ETOPHY: WEB PLATFORM FOR MANAGING THE IMPACTS OF PLANT PROTECTION PRODUCTS USED IN AGRICULTURE

Oussama MGHIRBI[1,2*], Philippe LE GRUSSE[1,2], Chaima GRIMENE[1,2,3], Elisabeth MANDART[1], Jacques FABRE[1], Julie CAUBEL[4], Isabelle NEMBROT[4], Jean Philippe BOULANGER[4], 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 3 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

[4] EcoClimaSol, Immeuble MIBI. 672 Rue du Mas Verchant, CS 37777, 34967 Montpellier Cedex 02, France

*Corresponding author: mghirbi@iamm.fr; oussama.mghirbi@gmail.com

Abstract

EToPhy is a web application/platform which aims to assess and control the impacts related to the phytosanitary products used in agriculture on the environment and on human health. The EToPhy web platform is presented as a dashboard to determine the phytosanitary footprint of agricultural phytosanitary practices based on indicators of phytosanitary pressure (TFI: Treatment Frequency Index), and of risk (IRSA: Indicator of Risk on the Applicator's Health, IRTE: Indicator of Toxicity Risk on the Environment). These risk indicators break down into acute and chronic IRSA and IRTE sub-indicators for terrestrial invertebrates, birds, and aquatic organisms. This tool provides two web applications to improve the management of pesticide use related risk to the applicator's health and to the environment for professionals involved in the management of plant protection products (PPPs):

- EToPhy *Simulateur* aims to assess the toxicity degree of PPPs and to find alternatives that are less harmful according to the crop and pest to be treated.
- EToPhy *Analyses* makes it possible to analyze the health and environmental impact of farmer phytosanitary practices at different scales (product, field, crop and farm).

The phytosanitary pressure and risk indicators have enabled us to analyze the impact of plant protection practices and to compare the cropping systems of conventional, integrated and organic agriculture.

Keywords: *EToPhy web platform, human health, environment, indicators, plant protection products.*

Introduction

The use of pesticides in agriculture has been steadily increasing in recent years in France and around the world, despite efforts by political and public decision-makers to implement sustainable strategies and measures for reducing the use of plant protection products (Auberto *et al.*, 2005; Guichard *et al.*, 2017; Sharma *et al.*, 2019). Several studies have shown the health and environmental impact of plant protection practices and the effect of frequent exposure to pesticides on public health and the environment (Alavanja, 2009; Hallenbeck & Cunningham-Burns, 2012; Baldi *et al.*, 2013; Mahmood *et al.*, 2016). As a result, the management of diffuse

pollution related to the use of plant protection products has become a concern for the different stakeholders involved in pesticide management (policy makers, land and natural resource managers, agricultural technicians/advisors and farmers).
These different stakeholders have expressed their need for decision support tools to improve the management of risks due to plant protection products used in agriculture to human health and the environment. Several tools have been developed based on technological and/or technical solutions in order to control the risks of phytosanitary diffuse pollution at different spatial scales, from the plot to the watershed or agricultural region (Bockstaller & Girardin, 2003; Bockstaller *et al.*, 2008; Houdart *et al.*, 2009; Ossard *et al.*, 2009; Ayadi *et al.*, 2014; Mghirbi *et al.*, 2015, 2017, 2018; Lammoglia *et al.*, 2017; Kanj, 2018; Juan *et al.*, 2018). The development of the EToPhy[4] tool by the CIHEAM-IAMM research team, as part of the TRam research project (Ayadi, 2013, Le Grusse *et al.*, 2014, Mghirbi, 2016), adds to the list of research work carried out to meet the expectations of the different stakeholders by improving the management of phytosanitary practices and reducing their sanitary and environmental impact.
EToPhy was initially developed as desktop software for use in teaching and research. This format was not operational enough for professionals involved in pesticide management, hence the idea of developing a simple and practical web version as a collaboration between the CIHEAM-IAMM and the R&D company Ecoclimasol within the GesPPEIR collaborative research project.

