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Predicting Plant Communities in the Vicinity of Wheat Crops and Vineyards in Europe using Participatory Modeling

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Abstract

The risk assessment of pesticide use on non-target terrestrial plants is currently based on standardized greenhouse tests with a limited number of mostly crop plant species. Higher tier tests or assessments of any kind (e.g., field, semi-field, landscape studies) are not standardized. In this study we explored an approach to inform such a higher level by collecting datasets and information at European scale to characterize the vegetation communities that are likely to grow in the off-field areas of wheat and vine crops. The EUNIS (European Nature Information System) habitat classification was used to identify eight man-made habitats considered characteristic of the off-field areas in the European agricultural landscape. These habitats are spatially identified on the bases of a modelling process where vegetation plots, taken from the European Vegetation Archive, were used as observations and climate, soil, topographic, population density parameters and Remote Sensed Essential Biodiversity Variables as predictors. This modelling results in habitat suitability maps. The habitats are also described in terms of species frequencies and abundances, and to plant traits underlying possible vulnerability to pesticide exposure requested from the TRY plant trait database. Wheat and vine crop spatial data were derived from EUROSTAT and the QUICKScan methodology was used to combine all these data. We conclude that this method is helpful in reaching the objective as described in this paper. Its potential is that it can be extended probabilistically or linked to plant effect models.

Keywords: QUICKScan tool • Pesticide risk assessment • Terrestrial plants • Agricultural landscape • Off-field

Introduction

Admission of pesticides to the European market is based on a tiered approach [1,2]. The first step is standardized and defined in regulation [1,2]. The second and higher steps are well developed for aquatic risk assessment but lag behind for terrestrial risk assessment [3,4].

For plants, the first step is currently based on testing 10 single species in two different test systems. Higher tier tests of any kind (e.g. field, semi-field) are not standardized [3,4]. From the field up to the landscape level, the question arises how such a higher tier assessment could be performed for terrestrial plants. At these higher levels, the biological organization is not the species, but rather the plant community. Therefore, this study focused on answering the questions which typical vegetation is likely to grow in the off-field areas of wheat and vine crops at European scale given particular biophysical (climate, soil, hydrology, elevation, aspect, slope), plant-sociological and potentially also landscape characteristics and how this vegetation can be characterized by its plant traits. We applied the QUICKScan method [5,6] to combine the available databases, datasets and expert information at European level to generate suitability maps (potential occurrence maps) and vegetation characteristics for the off-field areas.

Materials and Methods

The identification of plant communities, their species and characteristics in the off-field areas of wheat and vine crops was performed using a habitat-based and modelling approach. Eight man-made habitats characteristic of agricultural areas were selected from the EUNIS (European Nature Information System; habitat classification) [7-9]. These habitats had been linked to the European vegetation plot records from the EVA (European Vegetation Archive) database using classification rules based on expert knowledge. In total 46 579 plots (mostly including vegetation records since 2000) were assigned to the eight selected man-made habitats (Table 1). Where a habitat can potentially occur, was predicted (modelled) by drivers for the vegetation including climate, soil, topography and remotely sensed Essential Biodiversity Variables (RS-EBV's) using Maxent [10]. A total of 30 drivers were applied in this modelling exercise [11], resulting in a series of suitability maps with a resolution of 1 × 1 km. These maps cover most of Europe. Plant traits underlying possible vulnerability to pesticide exposure were requested from the TRY plant trait database (https://www.try-db.org/TryWeb/Home.php) [12] and were used to collate a characteristic trait spectrum for each EUNIS habitat. These traits include leaf type, monocotyledon/dicotyledon category, plant functional type, plant life span (longevity), seed longevity and Raunkiaer life form. The QUICKScan [5] tool was used to combine habitat suitability maps, wheat and vine crop distribution maps (EUROSTAT) and trait information in order to generate potential occurrence maps (Figure 1). QUICKScan is a participatory modeling method that links stakeholder and decision-maker knowledge and preferences to available spatial and spatio-statistical data, and is designed for group use in a multi-stakeholder workshop setting.

