RISK SPATIALIZATION OF AGRICULTURAL PHYTOSANITARY PRACTICES: CASE STUDY IN SOUTH-WEST FRANCE

Chaima GRIMENE[1,2,3*], Oussama MGHIRBI[1,2], Philippe LE GRUSSE[1,2], Jean-Paul BORD[2,3]

[1] CIHEAM-IAMM, Mediterranean Agronomic Institute of Montpellier, Montpellier University, 3191 Route de Mende, CS 43999, 34093 Montpellier cedex 5, France

[2] LAGAM, Laboratory for Geography and Territorial Planning in Montpellier, Paul Valéry Montpellier University (UPVM). Site Saint Charles, Rue du Professeur Henri Serre, 34090 Montpellier, France

[3] Paul Valéry Montpellier 3 University (UPVM). Route de Mende, 34199 Montpellier cedex 5, France

* Corresponding author: chaymagrimen@gmail.com; grimene@iamm.fr

Abstract

Despite the political efforts, France is among the main consuming countries of pesticides in the world and the first at European level with a consumption of more than 85,900 tons/year (BNV-D[1], 2019). The preservation of natural resources through the management of diffuse pollution related to pesticide use is considered as a major challenge in France and based on the identification of the highest risk areas. Our work aims to map the phytosanitary practices impact on human health and on natural resources, based on indicators of phytosanitary pressure (TFI: Treatment Frequency Index) and risk (IRSA: Indicator of Risk on the Applicator's Health, and IRTE: Indicator of Toxicity Risk on the Environment). These indicators are calculated with the EToPhy[2] software. This approach allows to present the spatial distribution of risk and phytosanitary pressure in the south-west of France (Gimone watershed). This mapping process is based on the scores of phytosanitary pressure and risk assigned to each plot, calculated from the applied dose of pesticides and their toxicity degree.

The spatialization of the health and environmental impact of farmers' phytosanitary practices enable us to identify the plots that represent the highest risk and their location to natural resources such as streams. The result could be used to improve the management of agricultural phytosanitary practices, taking into account the proximity of treated plots to different natural resources.

Keywords: *Risk, phytosanitary practices, spatialization, indicators, natural resources.*

Introduction

In the early 1960s, a period known as the "Green Revolution", agricultural production methods shifted towards the intensification of cropping systems with the aim of ensuring food security. Following this agricultural revolution, the use of pesticides was increased in France and all over the world (Guichard *et al.*, 2017; Sharma *et al.*, 2019). Thus, the types of plant protection products and the methods of application have diversified.

Indeed, the excessive use of phytosanitary products in agriculture has generated the contamination of surface and groundwater which constitutes the resources intended for human consumption. This pollution leads several problems of public health and on the environment such

[1] **BNVD:** National Bank of Plant Protection Sales by approved distributors, https://bnvd.ineris.fr/

[2] **EToPhy software (2020)**, APP deposit n°: IDDN.FR.001.090003.000. S.P.2020.000.31500. developed by CIHEAM-IAMM https://etophy.fr/

as the quality of water resources and agricultural products (Aouadi *et al.,* 2018). Monitoring and reducing the diffuse phytosanitary pollution have become major issues for water resources, human health and the balance of natural ecosystems.
Several research studies have been carried out to analyze the health and environmental impact of pesticide use and the contribution of agricultural practices to the diffuse pollution (Mghirbi *et al.*, 2015; Mghirbi *et al.*, 2018; Kanj 2018; Grimene *et al.*, 2021).
Our research is oriented towards the same perspective of risk assessment related to agricultural phytosanitary practices based on indicators of phytosanitary pressure (TFI: Treatment Frequency Index) and risk (IRSA: Indicator of Risk on the Applicator's Health and IRTE: Indicator of toxicity Risk on the Environment). These indicators make it possible to illustrate the spatial distribution of the phytosanitary pressure and the toxicity risk related to pesticide use at plots level on Gimone watershed in the south-west France.