Materials and methods

Design of the EToPhy web platform

A first step towards the identification of potential user needs was carried out through repeated workshops with technicians from agricultural cooperatives, and farmers from the south-west of France, as part of the GesPPEIR project. The objective of this participatory approach was to build a web platform according to the needs of professionals involved in the management of phytosanitary practices. This platform consists in evaluating and controlling the risks linked to the use of pesticides to human health and the environment at the level of plots and farms.
Indeed, the EToPhy web platform is a dashboard for determining the phytosanitary footprint of pesticides and agricultural phytosanitary practices based on pressure indicators such as the TFI (Treatment Frequency Index, an official French indicator used within the Ecophyto plan which characterises the intensity of pesticide use) and risk indicators such as the IRSA (*Indicateur de Risque sur la Santé de l'Applicateur*: Indicator of Risk on the Applicator's Health) and the IRTE (*Indicateur de Risque de Toxicité sur l'Environnement*: Indicator of Toxicity Risk on the Environment). Moreover, the EToPhy tool makes it possible to refine the analysis of the health and environmental impact of pesticides 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).
The IRSA and IRTE indicators were mainly developed based on the work of researchers from Quebec (Samuel *et al.*, 2012) and Norway (Spikkerud, 2000; Spikkerud *et al.*, 2004), as well as the work of European focus groups (Boesten *et al.*, 1997; Linder *et al.*, 2001; Klein *et al.*, 2003). These risk indicators differ from those used in Quebec in that they are adapted to European

[4] **EToPhy software (2020)**, APP deposit n°: IDDN.FR.001.090003.000. S.P.2020.000.31500.

standards, and take into account European approvals and regulations (Balderacchi & Trevisan, 2010).
IRSA is a generic scoring indicator that can be modified according to the application context. It assesses the acute and chronic toxicity of plant protection products by considering the physicochemical and toxicological properties of the active ingredients. It also expresses the potential risk associated with the use of the product by taking into account the exposure related to the type of formulation (Samuel *et al.*, 2012; Ayadi, 2013; Mghirbi, 2016).
IRTE is a scoring indicator, determined by the sum of six variables that evaluate eco-toxicological impacts on non-target living organisms (terrestrial invertebrates: earthworms and honeybees; herbivorous birds: Virginia quail, and granivorous birds: mallard; aquatic organisms: fish, daphnia, algae and aquatic plants) and physico-chemical behaviours in the receiving environment (mobility, persistence in soil and bioaccumulation). It assigns a weight to these variables (a score from 0 to 8 representing the level of toxicity), and then integrates them into the calculation, based on a toxicity/exposure ratio (Samuel *et al.*, 2012; Ayadi, 2013; Mghirbi *et al.*, 2015; Mghirbi, 2016).
These scoring indicators (IRSA and IRTE) are generic and can be modulated according to phytosanitary practices (commercial preparation, physicochemical and eco-toxicological characteristics), spatial scale (place of application: open field, greenhouse, garden, etc.), as well as according to the conditions of the physical environment and/or receiving environment (crop interception factor, drift, runoff and drainage potential) (Samuel *et al.*, 2012; Ayadi, 2013).
The calculation of these indicators is based on the use of 2 databases (updated several times a year): (i) one on the commercial characteristics and uses of registered plant protection products, Basagri[5] (provided by the company Lexagri), (ii) and one on the physico-chemical, toxicological and eco-toxicological properties of active ingredients, Footprint[6](Lewis et al., 2016). The databases were structured on the Ecoclimasol servers to automatically manage the regular updates of the two databases, as well as their possible changes in format. It was also necessary to structure the pairings between the Basagri parameters and those of Footprint (PPDB) to calculate the indicators.

Functionalities of the EToPhy web platform

Two applications have been developed on the "EToPhy web[7]" platform (also entitled "Dephyto"): EToPhy *Simulateur* and EToPhy *Analyses* (Figure 1). EToPhy *Simulateur* aims to assess the toxicity of plant protection products and active ingredients marketed (from the Basagri and Footprint databases) and to find alternatives that are less harmful to human health and the environment depending on the crop and the target/pest to be treated.
EToPhy *Analyses* makes it possible to analyze the sanitary and environmental impact of farmer phytosanitary practices at different levels (product, plot, crop and farm) in order to reduce the risk linked to the use of pesticides to human health and non-target organisms in the 3 environmental compartments: water, air and soil. This application works by means of 2 services used successively. First, the user should locate these plots on a map via the GEOLOC service. Then, the phytosanitary interventions of each plot must be stored in a record book via the LOGBOOK service. The database associated with this service is able to store information from

