Coupling two-dimensional fate and individual-based effects models

Colin Brown, Roman Ashauer & Annika Agatz
Environment Department

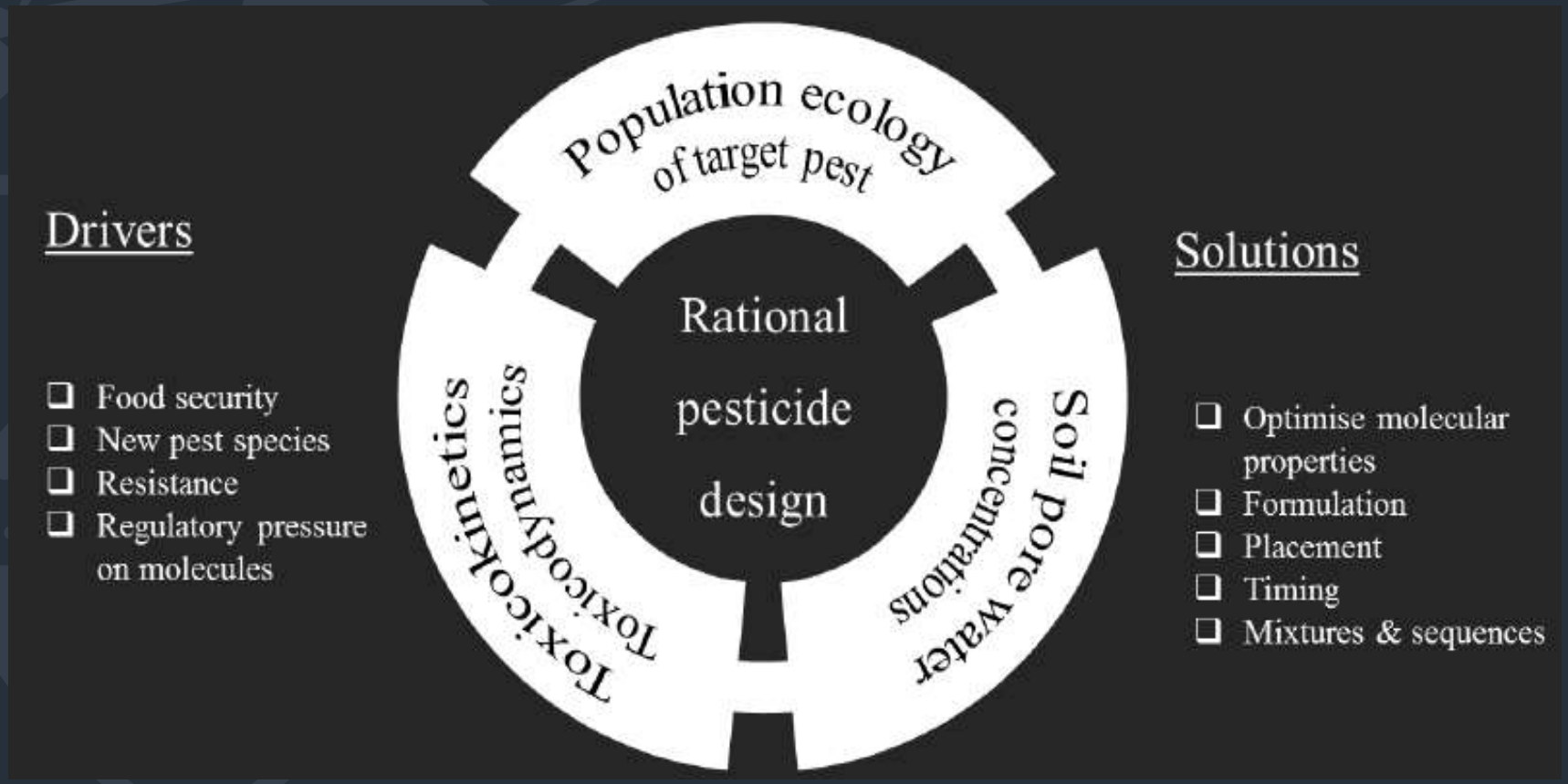
9th European Modelling Workshop. Copenhagen, October 2018

Regulatory relevant discussion point

- We can use models to incorporate fate knowledge earlier into the pesticide development pipeline
- Bridging disciplines using models will improve risk management for pesticides (with knock-on benefits for risk assessment)

