

# Our overall objective

- To improve our basic understanding of the biology of crop-weed systems.



# Models for thinking

Models help us formulate notions about the dynamics of the different species that an ecosystem comprises.

*Gutierrez 1996*

# Models as tools

Models are most useful when they help us to formulate and test theory, and to manage ecosystems in an environment-friendly manner.

*Gutierrez 1996*

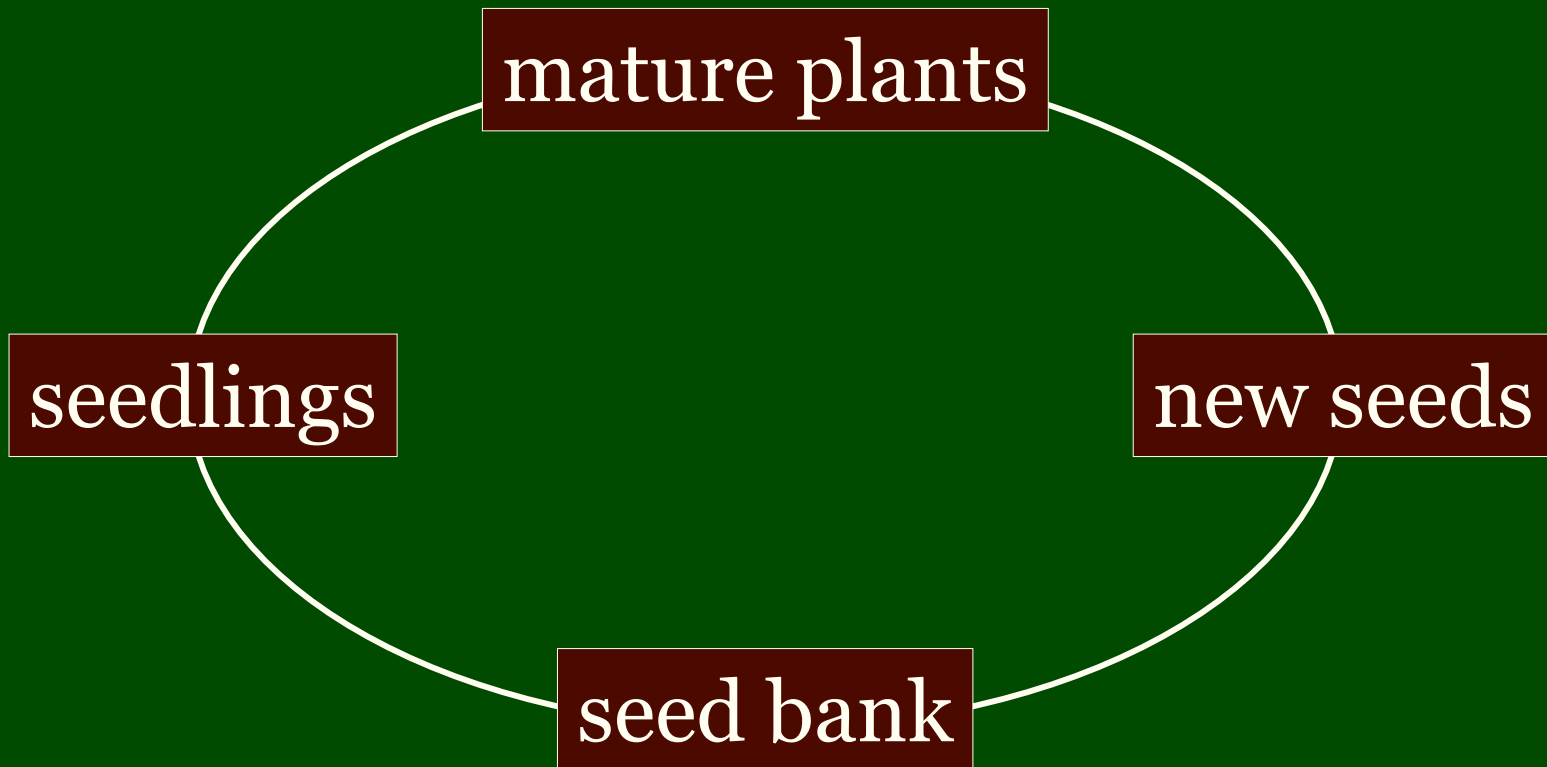
# Existing models

- Weed demographic models found in 134 scientific papers.

