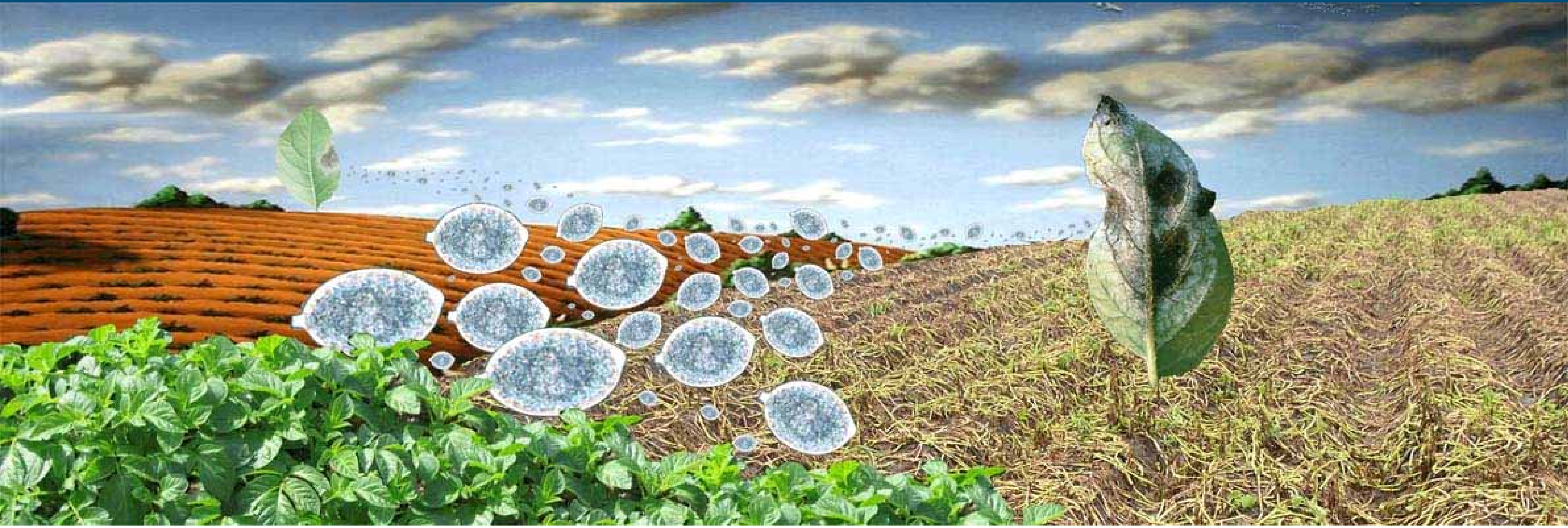
Invasion of a virulent *Phytophthora infestans* strain at the landscape level; does spatial heterogeneity matter?

P. Skelsey , G. J. T. Kessel, W. A. H. Rossing, and W. van der Werf .



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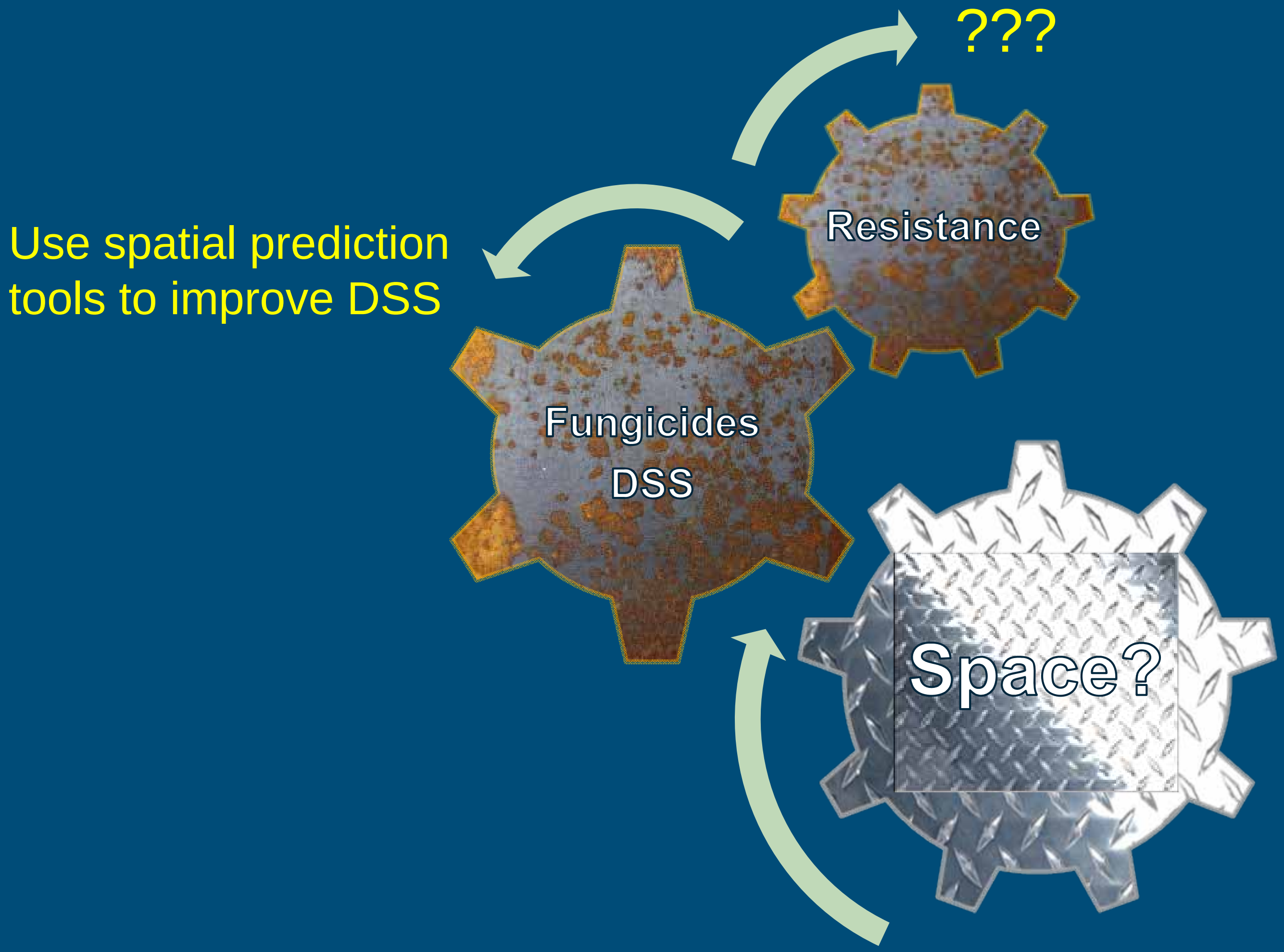
Potato late blight management



