Combining models of agricultural landscapes and soil-dwelling pest population dynamics to design novel management strategies against wireworms

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- Wireworm management is often implemented at the plot scale (e.g. biocontrol, chemical treatment) but...

  ...entanglement of grassy landscape elements (favourable habitats) and crops (e.g. maize, potatoes, cereals) facilitates crop colonisation within the agricultural mosaic

→ **landscape** is the relevant scale to design pest resilient agroecosystems

- Correlative studies do not provide a sound understanding of processes underpinning crop infestation

→ a **mechanistic** (process-based) approach is welcome!

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Hypothesis:

- Arrangement of land uses in space and time might efficiently contribute to pest regulation

Objectives

- **Provide a mechanistic framework** to study the spatiotemporal distribution of soil-dwelling insect populations within dynamic landscapes
- **Examine the role of grasslands** in crop colonisation by wireworms within contrasted dynamic agricultural mosaics
- **Infer** novel spatiotemporal pest management strategies

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1. **Derive a parsimonious population dynamics model** encompassing key biological and ecological mechanisms and considering space explicitly
2. **Parameterise the model** from an extensive review of literature dealing with the biology and ecology of wireworms
3. **Model various landscape contexts** (from analytics toward more realism) comprising grasslands and vulnerable crops characterised by their carrying capacity, providing situations with grassland in the history, the neighbourhood or the historic neighbourhood of crops

Poggi S. et al (2021) Dynamic role of grasslands as sources of soil-dwelling insect pests: new insights from *in silico* experiments for pest management strategies. *Ecological Modelling* 440

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Parsimonious, spatially explicit model

$$
\begin{cases}
\partial_t A(x,t) = \tau(t)B(x,t,m_c) + D\Delta A(x,t) - \vec{u}(x,t)\cdot\nabla_x A(x,t) \\
\qquad -\mu_A A(x,t) \\
\partial_t B(x,t,m) = -\tau(t)B(x,t,m_c) + \pi A(x,t) - c\partial_m B(t,x,m) \\
\qquad -\mu_B \left(\frac{B(x,t)}{K(x,t)}\right)^{\beta} B(x,t,m)
\end{cases}
$$

- A,B: aboveground and belowground compartments
- Emergence of adults from mature larvae
- Adult random (diffusion) and directed (advection) motions
- Oviposition
- Larval development along a maturity dimension (maturation)
- Adult **mortality** and larval density-dependent mortality

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4 contrasted and simple analytic models of landscape context:

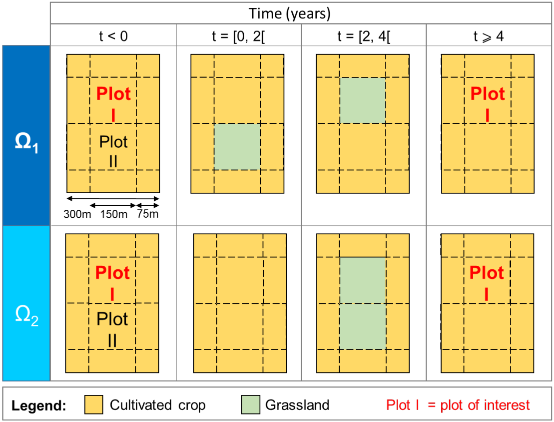
A. Homogeneous crop cultivated over 2 years (K_C=120 ind/m^2)

B. Grassland in the plot history: a 5-year cultivated area following a 5-year grassland (K_G=2000 ind/m^2)

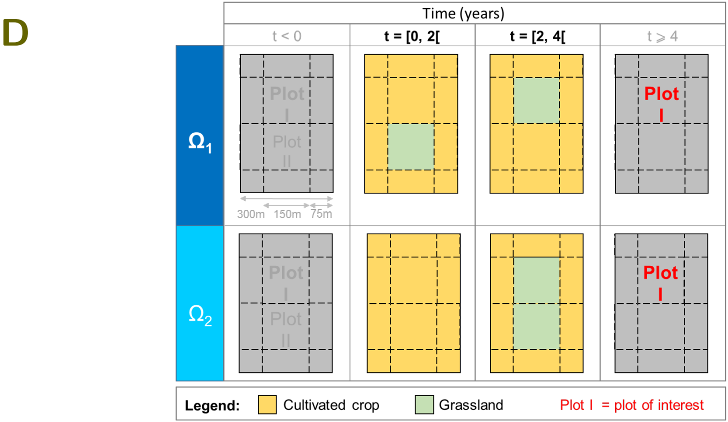
C. Grassland in the plot neighbourhood : a 10-year heterogeneous area consisting of 2 adjacent plots, one cultivated and the other unmanaged

D. Grassland in both plot history and neighbourhood

D



- 2 dynamic landscapes (Ω_1 and Ω_2) exhibiting the same duration of land use types (*composition*) but contrasted *configurations* over time.