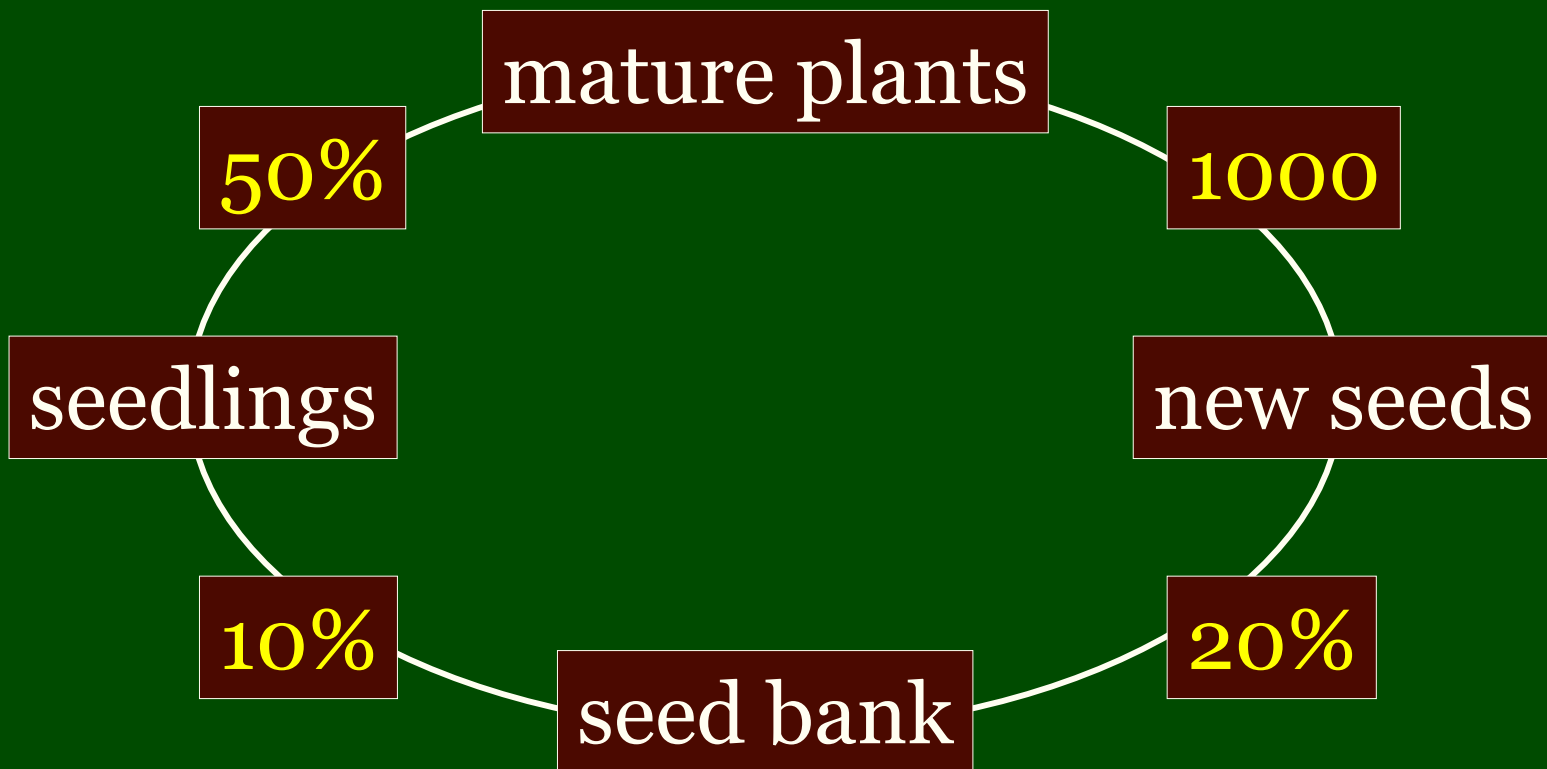
*Holst et al. 2007*



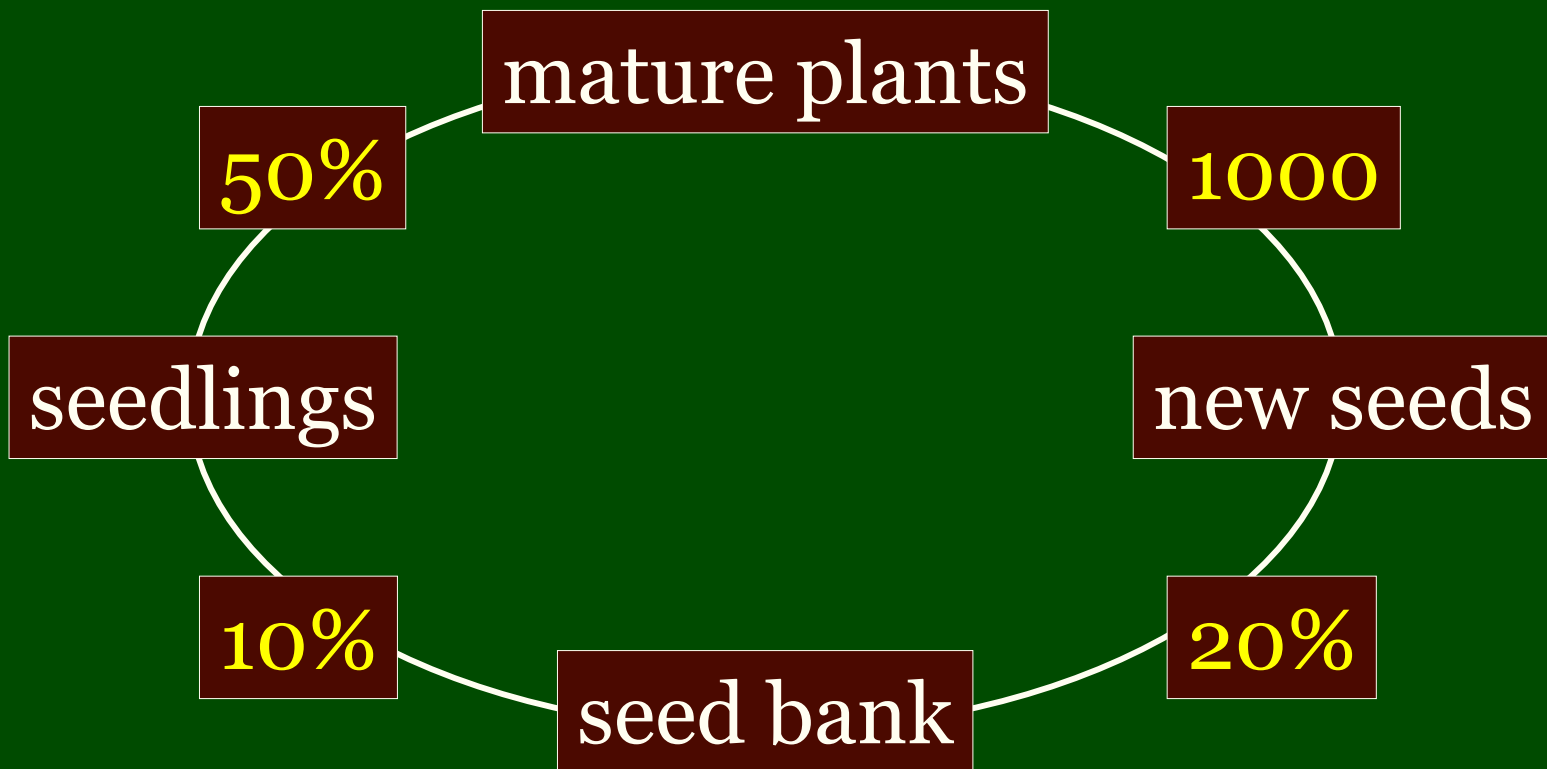
# Weed life cycle model



# Weed life cycle model

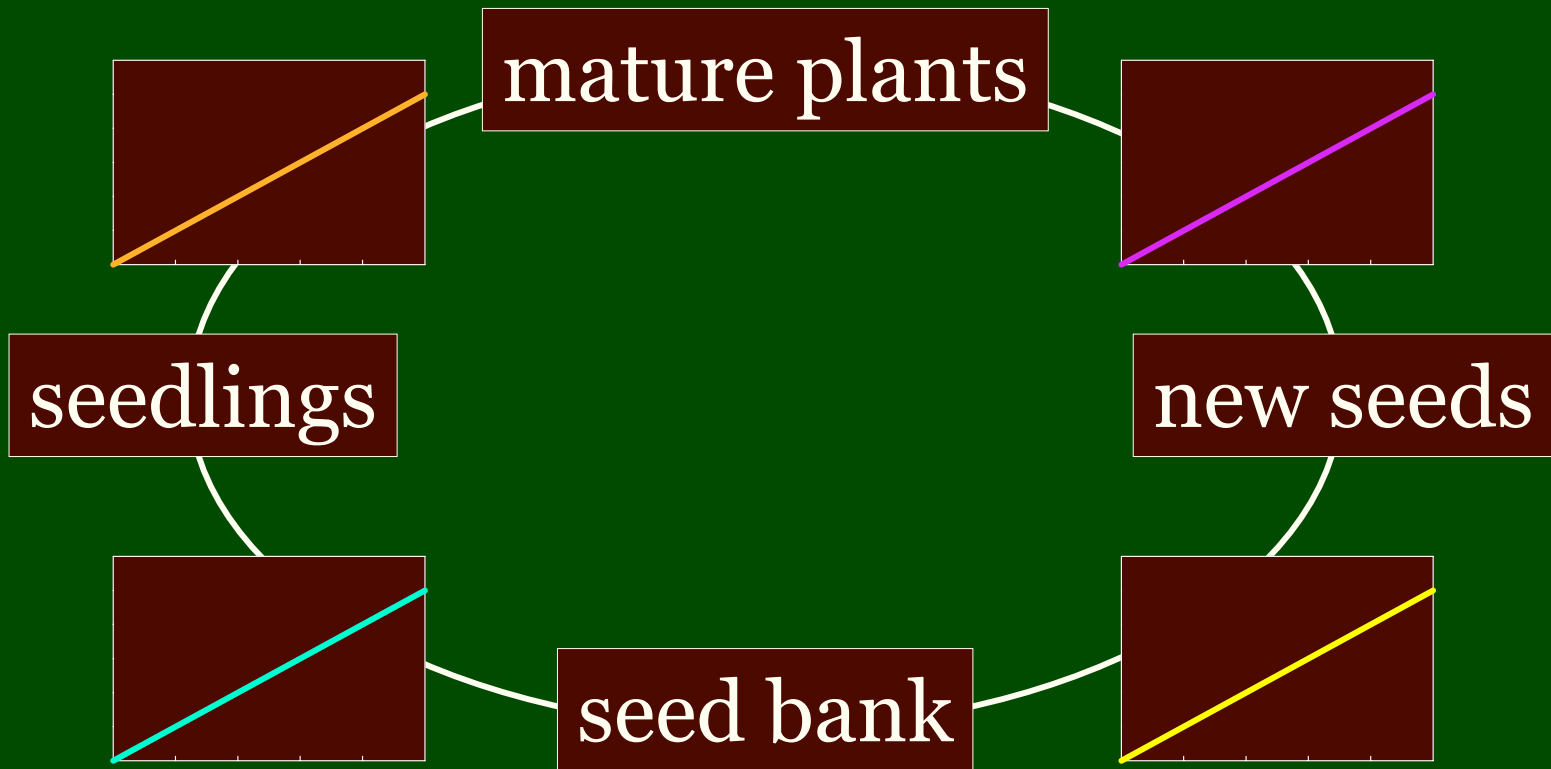


# Weed life cycle model

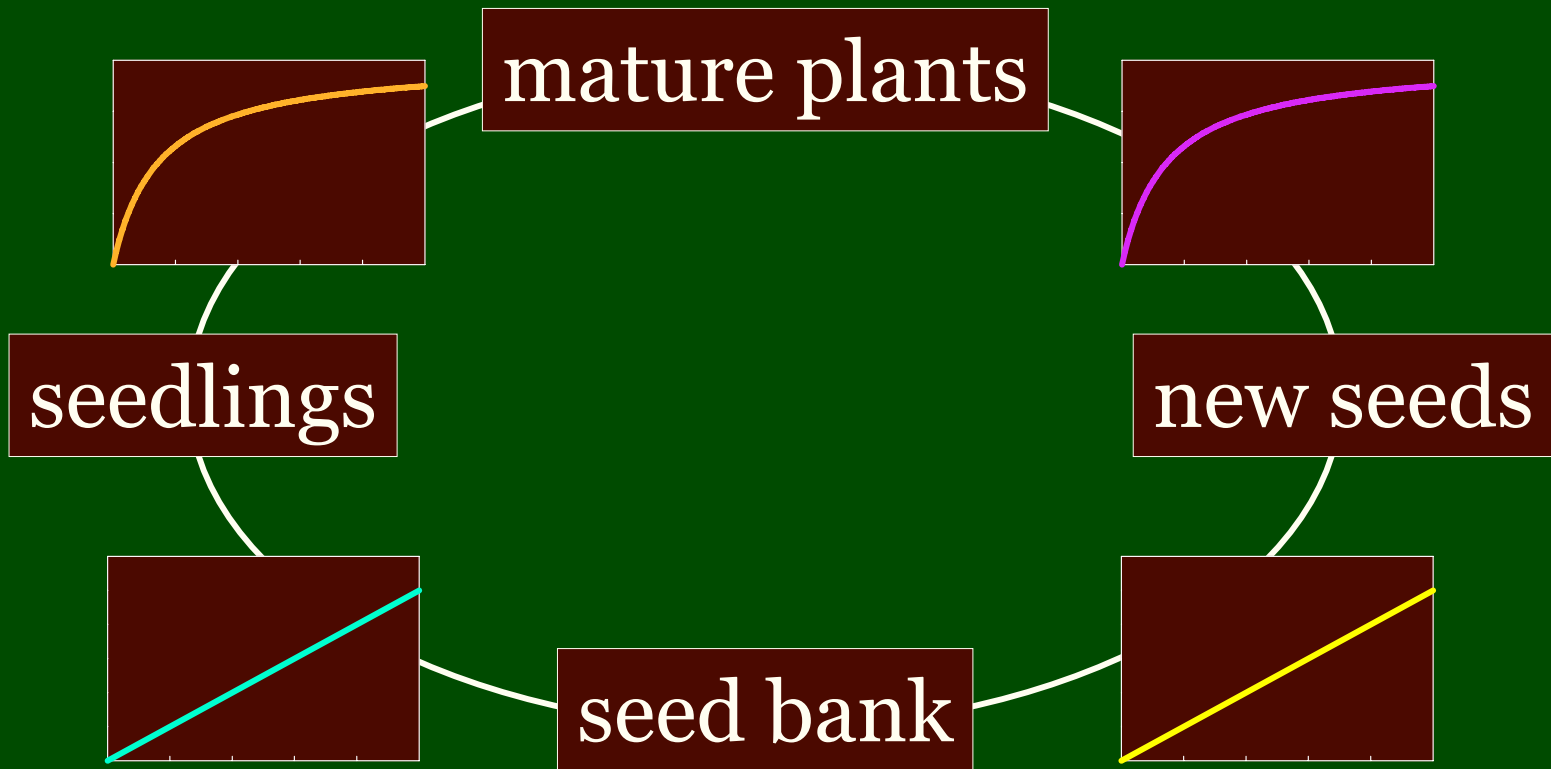


Annual growth rate:  $10\% \cdot 50\% \cdot 1000 \cdot 20\% = 10$

# Weed life cycle model



# Weed life cycle model

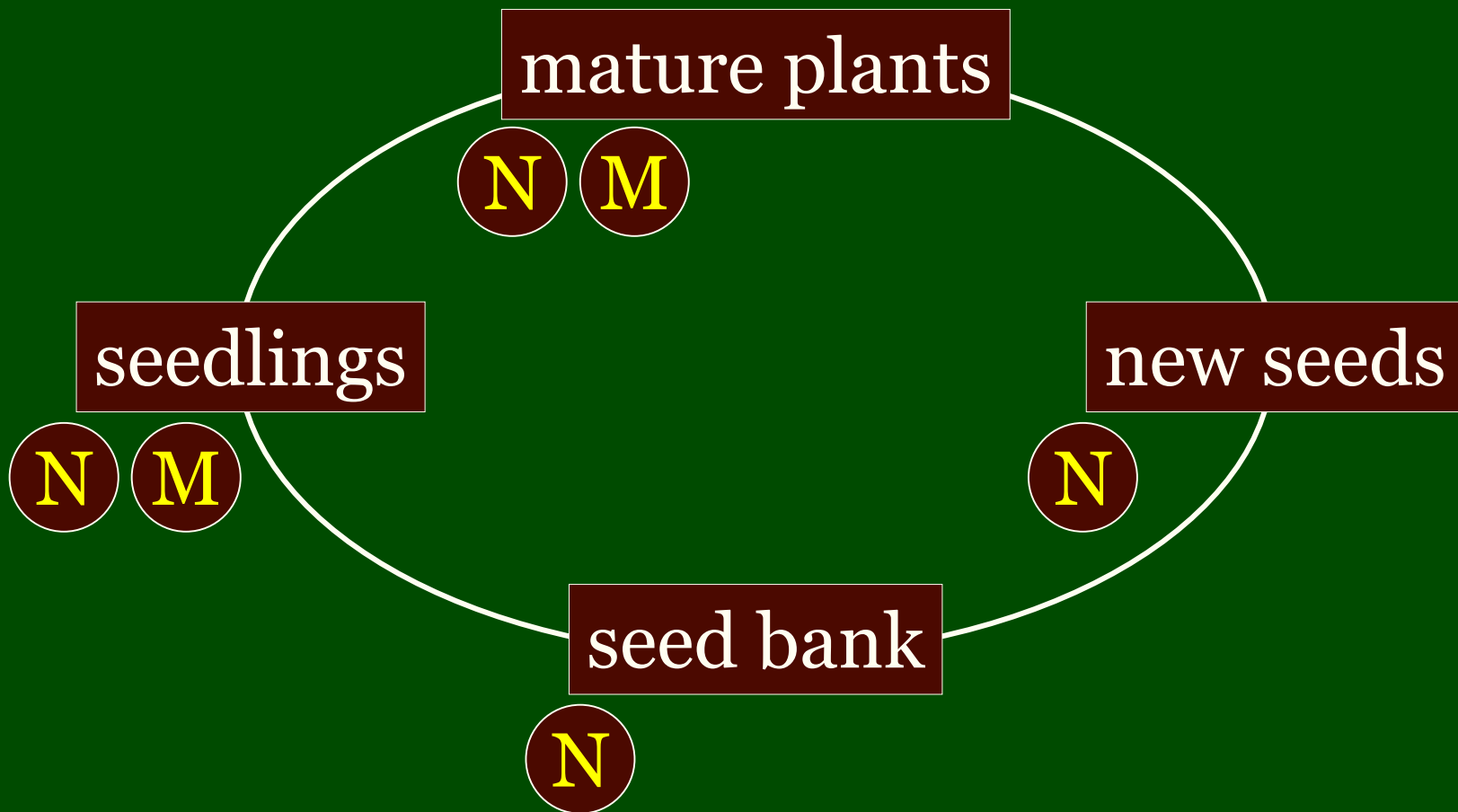


# Weed model wish list

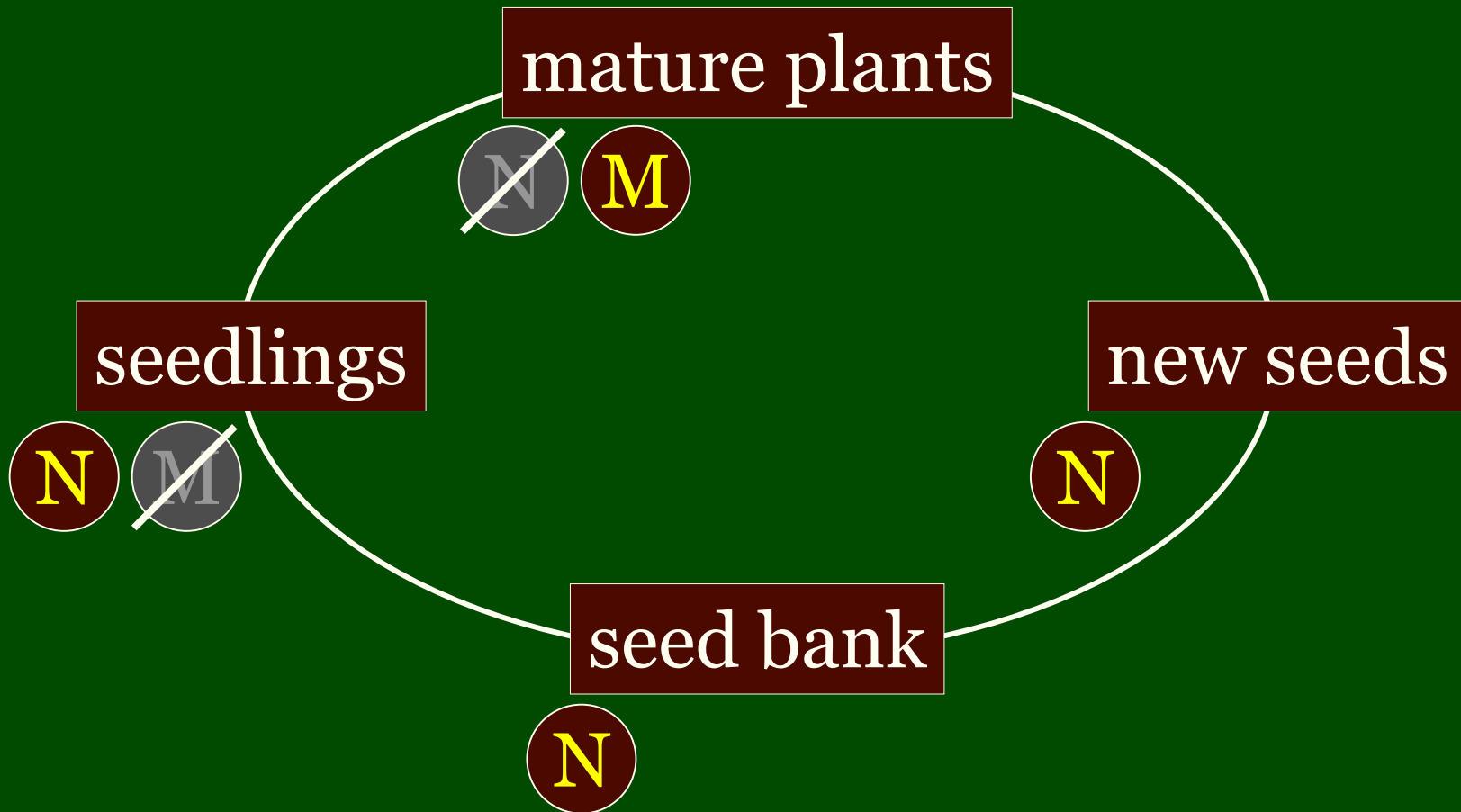
1. Weed number and mass
2. Yield loss
3. Cultivation
4. Weather
5. Stochasticity
6. Validation
7. Documentation



