Modelling Weed Spread

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[2] CSIRO, Div. Entomology.

Introduction

- Kate Stokes – Ecologist at CSIRO with experience on willow spread.
- Steve Barry – Applied Mathematician at UNSW with no experience in weed modelling.
- Roslyn Hickson – Electrical Engineer doing a PhD in Applied Mathematics.

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- But soon we needed:
  - (i) Seed dispersal,
  - (ii) Allee effects,
  - (iii) seed banks,
  - (iv) flood events,
  - (v) seedlings, rainfall, moisture content, ...

Which model to use?

Integro difference

$$N(x, n(t+1)) = \int_x K(x-z) f(N(z, nt))\, dz$$

with what type of Kernal?

Which model to use?

Integro difference with Matrix stage structure?

$$\mathbf{N}(x, n(t+1)) = \int_x \mathbf{K}(x-z) \cdot B(\mathbf{N}) f(\mathbf{N}(z, nt))\, dz$$

Which model to use?

Fractional derivative models?

$$\frac{\partial N}{\partial t} = \frac{\partial^\alpha N}{\partial x^\alpha} + f(N)$$

Which model to use?

Simulation based algorithms with seed banks, dispersal,

$$\frac{\partial N}{\partial t} = f(N) + a_1 S_1(N - dt) \quad \text{plants}$$

$$\frac{\partial S_1}{\partial t} = -a_1 S_1(t) + \int_x K(x - z)N \quad \text{seed bank}$$

Which model to use?

or

- Stochastic jump-diffusion models
- occupation models
- disturbance models

etc. All with various predictions.

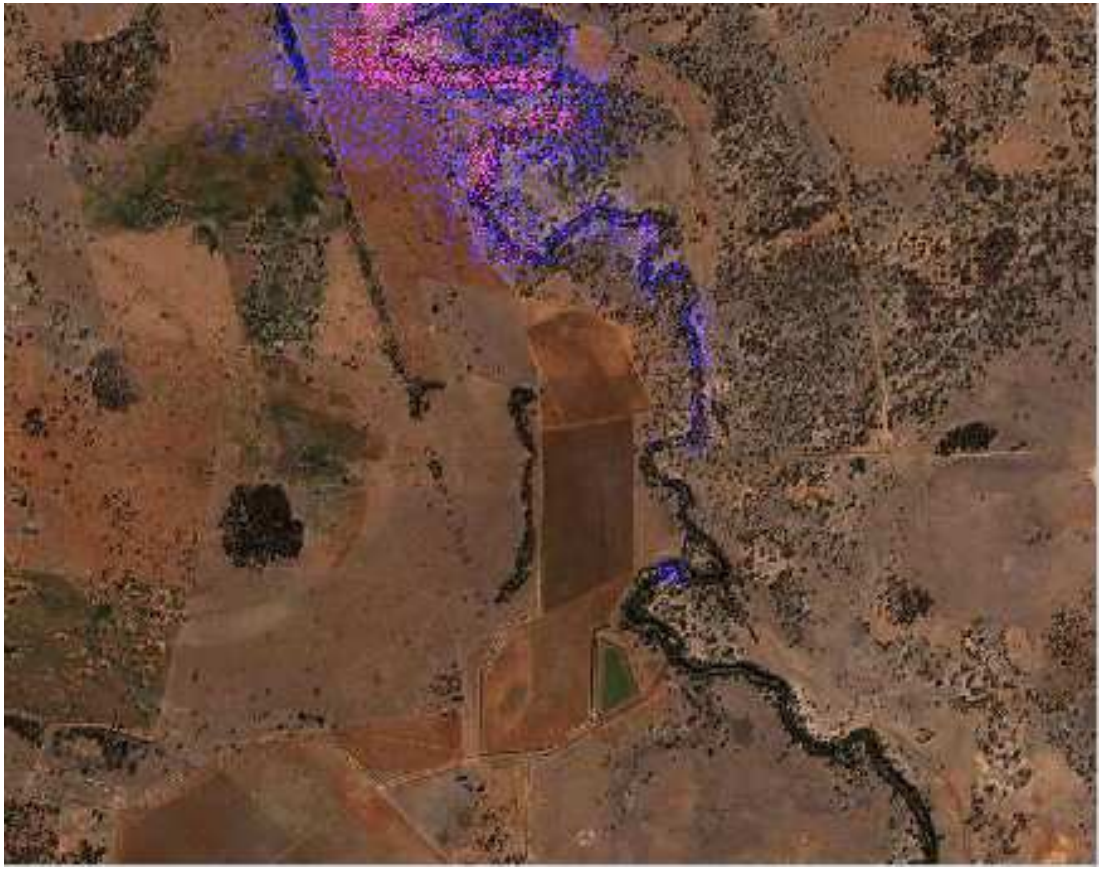
So we needed a package where we could

- do simulations of weed spread.
- easily compare different models.
- easily handle any number of parameters, each which may have time and space dependence.
- automatically produce digestable output.
- be easy to use and open-source.

Example simulation

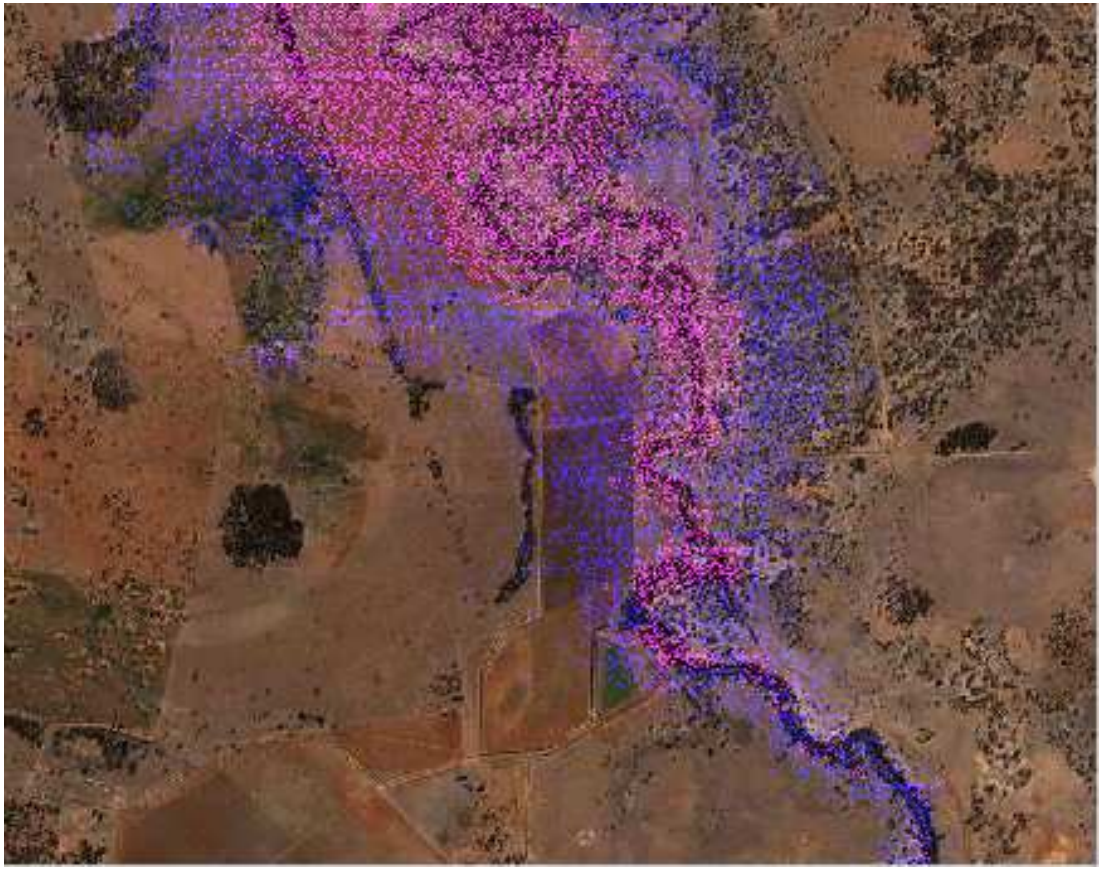
Here we model the spread of weeds along a river starting with one weed outcrop at top.

Example simulation

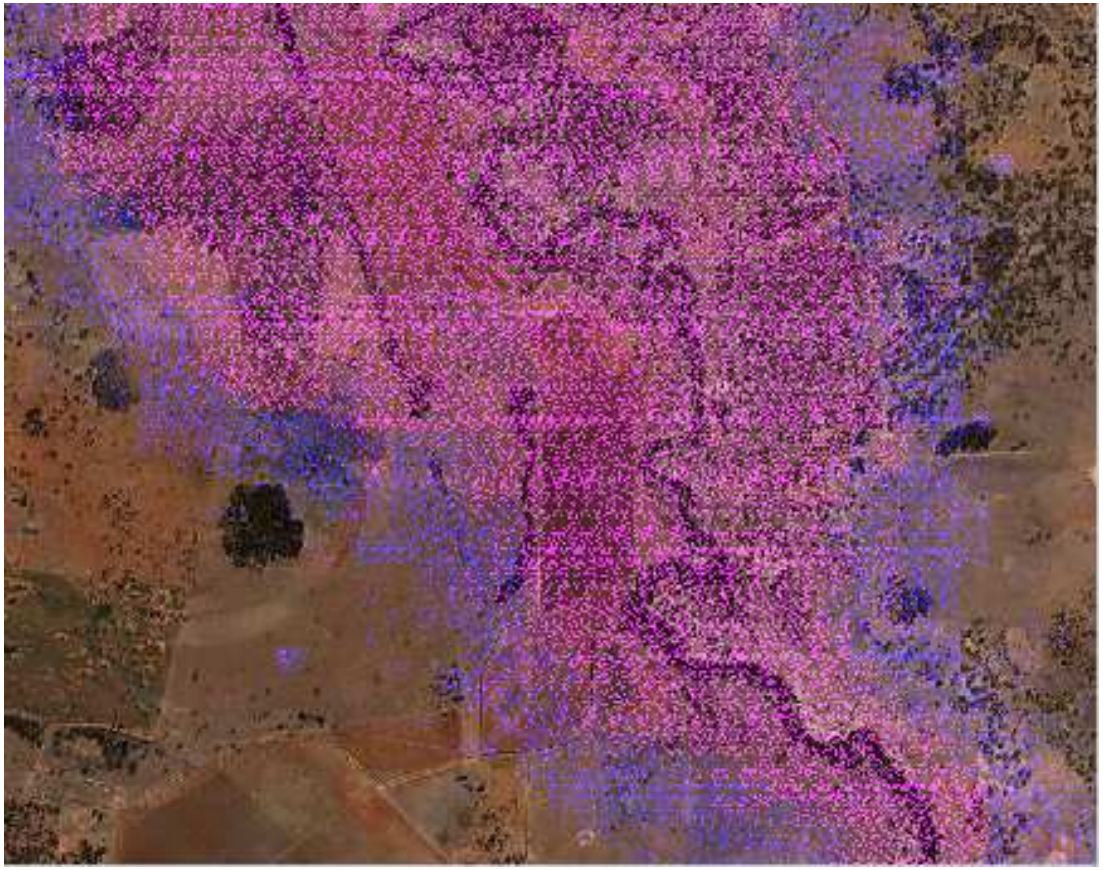


Here we have weeds spreading down the river.

Example simulation



Example simulation



What is required in a simulation package?