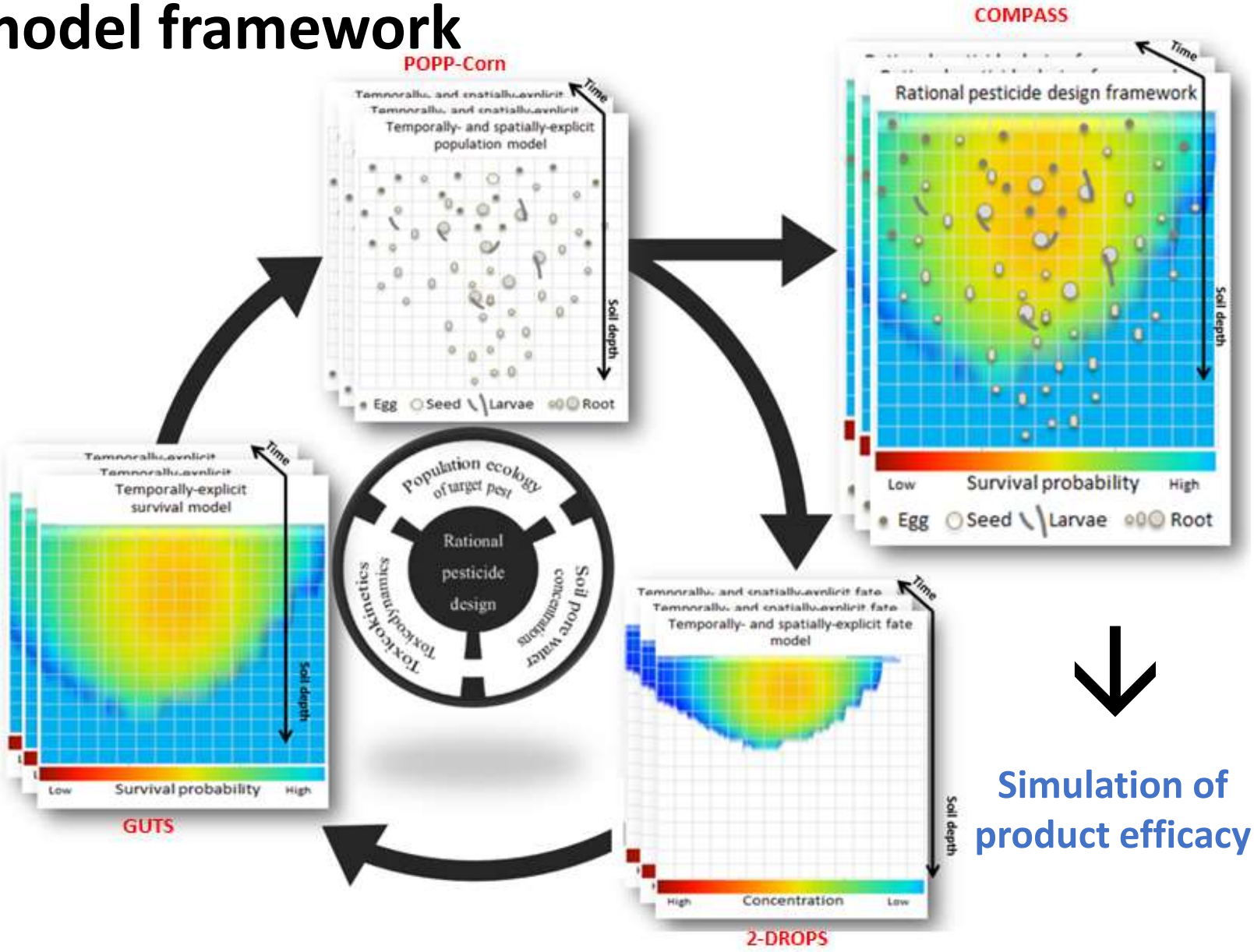
Framework

Integrating pesticide fate, pest ecology and toxicity modelling



Efficacy pipeline: Discovery → Lab screening → Glasshouse → Field studies

The model framework

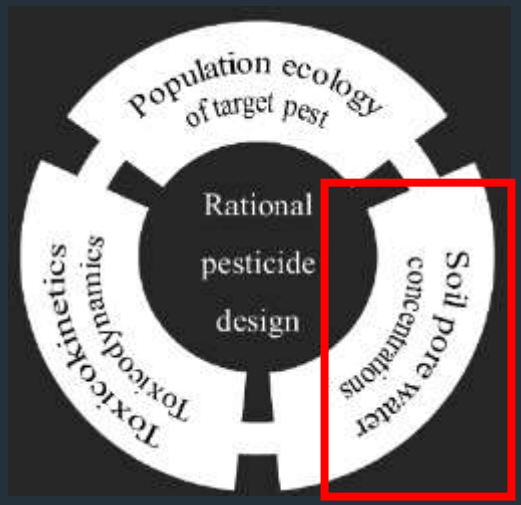


Talk structure: Models → Evaluation → Applications

Exemplar: corn rootworm in maize

Fate model

Root growth, water & pesticide
2-DROPS

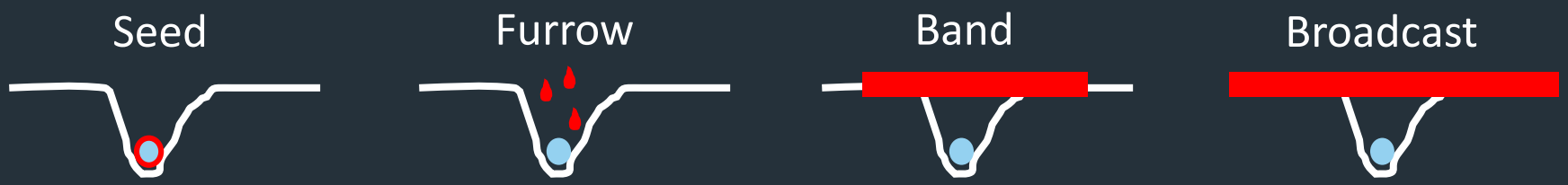


2-DROPS

Agatz, A. & Brown, C. D. (2017). Introducing the 2-DROPS model for two-dimensional simulation of crop roots and pesticide within the soil-root zone. Science of the Total Environment 586:966-975.

Problem formulation

- Models for pesticide fate in soil are primarily 1-D
  - Limiting to assess strategies for pesticide placement in soil (seed treatment, furrow or band applications etc.)



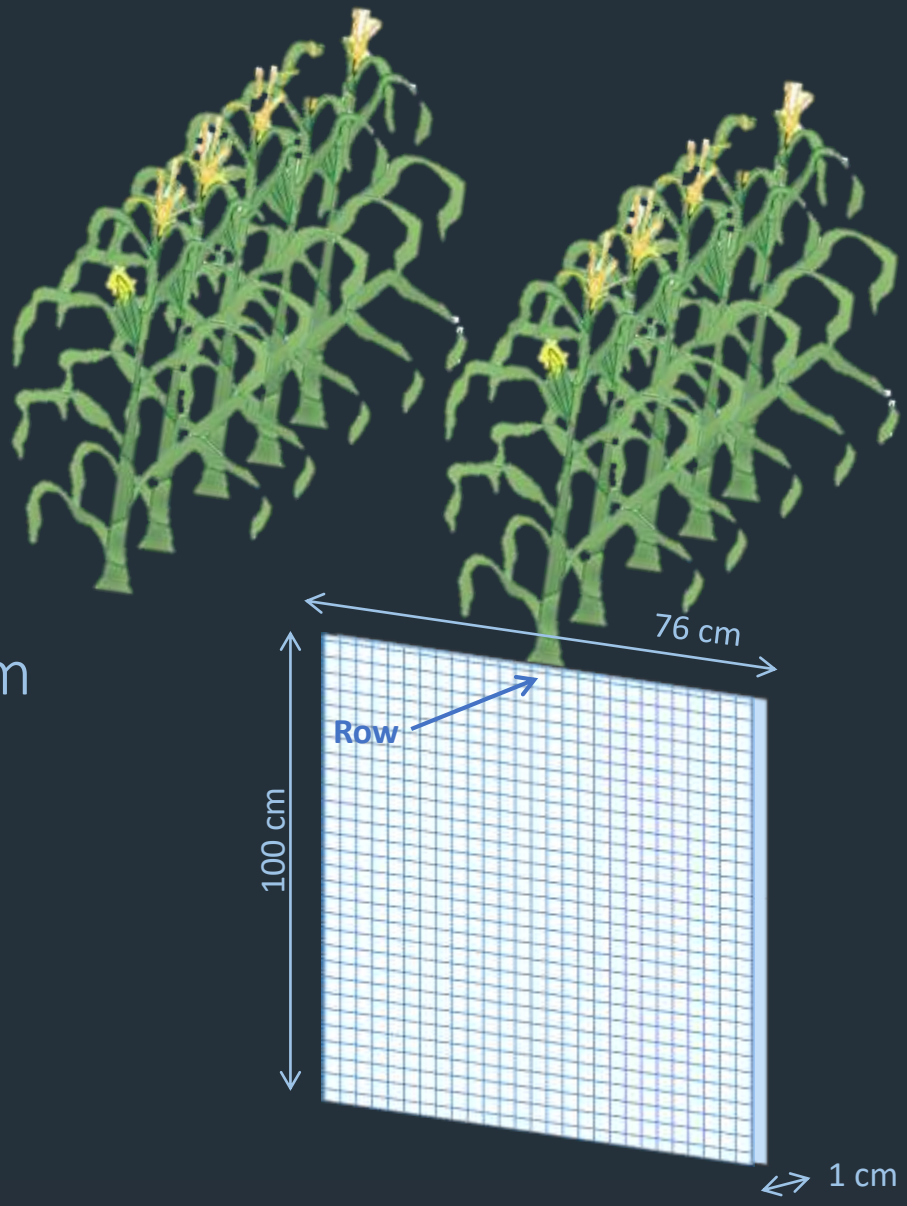
- Existing 2-D models are parameter/computation intensive and often have simplified representations of the crop root system
  - Limiting to integrate efficacy against root damaging pests

2-DROPS

Temporal and spatial resolution

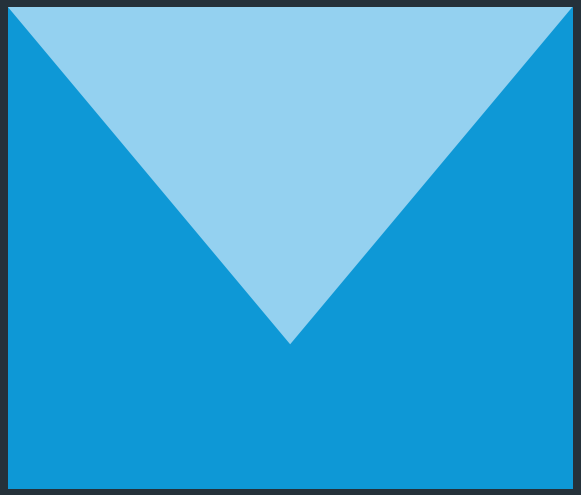
- Daily time step
- Grid cells of 1 * 1 * 1 cm
- Simulates a cross section through one plant row