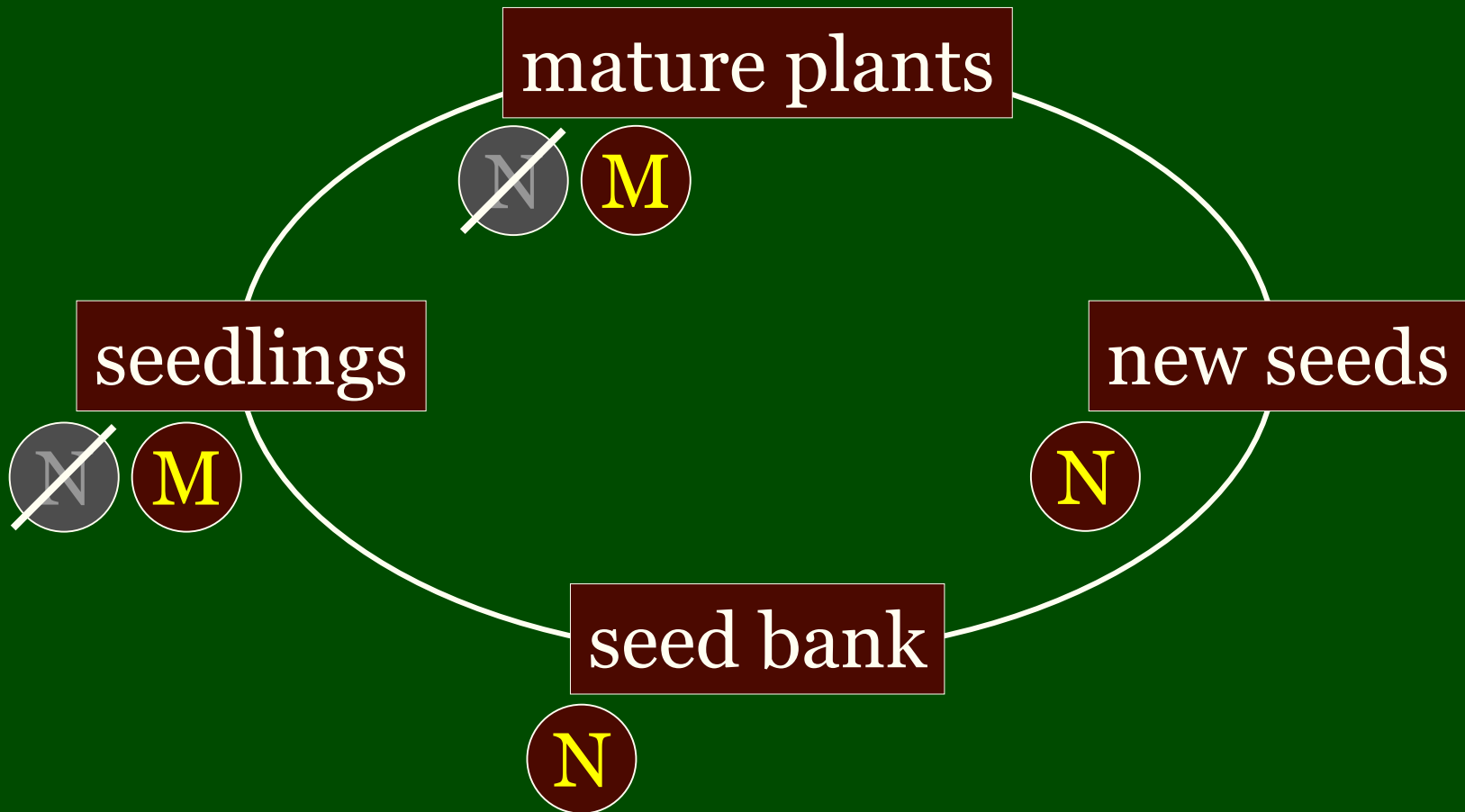
# 1. Weed number and mass



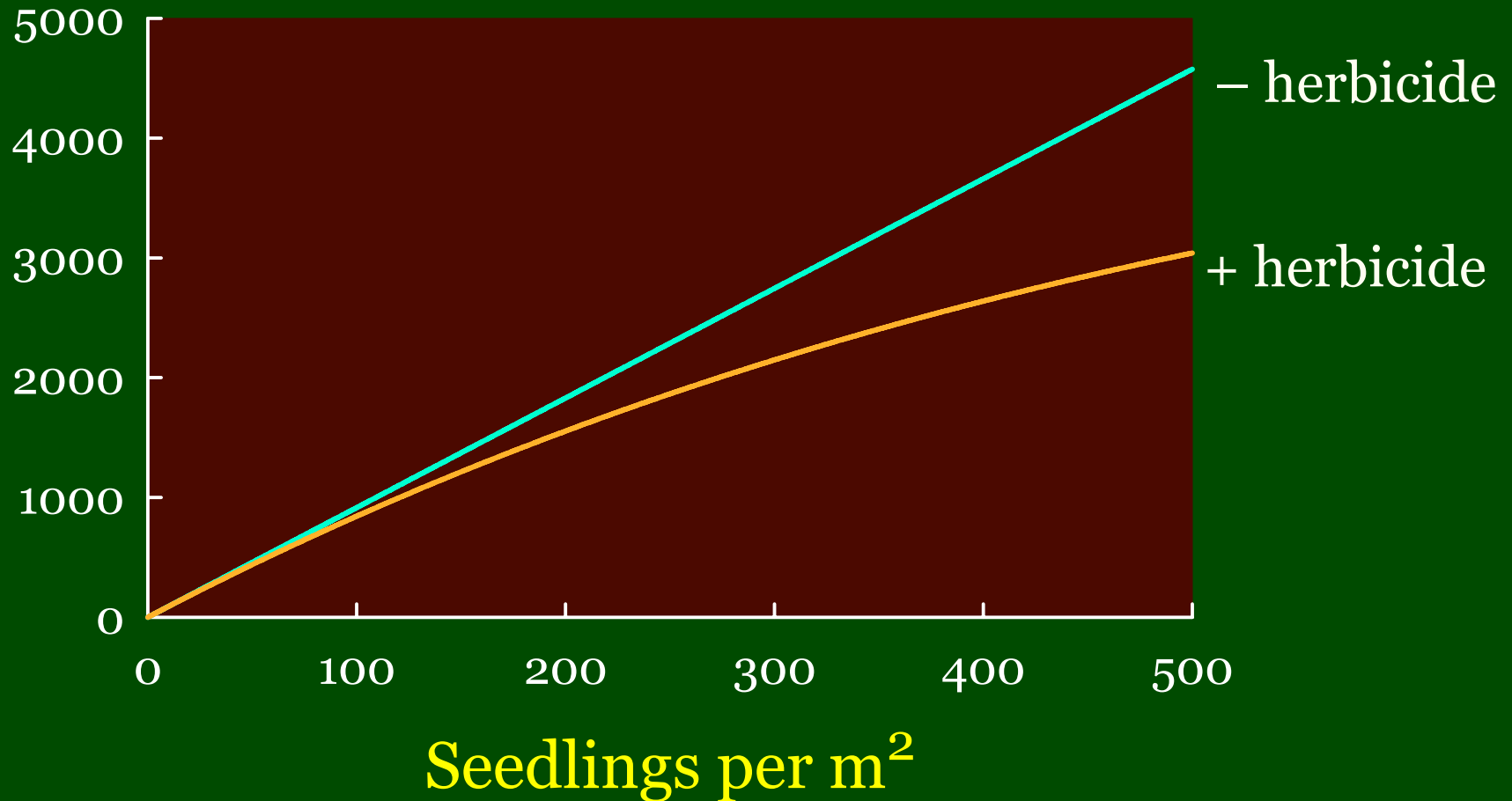
# 1. Weed number and mass



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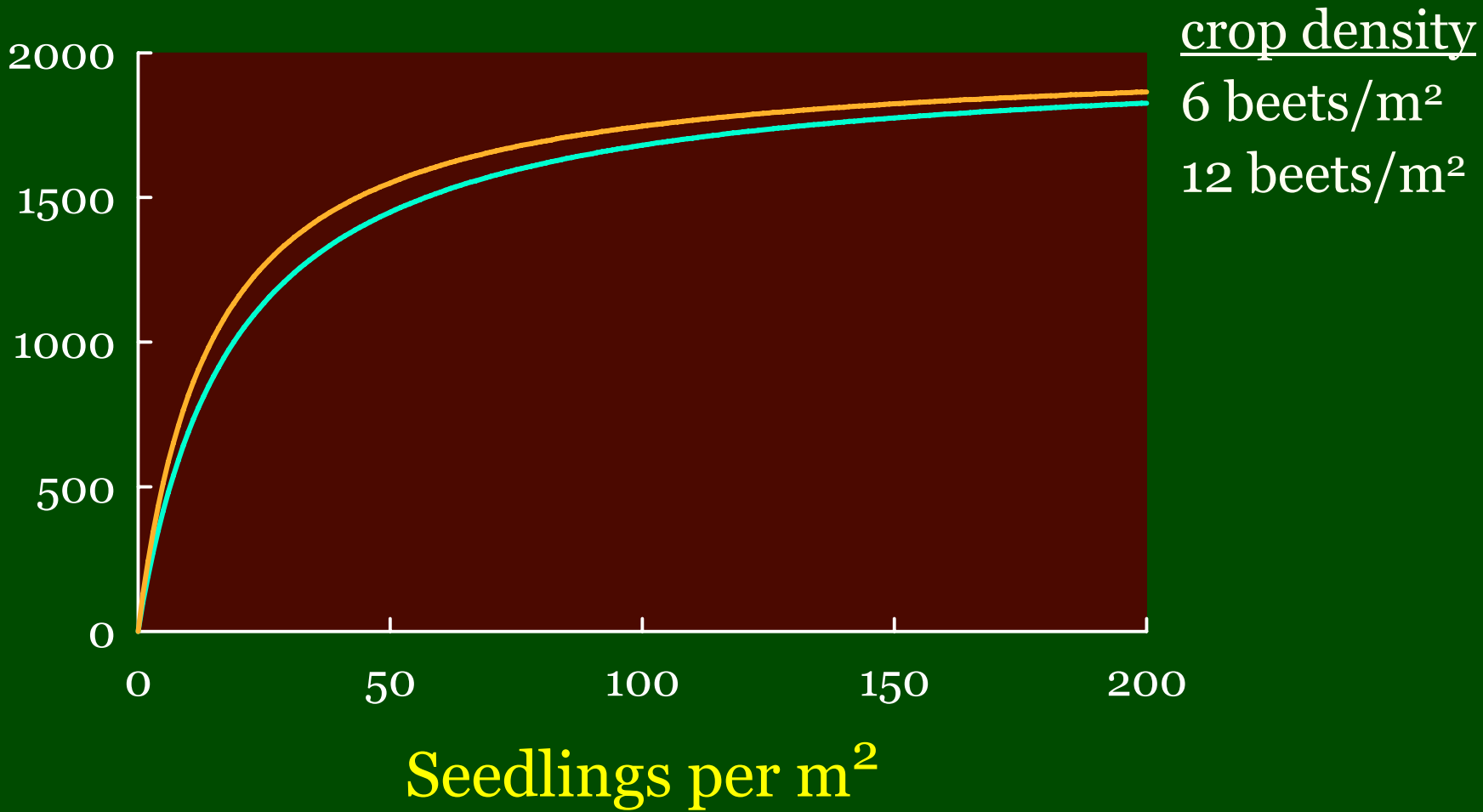
# Biomass of *Abutilon theophrasti* (g/m<sup>2</sup>)



*Bussan & Boerboom 2001*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

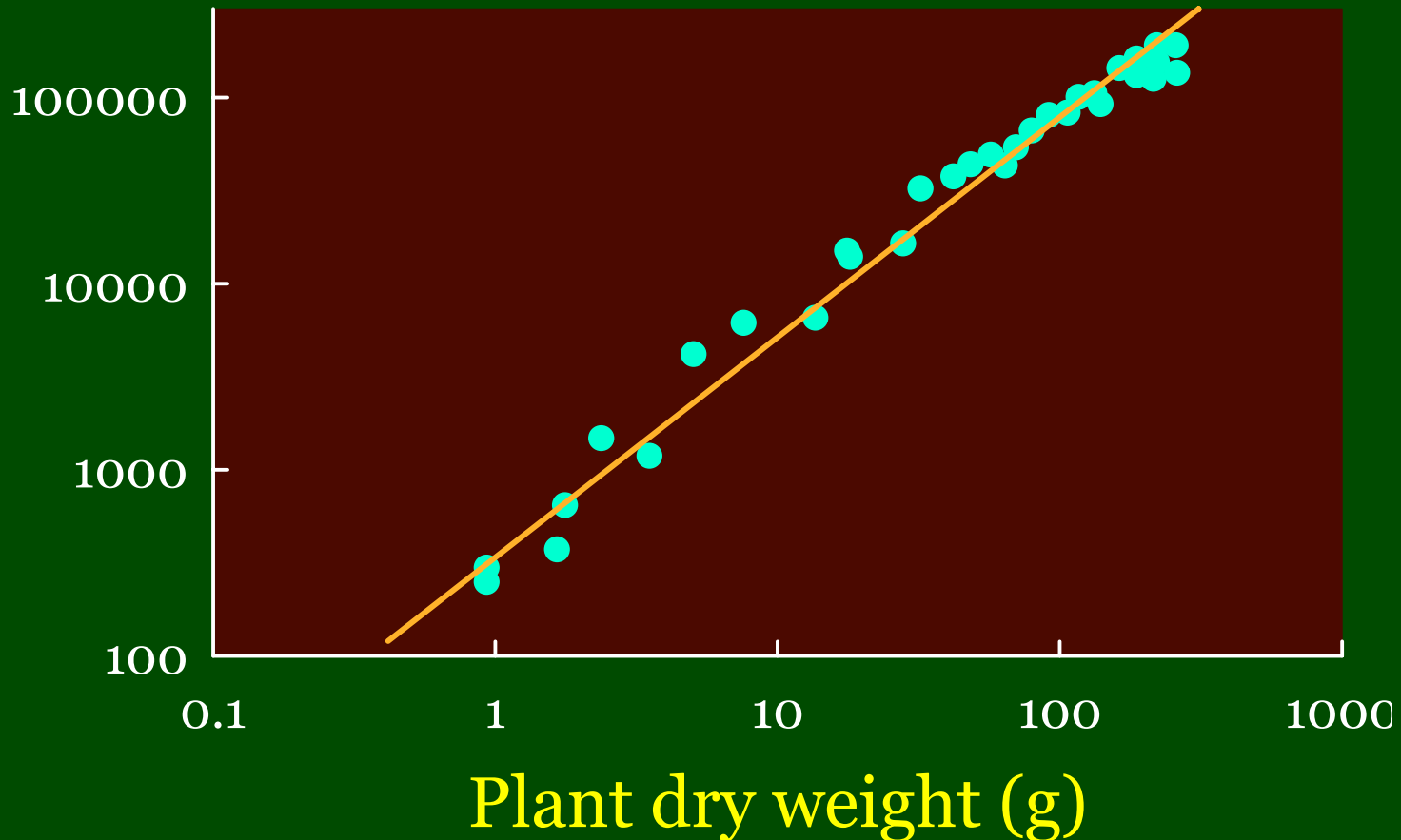
# Biomass of *Chenopodium album* (g/m<sup>2</sup>)



*Freckleton & Watkinson 1998*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

# Seeds per *Chenopodium album* plant



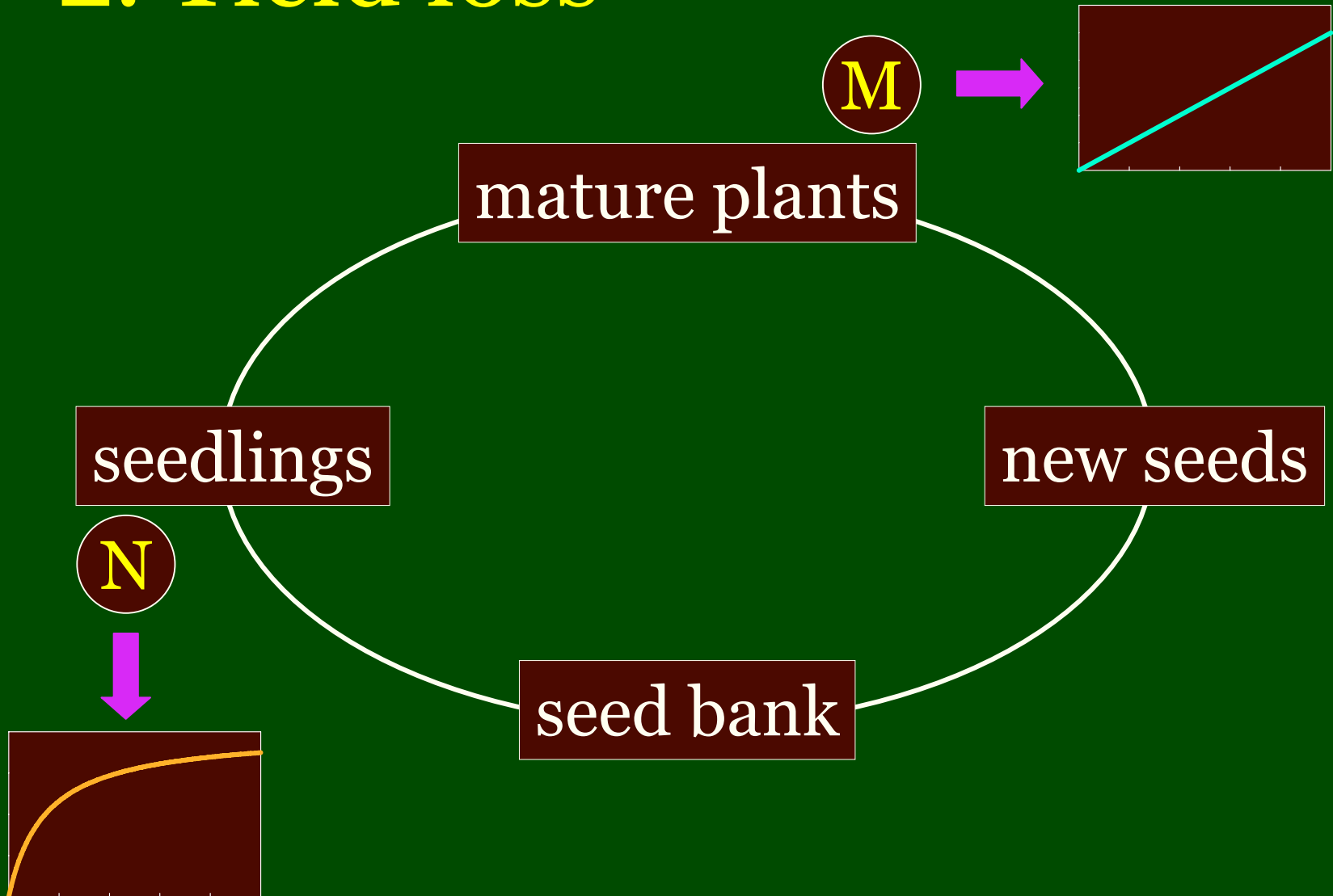
*Freckleton & Watkinson 1998*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