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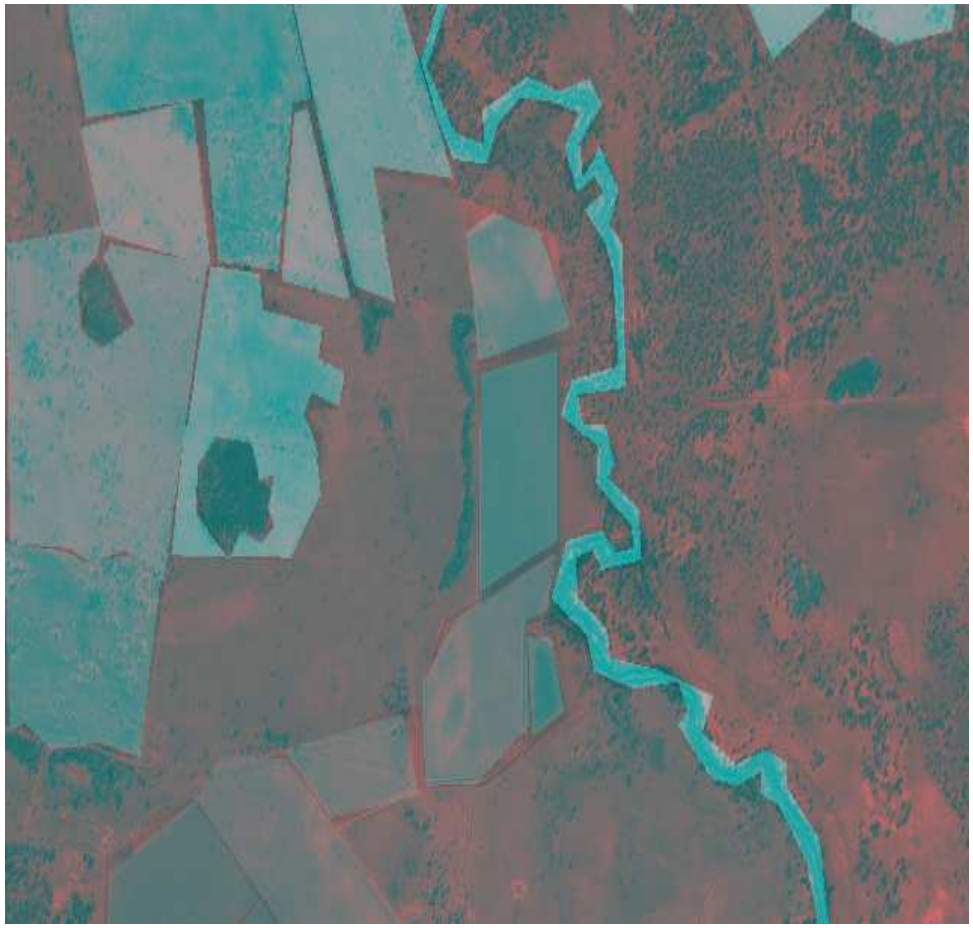
- Use realistic domains.

What is required in a simulation package?

- Easily describe properties to different regions.

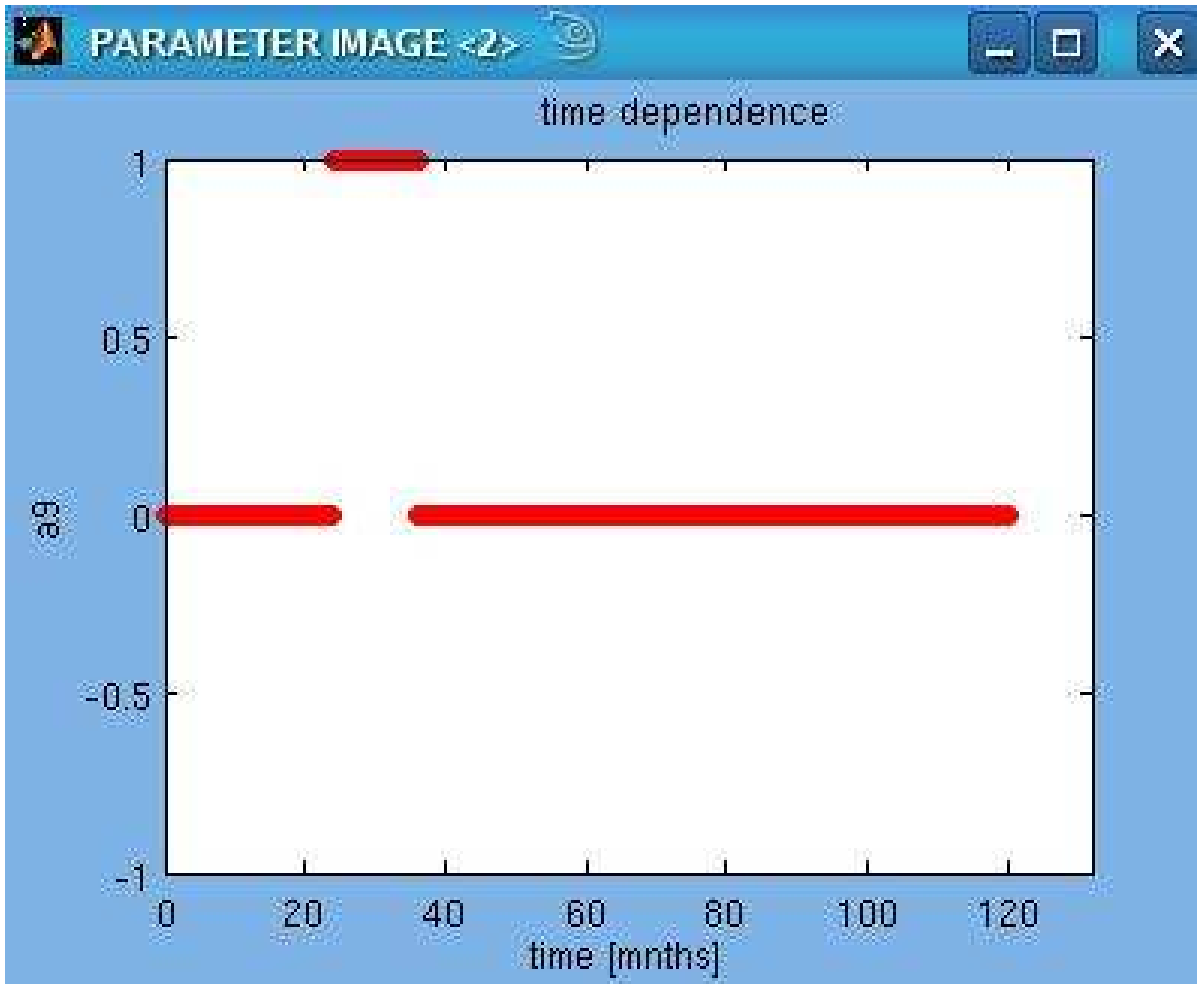


What is required in a simulation package?

- Easily define key features – like rivers.

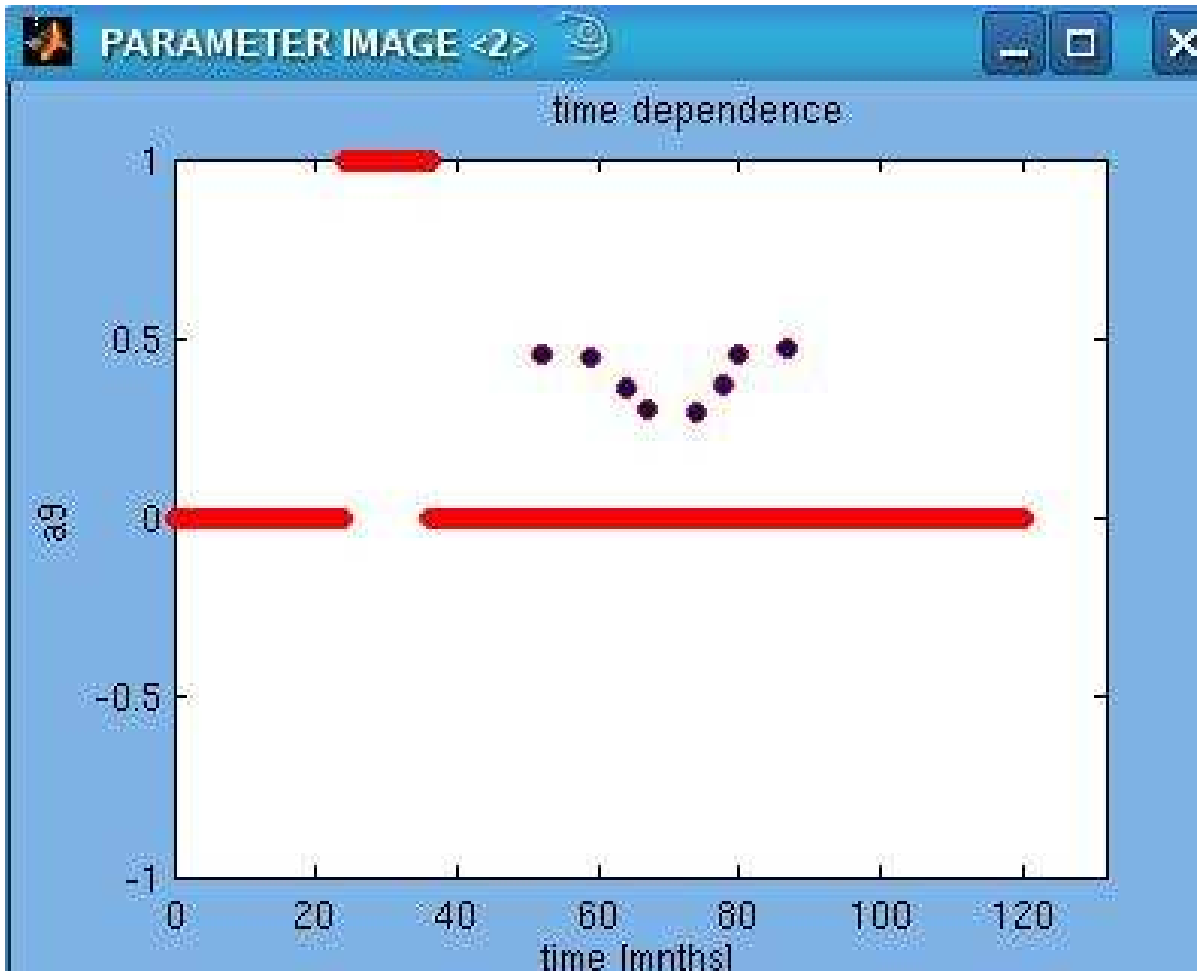
What is required in a simulation package?

- Illustrate time dependent parameters.



What is required in a simulation package?

- And modify them with mouse clicks



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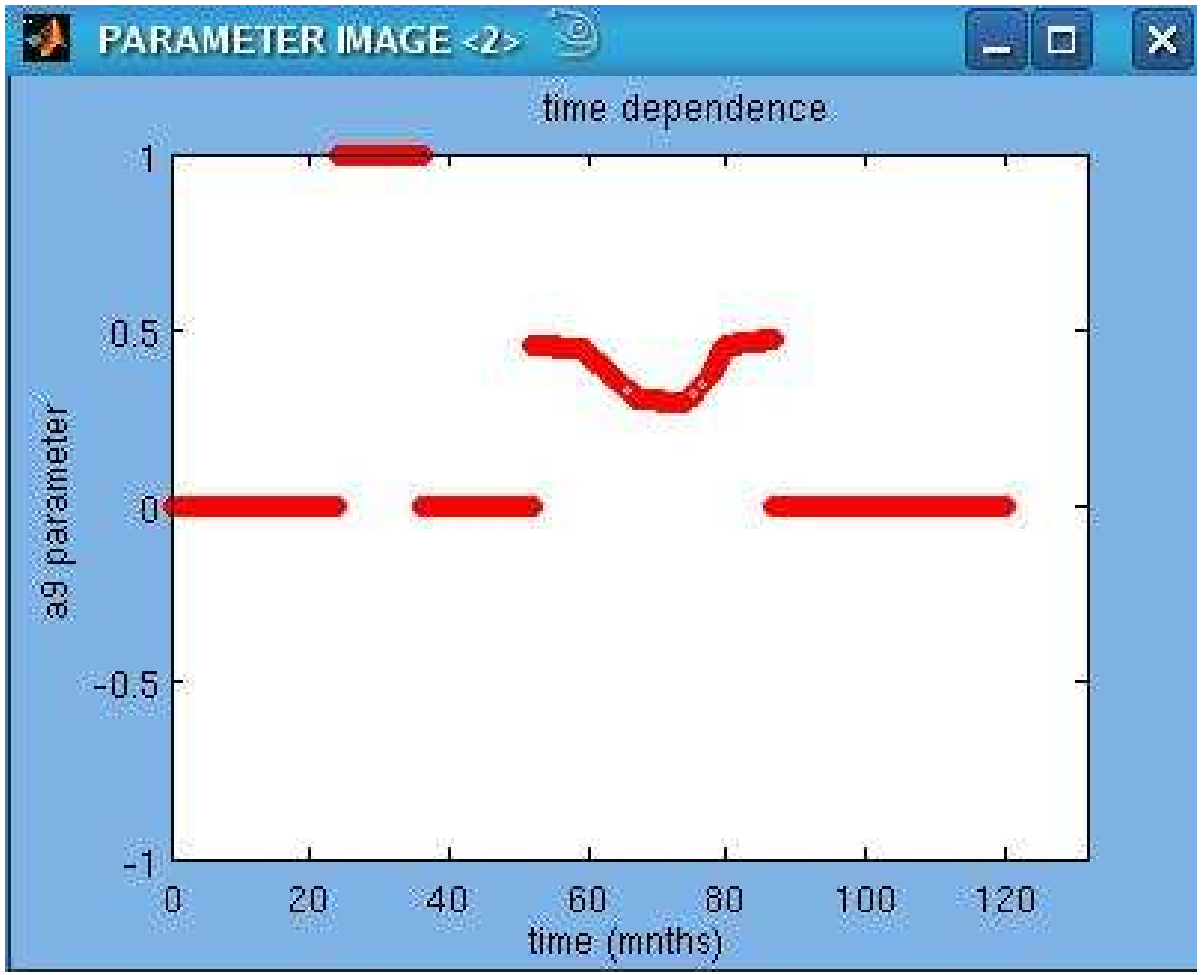
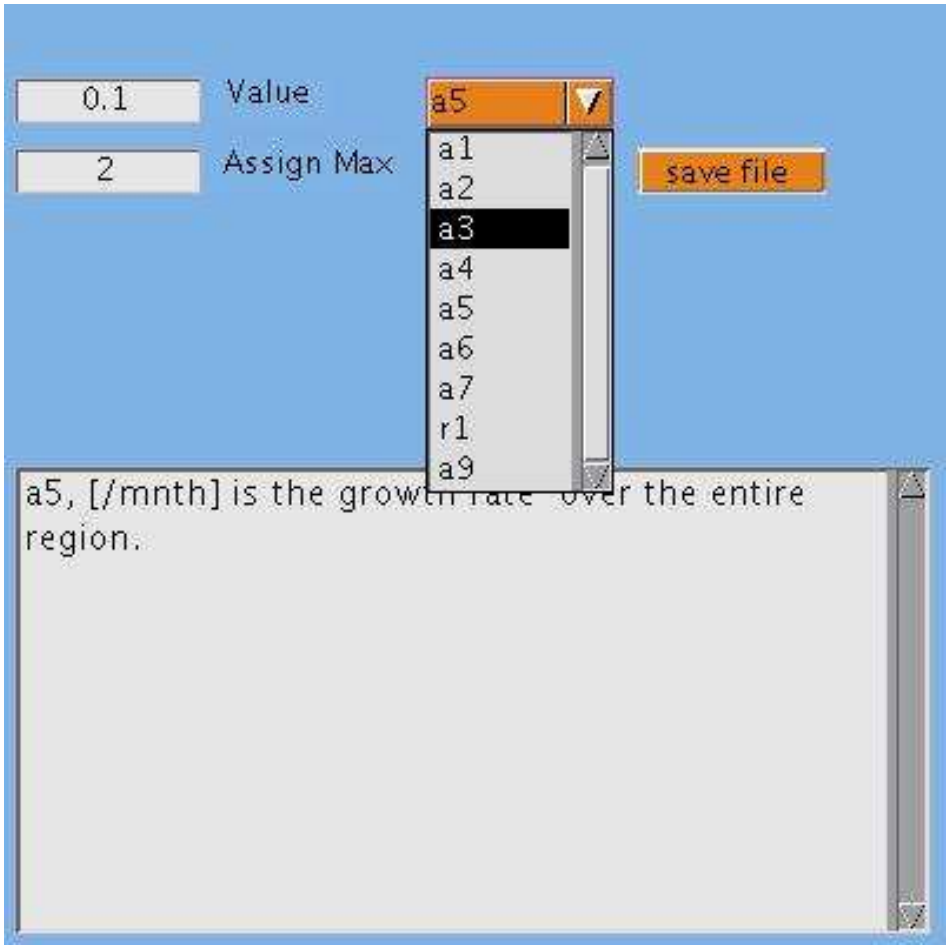


