Modelling of exposure and effects at the medium edge-of-field and field scale (EL-ME)

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BACKGROUND & CONTEXT

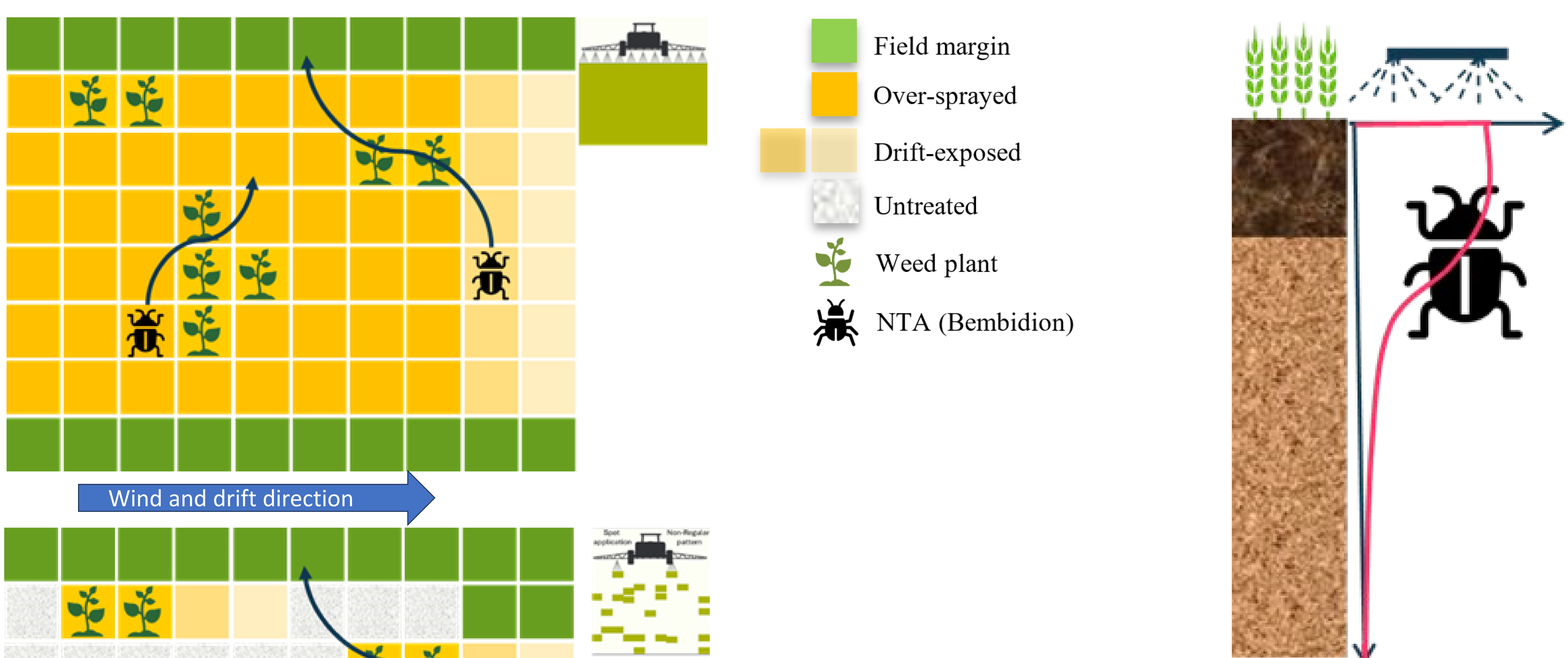
The medium scale in ELINK-2 is the scale of a single agricultural field and its immediate surroundings (field margins), thus covering the basic spatial unit for regulatory risk assessment of pesticides. The medium scale is specifically designed to assess the impact of exposure heterogeneity and ecological realism. The EL-ME modelling is fully aligned with the large-scale (EL-LA_Terra) and small-scale (EL-SA) modelling, applying the same basic parameterization regarding environmental (weather, soil, topography etc.) and agronomic (crop, pesticide treatments, crop rotation etc.) aspects.

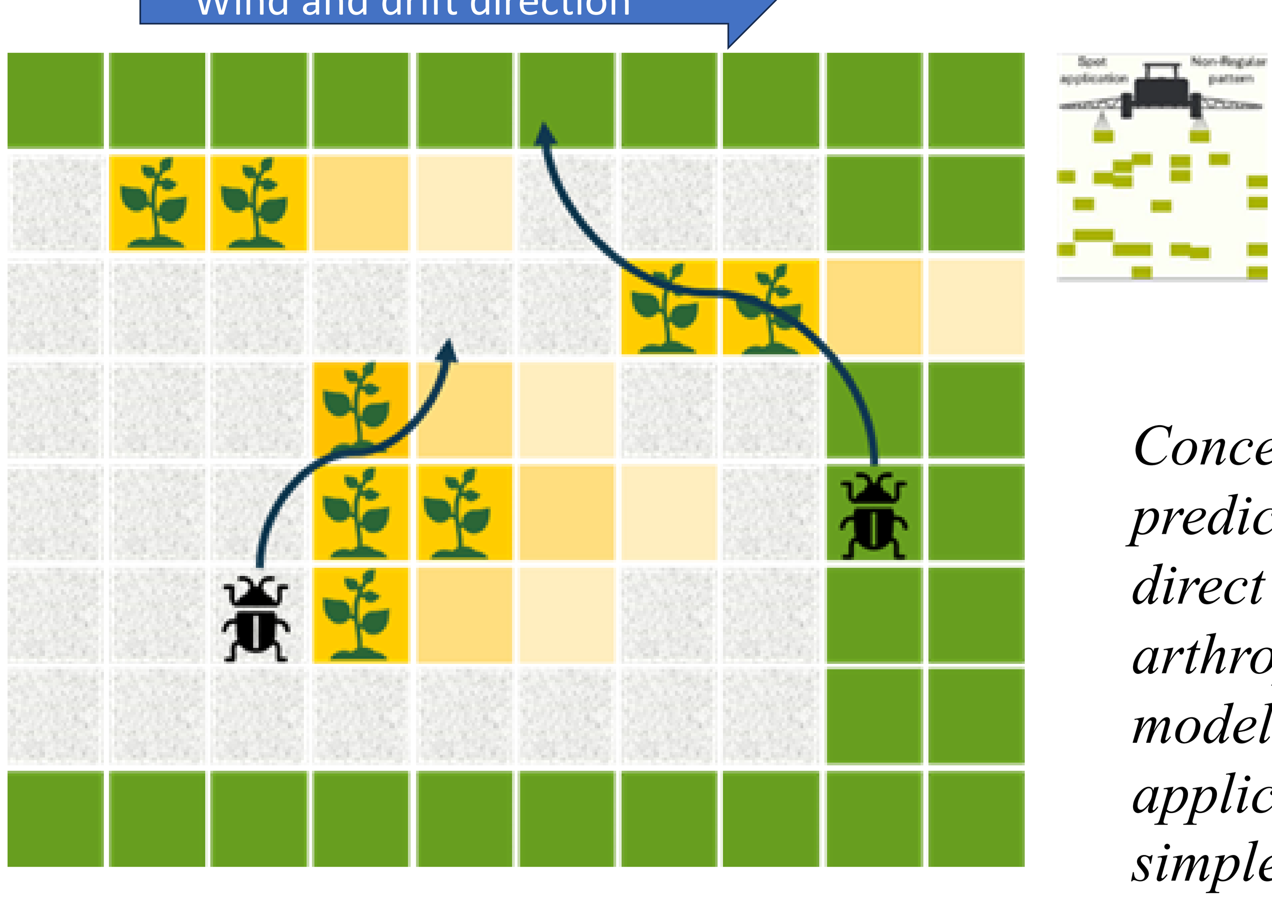
MATERIALS & METHODS

Standard regulatory exposure models are used to address the medium-scale exposure routes relevant for the investigated species, the ground beetle Bembidion: in-field soil deposition from direct application and spray drift, as well as off-field soil deposition from spray drift; in addition, temporal and spatial variation of substance concentrations in soil will be calculated. To predict the effects of applied pesticides, similar ecological models are used across spatial scales, with aligned parameterization.

