A mechanistic model for the population dynamics of invertebrate pests with above-belowground life stages: case study of click beetles and wireworms

Sylvain Poggi

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Sylvain POGGI – INRA – UMR IGEPP – F-3500 Rennes, France

with Mike SERGENT, Ronan LE COINTE, Youcef MAMMERI, Yoann BOURHIS

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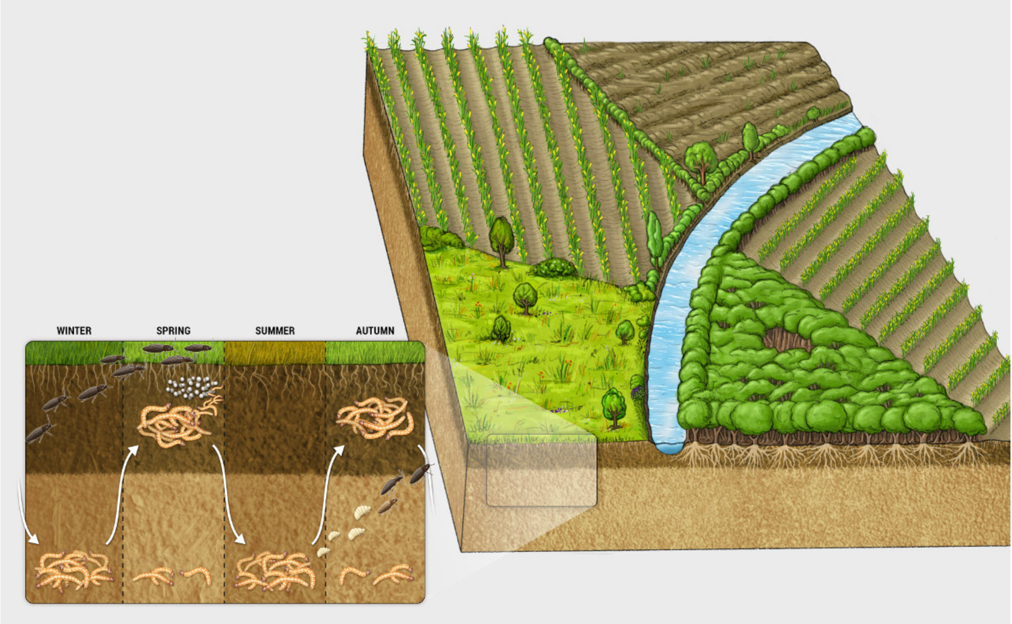
Our premise:

- Arrangement of the landscape (manipulation in space and time) in terms of habitat structure might efficiently contribute to pest regulation
  - Hard to experiment (cost, scale, great expenses for scarce repetitions)

Our approach:

- Combining population dynamics and landscape models can help design novel, environmentally friendly strategies for pest control [1,2]



- STARTAUP (Ecophyto II, 2018-2020)
- SoilServ (ANR, 2016-2020)

1. Parisey N, Bourhis Y, Roques L, Soubeyrand S, Ricci B, Poggi S (2016) Rearranging agricultural landscapes towards habitat quality optimisation: In silico application to pest regulation. *Ecological Complexity* 28:113–122
2. Bourhis Y, Poggi S, Mammeri Y, Le Cointe R, Cortesero AM, Parisey N (2017) Foraging as the landscape grip for population dynamics: A mechanistic model applied to crop protection. *Ecological Modelling* 354:26–36

- A mechanistic approach:
  - Biological and ecological processes are explicitly considered
  - Pest dynamics is considered
  - Space is explicit
  - Measurement error and uncertainty (inherent to biological monitoring) can be taken into account in this framework

- Our motivation:
  - Better understand the processes driving the population dynamics (at different stages)
  - Disentangle local vs non-local processes (e.g. immigration vs local reproduction, emigration vs mortality)
  - Asses the relative influence of each process on specified responses (sensitivity analyiss)

