



Modelling Weed Spread

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Introduction

Introduction

● Introduction

- Motivation
- Which model to use?
-

Example simulation

PLANTSIM

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- 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.



Motivation

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- Kate asked for some help modelling Lippia spread down river systems.



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- Kate asked for some help modelling Lippia spread down river systems.
- So I started coding a simple Reaction Diffusion Model.

$$\frac{\partial N}{\partial t} = \frac{\partial^2 N}{\partial x^2} + N(1 - N)$$



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- Kate asked for some help modelling Lippia spread down river systems.
- So I started coding a simple Reaction Diffusion Model.
- But soon we needed:
 - (i) Seed dispersal



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- Kate asked for some help modelling Lippia spread down river systems.
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- But soon we needed:
 - Seed dispersal
 - Allee effects,



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- Kate asked for some help modelling Lippia spread down river systems.
- So I started coding a simple Reaction Diffusion Model.
- But soon we needed:
 - (i) Seed dispersal
 - (ii) Allee effects
 - (iii) seed banks,



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- Kate asked for some help modelling Lippia spread down river systems.
- So I started coding a simple Reaction Diffusion Model.
- 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?

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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?

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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?

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Fractional derivative models?

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



Which model to use?

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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?

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or

- Stochastic jump-diffusion models
 - occupation models
 - disturbance models
- etc. All with various predictions.



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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 digestible output.
- be easy to use and open-source.



Example simulation

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● Example simulation

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



Example simulation

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● Example simulation

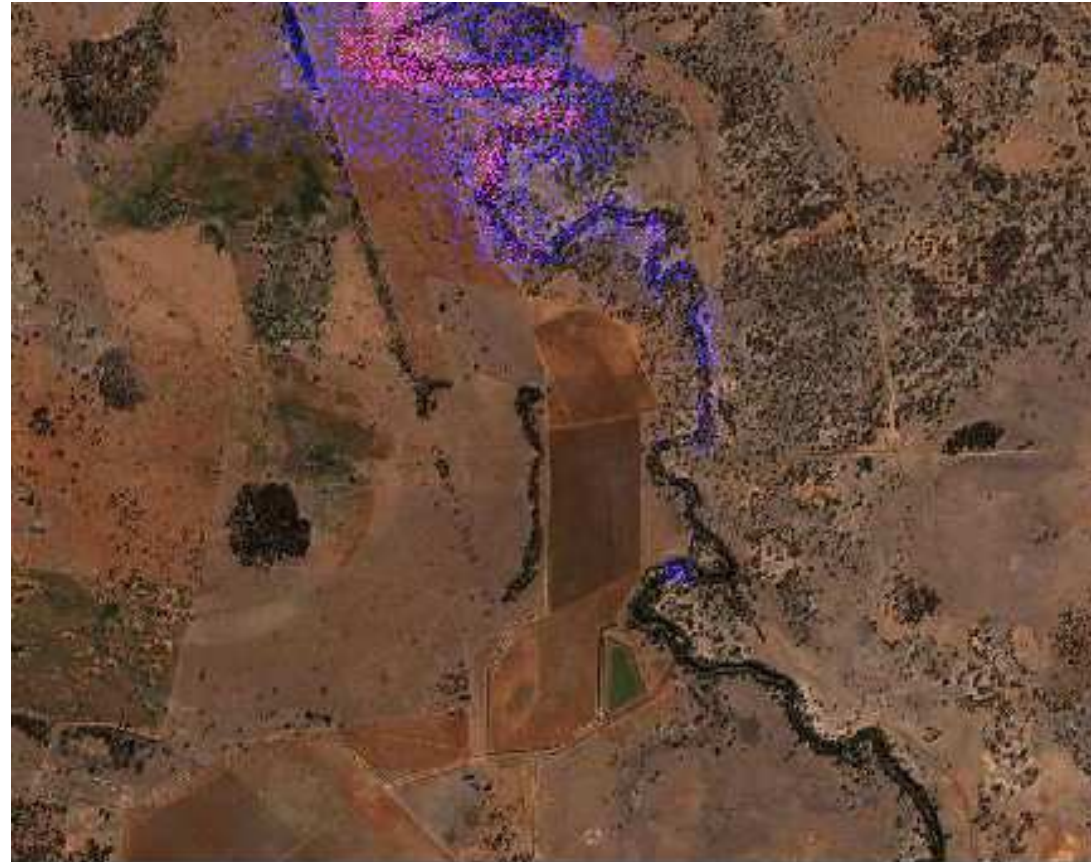
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Here we have weeds spreading down the river.



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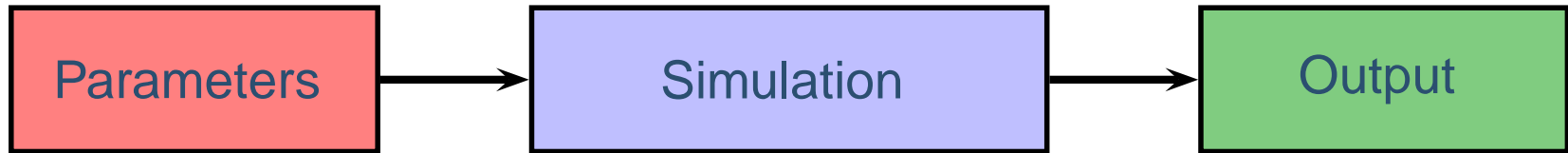
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What is required in a simulation package?



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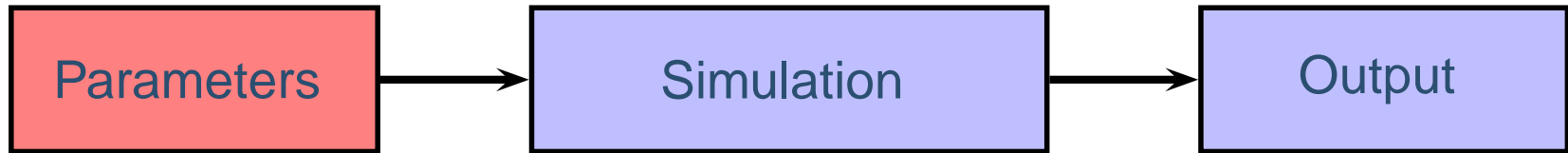
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What is required in a simulation package?



- Use realistic domains.



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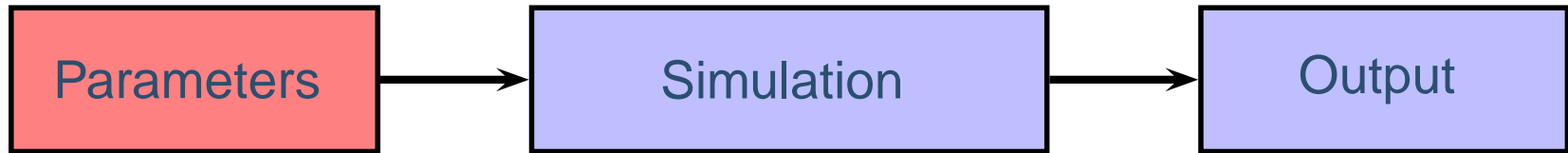
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What is required in a simulation package?



- Easily describe properties to different regions.



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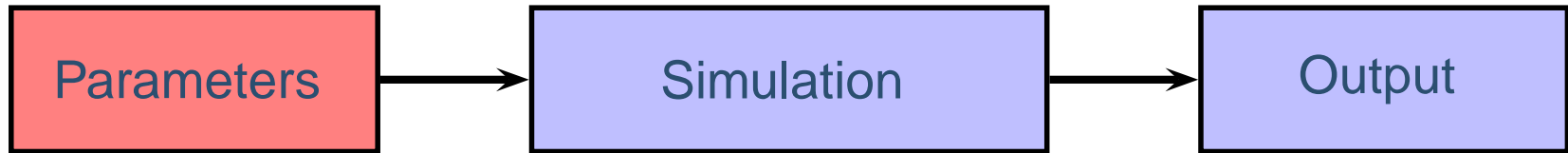
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What is required in a simulation package?



- Easily define key features – like rivers.



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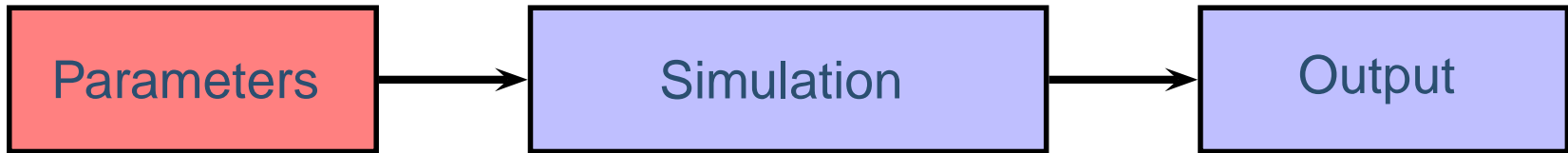
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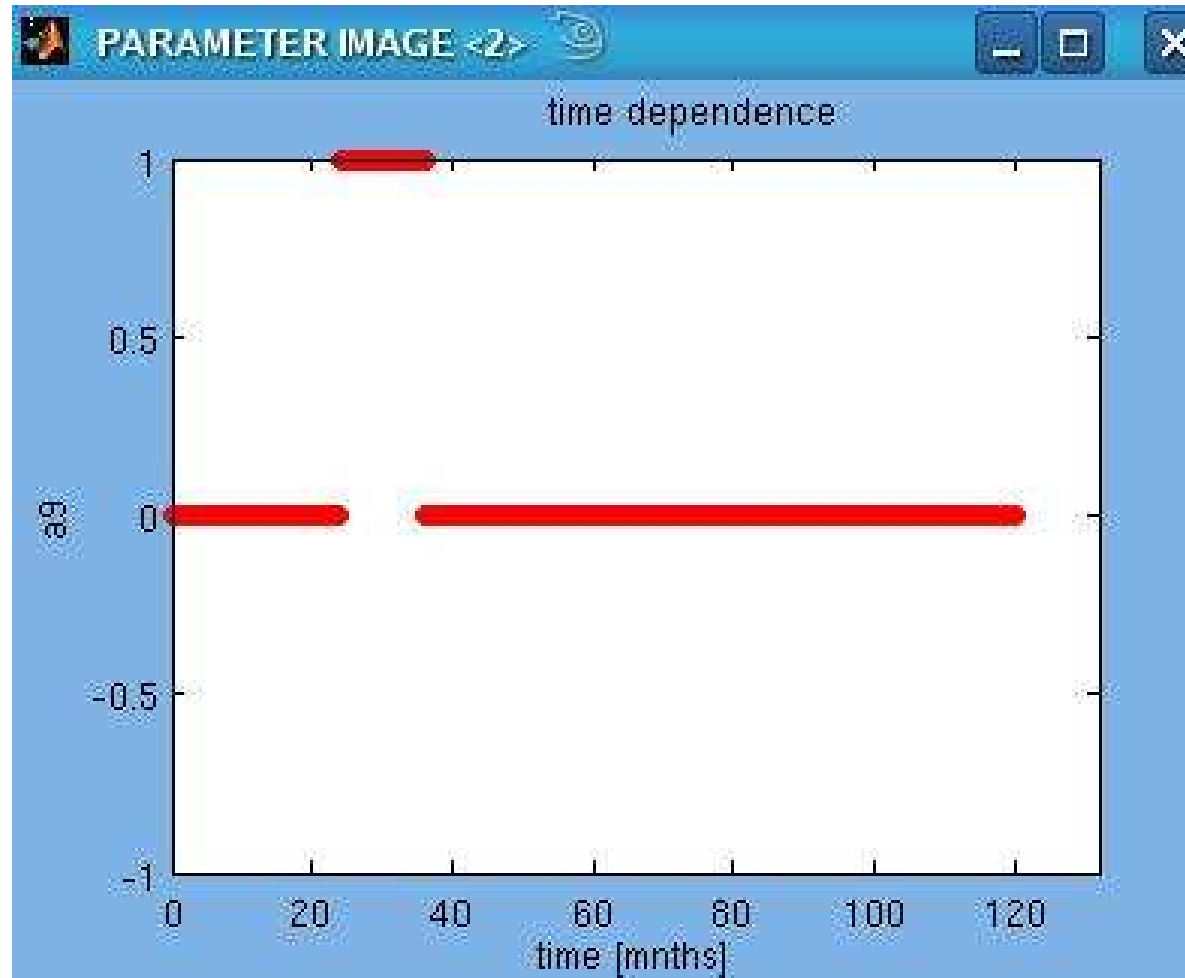
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What is required in a simulation package?