[5] https://www.lexagri.com/service_basagri.php
[6] http://sitem.herts.ac.uk/aeru/ppdb/
[7] https://www.etophy.fr

different databases, such as Basagri (database of commercial products used in EToPhy *Simulateur*), but also databases usually used by farmers and agricultural cooperatives in France (e.g. the Télépac[8] database for CAP declarations). Once all the information is filled in, EToPhy *Analyses* makes it possible to compare phytosanitary practices between plots, crops and farms. This operation makes it easier for users to identify the product(s) that have too high impact on health and the environment, in order to substitute them by using the risk comparator of plant protection products on EToPhy *Simulateur*. In addition to these EToPhy *Analyses* functions, the user can refine his/her choice of plant protection products according to environmental issues, and to the characteristics of the natural environment through the geolocation of plots via the GEOLOC service. Several other comparison queries provide users with a relatively rich field of analysis of phytosanitary practices according to agricultural campaigns, production methods (conventional, integrated or organic) and specificities of pesticide choices between synthetic and bio-control products.

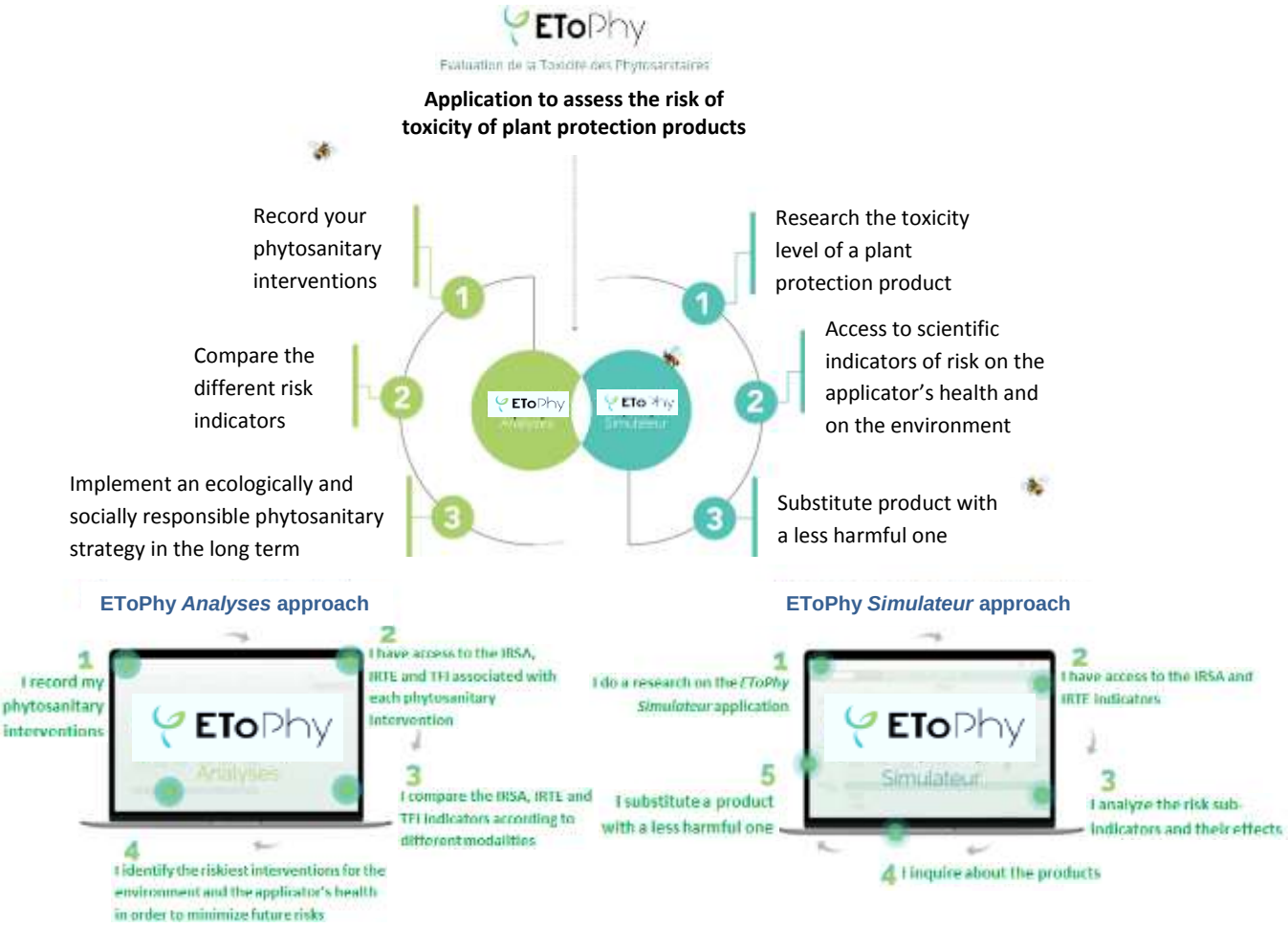

Figure 1. Illustrative diagram of the "EToPhy web" functionalities on the Dephyto platform