Materials and methods

The adopted approach in this work consists of a spatial risk assessment of agricultural phytosanitary practices through the Indicator of Risk on the Applicator's Health (IRSA) and the Environment (IRTE), calculated by EToPhy. The EToPhy tool makes it possible to refine the analysis of the health and environmental impact of pesticide use through the disaggregation of the IRSA and IRTE into 2 sub-indicators of risk to human health (IRSA acute, IRSA chronic) and 3 environmental sub-indicators relating to the three environmental compartments: water, soil and air (IRTE aquatic, IRTE terrestrial invertebrate, IRTE bird) (Mghirbi *et al.,* 2015; Mghirbi, 2016). These indicators are then integrated into a GIS in order to design spatial distribution maps of the health and environmental impact of agricultural phytosanitary practices. These maps will allow to identify the plots with high risk to human health and to the environment in the Gimone watershed, which extended over the two departments of Gers and Tarn-et-Garonne, located in the south-west of France (Figure 1).

Figure 1. Study area location: the Gimone watershed in south-west France (sources: IGN GEOFLA 2017, Carthage Database 2013).

The territory of the Gimone watershed is largely occupied by agriculture, about 57,400 ha of the UAA[3] (i.e. around 70% of its surface area). The land use is almost homogeneous with a predominance of agricultural areas dedicated to annual crops (wheat, sunflowers, soybeans, corn). Cereal crops dominated by soft wheat and durum wheat represent the main crops, followed by sunflower and soybeans.

Given the dominance of agriculture at the watershed level, it turns out that agricultural practices, including the phytosanitary products applied by farmers have an impact on the water quality. The Gimone watershed is considered to be a territory with high agricultural pressure and low potential for resilience to diffuse pollution given its physical characteristics which play a negative role in the pollutant transfer.

Our study is based on two types of data:

- A geographic database: represents the parcels data from the study area and which contains all the geo-referenced parcels from the geographic data sources (Graphical Parcels Register RPG).
- A phytosanitary practices database: represents all phytosanitary treatments (pesticide applications) on the surveyed plots and all parameters related to the application of the plant protection products (farm identifier, plot identifier, plot area, treated area, TFI, approved dose, applied dose, IRSA and its sub-indicators, IRTE and its sub-indicators).

The phytosanitary practices database will used to calculate risk indicators for the different surveyed plots. The IRSA is a scoring indicator which assesses the acute and chronic toxicity of plant protection products taking into account the physico-chemical and toxicological properties of the active ingredients. The IRTE assesses the toxicity risk of phytosanitary products on non-target living organisms in each environmental compartments (water, air, soil) based on the eco-toxicological and physico-chemical characteristics of the active ingredients. In order to carry out this analysis of agricultural phytosanitary practices, a sample of 161 farms (3,340 plots) was selected on the Gimone watershed, illustrated in the following table.

Table 1. Distribution of crops according to the plots surveyed in the Gers and Tarn-et-Garonne departments

Crop categorie	Crop	Plot number	Area (ha)
Field crops	Soft wheat	1,113	5,699
	Sunflower	685	3,049
	Grain corn	209	1,093
	Rape	200	1,113
	Durum wheat	182	882
	Barley	164	577
	Soya	103	517
	Sorghum	38	134
	Triticale	35	97
	Oilseed flax	32	167
	Chick pea	29	148
	Grassland	11	30
	Lentils	9	32
	Protein pea	9	33
	Horse bean	7	48

[3] **UAA :** Utilised Agricultural Land

	Forage corn	7	34
	Coriander	3	7
	Rye-grass	3	12
	Oat	1	4
	Subtotal	**2,840**	**13,673**
Arboriculture	Apple	308	216
	Organic apple	12	6
	Cherry	50	8
	Plum	32	22
	Organic plum	6	2
	Peach	8	1
	Organic pear	8	2
	Kiwi	3	1
	Organic kiwi	3	1
	Apricot tree	3	0.1
	Subtotal	**433**	**259**
Market gardening	Garlic	53	109
	Onions	2	1
	Carrot	1	4
	Subtotal	**56**	**114**
Viticulture	Vine	11	7
Total	**30 crops**	**3,340**	**14,053**

Results and discussion

Analysis of the agricultural phytosanitary practices

The analysis of agricultural phytosanitary practices enabled us to draw up graphs which illustrate the risk variability between the different crops (Figure 2) and also to compare the risk between the different production methods, conventional/integrated and organic (Figure 3).

