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Assessment of toxicity impacts of chemical protection of winter wheat in different tillage systems

Małgorzata Holka, Jerzy Bieńkowski
Department of Agricultural Production Systems, Institute for Agricultural and Forest Environment, Polish Academy of Sciences
Bukowska 19, 60-809 Poznań, Poland, malgorzata.holka@gmail.com

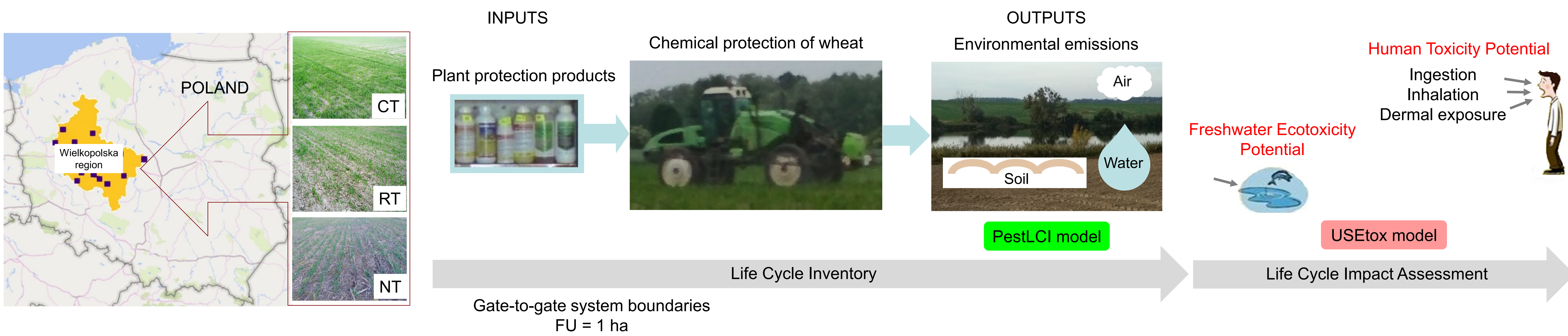
Introduction

In recent years, due to increasing costs of agricultural production and the need to protect the environment, much attention of researchers and farmers has been focused on non-inversion tillage systems, including reduced tillage and no-tillage (also referred to as direct sowing). However, the use of non-inversion tillage systems may lead to an increase in the occurrence of diseases and pests. This is related to more intensive plant protection. Higher use of plant protection products is associated with more harmful effects on the environment. Moreover, this impact may vary dependent on the potential toxicity of active substances of plant protection products.

The aim of this study was to assess the potential toxicity impacts of chemical protection of winter wheat (*Triticum aestivum* L.) in different tillage systems.

Material and methods

The material for the analyses was data on chemical protection of winter wheat in three soil tillage systems: conventional tillage (CT), reduced tillage (RT) and no-tillage (NT). The study was conducted in 2015–2017 on 15 agricultural farms located in the Wielkopolska region (Poland). The potential impact of chemical plant protection on the environment and human health was examined using the life cycle assessment (LCA) methodology. The system boundaries were set at the field gate, so the production of plant protection products, manufacture and use of machinery, fuel production and combustion were outside these boundaries. The functional unit (FU) was 1 ha of cultivated area. Routes and amounts of environmental emissions were determined with calibrated PestLCI 2.08 model. Within the ecotoxicity category, the freshwater ecotoxicity potential (FETP) impact was calculated, which determines an estimated fraction of species potentially affected by environmental stress and is expressed in the comparative toxic unit for ecotoxicity (CTUe). In the case of the human toxicity impact category, the human toxicity potential (HTP) impact was considered. The HTP impact includes two components: the human toxicity potential for carcinogenic effects (HTP cancer) and the human toxicity potential for non-carcinogenic effects (HTP non-cancer). Human toxicity impacts determine an estimated increase in morbidity in the total human population per unit mass of a contaminant (number of disease cases per 1 kg of emitted substance) and are measured in comparative toxic unit for human health (CTUh). The USEtox 2.02 characterization model was used to characterize human toxicity and ecotoxicity impacts in life cycle assessment of plant protection.