Rationale

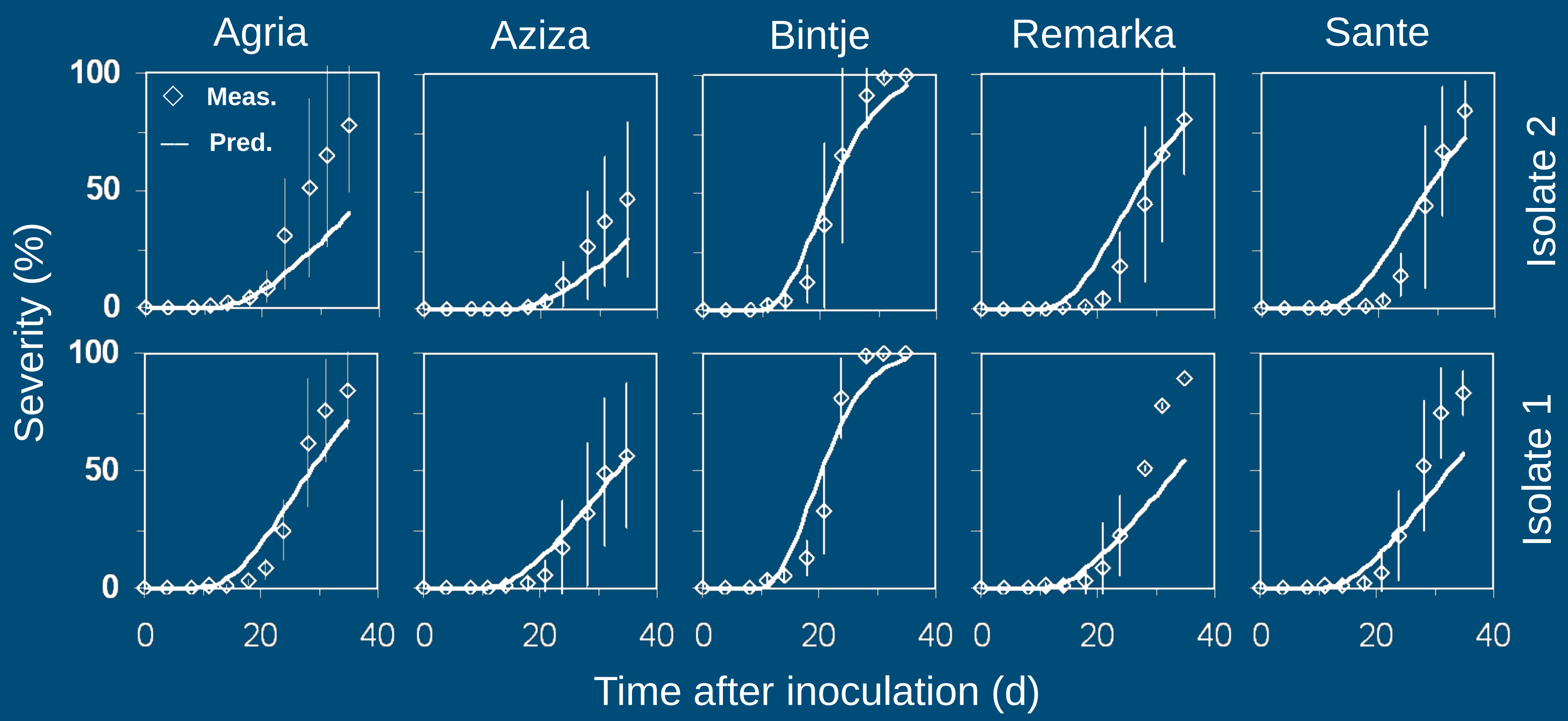
- Huge €€€ effort to produce new resistant varieties: are there optimal landscape designs for deploying them?
- Is the rate of invasion of a new, resistance breaking genotype of *Phytophthora infestans* higher in some landscapes and lower in others?
- Alternatively: can we design landscapes to lessen the impact of resistance breakthrough?
- We wanted to know which landscape characteristics have most impact on epidemic development.

Approach

- Theoretical studies of *P. Infestans* invasions in virtual landscapes.
- Based on proven models of epidemic processes:
  - disease development *in planta*;
  - spore transport;
  - spore survival.
- Multi-scale (plant / field / landscape) epidemic simulator.

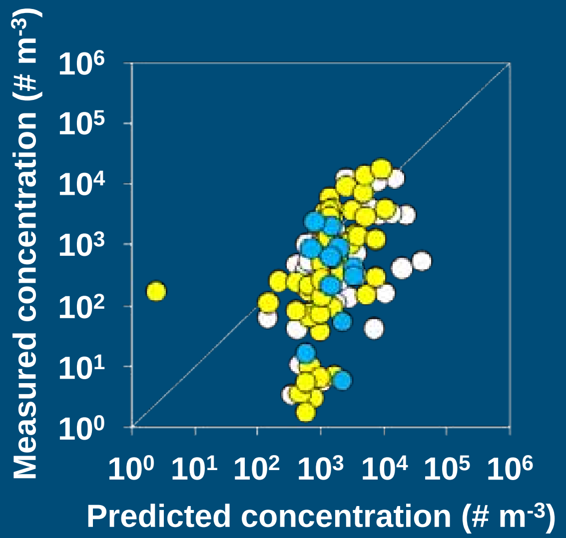
Potato late blight model – *field scale*

- Host and pathogen life cycles, spore dispersal, fungicides, weather.
- Refined and tested the model using field and laboratory data.

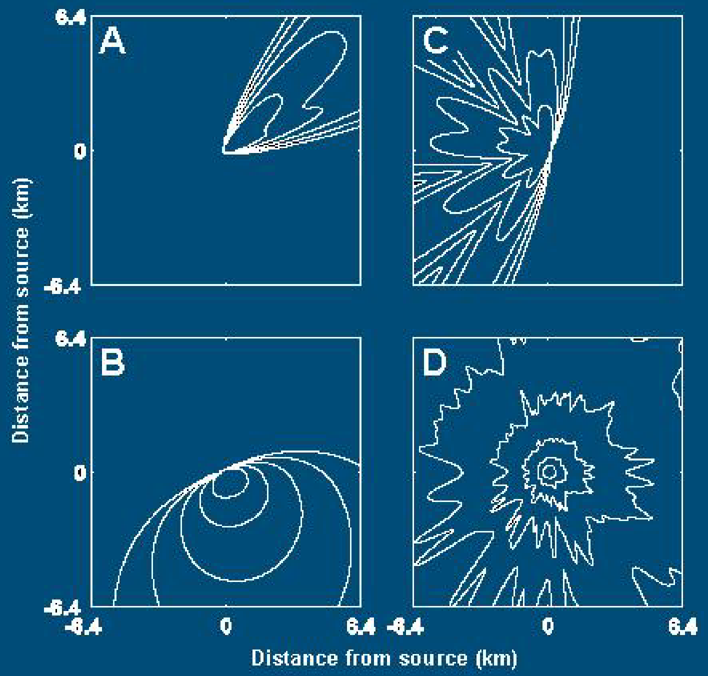


Spore dispersal between fields

- Atmospheric dispersion model – *heavy physics!!!*
- Simulate effects of wind speed, direction, turbulence, deposition.