The graph below shows an overall analysis of the risk and pressure indicators between some crops from four crop categories (field crops, arboriculture, market gardening and viticulture) in order to compare the health and environmental impact of phytosanitary practices according to the products applied by farmers. The results of the analysis show a remarkable difference between the risks related to different crop categories. The tree crops (arboriculture) presented the highest treatment frequency and risk, especially on human health. The risk is higher in the plots of apple trees with a treatment frequency more than 26.

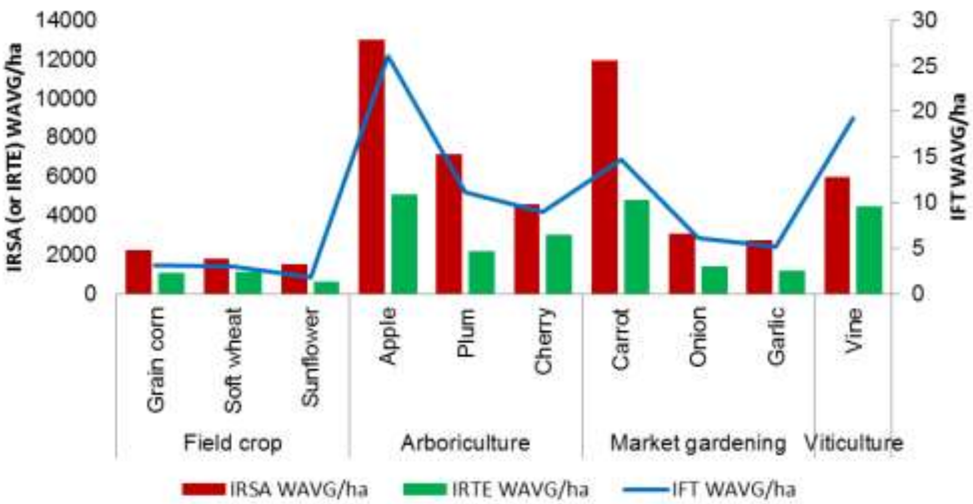

Figure 2. Variability of indicators according to crop categories from conventional/integrated production (values expressed as weighted average per hectare)

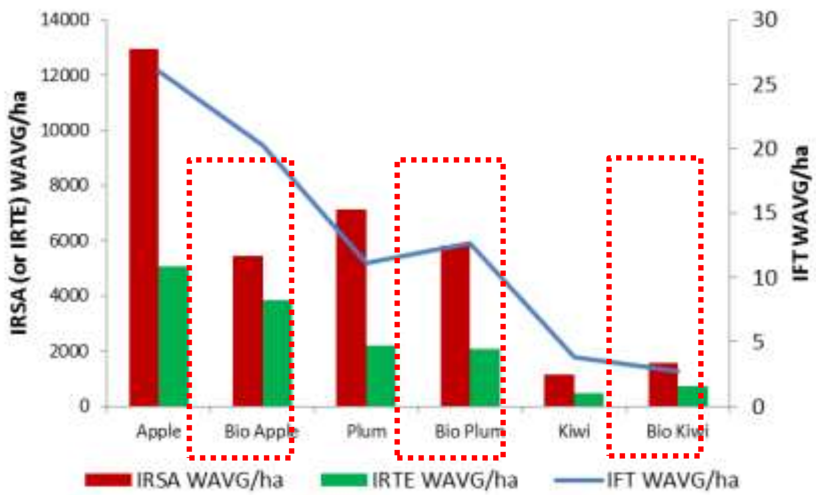

Figure 3. Variability of indicators according to the production mode (conventional/integrated and organic) between tree crops (values expressed as weighted average per hectare)

According to the production mode, the average TFI/ha in organic farming is lower than in conventional/integrated. This indicate that the treatment frequency of organic crops remain always lower than that of conventional production. The risk is lower in organic plots, but it is not negligible either.

