



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

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

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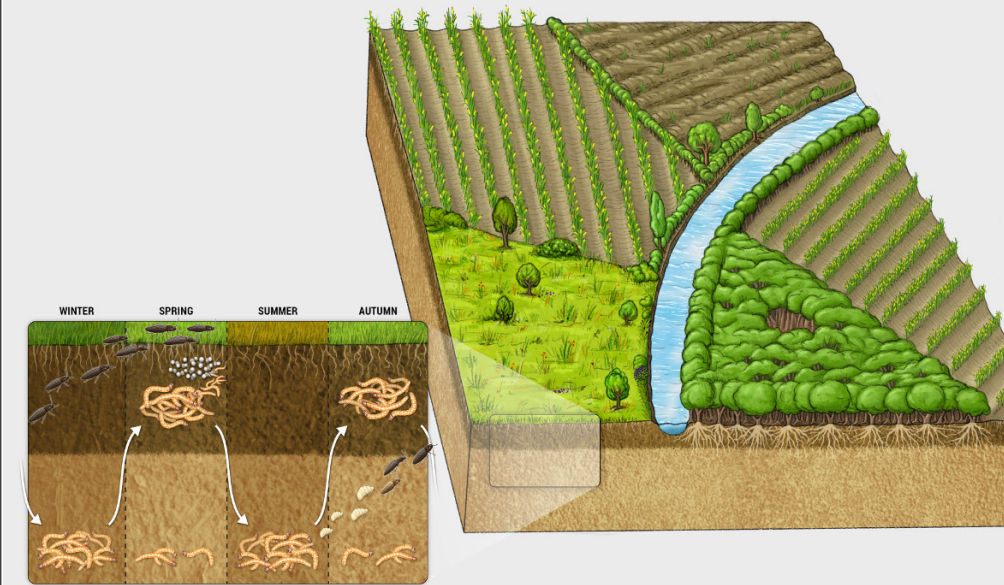
Our premise:

- 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}

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



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

■ 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

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

4

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

K: carrying capacity

A, B: aboveground and belowground population densities

KEY PROCESSES

Emergence

Diffusion

Advection

Mortality

Oviposition

Maturation

5

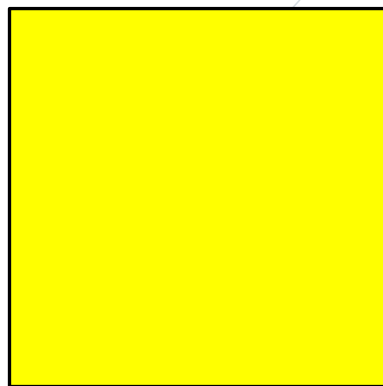
In progress:
realistic agricultural
landscapes



