Landscape effect on pest abundance –expert elicitation and national data analysis

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Résumé

Le contrôle biologique des ravageurs et maladies des grandes cultures a été étudié depuis des décennies. L'un des éléments clés qui affecte l'abondance des organismes nuisibles pourrait être la composition du paysage. Dans cet article, nous présentons les résultats de l'étude d'abondance de ravageurs et de maladies en relation avec le paysage. Dans notre étude, nous essayons d'élucider l'influence de l'occupation du sol à différentes échelles spatiales sur les abondances de maladies et de ravageurs en prenant en compte les processus écologiques qui sous-tendent ces relations. En s'appuyant sur des études d'élicitation préalable ayant recueilli les opinions d'experts agricoles et les résultats présents dans la littérature, nous avons comparé ces attendus aux liens observés par ailleurs entre l'abondance d' organismes nuisibles et de grands jeux de données nationaux français. Les modèles de régression multiple utilisés ont notamment intégré les surfaces de bois, forêts, prairies et cultures sensibles aux ravageurs considérés. Nous trouvons bien des effets notables des éléments paysagers, cohérents pour la plupart avec les attendus des experts et de la littérature. Cette

Introduction

Biological/ecological control of agricultural pests has been drawing greater attention for decades since it has huge potential in pest and crop disease management without relying on agrochemicals. One of the key elements affecting the abundance of pests is the landscape composition, which has growing number of studies (Bianchi et al., 2006). Regardless of species, landscape scale perspective with metapopulation approaches and ecological process approaches could be very important to understand the population dynamics and interactions in between local species which is also applicable for pest management (Dunning et al., 1992; Schellhorn et al., 2008).

On the other hand, natural habitats can have sometimes opposite effects on the life of pests and of their natural enemies (Tscharntke et al., 2016). What is in general their relative impact on the occurrence and abundance of pests?

Here, we raised 2 major research questions: 1. Does spatial arrangement in agricultural landscape have a positive or negative impact on pest abundance? 2. What are the main mechanisms determining the impact of land use on pest abundance?

A number of studies tried to assess the landscape effect by the spatiotemporal modeling and pattern simulation has been carried out. Although there is considerable recognition that knowledge of landscape effects has been accumulated by experts in agricultural field, it has been unexplored. Accordingly, in our study, we used expertise database elicited from agricultural experts and literature, and compared them with the actually measured pest-abundance influenced by the landscape variation. We began by analyzing the quantitative coherency of land-use effect on pest abundance according to experts, literature and national data analysis. For further analysis, the expected mechanisms in ecological process were classified and assigned to the land-use where these mechanisms were observed according to the experts, which

Matériels et Méthodes

Materials

We gathered three data sources: 1. Expert's knowledge, 2. Literature review, 3. Actual statistics. The data sets of expert's knowledge and literature review were collected by semi-structured interview and formalized literature-searching method (done in last year) respectively, and then described in questionnaire to extract the qualitative and quantitative information. On the other hand, statistical data-set was assembled from French national data: epidemiological surveillance (Vigiculture®) and geographical information database (BDTOPO® and RPG®). We gathered pest abundance information and land-use surface for each sample point with 200m, 1000m, 5000m and 10000m scales.

In this internship, we checked the coherence of the data sources and kept only the observations when the registered culture of Vigiculture® could be found in the RPG within 20 m of the point.

As we added several important pests, 16 agricultural pests, including 9 insect pests and 7 diseases in total, were investigated.

Quantitative analysis

Based on the statistical data source, we analysed the landscape effect on pest abundance quantitatively, using Generalized Linear Model (GLM). In our analysis, the GLM variables were adjusted by LASSO (Tibshirani, 1996, 2011) which is a regression analysis method that performs both variable selection and regularization to enhance the prediction accuracy.

All the statistical operation was done with a statistical software R. Especially a package "glmnet" (J. Friedman, T. Hastie, N. Simon, R. Tibshirani, version 2.0-10, 2017) facilitated our operation in generating and analyzing the LASSO multivariate regression model.

Qualitative analysis

We carried out a qualitative analysis to explore the ecological process corresponding to the observed landscape effects. First, we classified the characteristics of landscape elements, according to their direct impacts on the pest's presence or indirect impacts through its natural enemies. We also identified if the landscape elements provide essential or substitutable resources such as trophic aid and habitat, or brings physico-chemical alterations such as humidity, temperature, and wind barrier (Table.1). These categorized mechanisms were identified in the expert questionnaire and counted for each studied land-use: forest patch, hedge, prairies, cropland cover around in same year (y), cropland cover around in precedent year (y-1). Then, we interpreted the quantitative result based on these aggregates. This operation allowed to elucidate what mechanism was often expected by the experts and if it is explaining the pest abundance quantitatively.

