Assessing human health risks from pesticide use in conventional and innovative cropping systems with the BROWSE model

Sabine-Karen LAMMOGLIA[1], Marc C. KENNEDY[2], Enrique BARRIUSO[1], Lionel ALLETTO[3], Eric JUSTES[4], Nicolas MUNIER-JOLAIN[5], Laure MAMY[1,*]

[1] INRA (French National Institute for Agricultural Research) - UMR ECOSYS, 78850 Thiverval-Grignon, France
[2] Fera Science Ltd. (FERA), Sand Hutton, York, YO41 1LZ, United Kingdom
[3] Université de Toulouse - École d'ingénieurs de Purpan, UMR AGIR, 75 voie du TOEC, 31076 Toulouse, France
[4] INRA - UMR AGIR, Auzeville, 31326 Castanet-Tolosan, France
[5] INRA - UMR Agroécologie, 17 rue Sully, 21065 Dijon, France

* Corresponding author: laure.mamy@inra.fr

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Introduction

- Reducing the risks and impacts of pesticide use on human health and on the environment is one of the objectives of the European Commission Directive 2009/128/EC in the quest for a sustainable agriculture
- This Directive promotes the introduction of innovative cropping systems, e.g. relying on integrated pest management
- Risk assessment for environment and human health of the overall pesticide use in these innovative systems is required before their introduction

Objectives

To assess and to compare, with the BROWSE model:
(1) The human exposure to pesticides used in conventional and innovative cropping systems designed to reduce pesticide use
(2) The associated risks for human health

Materials and methods

BROWSE model

- **BROWSE is a mechanistic model predicting human exposure to pesticides and assessing the corresponding risk for human health** (Fig. 1)
  - Integrates many exposure routes, short and long term exposures
  - Leads to more realistic predictions than existing models

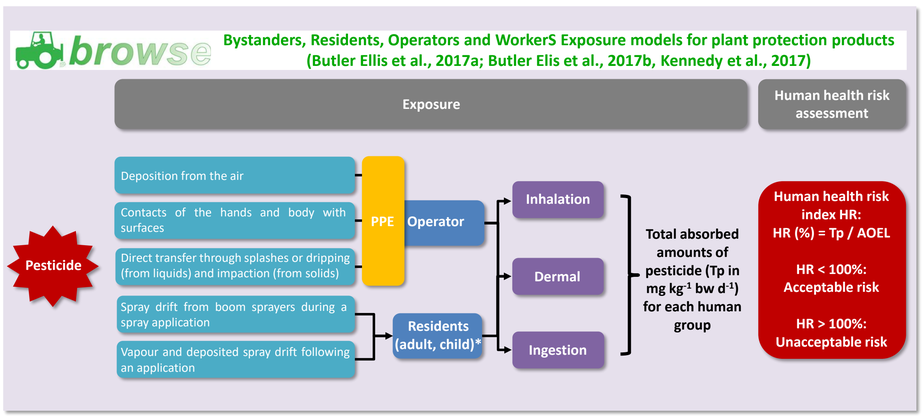


Fig. 1. Simplified description of the BROWSE model. *Residents group includes both residents and bystanders. PPE: Personal Protective Equipment, AOEL: Acceptable Operator Exposure Level (mg kg^{-1} bw d^{-1}), Ingestion: hand-to-mouth contact

- BROWSE considers only single pesticide usage per run
  - **To assess the overall pesticides risk for one system, all pesticides HR for the system will be presented as boxplots**
  - It allows displaying the HR distribution and identification of pesticides that may lead to unacceptable risks

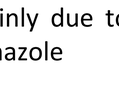
Cropping systems

- **12 cropping systems were tested in three French experimental sites (Table 1)**
  - Cover a wide diversity of crops, cropping practices and pesticide use

3 conventional systems
9 innovative systems

116 plant protection products containing 89 different pesticides

Table 1. Description of the cropping systems and corresponding number of pesticide applications. Cover crops are written in italic. IWM: Integrated weed management (Lammoglia et al., 2017)