But in a first step:
simple analytical
landscapes

Year	0	1, 2	3, 4	5
Dynamic landscape Ω_3				
Dynamic landscape Ω_4				

6

Landscape Ω_0 : $t = 0$ to 2 years

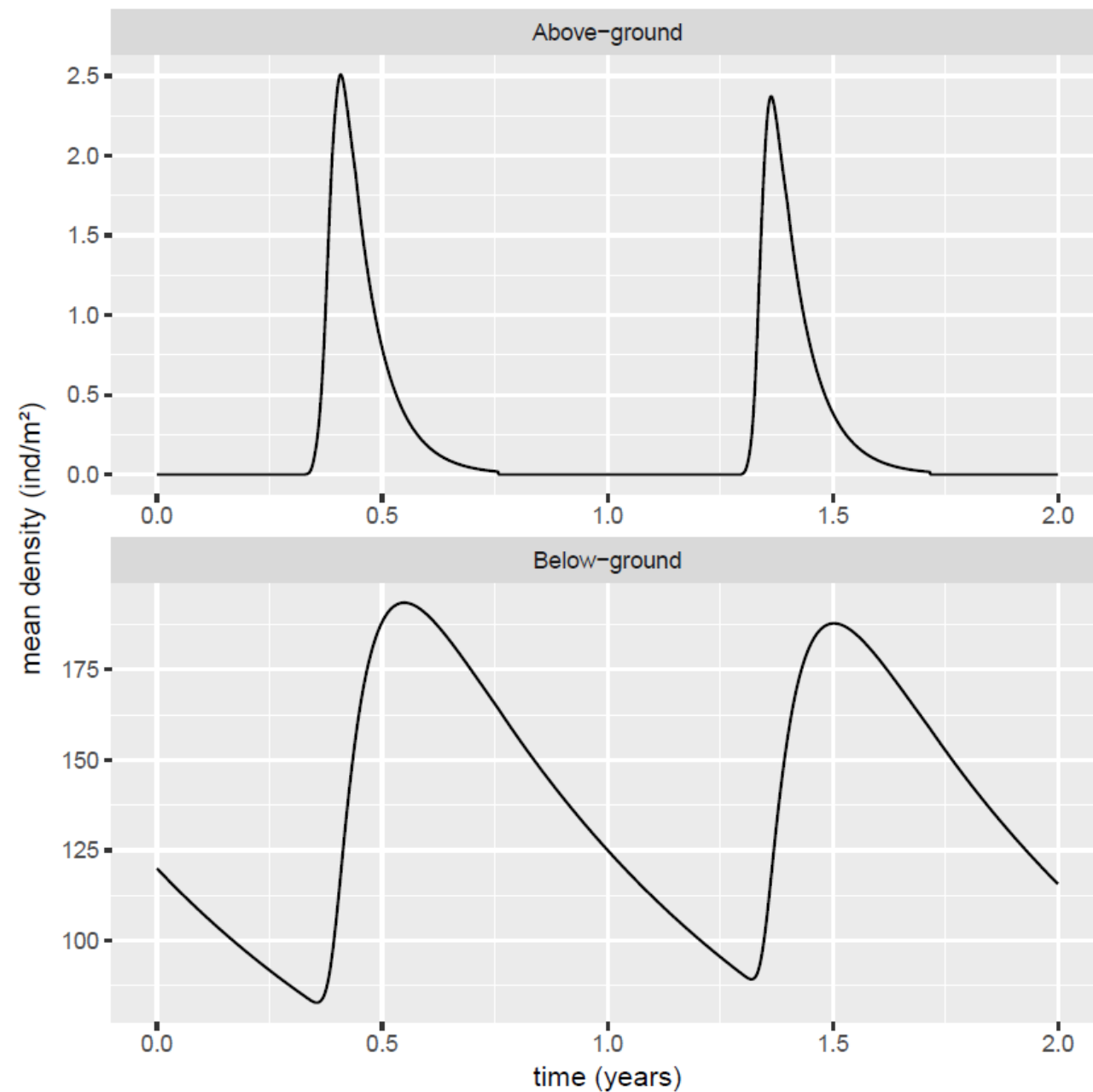
150m

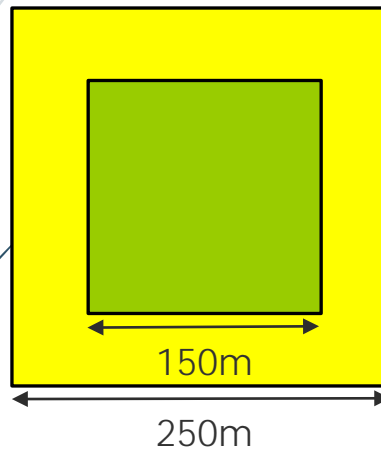
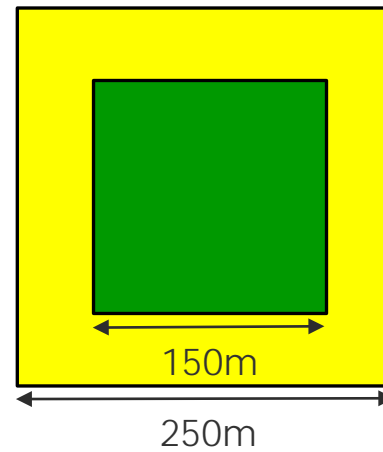
 $K=120$ ind/m²

Homogeneous initial density

Legend Cultivated crop

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



Landscape Ω_1 Landscape Ω_2 

Legend

 Cultivated crop ($K = 120 \text{ ind/m}^2$)