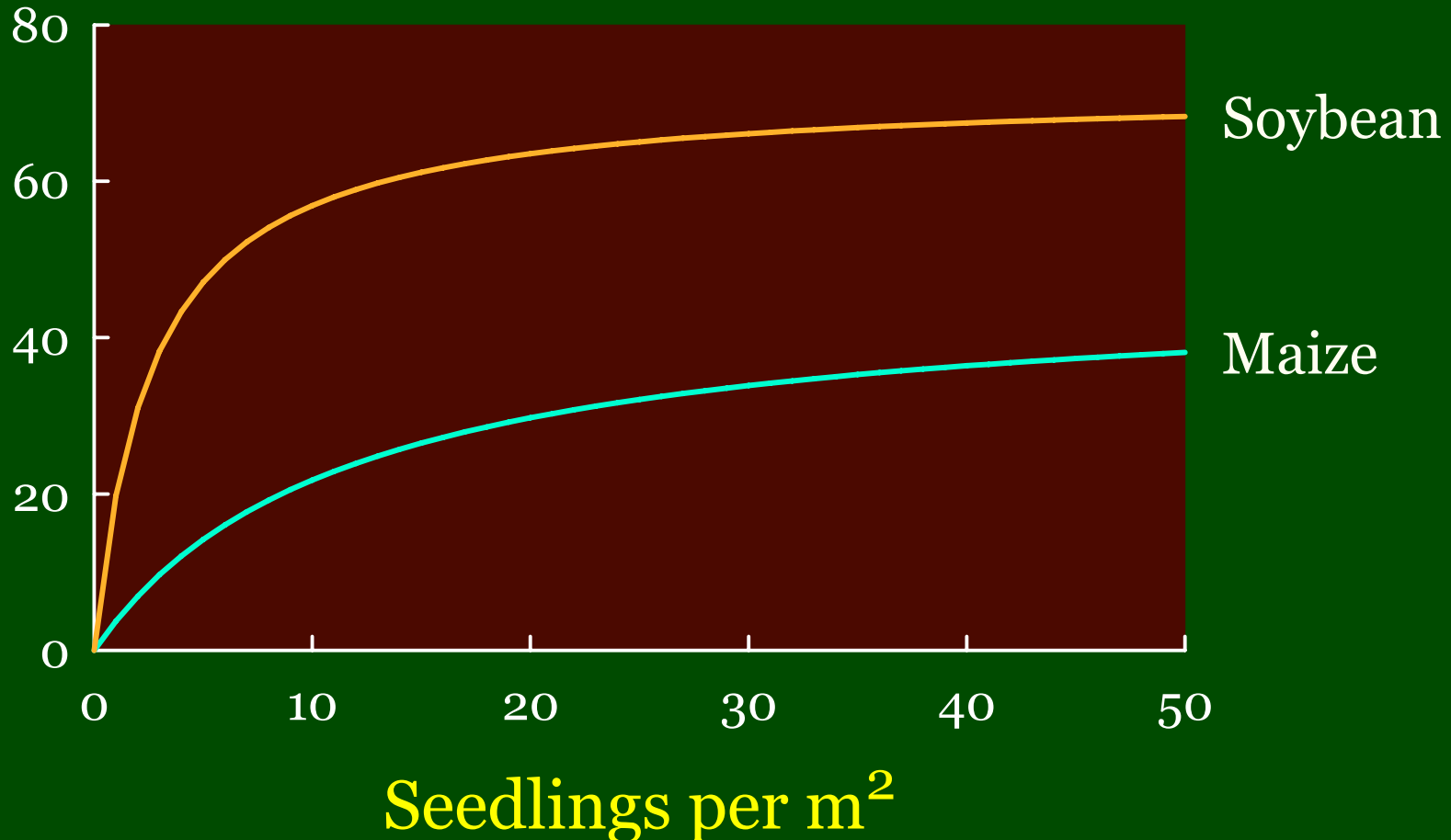
# Weed model wish list

1. Weed number and mass ✓
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## 2. Yield loss



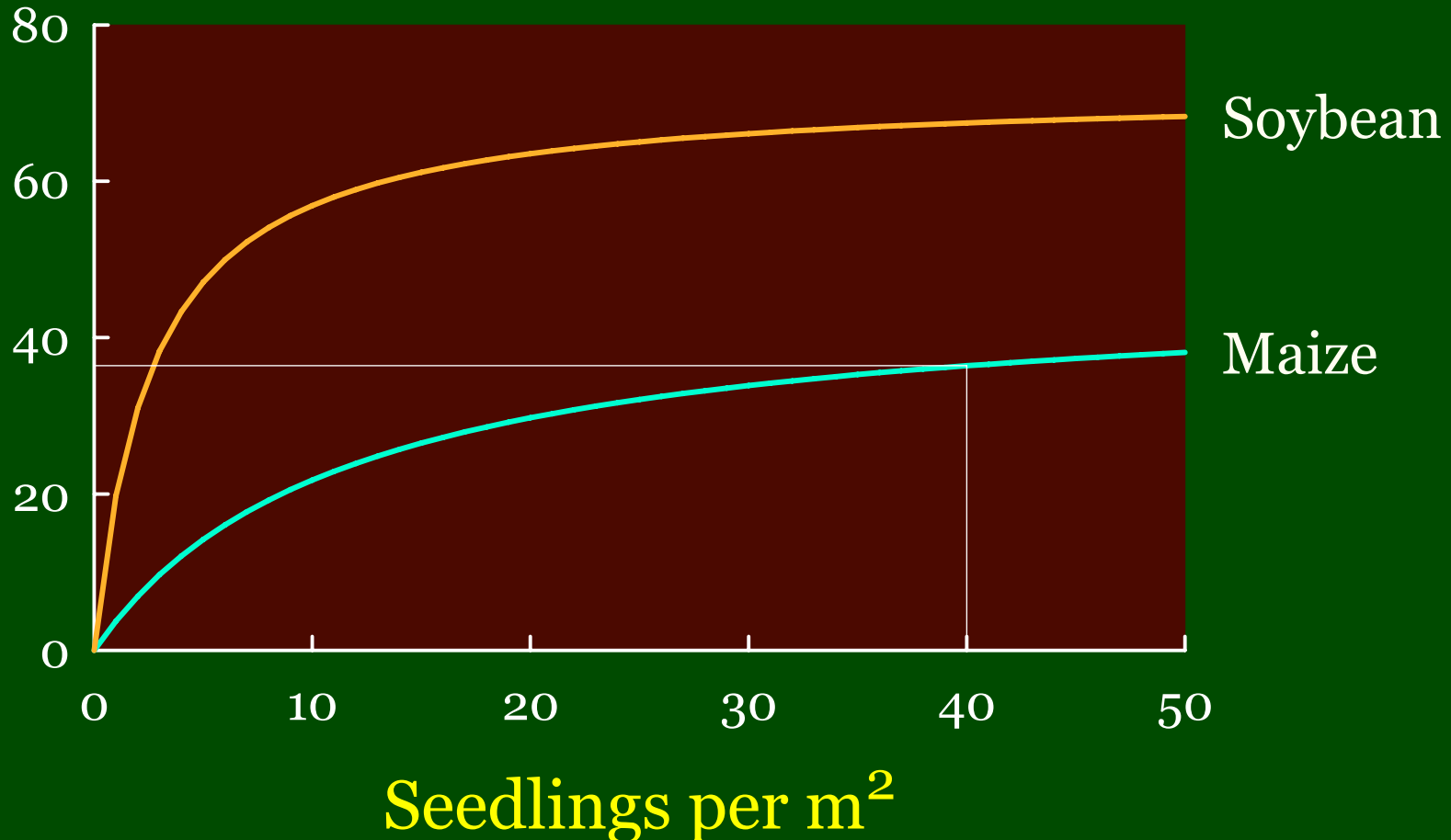
# Yield loss % caused by *Abutilon theophrasti*



*Lindquist et al. 1995*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

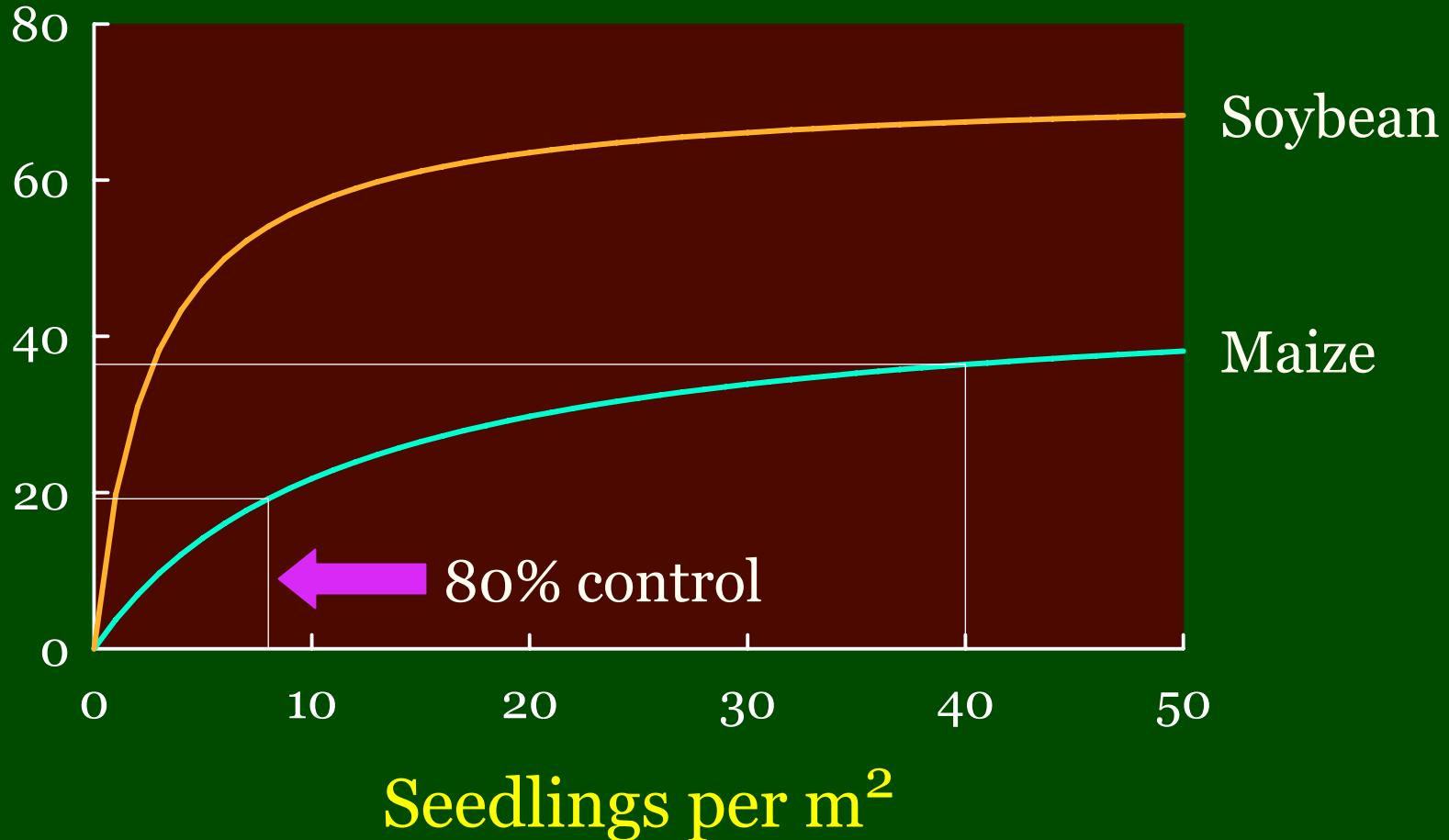
# Yield loss % caused by *Abutilon theophrasti*



*Lindquist et al. 1995*

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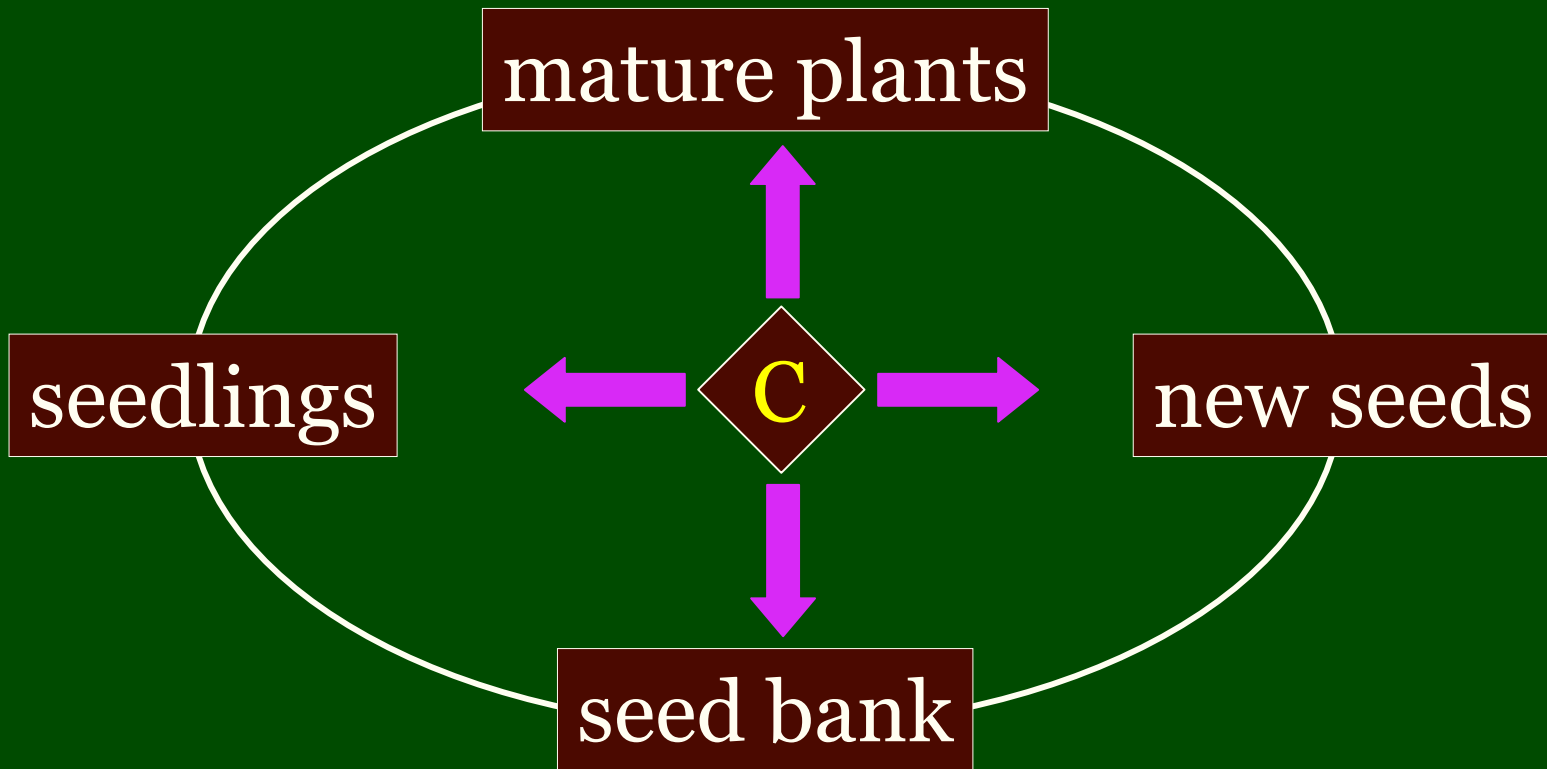
*Lindquist et al. 1995*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

# Weed model wish list

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# 3. Cultivation



# Parameters for each species × crop

<i>Alopecurus myosuroides</i>	Winter wheat	Winter barley	Spring barley	Sugar beets
Germination				
Seed mortality				
Seedling mortality				
Fecundity				

*Zwenger & Hurle 1990*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

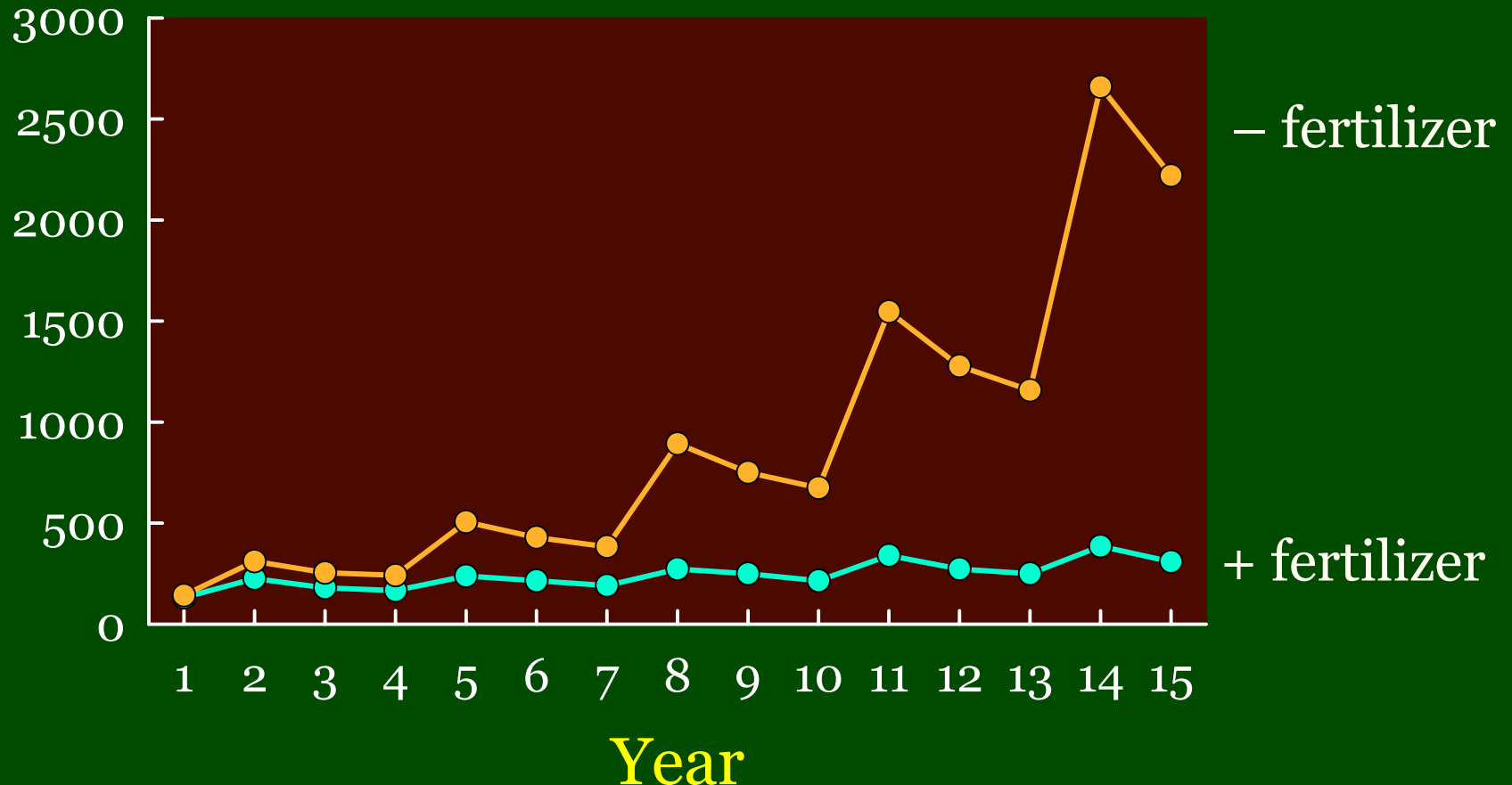
# Parameters for each species × crop

<i>Alonecurus</i>	Winter	Winter	Spring	Sugar
<i>Fallopia</i>	Winter wheat	Winter barley	Spring barley	Sugar beets
<i>convolvulus</i>				
G				
Se	Germination			
Se	Seed mortality			
Fe	Seedling mortality			
	Fecundity			

