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Does landscape composition affect pest abundance and their control by natural enemies? A review

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ABSTRACT

Landscape management could contribute to sustainable pest control. Landscape composition, in particular, could either directly impact a pest abundance by affecting its dispersal, mortality or reproduction, or indirectly by affecting its natural enemies. We performed an analysis of the scientific literature to assess how the proportion of different land covers at the landscape level is related to the abundance of pests or to their control by natural enemies. Of 72 independent case studies, 45 reported an effect of landscape composition. Results confirmed the suspected suppressive effect of landscape scale amounts of semi-natural areas on in-field pests: landscapes with higher proportions of semi-natural areas exhibited lower pest abundance or higher pest control in fields. Contrarily, there was no clear direction in relationships between pests and pest control and landscape when the latter was described as the overall proportion of cultivated area or as that of crops host to particular pests. The analysis of original articles indicates that this lack of direction may be due to the diversity of land use intensity in the studied landscapes and to a too rough categorizing of land covers. This pleads for a better consideration of the functionality of crops and of their management in landscapes.

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1. Introduction

Concerns over the impact of pesticides on the environment and human health call for alternative pest control methods. Among these, the manipulation of the landscape and habitat structures has been suggested as a means to influence the dynamics of both insect pests and their natural enemies (Jonsson et al., 2010). Pest outbreaks and pest control by natural enemies indeed have strong links to landscape patterns and do not depend only on local in-field conditions (With et al., 2002).

Up-scaling from field to landscape appears necessary because most pests and natural enemies need to move over the landscape to search for resources: either they use various resources during their life-cycle (e.g. aphids that change hosts) or their resources are short lived (e.g. flowering crops). Contrarily to other landscape types, agricultural landscapes are indeed very dynamic (Petit, 2009) and while semi-natural landscape elements such as woodlots or hedgerows are rather stable in time (Burel and Baudry, 1990; Petit et al., 2002), most crops are subject to a high frequency of disturbance caused either by soil and pest management, changes in crop phenology, harvest or crop rotation that makes them periodically unsuitable (Bianchi et al., 2006; Menalled et al., 1999). The impact of landscape features on pest abundance and pest control by natural enemies is thus expected to change within year and between years (Menalled et al., 2003). These dynamics, however, are rarely considered and agricultural landscapes are generally characterised by their composition, i.e. the proportions of different land-cover categories, and their configuration, i.e. a synthetic description of their land use/cover spatial distribution (Forman and Godron, 1986).

Recognizing the need for up-scaling, a number of authors have reported relationships between some landscape characteristics (e.g. proportion of semi-natural area or proportion of area grown with a particular crop) and pest abundance or pest control. In the following we shall ask what sort of relationships can be expected and what relationships are found in the literature. In general, because crops are habitats of pests, a positive relationship is expected between in-field pest abundance and the acreage of cultivated land at a landscape scale, in particular when considering a specialist pest and the particular crop it attacks. However, there are reasons for which this relationship could be flat or negative. First, some pests have alternative hosts and may spend an important part of their life cycle outside the crops (e.g. Ostman et al., 2001; Thies et al., 2005). Second, pests are generally fought against in crops where they could be the most abundant (e.g. Ricci et al., 2009). Their abundance in fields may thus largely depend on the presence of small isolated non treated elements in the landscape (e.g. garden trees or vegetables, feral plants in field margins...). Third, pest abundance may be reduced in landscapes providing more semi-natural areas because mortality caused by natural enemies may be higher. It has indeed been shown that the biodiversity and/or the abundance of pests' natural enemies in fields largely depend on the amount of non crop habitats at landscape scale (Langellotto and Denno, 2004; Bianchi et al., 2006; Tscharntke et al., 2007; Attwood et al., 2008). This enhancement of biodiversity in crops provides no guarantee for effective pest control (Bianchi et al., 2006; Straub et al., 2008) but there is a tendency for more diverse pest enemy communities to better control herbivorous arthropods (Letourneau et al., 2009).

In the following, we present the results from a literature review on the impact of landscape composition on the abundance of arthropod pests and on conservation biological control (CBC) effectiveness, measured in terms of parasitism or predation rates. We question separately the impact of landscape composition on pest abundance and on CBC because we did not find enough articles dealing both with CBC effectiveness and pest abundance. Our main three hypotheses are (i) that an increasing proportion of a given crop over the landscape correlates positively with its pest abundance. Further, because of the effect of semi-natural areas on biodiversity, we hypothesized that an increased area of semi-natural habitats (ii) leads to increased predation or parasitism and (iii) to a decreased pest abundance.

2. Material and methods

2.1. Literature search

We searched for scientific articles in the Web of Science using keywords: landscape, agri* and one scientific name of arthropod taxa (based upon Attwood et al., 2008) and extended our search to articles citing those that we had found. We also contacted colleagues of the ENDURE network (http://www.endure-network.eu/) for information on studies that would not be in our list. We restricted our search to years 1993–2008. We selected studies that analysed how (i) the abundance of a pest, (ii) the rate of a pest parasitism or (iii) the rate of a pest predation within a field depended on the proportion of cultivated area or of some semi-natural element (woodland, grassland...) at landscape scale. We defined 'landscape scale' as within a distance of at least 100 m from the sampled unit.

2.2. Data collection

The basic units in the database were named cases. They corresponded to one relationship between the abundance of an insect pest, its parasitism or predation and the area of one landscape feature. There were generally one to three cases per published study. In particular, we treated different pest taxa within a single study as independent cases. In case of multiple time periods, we used results from only one period, choosing the period for which the correlation had the lowest *P*-value. It is indeed likely that correlations between pest abundance, predation or parasitism and landscape composition will change within and between years and collecting the result with the lowest *P*-value allowed both collecting all observed landscape effects and avoiding to put disproportionately more weight on studies with multiple time sampling. In some articles the analysis was carried out at different scales, landscape composition being considered at different distances from the focal field. As it is likely that landscape effects, if present, cannot be detected at all scales but only at some scales that are relevant given the organism biology (Moilanen and Nieminen, 2002), we kept the results of the scale where the correlation between the studied variable and landscape composition took its highest value. If, for a given taxon, both the effects of the crop area and of some semi-natural area were reported in a single study, we considered them as independent cases only if these two categories did not cover the whole territory, i.e. they were not complementary. When more than one article reported about what appeared to be a single case, we considered the article that provided the more detailed results.

We first recorded variables describing characteristics of cases. Variable *ABUND* took value 1 if the case reported on abundance and 0 if it was about conservation biological control. Landscape descriptions were very heterogeneous. First some studies considered cultivated areas as a whole and others detailed area of a particular crop. Second some studies only reported on the area of some semi-natural element. We thus created the variable *CULT* that took value 1 if the case reported on the effect of any cultivated area and 0 if it was about semi-natural element. For studies that corresponded to *CULT* = 1, we created an additional variable *CROP* that took value 1 if the considered cultivated area was that of the particular crop host to the pest and 0 otherwise.

We created two dependent variables. First, to assess which type of studies showed a significant landscape effect, we created a vari-