Agriculture, Ecosystems and Environment 173 (2013) 20–27

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

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

Review

To close the yield-gap while saving biodiversity will require multiple locally relevant strategies☆

Saul A. Cunningham[a,*], Simon J. Attwood[b], Kamal S. Bawa[c], Tim G. Benton[d], Linda M. Broadhurst[e], Raphael K. Didham[f,g], Sue McIntyre[a], Ivette Perfecto[h], Michael J. Samways[i], Teja Tscharntke[j], John Vandermeer[h], Marc-André Villard[k], Andrew G. Young[e], David B. Lindenmayer[l]

[a] CSIRO Ecosystem Sciences, PO Box 1700, Canberra, ACT 2601, Australia
[b] Australian Centre for Sustainable Catchments, University of Southern Queensland, Toowoomba, Qld 4350, Australia
[c] Department of Biology, University of Massachusetts, Boston, MA 02125, USA
[d] Institute of Integrative and Comparative Biology, Faculty of Biological Sciences, University of Leeds, LS2 9JT, United Kingdom
[e] CSIRO Plant Industry, PO Box 1600, Canberra, ACT 2601, Australia
[f] CSIRO Ecosystem Sciences, Floreat, WA 6014, Australia
[g] School of Animal Biology, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
[h] School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI 48109, USA
[i] Department of Conservation Ecology and Entomology, Stellenbosch University, P/Bag X1, Matieland 7602, South Africa
[j] Agroecology, Georg-August University, Grisebachstr. 6, 37077 Göttingen, Germany
[k] Département de Biologie, Université de Moncton, Moncton, NB E1A 3E9, Canada
[l] Fenner School of Environment and Society, Australian National University, Canberra, ACT 0200, Australia

A R T I C L E I N F O

Article history:
Received 14 November 2012
Received in revised form 9 April 2013
Accepted 11 April 2013
Available online 9 May 2013

Keywords:
Conservation
Ecosystem services
Food
Agriculture
Land use
Society

A B S T R A C T

Increasing yield has emerged as the most prominent element in strategies to deal with growing global demand for food and fibre. It is usually acknowledged that this needs to be done while minimising harm to the environment, but historically land-use intensification has been a major driver of biodiversity loss. The risk is now great that a singular focus on increasing yields will divert attention from the linked problem of biodiversity decline, and the historical pattern will continue. There *are* options that increase yields while reducing harm to biodiversity, which should be the focus of future strategies. The solutions are not universal, but are locally specific. This is because landscapes vary greatly in inherent biodiversity, the production systems they can support, and the potential for them to be adopted by landholders. While new production techniques might apply at local scale, biodiversity conservation inevitably requires strategies at landscape and larger scales.

Contents

* Corresponding author. Tel.: +61 2 6246 4356.
E-mail address: saul.cunningham@csiro.au (S.A. Cunningham).

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http://dx.doi.org/10.1016/j.agee.2013.04.007

1. Introduction

Feeding the world's growing human population at escalating rates of per capita food consumption is one of the pivotal societal challenges for the coming decades. Doing so in an environmentally sustainable manner while maintaining a global commitment to the conservation of biodiversity will stretch trade-offs between production and conservation to breaking point. Recent global assessments (e.g. Bruinsma, 2009; Foley et al., 2011; Foresight, 2011; Godfray et al., 2010; Herrero et al., 2010) suggest that it will be possible to meet this challenge and limit harm to biodiversity because options exist to intensify food production per unit area, while halting further expansion of the area of land under production. The underlying principle is to close the "yield gap" (Lobell et al., 2009) – the gap between realised and achievable yields across the farms of the world. However, a yield growth prescription does not in itself provide actions for reducing the negative impacts of agricultural intensification on biodiversity. The problem, then, is that while we rally scientific resources to meet the global food and fibre production challenge, we risk falling even further behind on the challenge of reducing the rate of biodiversity loss. In other words, we might close the yield gap, but further widen the sustainability gap (*sensu* Fischer et al., 2007).

It has long been recognised that productive land-use and the practices we adopt to achieve this, are strong drivers of biodiversity loss (e.g. Carson, 1963). But there are concerns that recent rates of biodiversity loss from all causes, not just land-use, are so great (Barnosky et al., 2011) that we might already have exceeded the point where dangerous feedbacks on ecosystem capacity to support biodiversity are expected (Rockström et al., 2009). Moreover, these pressures are intensifying (SCBD, 2010), particularly from the direct and indirect effects of climate change on biodiversity (Bellard et al., 2012). Current rates of biodiversity loss are now considered so severe that the goal must be not just to stabilise them, but to *reduce* them (Butchart et al., 2010).