The use of risk sub-indicators to human health and the environment makes it possible to refine the analysis of the toxicity degree of plant protection products in order to improve the management of plant protection practices and the pesticide choice. The graphs 4 and 5 show a comparison of the toxicity part between different crop categories.

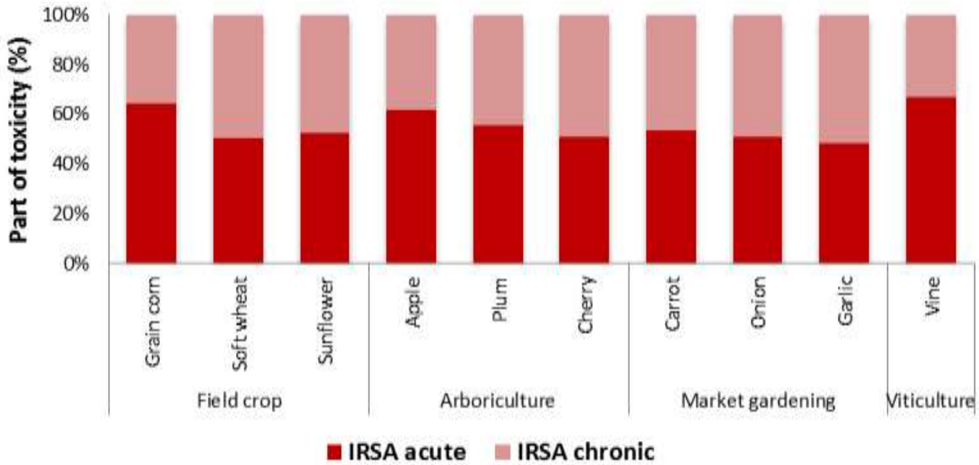

Figure 4. Comparison of acute and chronic toxicity part of plant protection practices between crops

Regardless of the crop, the acute toxicity risk of phytosanitary practices is greater than 50%. The majority of the products used on the surveyed plots have more acute health risk (irritation risk and risk via inhalation, dermal or oral route) than chronic (RMC risk, neurotoxicity and endocrine-disrupting effect).
The environmental risk sub-indicators presented in figure 5 show the toxicity part of phytosanitary practices for each environmental compartment: soil, air and water (IRTE terrestrial invertebrate, IRTE bird and IRTE aquatic) according to crops.

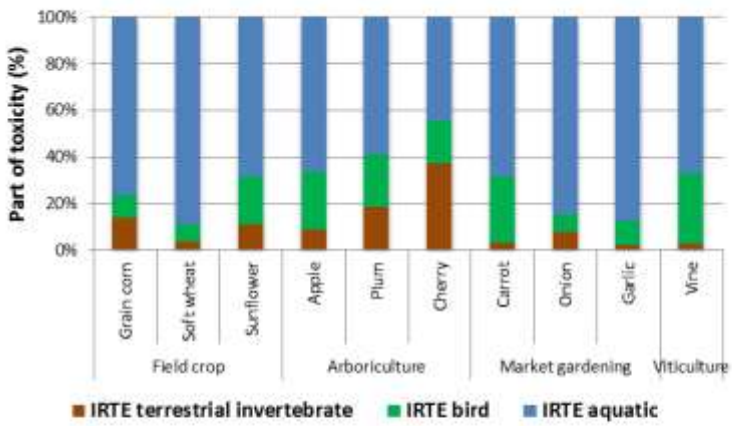

Figure 5. Comparison of the toxicity part of plant protection practices for each environmental compartment between crops

The proportion of the toxicity risk to the aquatic environment is over 70% for field crops, market gardening and in viticulture, which leads us to study in more detail the risk of phytosanitary diffuse pollution on the aquatic environment.

