A Spatiotemporally Explicit Modeling Approach for Exposure and Risk Assessment of Off-field Soil Organisms

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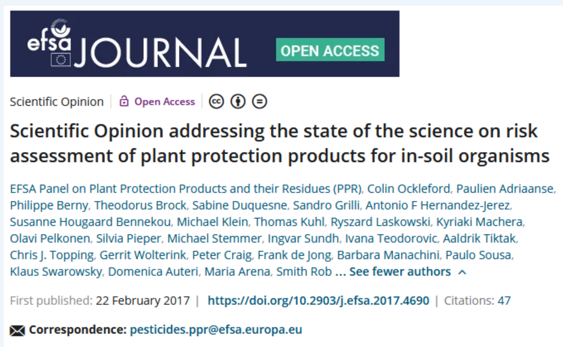
Introduction

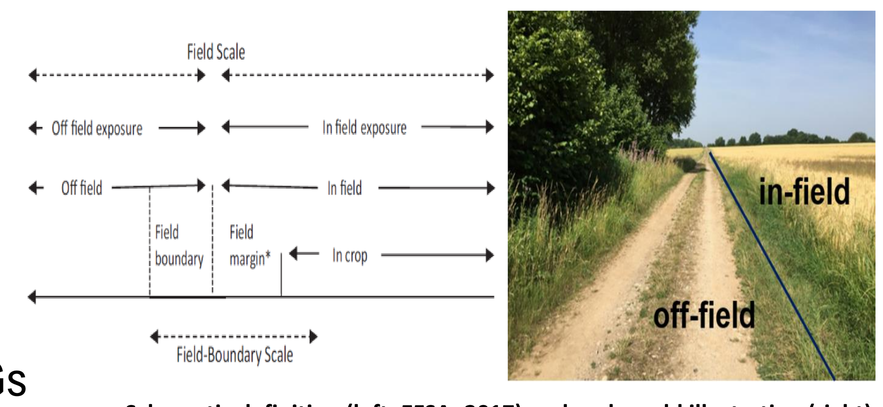
- The EU authorization process of Plant Protection Products (PPPs) includes comprehensive regulatory risk assessment (RA) for non-target species, including **soil organisms**
- The European Food Safety Authority (EFSA) released a scientific opinion "*addressing the state of the science on risk assessment of plant protection products for in-soil organisms*" in which **spray-drift and runoff** are identified as the most relevant potential exposure routes of off-field soil organisms (EFSA, 2017)
- EFSA outlined a first approach that assumes **independent conservative estimates** on local spray-drift and runoff entries and adds them at a **single location.** 100% of individuals in a population occurring 'off-field' in a cultivated landscape receive 'worst-case' exposures. This doesn't consider real-world variability of exposure in **space and time** which are essential when assessing effects and risk according to **Specific Protection Goals (SPGs)**
- The conservative nature of the approach, and the **necessity for model and scenario development**, is indicated in EFSA (2017)



Goals

1. Develop a **model approach** to appropriately combine off-field soil exposure due to runoff & drift
2. Develop **scenarios** based on real-world conditions
3. Develop a **case study** to gain first insights into off-field soil exposure and risk

