GfÖ
GfÖ Ecological Society of Germany, Austria and Switzerland
Basic and Applied Ecology 18 (2017) 1–12
Basic and Applied Ecology
www.elsevier.com/locate/baae

INVITED VIEWS IN BASIC AND APPLIED ECOLOGY

Designing agricultural landscapes for biodiversity-based ecosystem services

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Received 15 February 2016; accepted 20 July 2016
Available online 28 July 2016

Abstract

Sustainable and resilient agricultural systems are needed to feed and fuel a growing human population. However, the current model of agricultural intensification which produces high yields has also resulted in a loss of biodiversity, ecological function, and critical ecosystem services in agricultural landscapes. A key consequence of agricultural intensification is landscape simplification, where once heterogeneous landscapes contain increasingly fewer crop and non-crop habitats. Landscape simplification exacerbates biodiversity losses which leads to reductions in ecosystem services on which agriculture depends. In recent decades, considerable research has focused on mitigating these negative impacts, primarily via management of habitats to promote biodiversity and enhance services at the local scale. While it is well known that local and landscape factors interact, modifying overall landscape structure is seldom considered due to logistical constraints. I propose that the loss of ecosystem services due to landscape simplification can only be addressed by a concerted effort to fundamentally redesign agricultural landscapes. Designing agricultural landscapes will require that scientists work with stakeholders to determine the mix of desired ecosystem services, evaluate current landscape structure in light of those goals, and implement targeted modifications to achieve them.

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http://dx.doi.org/10.1016/j.baae.2016.07.005

I evaluate the current status of landscape design, ranging from fundamental ecological principles to resulting guidelines and socioeconomic tools. While research gaps remain, the time is right for ecologists to engage with other disciplines, stakeholders, and policymakers in education and advocacy to foster agricultural landscape design for sustainable and resilient biodiversity services.

Zusammenfassung

Nachhaltige und resiliente Agrarsysteme werden gebraucht, um die wachsende Weltbevölkerung zu ernähren und mit Brennstoffen zu versorgen. Indessen hat das gegenwärtige Modell der landwirtschaftlichen Intensivierung, das hohe Erträge liefert, auch Verluste zur Folge: bei der Biodiversität, bei ökologischen Funktionen und bei wichtigen Ökosystemleistungen in Agrarlandschaften. Eine entscheidende Folge der landwirtschaftlichen Intensivierung ist die Vereinheitlichung der Landschaft, wobei ehemals heterogene Landschaften zunehmend weniger Feldfrucht- und nicht bewirtschaftete Habitate enthalten. Die Vereinheitlichung der Landschaft verschärft die Biodiversitätsverluste, was zur Verminderung der Ökosystemleistungen führt, von denen die Landwirtschaft abhängt. In den letzten Jahrzehnten waren Forschungen in erheblichem Umfang darauf gerichtet, diese negativen Einflüsse abzumildern, vornehmlich durch Management der Habitate, um auf lokaler Ebene die Biodiversität zu fördern und Dienstleistungen zu stärken. Während gut bekannt ist, dass lokale und Landschaftsfaktoren interagieren, wurde wegen logistischer Beschränkungen nur selten eine Veränderung der gesamten Landschaftsstruktur in Erwägung gezogen. Ich schlage vor, dass der durch Vereinheitlichung der Landschaft begründete Verlust von Ökosystemleistungen nur mit einer konzertierten Anstrengung zur grundlegenden Neugestaltung der Agrarlandschaft angegangen werden kann. Die Planung von Agrarlandschaften macht es nötig, dass Wissenschaftler und Interessengruppen zusammenarbeiten, um die Mischung gewünschter Ökosystemleistungen festzulegen, die aktuelle Landschaftsstruktur vor diesem Hintergrund zu analysieren und gezielte Veränderungen vorzunehmen, um diese zu erreichen. Ich untersuche den gegenwärtigen Status der Landschaftsplanung, von fundamentalen ökologischen Prinzipien bis zu Richtlinien und sozio-ökonomischen Instrumenten. Auch wenn Forschungslücken bleiben, ist jetzt der richtige Zeitpunkt für die Ökologen gekommen, die Zusammenarbeit mit anderen Disziplinen, Interessengruppen und Entscheidungsträgern in Erziehungswesen und Meinungsbildung zu suchen, um die Agrarlandschaftsplanung für nachhaltige und belastbare Biodiversitätsleistungen zu stärken.

Keywords: Agricultural biodiversity; Ecosystem function; Ecosystem services; Pest suppression; Pollination

Introduction

Agriculture in the 21st century is confronting immense challenges. It is estimated that by 2050, human population of the earth will reach 9.7 billion people (United Nations, Department of Economic and Social Affairs & Population Division, 2015). How and where we produce the food and energy to support this increasing population is a major question given that agriculture is already a dominant land-use globally, with nearly 40% of the ice-free land surface dedicated to farming or grazing (Ramankutty et al., 2008; Foley et al., 2011). Moreover, in many of these areas humans are already appropriating more than 50% of the net primary productivity for their use as food, feed, and fuel (Haberl et al., 2007). While supporting high yields, the intensification of agriculture through monocultures of high-yielding varieties coupled with increased chemical and mechanical inputs, has led to negative environmental impacts on soil, water, air and biodiversity (Matson et al., 1997; Stoate et al., 2001, 2009; Firbank et al., 2008). In short, humans are exploiting the planet's most favorable areas for agriculture and the intensity of current production is pushing the boundaries of sustainability (Steffen et al., 2015), creating uncertainty regarding how agriculture can sustainably meet future human needs (Robertson, 2015).

Ecologists can play a key role in addressing this question. For example, the growing understanding among basic ecologists of the links between biodiversity and ecosystem function (Loreau et al., 2001), biodiversity and ecosystem services (Duncan et al., 2015), and the resiliency of systems to disturbance (Oliver et al., 2015) can also be applied to the study of agricultural systems (Tscharntke et al., 2005, 2007, 2012a). While the language used by basic and applied ecologists to describe these relationships may differ, there is much to learn from the exchange of concepts across sub-disciplines (Fig. 1). For example, the use of functional trait- versus species-based metrics of biodiversity in basic ecology has prompted similar approaches in agroecosystems, leading to novel findings. Gagic et al. (2015) found that functional traits, including body size and nesting habitat, are better predictors of pest suppression and pollination in agricultural landscapes than species identity. This suggests that trait-based approaches may be critical to inform landscape design, and highlights the unique insights that can be gained from the application of ecological theory to applied questions. In turn, the long-term quest for sustainability in agriculture is increasingly