REACTION-ADVECTION-DIFFUSION MODEL

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

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K: carrying capacity

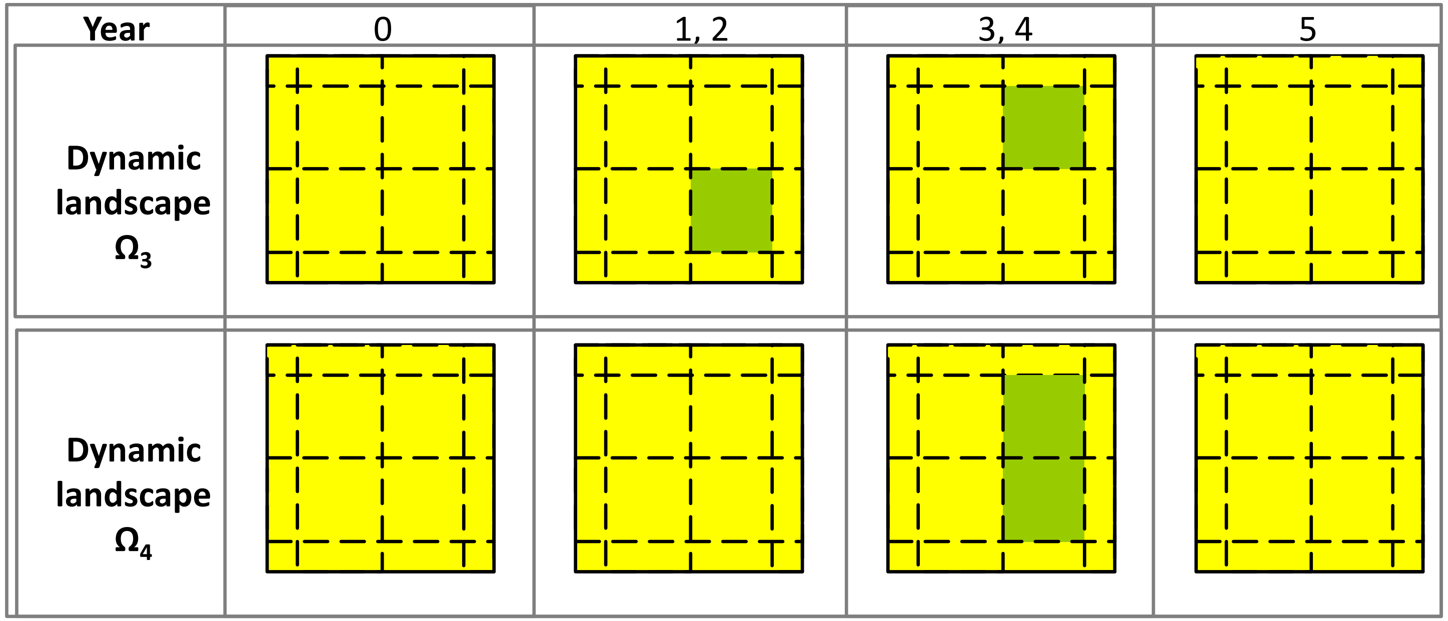
A, B: aboveground and belowground population densities

KEY PROCESSES

- **Emergence**
- **Diffusion**
- **Advection**
- **Mortality**
- **Oviposition**
- **Maturation**

In progress:
realistic agricultural landscapes

But in a first step:
simple analytical landscapes



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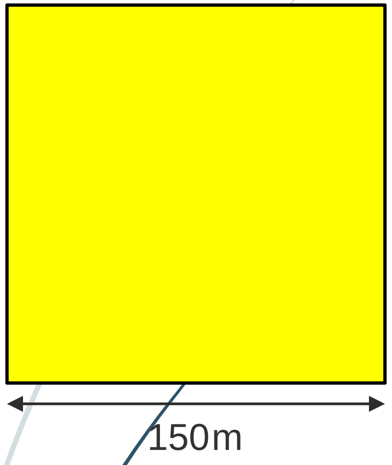
Landscape Ω_0 :