Table.1 Mechanism classification

Classe	Agent	Ressource substitut-able	Ressource essentiel	Altération physico-chimique	Autre alté-ration (agro-pratique)
Rav-ageur	Peste elle-même	1.1	1.2	1.3	1.4
	Spécialiste*	2.1	2.2	2.3	2.4
	Généraliste*	3.1	3.2	3.3	3.4
Mala-die	Phase parasite	1.1	1.2	1.3	1.4
	Phase de dispersion	(2.1)**	(2.2)**	2.3	2.4

* Natural enemies (specialists are mainly parasitoids)
** Not applicable to the classification

Résultats

Quantitative analysis

Culture (y) resulted in suppressive effect for 5 insect species (highest) at 680 m scale in average (Figure.1). Culture (y-1) showed augmentative effect for 5 insect species (highest) at 3440 m scale in average. Generally, all the land-uses indicated relatively positive effect on pest abundance except culture (y). Semi natural habitats (Bois, haies, and prairies) were suppressive

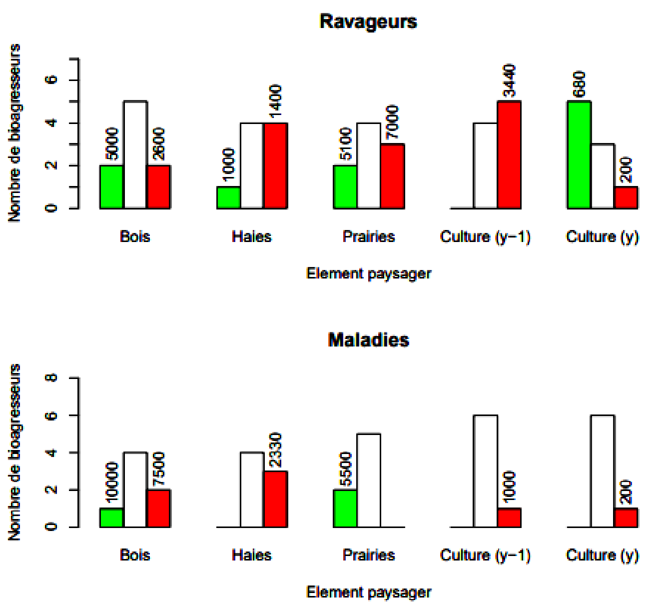


Figure.1 Number of species showing positive (red) or negative (green) response to each land-use

Numbers above bar graph indicate the mean of sampled scales.

only for 1 or 2 species, while those were augmentative for 2-4 species.

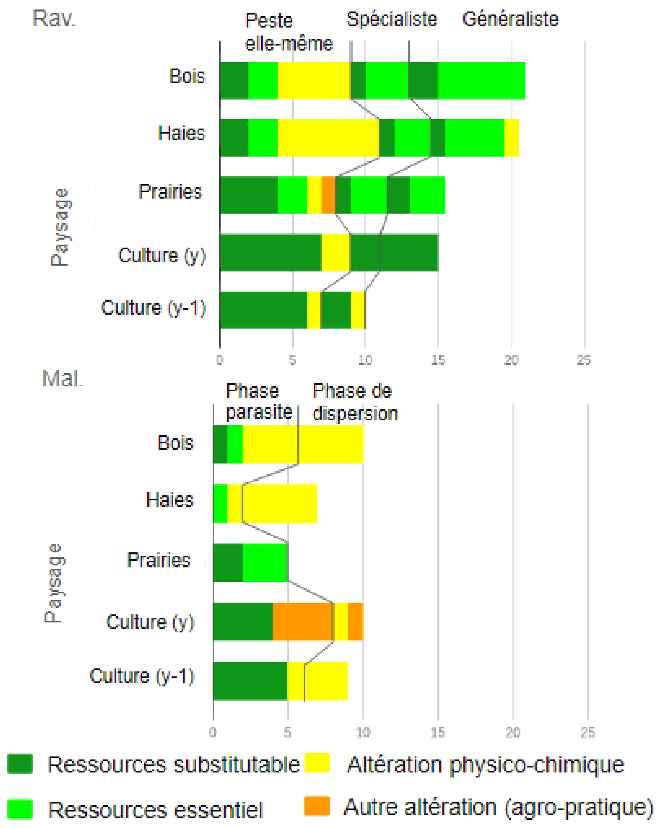
As regards diseases, hedgerow showed augmentative effect on 5 species (highest), while prairies showed suppressive effect on 2 species (highest). However, the R^2 of the model for each disease was relatively lower (ranging 0.02~0.2), which meant that the disease abundance was explained by its model at 2% to 20%, and the other percentage could attribute to agro-climatic effects.

No relevant land-use parameter was detected in 9 out of 16 pests by the LASSO regression model, which meant that the variables, namely each land use surface and pedo-climatic factor, could not explain the pest abundance sufficiently. A few valid correlations of landscape elements with disease abundance indicated that the disease occurrence was not simply related to the surface of specific land-uses.