[8] https://www.telepac.agriculture.gouv.fr

Results and discussion

ETоPhy *Simulateur*

The ETоPhy *Simulateur* web application takes the form of a search engine. It calculates the IRSA and IRTE risk indicators linked to the use of a plant protection product based on a search by product name (Figure 2), by active ingredient name, or for a specific target on a given crop. It provides regulatory information on the product uses (Figure 2) and details of the risks to the environment such as the eco-toxicological impact on non-target organisms (earthworms, bees, birds, aquatic plants, fish, etc.), as well as to human health, such as chronic and acute toxicity (Figures 3 and 4). Finally, it allows the comparison of the toxicity of different products and helps the user to choose products that are less toxic to human health and to the 3 environmental compartments: soil, air and water (Figure 5).

Figure 2. ETоPhy Simulateur screenshot – Visualisation of the applicator health risk indicator (IRSA) and environmental toxicity risk indicator (IRTE) for the Fury 10 EW product with a 0.1 l/ha dose, and regulatory information on these uses.

Figure 3. EToPhy Simulateur screenshot showing the details of the applicator health risk indicator (IRSA) for Fury 10 EW with a 0.1 l/ha dose.

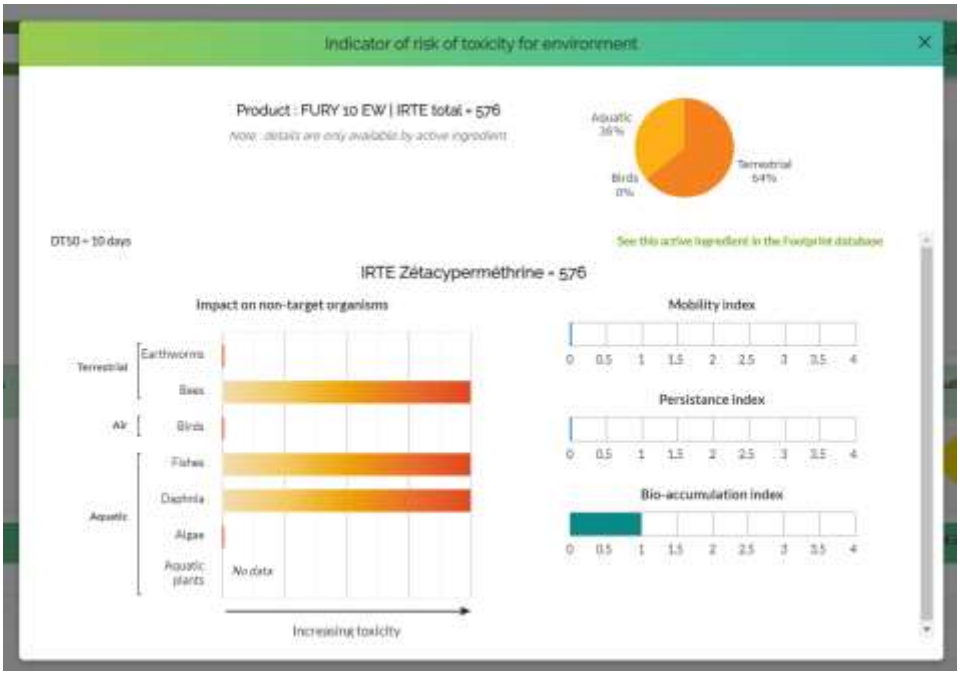

Figure 4. EToPhy Simulateur screenshot showing the details of the environmental toxicity risk indicator (IRTE) for Fury 10 EW with a 0.1 l/ha dose.

Figure 5. EToPhy Simulateur screenshot showing the comparative table of the toxicity risk of different phytosanitary products for a given crop-target (Wine grape vine - Powdery mildew).