Zwenger & Hurle 1990

Niels Holst, Aarhus University, niels.holst@agrsci.dk

# Simulated seed bank of *Viola arvensis* (m<sup>-2</sup>)



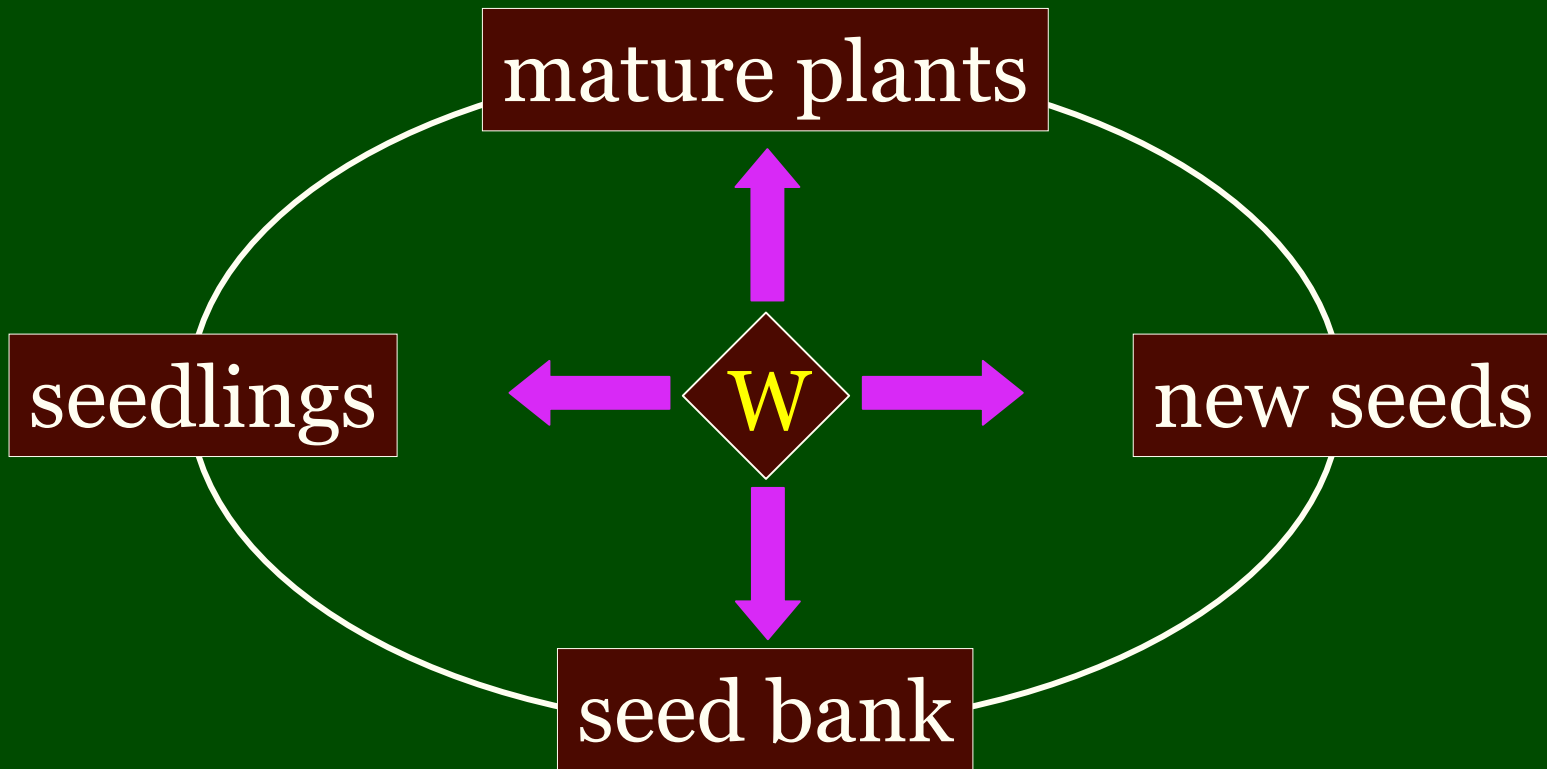
*Gerowitt & Bodendörfer 2001*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

# Weed model wish list

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# 4. Weather



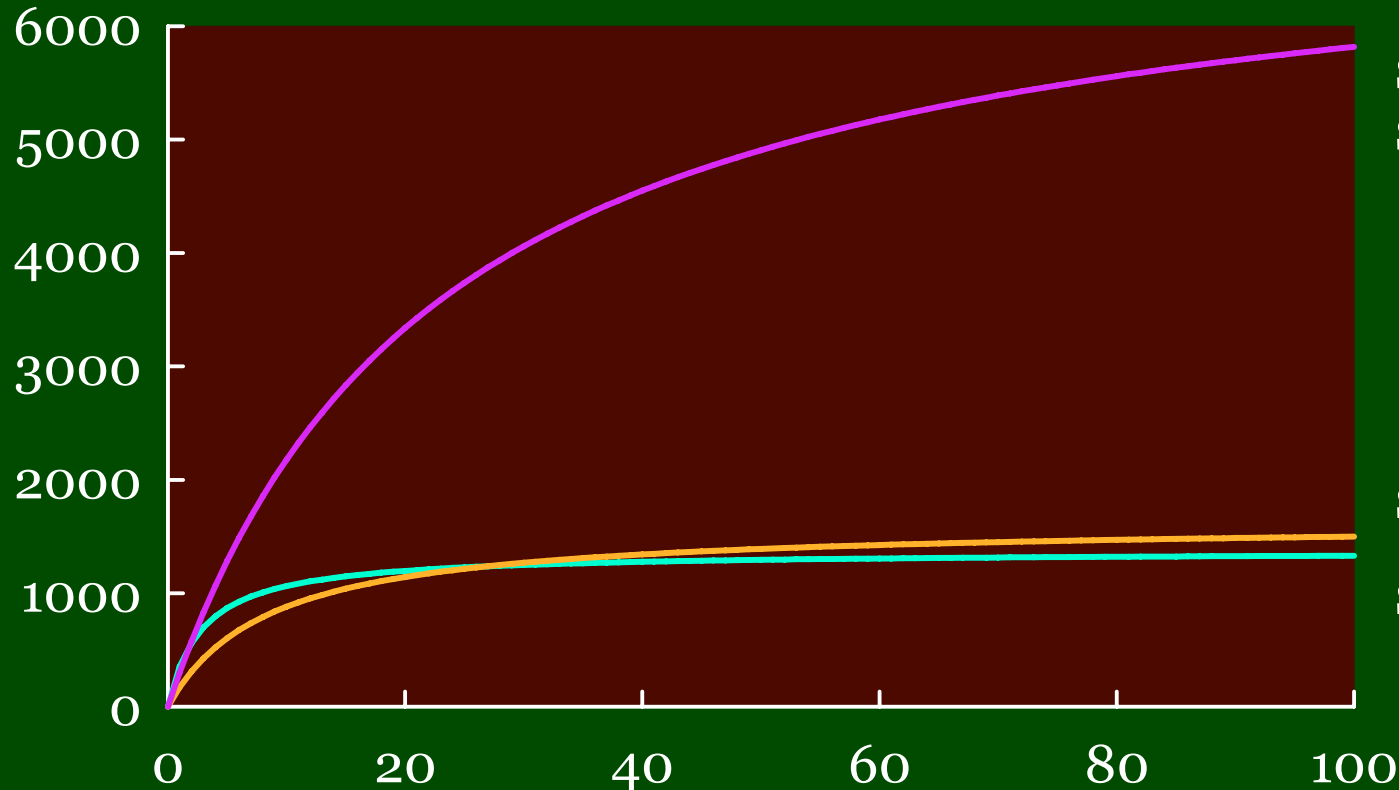
# *Xanthium occidentale* seed production

rainfall

spring & summer

summer

spring



Seedlings per m<sup>2</sup>

*Martin & Carnahan 1983*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

# Stratified model of *Hypericum perforatum*

Parameters specific to shade/sunlight

- growth rate
- fruit production rate
- survival

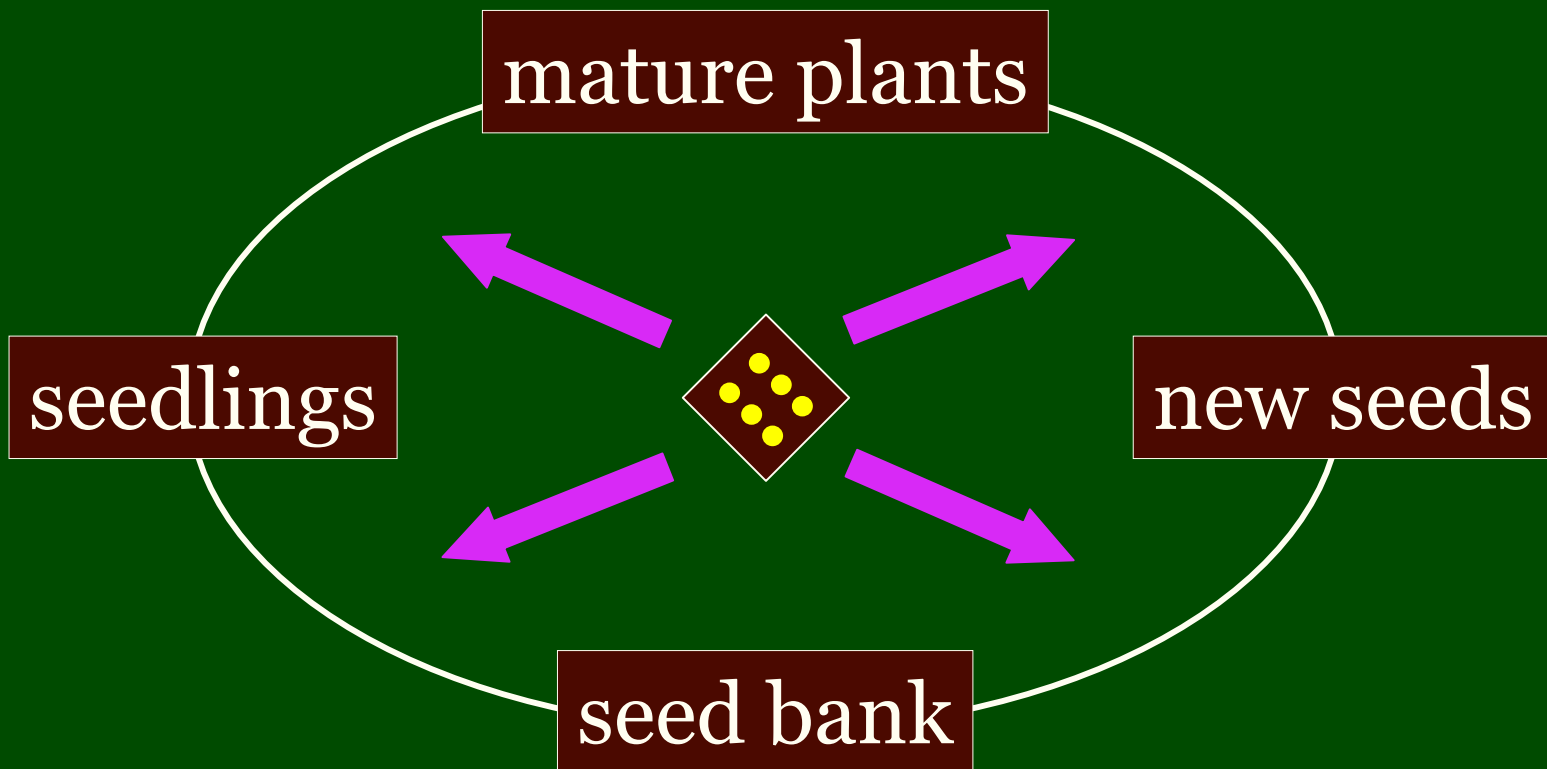
*Buckley, Briese & Rees 2003*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

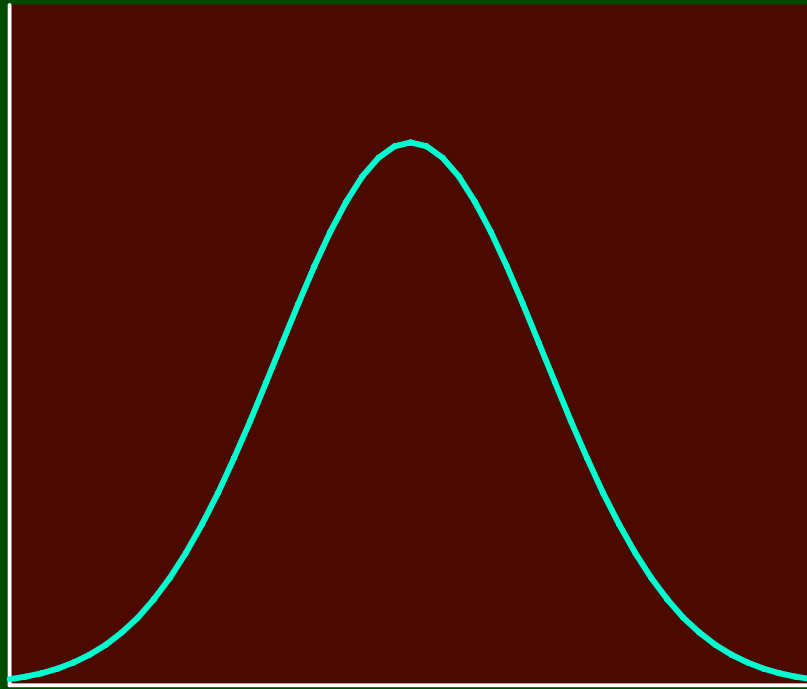
# Weed model wish list

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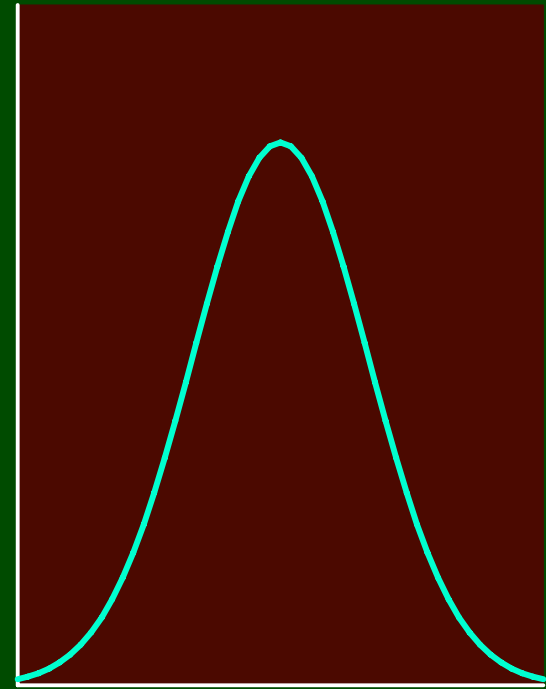
# 5. Stochasticity



