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Agricultural landscape simplification reduces natural pest control: A quantitative synthesis

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ABSTRACT

Numerous studies show that landscape simplification reduces abundance and diversity of natural enemies in agroecosystems, but its effect on natural pest control remains poorly quantified. Further, natural enemy impacts on pest populations have usually been estimated for a limited number of taxa and have not considered interactions among predator species. In a quantitative synthesis with data collected from several cropping systems in Europe and North America, we analyzed how the level and within-field spatial stability of natural pest control services was related to the simplification of the surrounding landscape. All studies used aphids as a model species and exclusion cages to measure aphid pest control. Landscape simplification was quantified by the proportion of cultivated land within a 1 km radius around each plot. We found a consistent negative effect of landscape simplification on the level of natural pest control, despite interactions among enemies. Average level of pest control was 46% lower in homogeneous landscapes dominated by cultivated land, as compared with more complex landscapes. Landscape simplification did not affect the amount of positive or negative interactions among ground-dwelling and vegetation-dwelling predators, or the within-field stability of pest control. Our synthesis demonstrates that agricultural intensification through landscape simplification has negative effects on the level of natural pest control with important implications for management to maintain and enhance ecosystem services in agricultural landscapes. Specifically, preserving and restoring semi-natural habitats emerges as a fundamental first step to maintain and enhance pest control services provided by predatory arthropods to agriculture.

1. Introduction

Agricultural intensification since the mid-20th century has resulted in a loss of habitat heterogeneity with important implications for biodiversity and ecosystem function within agricultural landscapes (Benton et al., 2003). During this time, agricultural production increased in part by converting natural and semi-natural habitats within agricultural landscapes into arable fields and partially replacing ecological functions, originally provided by communities of beneficial organisms, with external fossil and agrochemical inputs. But this has come at the cost of negative impacts on water and soil, human and ecosystem health,

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biodiversity (Tscharntke et al., 2005) and thereby possibly agricultural yields (Ray et al., 2012). A healthy ecosystem and the organisms it contains underpin agricultural productivity with ecosystem services such as crop pollination, pest control, and nutrient cycling (Bommarco et al., 2013). To achieve food security and environmental well-being in the long term, we need to better

Table 1
Summary of the exclusion experiment studies for the quantitative synthesis on the effect of landscape simplification on natural pest control.

Study code	Crop	Prey species	Exclusion treatment: open and total exclusion	Exclusion treatment: open, partial and total exclusion	Duration of the experiment	Location	Number of fields	Replicates per field	Landscape gradient (range of % of cultivated land in 1 km radius)	References
Study 1a	*Brassica oleracea*	*Brevicoryne brassicae* (Linnaeus)	Yes	No	12 days	USA, California	9	3	02–94%	Chaplin-Kramer and Kremen (2012)
Study 1b	*Brassica oleracea*	*Brevicoryne brassicae* (Linnaeus)	Yes	No	12 days	USA, California	10	2	02–94%	Chaplin-Kramer and Kremen (2012)
Study 1c	*Brassica oleracea*	*Brevicoryne brassicae* (Linnaeus)	Yes	No	12 days	USA, California	10	2	02–94%	Chaplin-Kramer and Kremen (2012)
Study 2	*Triticum aestivum*	*Sitobion avenae* (Fabricius), *Metopolophium dirhodum* (Walker), *Rhopalosiphum padi* (Linnaeus)	No	Yes	13 or 14 days	Germany, Göttingen	8	2	26–93%	Thies et al. (2011)
Study 3a	*Triticum aestivum*	*Sitobion avenae* (Fabricius)	No	Yes	14 days	UK, Dorset and Hampshire	14	2	33–87%	Holland et al. (2012)
Study 3b	*Triticum aestivum*	*Sitobion avenae* (Fabricius)	No	Yes	14 days	UK, Dorset and Hampshire	12	2	27–87%	Holland et al. (2012)
Study 4	*Triticum aestivum*	*Sitobion avenae* (Fabricius), *Metopolophium dirhodum* (Walker), *Rhopalosiphum padi* (Linnaeus)	No	Yes	11–23 days	Germany, Jena	8	2	48–98%	Thies et al. (2011)
Study 5	*Triticum aestivum*	*Sitobion avenae* (Fabricius), *Metopolophium dirhodum* (Walker), *Rhopalosiphum padi* (Linnaeus)	No	Yes	16–19 days	Poland	8	2	39–94%	Thies et al. (2011)
Study 6	*Hordeum vulgare*	*Rhopalosiphum padi* (Linnaeus)	Yes	No	5 days	Sweden, Scania	31	4	14–88%	Rusch et al. (2013); unpublished data
Study 7	*Hordeum vulgare*	*Sitobion avenae* (Fabricius), *Metopolophium dirhodum* (Walker), *Rhopalosiphum padi* (Linnaeus)	No	Yes	20–22 days	Sweden, Uppsala	8	2	56–100%	Thies et al. (2011)
Study 8	*Hordeum vulgare*	*Sitobion avenae* (Fabricius), *Metopolophium dirhodum* (Walker), *Rhopalosiphum padi* (Linnaeus)	No	Yes	21–27 days	Sweden, Scania	8	2	48–100%	Winqvist 2011; unpublished data
Study 9a	*Glycine max*	*Aphis glycines* (Matsumura)	Yes	No	7–14 days	USA, Michigan	12	4	9–79%	Woltz et al. (2012); unpublished data
Study 9b	*Glycine max*	*Aphis glycines* (Matsumura)	Yes	No	7–14 days	USA, Michigan	12	4	16–89%	Woltz et al. (2012); unpublished data
Study 10a	*Glycine max*	*Aphis glycines* (Matsumura)	Yes	No	14 days	USA, Michigan, Wisconsin, Iowa, Minnesota	12	4	39–92%	Gardiner et al. (2009)
Study 10b	*Glycine max*	*Aphis glycines* (Matsumura)	Yes	No	14 days	USA, Michigan, Wisconsin, Iowa, Minnesota	13	4	32–97%	Gardiner et al. (2009)