Experimental site	Cropping systems	Crops sequence	Number of pesticide applications
Lamothe Irrigated maize monoculture systems, Northern France (2011-2014) © L. Alletto (INP)	Conventional (MM_{Conv})	Maize – Maize – Maize – Maize	27
	Low input maize monoculture (MM_{LI})	Maize – *Hybrid ray grass + Red clover* – Maize – *Hybrid ray grass + Red clover* – Maize – *Hybrid ray grass + Egyptian clover* – Maize	16
	Conservation tillage maize monoculture (MM_{CT})	Maize – *Vetch + Phacelia + Oat* – Maize – *Vetch + Phacelia + Oat* – Maize – Faba bean + Sorghum – Maize	24
	Integrated maize rotation (MSW)	*Purple vetch + Phacelia* – Maize – Oat – Soybean – *Mustard* – Winter wheat	16
Dijon-Epoisses Cereals systems, Southern France (2003-2013)  © P. Farcy (INRA)	Conventional (S1)	Winter barley – Oilseed rape – Winter wheat – Winter barley – Oilseed rape – Winter wheat – Winter barley – Oilseed rape – Winter wheat – Winter barley – Oilseed rape	106
	IWM reduced tillage (S2)	Oilseed rape – Winter wheat – Spring barley – Sorghum – Faba bean – *Mustard* – Triticale – Oilseed rape – Winter wheat – *Oat + Vetch – Phacelia* – Spring barley – Oat – Soybean – Winter wheat	69
	IWM without mechanical weeding (S3)	Mustard – Winter wheat – Oilseed rape – Winter wheat – Triticale – Maize – Faba bean – Winter wheat – Spring barley – Oilseed rape – Winter wheat – Soybean – Triticale	71
	IWM with mechanical weeding (S4)	Winter wheat – Sugar beet – Triticale – Faba bean – Winter wheat – Oilseed rape – Winter wheat – Maize – Winter wheat – Spring barley – Triticale + Pea	63
	IWM no herbicide (S5)	Winter barley – Faba bean – Triticale – Oilseed rape – Winter wheat – Sorghum – Faba bean – Winter wheat – Alfalfa – Maize – Alfalfa – Winter wheat	25
Auzeville Diversified rainfed systems (2011-2015)  © E. Justes (INRA)	Conventional (Conv)	Durum wheat – Sunflower – Durum wheat – Sunflower	24
	Low input with cover crops (LI)	*Phacelia + Purple vetch* – Sorghum – Sunflower + *Alfalfa + Egyptian clover + Red clover* – Durum wheat – *Mustard + Vetch* – Sorghum	17
	Very low input with intercrops and cover crops (VLI)	Triticale + Faba bean – *Mustard + Purple vetch* – Durum wheat + Pea – *Vetch + Oat* – Sunflower + Soybean – Durum wheat + Pea	15

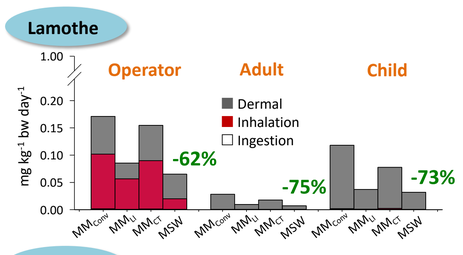
Parameterization

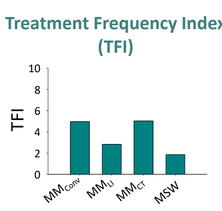
- **Plant protection product (PPP)**
  Formulation, Concentration
  - E-Phy database
- **Pesticide**
  MW, Sw, Pvap
  $DT50_{Vegetation}$, Kom
  AOEL, dermal, oral and inhalation absorption coefficients
  - PPDB & Agritox databases
- **Management techniques**
  Dose and date of application of PPP
  Crop height
  - Field data
- **Operator PPE**
  - Most protective ones
- **Resident characteristics**
  Body weight
  Skin to mouth transfer factor…
  - Default values
- **Machinery setup**
  - Default values

Results and discussion

Human exposure to pesticides

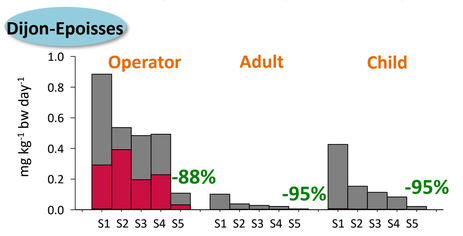
Lamothe

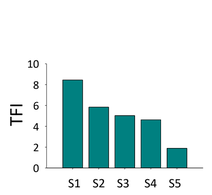




Irrigated maize monoculture systems, Southern France
- **Best system:** "Integrated maize rotation" (MSW)

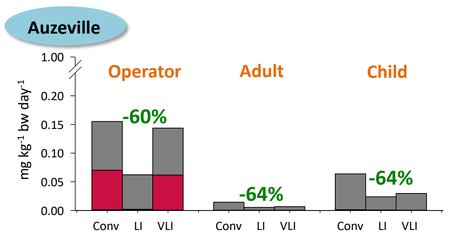
Dijon-Epoisses

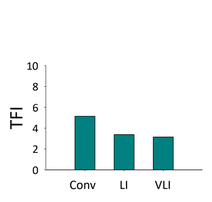




Cereals systems, Northern France
- **Best system:** "No herbicide" (S5)