What is required in a simulation package?

- Change to different parameters and save data.



What is required in a simulation package?

- A choice of simulation options.

Reaction Diffusion

Integro-difference

Logistic growth

Stochastic PDE's

Occupation Models

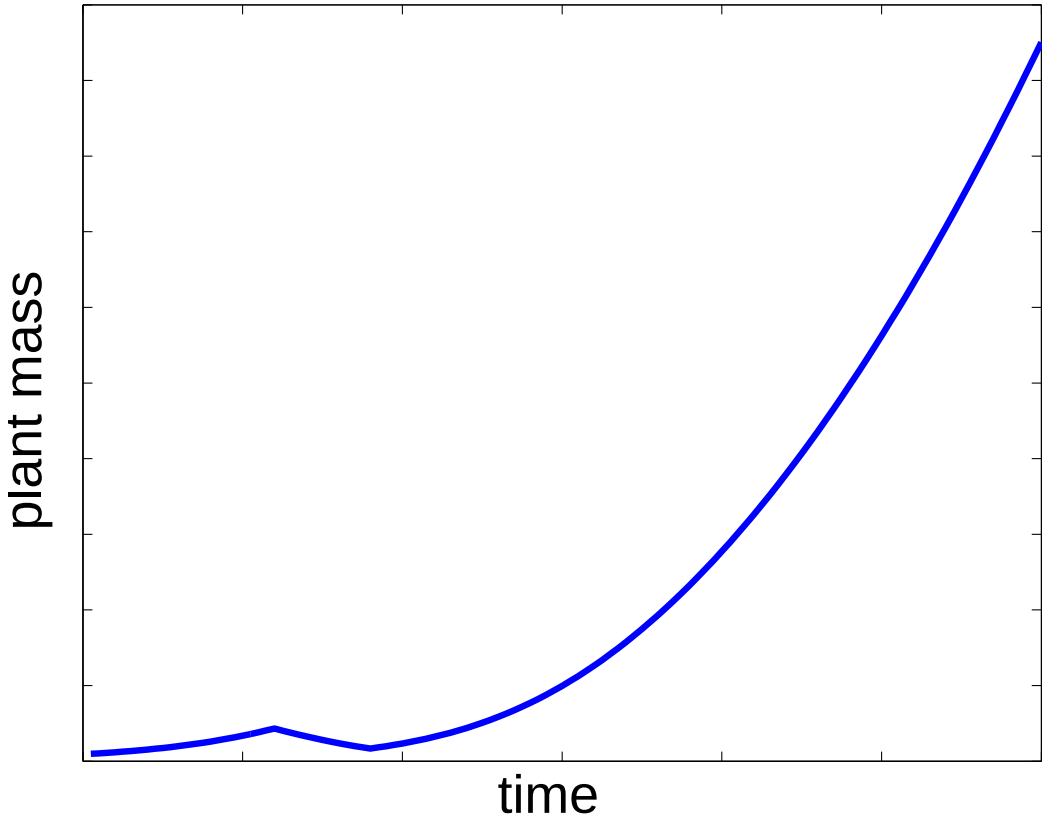
Stage structure

Long tail distributions

Difference Equations

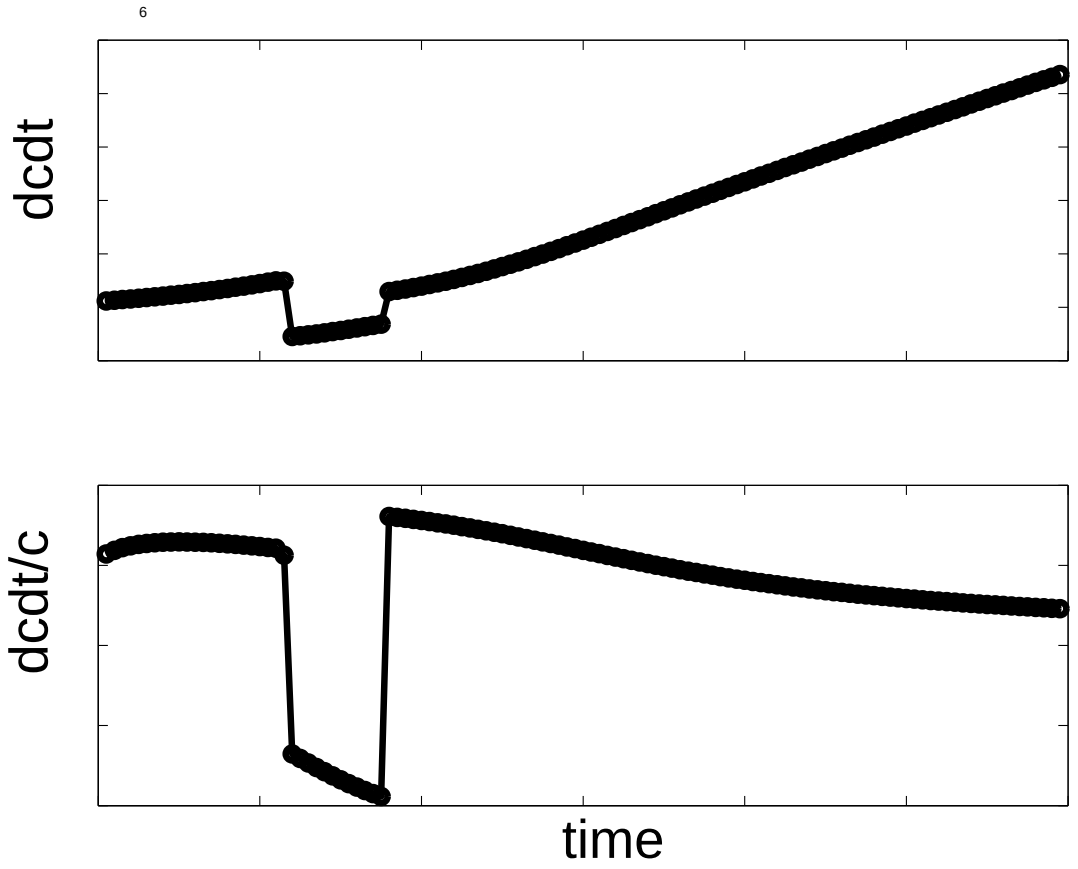
What is required in a simulation package?

- A variety of output automatically generated – total plant mass.



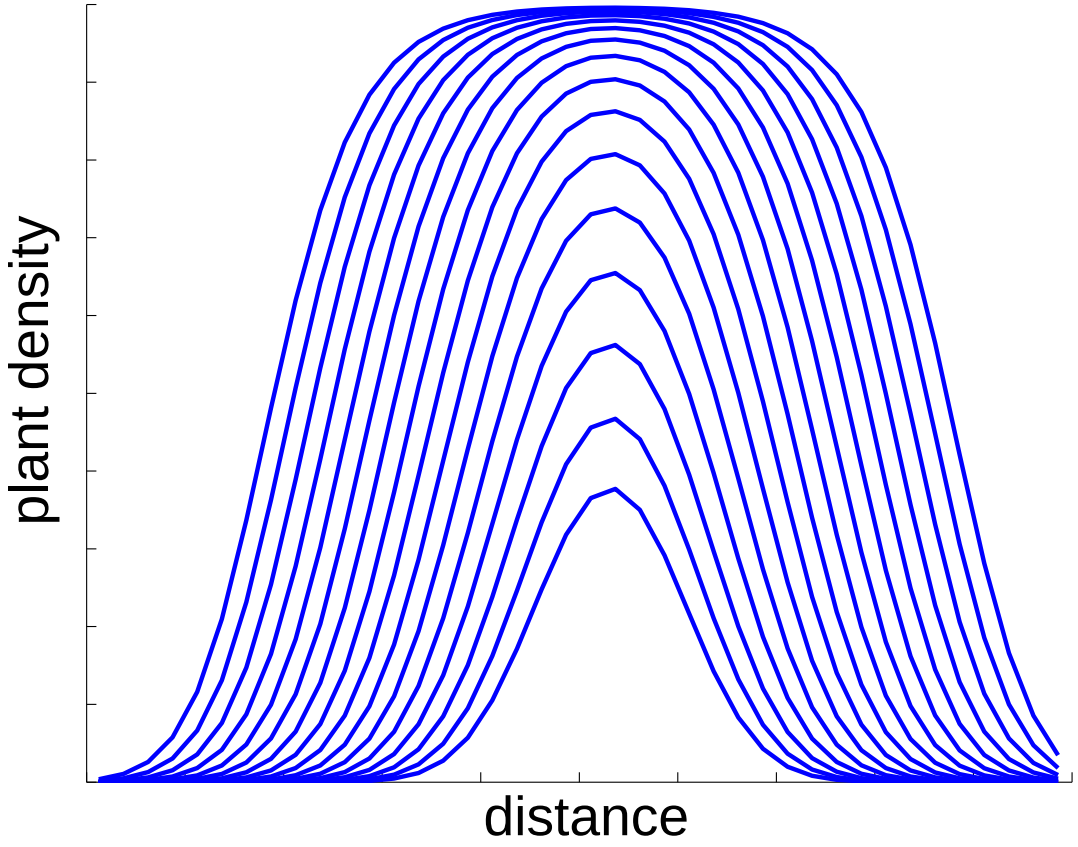
What is required in a simulation package?

- Rate of change of plant mass dc/dt and $(dc/dt)/c$.



