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Arthropod communities and biological control in soybean fields: Forest cover at landscape scale is more influential than forest proximity

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ABSTRACT

Natural habitats surrounding annual crops influence biodiversity and the provision of ecosystem services within the cultivated habitats. Soybean, an important crop worldwide and the main crop in Argentina, is affected by several pest species, including stink-bugs that damage soybean pods. Here, we studied the effects of Chaco Serrano forests on arthropod herbivores and natural enemies and on biological control of stink bugs on soybean, at landscape (forest cover) and local (forest proximity) scales. We sampled arthropods on soybean plants by using the beating-sheet method, on nine landscapes (with low and high forest cover) and at 5, 25, 50 and 100 m from the forest, during soybean flowering and pod-filling stages. Biological control of stink bug eggs was assessed via sentinel-egg experiments in soybean and forest habitats. We found that landscapes with high forest cover presented higher richness and abundance of natural enemies and higher levels of biological control on stink bug eggs (both in the cropland and in the forest), while a similar trend for herbivores was restricted to soybean flowering stage. Community composition of both functional groups was also affected by forest cover and crop phenological stage. Forest proximity had more limited effects: natural enemies showed more species and individuals at 5 m from the forest than at larger distances and, conversely, stink bug abundance was lower at the closest distance to the forest. We conclude than forest amount at landscape scale is more influential for arthropod biodiversity and biological control in soybean than forest proximity. Moreover, our results suggest that maintaining remnants of forest in agricultural landscapes can be effective for conservation of arthropod biodiversity while contributing to biological control of stink bugs in soybean fields.

1. Introduction

Agricultural intensification is a dominant trend in the global land use change (Sala et al., 2000; Tilman et al., 2001a). As a result, complex and diverse ecosystems with high proportion of natural habitats are transformed into simpler, predominantly man-managed landscapes (Tscharntke et al., 2005). In this scenario, biodiversity losses occur both in the natural (Fahrig, 2003; Steffan-Dewenter et al., 2002) as well as in the cultivated (Benton et al., 2003; Chaplin-Kramer et al., 2011) components of the landscape.

Within cultivated fields, insect communities are influenced by the surrounding landscape structure, most frequently showing increased diversity in complex landscapes where non-crop habitats enhance environmental heterogeneity (Benton et al., 2003). However, not all species respond in the same way to landscape scale changes (Attwood et al., 2008; Rossetti et al., 2014). Thus, the number of pest species tends to increase with landscape complexity (Chaplin-Kramer et al., 2011), but their specific abundance may be negatively affected by such complexity, benefitting instead from simpler, mostly cultivated areas (Veres et al., 2013). The latter trend can be explained by the resource concentration hypothesis (Kareiva, 1983; Root, 1973), which postulates that large, monospecific and dense plant patches promote establishment and population growth of specialist herbivores, although generalist species can perform better in habitats with higher plant diversity. On the other hand, natural enemies tend to increase both their richness as well as their abundance in complex landscapes (Bianchi et al., 2006; Chaplin-Kramer et al., 2011) where natural or semi-natural habitats provide necessary alternative resources (Bianchi et al., 2006; Duelli and Obrist, 2003; Landis et al., 2000). An increase in natural enemies can also explain reductions of herbivore abundance in complex landscapes, as proposed in the enemies' hypothesis (Kareiva, 1983; Root, 1973).

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In addition to the influence of landscape-scale changes, distance to natural habitats is a relevant aspect at the local scale for arthropods associated with crops. Since non-crop habitats generally act as sources of biodiversity for croplands (Duelli and Obrist, 2003), higher richness and/or abundance of arthropods are expected and frequently found near these habitats (Clough et al., 2005; González et al., 2015; Miliczky and Horton, 2005; Tscharntke et al., 1998).

As a result of changes in biodiversity (Balvanera et al., 2006; Cardinale et al., 2012), ecosystem processes such as herbivory (Valladares et al., 2006) and biological control (Fenoglio et al., 2012; Thies et al., 2011; Tylianakis et al., 2006) have been affected at both landscape and local scales. In particular, the positive responses of natural enemies to landscape complexity tend to result in higher levels of the ecosystem service of biological pest control in diverse landscapes with high amounts of non-crop habitats (Bianchi et al., 2006; Gardiner et al., 2009; Veres et al., 2013) and near fragments of natural vegetation (Bianchi et al., 2008; Kruess and Tscharntke, 2000; Thies and Tscharntke, 1999; Tscharntke et al., 1998).

In Argentina, a main force driving land use change is soybean cultivation. Soybean is an important crop worldwide (Leff et al., 2004), sown in more than 111 million hectares and yielding 276 million metric tons in 2013 (FAO, 2016). Soybean cultivation dramatically expanded in Argentina in the last 30 years, to the point of occupying more than half of the cultivated surface of the country (Aizen et al., 2009). This expansion has led to the displacement of other crops and the advance of the agricultural frontier at the expense of natural ecosystems like Chaco forest (Grau et al., 2008).