	Man-made habitats characteristic of agricultural areas
V11	Intensive unmixed crops (Cereal and other non-woody crops grown on large, unbroken surfaces in open field landscapes)
V12	Mixed crops of market gardens and horticulture: Intensive cultivation of vegetables, flowers, small fruits, usually in alternating strips of different crops. Includes allotments and small-scale market gardens
V13	Arable land with unmixed crops grown by low-intensity agricultural methods
V34	Trampled xeric grassland with annuals
V35	Trampled mesophilous grassland with annuals
V37	Annual anthropogenic herbaceous vegetation: Stands dominated by annual herbaceous plants developing on recently abandoned urban or agricultural land

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V38	Dry perennial anthropogenic herbaceous vegetation: Stands dominated by perennial herbaceous plants, frequently ruderals, developing on dry abandoned urban or agricultural land
V39	Mesic perennial anthropogenic herbaceous vegetation: Stands dominated by perennial herbaceous plants, frequently ruderals, developing on mesic to slightly wet abandoned urban or agricultural land

Table 1. Eight man-made habitats characteristic of agricultural areas selected from the EUNIS habitat classification [7].

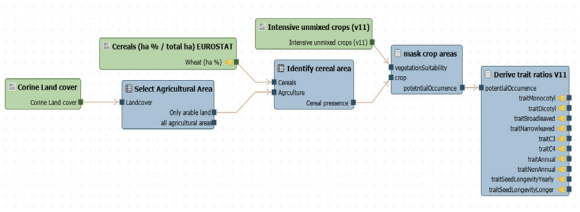

Figure 1. Flow diagram in QUICKScan.

Results and Discussion

The eight identified EUNIS habitats include 329 species with a frequency larger than 5% (that means occurring in more than 5% of the relevés), belonging to 45 plant families. The QUICKScan tool generated potential occurrence maps for each EUNIS habitat and for each trait. Examples of such potential occurrence maps for one of the habitats and one of its traits are presented in Figures 2 and 3. Here, we focus on the agricultural off-field area surrounding wheat crops and EUNIS habitat V11 is taken as an example. The map in Figure 2 shows the off-field area of EUNIS habitat V11, which relates to intensive unmixed, crops (off-field areas of cereal and other non-woody crops grown on large, unbroken surfaces in open field landscapes). Hot-spot maps were generated presenting the potential occurrence of both habitats as well as traits at European level (Figures 2 and 3 as examples). Figure 2 shows the areas in Europe where the potential occurrence of habitat V11 in the off-field area of wheat crops is absent, low, reasonable or high, represented by a an increasingly dark green color. This map also shows that the highest occurrence of this habitat is centered in the eastern part of Europe. Figure 3 shows the potential occurrence of the "annual species" trait in agricultural land surrounding wheat crops. The darker the color – in this case the purple color – the higher the trait percentage in this habitat. Annual species seem to be more represented in central and eastern Europe. These species are dependent on seed production in the growing season and germination at the start of their next growing cycle.