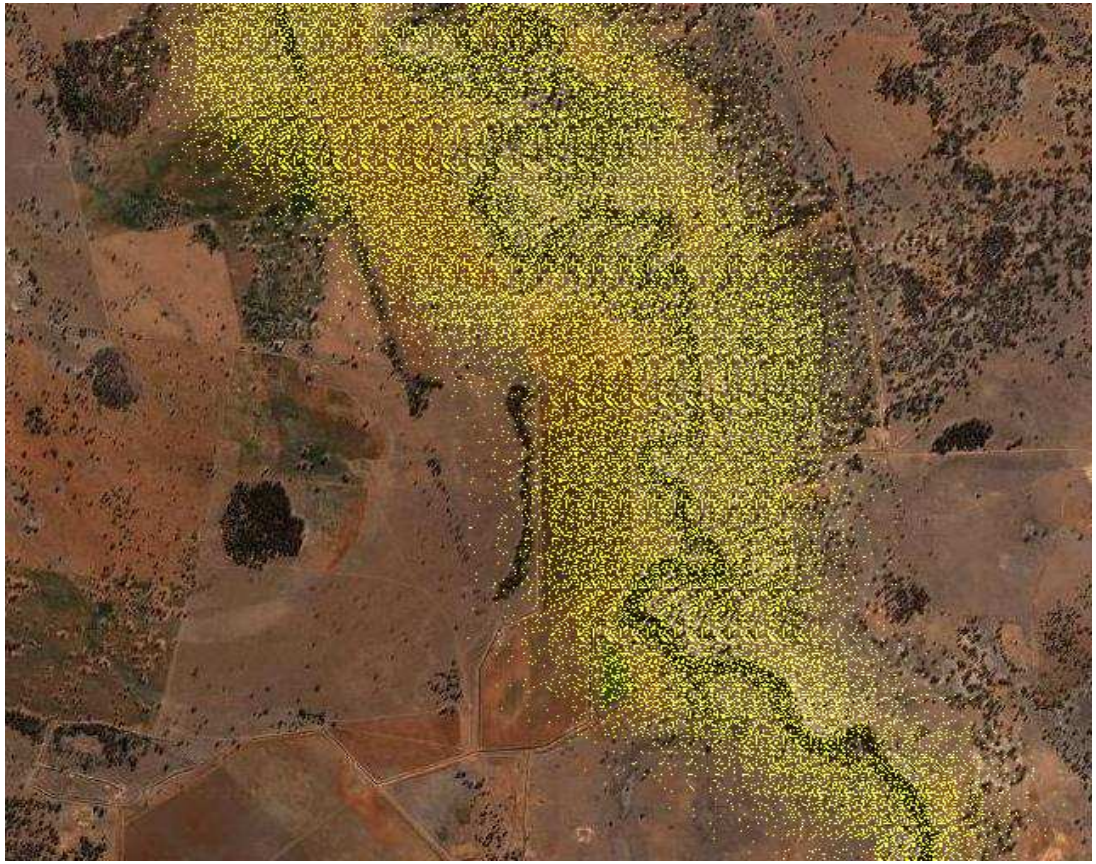
What is required in a simulation package?

- Travelling wave fronts.



What is required in a simulation package?

- A variety of visualisation options - dot density.



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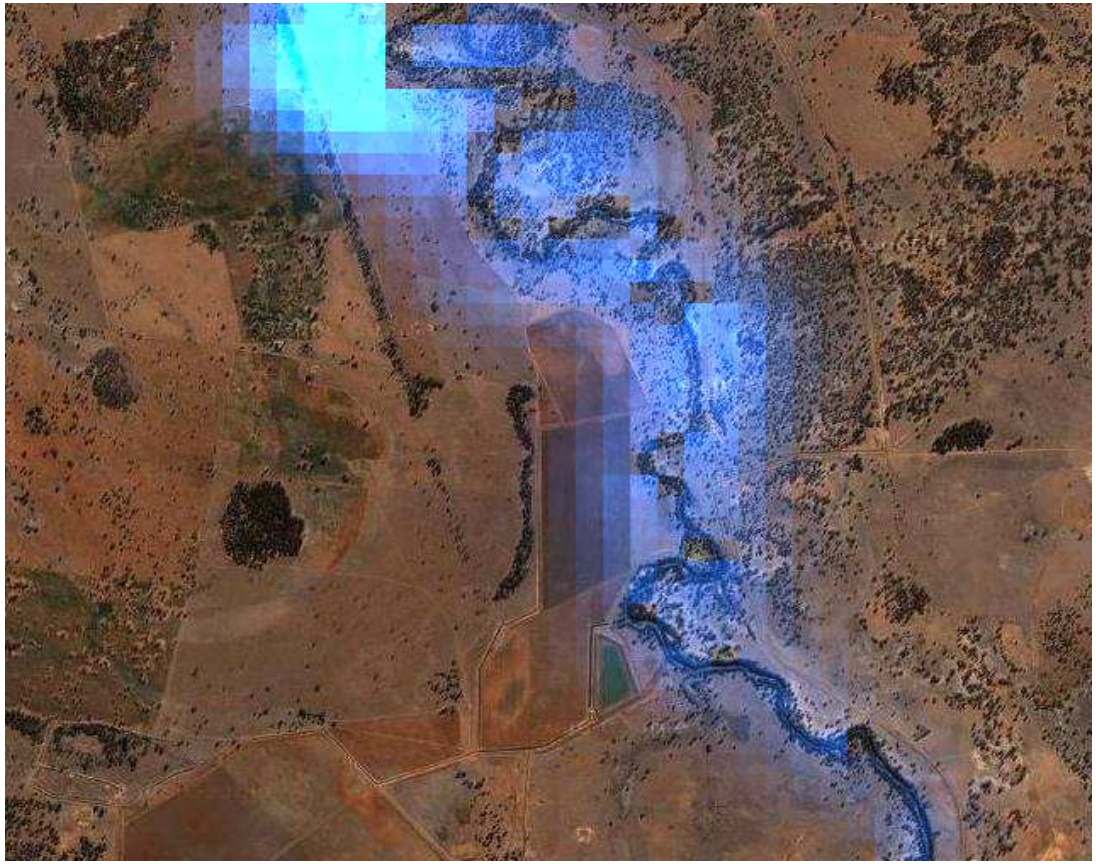
- A variety of visualisation options - coloured density.



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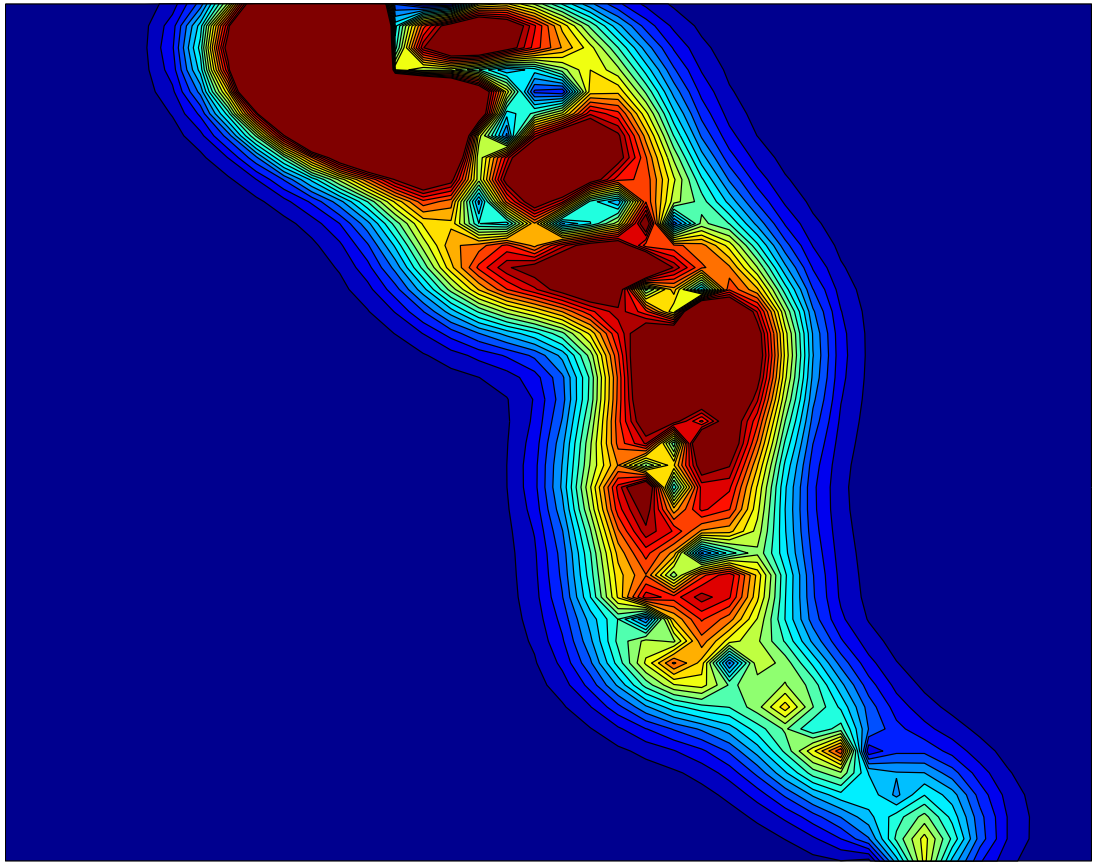

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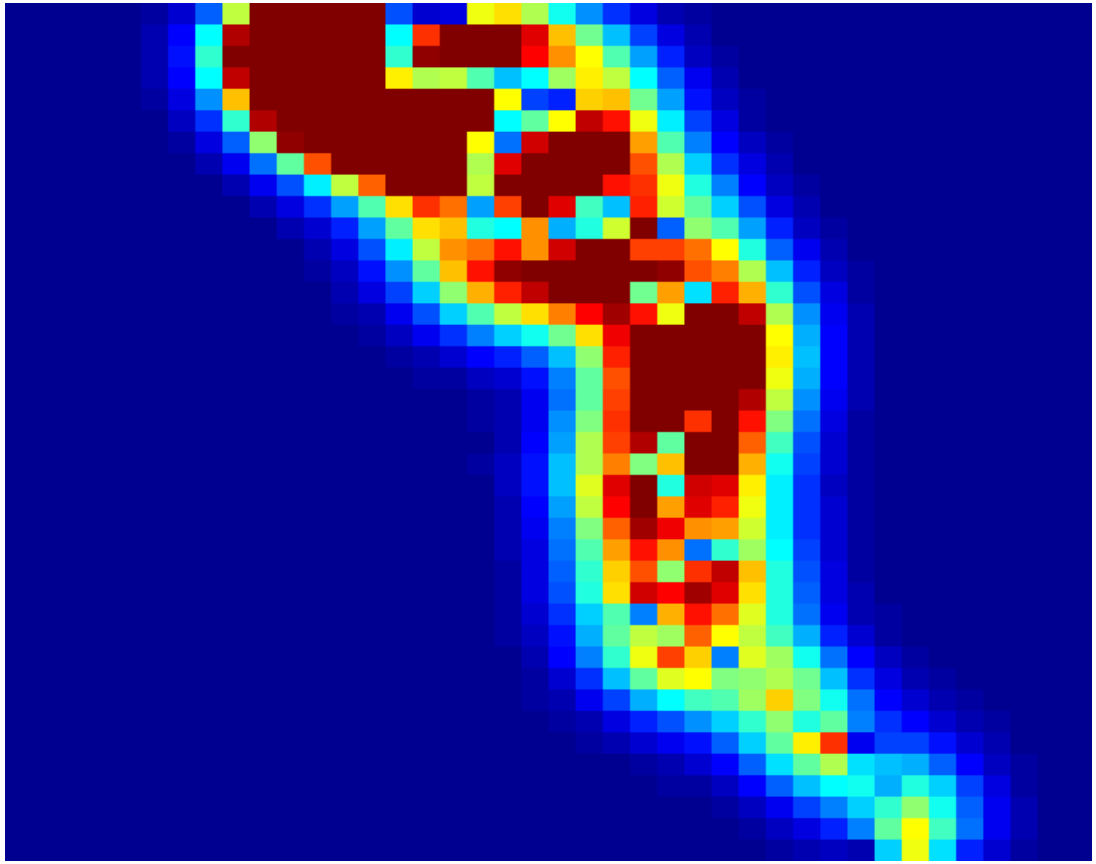


What is required in a simulation package?

- Automatically generated summary documents for each run.

A single simulation of plant growth and spread

Steven Barry, Roslyn Hickson, Kate Stokes

March 20, 2007

Abstract

This report was generated from the matlab code *aSHOW.m* to consider a simulation of plant growth with a given parameter set.

Contents

What is required in a simulation package?

- with parameter summaries.