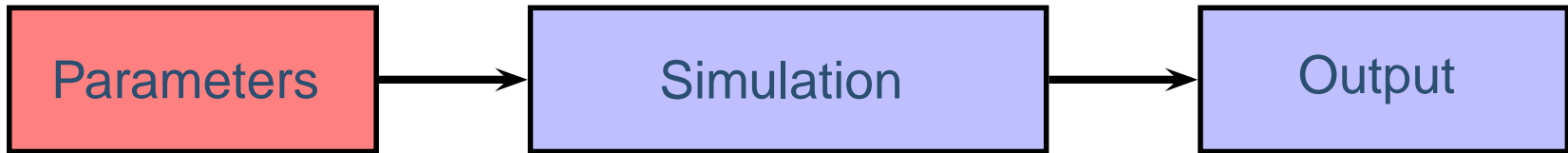


- Illustrate time dependent parameters.

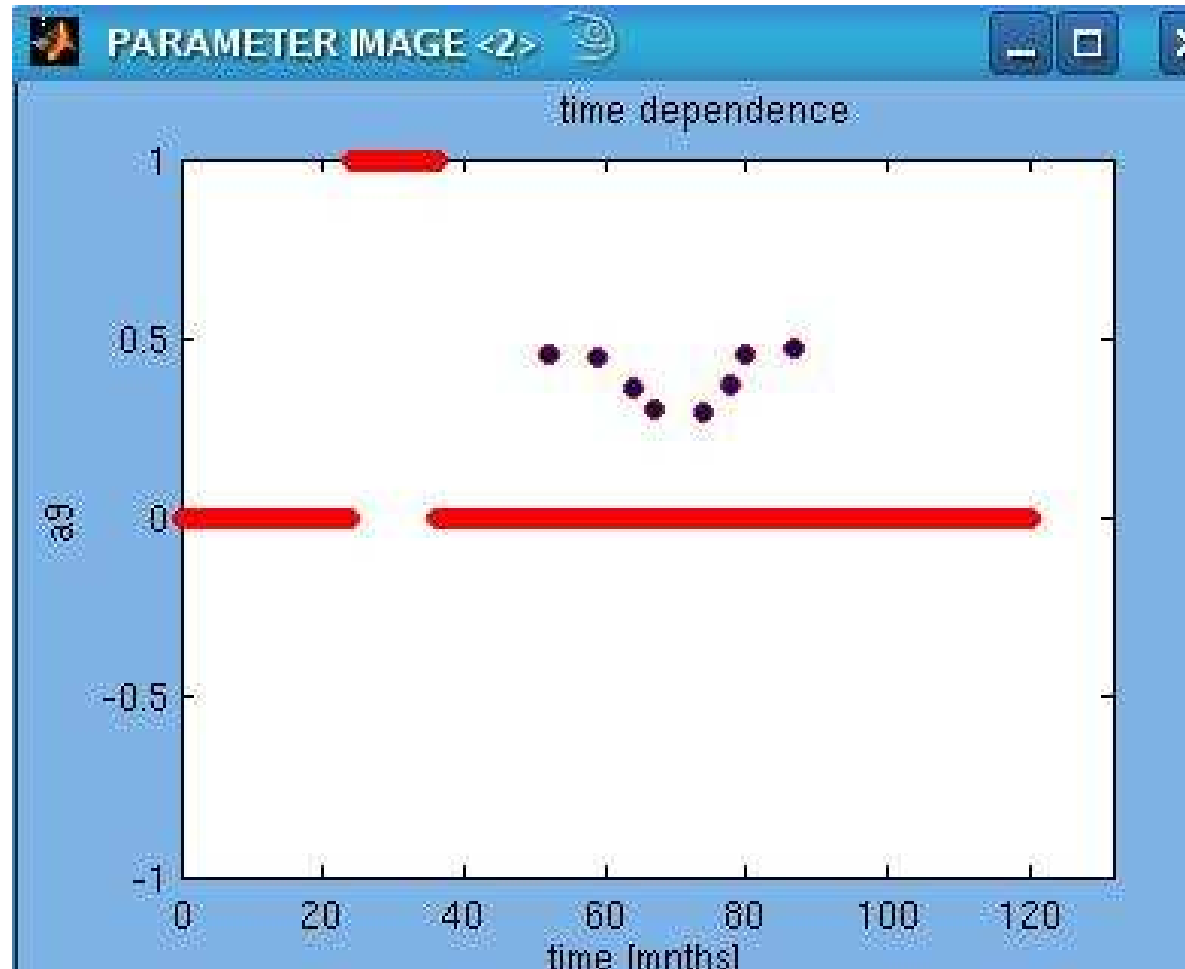




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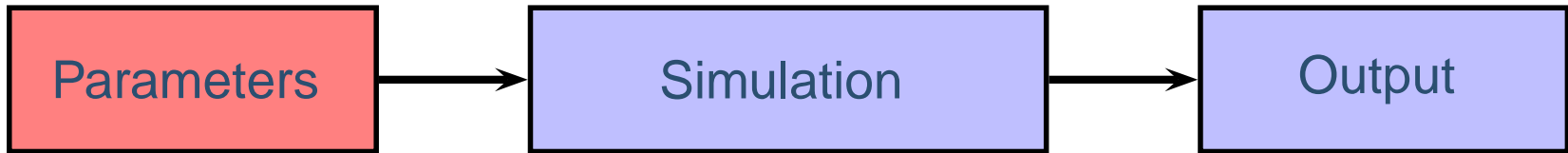


- And modify them with mouse clicks

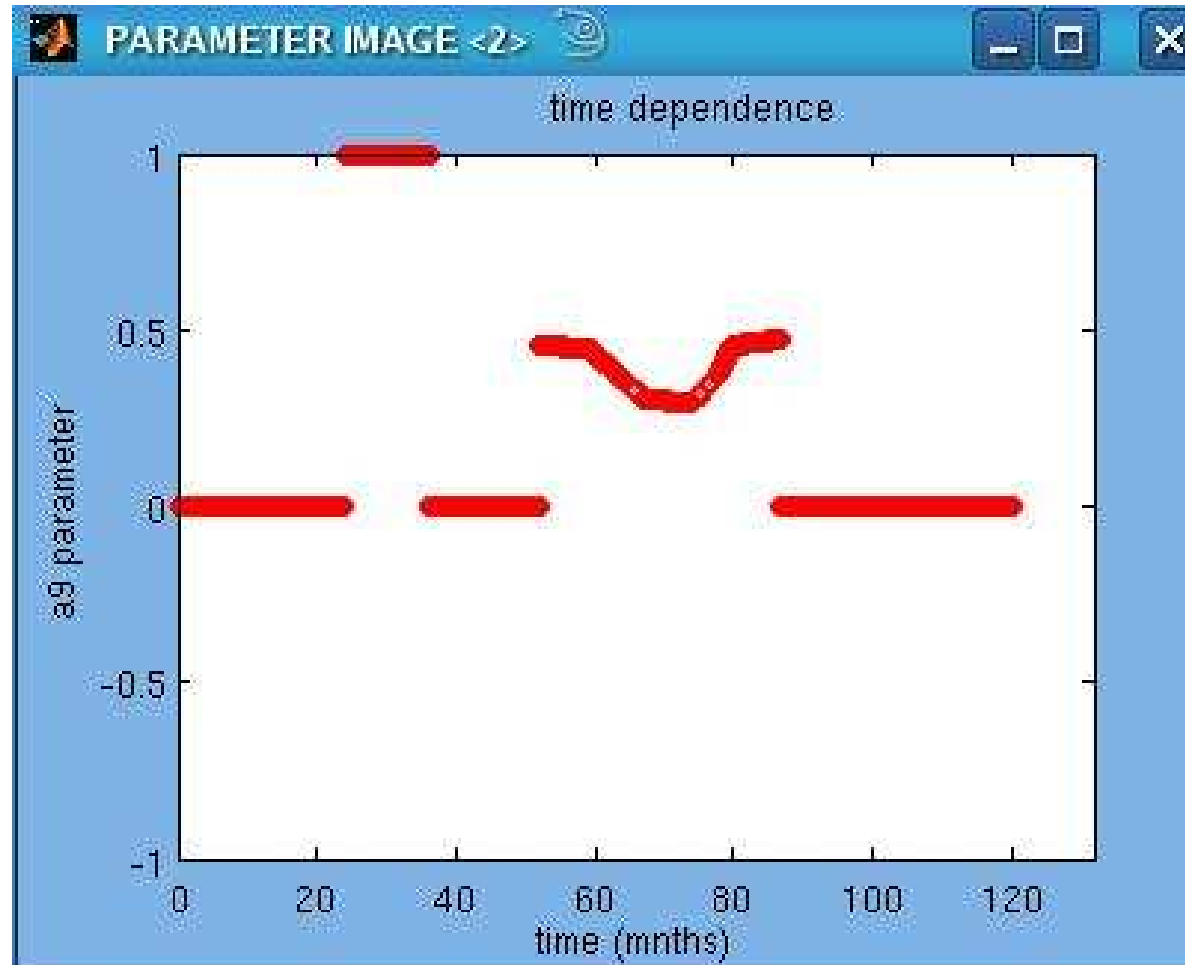




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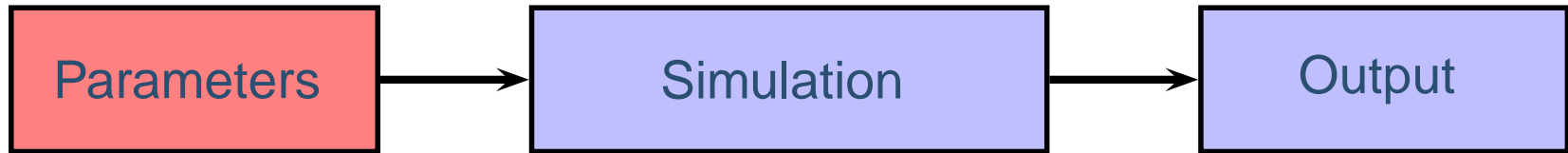