EToPhy *Analyses*

EToPhy *Analyses* calculates the phytosanitary footprint of each phytosanitary intervention applied on the plot in question and recorded in LOGBOOK (Figure 6). The phytosanitary footprint is expressed via the IRSA and IRTE risk indicators (and the sub-indicators), and the TFI. EToPhy *Analyses* consists of a tool for selecting farms, crop years, plots and crops, for which the user wishes to visualise the results of the risk indicators and the TFI (Figure 7). Based on this selection, graphs offer a comparison of TFI, IRSA and IRTE indicators between the applied products (synthetic or bio-control), between plots or crops, between seasons and between farms, while taking into account the production mode (conventional, integrated or organic). Figure 7 shows an example of the contribution to the phytosanitary footprint (indicators in values/ha and in %) of the different products applied on a farm (conventional/integrated production for durum wheat, winter oilseed rape and maize plots). The user can then evaluate the environmental performance according to the levels of analysis (product, plot, crop), identify practices to be improved, as well as simulate crop treatment practices that are less toxic to human health and the environment.

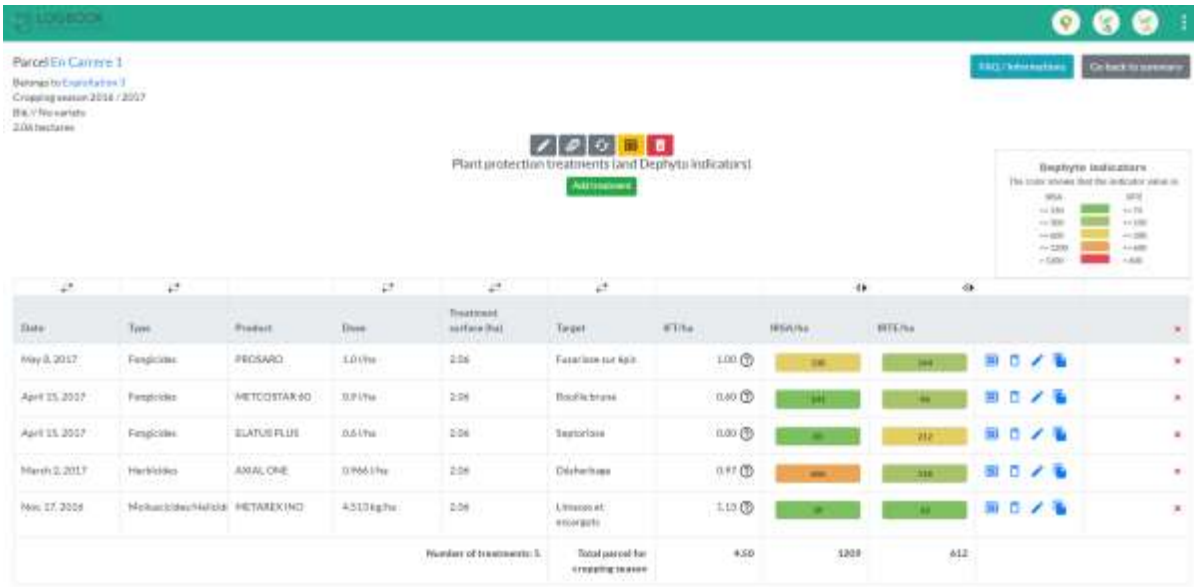

Figure 6. Screenshot of the LOGBOOK agricultural practice recording service – Visualisation of phytosanitary interventions applied on a plot of winter durum wheat, as well as the TFI, IRSA and IRTE indicators (values/ha) related to each intervention.