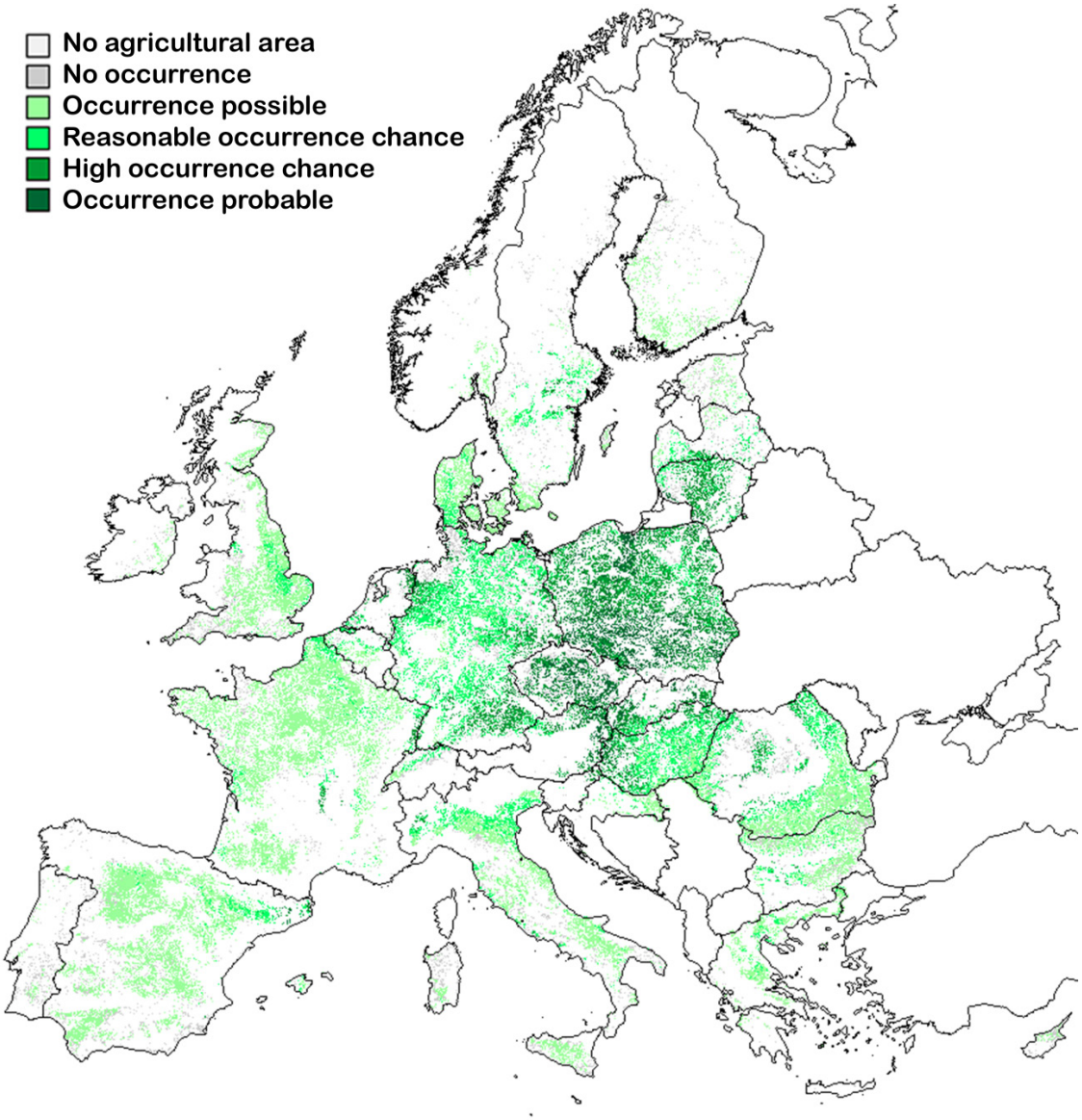

Figure 2. Potential occurrence of one of the EUNIS habitats (V11) in agricultural land surrounding wheat crops. The higher the potential occurrence, the more intense the green colour.