This routine was created at roughly 20-Mar-2007

1 Parameter summary: z1.m

xN: The number of x grid spacings is 40.

yN: The number of y grid spacings is 40.

xm: The maximum x scale is 5408 [m].

xm: The maximum x scale is 4992 [m].

tN: The number of time steps is 80.

dt: The time step is 1 [mnths].

a1(x,y):

- a1(x,y), defines different regions.
- The nominal value is 1.The nominal stochasticity is 0.The mean is 5.811. The assigned maximum is 50.

a2(x,y):

- a2(x,y), [br/m2] are the initial concentration of plants.
- The nominal value is 10.The nominal stochasticity is 0.The mean is 0.0081029. The assigned maximum is 20.

a3(x,y):

- a3(t) = 1 at the time steps when the results will be printed and plotted.
- The nominal value is 1.The nominal stochasticity is 0.The mean is 0.0081029. The assigned maximum is 2.

What is required in a simulation package?

- and graphical/summary plot outputs.

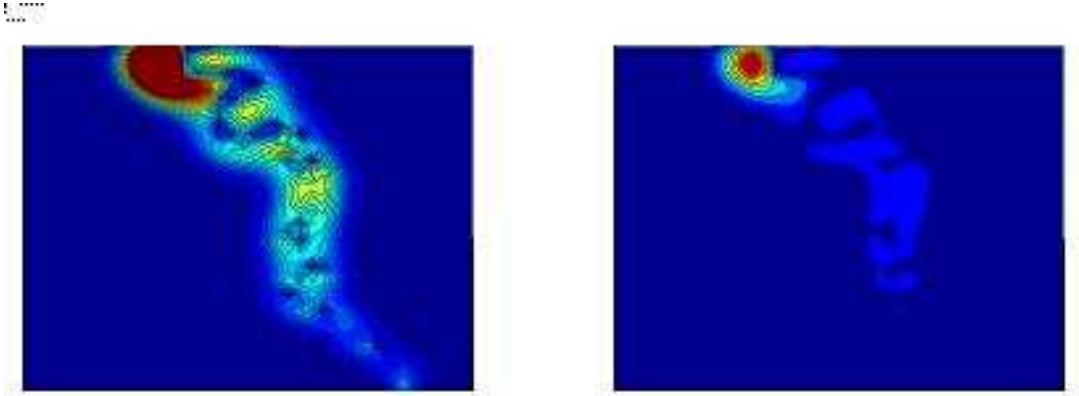


Figure 20: Plotting species 1 at time step 69

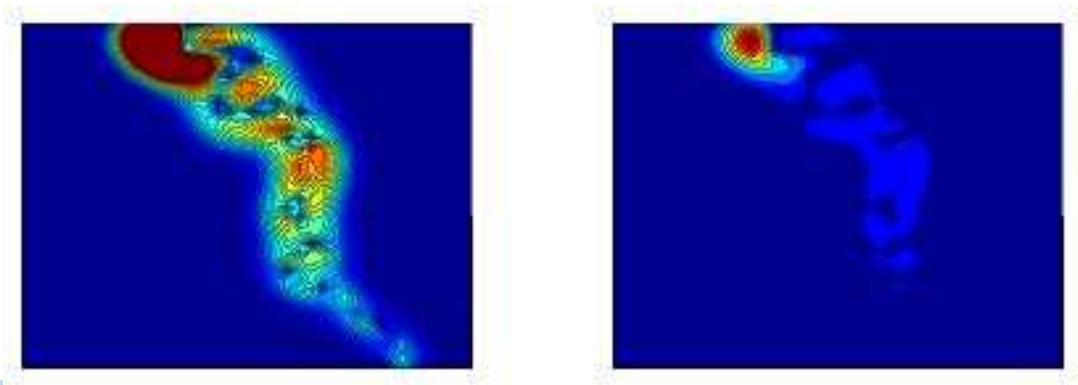
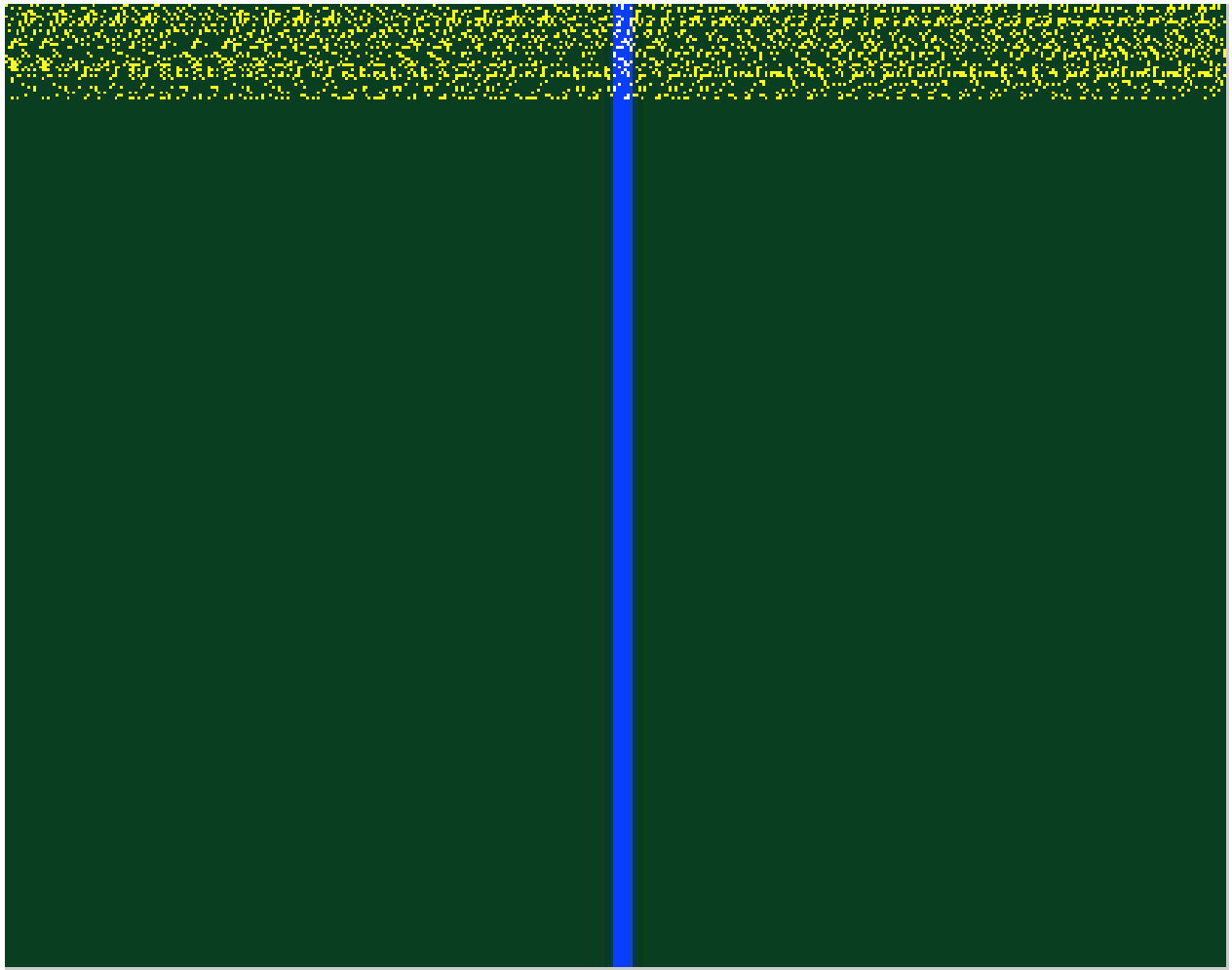


Figure 21: Plotting species 1 at time step 73

Integro-difference.

$$N_{t+1}(x,y) \approx \int\int K(x,y,x',y') N_t(x',y')\, dx'dy'$$



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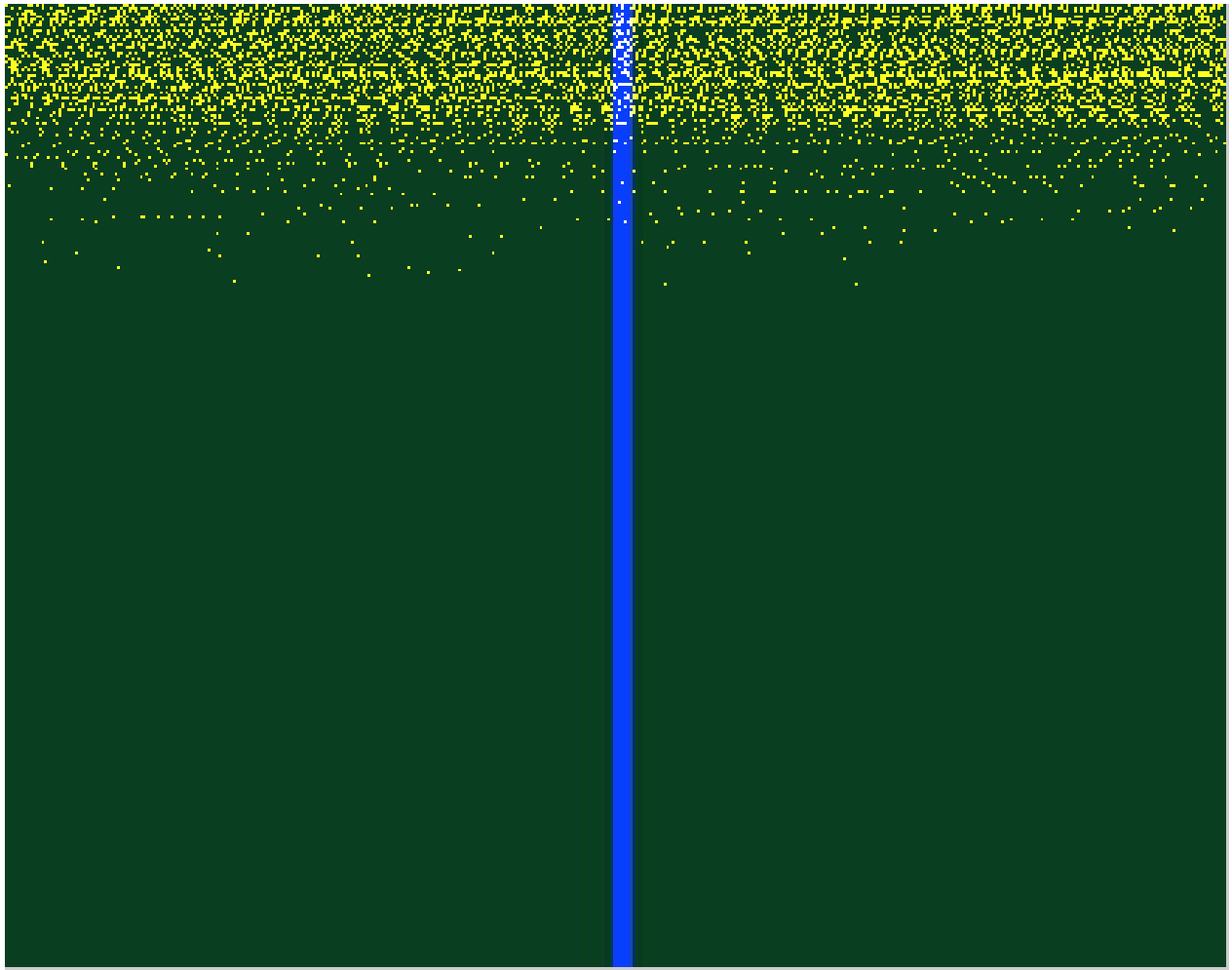