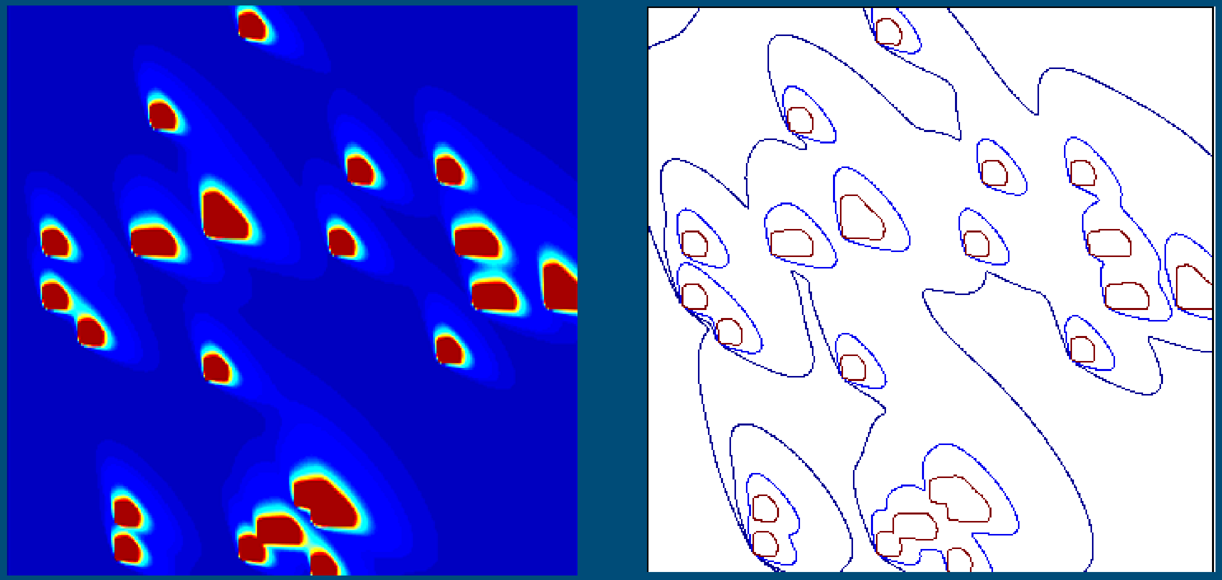
Dispersal from a single field over 8 hours



Spore dispersal between fields

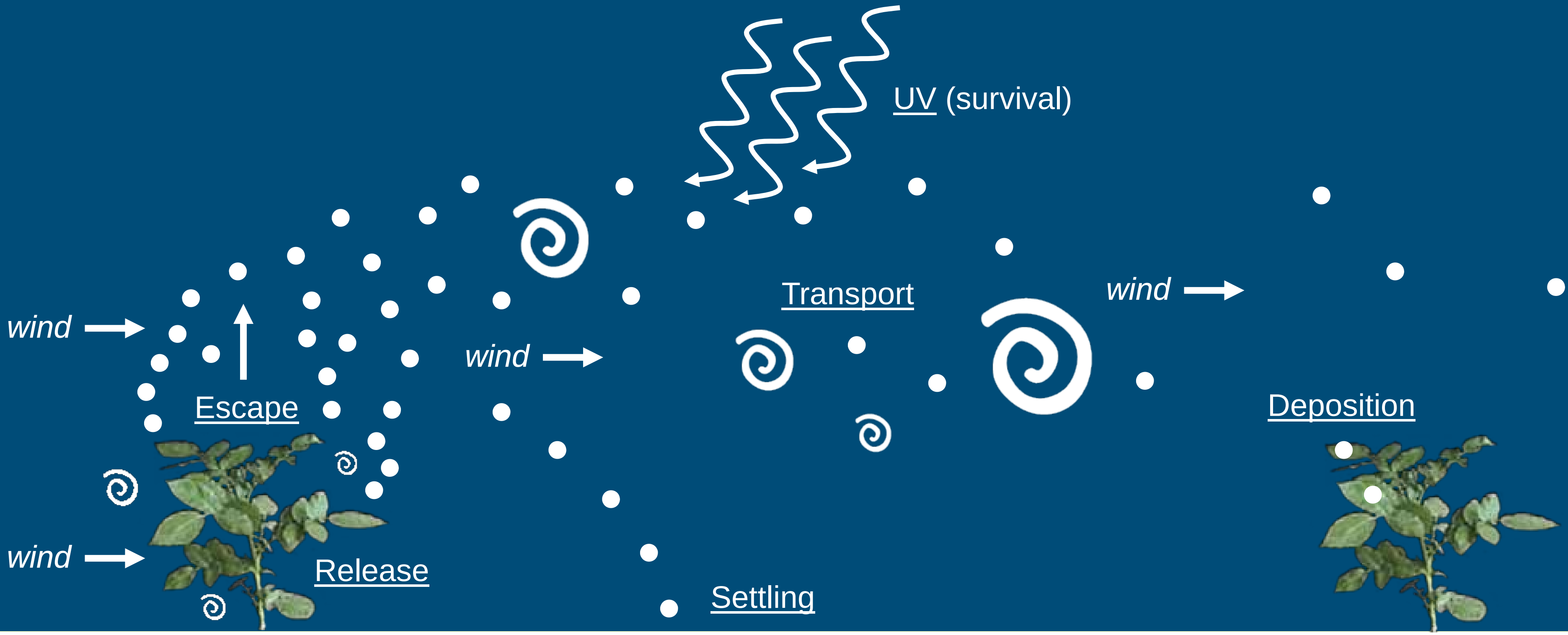
- Fully analytical, partial reflection Gaussian plume model.
- Simulate effects of wind speed, direction, turbulence, deposition.