- And modify them with mouse clicks

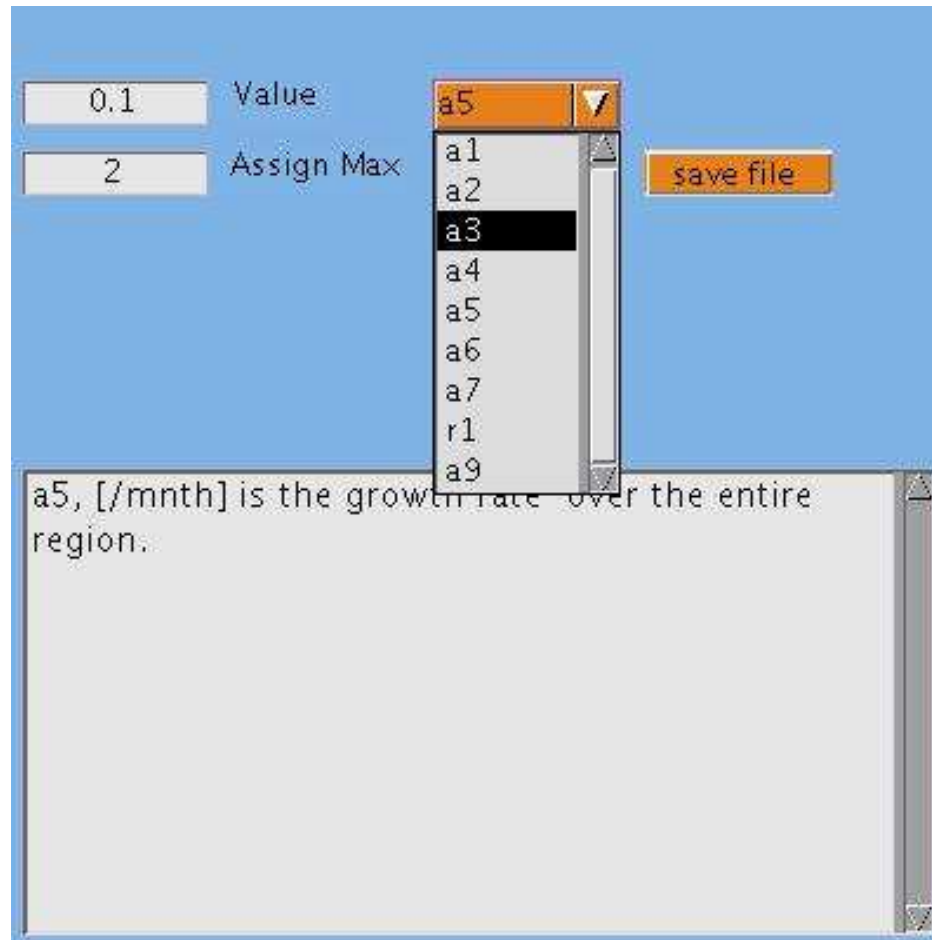




What is required in a simulation package?



- 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

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● What is required in a simulation package?

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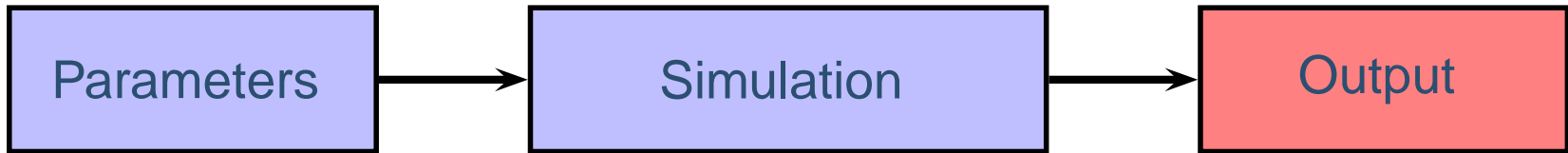
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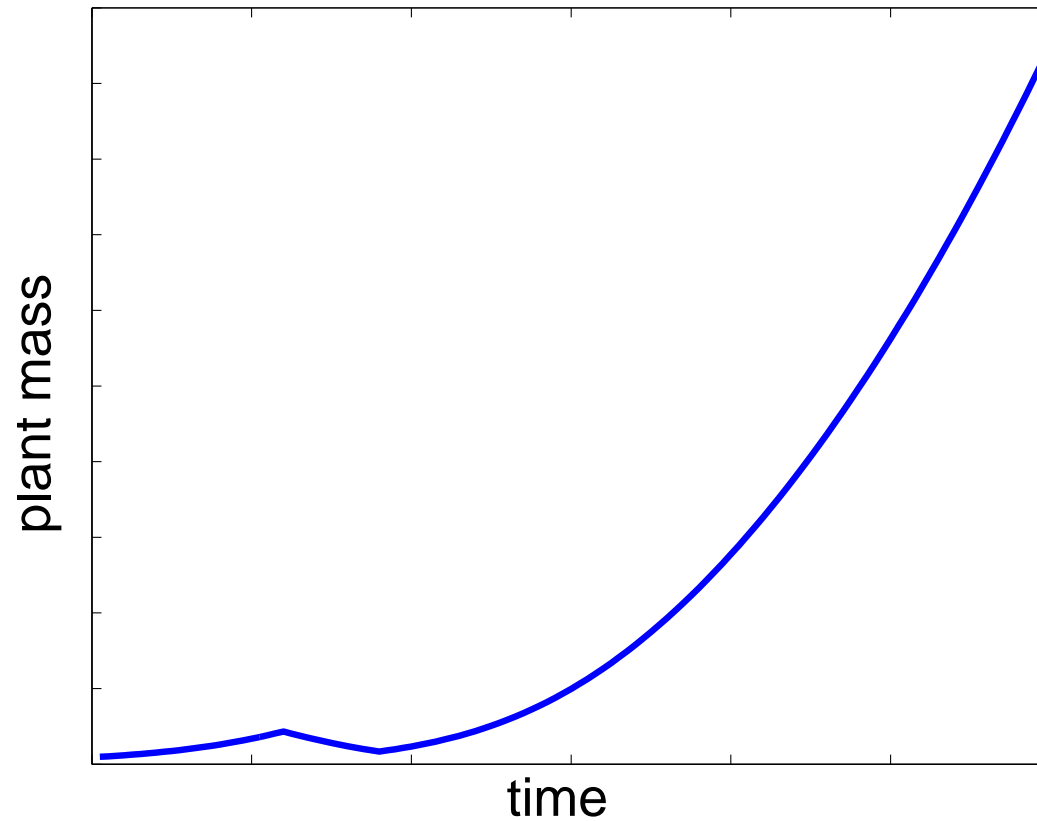
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What is required in a simulation package?

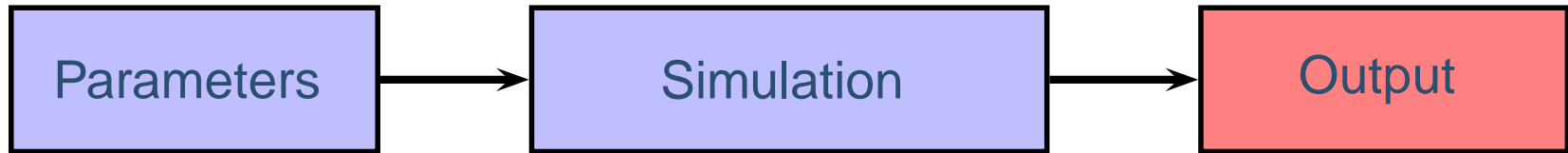


- A variety of output automatically generated – total plant mass.



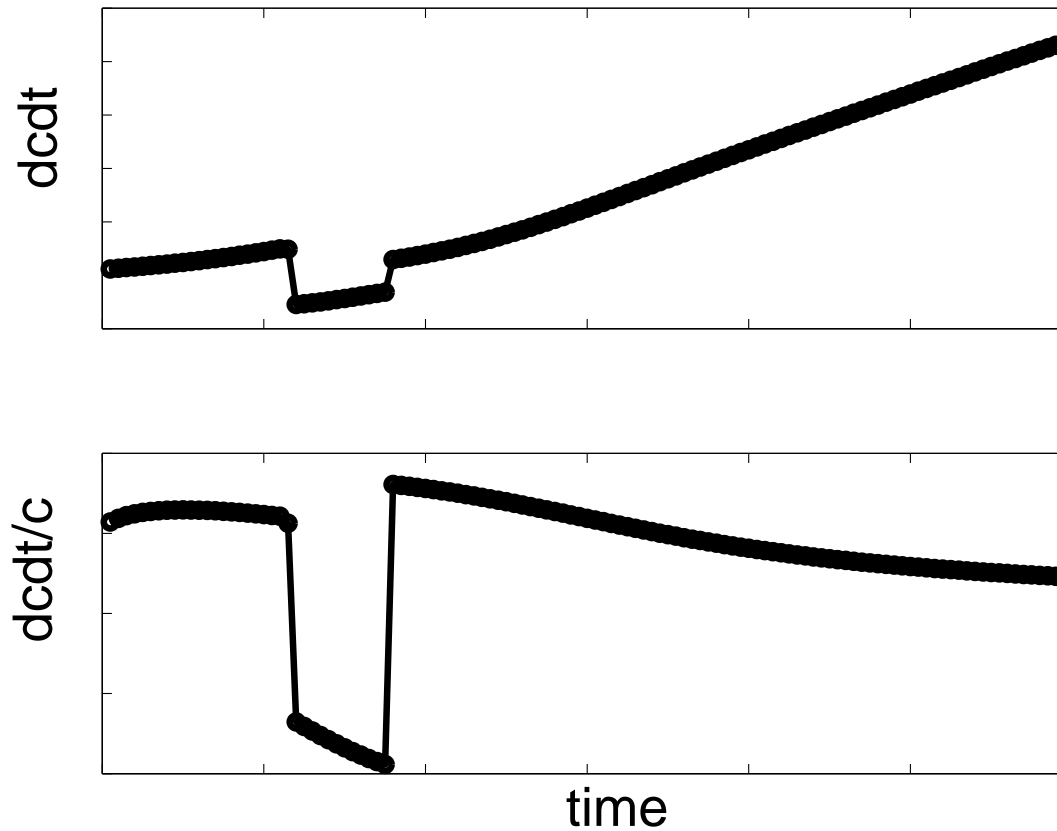


What is required in a simulation package?



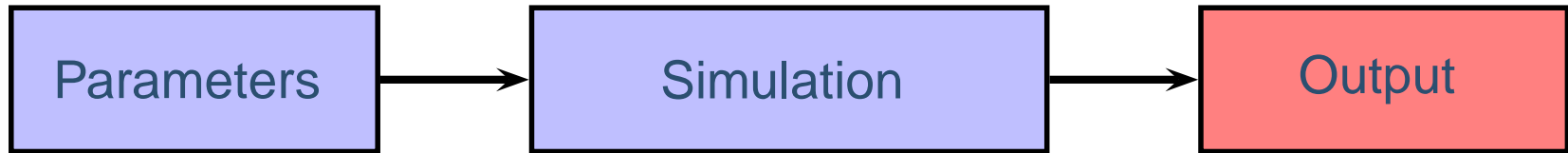
- Rate of change of plant mass dc/dt and $(dc/dt)/c$.