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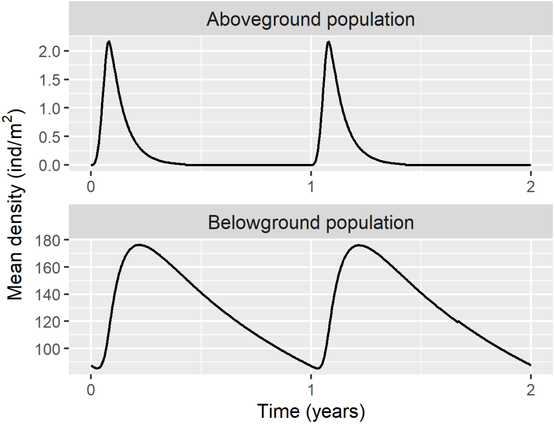
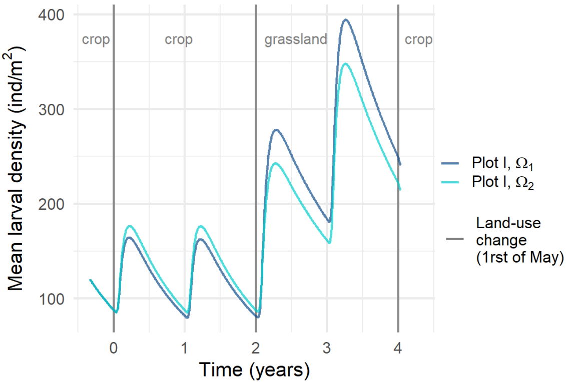
A



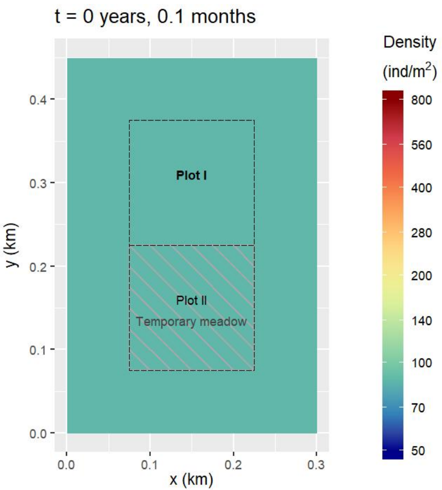
- Stationary dynamics
- Oviposition
- Adult emergence
- Mortality

D



- ≈11% difference in larval density at the end of the scenario (year 4)
- Results from contrasted scenarios of diffusive and advective motions over time

Context D : Illustration of population redistribution in the dynamic landscape Ω_1



- Effects of plot history and landscape context on wireworm infestation are complex, justifying our modelling approach (combining population dynamics and landscape models)
- Our modelling framework enables to investigate how the arrangement in space and time of grasslands and cultivated crops can mitigate crop infestation

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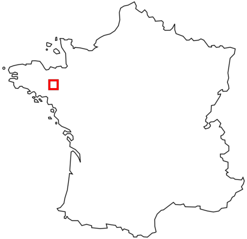
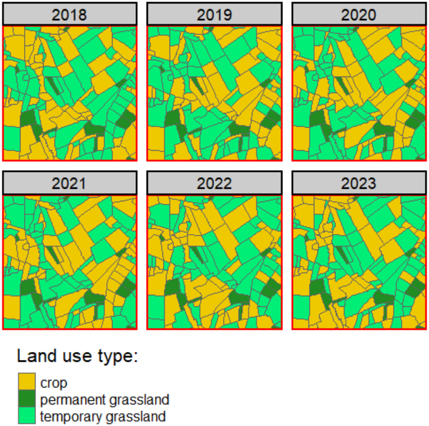
- Explore more realistic agricultural landscapes (i.e. generated under agronomic constraints at the farm or landscape scales)
  - Multi-year cover allocation simulator CapFarm©
  - Simulation of scenarios





- Study suppressive patterns on a continuum of landscape complexity (composition and configuration)

Poggi S. et al (2021) How can models foster the transition towards future agricultural landscapes? In: *Advances in Ecological Research*, Volume 64, pp. 305–368

Thank you for your attention!