t = 0 to 2 years



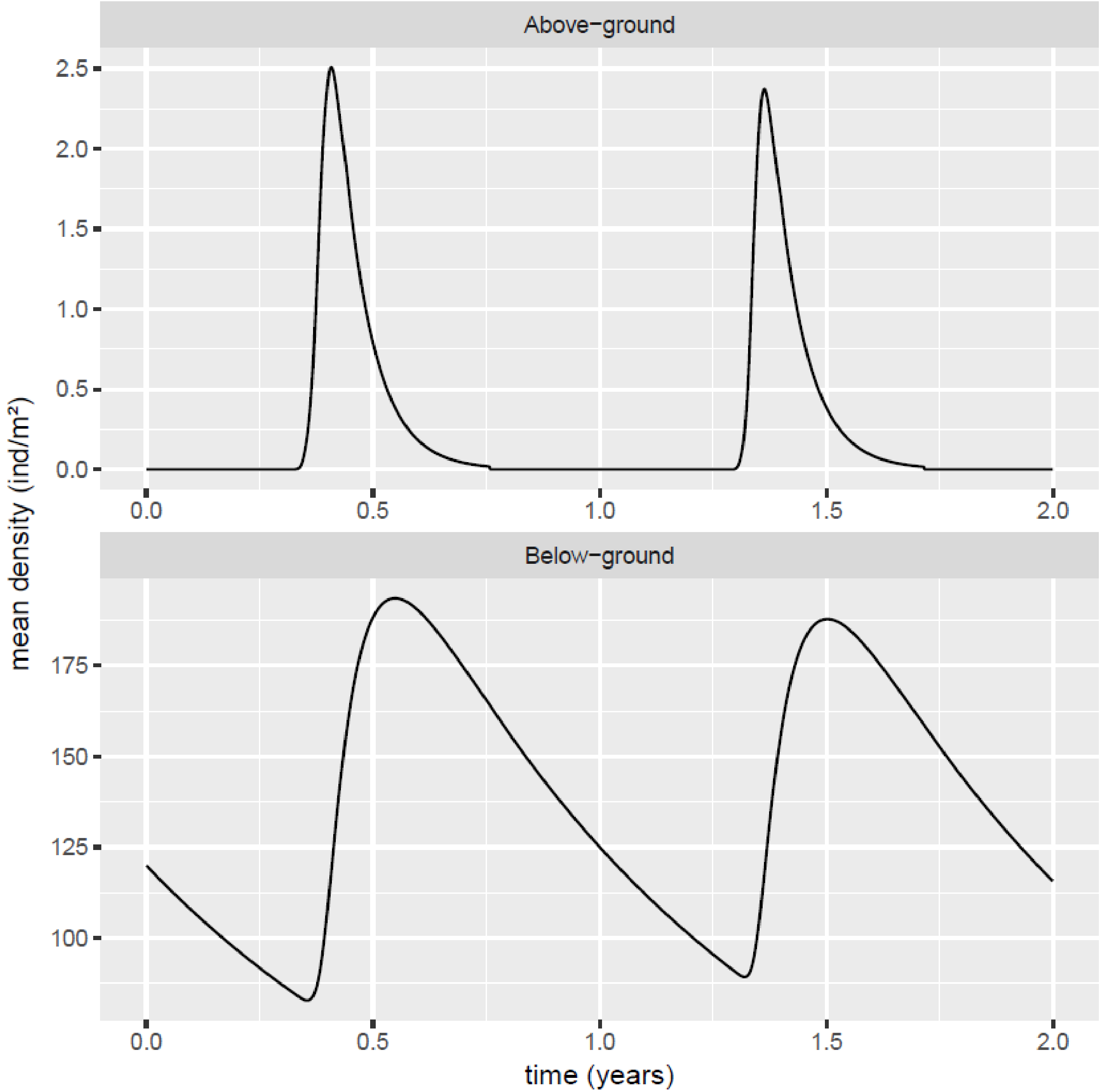
K=120 ind/m²

Homogeneous initial density

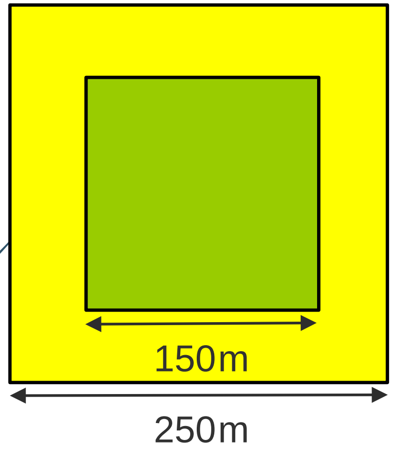
Legend

Cultivated crop

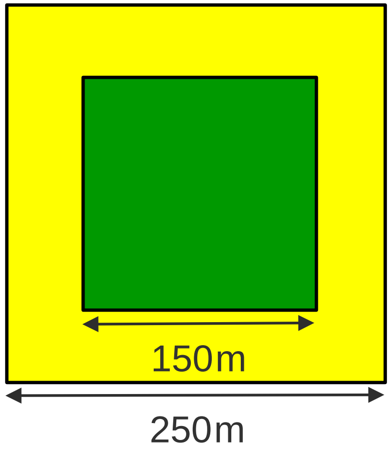
- Stationary dynamics
- Density-dependent mortality
- Adult emergence
- Oviposition