- Maize example: 76 * 100 * 1 cm



Main difference from most 2-D fate models

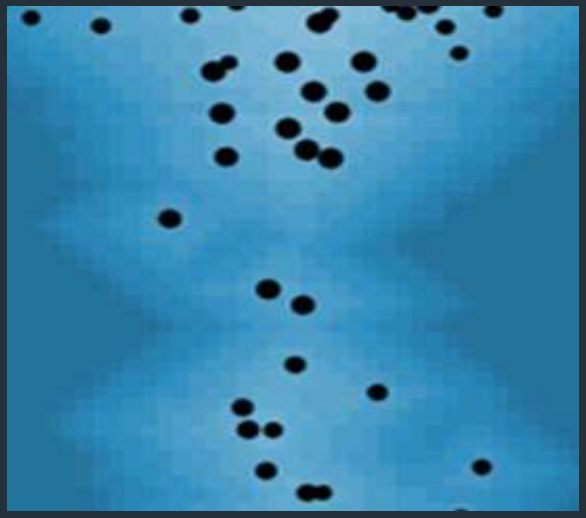
Other 2-D models



Root distribution with total biomass

Water extraction from root distribution zone according to hydraulic gradient

2-DROPS

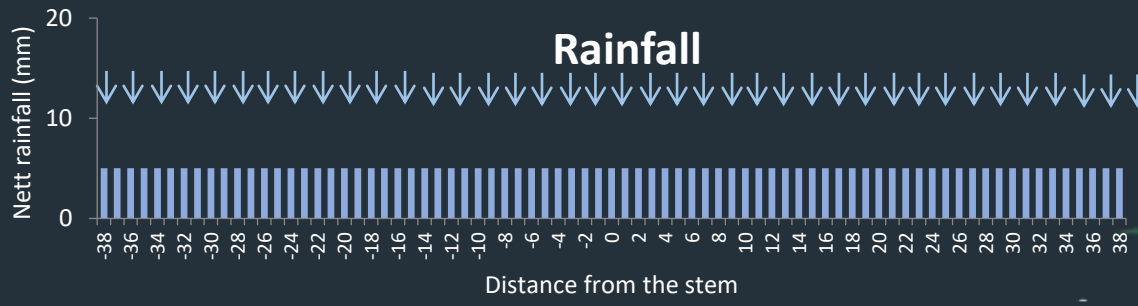


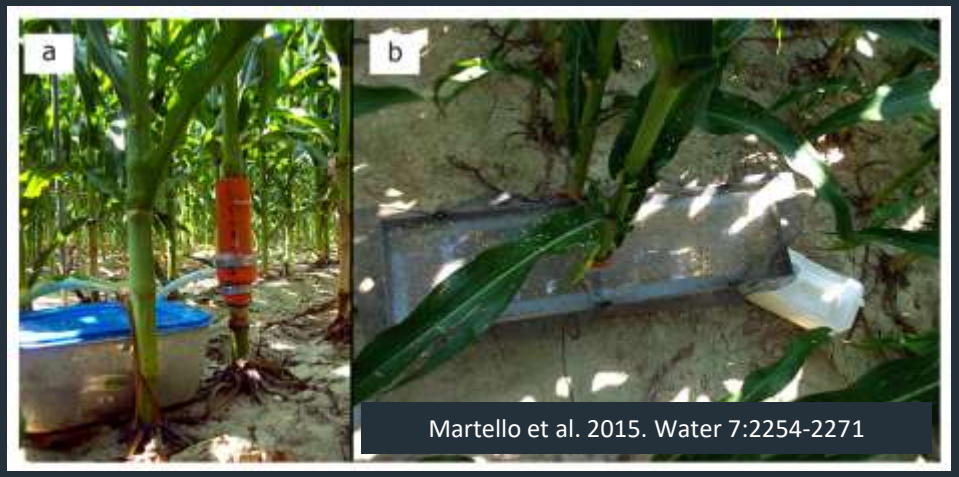
Root segment with individual biomass

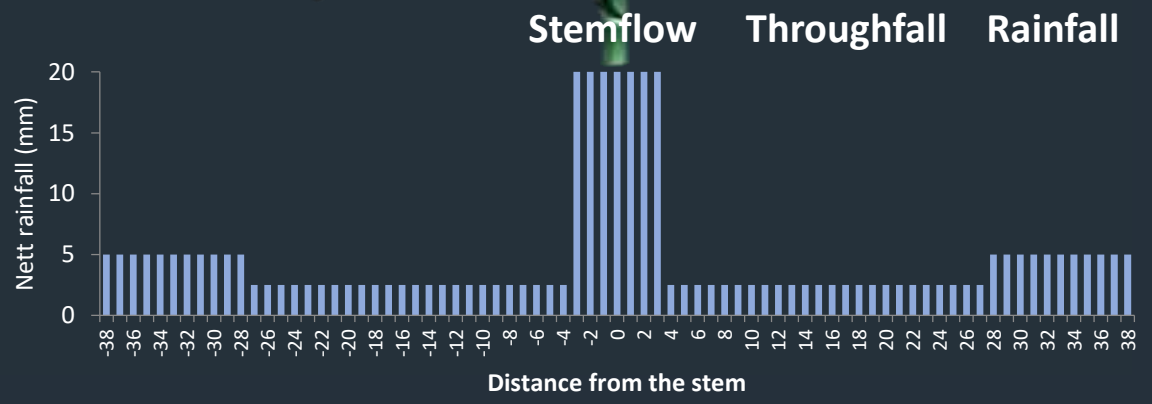
Water extraction from individual root segments