One special aspect of the medium-scale approach of EL-ME is the explicit consideration of precision application: various patch application patterns based on real-world application maps are used to represent realistic in-field heterogeneity of exposure. Standard broadcast application is modelled to represent homogeneous baseline exposure for comparison.

Each exposure scenario will be combined with a simple (fixed effect threshold, ecology not considered) and with a more ecologically realistic (population modelling, ecology explicitly considered) effect modelling scenario. Currently, certain limitations of the Bembidion model (e.g., movement implementation, population regulation via density dependence) are addressed to ensure the model is fit for purposes of ELINK2.





Conceptual approach of EL-ME modelling: Exposure on and in soil predicted with standard regulatory exposure models considering direct overspray and spray drift (top right), effects on non-target arthropods and arthropod populations predicted with the Bembidion model in a broadcast application scenario (top left) and a precision application scenario (bottom left); both scenarios are modelled with simple and with complex ecology.

HIGHLIGHTS OF EL-ME

- Predicting the effects of pesticides on a non-target arthropod and arthropod population at field-scale
- Linking exposure and effect modelling in a common data framework across scales
- Heterogeneity of exposure based on realistic precision application patterns
- Impact of exposure heterogeneity and level of ecological detail on modelling results

The ELINK EL-ME approach provides a robust analysis of the feasibility and plausibility of combined ecological modelling at the highly relevant field scale, under heterogeneous exposure situations, and will reveal gaps and deficiencies that require further work.

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ELINK-2 Data
Exposure and Effect Models for Pesticide Risk Assessment Across Scales: Availability, Limitations, and Data Gaps

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INTRODUCTION

Linking spatially and temporally explicit exposure models with effect models is a key objective of the ELINK-2 project [1]. Achieving this requires a clear understanding of what existing exposure and effect models can – and cannot – deliver in terms of data quality, spatial and temporal resolution, environmental compartments, and represented processes. Addressing this need is a core focus of the ELINK-2 Data group.

Are existing models fit for this purpose?

METHODS

- Unify **definitions on terms across scales** for the ELINK-2 workshop: extent, resolution, scale, complexity.
- Gather existing and regulatory accepted models, categorise by extent, scale, resolution and complexity to identify **potential challenges for linking exposure and effect models**.
- Keep track of how **ELINK-2 case studies connect across scales** and ensure harmonisation regarding data selection, statistical methods and terminology.

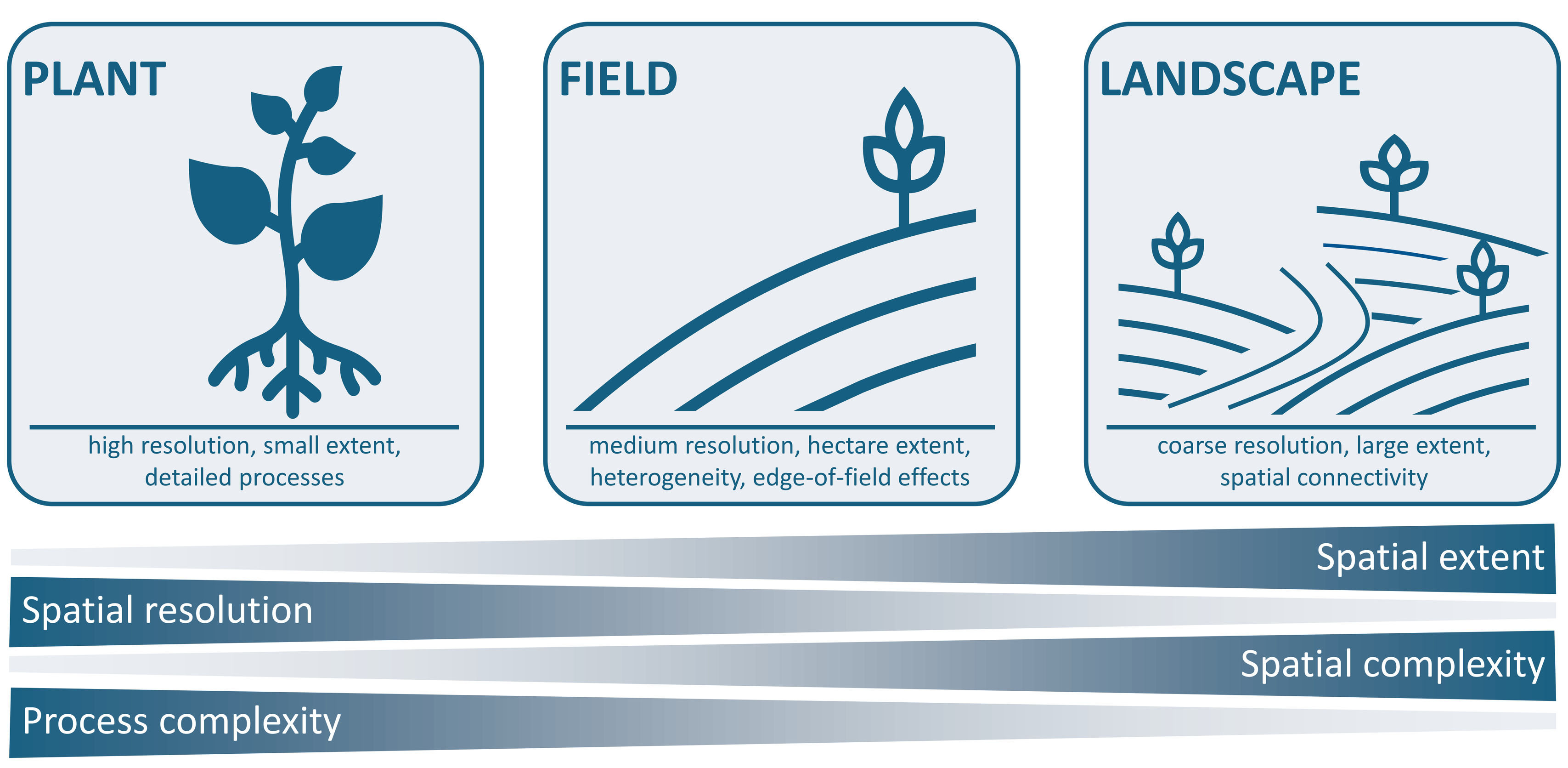

Figure 1: Spatial extent, spatial resolution, spatial complexity, and process complexity across plant, field, and landscape scale.

Figure 2: Key challenges associated with linking exposure and effect models, grouped into model availability, data gaps, and methodological limitations.