Auzeville





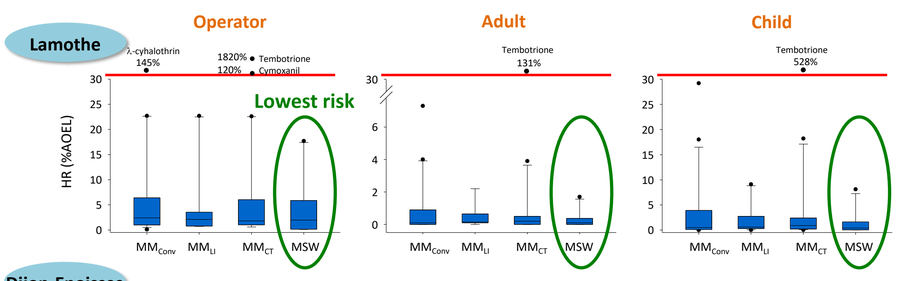
Diversified rainfed systems
- **Best system:** "Low input" (LI)
- Unexpected high absorbed amounts of pesticides in VLI compared to LI are mainly due to high doses of prothioconazole

Fig. 2. Cumulative amounts of pesticides absorbed via dermal, inhalation and ingestion routes in the short term (similar trends were observed in the long term but with lower absorbed amounts). % in green: Decrease in exposure compared to conventional system. TFI: Number of registered doses of pesticides used per hectare for one cropping season (Lammoglia et al., 2017)

- **In any case, pesticide exposure Operator > Child > Adult**
- **Dermal absorption is the predominant route of exposure**
- **In general, the exposure is correlated to the Treatment Frequency Index (TFI)**
- High human exposure to pesticides should not necessarily represent a risk for human health as it depends on the toxicity of pesticides ➡ HR

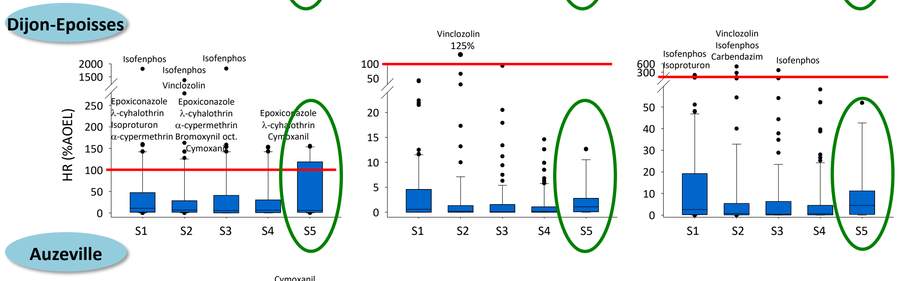
Human health risk assessment

Lamothe



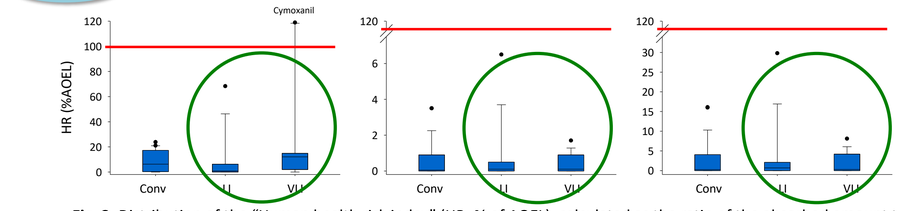
Irrigated maize monoculture systems, Southern France
- **Best system:** "Integrated maize rotation" (MSW)
- Reducing the use of tembotrione (high toxicity) could help make risks of MM_{CT} system acceptable

Dijon-Epoisses



Cereals systems, Northern France
- **Best system:** "No herbicide" (S5)
- Vinclozolin and isofenphos were withdrawn since their application in the experiment

Auzeville



Diversified rainfed systems
- **Best systems:** "Low input" (LI) and "Very low input" (VLI), if the use of cymoxanil is reduced in the latter

Fig. 3. Distribution of the "Human health risk index" (HR, % of AOEL), calculated as the ratio of the absorbed amount to the AOEL, for each pesticide applied on the cropping systems of Lamothe, Dijon-Epoisses and Auzeville. Results are showed for short term exposure (similar trends were observed in the long term but with lower HR) (Lammoglia et al., 2017).

- **Innovative low input cropping systems, having low TFI, would reduce human health risks in comparison to the corresponding conventional systems**
- **Conservation tillage system would lead to unacceptable risks for human health because of a high number of pesticide applications, and especially of some herbicides**
- **Identification of pesticides leading to unacceptable risks will help to improve the systems**

Conclusion and perspectives

- **Assessment with the BROWSE model helped to identify cropping systems with decreased risks for human health and to propose improvements for redesigning systems**
- **Human exposure and human health risks are correlated to the TFI, confirming the relationship between the reduction of pesticide use and the reduction of risks**
- **Risks assessment for human health, based on the BROWSE model, represents a step forward in the estimation of the performances of cropping systems**

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