Contour plots at landscape scale

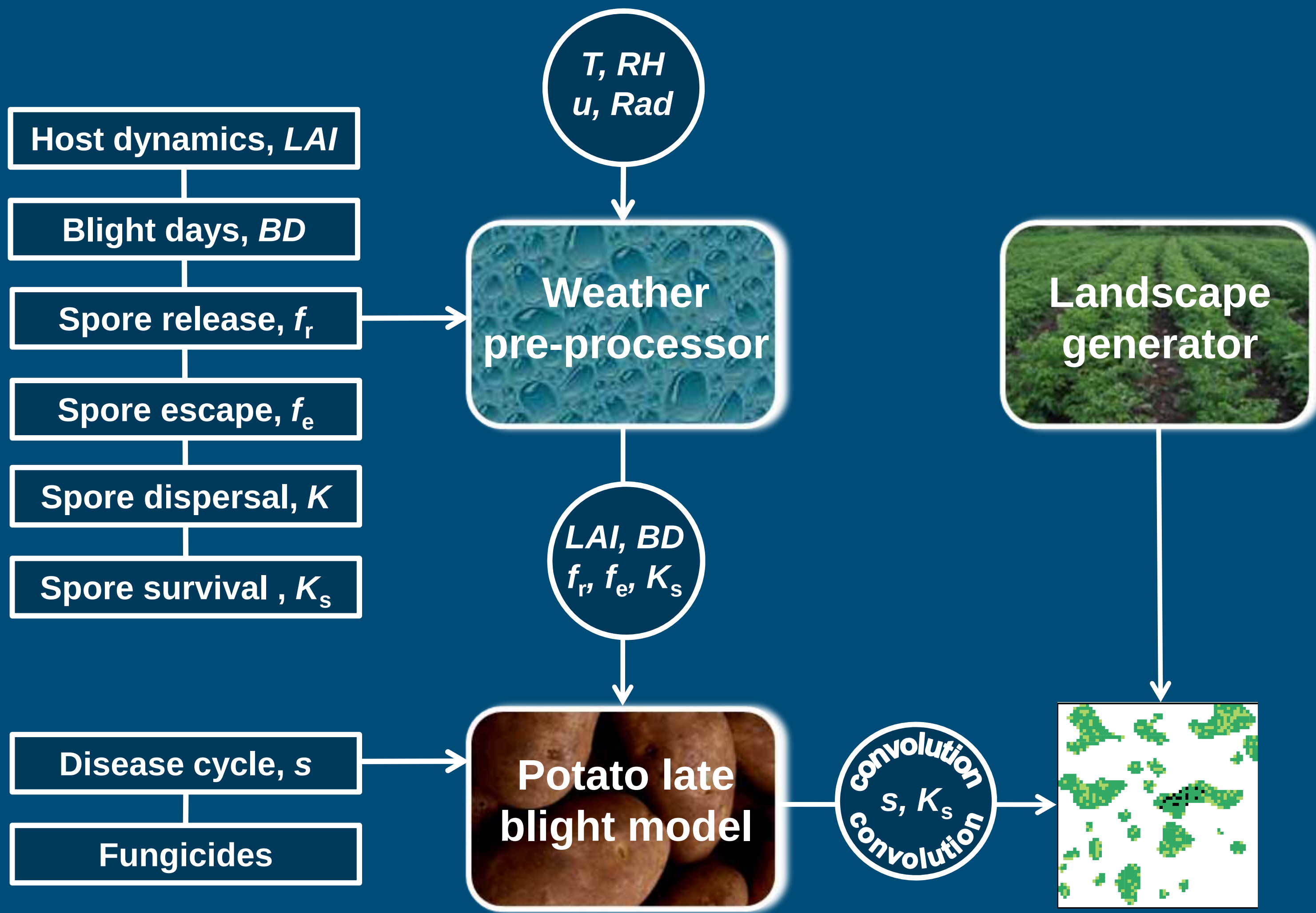


Aerobiology

- We included other proven models of the aerial component of the disease cycle.



Simulation framework



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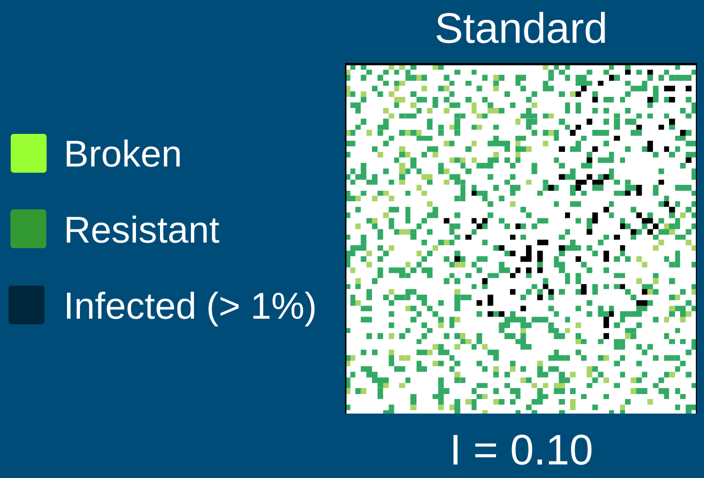
Scenario studies

- Landscapes are 6.4 x 6.4 km.
- Resistant potatoes, susceptible potatoes, and non-host areas.
- Landscapes vary in: (i) proportion of potato; (ii) number of varieties; (iii) field size; (iv) field aggregation; (v) between-field versus within-field mixing of varieties.
- Protectant and curative fungicides.
- Simulate a breakthrough of resistance, i.e., emergence of a single new, aggressive pathogen strain = 1 ‘susceptible’ potato variety per landscape. ‘Resistant’ varieties can still be infected.
- Generate landscape with random placement of resistant and susceptible fields and inoculate 1 susceptible field. Run for the whole season. Repeat for 10 different random maps x 10 different growing seasons and average our results over all iterations.

Example epidemics - *standard*

- ¼ potato / ¼ broken (3 R) / 1 ha / randomly distributed / 1 variety per field



Increase the amount of potato

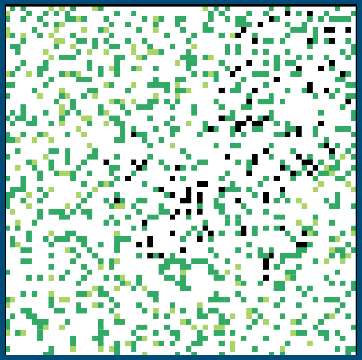
- All potato / ¼ broken (3 R) / 1 ha / randomly distributed / 1 variety per field

Broken

Resistant

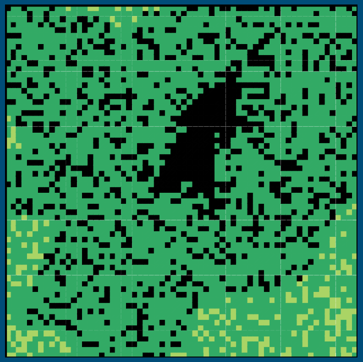
Infected (> 1%)

Standard

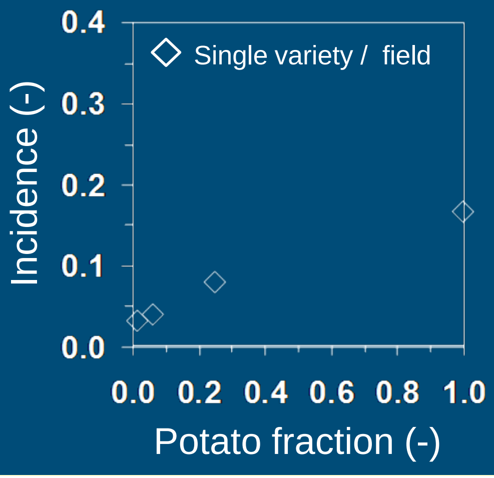


I = 0.10

All potato



I = 0.25



- Full set of results: 10 years weather x 10 maps

Decrease the number of varieties

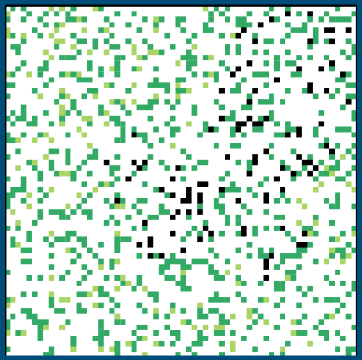
- ¼ potato / 1 variety / 1 ha / randomly distributed / 1 variety per field

Broken

Resistant

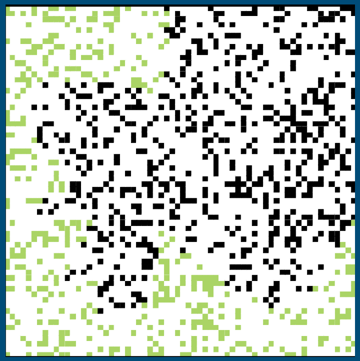
Infected (> 1%)

