GfÖ
GfÖ Ecological Society of Germany, Austria and Switzerland
Basic and Applied Ecology 14 (2013) 1–11
Basic and Applied Ecology
www.elsevier.com/locate/baae

REVIEW

Land-cover change effects on trophic interactions: Current knowledge and future challenges in research and conservation

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Received 26 March 2012; accepted 21 November 2012
Available online 29 December 2012

Abstract

Understanding the effects of land-cover alterations on ecosystem functioning has become a major challenge in ecological research during the last decade. This has stimulated a rapid growth in research investigating the links between land-cover change and biotic interactions, but to date no study has evaluated the progress towards achieving this scientific goal. With the aim of identifying gaps in current knowledge and challenging research areas for the future, we reviewed the scientific literature published during the last decade (1998–2010) investigating land-cover change effects on trophically-mediated biotic interactions. Our results reveal a disproportionate focus on particular trophic interactions and ecosystem types. Furthermore, in most cases, the measurement of trophic interactions is carried out neglecting the identity of the interacting species and the interrelation between the type of land-cover change effects. Finally, inappropriate temporal scales are applied to cope with spatiotemporal resource fluctuations for the interacting species. We suggest that the ongoing patterns and trends of research hamper efforts to achieve a truly comprehensive understanding of the effects of land-cover alterations on trophic interactions, and hence on ecosystem functioning in human-impacted landscapes. We therefore recommend alternative research trends and indicate gaps in current knowledge that need to be filled. Furthermore, we highlight that these biases could also limit the effectiveness of management actions aimed at ensuring the resilience and long-term conservation of natural habitats worldwide.

Zusammenfassung

Die Einflüsse der Änderungen der Bodenbedeckung auf das Funktionieren von Ökosystemen zu verstehen, ist während der letzten Dekade zu einer bedeutenden Herausforderung für die ökologische Forschung geworden. Dies hat eine rapide Zunahme von Untersuchungen zur Verbindung zwischen Landbedeckungsänderung und biotischen Interaktionen angeregt. Aber bis heute hat keine Studie den Fortschritt in Richtung auf dieses Ziel ausgewertet. Mit dem Ziel, Lücken im aktuellen Wissen und interessante Forschungsaspekte für die Zukunft zu identifizieren, analysierten wir die in der letzten Dekade (1998–2010) veröffentlichten Arbeiten, die sich mit den Effekten von Landbedeckungsänderungen auf trophische Interaktionen befassten.

Unsere Ergebnisse zeigen eine Überbetonung von bestimmten trophischen Interaktionen und Ökosystemtypen. Darüberhinaus wurden in den meisten Fällen die trophischen Interaktionen quantifiziert unter Vernachlässigung der Identität der beteiligten Arten und der Wechselbeziehung zwischen den Effekten, die auf den Typ der Landbedeckungsänderung zurückgehen. Schließlich werden unangepasste Zeitskalen angewendet, um den räumlich-zeitlichen Fluktuationen der Ressourcen der interagierenden Arten gerecht zu werden.

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http://dx.doi.org/10.1016/j.baae.2012.11.008

Wir meinen, dass die gegenwärtigen Untersuchungsmuster und -tendenzen ein wirklich umfassendes Verständnis der Auswirkungen von Landbedeckungsänderungen auf trophische Interaktionen und damit auf das Funktionieren von Ökosystemen in anthropogen beeinflussten Landschaften behindern. Wir empfehlen deshalb alternative Forschungsrichtungen und zeigen Lücken im gegenwärtigen Wissen auf, die geschlossen werden müssen. Darüberhinaus betonen wir, dass diese Unausgewogenheiten auch die Effektivität von Managementmaßnahmen einschränken können, die darauf zielen, die Resilienz und langfristige Bewahrung natürlicher Habitate weltweit sicherzustellen.