Results

Table 1. Inventory data of a set of the main inputs and outputs in relation to 1 ha of chemical protection of winter wheat in three tillage systems (mean for 2015–2017)

Specification	Unit	CT	RT	NT
INPUTS				
Consumption of active substances, of which:	kg/ha	2.03	2.16	1.43
- herbicides	kg/ha	1.31	0.91	0.52
- fungicides	kg/ha	0.64	0.62	0.57
- insecticides	kg/ha	0.05	0.10	0.04
- plant growth regulators	kg/ha	0.04	0.54	0.30
OUTPUTS				
Environmental emissions, of which:	kg/ha	0.913	0.908	0.602
- emissions to air	kg/ha	0.140	0.039	0.105
- emissions to groundwater	kg/ha	0.004	0.005	0.025
- mass of the substances available for leaching and surface runoff	kg/ha	0.769	0.864	0.472

Table 2. Values of the freshwater ecotoxicity potential and human toxicity potential impacts per ha, resulted of chemical protection of winter wheat in the analysed tillage systems

Impact category indicator	Unit	CT	RT	NT
FETP	CTUe ha^{-1}	2512.4 a	2264.6 a	10365.7 b
HTP, of which:	CTUh ha^{-1}	$3.51 \cdot 10^{-6}$ ns	$2.58 \cdot 10^{-6}$ ns	$8.51 \cdot 10^{-6}$ ns
- HTP cancer	CTUh ha^{-1}	$2.05 \cdot 10^{-6}$ ns	$1.40 \cdot 10^{-6}$ ns	$3.99 \cdot 10^{-6}$ ns
- HTP non-cancer	CTUh ha^{-1}	$1.45 \cdot 10^{-6}$ ns	$1.18 \cdot 10^{-6}$ ns	$4.52 \cdot 10^{-6}$ ns

Note. Within a row the means for individual systems marked by different letters are significantly different ($p < 0.05$); ns – no significantly different.