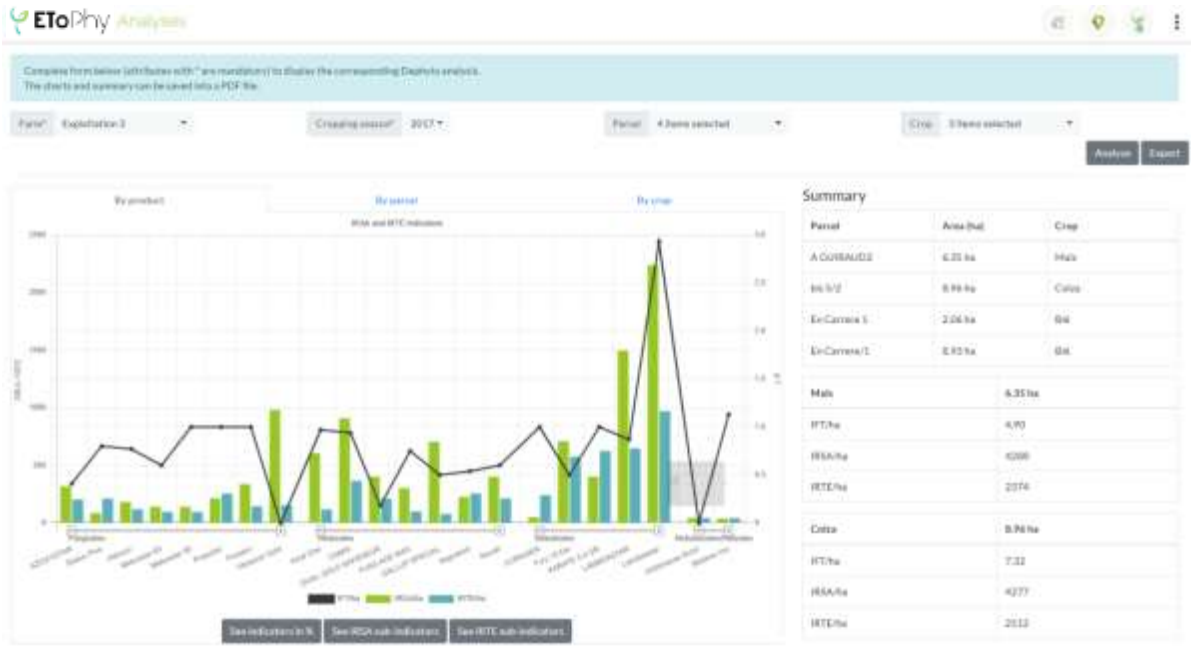

Figure 7. Screenshot of the EToPhy *Analyses* service - Contribution to the phytosanitary footprint (indicators in values/ha and in %) of the different products used on a farm with durum wheat, rape and maize plots.

Conclusion

The development of the EToPhy web platform, as a decision support and risk analysis tool for pesticide use, is part of the precision agriculture and smart agriculture concepts to improve the management of agricultural phytosanitary practices. The deployment of big data technology makes it possible to manage the significant number of parameters (characteristics of commercial products and active ingredients), in order to simplify user access to information from databases. The pressure and risk indicators calculated on the platform represent a decision support dashboard for the better integrated management of the health and environmental impact of plant protection products applied on plots. The functionalities of the EToPhy web platform (EToPhy *Analyses* and EToPhy *Simulateur*) play a dual role in the monitoring and the control of the diffuse phytosanitary pollution, depending on the spatial scale of phytosanitary practice management: at a local level (plot/farm) and at a territorial level (catchment area, agricultural region).

Acknowledgments

ETоPhy web developed by CIHEAM-IAMM and the R&D Company Ecoclimasol as part of the collaborative research project GesPPEIR "*Gestion eau, Phytosanitaires, Prévisions et Indicateurs de Risques*" funded by the ERDF and the Occitanie region, France (2016-2021). https://etophy.fr/

References

Alavanja, M. C. (2009). Pesticides use and exposure extensive worldwide. Reviews on environmental health, 24(4), pp. 303-309.

Aubertot J.-N., Barbier J.-M., Carpentier A., Gril J.N., Guichard L., Lucas P., Savary S., Savini S., Voltz M. (2005). Pesticides, agriculture et environnement. Réduire l'utilisation des pesticides et limiter leurs impacts environnementaux. Rapport d'expertise scientifique collective, INRA et CEMAGREF.

Ayadi H. (2013). Outils de gestion de la pollution phytosanitaire diffuse au niveau d'un territoire : cas d'application zone humide Ramsar de la Merja Zerga au Maroc. Thèse de doctorat en Géographie et Aménagement de l'Espace, spécialité Agronomie: Université Montpellier 3.

Ayadi H., Le Bars M., Le Grusse P., Mandart E., Fabre J., Bouaziz A., Bord J.P. (2014). SimPhy: a simulation game to lessen the impact of phytosanitaries on health and the environment-the case of Merja Zerga in Morocco. Environmental Science and Pollution Research, vol. 21, pp. 4950-4963.

Bockstaller C., Girardin P. (2003). How to validate environmental indicators. Agricultural Systems, vol. 76, pp. 639-653.

Bockstaller C., Guichard L., Makowski D., Aveline A., Girardin P., Plantureux S. (2008). Agri-environmental indicators to assess cropping and farming systems. A review. Agronomy for Sustainable Development, vol. 28, pp. 139-149.