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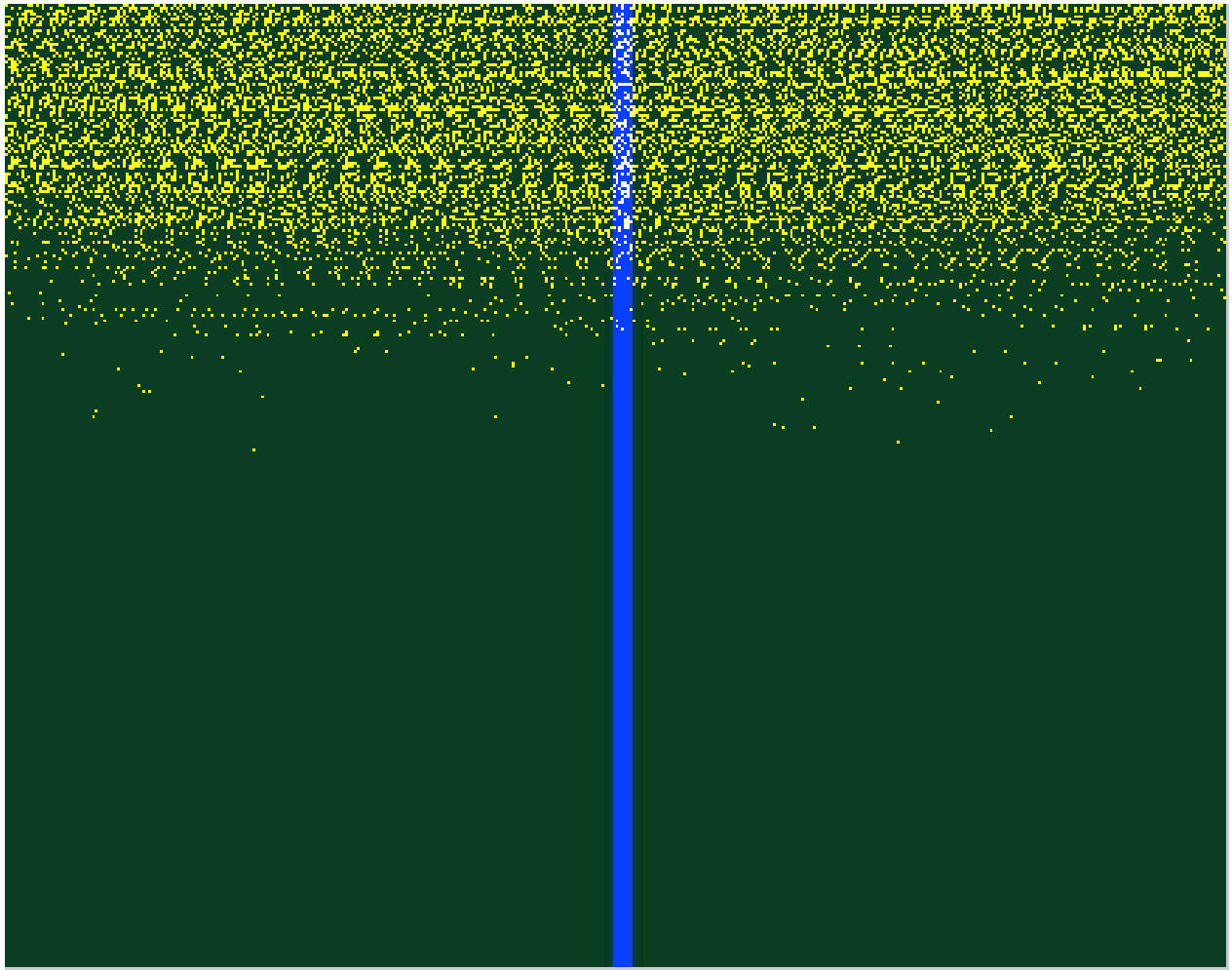

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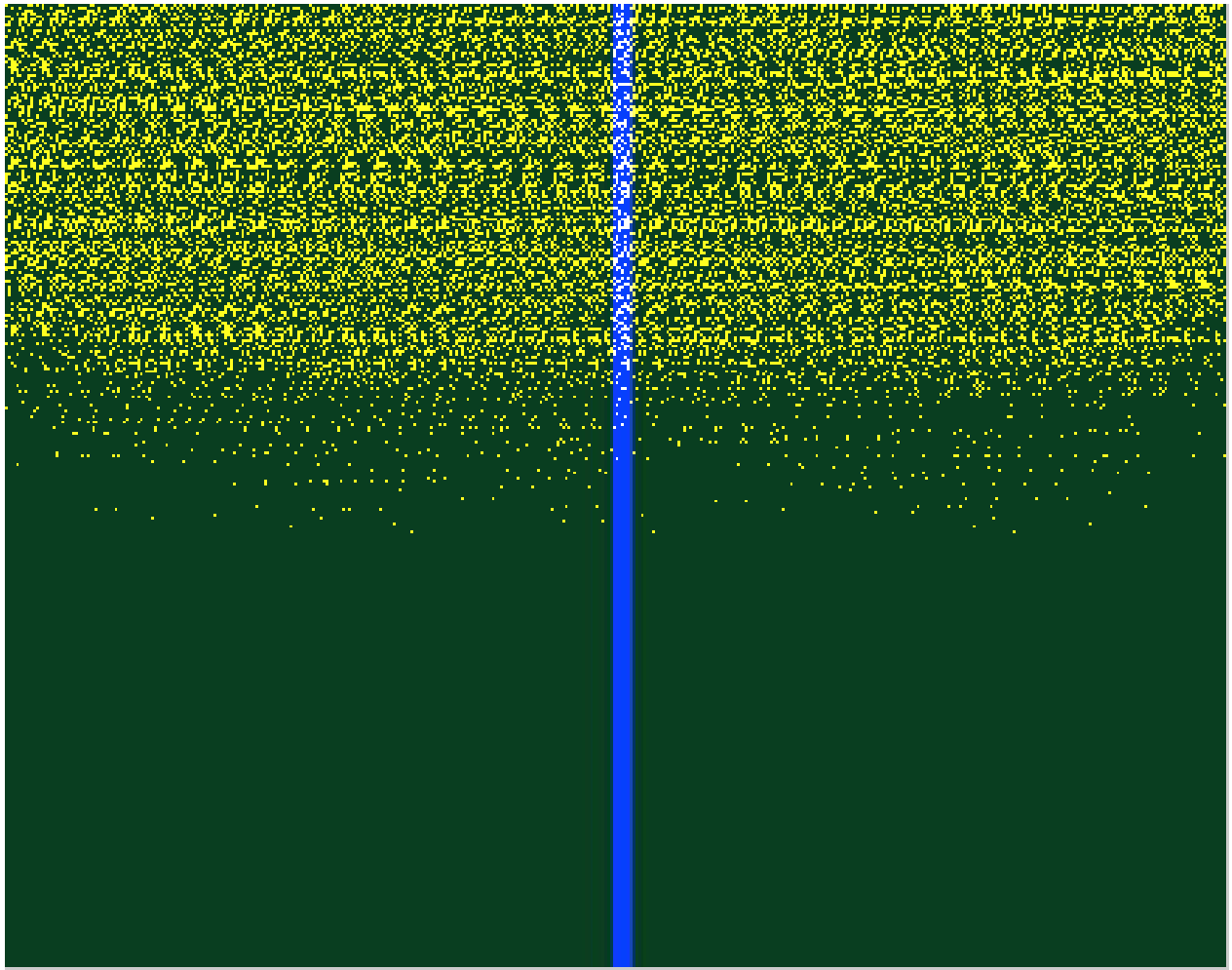
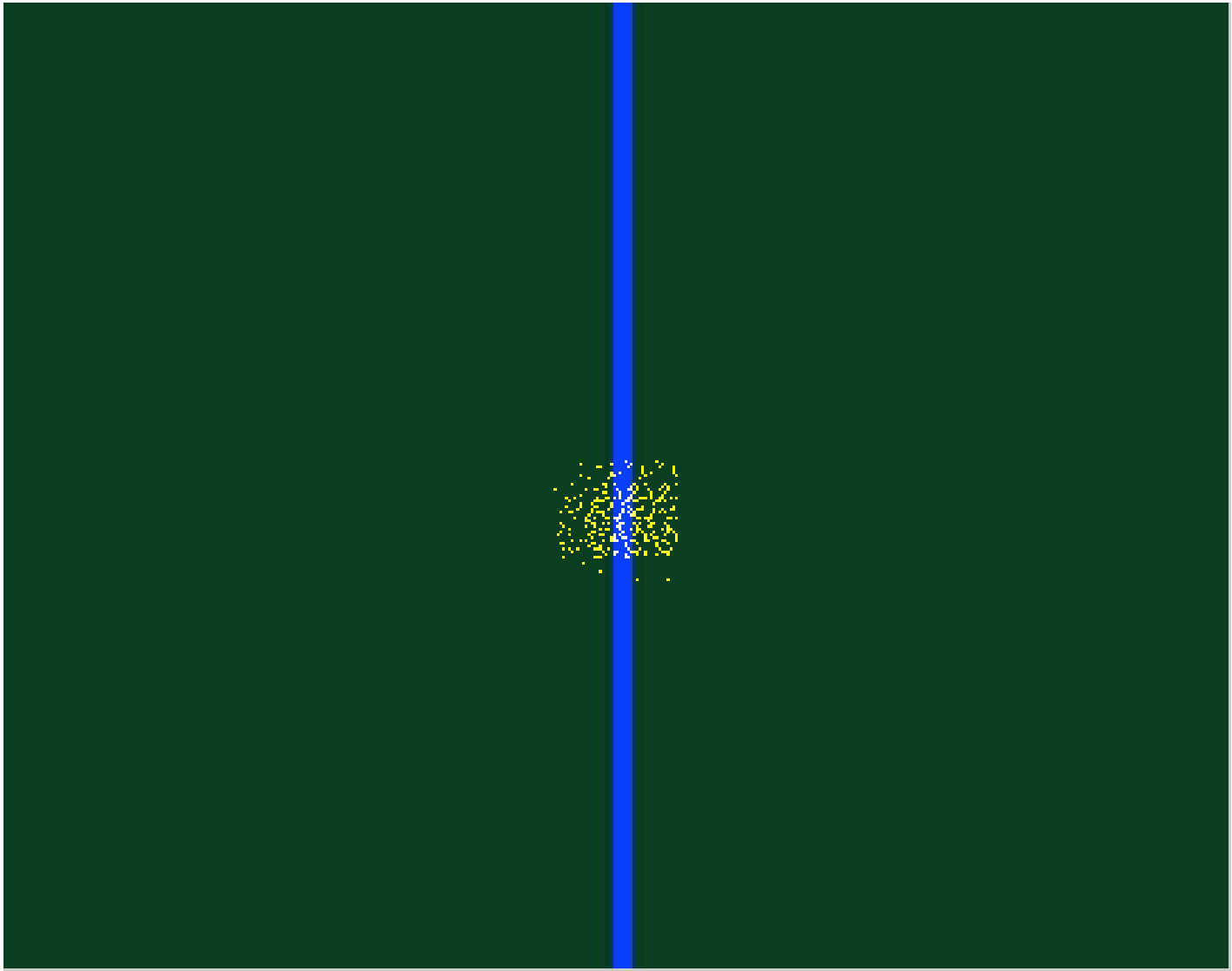


Stage structured model

Plants → seeds → dispersal → seedbank → seedlings → plants.



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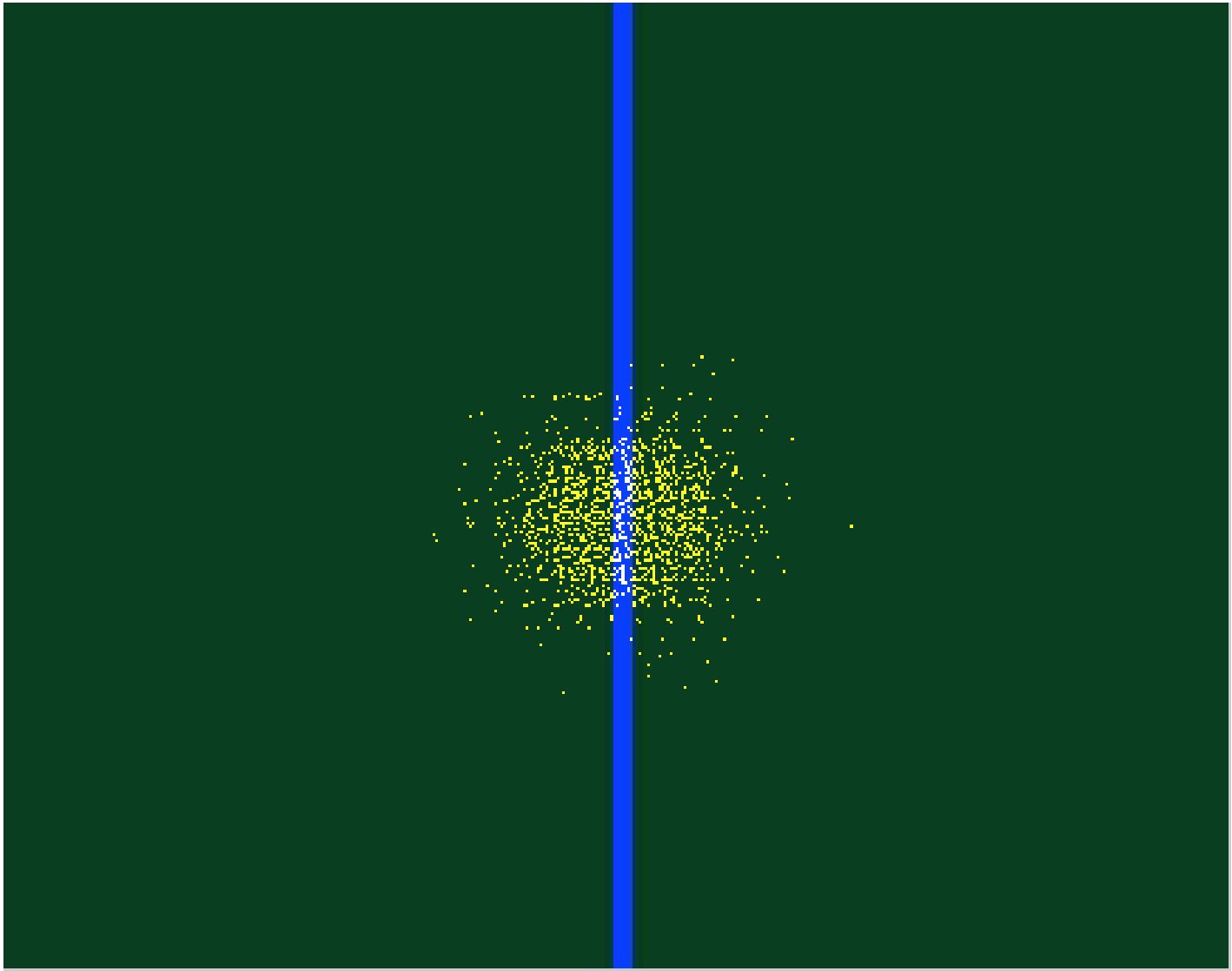

