Temporal dynamics of grasslands as sources of soil-dwelling insect pests: implications for landscape-scale pest management strategies

Sylvain Poggi, Mike Sergent, Youcef Mammeri, Manuel Plantegenest, Ronan Le Cointe, Yoann Bourhis

Temporal dynamics of grasslands as sources of soil-dwelling insect pests: new insights from *in silico* experiments for pest management strategies

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- Wireworms are serious pest of food crops worldwide, inflicting ≈ $100M/year economic damage
- Progressive phase-out of chemical pesticides (e.g. neonicotinoids in UE, 2018) enhances crop vulnerability
- Entanglement of grassy landscape elements (favourable habitats) and crops (e.g. maize, potatoes, cereals) facilitates crop colonisation within the agricultural mosaic
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Premise:

- Landscape is the relevant scale to design pest resilient agroecosystems that minimise the use of pesticides

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, and 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** 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

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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 models of landscape context:

A. Homogeneous crop (K_C=120 ind/m^2) cultivated over 2 years
B. Grassland in the plot history: a 5-year cultivated area following a 5-year grassland (K_G=2000 ind/m^2)
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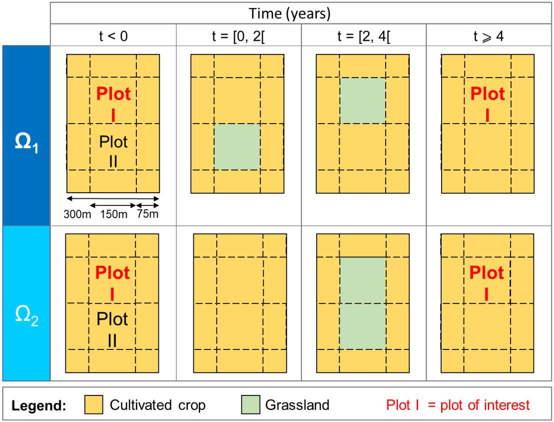
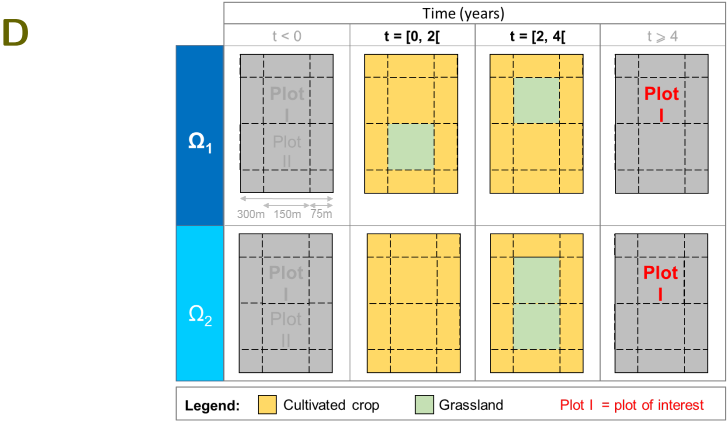
D



- 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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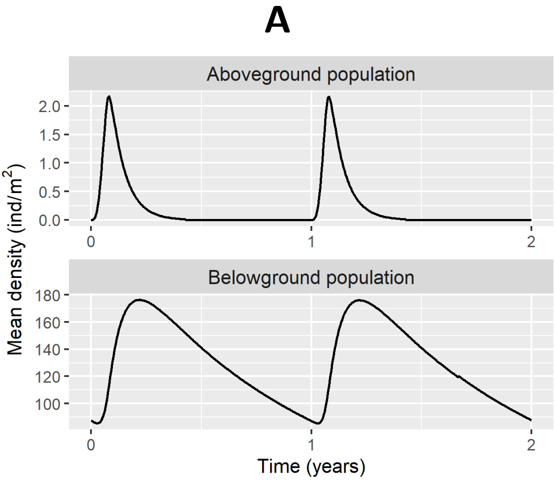
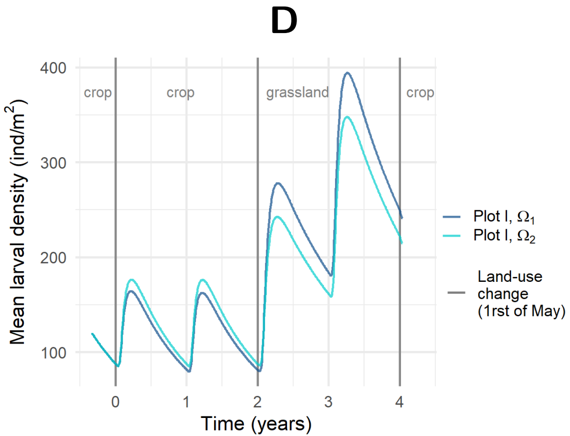
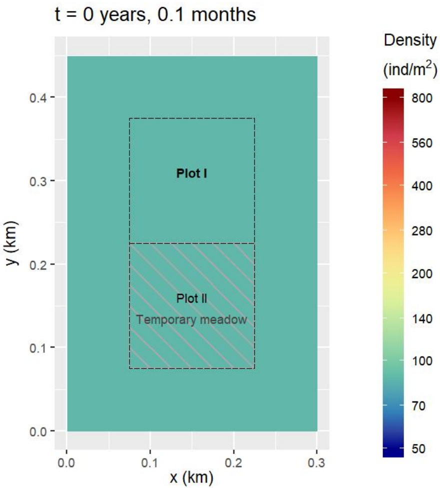


- Stationary dynamics
- Oviposition
- Adult emergence
- Mortality



- ≈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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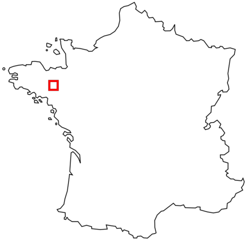
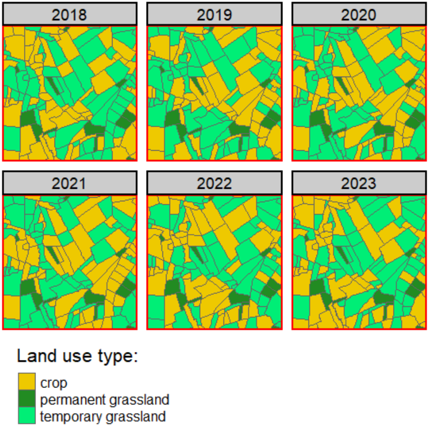
- Exploration of suppressive patterns in realistic agricultural landscapes (i.e. generated under agronomic constraints at the farm or landscape scales)





Thank you for your attention!