Guichard L., Dedieu F., Jeuffroy M.-H., Meynard J.-M., Reau R., Savini I. (2017). Le plan Ecophyto de réduction d'usage des pesticides en France: décryptage d'un échec et raisons d'espérer. Cahiers Agricultures 26(1):14002.

Hallenbeck W.H., Cunningham-Burns K.M. (2012). Pesticides and human health. Springer Science & Business Media.

Houdart M., Tixier P., Lassoudière A., Saudubray F. (2009). Assessing pesticide pollution risk: from field to watershed. Agronomy for sustainable development, 29(2), pp. 321-327.

Baldi I., Cordier S., Coumoul X., Elbaz A., Gamet Payrastre L. et al. (2013). Pesticides : Effets sur la santé. [Rapport de recherche] Institut national de la santé et de la recherche médicale (INSERM). Paris : Inserm : Editions EDP Sciences (ISSN : 1264-1782).

Juan G., Barataud F., Billy C., Bouchet L., Carpentier A., Gouy V., Le Hénaff G., Voltz M. (2018). Référentiel sur les outils de la recherche pour réduire les pollutions de l'eau par les pesticides. Rapport final, convention INRA-AFB.

Lammoglia SK., Moeys J., Barriuso E. et al. (2017). Sequential use of the STICS crop model and of the MACRO pesticide fate model to simulate pesticides leaching in cropping systems. Environ Science and Pollution Research, vol. 24, pp. 6895–6909.

Le Grusse P., Mandart E., Bouaziz A., Le Bars M., Bord J-P., Fabre J. (2014). Gestion de la toxicité en zone Ramsar (TRam). Rapport scientifique du programme pesticides: Programme évaluation et réduction des risques liés à l'utilisation des pesticides. APR Pesticide 2009.

Mahmood I., Imadi S.R., Shazadi K., Gul A., Hakeem K.R. (2016). Effects of Pesticides on Environment. In: Hakeem K., Akhtar M., Abdullah S. (eds) Plant, Soil and Microbes, pp. 253-269.

Mahmood, I., Imadi, S. R., Shazadi, K., Gul, A., & Hakeem, K. R. (2016). Effects of pesticides on environment. In Plant, soil and microbes, pp. 253-269.

Mghirbi O., Ellefi K., Le Grusse P., Mandart E., Fabre J., Ayadi H., Bord J.P. (2015). Assessing plant protection practices using pressure indicator and toxicity risk indicators: analysis of the relationship between these indicators for improved risk management, application in viticulture. Environmental Science and Pollution Research, vol. 22, pp. 8058-8074.

Mghirbi O. (2016). Résilience des exploitations agricoles face au changement des pratiques phytosanitaires: Conception d'outils de gestion des risques liés aux pesticides – Cas du bassin versant de l'étang de l'Or en France. PhD dissertation, Université Paul Valéry Montpellier 3.

Mghirbi O., Le Grusse P., Fabre J., Mandart E., Bord J.-P. (2017). OptiPhy, a technical-economic optimisation model for improving the management of plant protection practices in agriculture: a decision-support tool for controlling the toxicity risks related to pesticides. Environmental Science and Pollution Research, vol. 24, pp. 6951–6972.

Mghirbi O., Bord J-P, Le Grusse P, Mandart E, Fabre J (2018) Mapping for the management of diffuse pollution risks related to agricultural plant protection practices: case of the Etang de l'Or catchment area in France. Environmental Science and Pollution Research, vol. 25, pp.14117–14137.

Ossard A., Galan M. B., Boizard H., Leclercq C., Lemoine C. (2009). Évaluation des impacts environnementaux des pratiques agricoles à l'échelle de la parcelle et de l'exploitation en vue de l'élaboration d'un plan d'actions: une méthode de diagnostic spatialisé fondée sur des indicateurs, le DAE-G. Ingénieries, (59-60), pp. 71-87.

Samuel O., Dion S., ST-Laurent L., April M.H. (2012). IRPeQ, Indicateur de risque des Pesticides du Québec. 2 ed. Québec: Ministère de l'Agriculture, des Pêcheries et de l'Alimentation / Ministère du Développement durable, de l'Environnement et des Parcs / Institut national de santé publique du Québec.

Sharma A., Kumar V., Shahzad B., Tanveer M., Sidhu G. P. S., Handa N., ... & Thukral A. K. (2019). Worldwide pesticide usage and its impacts on ecosystem. SN Applied Sciences, 1(11), pp. 1-16.