2-DROPS

Canopy interception

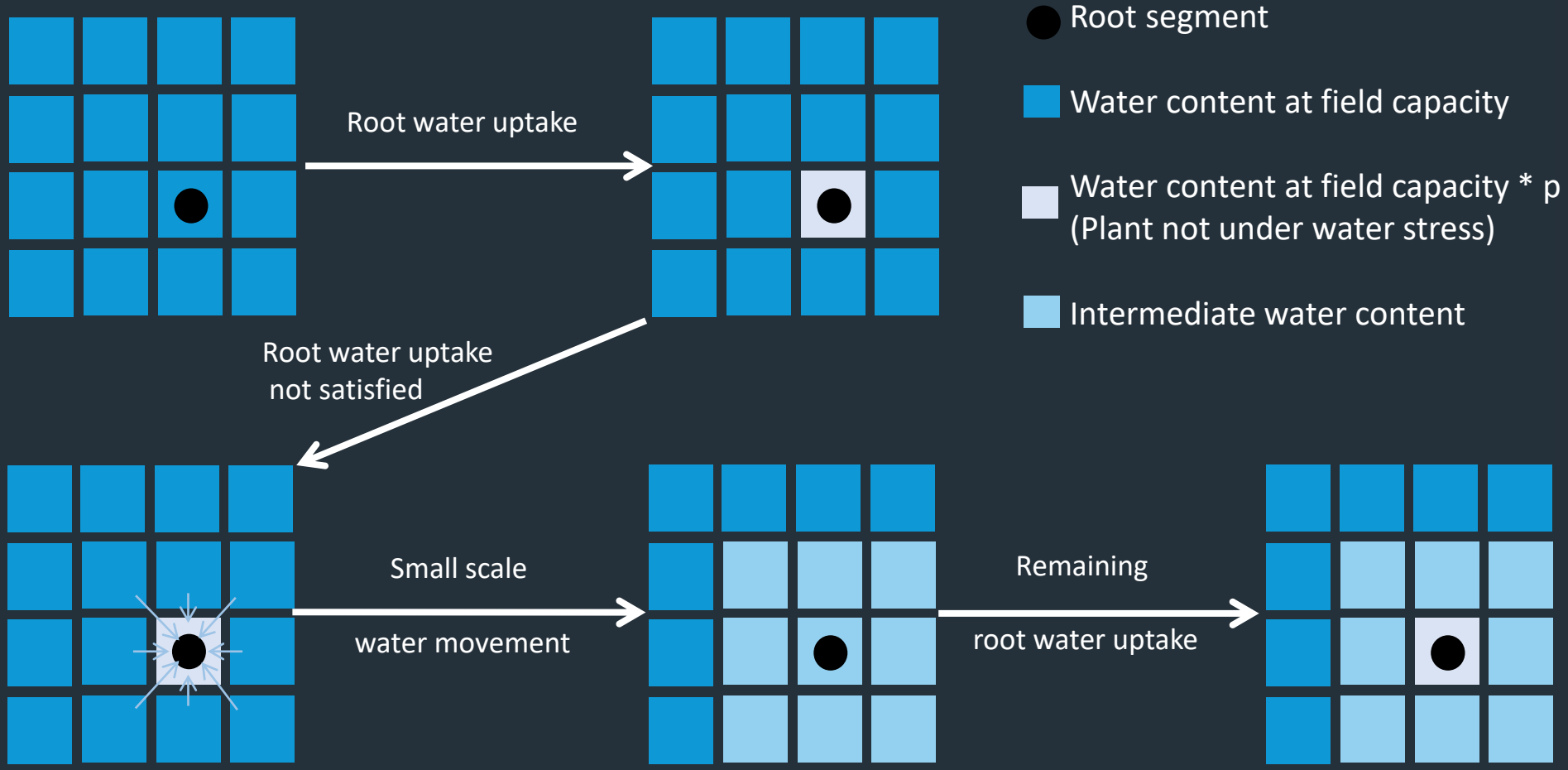






2-DROPS

Sequence for water uptake by roots

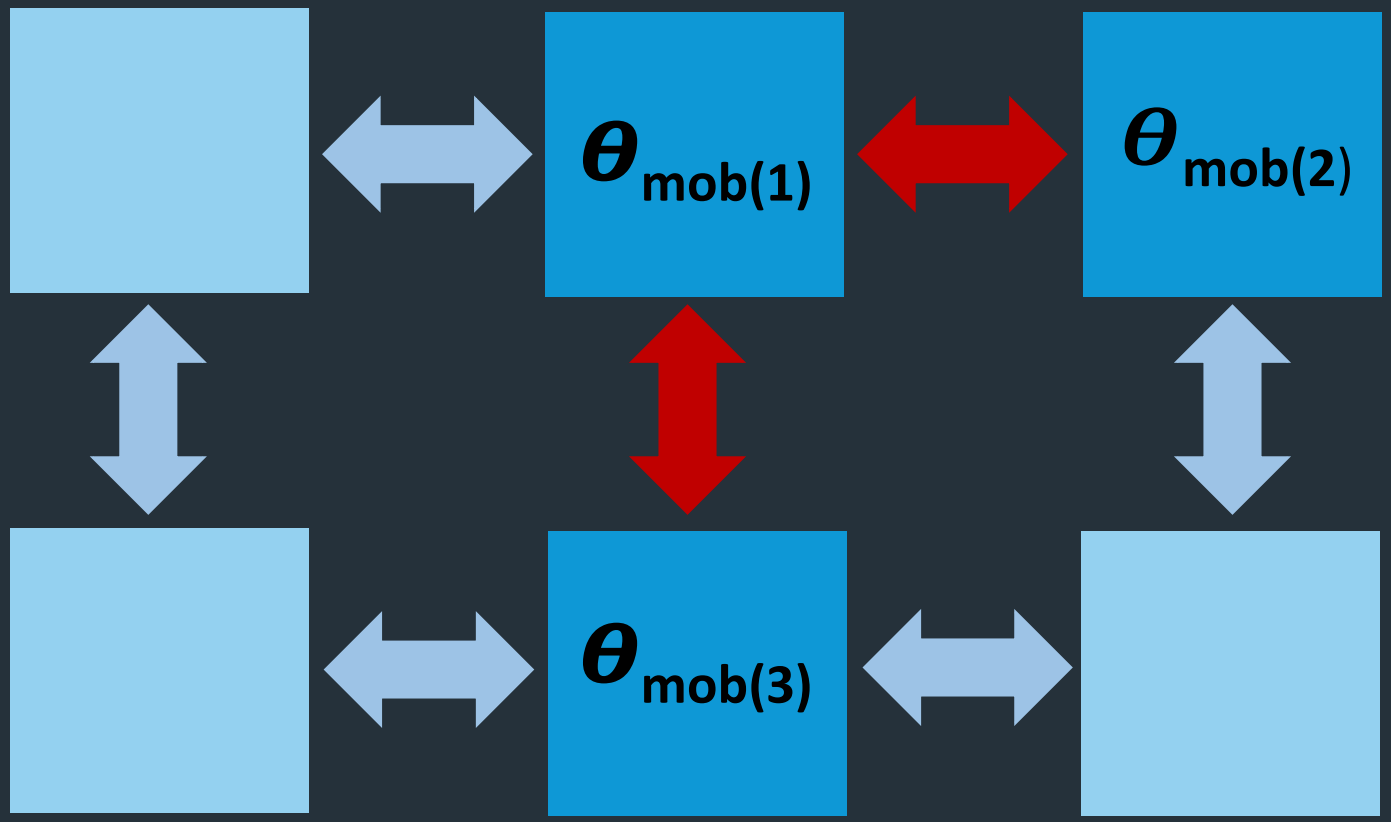


2-DROPS

Water transport in the soil profile

Horizontal hydraulic gradient = $\boldsymbol{\theta}_{mob(1)}/\boldsymbol{\theta}_{mob(2)}$