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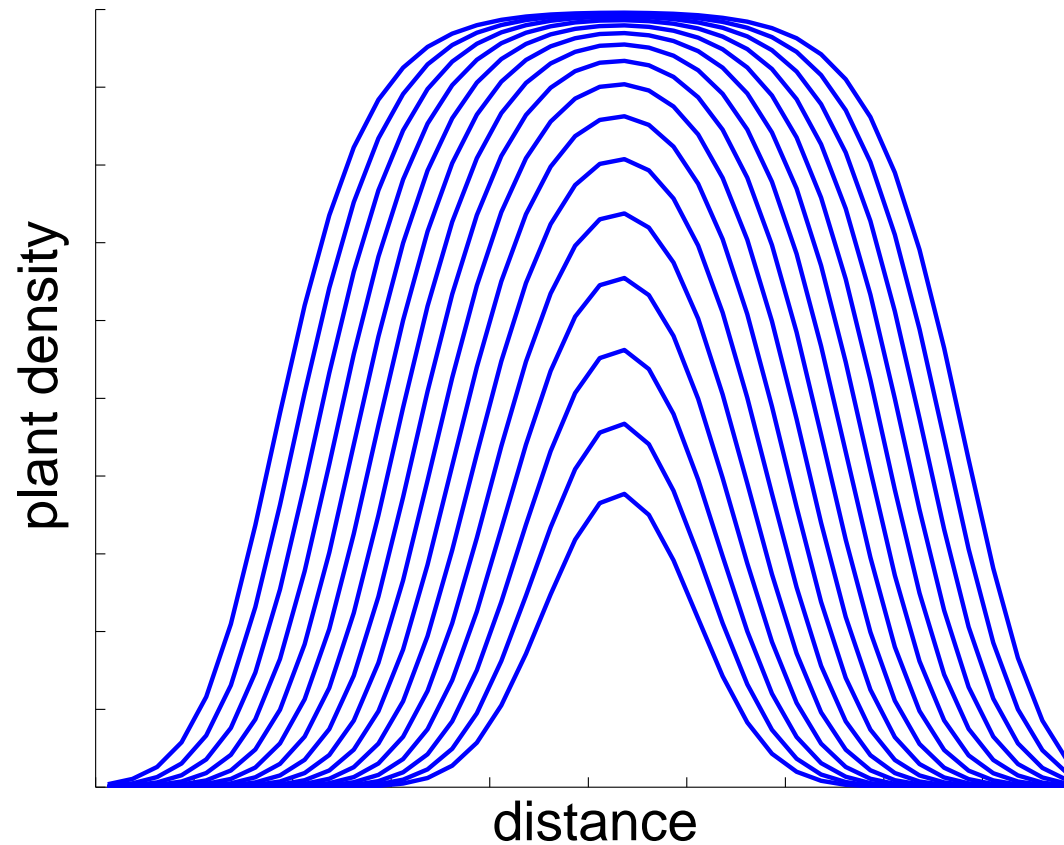




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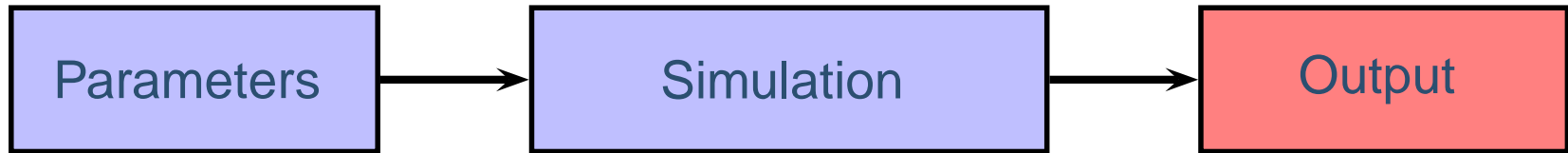


■ Travelling wave fronts.





What is required in a simulation package?

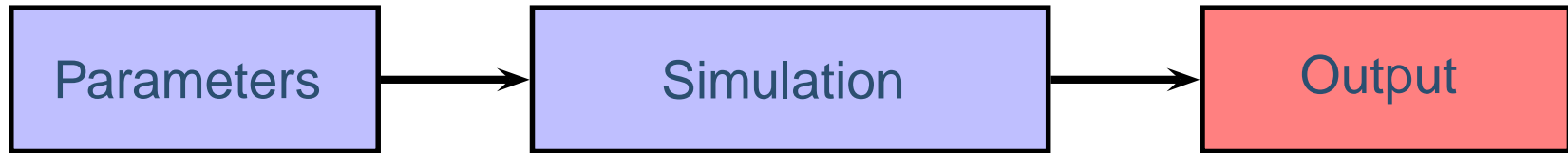


- A variety of visualisation options - dot density.





What is required in a simulation package?



- A variety of visualisation options - coloured density.



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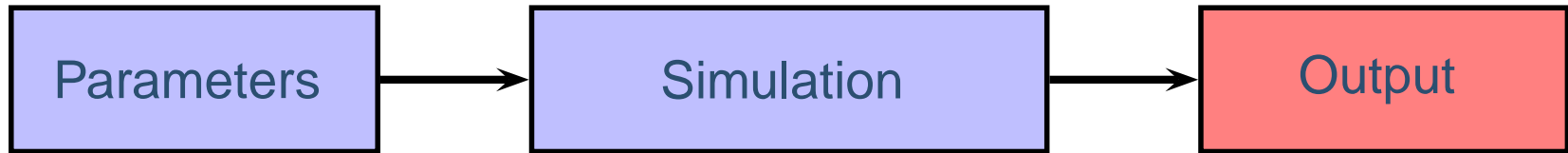
Other work

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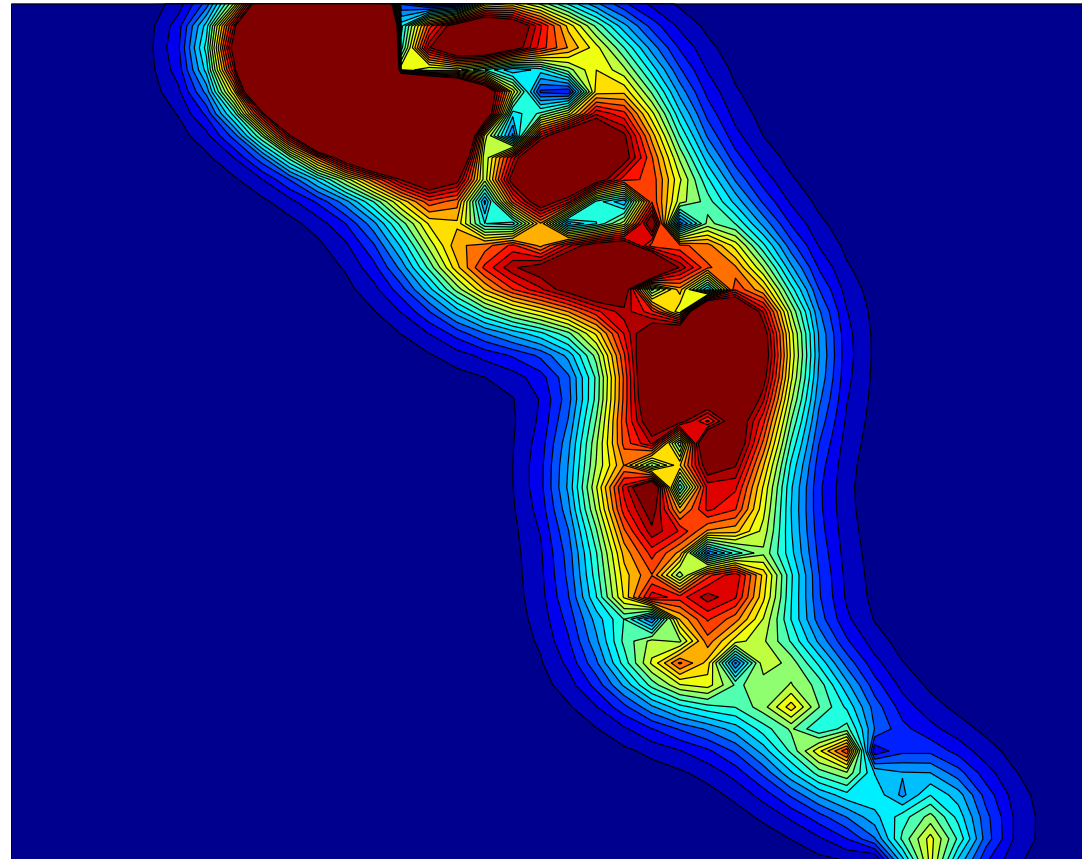
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What is required in a simulation package?



- A variety of visualisation options - coloured contours.



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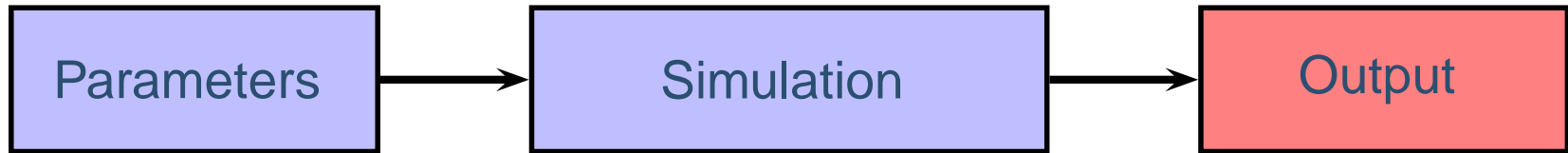
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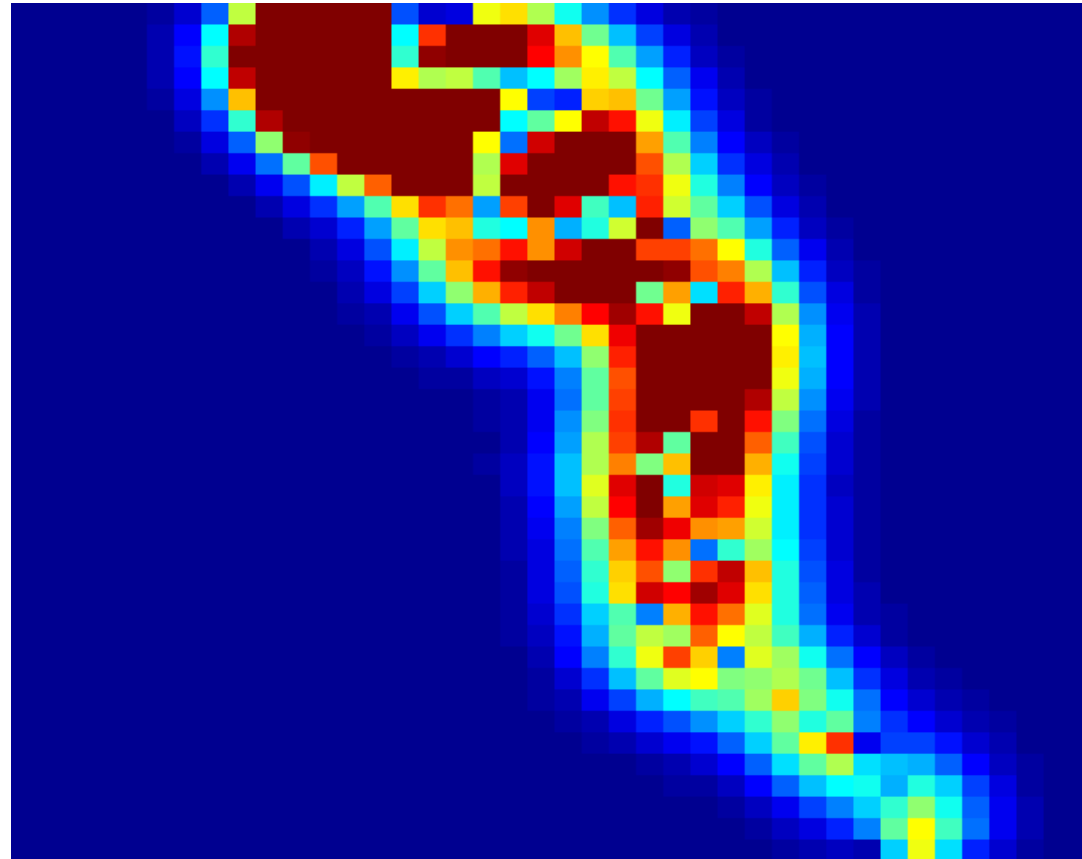
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What is required in a simulation package?



- A variety of visualisation options - coloured density.