Standard

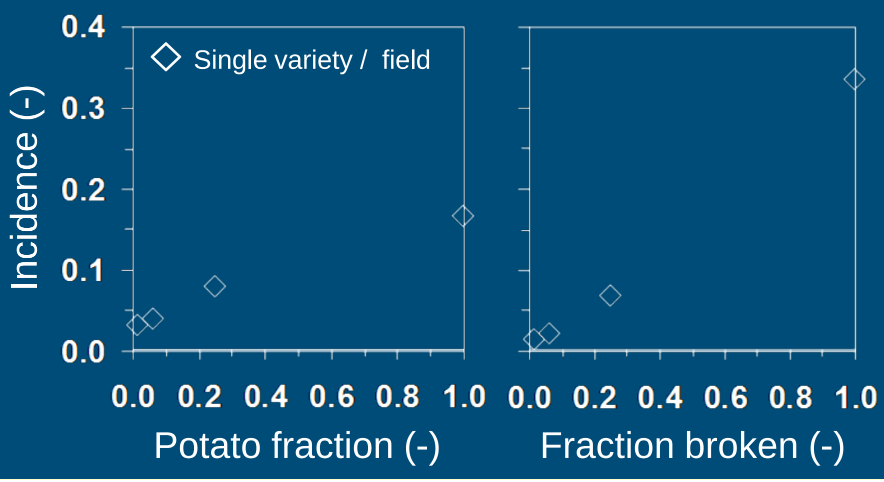


I = 0.10

1 variety – broken

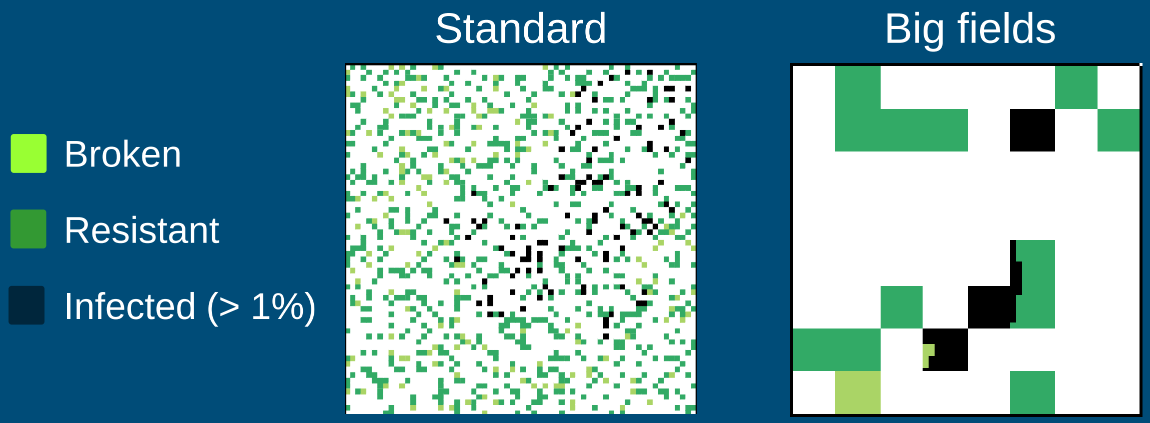


I = 0.61



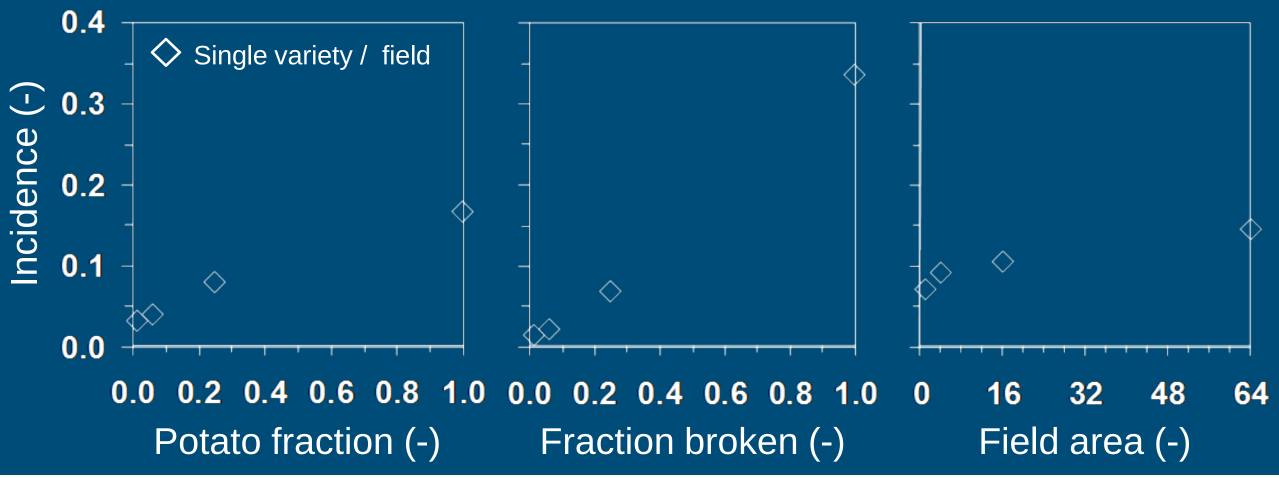
Increase field size

- ¼ potato / ¼ broken (3 R) / 64 ha / randomly distributed / 1 variety per field



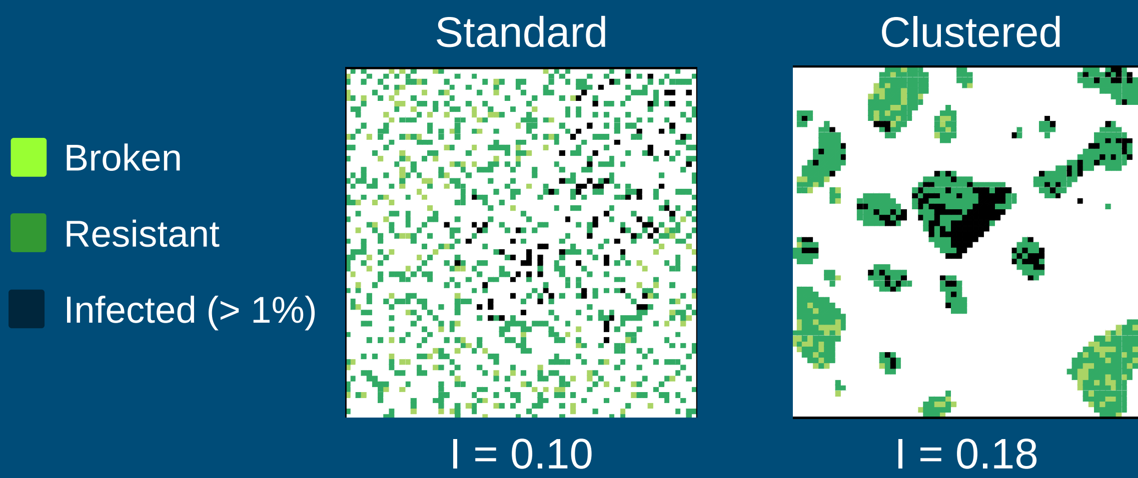