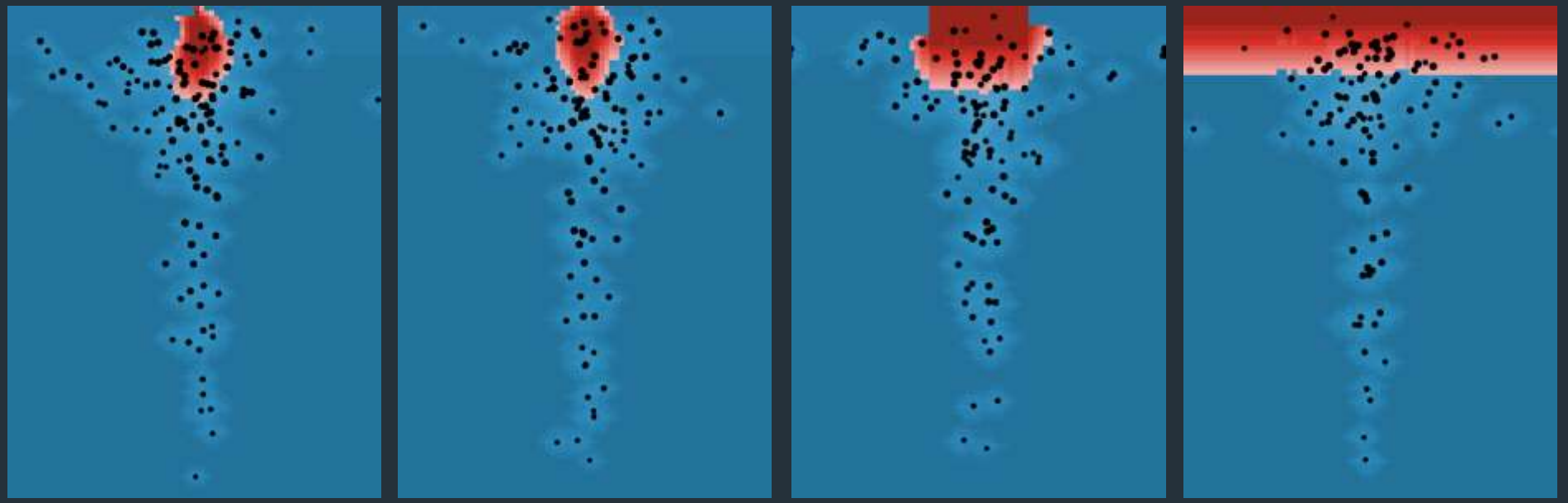
Vertical hydraulic gradient = $\boldsymbol{\theta}_{mob(1)}/\boldsymbol{\theta}_{mob(3)}$



2-DROPS

Clothianidin

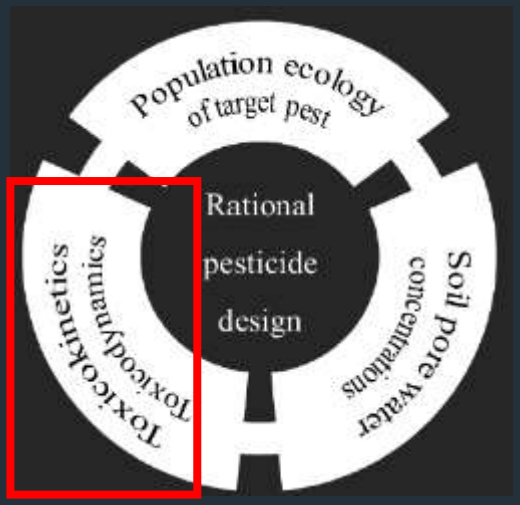
60 days post-application



Seed | Furrow | Band | Broadcast

Toxicity model

Toxicokinetics & Toxicodynamics
GUTS



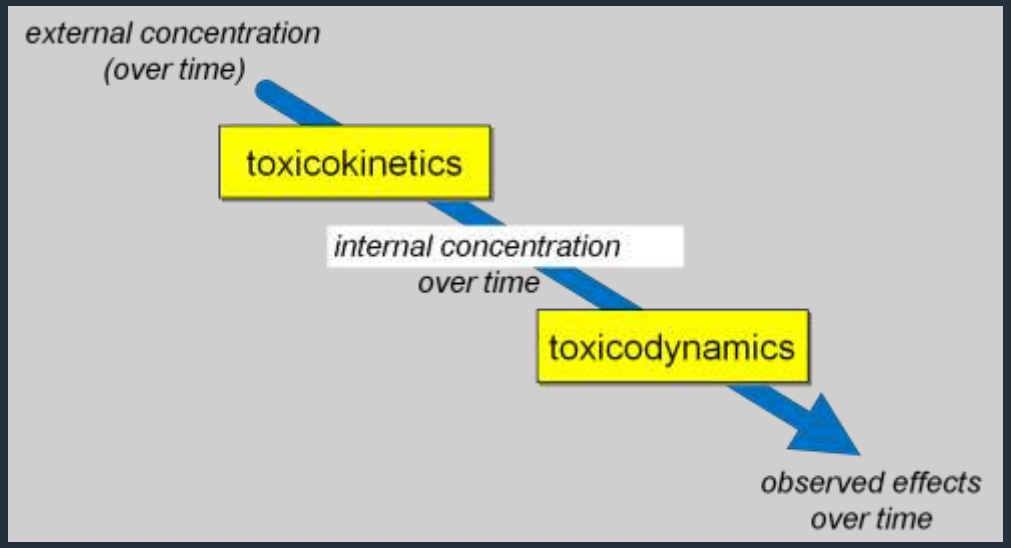
GUTS

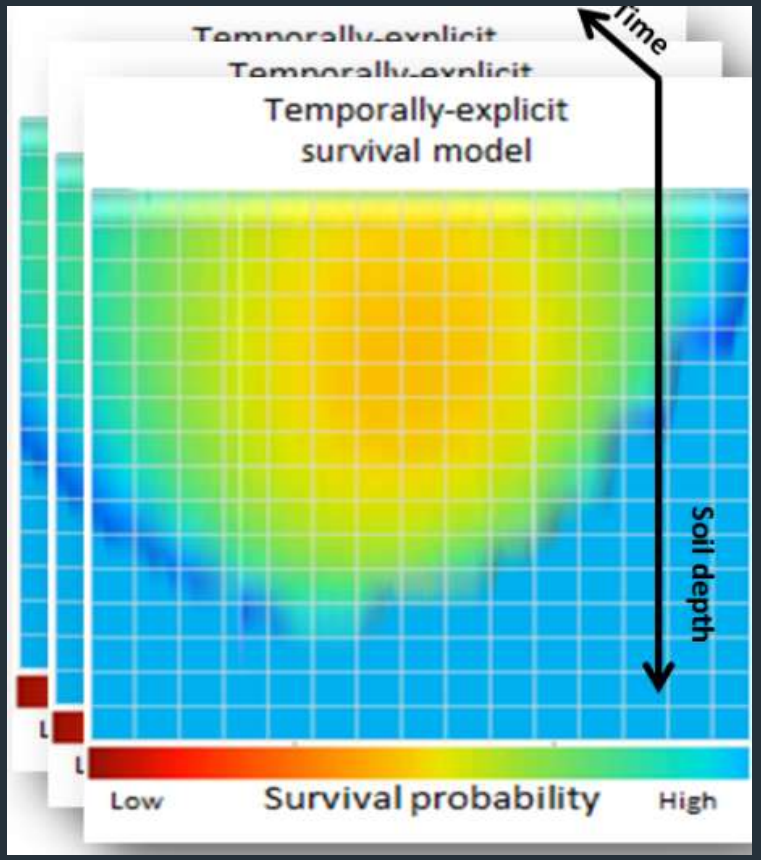
Agatz, A., Schumann, M. M., French, B. W., Brown, C. D. & Vidal, S. (2018). Assessment of acute toxicity tests and rhizotron experiments to characterise lethal and sub-lethal control of soil-based pests. Pest Management Science. E-pub ahead of print: https://doi.org/10.1002/ps.4922

Toxicity model

Toxicokinetics & Toxicodynamics
GUTS

Temporally explicit pest mortality from a.i. in the soil profile.