Keywords: Biodiversity; Fragmentation; Habitat loss; Literature review; Perspectives; Trophic interactions

Introduction

A large proportion of the planet's land surface is undergoing rapid and profound changes due to human activities (Steffen et al. 2004; Foley et al. 2005). By intensifying farmland production, expanding urban areas or building road networks, human actions are altering both the spatial configuration and composition of natural ecosystems and, in consequence, species population dynamics and community structure worldwide (Meyer and Turner 1992). Not surprisingly, land-cover change (hereafter LCC), is often cited as one of the major threats to global biodiversity conservation (Sala et al. 2000). This is because LCC and the resulting net habitat loss and fragmentation have severe impacts on key landscape properties from the species perspective such as habitat connectivity and isolation (Fahrig 2003). However, there is growing consensus that the effects of LCC go beyond species richness and abundance alterations and a rapidly growing body of research investigates their concomitant consequences on ecosystem functioning (i.e., the collective biological, chemical and physical processes that characterize and sustain each ecosystem) (Hillebrand & Matthiessen 2009). Indeed, ecosystem functioning is now emerging as an aspect of crucial importance in understanding the complexity of natural ecosystems and, from a conservation point of view, their resilience to global change drivers such as LCC (Chapin et al. 2000; Garnier et al. 2007).

Networks of species interactions, and especially trophically-mediated interactions, are considered critical for ecosystem functioning (Worm & Duffy 2003; Thébault & Loreau 2005). To a large extent, this is because trophic interactions play an important role in a great variety of ecosystem functions, such as plant regeneration processes (e.g., Herrera & García 2010), nutrient cycling (Ferris, Venette, & Scow 2004), soil formation and retention (Welbaum, Sturz, Dong, & Nowak 2004), pollination (Steffan-Dewenter & Westphal 2008) and decomposition (Wardle 1999), as well as on ecosystem properties, such as genetic and species diversity (McPeek 1996). An increasing number of studies reveal that trophic interactions can be highly responsive to LCC (e.g., García & Chacoff 2007; Kremen et al. 2007; Herrera, García, Martínez, & Valdés 2011). Indeed, several previous reviews have already shown how patterns and processes that accompany LCC affect networks of species trophic interactions (Aguilar, Ashworth, Galetto, & Aizen 2006; Valladares, Salvo, & Cagnolo 2006; Kremen et al. 2007; Tylianakis, Didham, Bascompte, & Wardle 2008). Yet, to date no study has been focused on the extent to which scientific literature has progressed towards clearly understanding the impact of LCC on ecosystem functioning. In addition to theoretical implications, such an assessment would provide useful insights for evaluating the effectiveness of management actions aimed at ensuring ecosystem resilience and the long-term conservation of natural habitats worldwide (Eriksson and Hammer 2006; Priess et al. 2007; Fernández, Paruelo, & Delibes 2010).A number of key points need to be taken into consideration when trying to link LCC and ecosystem functioning through the study of trophic interactions. First, disruptions in trophic interactions occur because of the sensitivity of the interacting species to changes in habitat quantity and quality triggered by LCC (e.g., García & Chacoff 2007). Accordingly, because different species perceive and respond to environmental changes in different ways (Manning, Lindenmayer, & Nix 2004), the response to LCC of each individual trophic interaction shows only a partial view of the effects of LCC on the functioning of the whole ecosystem (Maestre et al. 2010). Second, as LCC increases, the disruption of processes that maintain ecosystem integrity depend on patterns of species loss from, or potentially added to, the ecosystem (Larsen, Williams, & Kremen 2005). This might have important ecological consequences as the loss of one species could be compensated by other competing species that occupy a similar niche, thus giving the apparent impression that LCC have no effects on ecosystem functions: a false impression that can have time-lag consequences for ecosystem stability (e.g., Farwig, Böhning-Gaese, & Bleher 2006). Third, each ecosystem type exhibits characteristic ecosystem functions which act as biological insurance for ecosystem functioning that may not be applicable to other ecosystem types (Shennan 2008). Fourth, although LCC produces a wide range of frequently interrelated effects such as habitat isolation, habitat loss and edge effects (Lindenmayer & Fischer 2007), each one has unique impacts on biodiversity. Accordingly, disentanling the impacts from each LCC effect is crucial to identify and quantify the underlying process actually impacting species, and in turn, ecological processes (e.g., Herrera, García, et al. 2011). Fifth and last, the magnitude and sign of interactions commonly show strong temporal variations –mainly related to spatiotemporal variations in the distribution of food resources for the