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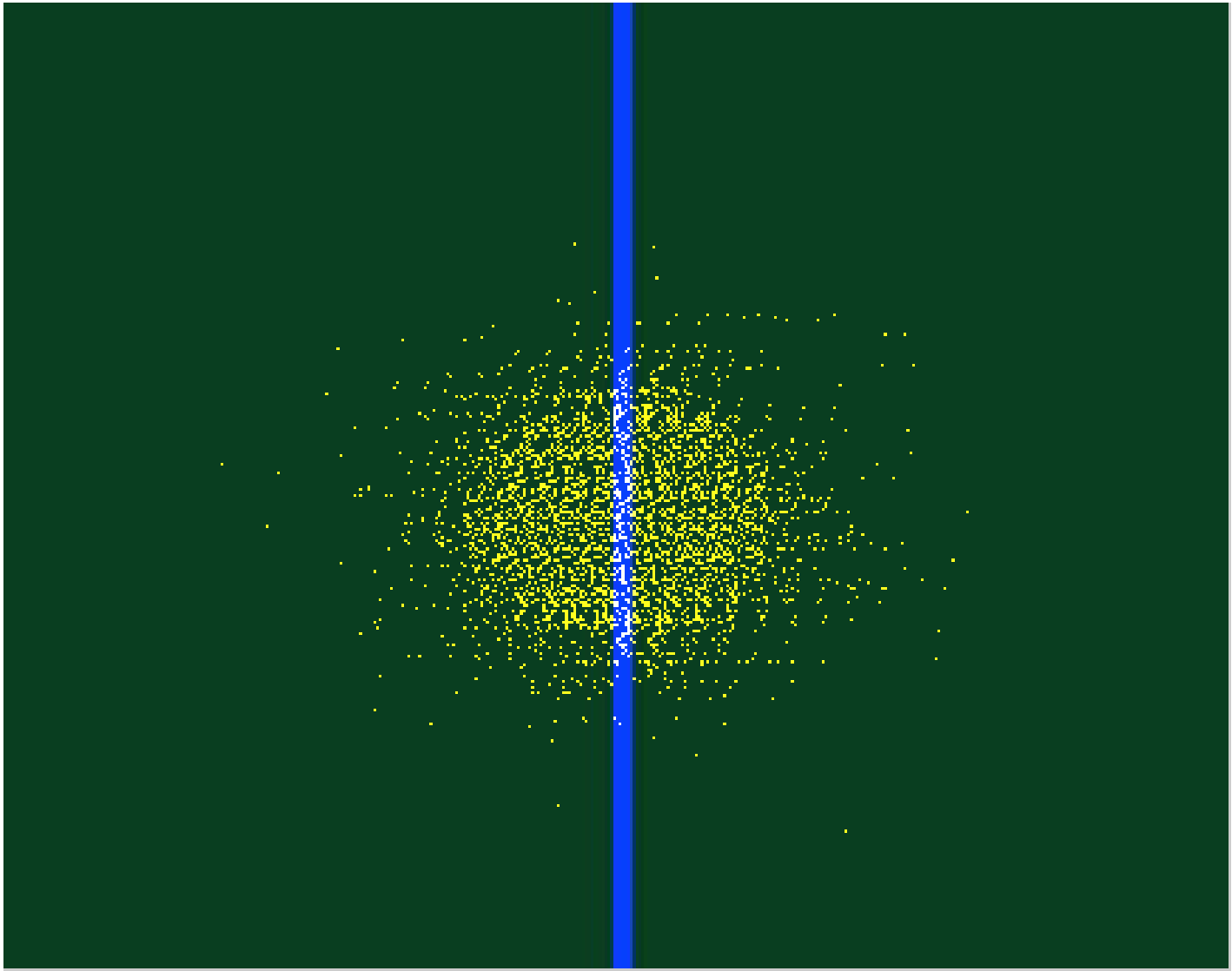

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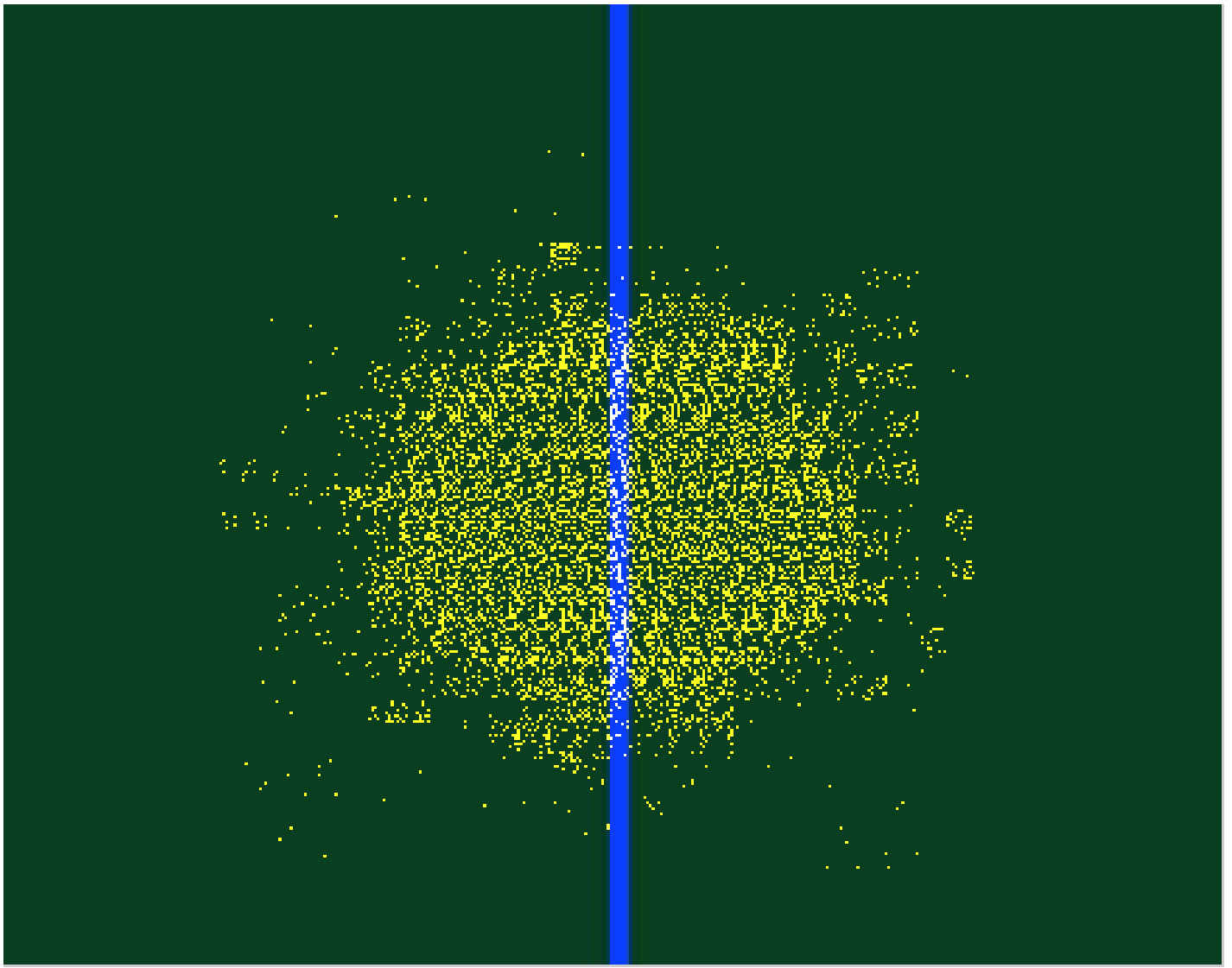

Two species reaction diffusion with logistic grow

$$\frac{\partial N_1}{\partial t} = D_1 \nabla^2 N_1 + \gamma_1 N_1 \left(1 - \frac{N_1}{N_1 + N_2}\right)$$

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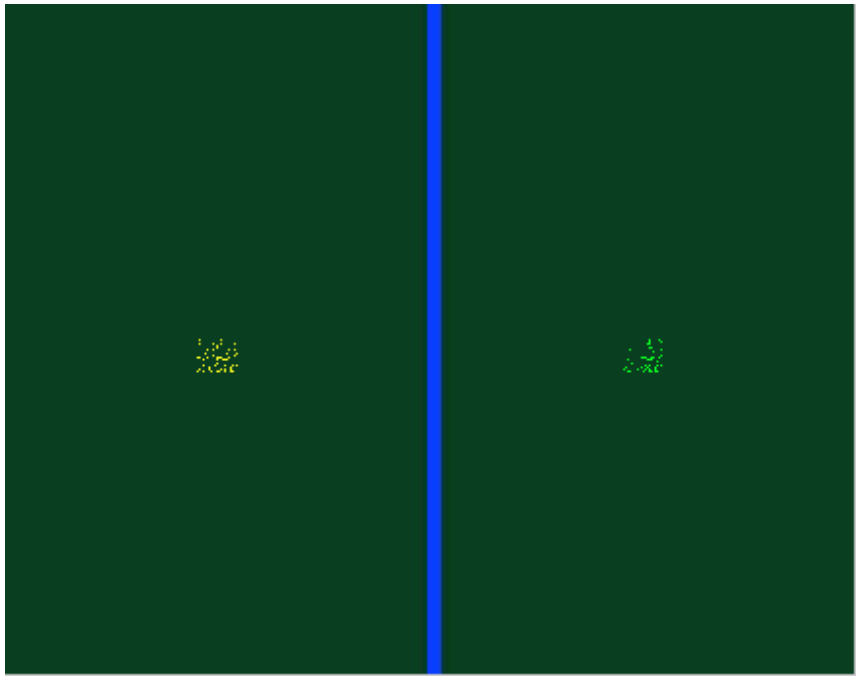

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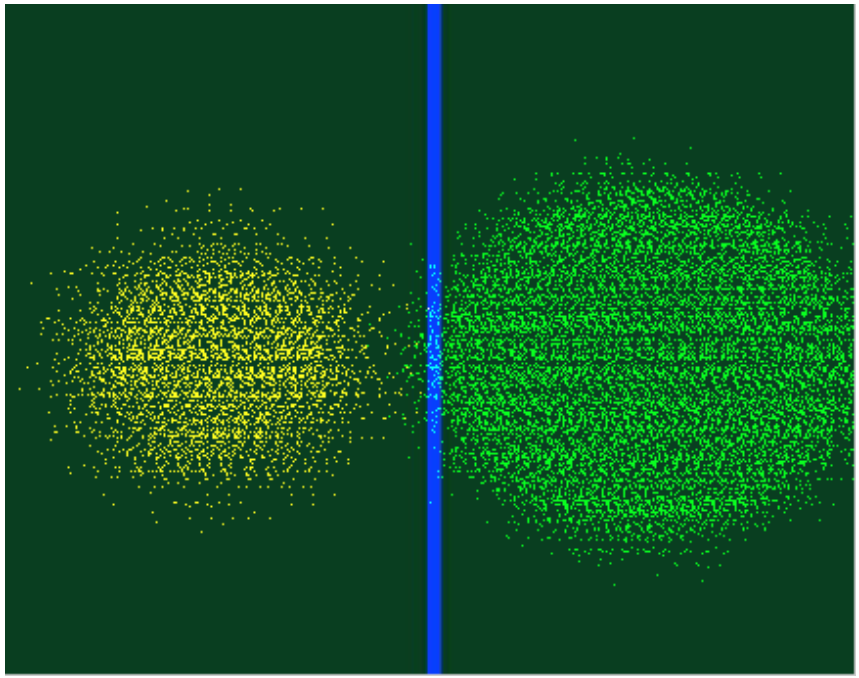