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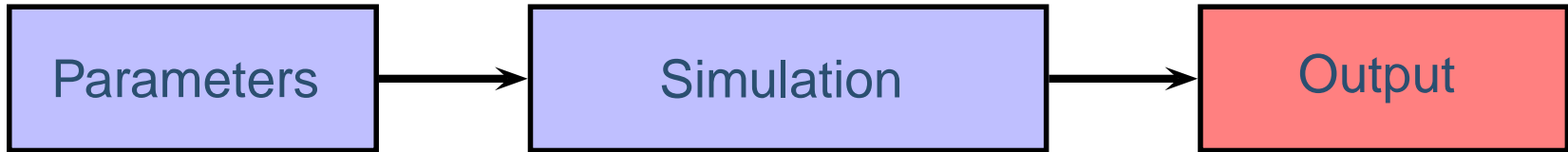
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What is required in a simulation package?



- 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

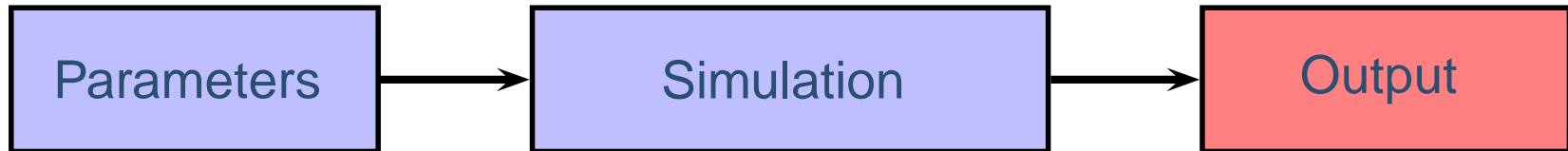
This report was generated from the matlab code `aSHOW.m` to consider a simulation of plant growth with a given parameter set.

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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):

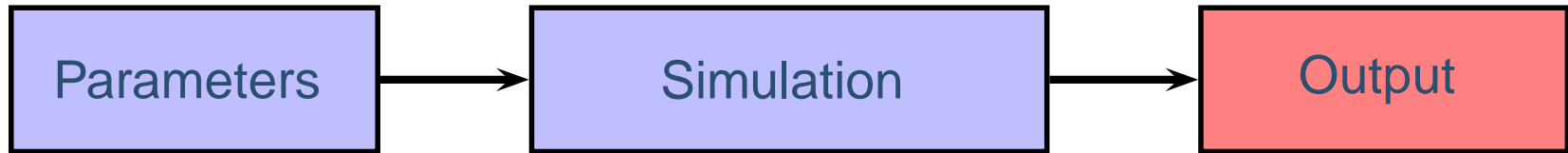
- a2(x,y), [br/m²] are the initial concentration of plants.
- The nominal value is 10. The nominal stochasticity is 0. The mean is 0.0081029. The assigned maximum is 20.

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.

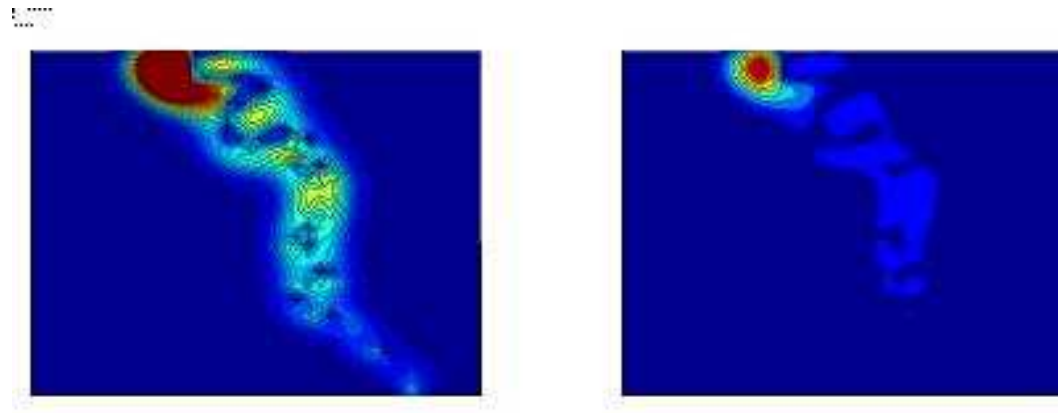


Figure 20: Plotting species 1 at time step 69

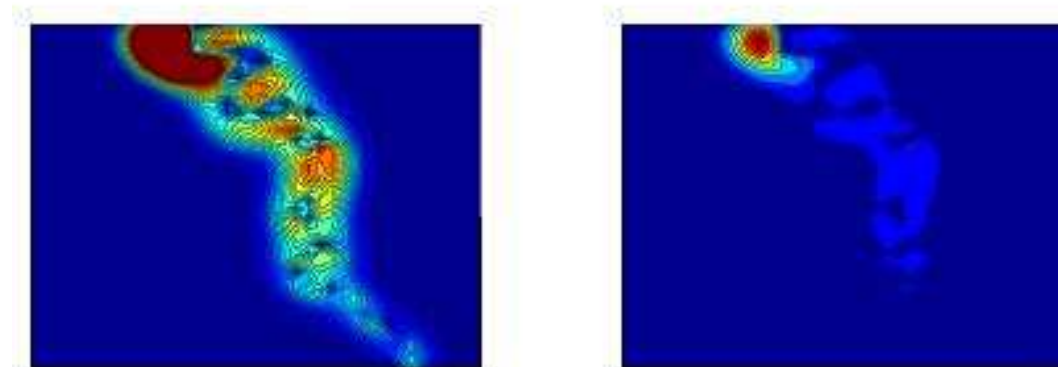
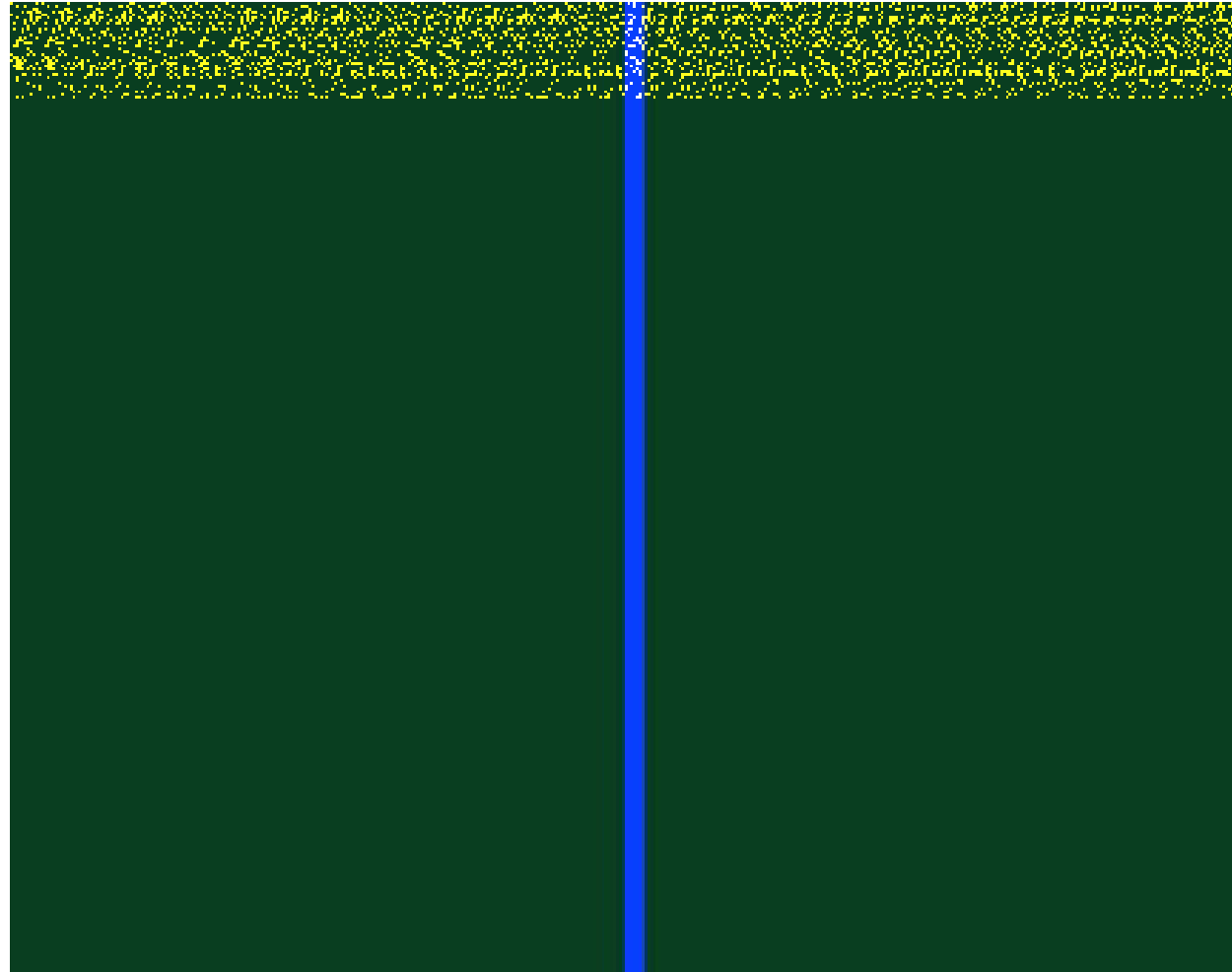


Figure 21: Plotting species 1 at time step 73



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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● **Integro-difference.**

- Stage structured model
- Two species reaction diffusion with logistic growth

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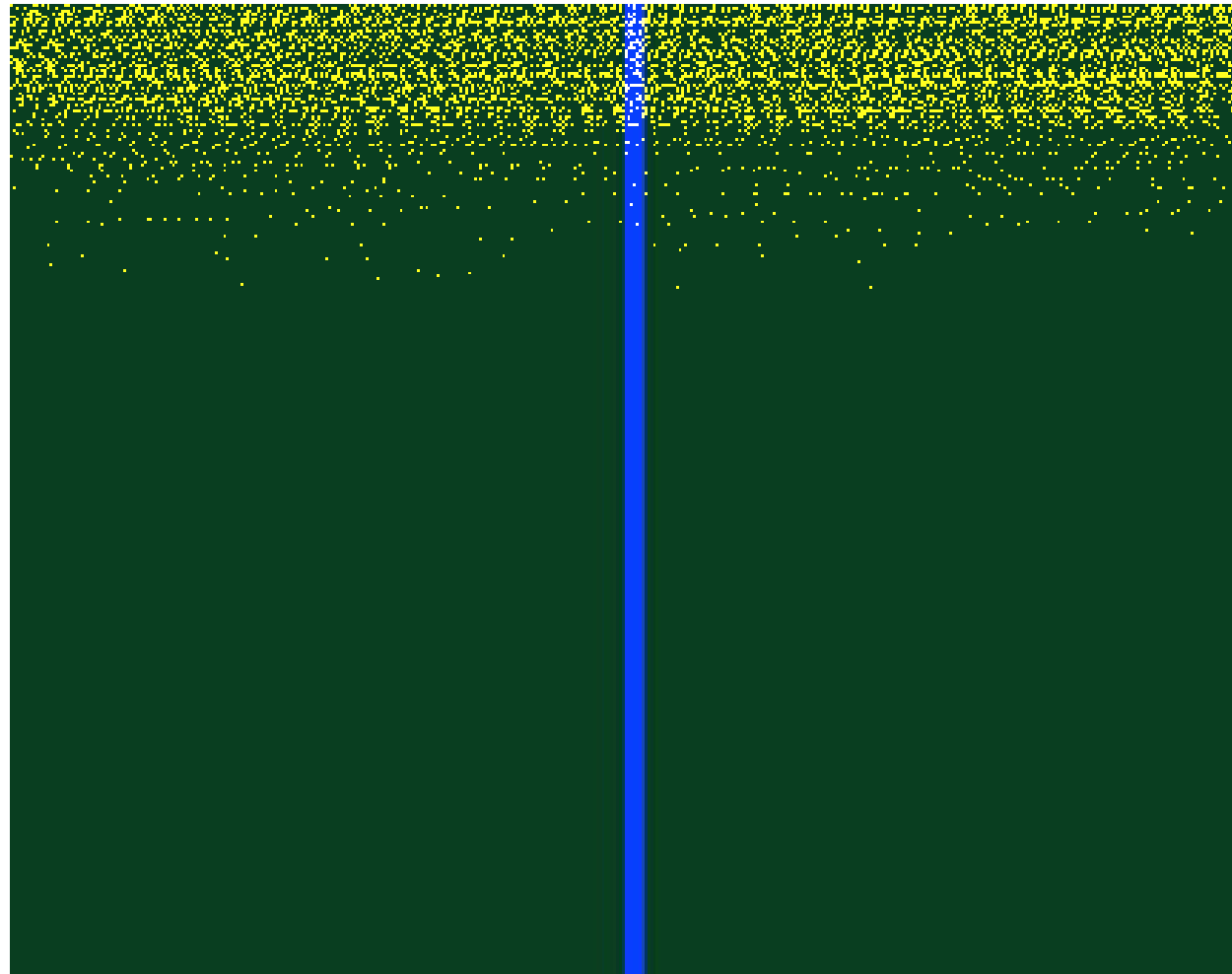
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Integro-difference.