I = 0.10

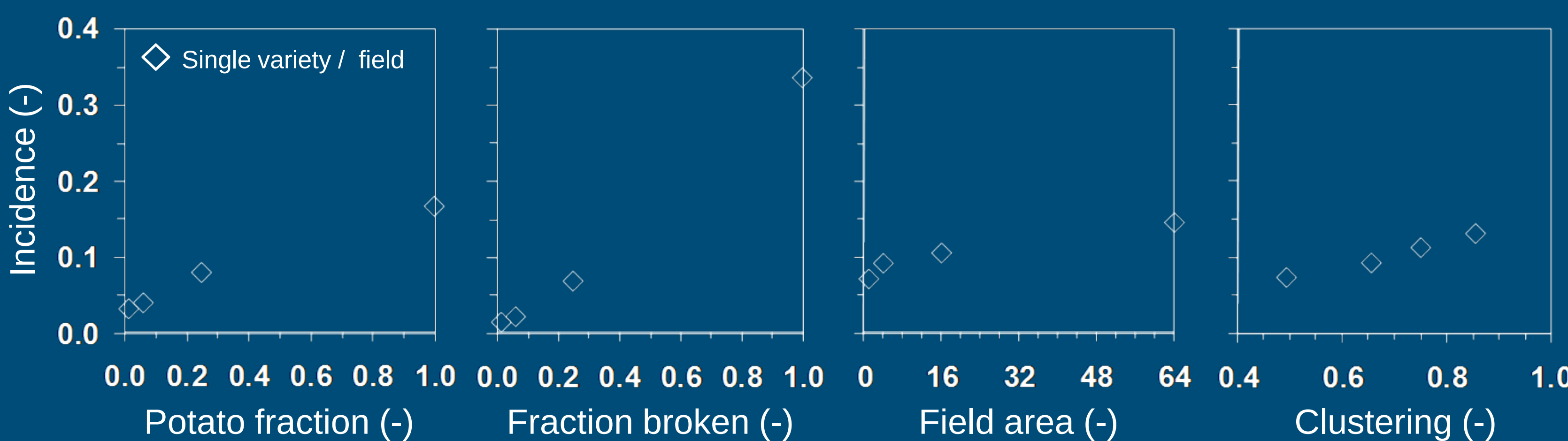
I = 0.22



Increase field aggregation

- ¼ potato / ¼ broken (3 R) / 1 ha / clustered / 1 variety per field





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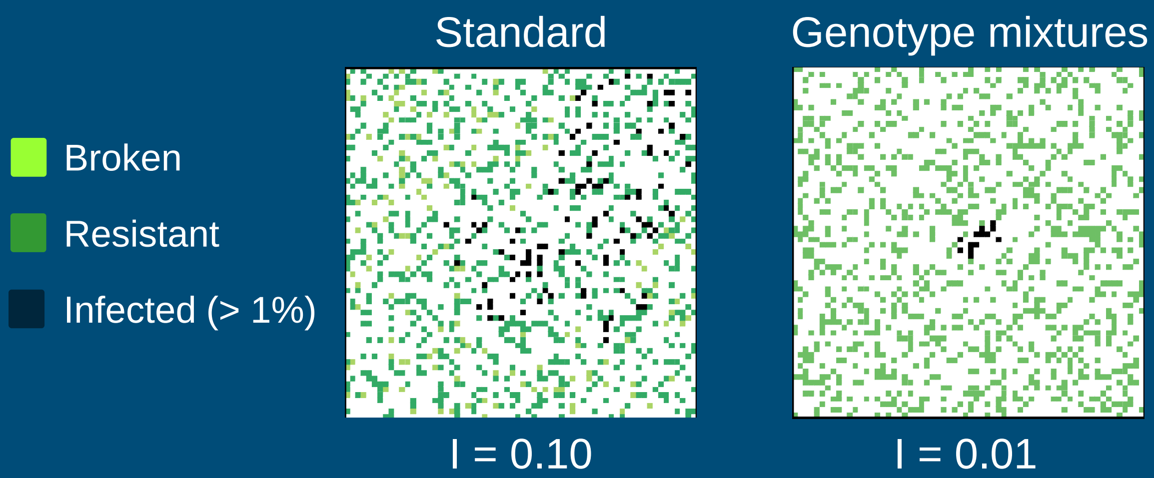
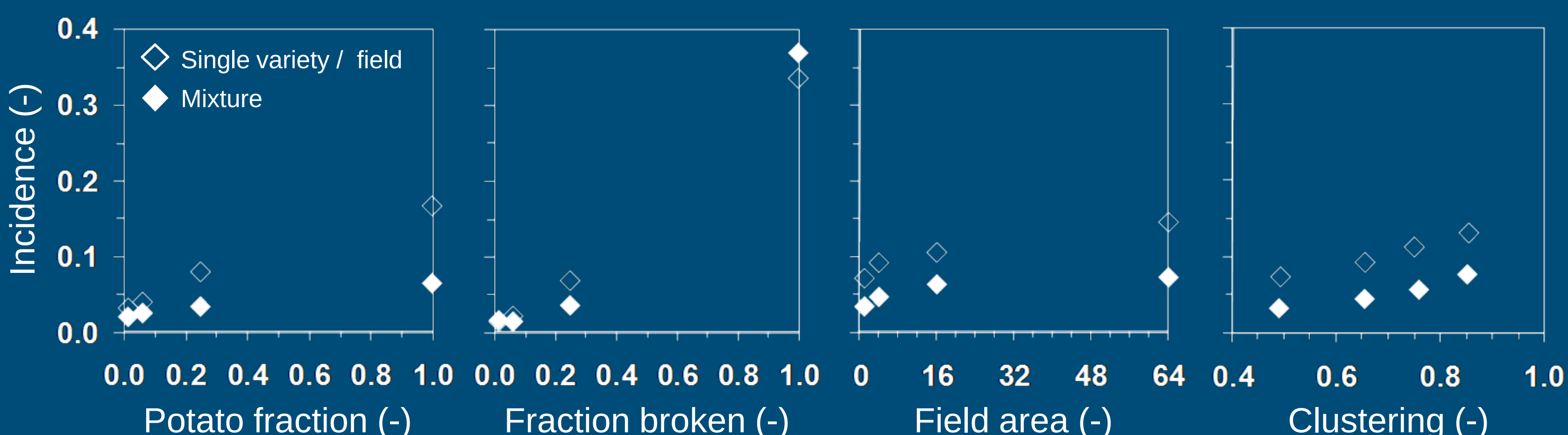
Within-field mixing