# Monte Carlo simulation

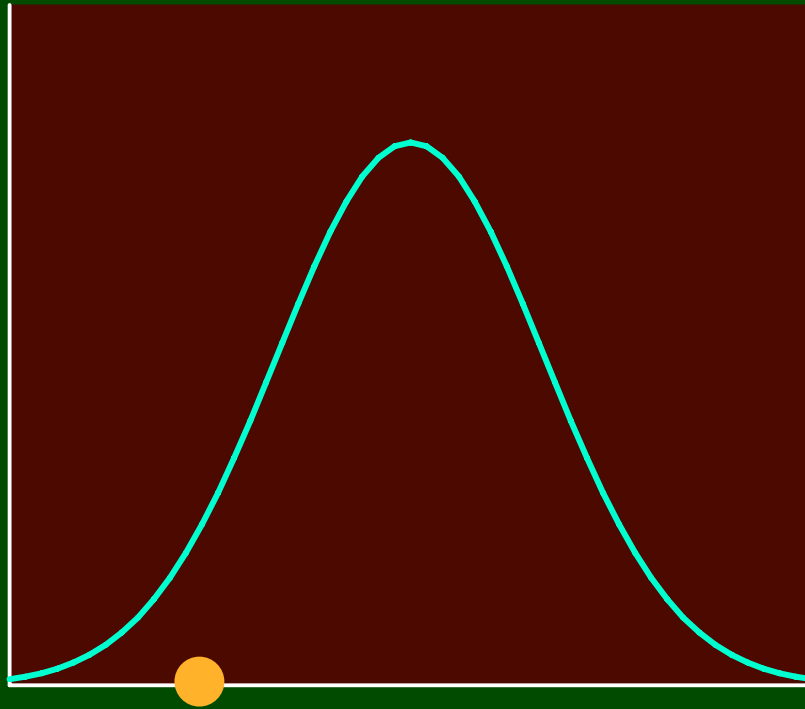


Parameter 1

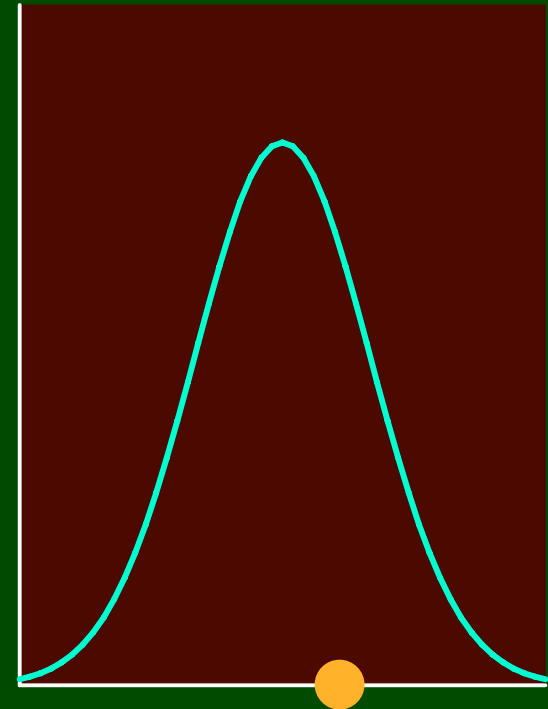


Parameter 2

# Monte Carlo simulation

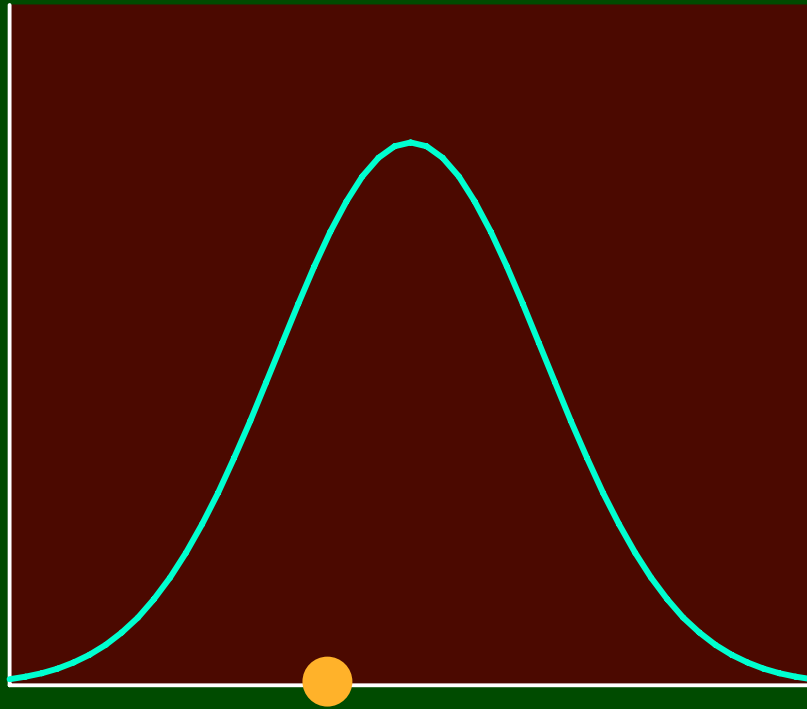


Parameter 1

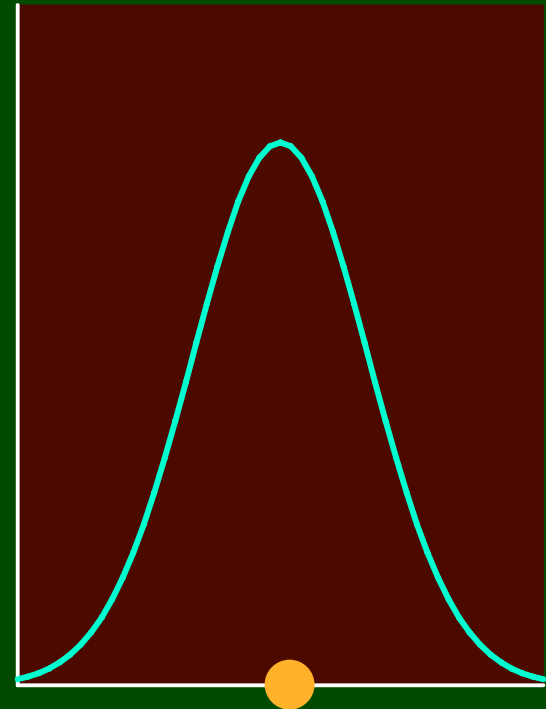


Parameter 2

# Monte Carlo simulation

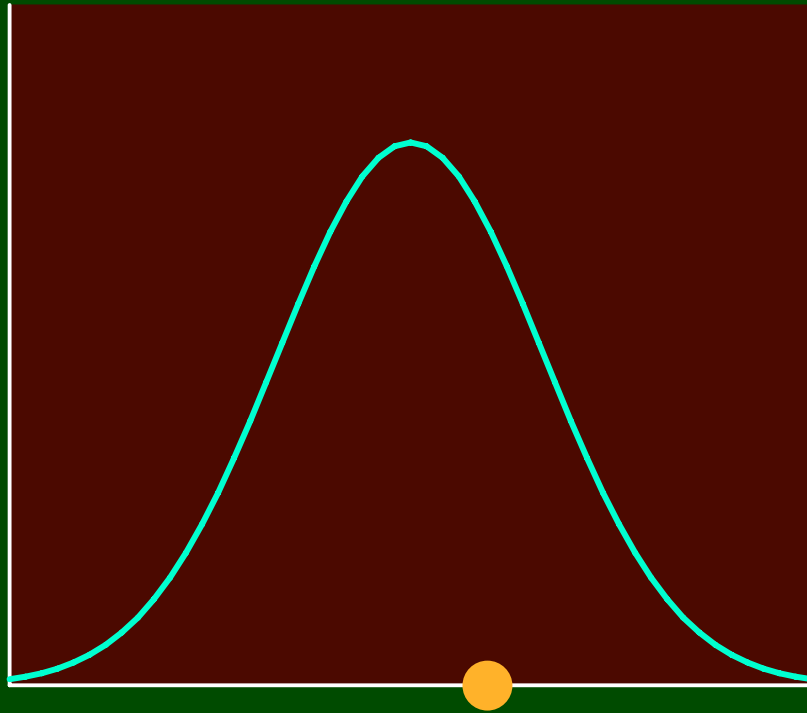


Parameter 1

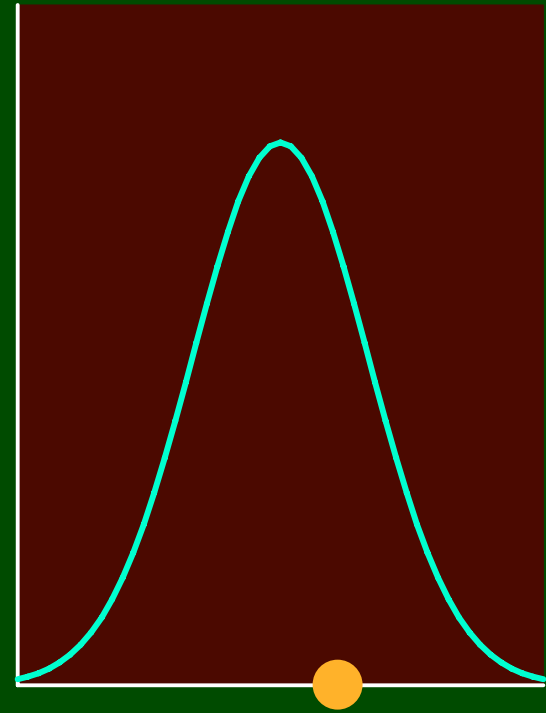


Parameter 2

# Monte Carlo simulation

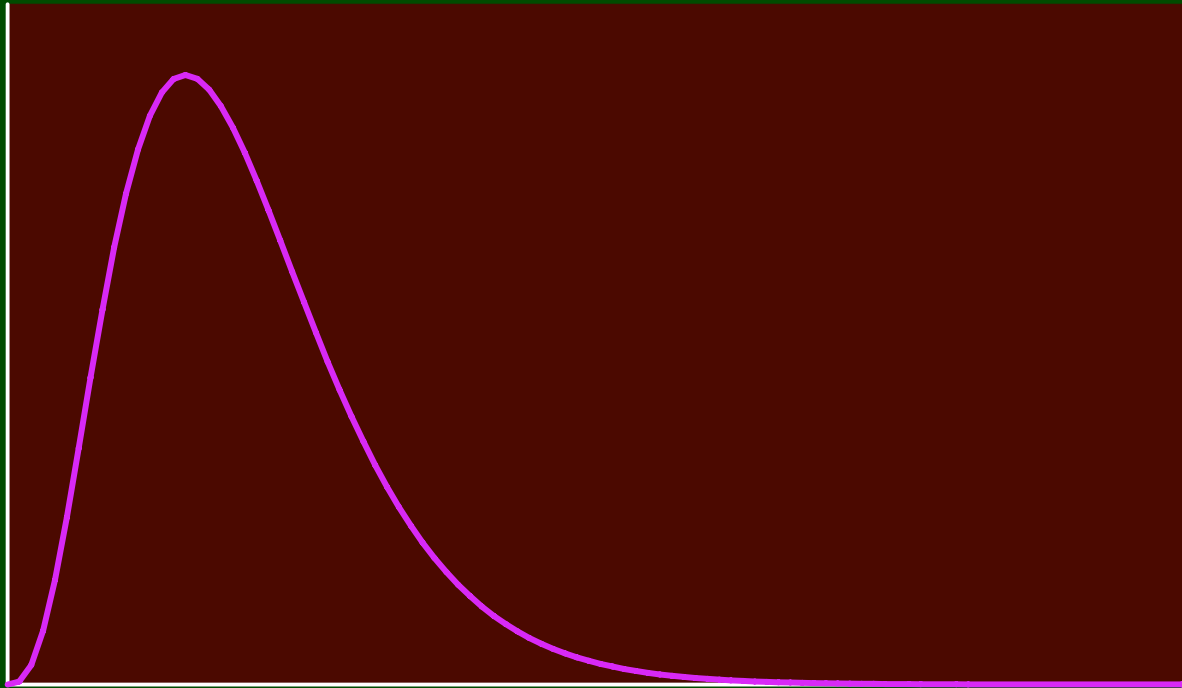


Parameter 1



Parameter 2

# Monte Carlo simulation



Model output distribution

# Stochastic model of weedy oilseed rape

Variable parameters include

- Flower mortality
- Seeds-on-plant mortality
- Time from sowing to spraying
- Herbicide efficacy

*Squire, Burn & Crawford 1997*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