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



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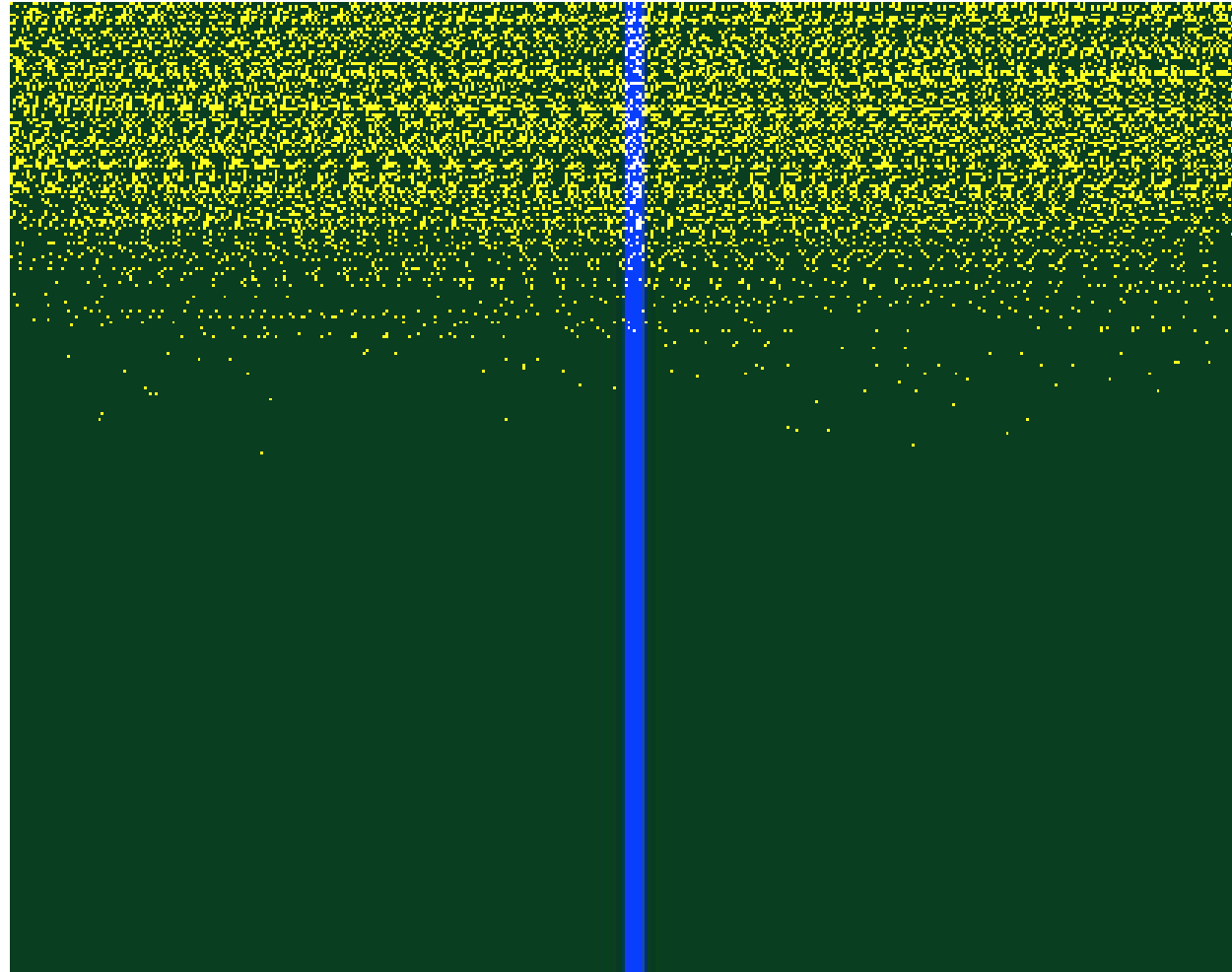
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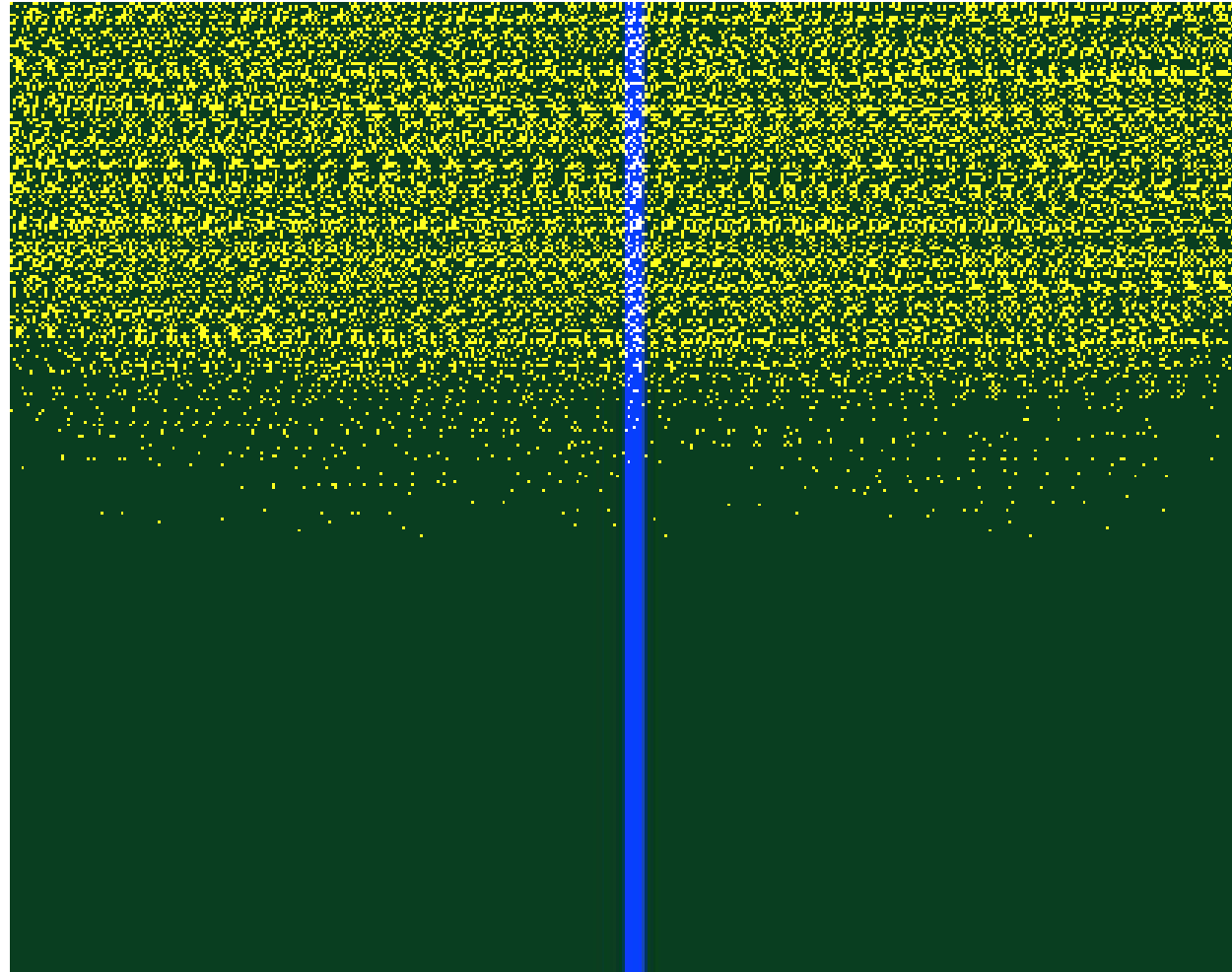
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Integro-difference.

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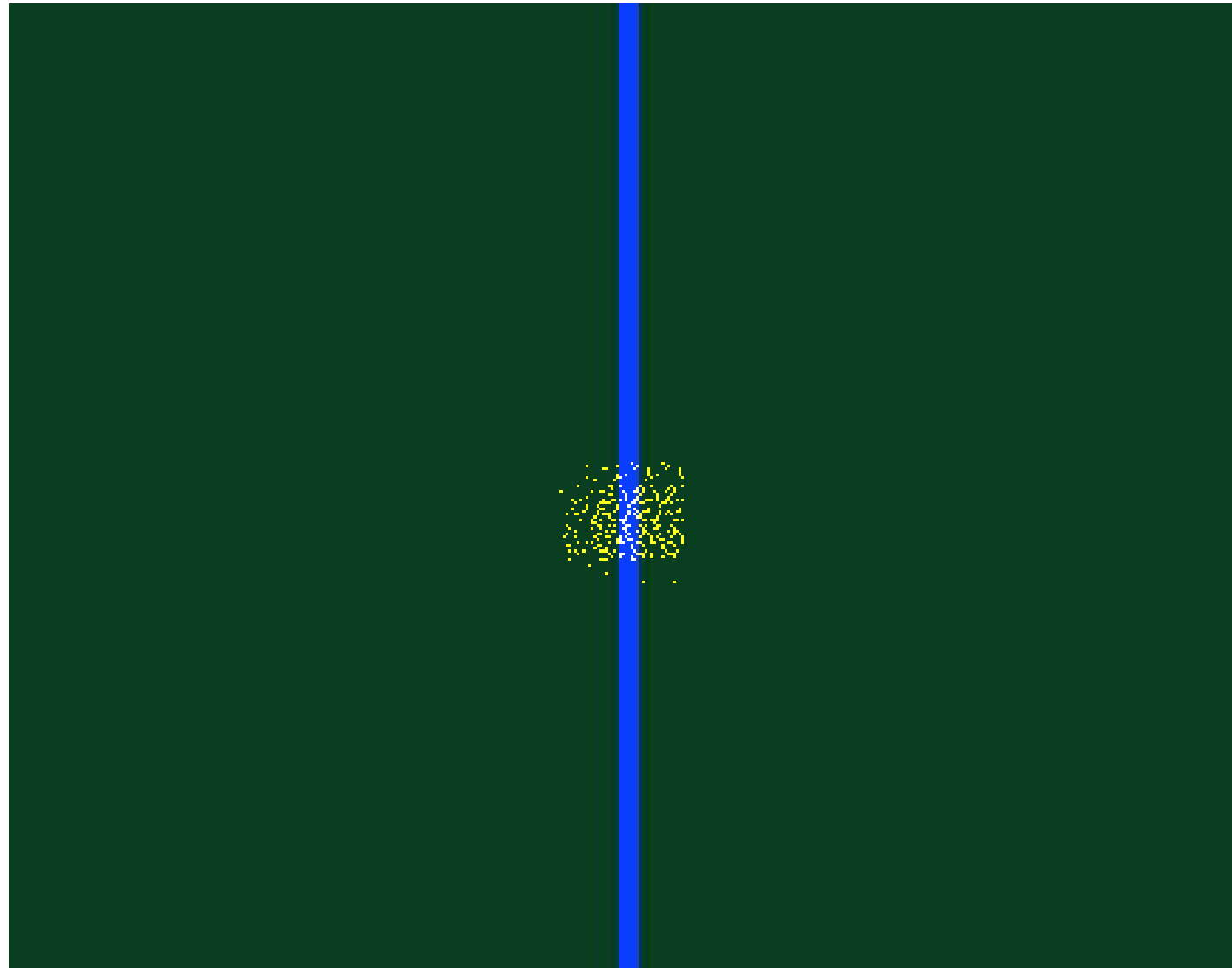
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Stage structured model

Plants \rightarrow seeds \rightarrow dispersal \rightarrow seedbank \rightarrow seedlings \rightarrow plants.