Landscape Ω_1



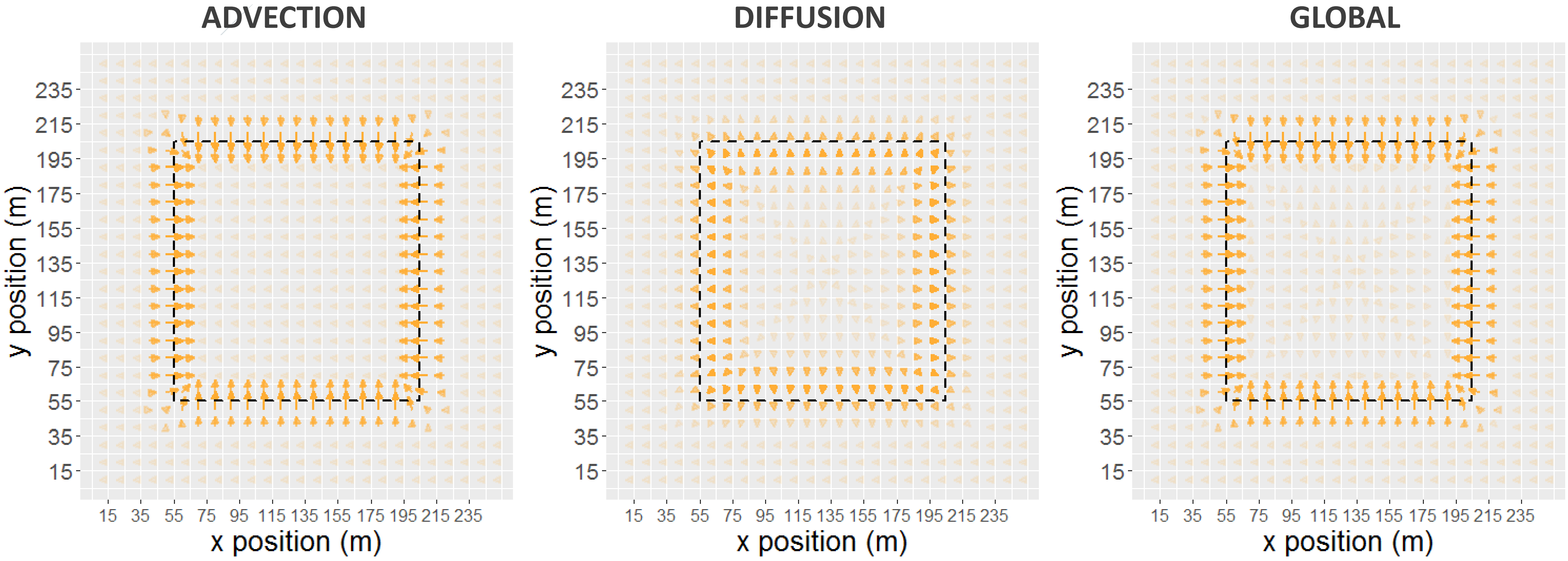
Landscape Ω_2



Legend

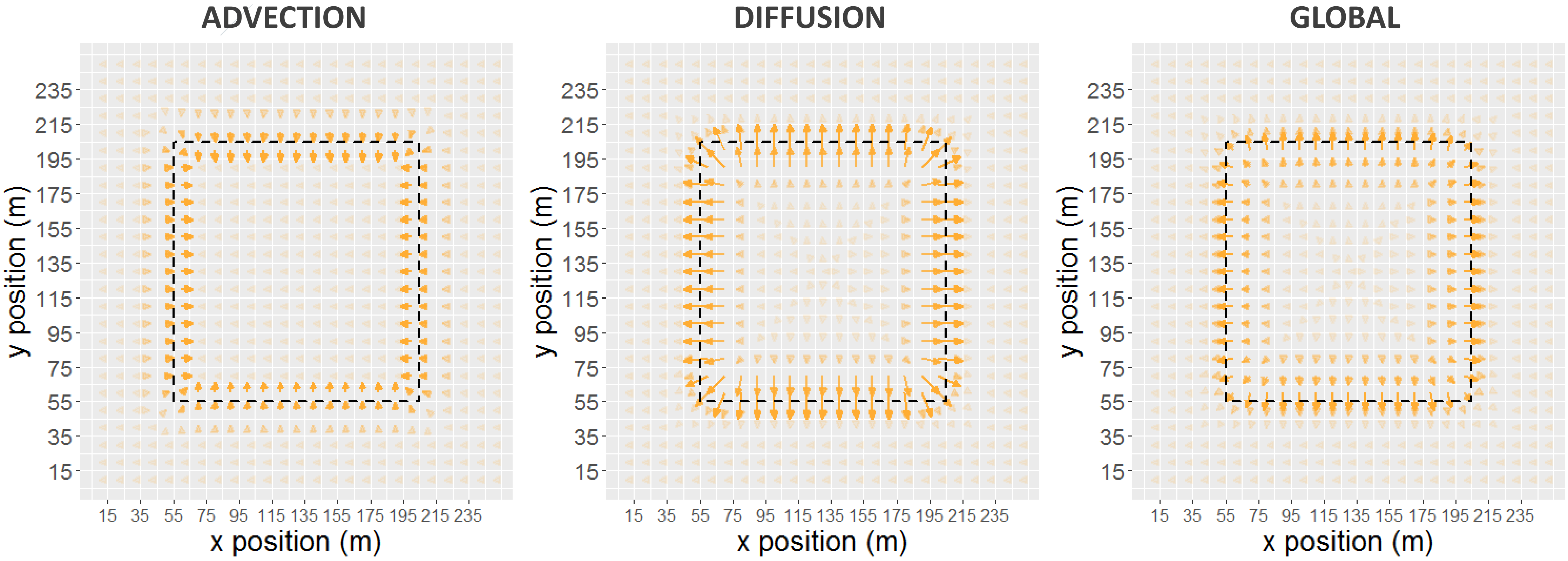
- Cultivated crop (K = 120 ind/m²)
- **Temporal** grassand (K = **160 ind/m²**)
- **Permanent** grassland (K = **2000 ind/m²**)

Landscape Ω_1 :



- Antagonistic effects
- Constant advection for a given Ω
- Time-varying diffusion
- Global movement depends on (i) land uses and (ii) density

Landscape Ω_2 :