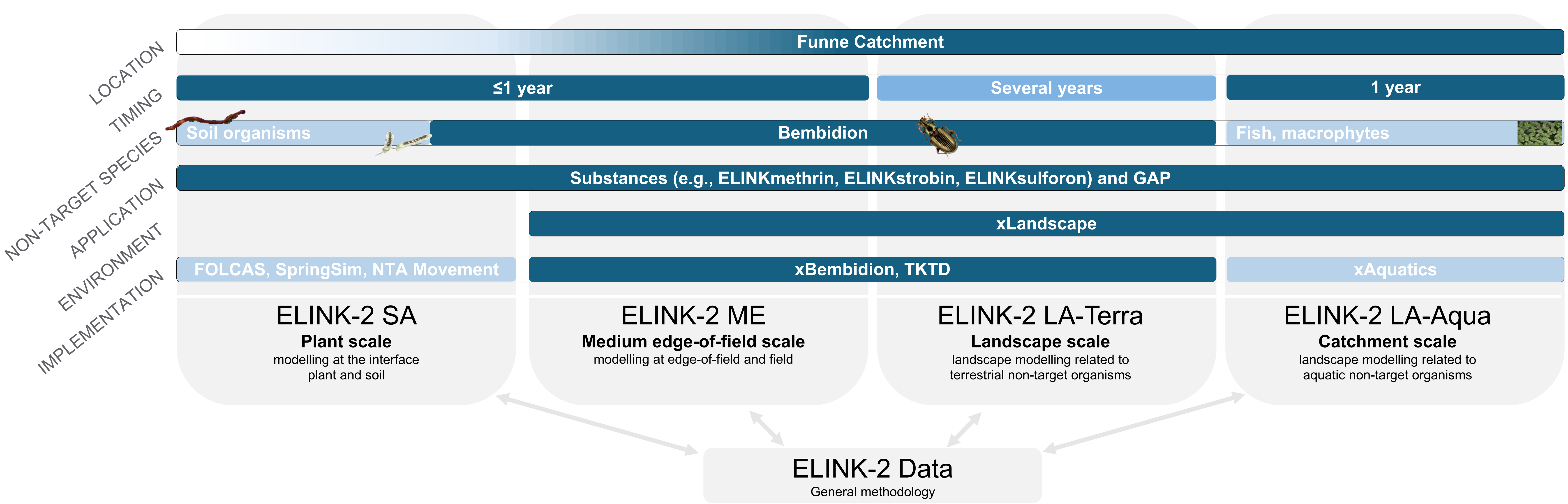

Figure 3: Overview of case studies and working groups of the ELINK-2 project spanning across the small scale plant (SA) – medium edge-of-field (ME) – landscape (LA). In the landscape domain, two case studies are established: Terra and Aqua.

RESULTS & OUTLOOK

- **Terminology for "scale" varies across disciplines.** The ELINK-2 data group will develop an agreed terminology across all subgroups, providing a shared basis for ELINK-2 and potentially supporting future risk-assessment terminology.
- **All regulatory models have limitations – combining models introduces additional challenges.** These include, e.g., data gaps for parameterisation and validation as complexity increases, mismatches between exposure and effects endpoints, and issues of model governance.
- **ELINK-2 will use case studies to evaluate the relevance and impact of these challenges.** This will help prioritise needs and resources for further development of risk-assessment models.

REFERENCES [1] SETAC endorsed ELINK-2 workshop. (2026). ELINK-2: Linking exposure and effect modelling. https://elink2.info

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Modelling aquatic exposure and effects on catchment scale

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ELINK-2

EL-LA-AQUA

BACKGROUND

Aquatic risk assessment of plant protection products within the European regulatory framework follows a tiered approach, where lower tiers apply conservative edge-of-field scenarios, while higher tiers allow refinement through increased ecological and spatial realism where scientifically justified. Landscape-scale modelling provides a means to explore this additional realism in higher-tier assessments.

Although a wide range of tools and models for PPP exposure and effects is available, their combined and consistent application across spatial scales has not yet been corroborated for regulatory risk assessment. In parallel, interest is increasing in approaches that support catchment-scale risk management and stewardship in line with wider EU water protection objectives.

METHODS

Model applications were implemented within the xLandscape framework [1], integrating established regulatory exposure models for spray drift, runoff, drainage, and aquatic fate with mechanistic effect models. Three illustrative case studies were defined for an agricultural mesoscale catchment (Funne catchment, Germany).

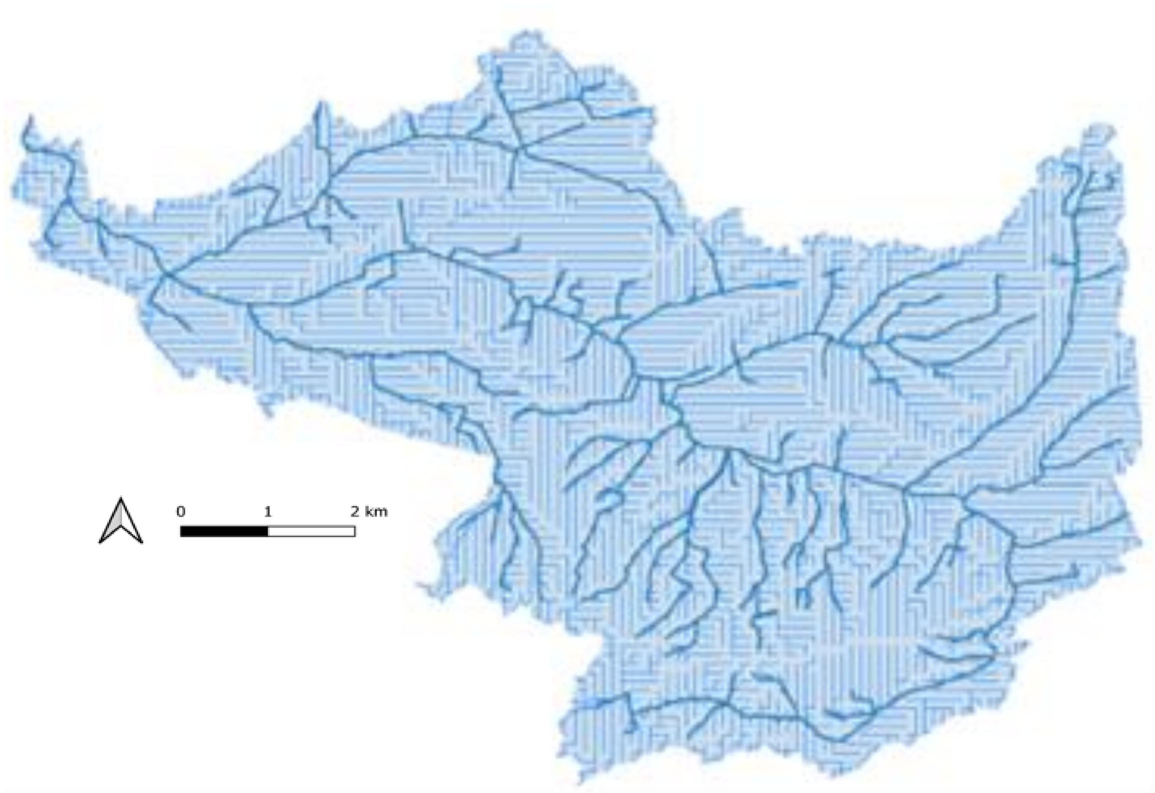
Ongoing work within ELINK-2 aims to provide a proof-of-concept for technical implementation and to explorer key challenges for future work, including mixture toxicity, data availability, validation strategies, transparent uncertainty communication, and pragmatic pathways for regulatory consideration.