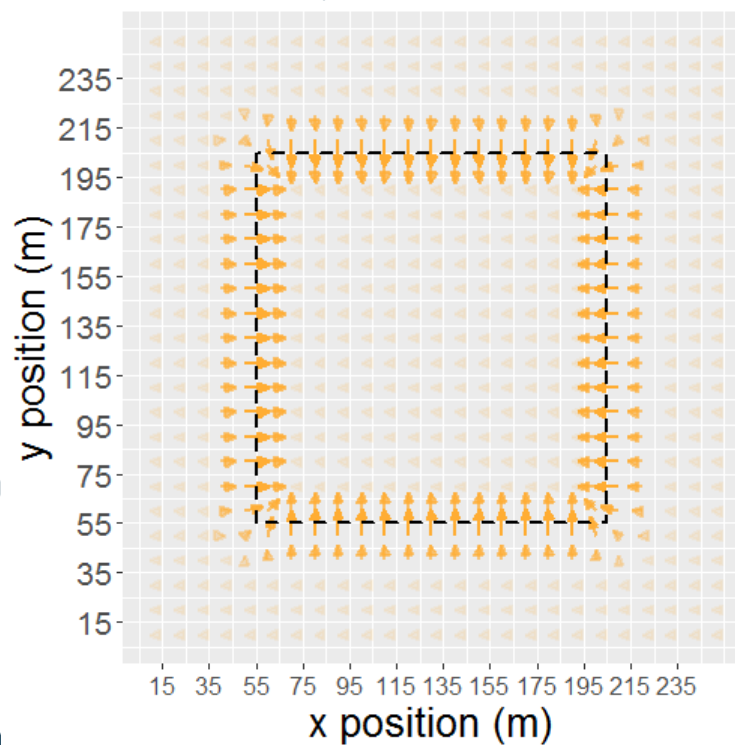
 **Temporal** grassland
($K = 160 \text{ ind/m}^2$)

 **Permanent** grassland
($K = 2000 \text{ ind/m}^2$)

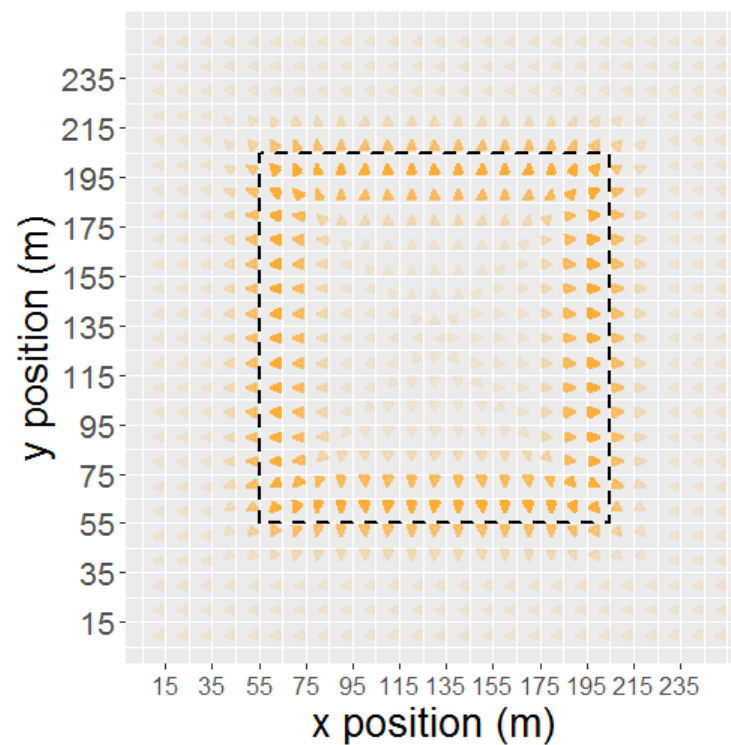
8

Landscape Ω_1 :