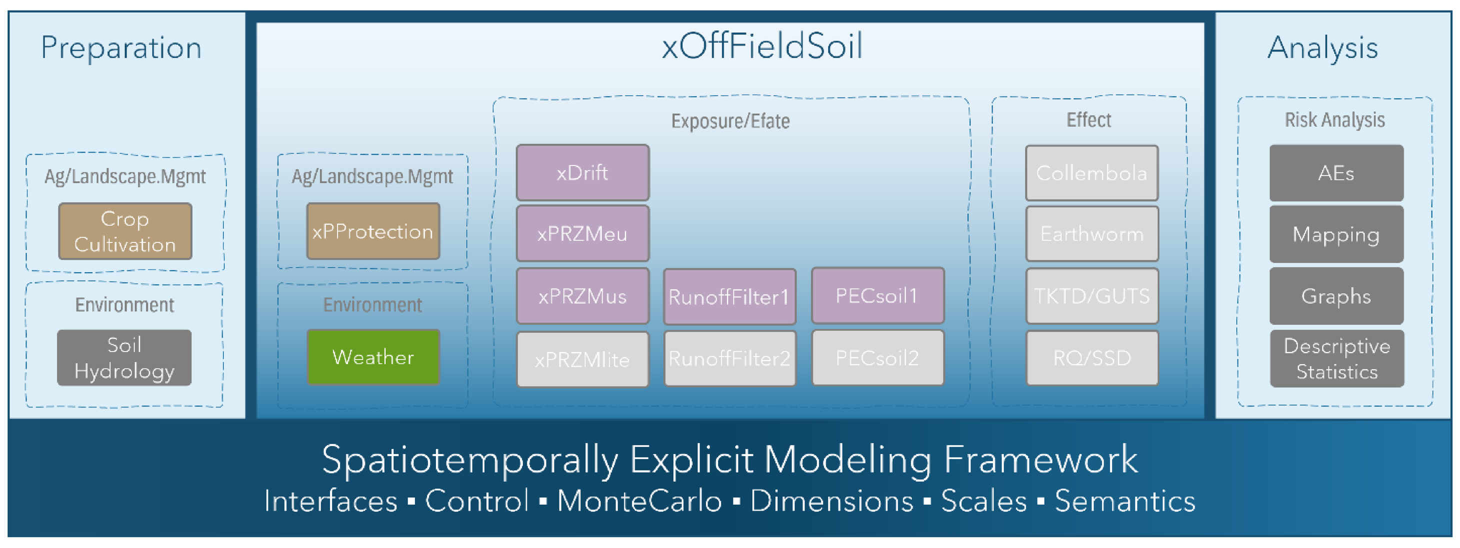
- Include the analysis of effective **risk mitigating** options
- Support the **development of Assessment Endpoints,** e.g., spatiotemporal percentiles of off-field exposure and effects addressing SPGs
- **Open source development**



Schematic definition (left, EFSA, 2017) and real-world illustration (right) of off-field and in-field areas in cultivated landscapes

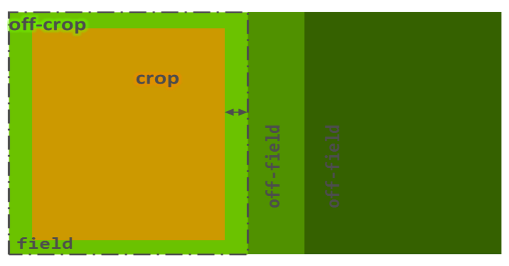
xOffFieldSoil Model

- **Modular landscape model**, **spatiotemporally explicit**, using Monte Carlo
- Composed of **components** that provide major model functionality (e.g., spray-drift or runoff exposure calculation), by wrapping existing models (e.g., PRZM) or by developing new ones (e.g., "RunoffFilter1")
- **Scales** are explicitly considered in the representation of spatial and temporal variability
- Real-world variabilities result in a **spatiotemporal pattern of exposure and effects**
- **Assessment Endpoints** can be built that directly **address SPGs** for off-field soil organisms. Exposure endpoints can be used together with standard ecotoxicological data, in a risk quotient approach



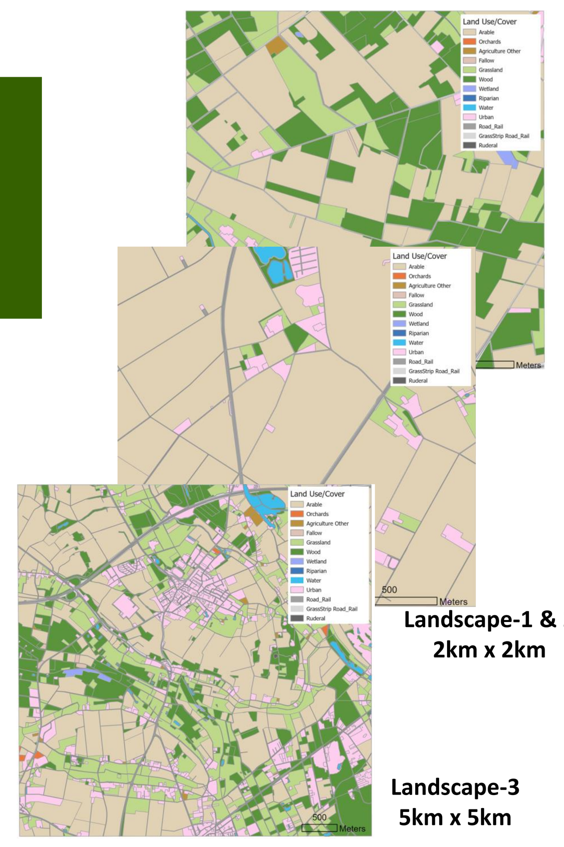
Scenarios

- Simple **schematic scenarios** were developed addressing the edge-of-field scale
- Besides their use in RA, they are important to understand and verify the complex spatiotemporally explicit system behavior