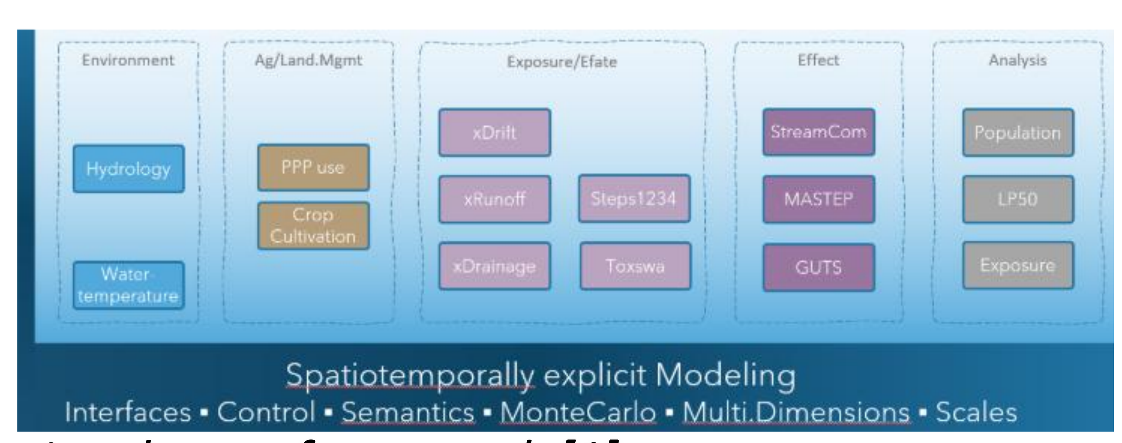
OBJECTIVES

This poster outlines the current status, key discussion topics, and planned work of the ELINK-2 Aquatic Landscape Working Group, based on exchanges during the inaugural workshop held in March 2026. The group aims to publish its first results in mid-2027.

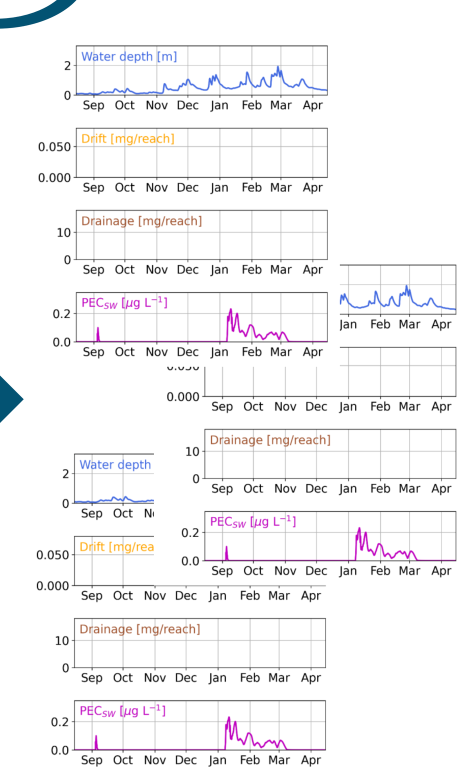
The workshop explored the applicability, transparency, and regulatory relevance of landscape-scale aquatic risk assessment using linked exposure and effect models, building on established regulatory concepts and tiered assessment principles.

- ❑ **Adress key aspects such as**
  - ❑Spatially explicit vs implicit
  - ❑Integration and Feedback
  - ❑Extrapolation / Aggregation
  - ❑Uncertainty
  - ❑Tools and data gaps



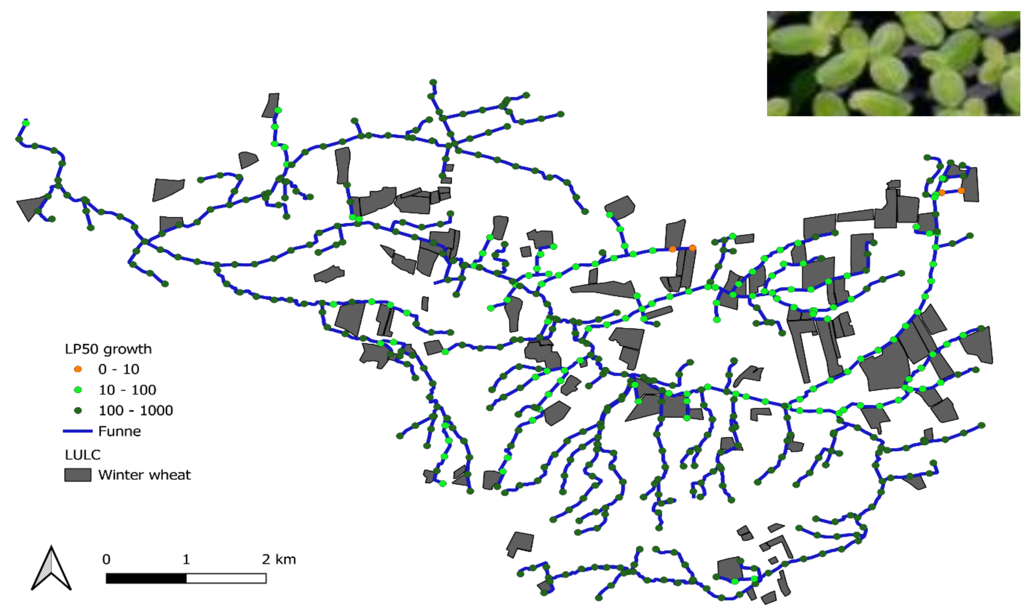


xLandscape framework [1].



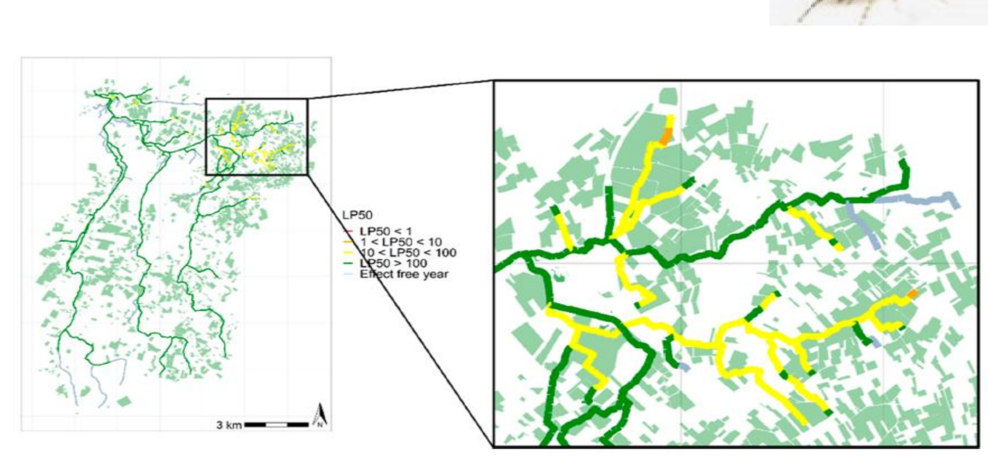
CASE STUDIES

(1) Macrophytes | *Lemna sp.* | Herbicide



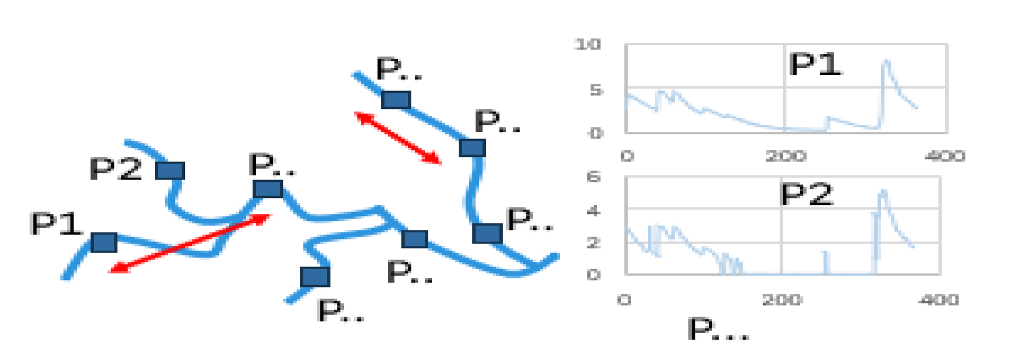
Macrophytes exposed to a herbicide using a toxicokinetic–toxicodynamic model for Lemna sp. [2].