Expected Mechanisms from expert views (Qualitative analysis)

In tems of insect pests, the forest patches and hedgerows exhibited similar variations and number of mechanism, while the grassland had a different pattern (Figure.2). This suggest that contrary to common perception in landscape ecology, grasslands cannot be clustered together with woodlands in a supposedly homogenous "semi-natural habitat" class. In crop-cover (y and y-1), substitutable resource for pest itself represented the largest proportion of these land-use mechanisms. From these observations, forest patch and hedgerow represent one end of the spectrum, crop-cover (y) and (y-1) do another end, and grassland mediate between two sides by its characteristics.

Figure.2 Observed mechanism in each land-use



The distribution of the ecological processes mentioned by experts for diseases followed a very different pattern. First, the total number of observed mechanisms was lower than that of insect pest. The experts mentioned substitutable resources for parasitic phase most often and physicochemical alteration for dispersion phase at second, regardless of land uses. Physico-chemical alterations account for most of the mechanisms in forest patch and hedgerow, and half of the one in crop-cover (y-1) for both life cycle of diseases. However, they were different in contents. The major physicochemical alteration in the semi natural habitat was such as wind barrier mitigating disease dispersion, whereas the one in crop-cover (y-1) was

Table.2 Result of quantitative analysis and number of expert mentioning the mechanism (e.g. *Meligethes aeneus*)

subject	Land use**	buffer	Regression coefficient	Partial correlation	No: Exp	*1. Pest itself / parasitic phase				*2. Specialist / dispersion phase				*3. Generalist / -			
						1.1	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**2.4**	**3.1**	**3.2**	**3.3**	**3.4**
Meligethes aeneus	forest	1000	0.0517	0.0489	4	0	2	0	0	0	1.5	0	0	0	0.5	0	0
	hedge	200	0.0719	0.0567	4	0	2	1	0	0	3	0	0	0	2	0	0
	grass	10000	0.1370	0.0768	4	1	0	0	0	0	0.5	0	0	0	0.5	0	0
	(y)	1000	-0.0910	-0.0454	4	3	0	0	0	2	0	0	0	2	0	0	0
	(y)	5000	-0.0876	-0.0335	4	3	0	0	0	2	0	0	0	2	0	0	0

* actor or agent of mechanism (insect pest / disease) ** land use: (y) same crop-cover in peripheral in a same year; (y-1) same crop-cover in peripheral in a previous year. Mechanism indicator (**Bold figure**) was detailed in Table.1. When a expert mention "predator", the number is divided and assigned to both specialist and generalist (shown as 0.5).

physical proximity from alternative host or plant debris in the field or at its immediate proximity insuring the permanence of the infection in the medium from harvest to sowing.

Statistics + mechanism elicited from expert

The expected landscape mechanisms by experts could explain the outcome of quantitative response from statistics. Here, we focus on Meligethes aeneus, a well-studied species. The observed mechanism of *Meligethes aeneus* clarified the difference of resource provision of land use between semi natural habitats and infield land-use (crop-cover (y)). Substitutable resource was mentioned in infield land-uses and essential one was done in semi natural habitats (Table.2). Although the grassland mechanism was discussed less, it showed the strongest coefficients.

The infield land-uses (y and y-1) can provide the pests with substitutable resources. This may cause the landscape supplementation which occurs when individuals move between patches to access the substitutable resources (Dunning et al. 1992). The organisms may supplement their resource intake by utilizing resources in nearby patches within the same habitat. Our result of quantitative analysis and related mechanism (not shown in the table) for all the 3 insects valid in LASSO model reached to grasp this mechanism, telling that the existence of substitutable resource for these pests at small scale could affect their abundance negatively. This was presumably referred to the dispersion of population to different patches around the habitat, and thus it was just a temporary effect and not sure to decrease the whole habitat population.

On the other hand, essential resources for *Meligethes aeneus*, often observed in forest patch and hedge, influenced its abundance positively (Table.2). Both substitutable and essential resources are required for organisms to maintain the population, but for different reasons. Essential resource is a driving force of another mechanism, landscape complementation, that support a larger population by complementing the resource intake in proximity (Tilman, 1983). Our result raised an assumption that scattering the population density could be one of the pest-related mechanisms of landscape supplementation, while landscape complementation could lead to support or grow the larger population of pests.

Besides, the accessibility of resources for their natural enemies also might influence their abundance as well. This mechanism has been well studied by Rusch, 2010 and Rusch et al., 2013 confirmed that the rate of parasitism was positively correlated with proximity to previous year rapeseed fields. Ulber et al., 2010 and Hokkanen, 2006 reported that parasitism can be a major factor for the population dynamics of Meligethes. Though the difference between substitutable and essential resource for the predators is ambiguous, the trophic resource for the predators is nothing but the host organisms, the larvae or eggs of *Meligethes*, and they usually grow in flowers of rapeseed. Therefore, since our result indicated that substitutable resource for the specialist predator impacted the pest abundance, we could alternatively interpret that the *meligethes* is their substitutable resource which is abundant in the field close to the rapeseed cultivated in previous year.

Conclusion

We captured the tendency of relationship between

En savoir plus

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2) BIANCHI, F., BOOIJ, C. & TSCHARNTKE, T. Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and

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