Risk mapping of agricultural phytosanitary practices

Risk mapping is carried out at plot scale which associated to a crop. Each crop has an average toxicity risk value/ha. The risk indicators are represented according to 3 classes from low to high, from green to red, respectively (Figure 6). The spatial analyse of the toxicity risk of phytosanitary practices on human health reveals that the medium to high health risk patches cover 40% of the total UAA of the catchment area (Figure 6A). This analysis clearly shows us the issue of health security for farmers and their neighbourhood through the identification of areas with high risk on human health. The risk of aquatic toxicity varies between medium and high scores and represents around 30% of the total UAA of the Gimone area. The issue associated with this medium-high toxicity risk is the proximity of the treated plots to the streams or rivers, which makes it possible a direct transfer of pollutants towards the aquatic environment (Figure 6B). This spatial analyse leads us to act on phytosanitary practices through the improvement of the active ingredients/products choice by farmers depending on the proximity of plots to the natural environment, in order to replace the phytosanitary products with a high toxicity risk to the aquatic environment with less harmful one.

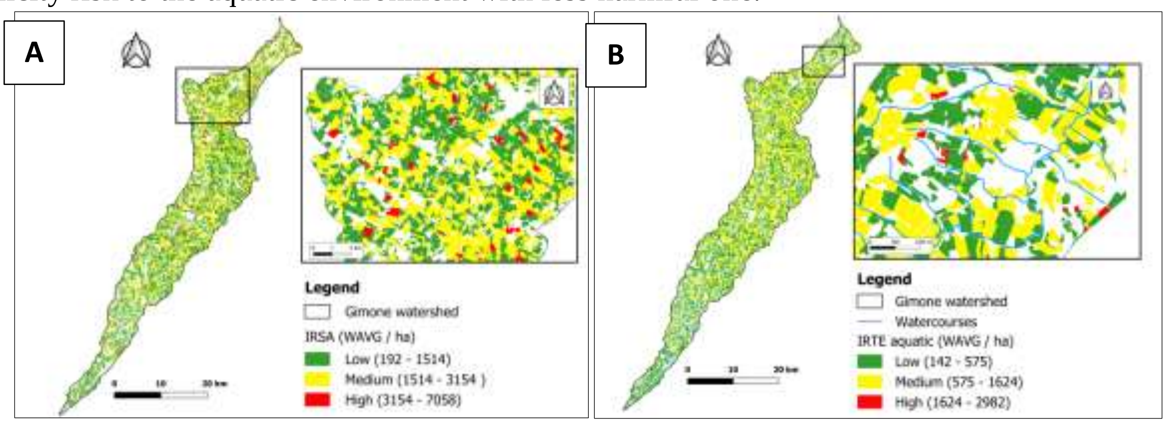

Figure 6. Map of human health risk related to agricultural phytosanitary practices on the plots of the Gimone watershed (A); Map of aquatic toxicity risk related to agricultural phytosanitary practices on the plots of the Gimone watershed (B) (Sources: Carthage DB, RPG 2017)

Conclusion

The evaluation of phytosanitary practices is based on the complementarity between TFI, IRSA, IRTE and the risk sub-indicators used to determine the toxicity degree of plant protection products on human health and on the 3 environmental compartments: soil, air and water.

An improved management of phytosanitary practices can be implemented through the right choice of products depending on the proximity of plots to natural environment and using decision support tools to analyse the health and environmental impact of pesticide use.

An increasing orientation of several famers towards the organic production mode cannot ensure a reduction in the toxicity risk associated to phytosanitary practices because the organic farming is not safe to human health and to the environment.Spatial analysis of the health and environmental impact of agricultural phytosanitary practices using GIS is considered as a decision support tool to improve the management of the pesticide use at plots and farms level. Furthermore, this spatial analysis provides to the natural resources managers a reflection support tool to improve the management of the diffuse phytosanitary pollution through the identification of areas with high risk on non-target living organisms in the different environmental compartments (water, air and soil). These tools make it possible to set up agri-environmental measures and action plans at different scales from plot to the watershed. These measures aim to reduce the toxicity risk of agricultural phytosanitary practices on human health and on the environment.

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