Schematic 100m x 100m field

- **Real-world landscape scenarios** address **natural variability** of land use composition, landscape structure, environmental and agricultural conditions and their dynamics
- Besides their use in RA, real-world landscape scenarios allow the analyse the effectiveness and efficiency of **risk mitigation options** for individual PPP use (e.g., in-crop buffer) or for generic risk management (e.g., runoff filter strips, landscape design)
- Three example landscape scenarios were developed located in North Rhein Westfalia (Germany)



Landscape-1 & 2
2km x 2km

Landscape-3
5km x 5km

Case Study Chemicals

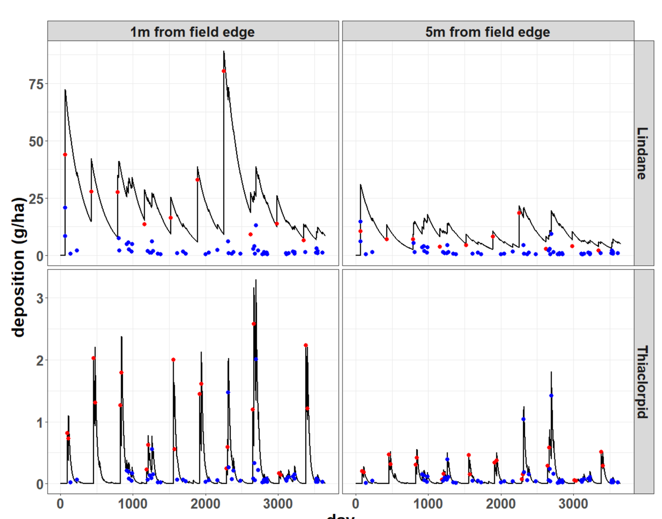
Experiments were conducted using two substances of contrasting environmental fate properties

Aspect	Lindane	Thiacloprid
Chemical		
Aerobic soil half-life (DT_{50})	148 days	18 days
Organic carbon-water partition co-efficient (Koc)	477 mL/g	615 mL/g
Freundlich exponent 1/n	0.957	0.88
# of applications & rate	1 application, 2400g a.s./ha	2 applications, 72g a.s./ha
Application time window	March 1-7 [Jun 1-7, Sep 1-7]	April 1-7, April 21-28
Scenario		
Landscape	Schematic, Landscape-1, Landscape-2, Landscape-3	
Crop	Cereals	
Weather	Agri4Cast (MARS) Grid ID 97100 (https://agri4cast.jrc.ec.europa.eu)	
Wind direction	schematic scenario: permanent worst-case (towards off-field) [variable, uniform distribution] Landscape-1/-2/-3 scenarios: variable (uniform distribution)	
Spray drift exposure	Component: xDrift [no drift]	
Drift reduction	0 [0.5]	
Runoff exposure (FOCUS R1 soil params)	Component: Pesticide Root Zone Model (PRZM) [no runoff], Landscape-1/-2/-3: local slope derived from elevation data (EU-DEM, https://www.eea.europa.eu)	
Runoff-filtering	based on FOCUS 2017 (SI/Section 0)	
In-crop buffer (icb)	0 m [5 m]	
In-field margin (ifm)	0 m [5 m, 10 m]	
Off-field Soil	dry bulk density of 1.5 kg/L, 5 cm soil depth	
Simulation period	1/1/2006-12/31/2015	
Number of MC runs	30	

Case study default settings with alternative settings in square brackets '[ ]'