Soybean crops are attacked by several pests, among which stink bugs (Hemiptera: Pentatomidae) are particularly harmful in South America fields (Frana et al., 2008; Panizzi et al., 2000). The influence of natural vegetation cover and proximity on soybean pests has been addressed mostly for the soybean aphid in USA and Canada (Mitchell et al., 2014a; Ragsdale et al., 2011), its biological control (Gardiner et al., 2009; Mitchell et al., 2014b) and natural enemies in the crop (Gardiner et al., 2010; Mitchell et al., 2014a). The influence of natural habitats, at local or landscape scales, on biological control of stink bugs on soybean remains unknown, although increased stink bug density at the edges of soybean crops has been observed (Venugopal et al., 2014). Furthermore, there is only scant information on non-crop influence for insect communities in general, on soybean fields outside North America (González et al., 2015).

Here, we studied richness, abundance and community composition of total herbivores, stink bugs and natural enemies, in soybean fields from central Argentina with varying forest cover in the landscape and at varying distances from the forest. In addition, we evaluated the ecosystem service of pest control by means of stink bug egg exposure experiments in the same fields and within the forest fragments, the latter in order to assess the forest potential as reservoir of natural enemies for soybean pests. We expected both herbivores and natural enemies to show higher richness in landscapes with higher forest cover and at smaller distances from it. Abundance of natural enemies should follow the same pattern as richness, but herbivores could be more abundant at crop-dominated landscapes and at larger distance from the forest, following the resource concentration and the enemies' hypotheses. Finally, if natural habitats represent sources of natural enemies, higher levels of biological control would be expected in sites with more forest, and in its proximity.

2. Methods

2.1. Study sites

The study was conducted in a fragmented landscape (31.10°–31.30° S and 64°–64.30° W) within Córdoba province, in central Argentina. The area belongs to the Chaco Serrano phytogeographical district, with 750 mm of annual rainfall and average temperatures of 10–26 °C. Vegetation is characterized by a tree layer (height 8–15 m) dominated by *Aspidosperma quebracho-blanco* Schltdl., *Prosopis* spp., *Fagara coco* Engl. and *Lithrea molleoides* (Vell.) Engl.; a shrub layer (1.5–3 m) dominated by *Celtis ehrenbergiana* Torr. and *Acacia* spp.; pastures (0–1 m), vines, and epiphytic bromeliads (Cabido et al., 1991). This system is one of the most affected by agricultural expansion, having lost more than 95% of its original area in Córdoba province (Zak et al., 2004). Based on Landsat Thematic Mapper and field corroboration, nine landscape circles of 500 m diameter were selected (from now on, sites; Fig. 1; Table S1). At all sites, the centre was located on a forest-soybean boundary. Five sites had more than 30% of forest with the remaining area occupied by soybean fields (from now on, sites with high forest cover). In the other four sites, the proportion of forest was below 15% (low forest cover), the rest being occupied by

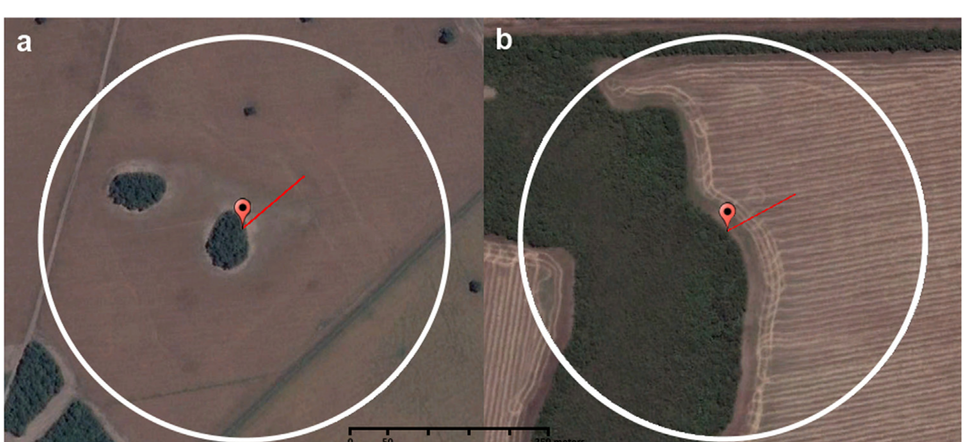

Fig. 1. Examples of circular landscapes with low (a) and high (b) forest cover. Dark green areas are fragments of Chaco Serrano forest, while the crop matrix (uncultivated to enhance the contrast between habitats) is observed in light color. Satellite images were obtained with Google Earth. The landscape with low forest cover is covered by 2.65% of forest and the landscape with high forest cover by 40.39%. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)