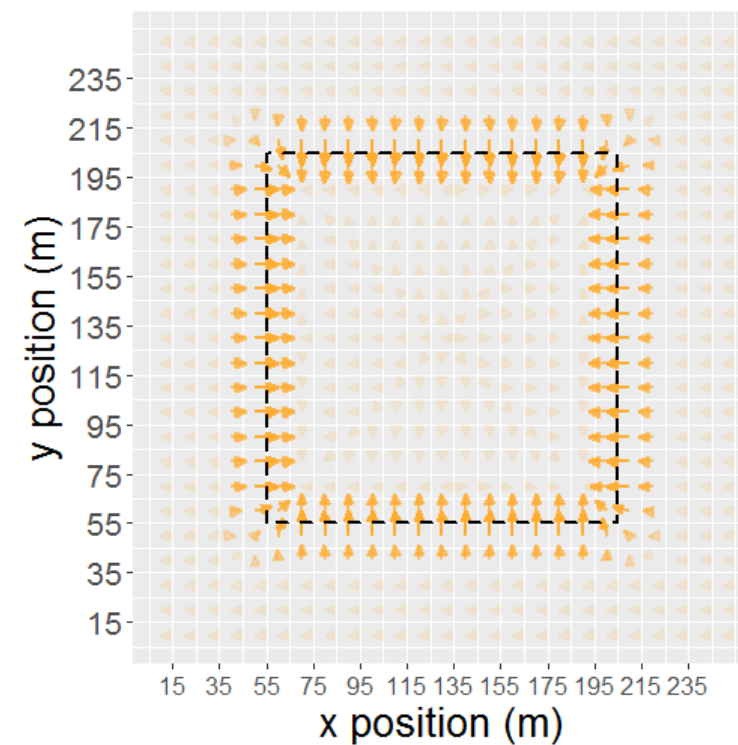
ADVECTION



DIFFUSION



GLOBAL



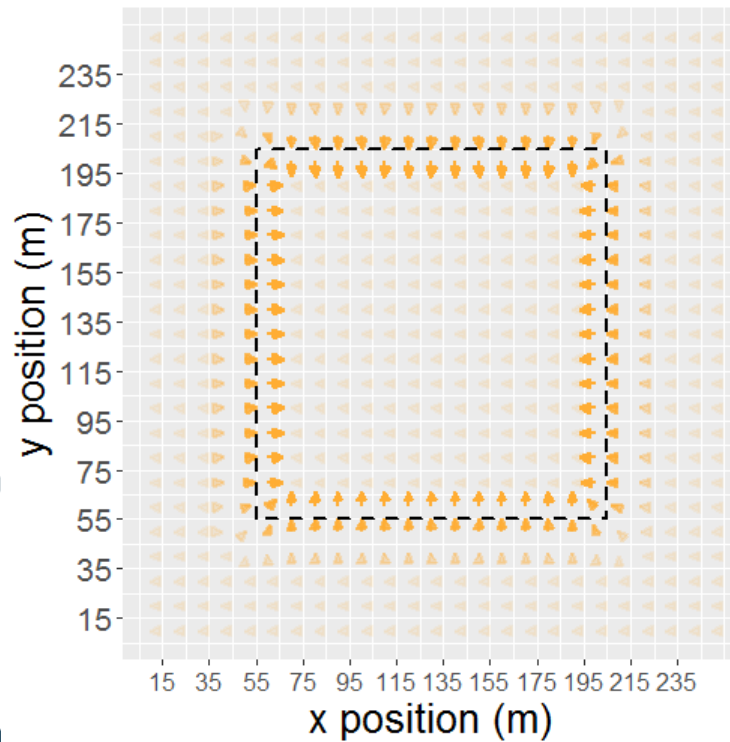
- Antagonistic effects
- Constant advection for a given Ω
- Time-varying diffusion

- Global movement depends on (i) land uses and (ii) density

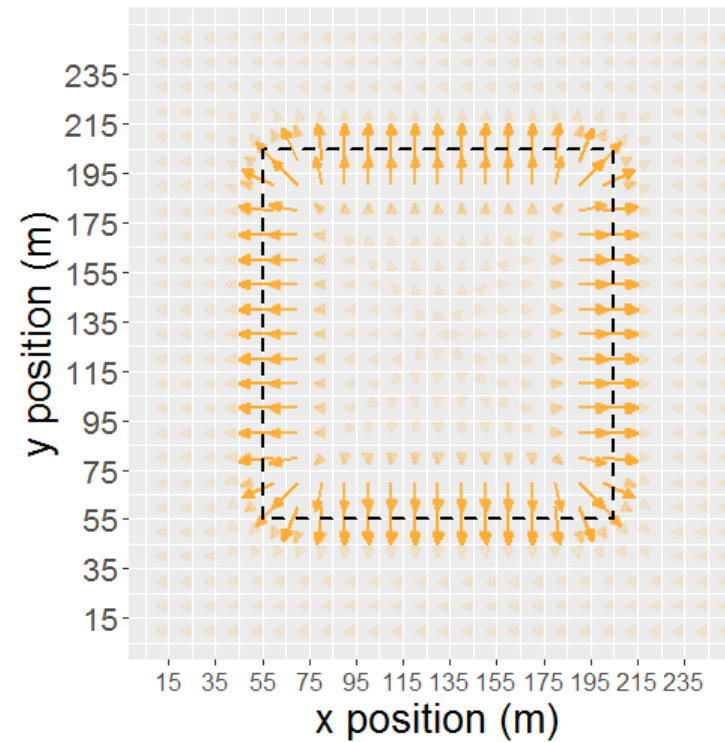
9

Landscape Ω_2 :

