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Approaches and mechanisms for ecologically based pest management across multiple scales

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ABSTRACT

The past 50 years have seen substantial change of agroecosystems in the world, including an intensified use of agrochemicals and expansion of cropland, resulting in a rapid loss of biodiversity and a reduction of ecosystem services. The effects of these changes, at both the field and landscape scale, on ecologically based pest management (EBPM) in agroecosystems have become increasingly important. Here, we review the theories, important approaches and mechanisms of habitat management practices (at multiple spatial scales) that can be applied to facilitate EBPM in crop fields and even over larger landscapes. In particular, we discuss links between pest outbreaks and rapid changes of habitat composition at local and regional scales. We also summarize recent progress of habitat management and their application to pest management, which is an activity that we believe must be implemented at multiple spatial scales to successfully conserve ecosystem services and address environmental issues related to crop pest control.

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1. Introduction

Landscape-level patterns of land use can affect both ecosystem processes and local food web structures (Gagic et al., 2012; Zhao et al., 2015). Over the past 50 years, rapid development, urbanization and agricultural intensification have resulted in extensive conversion of land cover, resulting in habitat loss and fragmentation of rural and semi-natural landscapes, which has in turn reduced biodiversity and natural biocontrol in agroecosystems (Bianchi et al., 2006; Tscharntke et al., 2007). This has been the result of change both in crop fields and, at the landscape level, changes around crops. In fields, the increased use of fertilizer and pesticides has changed plant nutrition levels and soil structure in ways that favor agricultural pests (Gagic et al., 2012; Jonsson et al., 2012). Concurrently, at the landscape level, cropland expansion into formerly semi-natural habitats has altered the vegetative

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composition at this spatial scale, affecting arthropod communities and facilitating outbreaks of agricultural pests (Macfadyen et al., 2011; Tscharntke et al., 2012b).

Although many tactics have been applied to enhance biodiversity conservation in agricultural landscapes, largely by adding semi-natural habitats (Brevault et al., 2014; Deguine and Penvern, 2014), their effects on the functional biodiversity of natural enemies are still unclear, especially for enhancing the efficacy of biocontrol through boosting natural enemies. In addition, how to simultaneously improve ecosystem healthy and functional biodiversity through habitat management has yet to be explored (Landis et al., 2000; Macfadyen et al., 2012). Therefore, we focused on summarizing methods for management aiming at boosting biocontrol through enhancing natural enemies and their associated functional biodiversity, which could help to narrow the gap between sustainable agriculture and biodiversity conservation (Tscharntke et al., 2012b).

2. Sustainable agriculture and ecologically based pest management

To reverse aforementioned negative trends, ecologically based pest management (EBPM) proposes strategies that link agricultural fields to the broader landscape through deliberate landscape design and modification (Landis et al., 2000; Altieri and Nicholls, 2003b). Such habitat management has been successfully applied to pest population management at both the local and the broader landscape levels (Beduschi et al., 2015; Schneider et al., 2015). When using habitat management to recover the biocontrol potential of natural enemies in modern agroecosystems, it is important to understand the effects of agricultural intensification, including agrochemical inputs, within the context of field and cropland expansion at the landscape scale (Fig. 1).

With the development and improvement of spatial ecology (3S technology: Remote Sensing System, Geographical Information System, and Global Positioning System), habitat composition and landscape structure across multiple spatial scales can now be analyzed quantitatively with ease. Therefore, the relationship between landscape structure and the tritrophic interactions of crops, pests, and natural enemies can be thoroughly investigated in insect ecology (O'Rourke et al., 2011). However, while many studies have indirectly determined the effects of agricultural intensification on pest population control by natural enemies at either a local or a landscape scale, none have examined both, due to the different paradigms involved (Batary et al., 2012; Zhao et al., 2013a).

The EBPM emphasizes that habitat management to control crop pests should consider effects of controls applied on other ecosystem services such as environmental issues, pollination, and biodiversity, especially at the landscape or regional scales (Koul and Cuperus, 2006; Brewer and Goodell, 2012; Macfadyen et al., 2012). In China, changes in the agricultural landscapes have led to both spatial and temporal rearrangements of croplands and semi-natural habitats. The result has been a mosaic cycle of plantings and greater fragmentation of semi-natural habitats (Thies et al., 2008; Zhao et al., 2012).

In addition to the influence of such landscape-level changes on the abundance and intraspecific interactions between pests and natural enemies, agricultural practices (e.g., increasing fertilizer

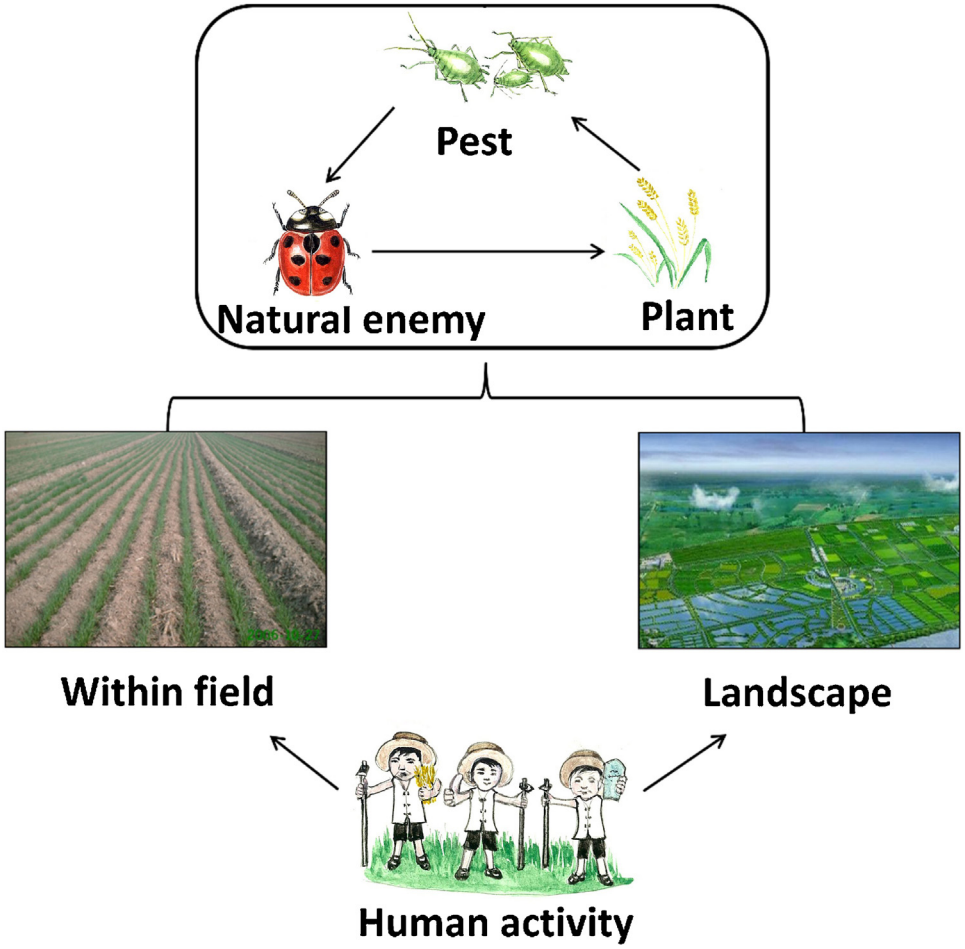

Fig. 1. The processes of human activity affecting insect community through agricultural practice within field and at landscape scale.