Results

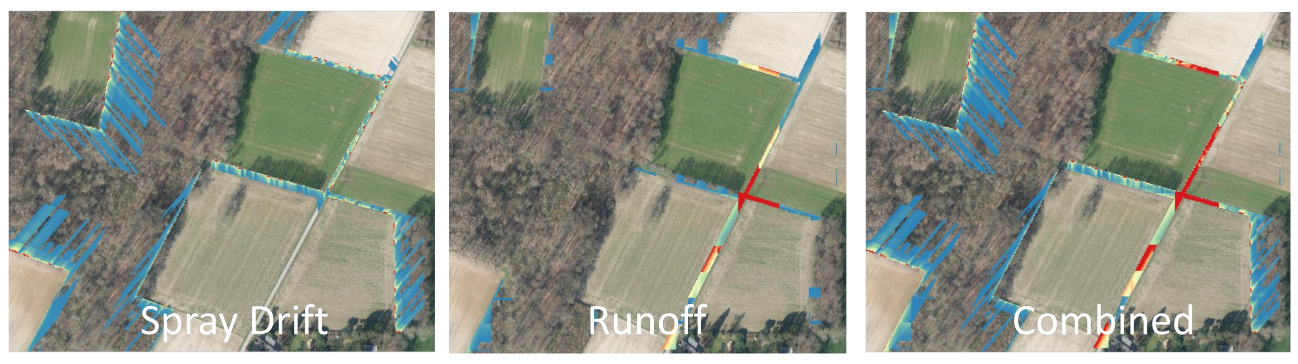
Temporal Variability



Red dots represent spray-drift depositions, blue dots runoff, respectively (before calculating PECsoil). The black line shows the combined deposition for the single grid cell over 10 years. Local exposure is increased by individual events and is subject to degradation.

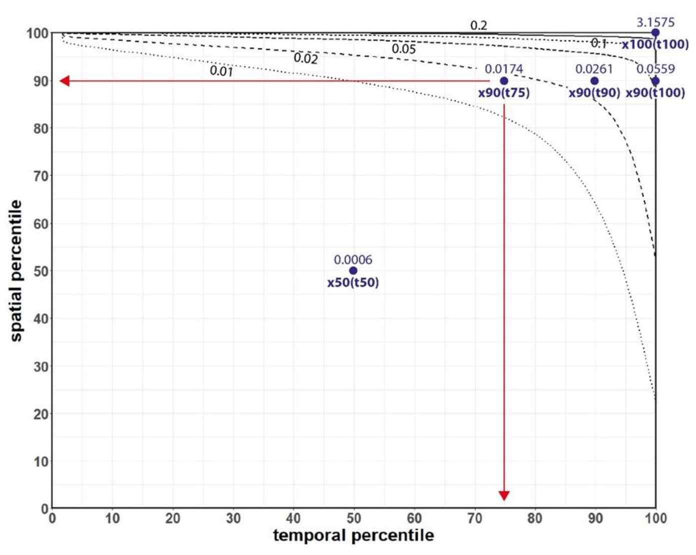
- 10-year temporal variability of depositions to a single local off-field grid cell (1m²)
- For persistent lindane, considerable carryover between exposure events occurs
- For fast-degrading thiacloprid, local deposition largely corresponds to the exposure event pattern

Spatial Variability



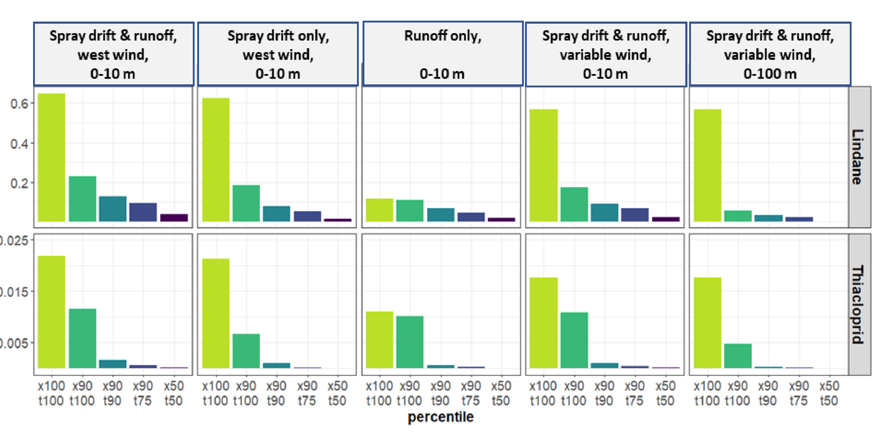
Local (1 m²) maximum PECsoil over a 10-year experiment using 30 Monte Carlo simulations (max PECsoil for illustration only)