# Stochastic model of *Hypericum perforatum*

Variable parameters include

- Flowering rate
- Fruit production rate
- Seasonal rainfall

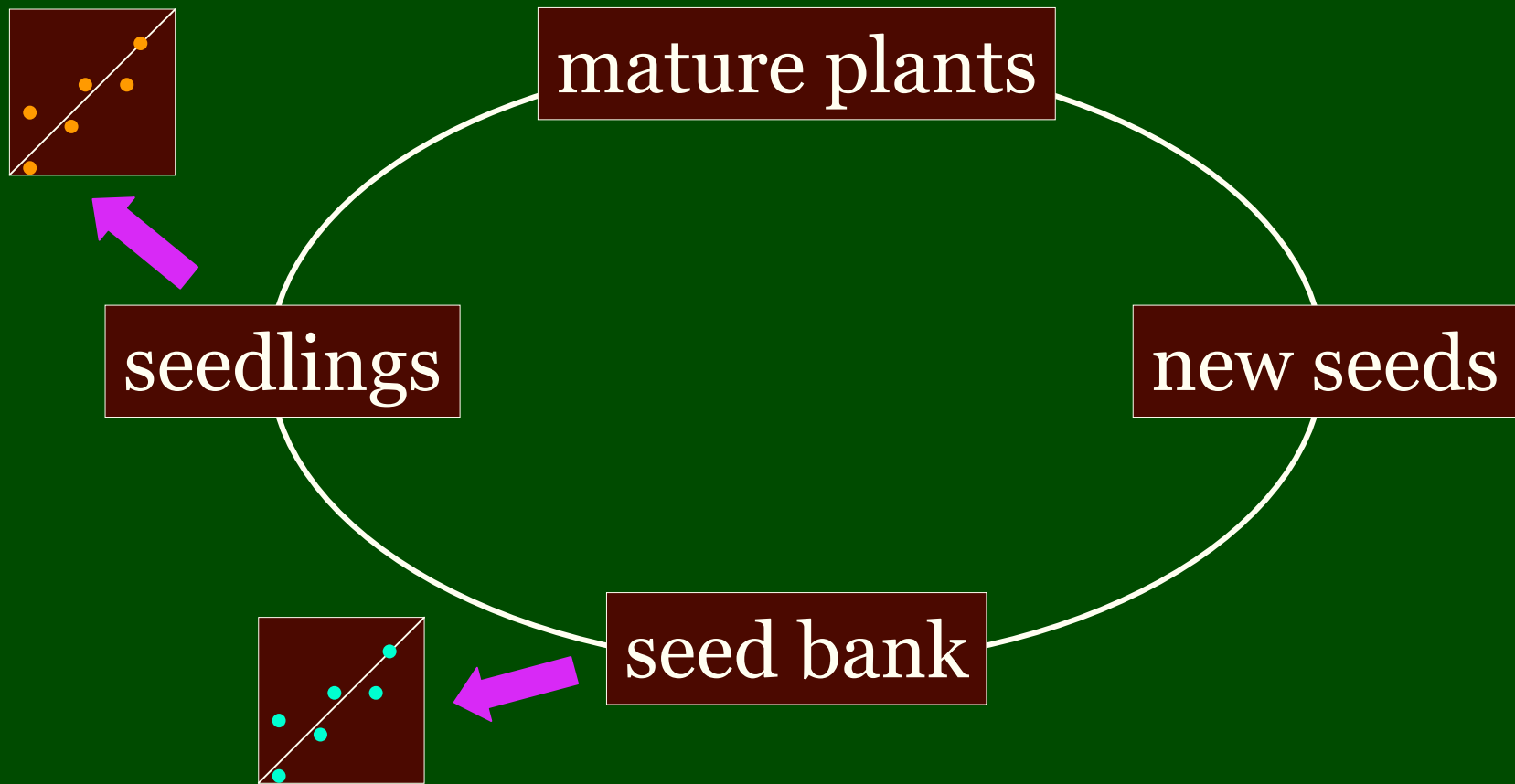
*Buckley, Briese & Rees 2003*

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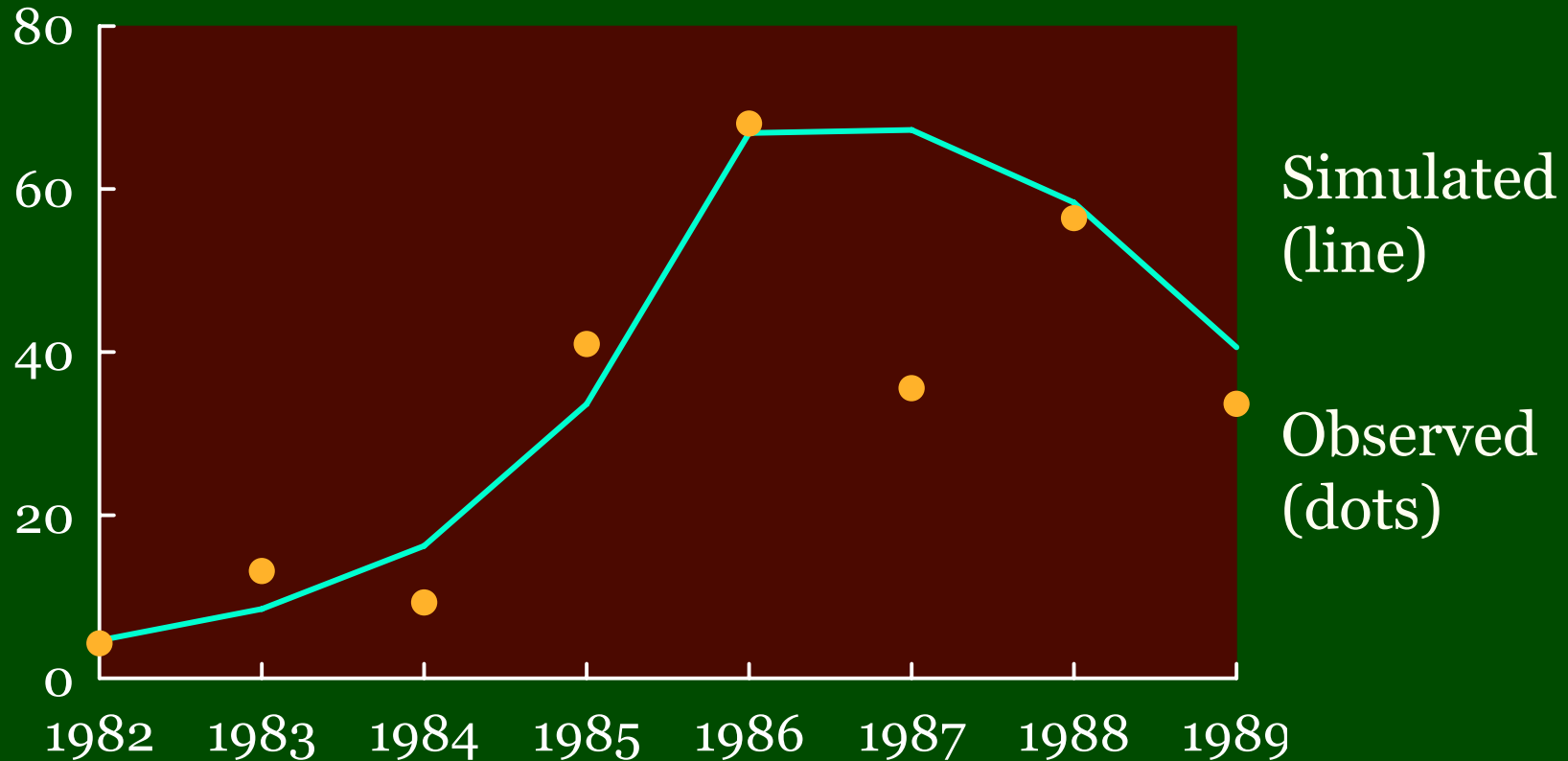
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# 6. Validation



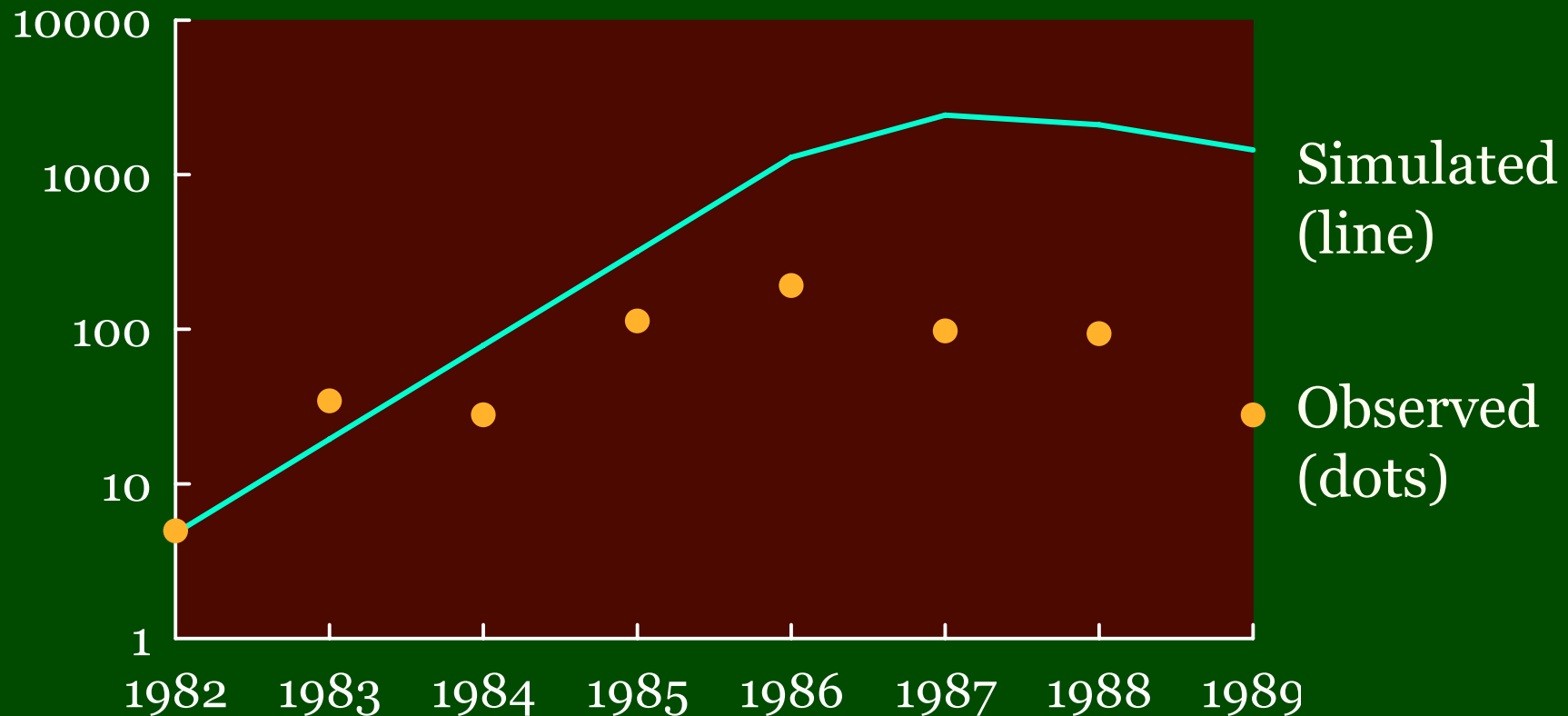
## *A. myosuroides* plants per m<sup>2</sup>



*Zwenger & Hurle 1990*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

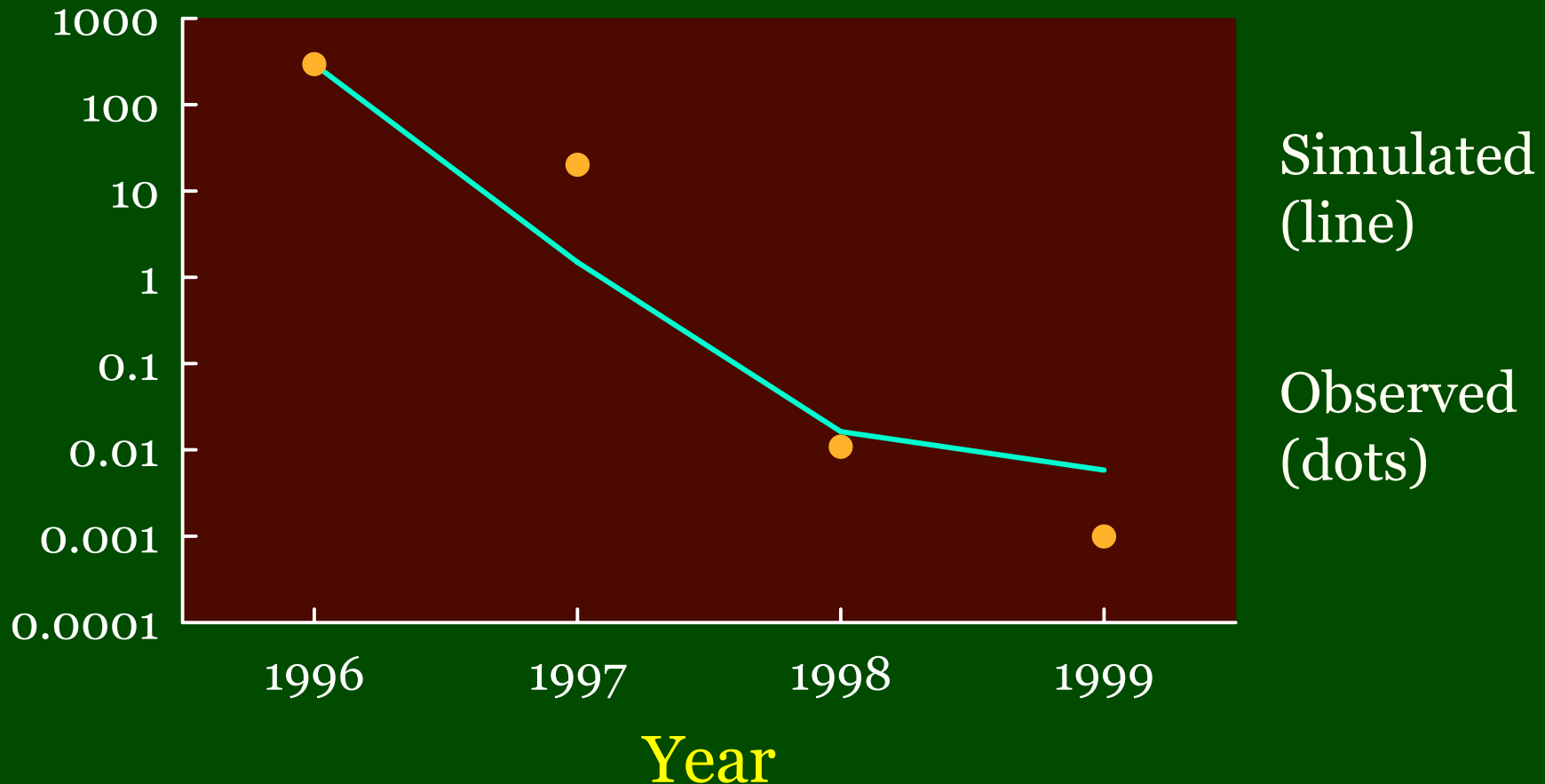
# *A. myosuroides* plants per m<sup>2</sup>, no control



*Zwenger & Hurle 1990*

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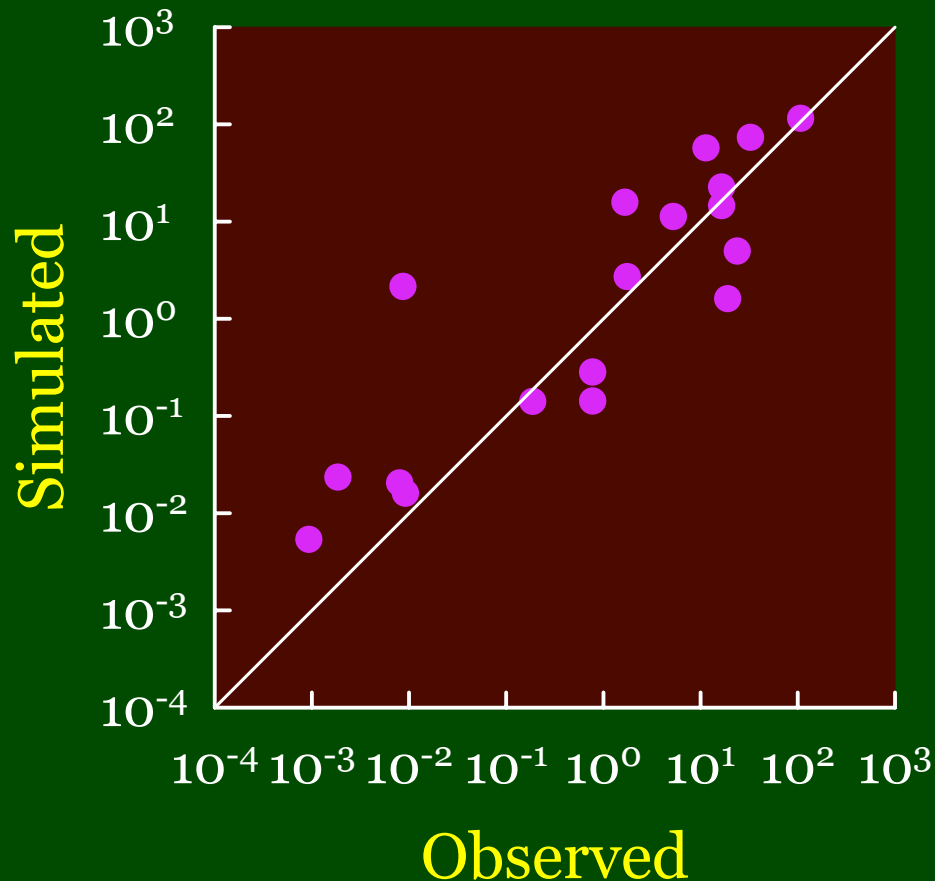
# *A. myosuroides* plants per m<sup>2</sup>, new model