(2) Invertebrates | *Asellus Aqu.* | Insecticide



Aquatic invertebrates exposed to an insecticide using an individual-based model for Asellus aquaticus [3].

(3) Fish | *Stickleback* | Fungicide



Fish exposed to a fungicide using an individual-based model incorporating habitat structure and mobility [4].

Exposure estimates were derived for one or more pathways using FOCUS models adapted to landscape scale (Rautmann drift curves, MACRO, PRZM) and newly developed tools (e.g., mechanistic drift modelling with DAD-Drift) integrated with xLandscape. Concentrations in water bodies and sediment were calculated using a simplified fate model based on STEPS1234 (one water layer, two sediment layer; hourly timestep).

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ELINK-2 Terrestrial Landscape: Modelling exposure and effects across terrestrial landscapes – a case study of a non-target arthropod

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Background and context

- The **Terrestrial Landscape Working Group** (EL-LA-Terra WG) forms part of the broader ELINK-2 framework (Figures 1 and 2).
- Its objective is to develop and apply **a spatially explicit modelling framework** that links pesticide exposure to effects on the non-target arthropod *Bembidion lampros* across terrestrial landscapes.
- The framework is designed to **align closely with current regulatory requirements** and assessment approaches.
- It will assess how spatial heterogeneity-including crop diversity and the proportion of semi-natural habitat-influences species abundance and population resilience under realistic agricultural scenarios.
- Ultimately, the WG aims to evaluate how in-field effects translate into effects at the landscape scale.

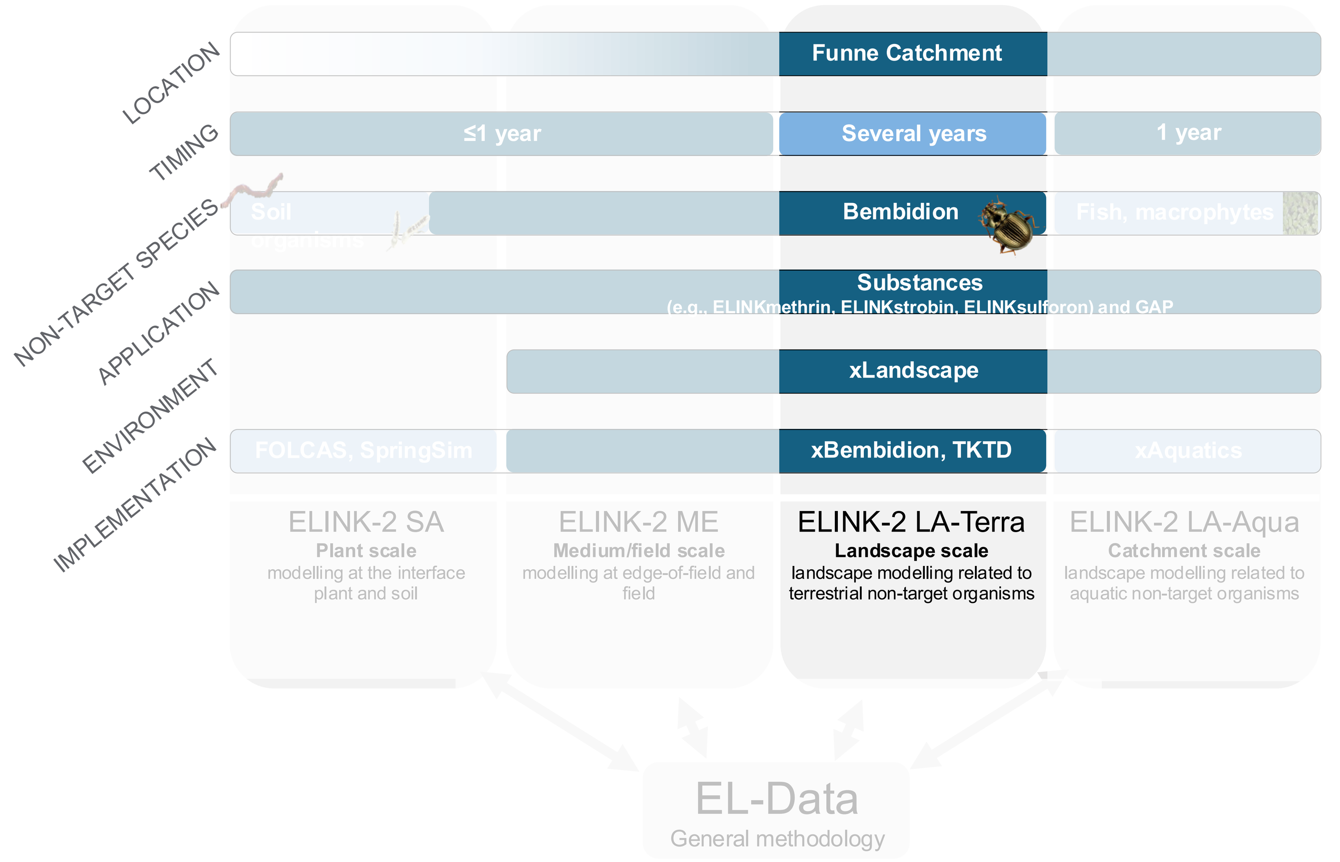

Figure 1. Overview of case studies and working groups of the ELINK-2 project spanning across the scales.