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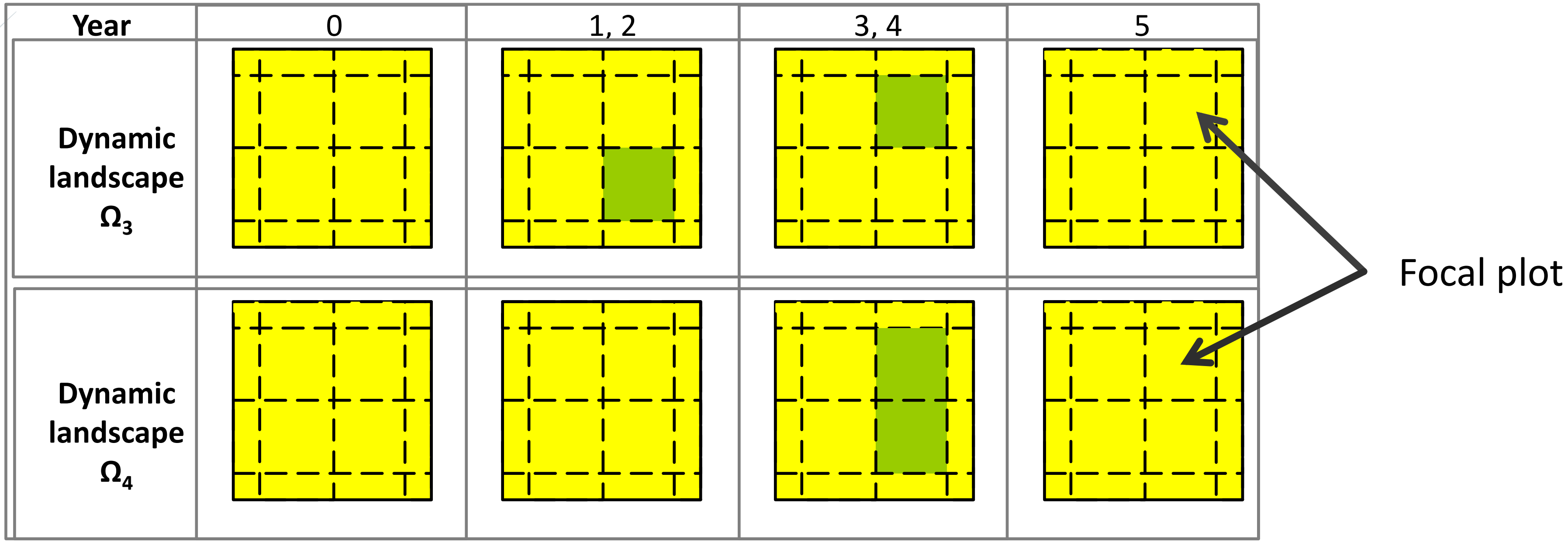
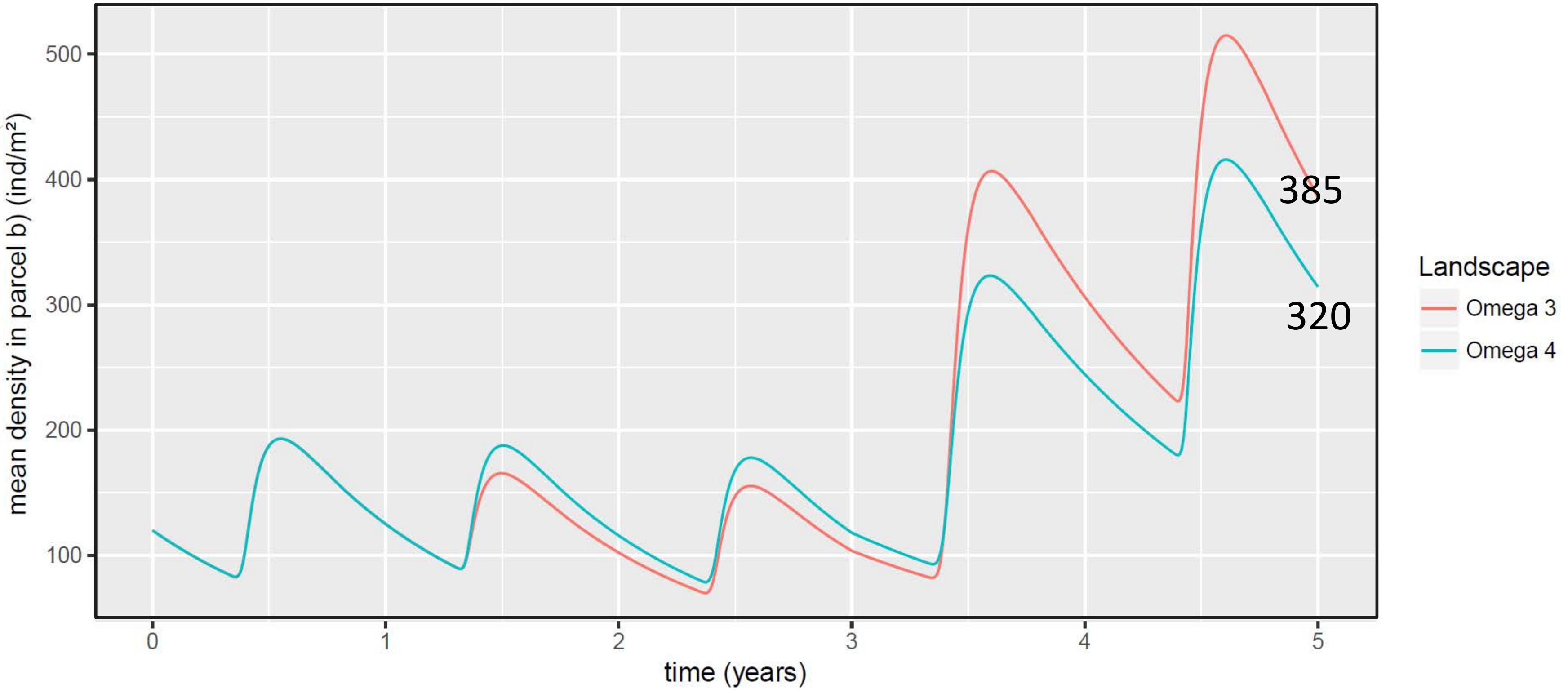


- Dynamic landscape (5 years)
- 2 land uses (crop, temporary grassland)
- Homogeneous initial density (120 ind/m²)
- Same history on the focal plot, same composition in the landscape but different spatiotemporal patterns



- 20% difference in density at year 5
- Results of diffusive and advective movements over the time
- Parameter dependent

- Local habitat quality is **dynamic** (grassland : source-sink)
- The effects of history and landscape context on wireworm density is complex, thus bolstering our premise and our modelling approach
- Our results foster the assessment of carrying capacity related to different agricultural systems (i.e. conservation agriculture, etc.) $\rightarrow$ investigation of scenarios & strategies

- Climate: ElatPro DSS as a possible module
- Historical and georeferenced data $\rightarrow$ qualitative validation of the model
- Longer term perspective: combine a socio-economic module

Thank you!