*Munier-Jolain et al. 2002*

Niels Holst, Aarhus University, niels.holst@agrsci.dk

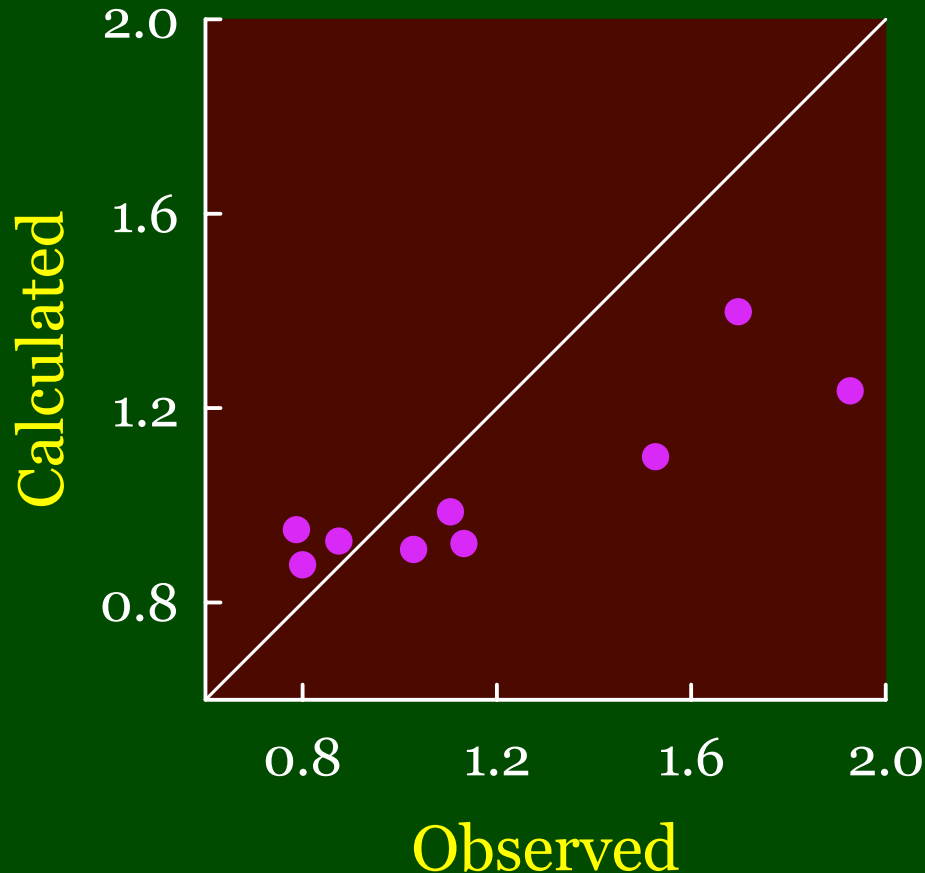
# *A. myosuroides* plants per m<sup>2</sup>, new model



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# Validation by annual growth rate ( $\lambda$ )



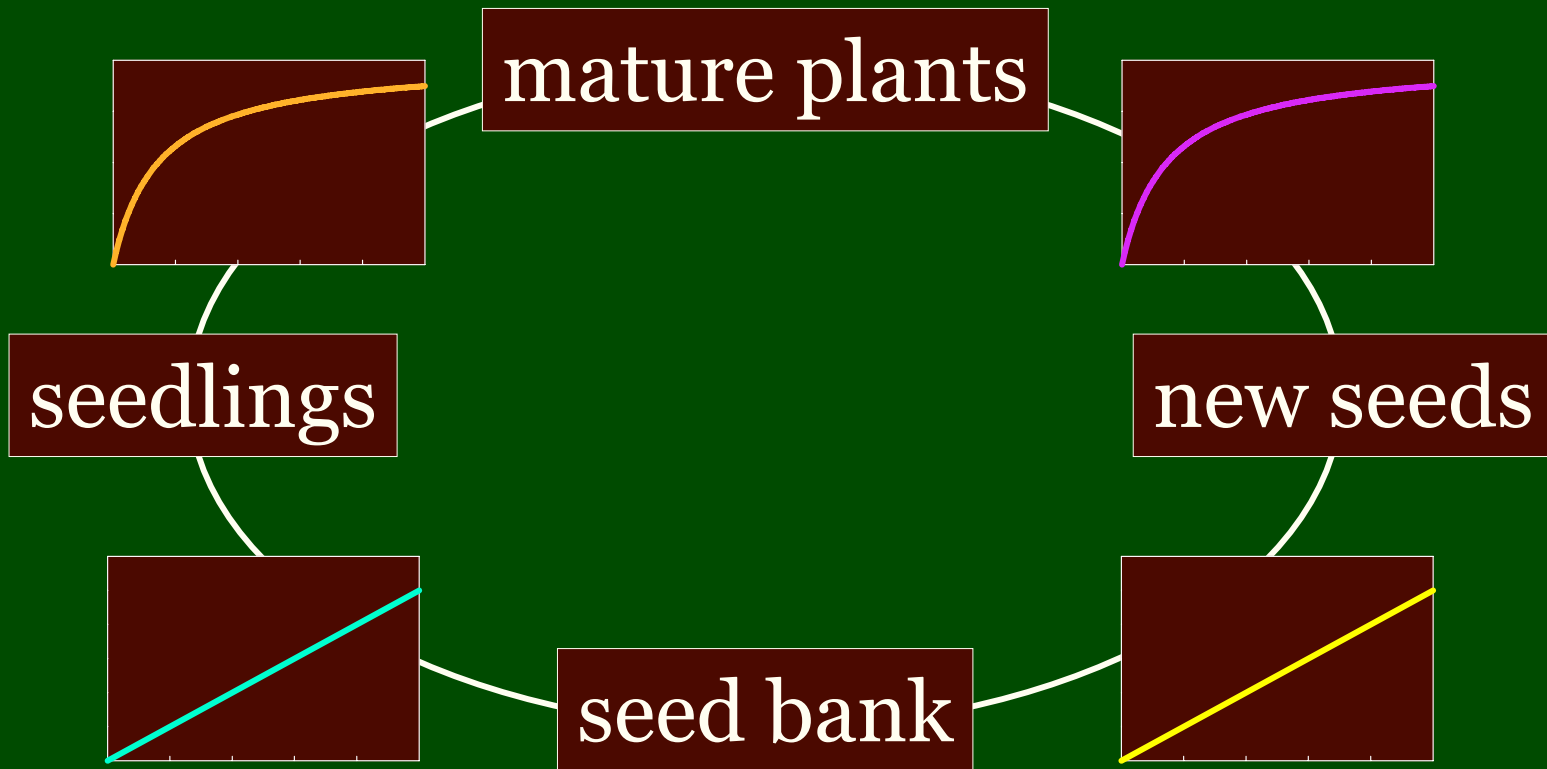
$$\lambda = N_{y+1} / N_y$$

*Debaeke 1988*

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# Weed life cycle model



# A generic model of annual weed development and reproduction

Niels Holst (2008, *in prep*)

# Weed life stages

- Seed in soil
- Seedling
- Juvenile
- Reproductive
- Immature seed
- Mature seed

# Weed life stages

- Seed in soil ➤ germinates
- Seedling ➤ hardens
- Juvenile ➤ grows
- Reproductive ➤ produces seeds
- Immature seed ➤ ripens
- Mature seed ➤ is shed

# Model

Components:  
variables (per m<sup>2</sup>)

- Seed in soil
- Seedling
- Juvenile
- Reproductive
- Immature seed
- Mature seed

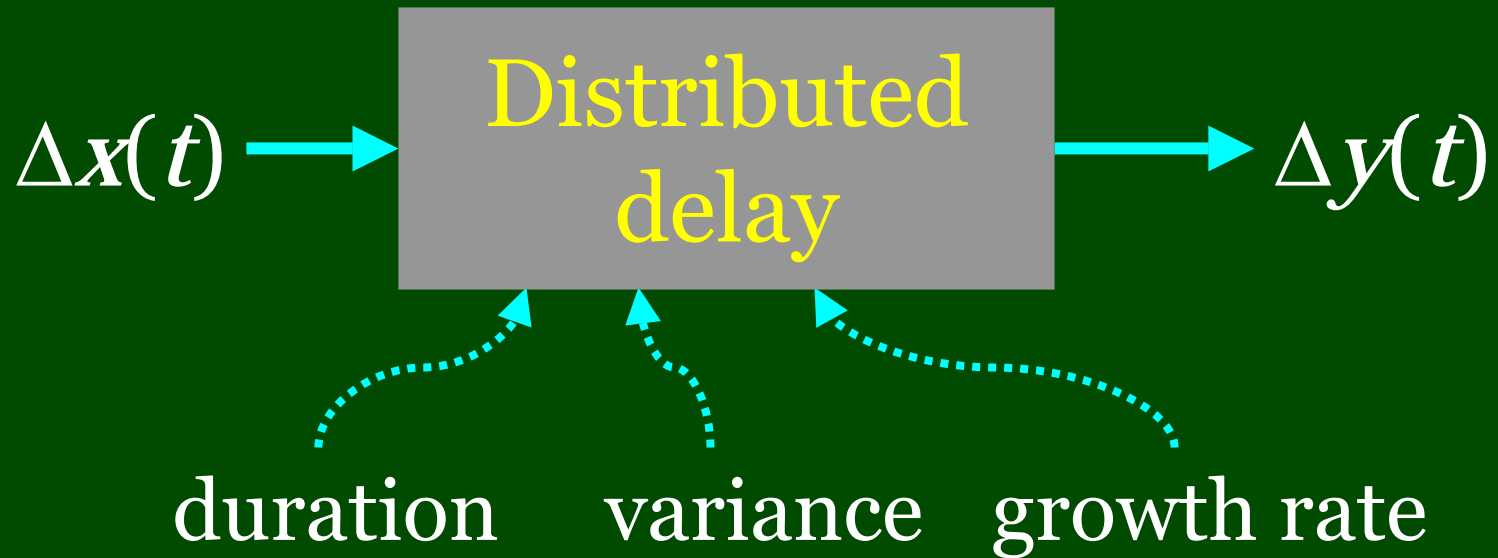
Processes:  
rates (per day)

- germinates
- hardens
- grows
- produces seeds
- ripens
- is shed

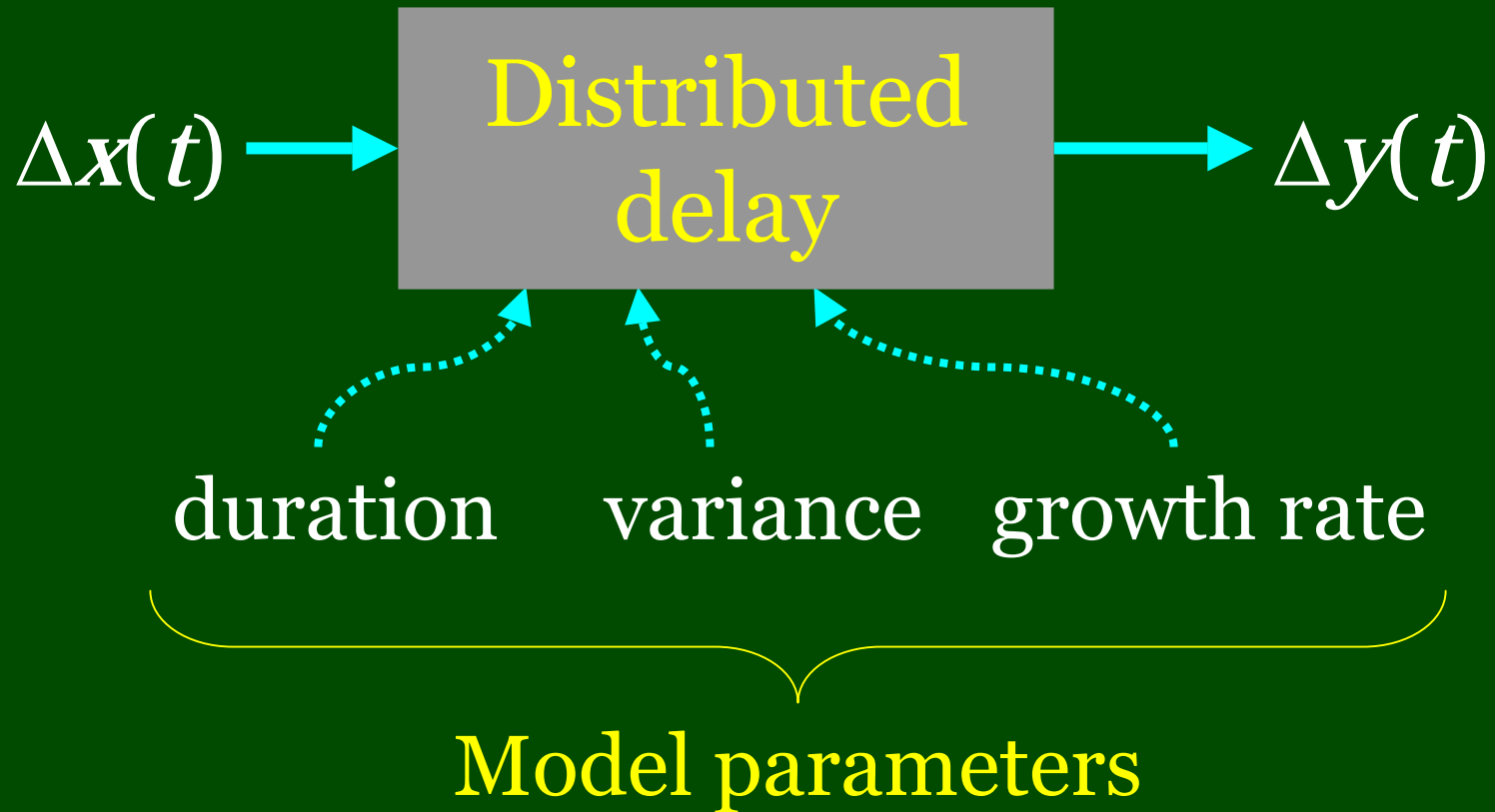
# Algorithm



# Algorithm



# Algorithm



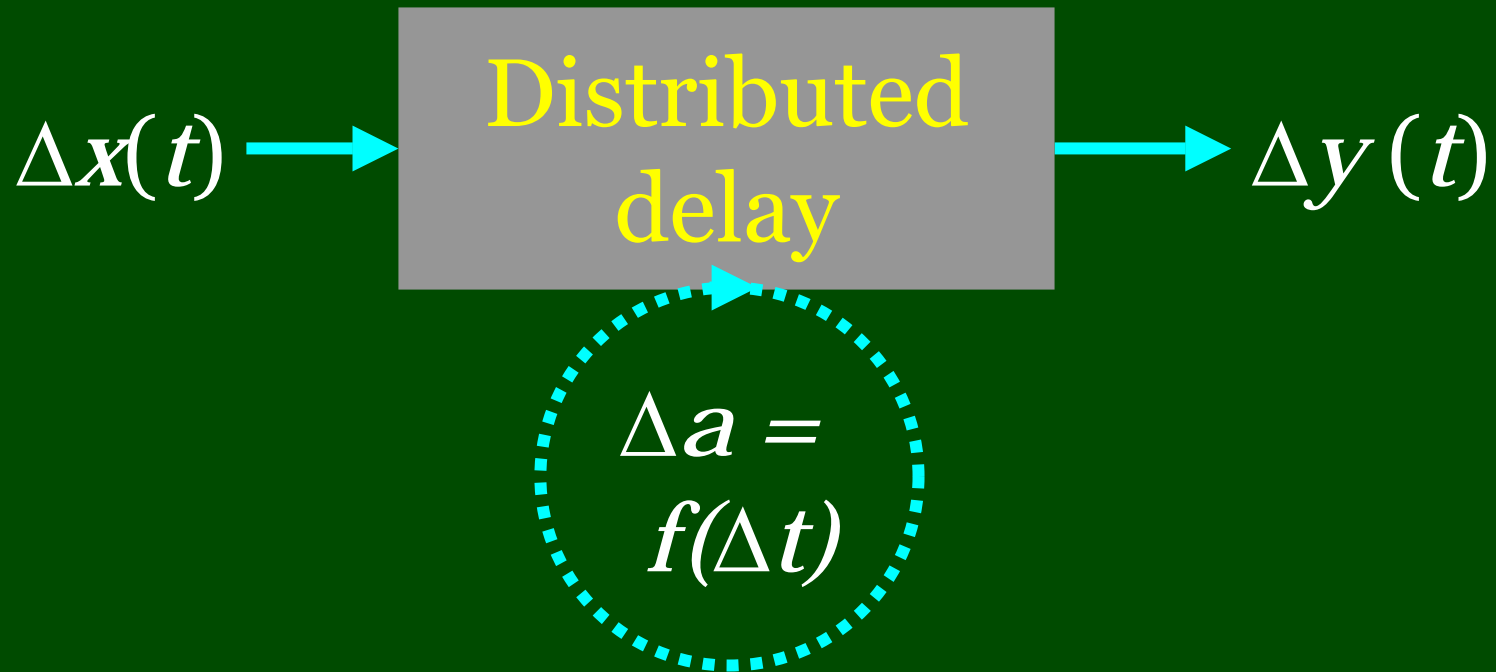
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# Physiological time scales

- Day-degrees
- Sunshine hours
- Photothermal time
- Hydrothermal time
- Vernalisation
- Stratification
- and more...

# Algorithm



Daily time step turned  
into age increment

# Model simulation

