service management and accounting. Most research focuses on proving that a service exists (or valuing it) rather

than demonstrating how a change in management practices might enhance it. We need to better understand the management options that link ecosystem function and the provision of a service, but also determine biodiversity conservation outcomes. Mapping efforts to date, which typically rely on coarse land-use classes and the assumption that a service is being provided, are insufficient, particularly when we start to model relationships among multiple ecosystem services (Bennett, Peterson & Gordon 2009). A review of ecosystem services studies by Seppelt *et al.* (2011) found that < 40% used primary data from observations and two-thirds used un-validated secondary data. These maps can easily give the false impression that win-win situations should be common, but when we try to implement ecosystem services management at the appropriate spatial scale this synergy may prove unattainable (Eigenbrod *et al.* 2009). Until these knowledge gaps are addressed, we will, unfortunately, rely on communicating generic ideas (i.e. spatial heterogeneity is good, species diversity is good) that in some circumstances will not produce the desired outcomes.

Concluding remarks

We have shown that an ecosystem services informed view can influence how we think about biodiversity conservation in agricultural landscapes but we must exercise caution. While we would like to see win-win scenarios (Fig. 1c), in practice other outcomes are likely, including those where there is little or no synergy (Fig. 1a,b,d). Practices associated with agricultural intensification can erode biodiversity and lead to a loss of ecosystem services that are important not only for agricultural production but also human health and well-being. Agriculture needs biodiversity, but most biodiversity does not need agriculture. We predict that a focus on biodiversity conservation will *sometimes* support ecosystem services, but a pure focus on ecosystem services will not generally provide good biodiversity conservation outcomes. Because of this asymmetry, there will rarely be a 'best strategy' for both outcome areas.

It should be recognized that biodiversity is, by definition, not substitutable, whereas ecosystem services can often be substituted by other agricultural inputs (albeit at an economic cost); therefore, it is not appropriate to assume joint optimization can be achieved. A caveat to this statement would be that optimization might be possible if only economic values are considered – but biodiversity conservation is not usually seen as a problem where the benefit side is solely one of economics. Some ecosystem services management is attractive to landholders simply because of direct economic benefit to the farmer. Some ecosystem services are used to defray losses that arise from conservation land management (i.e. removal of land from production), or for reducing some of the negative effects of agriculture on biodiversity. The ecosystem services framework can be used as an important driver for change in agricultural land management, which may sometimes improve biodiversity conservation, but in the majority of cases will not be sufficient alone to achieve the gains in biodiversity we require. We must be realistic about the contexts in which ecosystem services are useful to avoid disillusionment among

practitioners (both farmers and conservation managers) (Fig. 1a,b). Although there is certainly a relationship between biodiversity conservation and management for ecosystem services, it does not follow that focusing solely on one or the other will provide reciprocal benefits.

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