The emerging problem we see is that the scale of the global food and fibre production challenge (and the implied risks it brings in terms of social disruption, conflict and famine) is overwhelming environmental concerns. Although the risks to biodiversity arising from the food and fibre challenge are well recognised in the scientific literature (e.g. Godfray et al., 2010; Tilman, 1999) there are few signs that the size and scope of the problem, and the interlinked nature of biodiversity and agriculture, are sufficiently appreciated in broader society. Biodiversity loss continues to be treated as a stand-alone problem, tackled independently from the food and fibre problem. As a consequence, biodiversity conservation risks being relegated to a secondary matter to be considered while solving the primary problem of supplying sufficient food and fibre to the human population. History suggests that as long as we view biodiversity conservation as a secondary consideration it will lose out (Wood, 2000). Prescriptions for better conservation outcomes will suffer from a lack of implementation, especially are if they are perceived as complicated (Hall and Fleishman, 2010) or interfering with other goals.

The first risk of the "closing the yield gap" strategy is that it will fail to prevent further expansion of agriculture. Growth in food production in the past has been strongly correlated with growth in agricultural land area (Pretty, 2008). While opportunities to expand the areal extent of agriculture in some regions are limited because the best land is already developed (Young, 1999), there are other regions where agriculture has expanded dramatically in recent times. Significantly, some of this expansion has occurred in high biodiversity tropical regions, such as for soybean production in South America (Grau et al., 2005) and palm oil in Southeast Asia (Koh and Wilcove, 2007). Moreover, history shows that increasing yield does not by itself prevent expansion of the area under

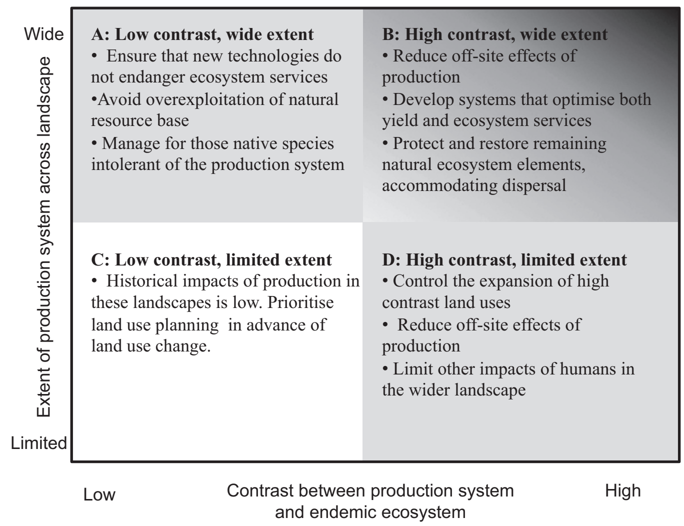

Fig. 1. A global typology of agricultural landscapes, and the top priorities for the management of local biodiversity in a context of increasing demand for agricultural products (dot points). The *y*-axis represents the degree to which the production system extends across the landscape of interest. If production has a relatively low extent then there are many and widespread places in the landscape where endemic biodiversity can persist without coming into conflict with production practice. The *x*-axis represents the degree to which the production system contrasts with the pre-conversion ecosystem in structural traits and disturbance regimes. Thus, a low contrast production system mimics endogenous structural complexity and disturbance regimes. High contrast production systems share little in common with the pre-conversion ecosystem and often involve high levels of inputs and mechanisation. The landscape types are chosen to represent the extremes of the gradients, but in reality intermediates will be common.

production (Angelsen and Kaimowitz, 2001; Ewers et al., 2009), and is only likely to do so where regulation supports this outcome (Matson and Vitousek, 2006). The second risk of the closing the yield gap strategy, however, is even more difficult to solve. The danger is that the technical solutions to closing the yield gap will increase harm to biodiversity. This problem is typically framed as a trade-off between land-use intensification (LUI) and biodiversity conservation.

Here we aim to provide context for the challenges of achieving biodiversity conservation goals while meeting demand for food and fibre production. We examine the way in which good solutions for both biodiversity and production are shaped by understanding and accommodating differences among landscapes in biodiversity, productive potential, and human populations. To help understand the diversity of landscapes we present a typology that is structured around two axes that are critical to the relationship between production and biodiversity (Fig. 1). The first axis describes the extent to which productive land use occupies the landscape of interest, the second axis describes the degree to which the production system contrasts with the properties of the pre-agricultural ecosystem. The first axis recognises the critical impact of land use conversion, and the second axis reflects that different agricultural systems have different potential to support elements of endemic biodiversity. Replacement of endemic diversity with widespread species is the pattern at the heart of global biodiversity decline. We discuss some archetypal agricultural systems to illustrate landscape diversity and explore these axes. Finally, we consider strategies for attaining better outcomes for biodiversity and production systems that reflect this diversity.

2. Land-use intensification and cross-scale effects

It is widely acknowledged that past LUI has been a primary driver of global biodiversity decline (Foley et al., 2005; Gibson et al.,