- Spray-drift deposition varies along the field edge
- Off-field soil cells located down gradient from fields receive runoff
- Co-occurrence of exposure also depends on substance properties
- These largely random and independent processes result in local variability of exposure



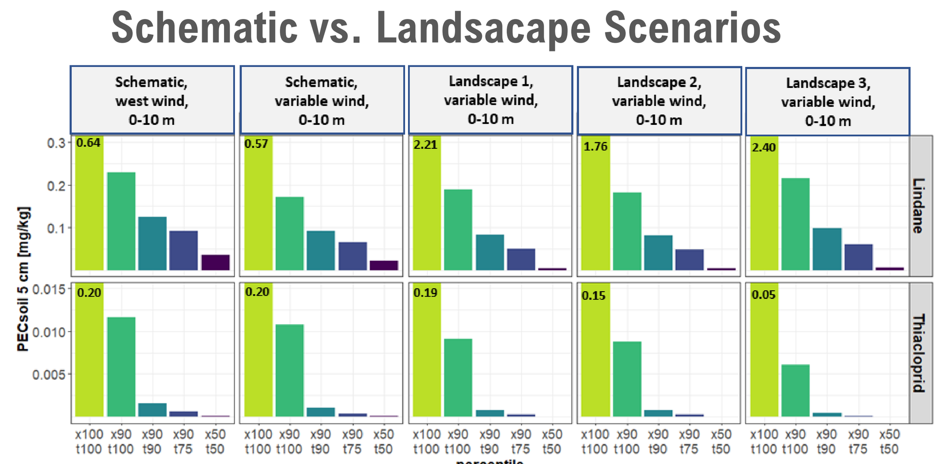
Contour plot of edge-of-field (0–10 m) off-field PECsoil (upper 5 cm [mg/kg]) for lindane using Landscape-1 scenario, variable wind, and a 5m in-crop buffer; abbreviations "x_t" stand for calculated PECsoil percentiles, for example, the red arrows at x90t75 = PECsoil(x90[t75]) that represent the 90th spatial percentile over the 75th temporal percentile PECsoil.

Schematic Scenario



- High variability of exposure in space and time
- Local maximum PECsoil over time and space represent singular extremes
- Spray-drift and runoff are not simply additive

Schematic vs. Landsacape Scenarios



- Local extremes are driven by runoff due to landscape morphology, typically runoff occurs on local 'hot-spots'
- 75% of the off-field PECsoil values in the upper spatiotemporal percentiles are lower for the real-world landscapes than for the schematic

Conclusions

- A spatiotemporally explicit approach is available to more realistically assess exposure and risk of off-field soil organisms due to spray-drift and runoff (https://github.com/xlandscape/xOffFieldSoilRisk)
- Raw output can transparently be aggregated to build meaningful endpoints for regulatory RA
- Risk mitigation options can be analyzed
- The modular architecture of xOffFieldSoil allows the flexible use of process components of different complexity (and reality) levels

The xOffFieldSoil model, scenarios and case study demonstrate the need and the value of a detailed foundation to derive more realistic RA and risk management for off-field soil organisms

Outlook

- **Exchange** with the regulatory scientific community
- **Application** of the approach to refine standard RA
- **Integration of effect models** (e.g., earth worm, collembola). Provide population level endpoints
- Development of further components, e.g., using US-PRZM, VFSMOD for run-off and PECsoil

EFSA Panel on Plant Protection Products and their Residues (EFSA PPR Panel). (2017). Scientific Opinion addressing the state of the science on risk assessment of plant protection products for in-soil organisms. EFSA Journal, 15(2), e04690. https://doi.org/10.2903/j.efsa.2017.4690

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Schad, T., Bub, S., Wang, M., Holmes, C.M., Kleinmann, J., Hammel, K., Ernst, G., Preuss, T.G., (2023). A spatiotemporally explicit modeling approach for more realistic exposure and risk assessment of off-field soil organisms. Integr Envir Assess & Manag ieam.4798. https://doi.org/10.1002/ieam.4798

xOffFieldSoil is available on GitHub, including code, scenarios and input files: https://github.com/xlandscape/xOffFieldSoilRisk

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