- ¼ potato / ¼ broken (3 R) / 1 ha / randomly distributed / genotype mixtures





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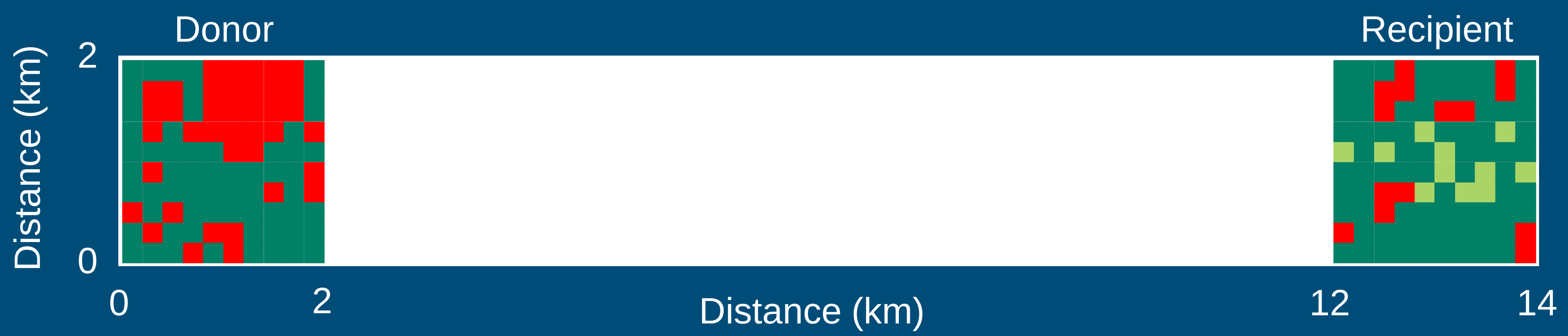
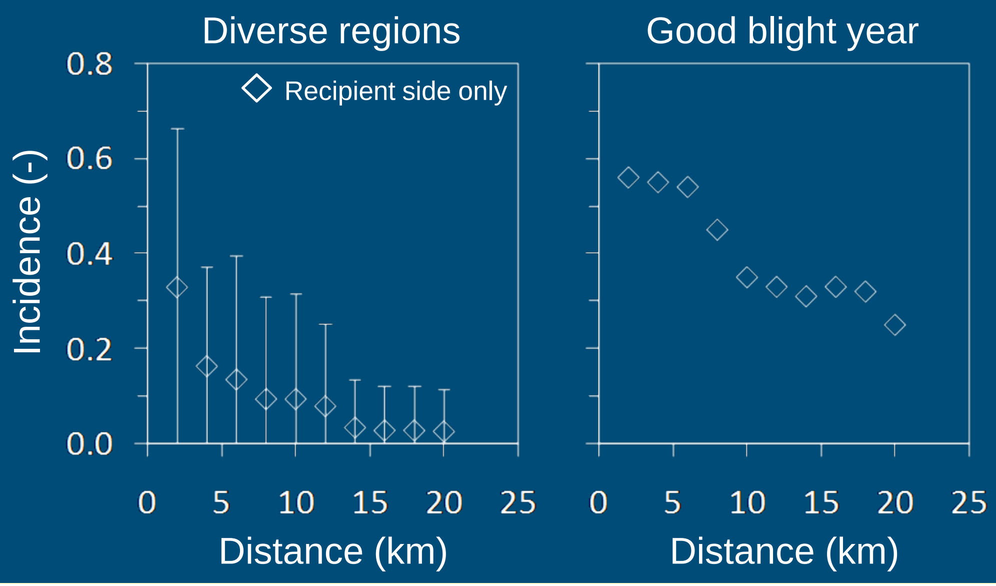
Separation of diverse regions

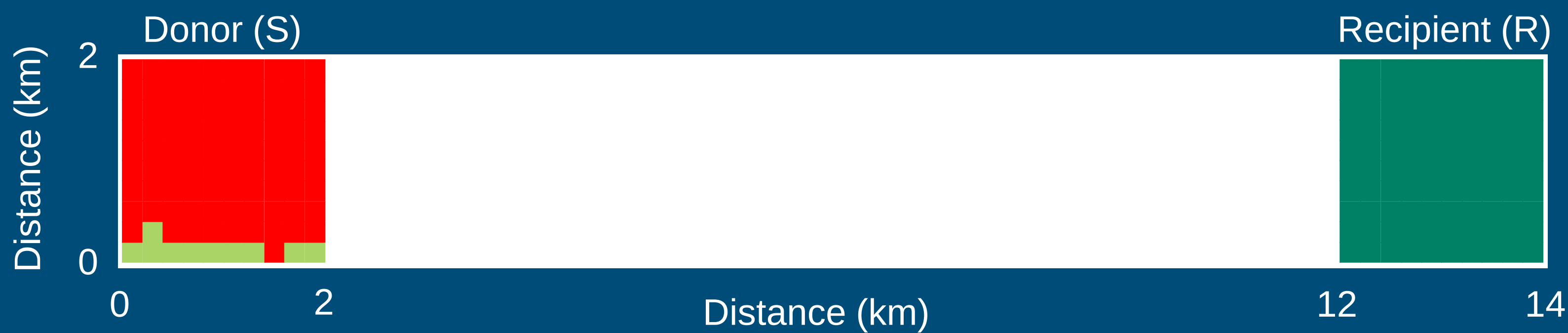
- Can we create spatial barriers that completely prevent spread?

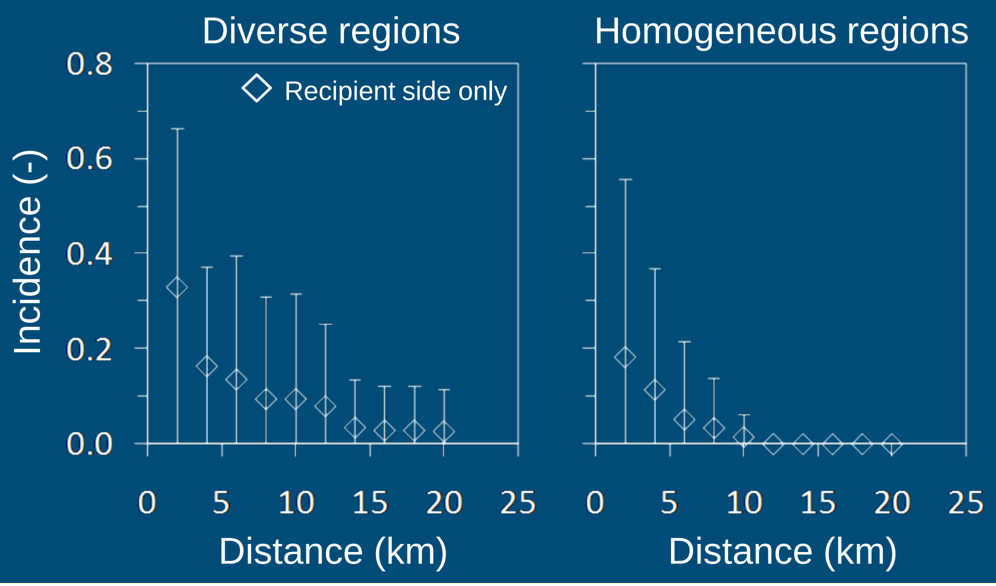




Separation of homogeneous regions

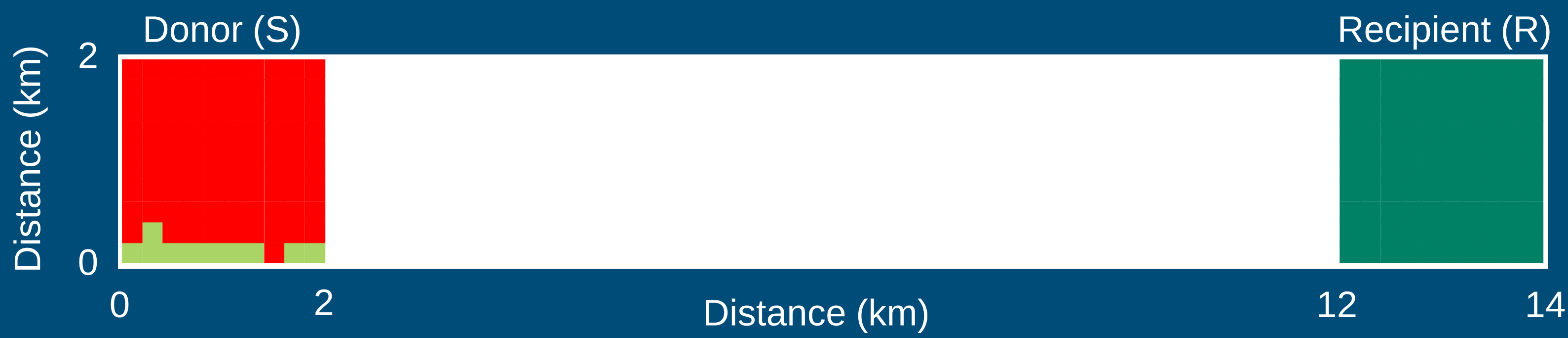
- Can we create spatial barriers that completely prevent spread?