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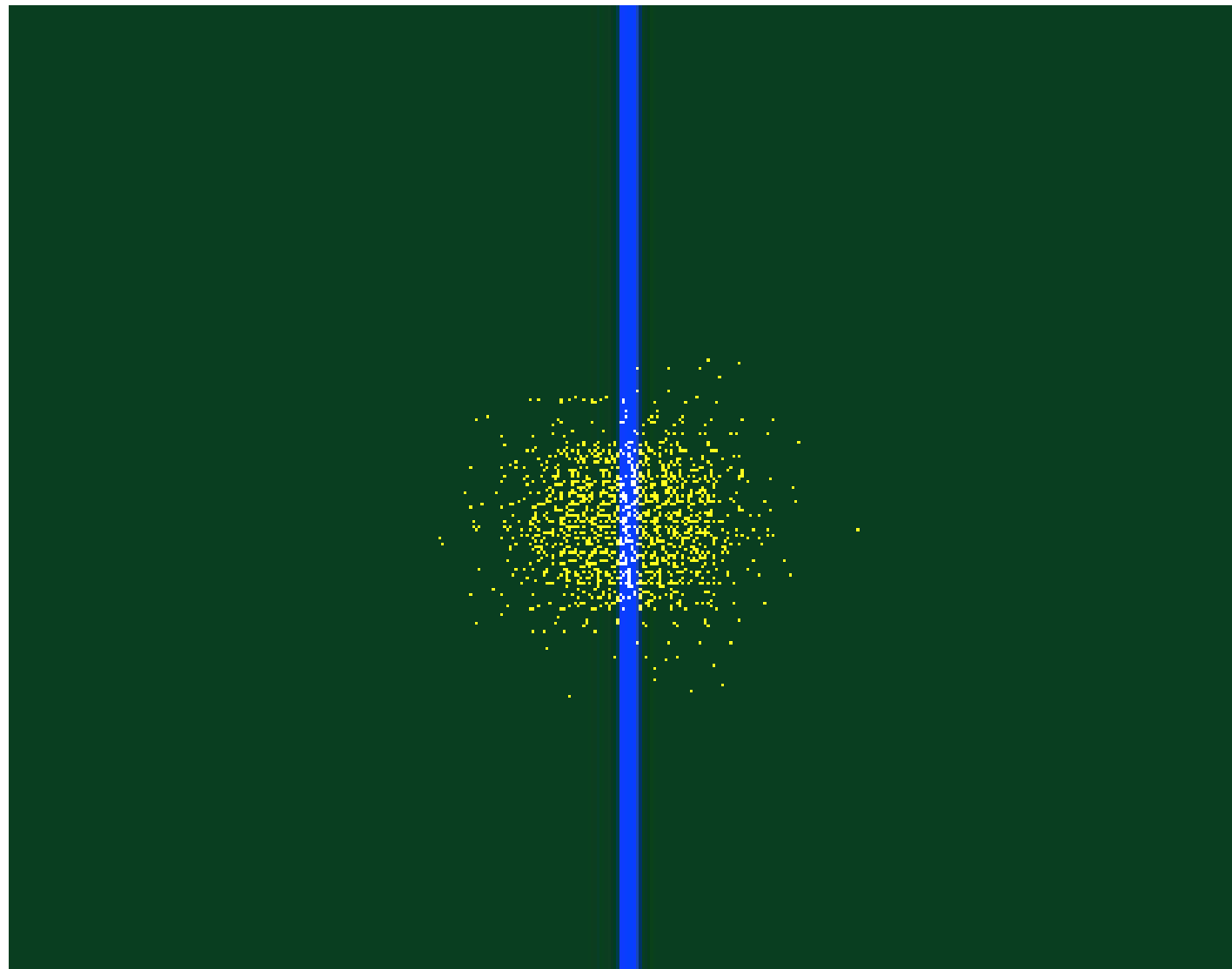
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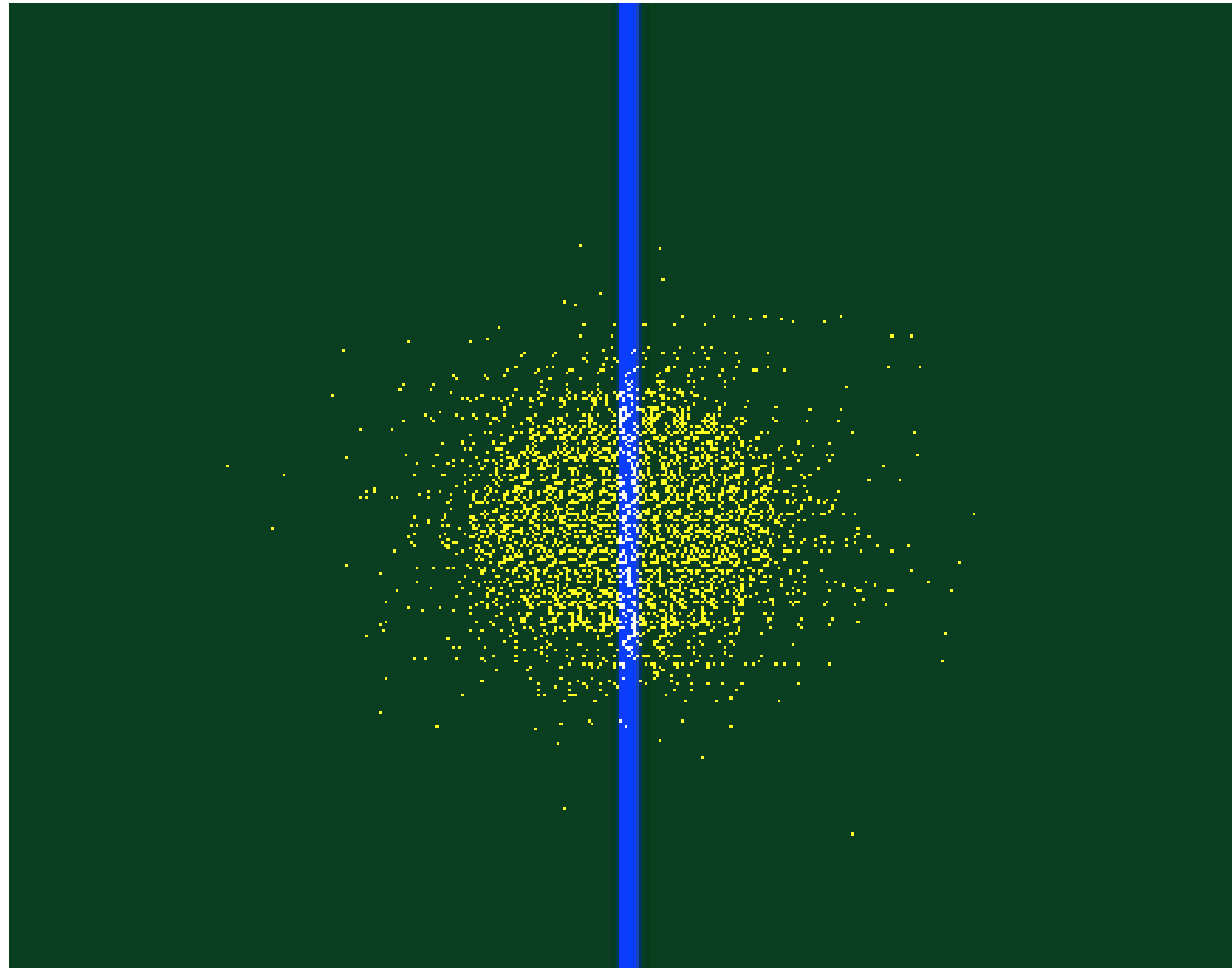
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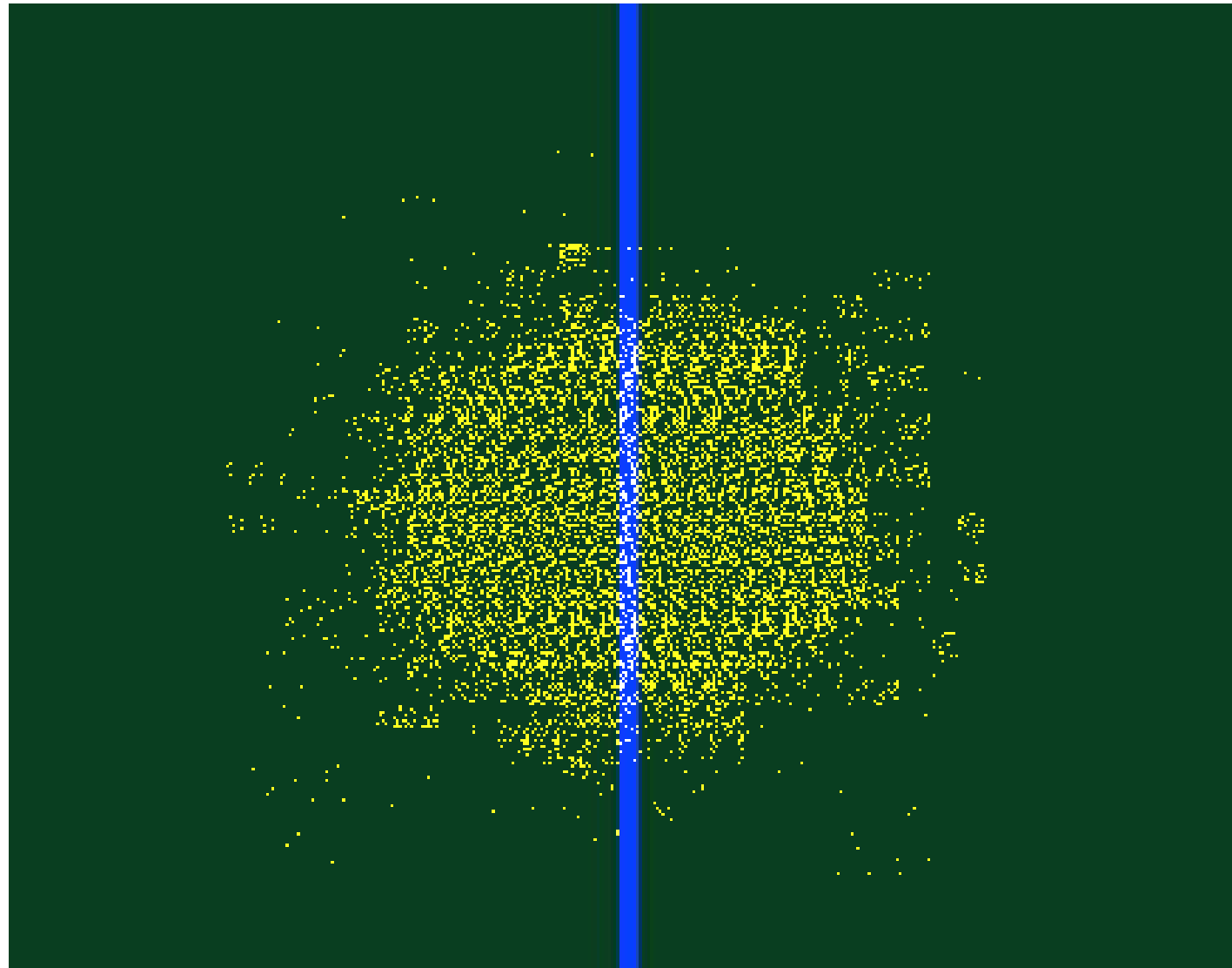
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Stage structured model