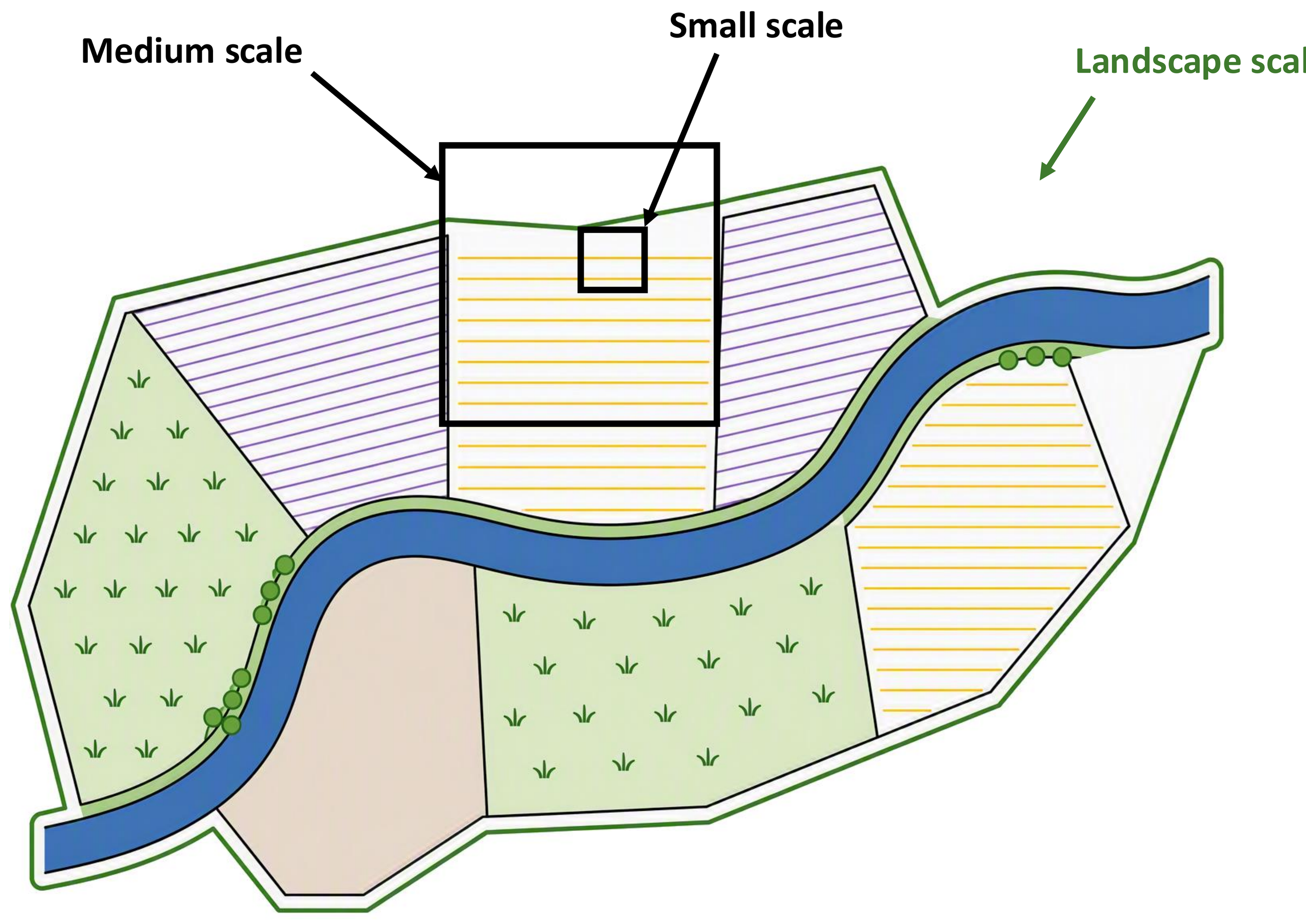

Figure 2. The landscape level integrates the small and medium scales across the three terrestrial subgroups.

Materials and Methods

- The work focuses on the univoltine carabid *Bembidion lampros* (Figure 3), a ground-dwelling predatory beetle widely distributed across European agricultural landscapes.
- An existing individual-based population model for *B. lampros* was selected for the working-group application.
- The model originates from the ALMaSS modelling framework [1] and is re-implemented within the open source xLandscape framework [2].
- Simulations are conducted across multiple scenarios designed to represent European agricultural landscapes (Figure 4).

Figure 3. The carabid *Bembidion lampros* is the model species in this case study.
Photo by David Nicholls.

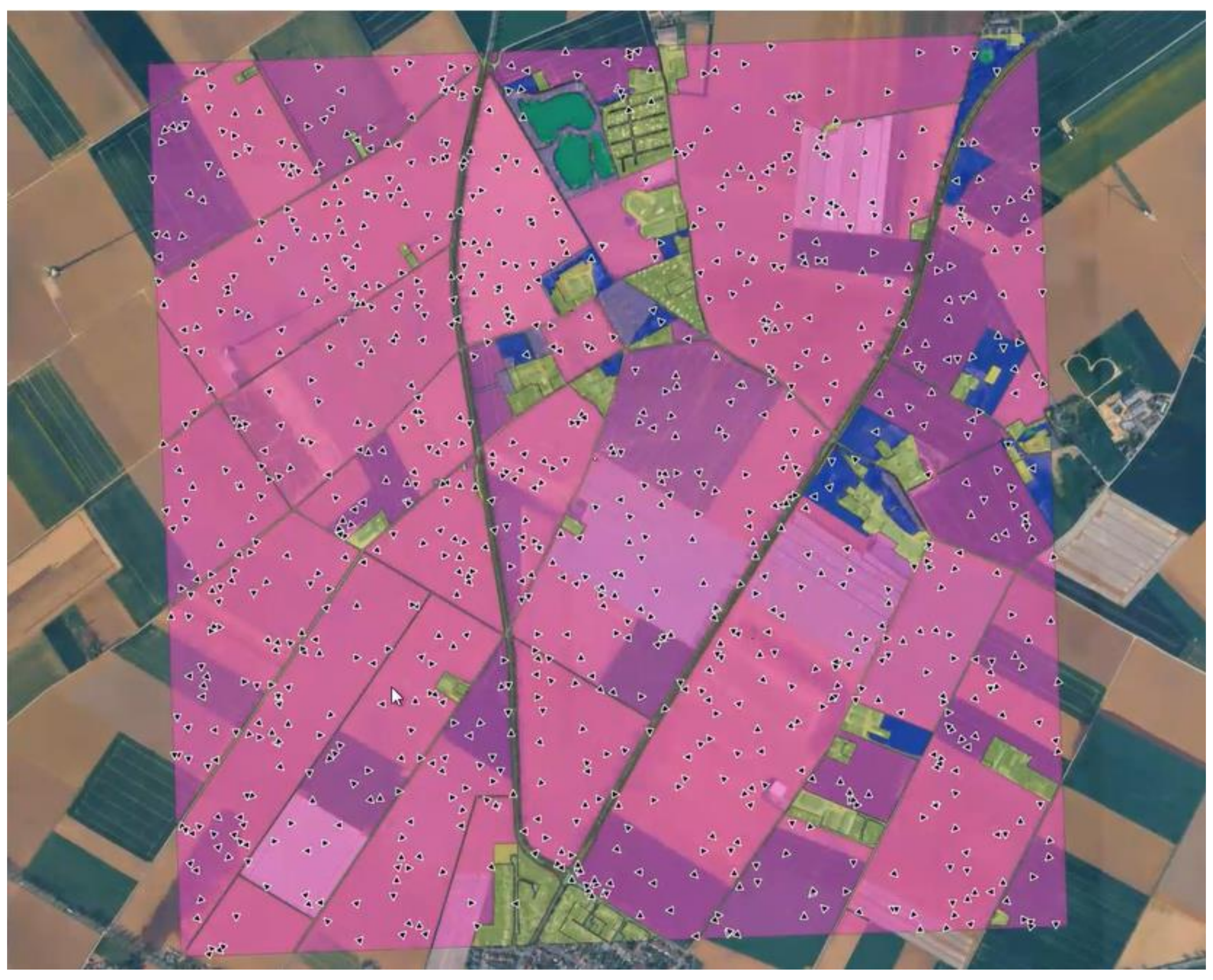

Figure 4. A landscape in North-Rhine-Westphalia in Western Germany (satellite imagery) with a 2 km x 2 km region digitized for Bembidion modeling (overlay). Colors represent different types of landscape elements (fields, wood, water, roads, etc.), which exhibit different habitat suitability for the Bembidions (full, partial, none). The triangles are ~1000 Bembidions distributed randomly within habitats.

Highlights and Challenges of EL-LA-Terra

Highlights

- Part of the broader ELINK-2 initiative, leveraging established modelling tools to investigate **pesticide exposure and effects in realistic agricultural landscapes**.
- Selection of focal species and development of representative scenarios ensure **relevance to the current EU regulatory context**.
- Integration of complementary modelling approaches supports **extrapolation across biological levels of organisation and spatial scales**.