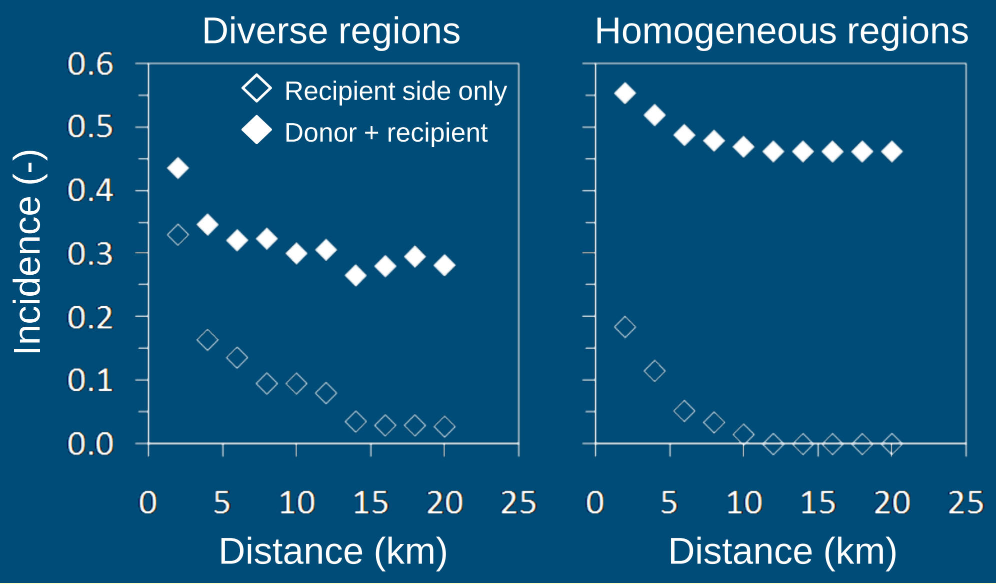




Effect on whole landscape

- Can we create spatial barriers that completely prevent spread?





Lets puts it in perspective....

- Capacity for long-distance dispersal of sporangia is excellent, and *Phytophtora infestans* could overcome geographic isolation barriers at the scales tested.
- Attempts to increase between-field distances by increasing field size is not effective.
- Attempts to create spatial barriers by aggregating fields is not effective.
- Number of varieties in the landcape had a large effect.
- *Within field* mixed cultivation of different genotypes minimizes spore dispersal onto susceptible plants and reduces epidemic progress. <u>It is always effective</u>.
- Strategies that increase the level of diversity and/or the degree of spatial mixing of varieties are more effective than those that try to create large spatial barriers.

Future

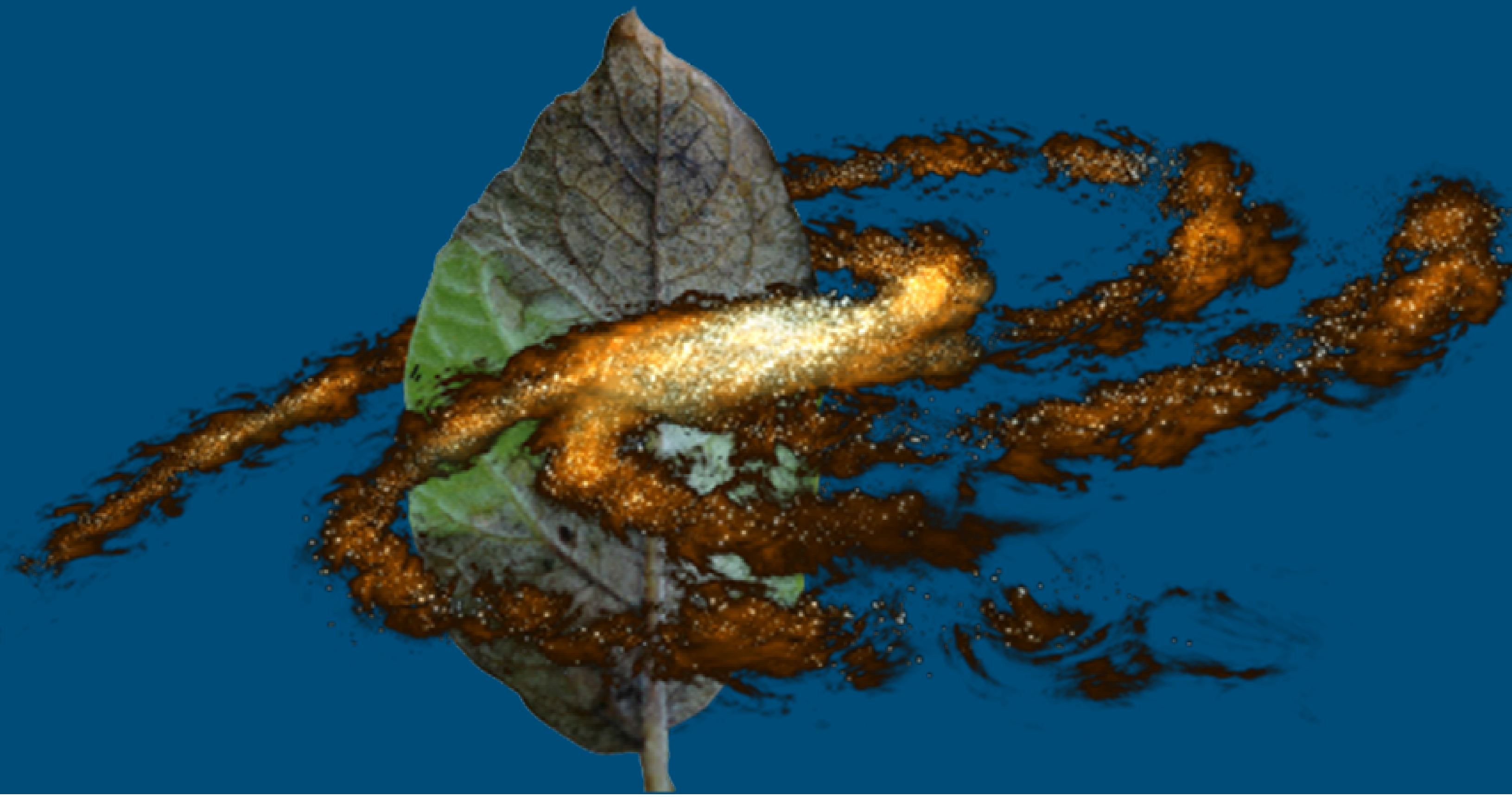
- Our simulation platform with parsimonious but validated components allows the addressing of many pertinent questions on the spatial epidemiology of potato late blight, and its control, at the landscape scale:

    - Can we reduce fungicide usage at the regional level by a significant amount if we optimize landscape designs?

    - Would a system of spore traps be useful as an early warning system – and how should we optimize their deployment?

    - If we add pathogen evolution, we can study the interactions between spatial epidemiology, landscape design and resistance durability.

Thanks for listening..........



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p.skelsey@rug.nl