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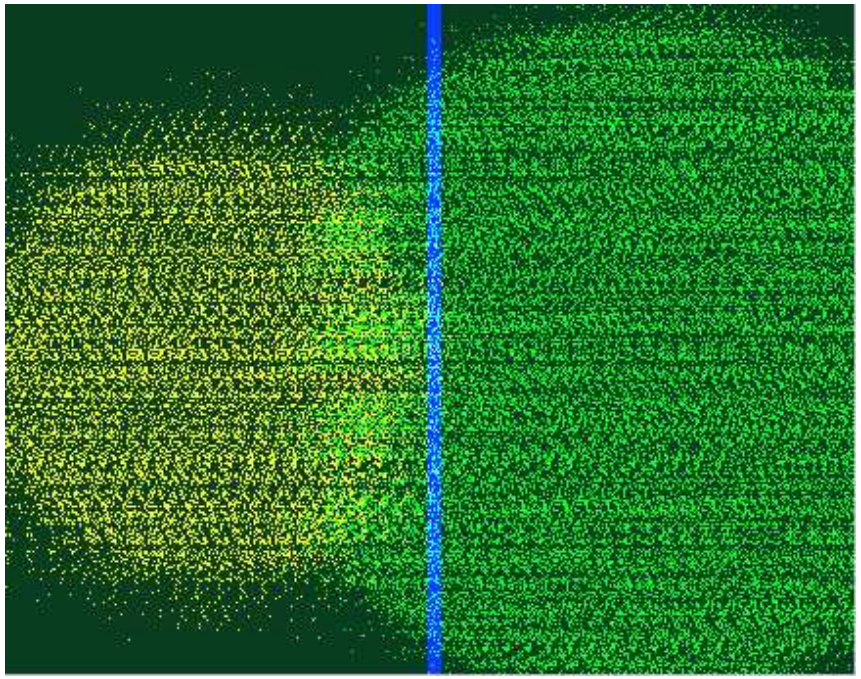

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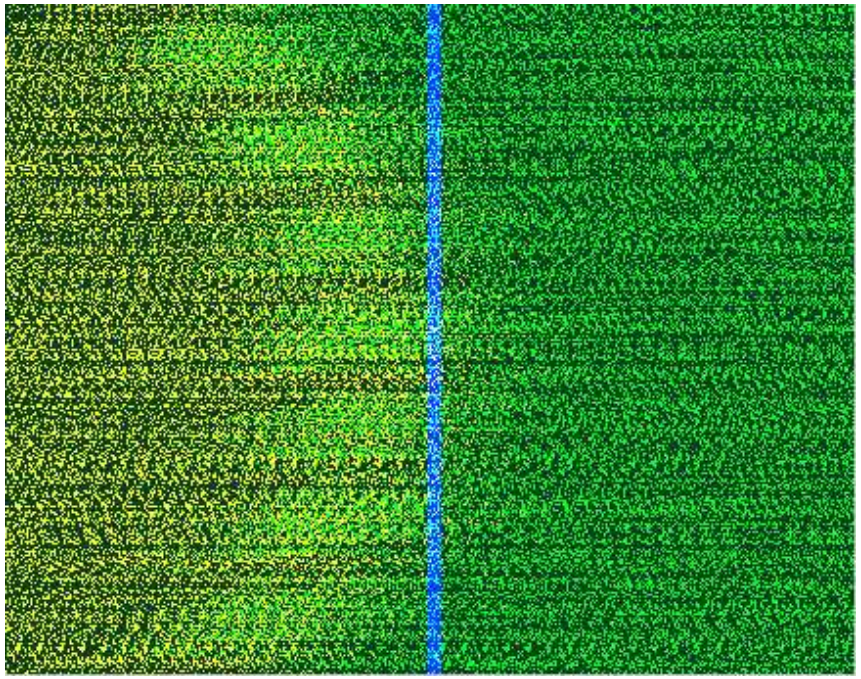
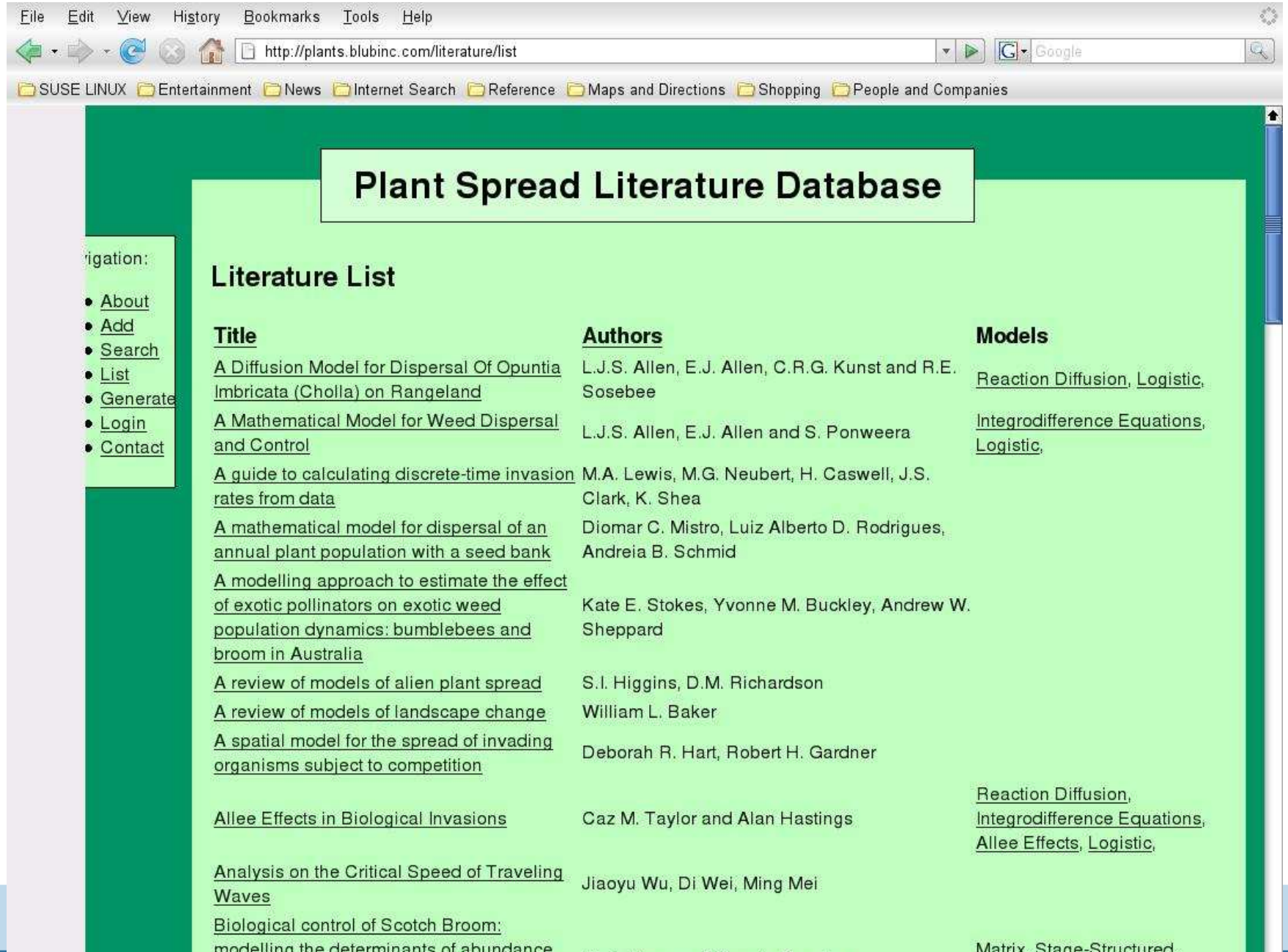


Online Plant Spread Database.

- As we were new to this area we have been rapidly trying to read the literature.
- So we have set up an online database of publications in the area (that we are still adding to).

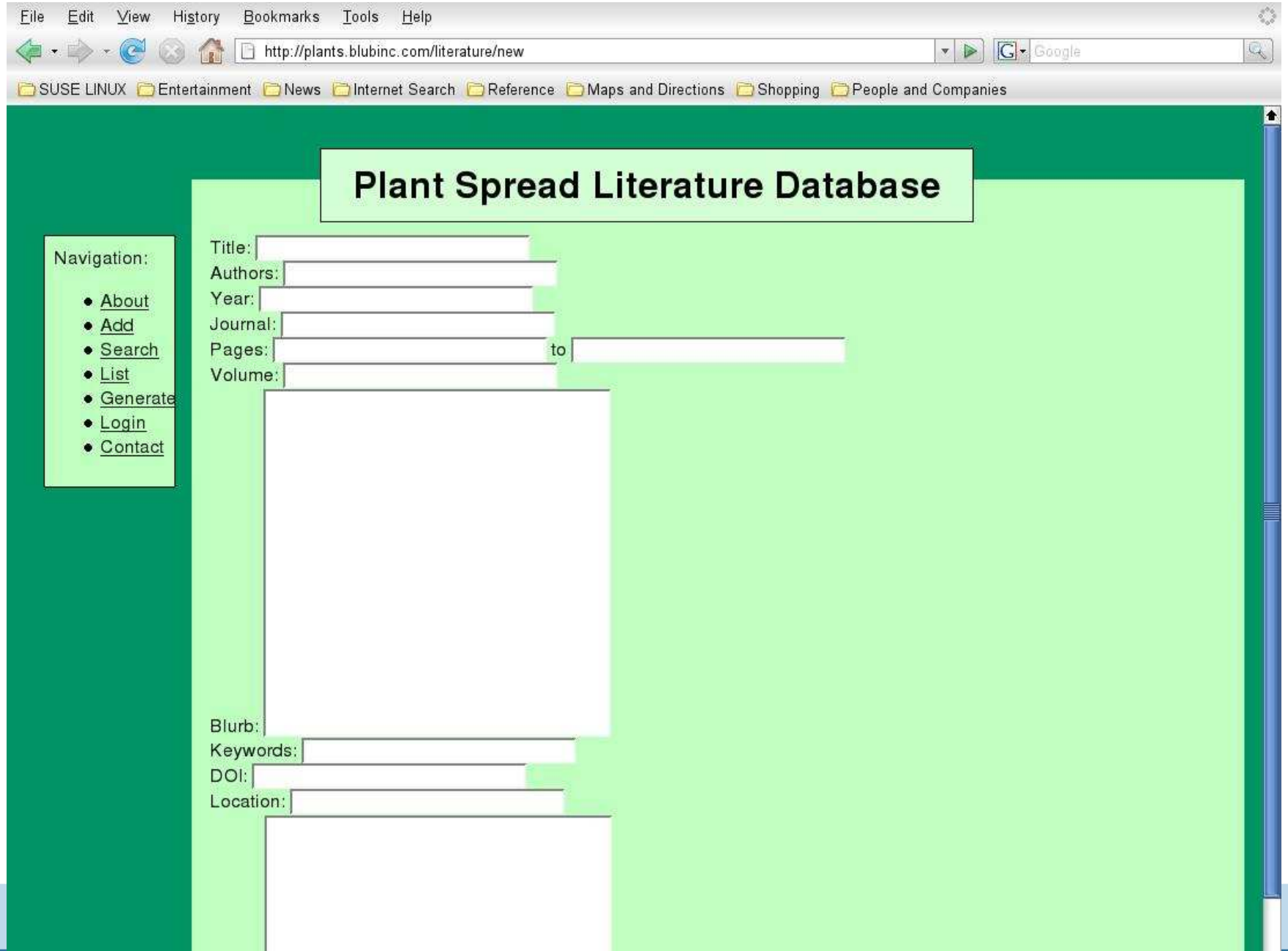
Online Plant Spread Database.

- Online searchable list of publications.



Online Plant Spread Database.

- Online addition of articles (by anyone).



Work in progress

- Incorporation of new simulation routines
- Improved user guide
- Additional data sets
- Make it open source.

Web Links + contacts

These links are still under construction. Please feel free to email us.

- **http://culpeo.pems.adfa.edu.au/∼rhickson/** Our Plant Spread database + Forum.
- **http://culpeo.pems.adfa.edu.au/∼s8704008/PLANTS/plants.html** My plant spread web page.
- **http://culpeo.pems.adfa.edu.au/∼s8704008/** my home page.
- **s.barry@adfa.edu.au**. My email.
- Our open-source Matlab software will be available soon. Please see my plant spread web page for updates.

Thanks

Any questions?