Challenges

- The existing *Bembidion* **model requires further refinement and testing**, including potential adaptations to density dependence and organism movement within the modelled landscape.
  - Proposed modifications are being evaluated for their impact on run time and model outputs.
- As Bembidion is not a standard test species, surrogate species and relevant data were identified to support TKTD modelling.
  - An **NTA GUTS model** now requires calibration, integration, and testing within the overall framework.
- The **lack of validation data** currently limits the ability to substantiate model predictions.
- **Representative landscape and modelling scenarios** must be defined, while maintaining coordination across groups to connect processes and aggregate them appropriately across relevant spatial and temporal scales.

REFERENCES

[1] Topping CJ (2022) The Animal Landscape and Man Simulation System (ALMaSS): a history, design, and philosophy. Research Ideas and Outcomes 8: e89919. https://doi.org/10.3897/rio.8.e89919

[2] https://github.com/xlandscape

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ELINK-2: Linking Exposure and Effect Models Across Scales for Pesticide Risk Assessment: Concepts, Case Studies and Data Gaps for Small-Scale Considerations

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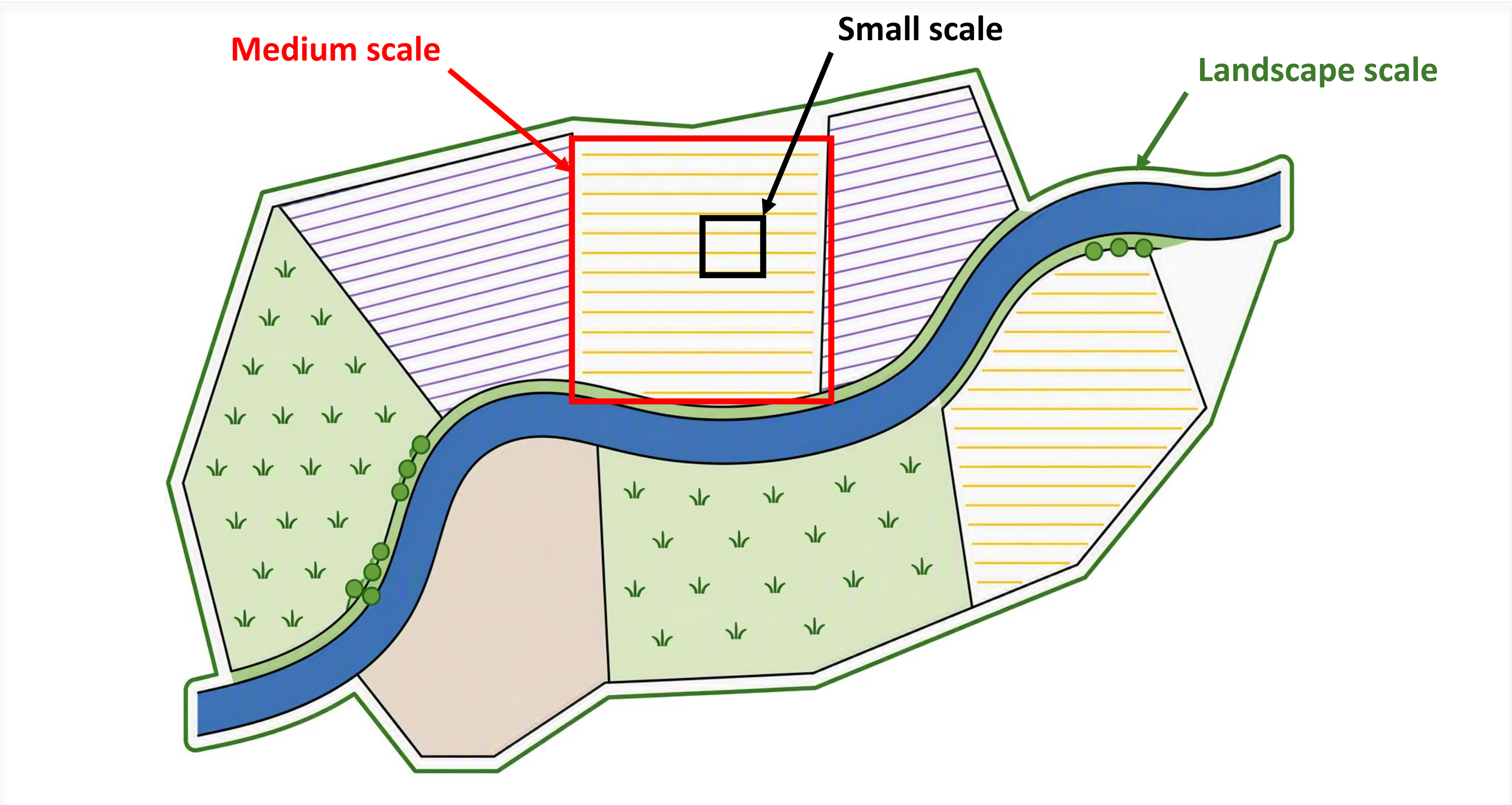
INTRODUCTION

- **Linking spatially and temporally explicit** exposure models with ecological effect models is a **central challenge** for advancing pesticide environmental risk assessment and assessing how the current practices comply with the environmental protection goals.
- The ELINK-2 initiative addresses this challenge by developing and testing **coherent modeling concepts across scales**.

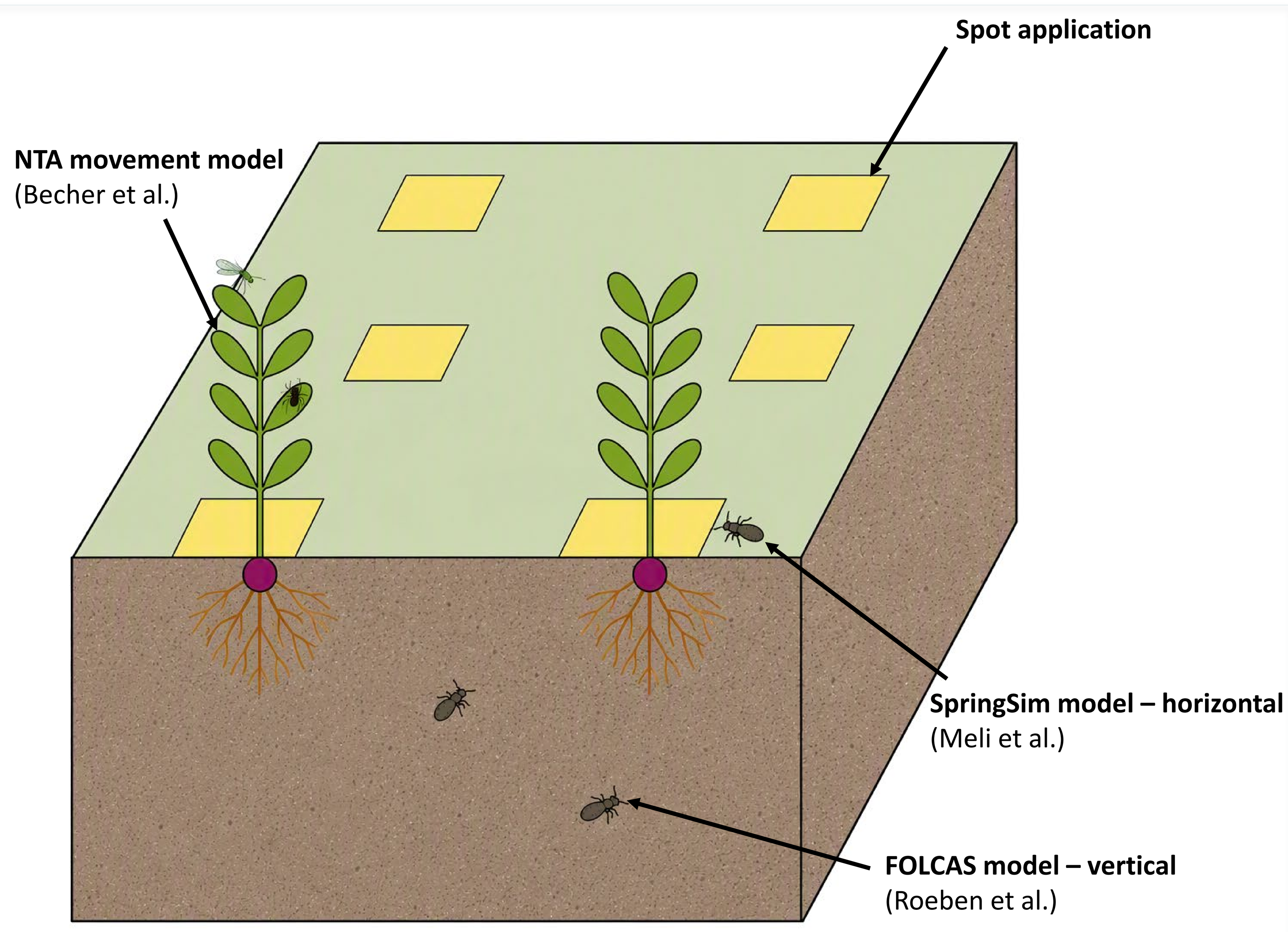
ELINK-2 Small-Scale Working Group (EL-SA)