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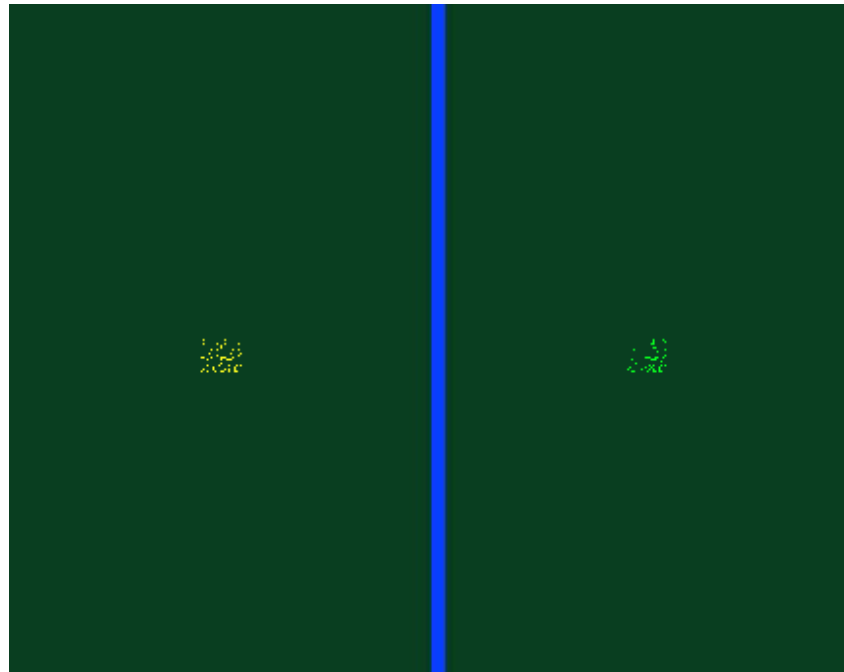
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Two species reaction diffusion with logistic growth

$$\frac{\partial N_1}{\partial t} = D_1 \nabla^2 N_1 + \gamma_1 N_1 \left(1 - \frac{N_1}{N_1 + N_2} \right)$$
$$\frac{\partial N_2}{\partial t} = D_2 \nabla^2 N_2 + \gamma_2 N_2 \left(1 - \frac{N_2}{N_1 + N_2} \right)$$



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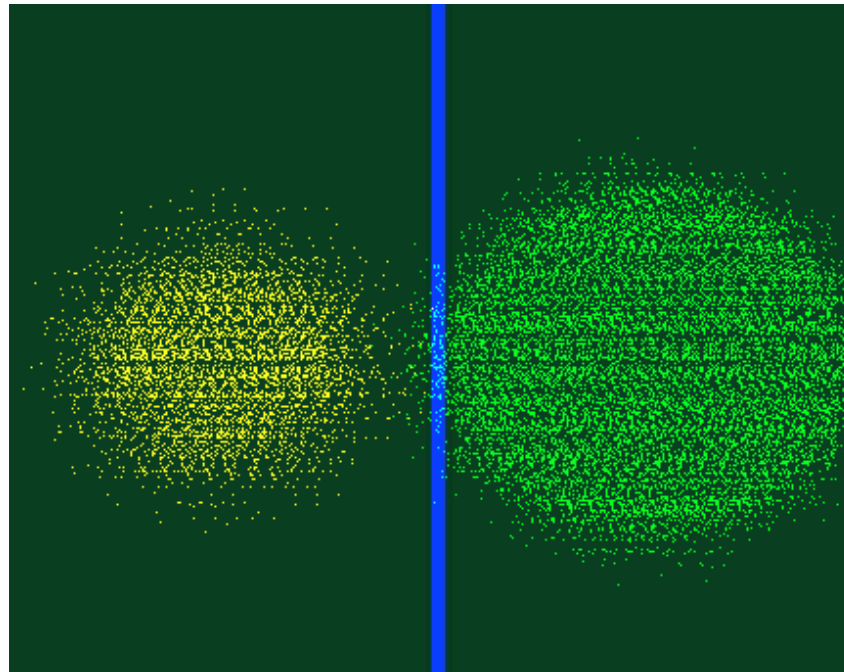
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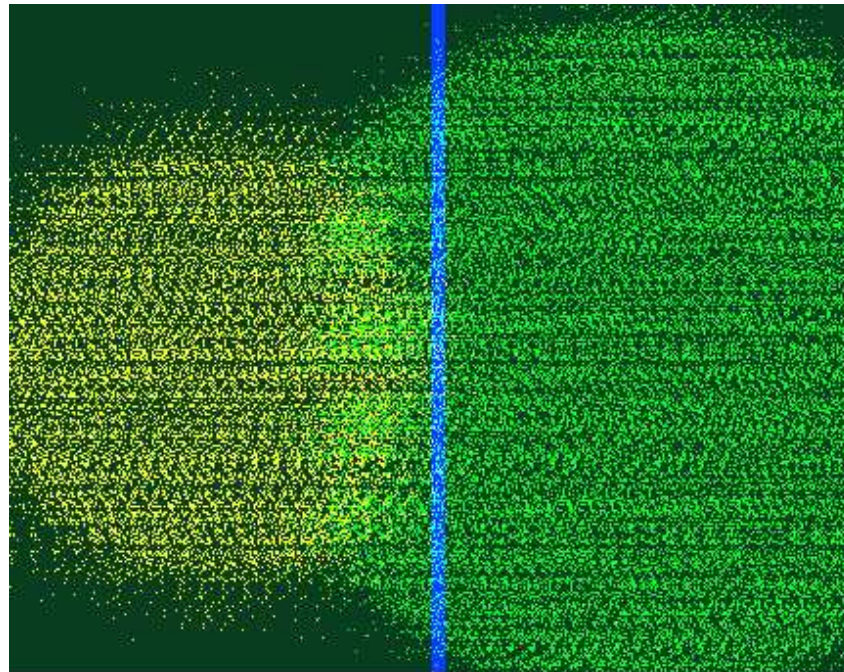
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Two species reaction diffusion with logistic growth

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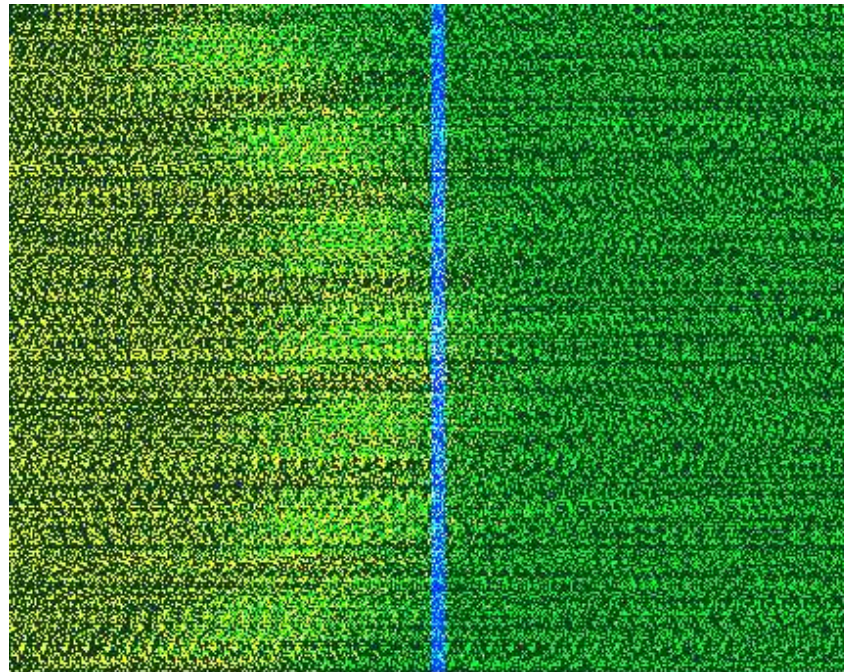
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Two species reaction diffusion with logistic growth

$$\frac{\partial N_1}{\partial t} = D_1 \nabla^2 N_1 + \gamma_1 N_1 \left(1 - \frac{N_1}{N_1 + N_2} \right)$$
$$\frac{\partial N_2}{\partial t} = D_2 \nabla^2 N_2 + \gamma_2 N_2 \left(1 - \frac{N_2}{N_1 + N_2} \right)$$



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- 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.

File Edit View History Bookmarks Tools Help

http://plants.blubinc.com/literature/list

SUSE LINUX Entertainment News Internet Search Reference Maps and Directions Shopping People and Companies

Plant Spread Literature Database

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Literature List

| <u>Title</u> | <u>Authors</u> | <u>Models</u> |
|---|--|---|
| A Diffusion Model for Dispersal Of Opuntia Imbricata (Cholla) on Rangeland | L.J.S. Allen, E.J. Allen, C.R.G. Kunst and R.E. Sosebee | Reaction Diffusion , Logistic |
| A Mathematical Model for Weed Dispersal and Control | L.J.S. Allen, E.J. Allen and S. Ponweera | Integrodifference Equations , Logistic |
| A guide to calculating discrete-time invasion rates from data | M.A. Lewis, M.G. Neubert, H. Caswell, J.S. Clark, K. Shea | |
| A mathematical model for dispersal of an annual plant population with a seed bank | Diomar C. Mistro, Luiz Alberto D. Rodrigues, Andreia B. Schmid | |
| A modelling approach to estimate the effect of exotic pollinators on exotic weed population dynamics: bumblebees and broom in Australia | Kate E. Stokes, Yvonne M. Buckley, Andrew W. Sheppard | |
| A review of models of alien plant spread | S.I. Higgins, D.M. Richardson | |
| A review of models of landscape change | William L. Baker | |
| A spatial model for the spread of invading organisms subject to competition | Deborah R. Hart, Robert H. Gardner | |
| Allee Effects in Biological Invasions | Caz M. Taylor and Alan Hastings | Reaction Diffusion , Integrodifference Equations , Allee Effects , Logistic |
| Analysis on the Critical Speed of Traveling Waves | Jiaoyu Wu, Di Wei, Ming Mei | |
| Biological control of Scotch Broom: modelling the determinants of abundance | | Matrix , Stage-Structured |

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Online Plant Spread Database.

- Online addition of articles (by anyone).

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



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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?



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