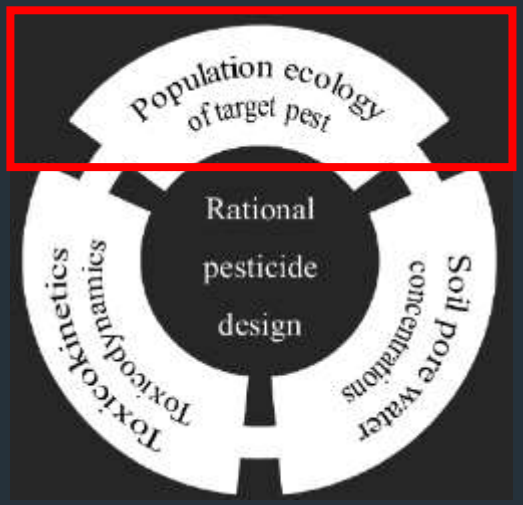




Efficacy ←

Pest model

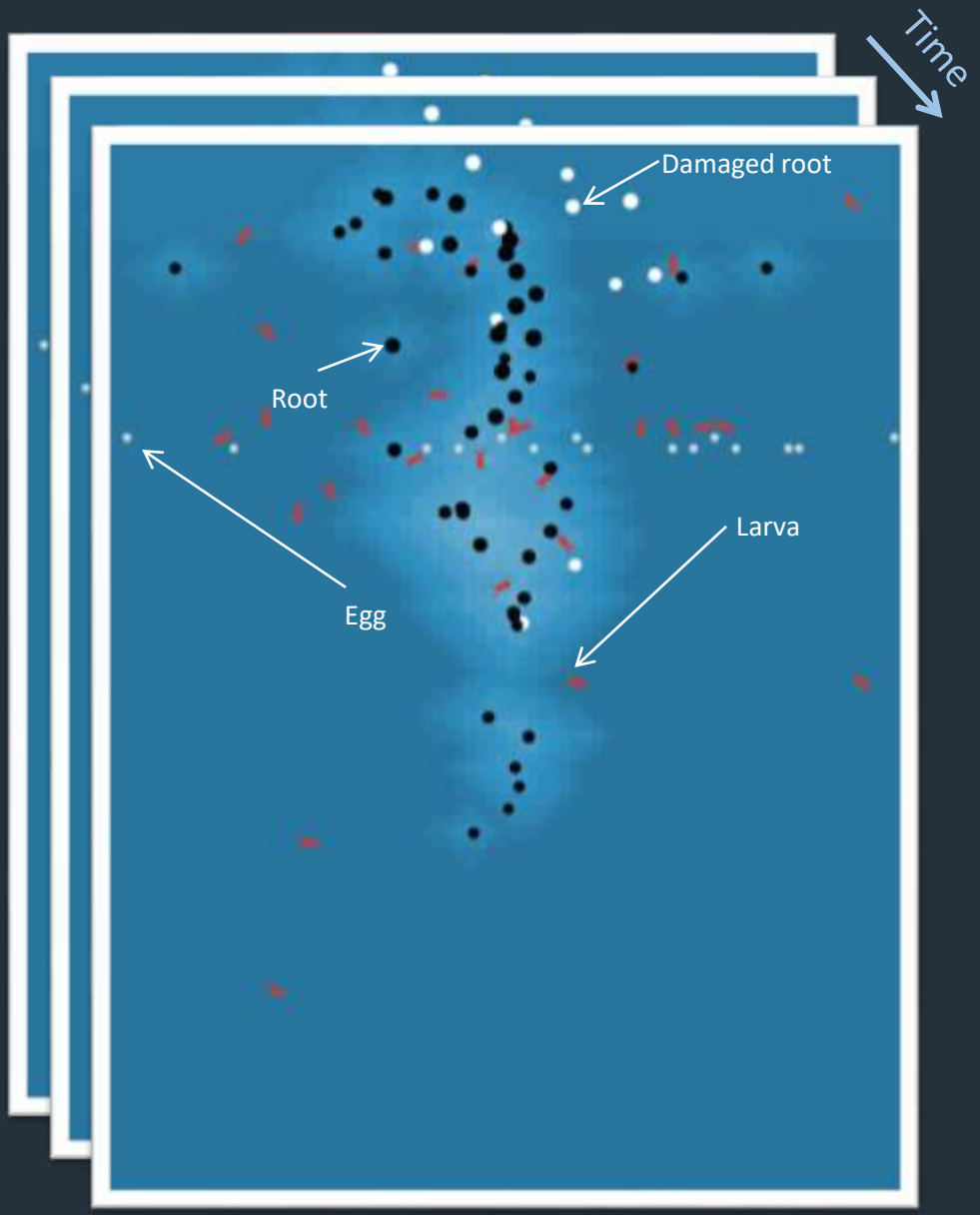
Pest ecology & crop damage
POPP-Corn



Agatz, A., Ashauer, R., Sweeney, P. & Brown, C. D. Prediction of pest pressure on corn root nodes: the POPP-Corn model. *Journal of Pest Science* **90**, 161-172 (2016).

Pest model

Pest ecology & crop damage
POPP-Corn



J Pest Sci
DOI 10.1007/s10340-016-0788-x

ORIGINAL PAPER

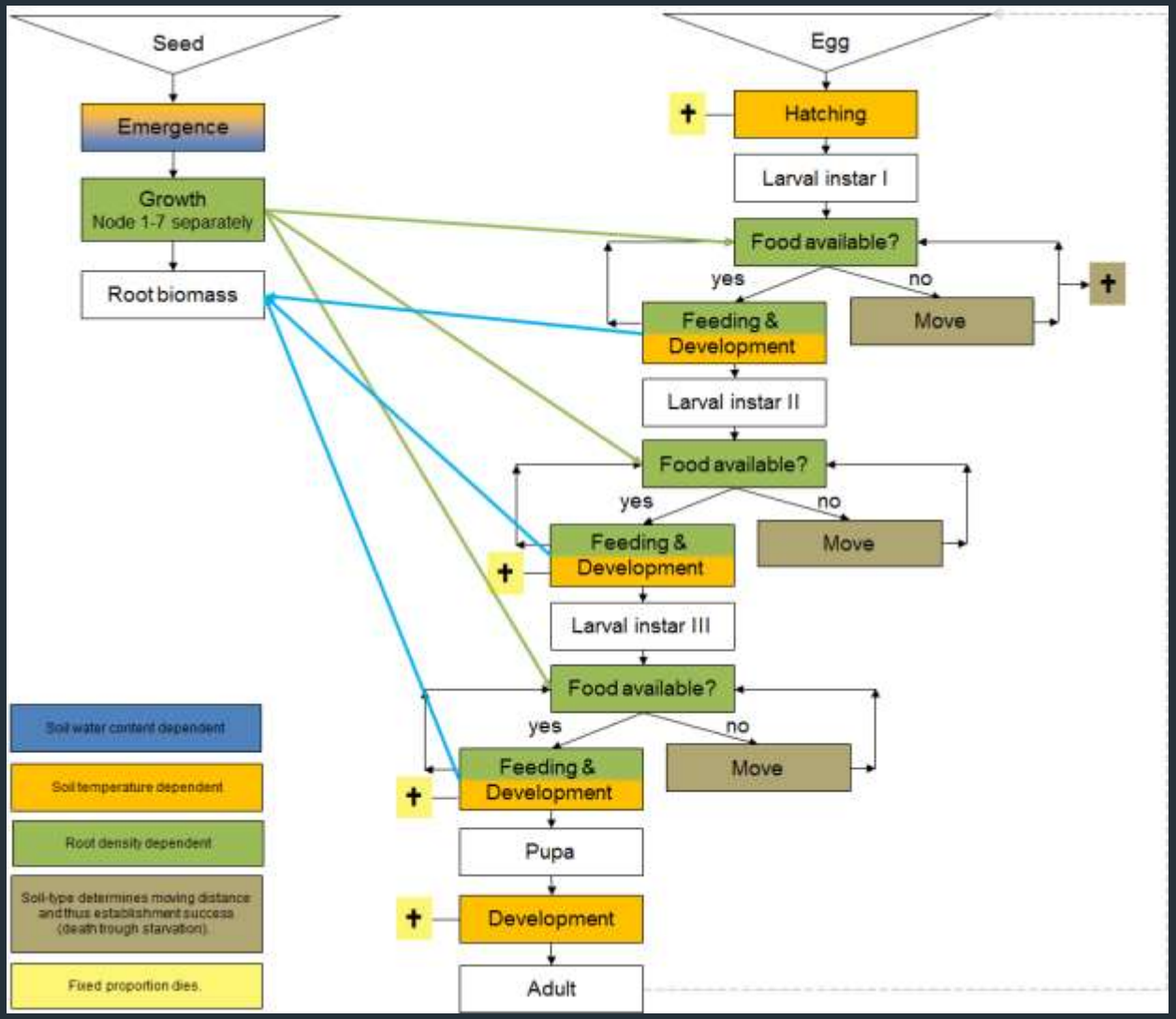
Prediction of pest pressure on corn root nodes: the POPP-Corn model