- EL-SA explores the **implications of organism movement and spatially heterogeneous exposure** at a **sub-field scale** with case studies **on soil organisms** and **non-target arthropods (NTAs)**, highlighting when spatially explicit modeling is required to capture relevant exposure pathways and effects.



Integration of the various scales of interest of the ELINK-2 workgroups

MATERIAL & METHODS



Overview of case studies: Collembola exposure across horizontal and vertical distributions and NTA exposure on a treated plant

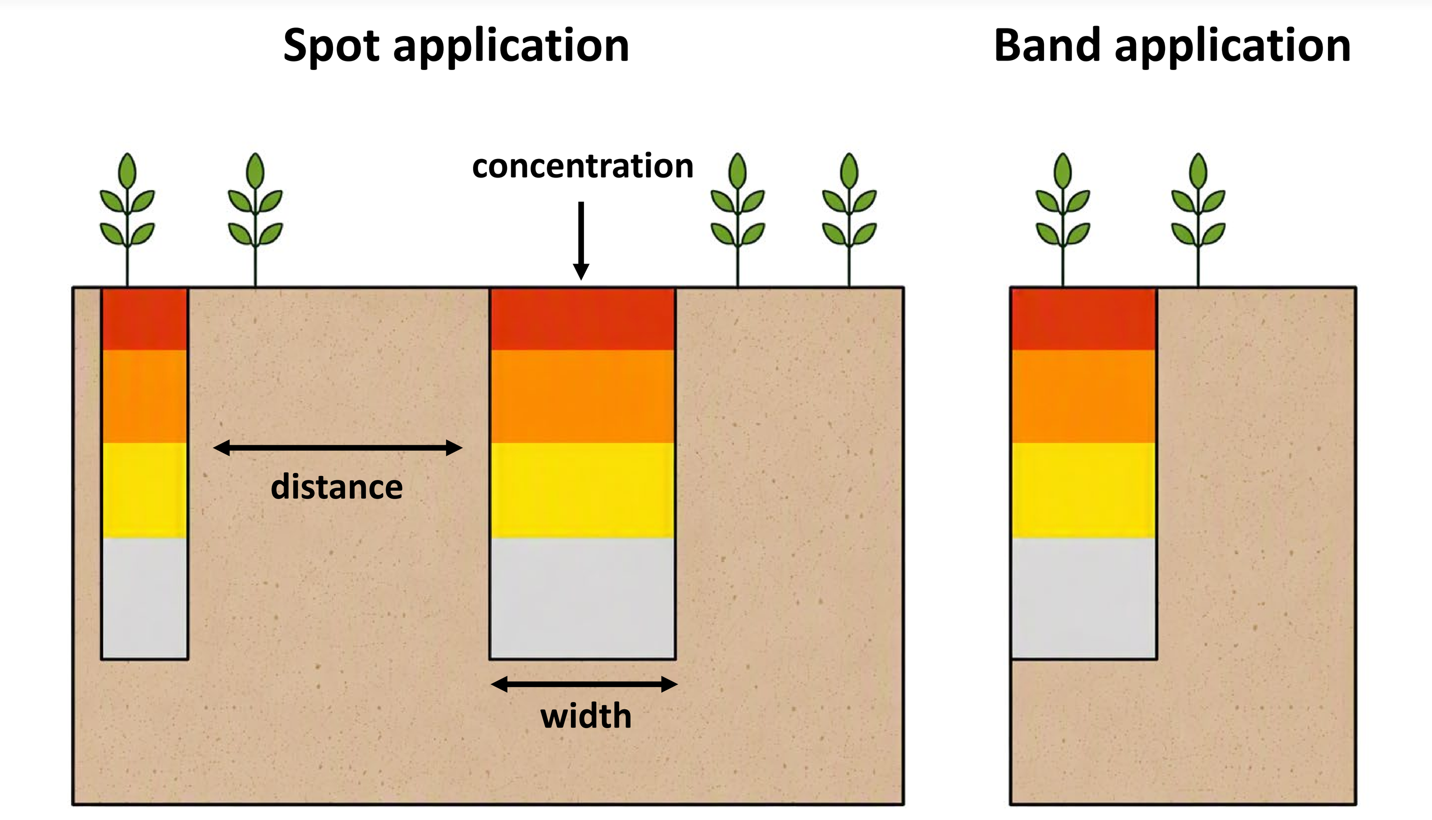
CASE STUDIES

Two different organism groups (Collembola and NTAs) with three different models:

- Collembola model **SpringSim** (Meli et al.) [1] focussing on **horizontal exposure**
- Collembola model **FOLCAS** (Roeben et al.) [2] focussing on **vertical distribution** and exposure of Collembola
- **NTA Movement Model** (Becher et al.) [3] focussing on the movement of **NTAs within a plant**

EXPOSURE SCENARIOS

- To investigate **effects across scales**, all ELINK-2 workgroups consider **the same agricultural water catchment**: the Funne catchment in Germany.
- Exposure and effect models will be parameterized for the composite substance **ELINKmethrin** (from the ELINK and SETAC Modelink workshops)**.**
- **Exposure in soil** for the Collembola case study will be defined for an existing field selected from the Funne catchment. Applications to **oilseed rape** will be simulated to produce the soil concentration profile exposing the organisms.
- Computational Fluid Dynamic (CFD) modeling will be used to establish **the exposure profile in a 3D model** of an applied flowering oilseed rape plant for the NTA case study.
- Considering **precision application**, 3 different scenarios will be investigated: (i) spot application, (ii) band application and (iii) broadcast application.



Spatialized exposure profile following application patterns

PERSPECTIVES & CONCLUSIONS

- Small-scale modeling can be used to investigate how **spatial heterogeneity** and **organism movement** influence **exposure-effect relationships**
- Coupling of exposure and effect models at the small scale enables **process-based understanding** that supports interpretation and extrapolation to higher-tier assessments
- **Harmonized case studies** across ELINK-2 can **reveal temporal and spatial mismatches** between exposure profiles and effect model requirements
- **Integration across scales** highlights **methodological limitations and key data gaps**, supporting prioritization of future model development
- The EL-SA work contributes to a **coherent, scale-explicit risk assessment framework**, improving ecological realism while maintaining regulatory relevance

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