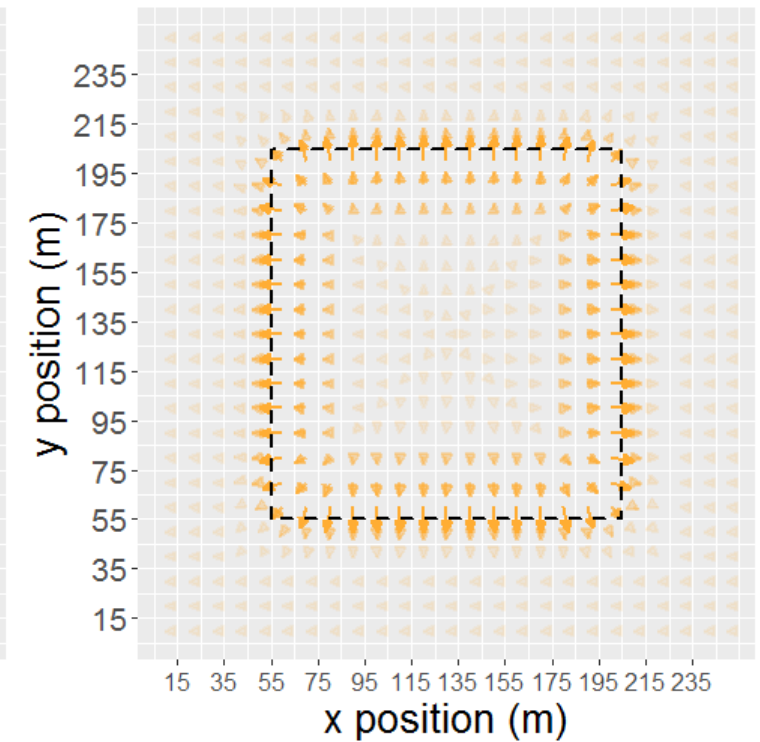
ADVECTION



DIFFUSION

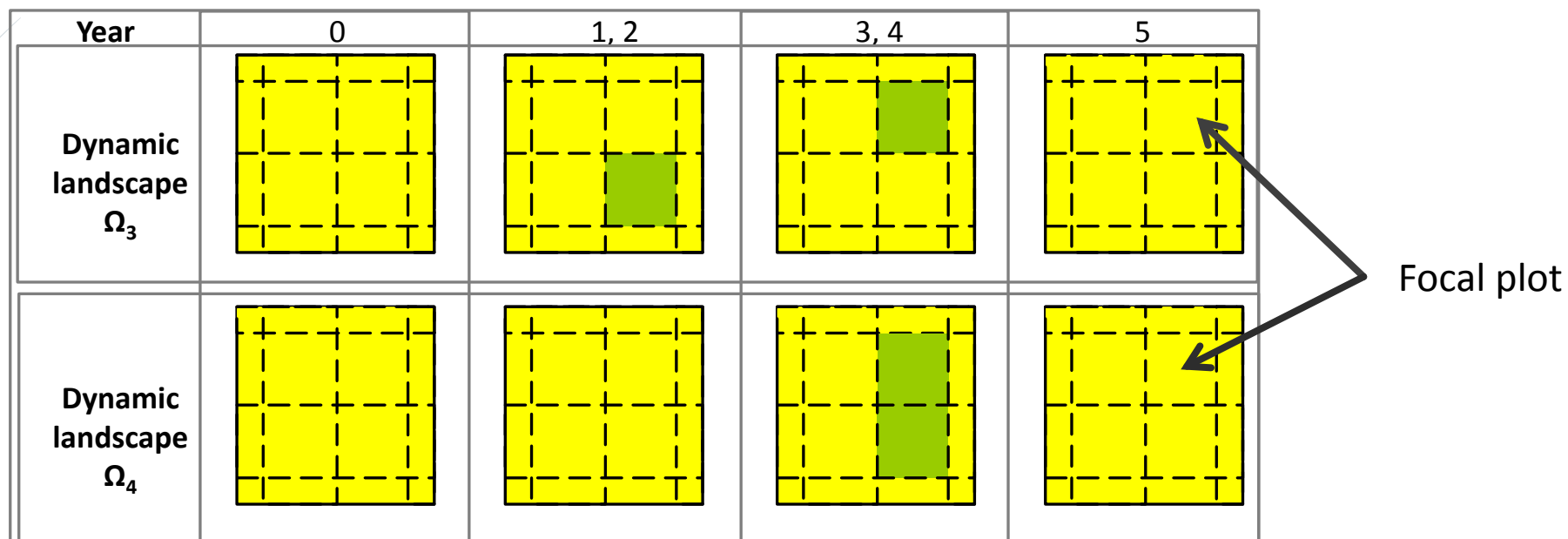


GLOBAL



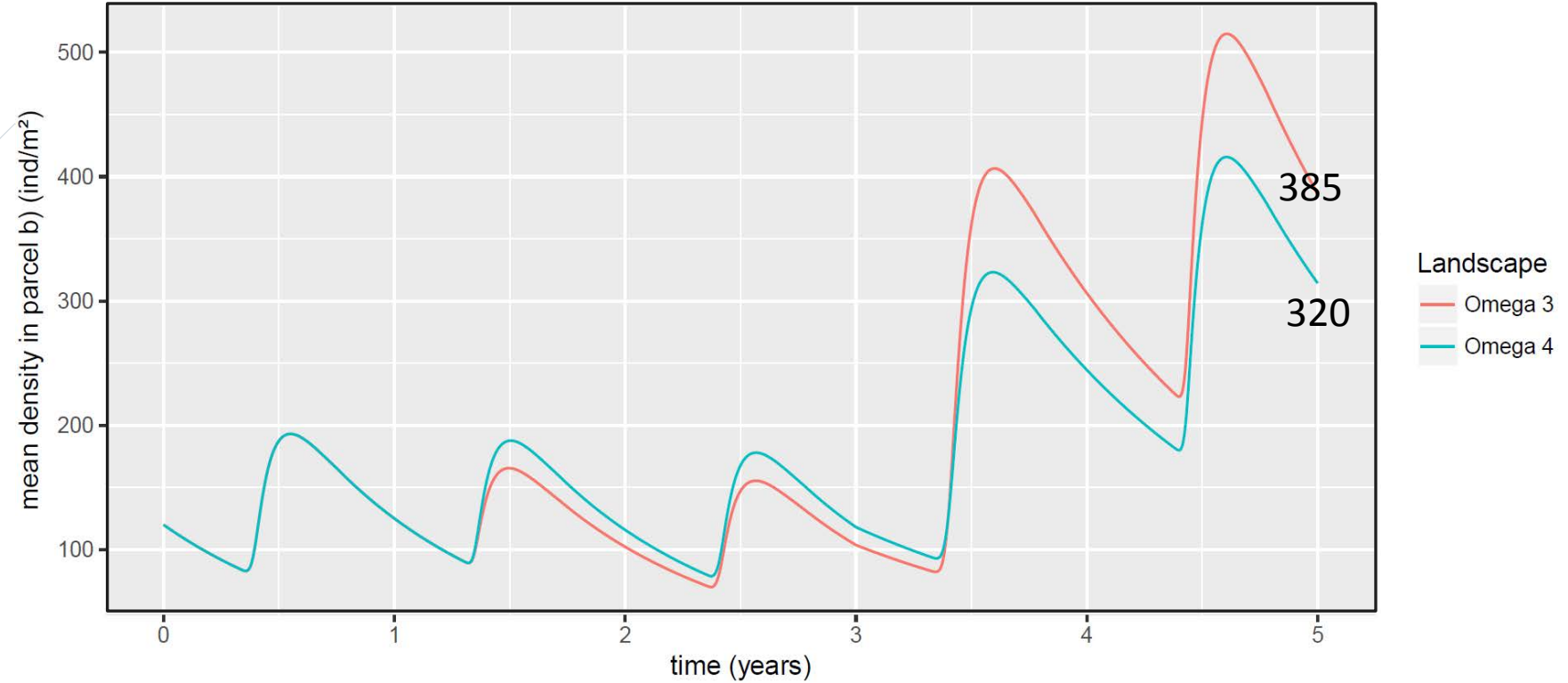
- Antagonistic effects
- Constant advection for a given Ω
- Time-varying diffusion

- Global movement depends on (i) land uses and (ii) density



- 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

11



- 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.) → investigation of scenarios & strategies
-
- Climate: ElatPro DSS as a possible module
 - Historical and georeferenced data → qualitative validation of the model
 - Longer term perspective: combine a socio-economic module

Thank you!