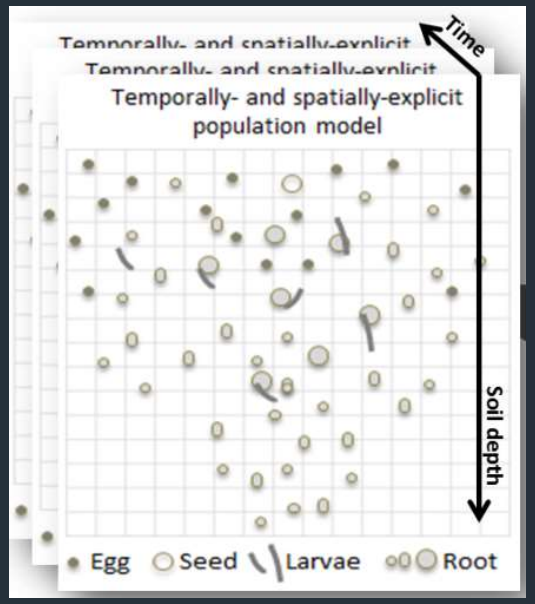
Annika Agatz[1] · Roman Ashauer[3] · Paul Sweeney[2] · Colin D. Brown[1]

Pest model

Pest ecology & crop damage
POPP-Corn

Rootworm IBM



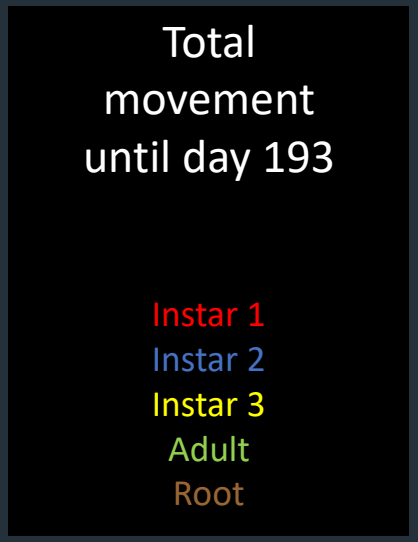


Pest model

Pest ecology & crop damage
POPP-Corn

- Movement only when not enough food in patch
- Moving distance (frequency of movement) for all 3 instars the same
- Moving distance depends on soil type
  - "Sandy loam" 1 cm / 6h (Strnad 1987)
  - "Silt loam" 1 cm / 4h (Strnad 1987)
  - "Sand" 1cm/h (Strnad 1987)
- Movement preference for larvae:
  - 1st instar: root tips (young roots)
  - 2nd instar: middle aged roots
  - 3rd instar: oldest roots *

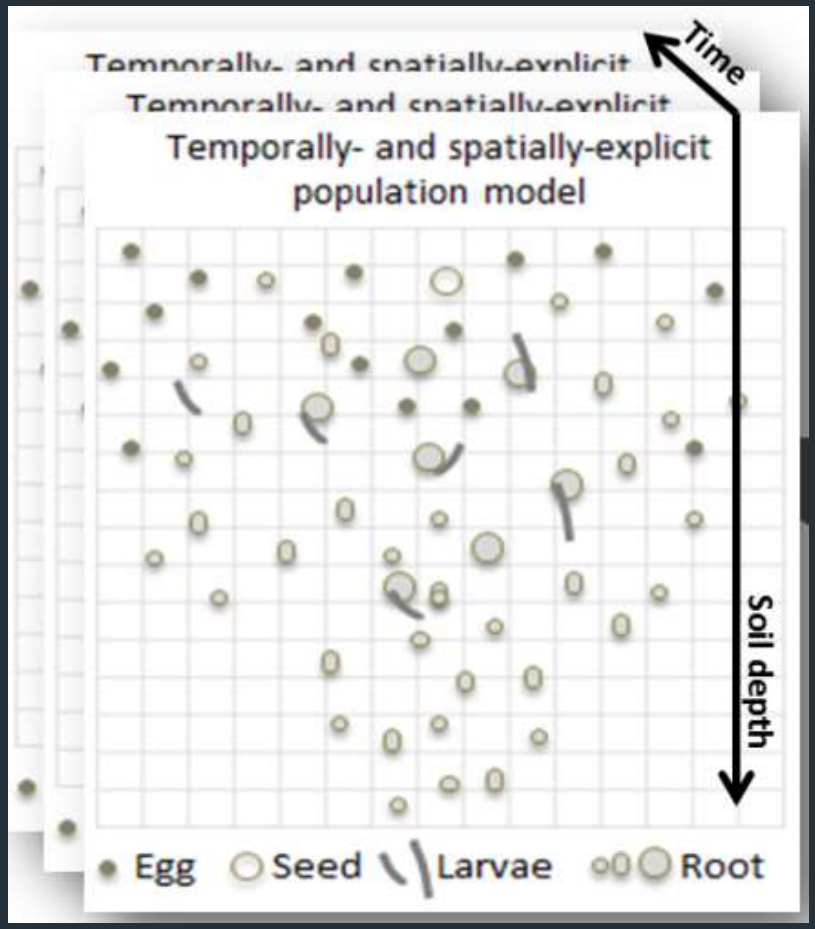
[* Approximation following Clark et al. 2006]