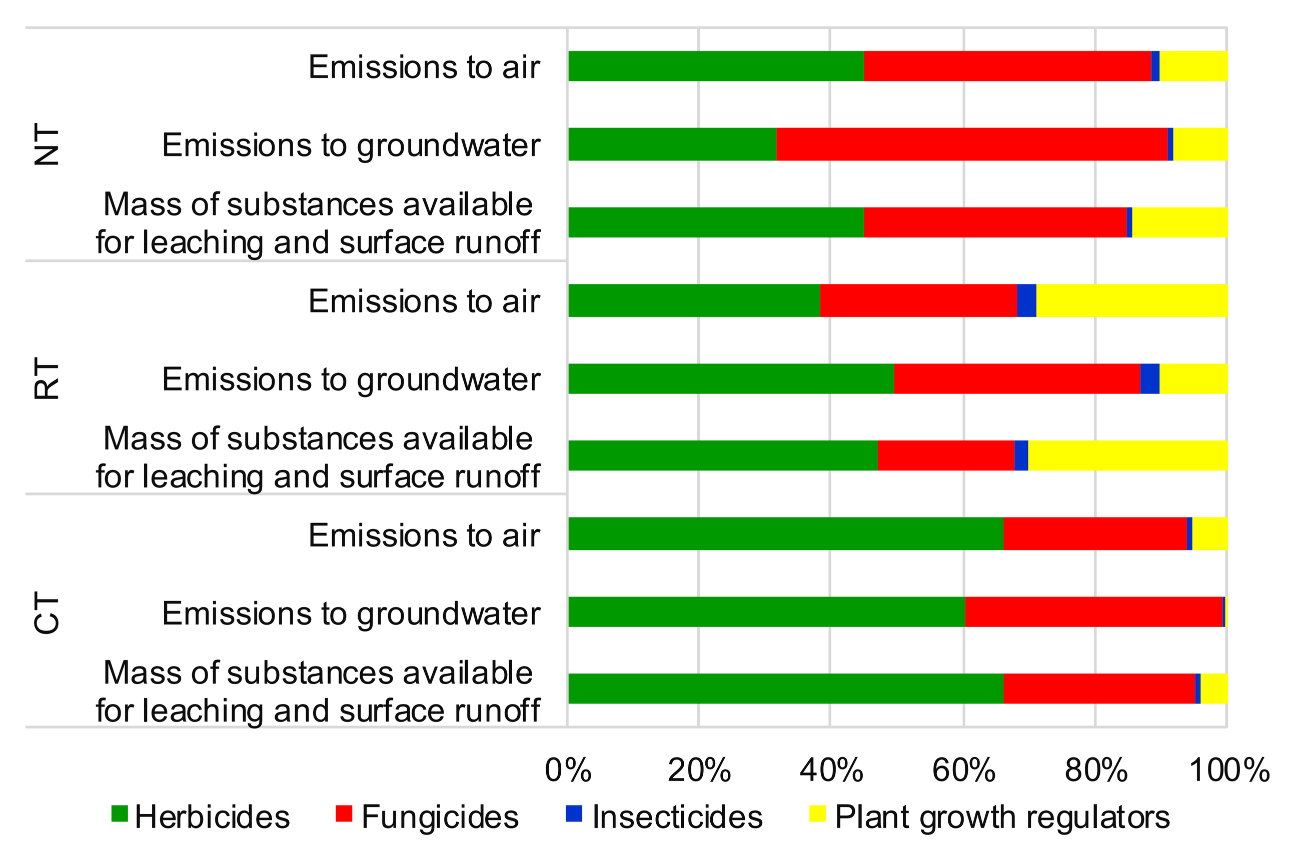


Fig. 1. Percentage share of environmental emissions of active substances by type of plant protection products applied in wheat in different tillage systems

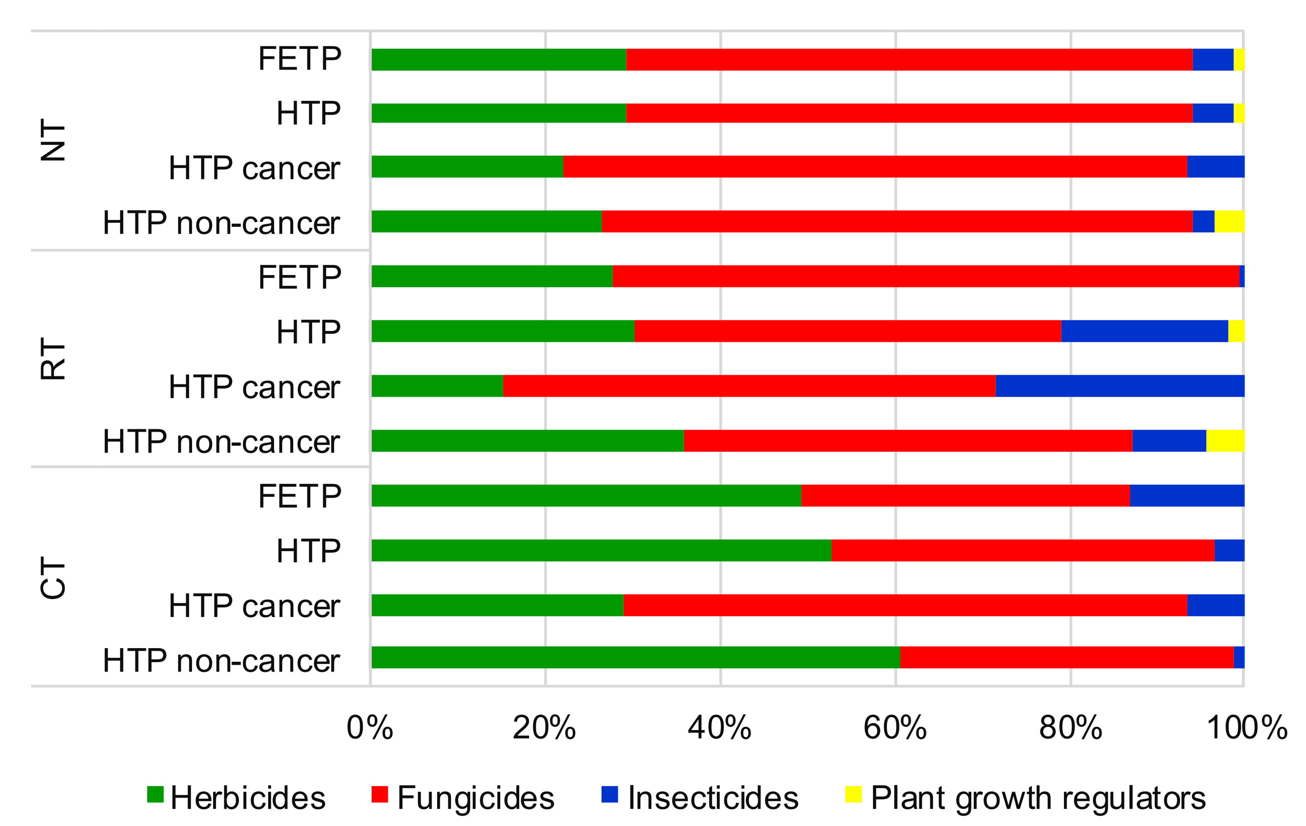


Fig. 2. Percentage share of types of plant protection products in formation of the values of toxicity potential impacts of chemical protection of wheat in three tillage systems

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