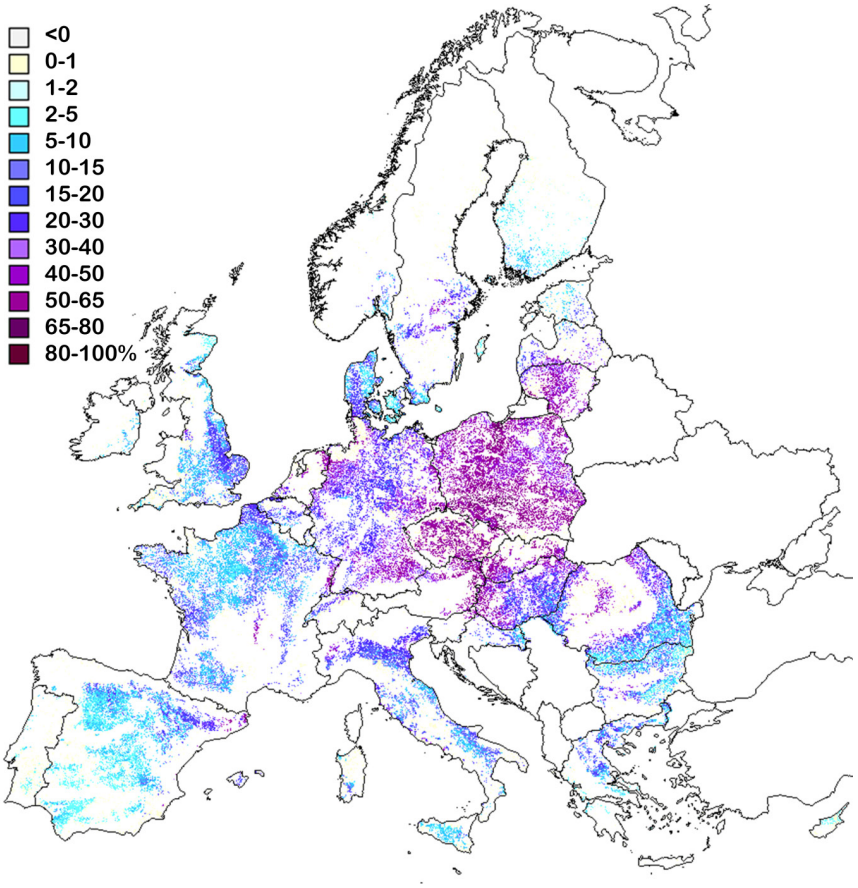

Figure 3. Potential occurrence of the "annual species" trait in agricultural land surrounding wheat crops. The higher the trait percentage in this habitat, the more intense the purple colour.

All maps generated in this research, and their underlying information provide insight into the potential occurrence of vegetation communities and their plant species with their abundance, frequency and traits, in the off-field areas of wheat and vine crops. This information can be used to identify vulnerable vegetation in off-field areas. This can inform pesticide risk assessment for non-target terrestrial plants, e.g. provide information on what needs to be protected in off-crop areas. This information might also inform higher tier testing, e.g. which species need to be studied in these tests or which traits need to be considered in a risk assessment. The model can be further developed to predict effects of herbicide use on the off-field vegetation, if the sensitivity of plants to specific compounds is added to the current tool by probabilistic modelling. Another option is to combine the model with an effect model like IBC Grass [13-15]. IBC grass is a spatially explicit and individual-based plant community model that predicts the effects of herbicides on a number of terrestrial plant species in a community setting, using endpoints generated in toxicity tests.

The current data analysis only considered a limited number of traits, i.e., those considered relevant and present in the available data. We were able to use data of five traits for the 329 species we identified as characteristic of the EUNIS habitats in the off-field areas. The trait spectra can be extended to include, e.g. plant size, competitiveness, and reproduction type (e.g., seeds, stolon etc.) by collecting these data from – as yet unexplored – databases.

The predictions of plant communities and traits can serve as a reference tier in the risk assessment for non-target plants.

Conclusions

• The QUICKScan tool is a very transparent tool, which is considered an advantage in regulatory risk assessment;

• We were able to identify plant communities, their species frequencies and abundances and traits characteristically found in the off-field areas of wheat and vine crops. These data can inform the pesticide risk assessment and possible higher tier approaches for non-target terrestrial plants and can be used to develop a representative reference tier.

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