Pest model

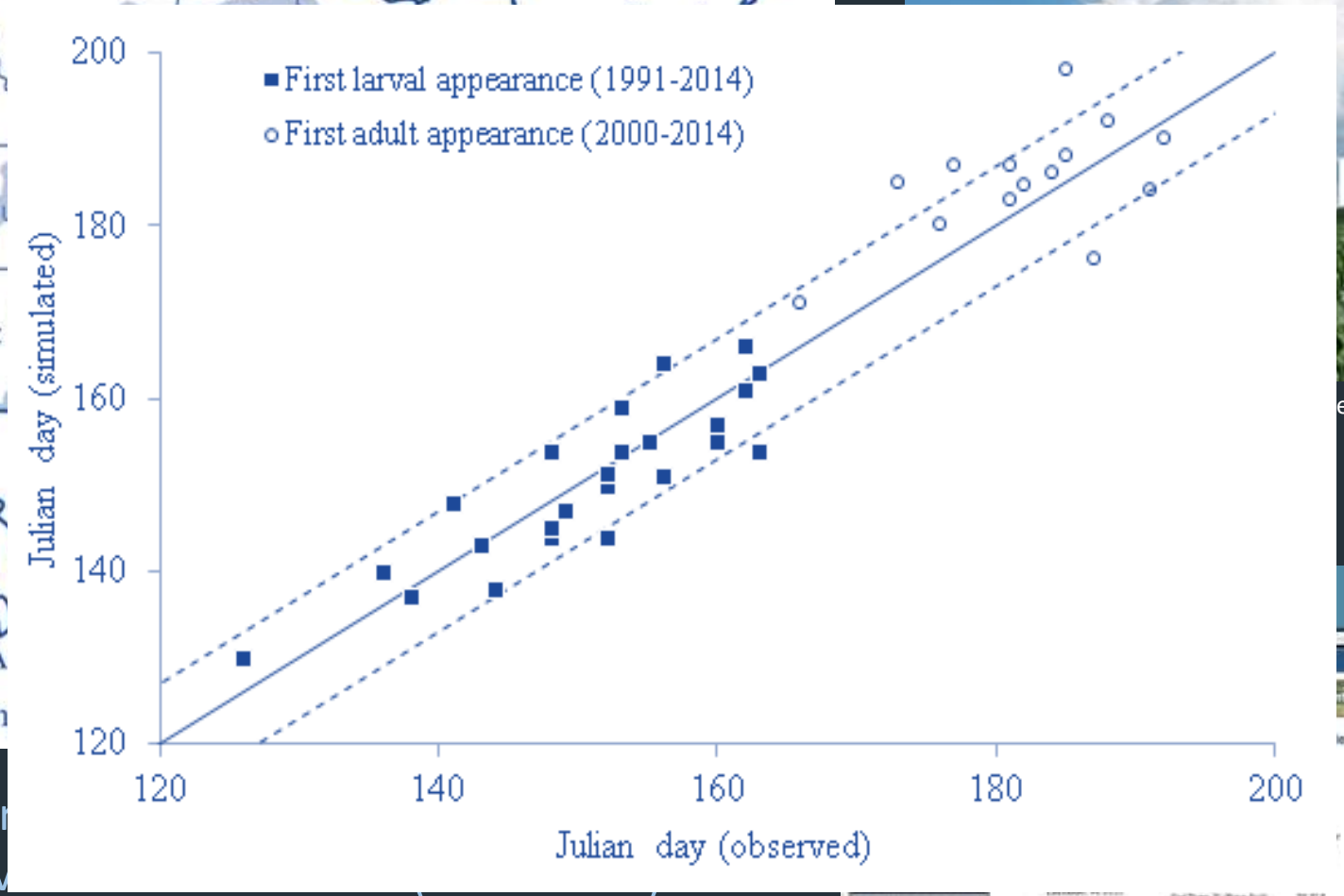
Pest ecology & crop damage
POPP-Corn

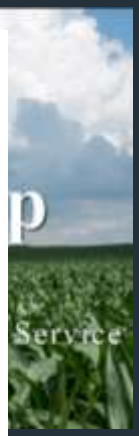
Model predicts root damage due to larval feeding using a node injury scale (NIS) for comparison with field observations



Pest model

Pest ecology & crop damage
POPP-Corn





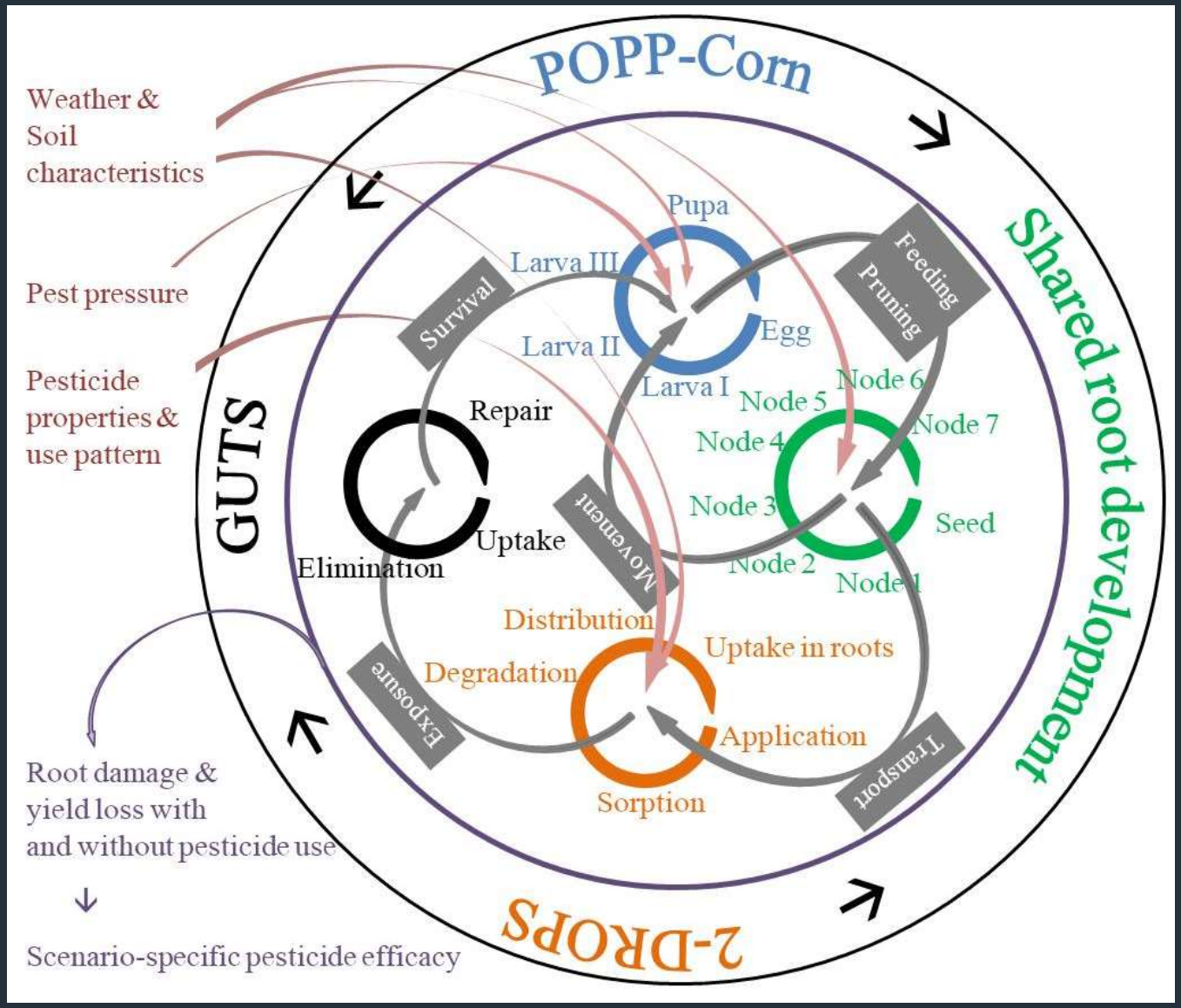
estcrop/

- Weather
- First larv
- First adult found in the field (2000 – 2014)

http://www.isws.illinois.edu/warm/stationmeta.asp?site=BVL&from=wx

The framework
(combined model in NetLogo)

Pesticide activity in soil
COMPASS



Conclusions

- Temporally- and spatially explicity
  - Co-location of root / pest / pesticide ?
- In silico test bed that allows virtual field trials
- Bridging across disciplines changes the questions that can be asked
  - e.g. influence of fate profile in driving variability in efficacy

Regulatory relevant discussion point

- We can use models to incorporate fate knowledge earlier into the pesticide development pipeline
- Bridging disciplines using models will improve risk management for pesticides (with knock-on benefits for risk assessment)
- Thank you!