Uses of dynamic system models

Jean-Noël Aubertot

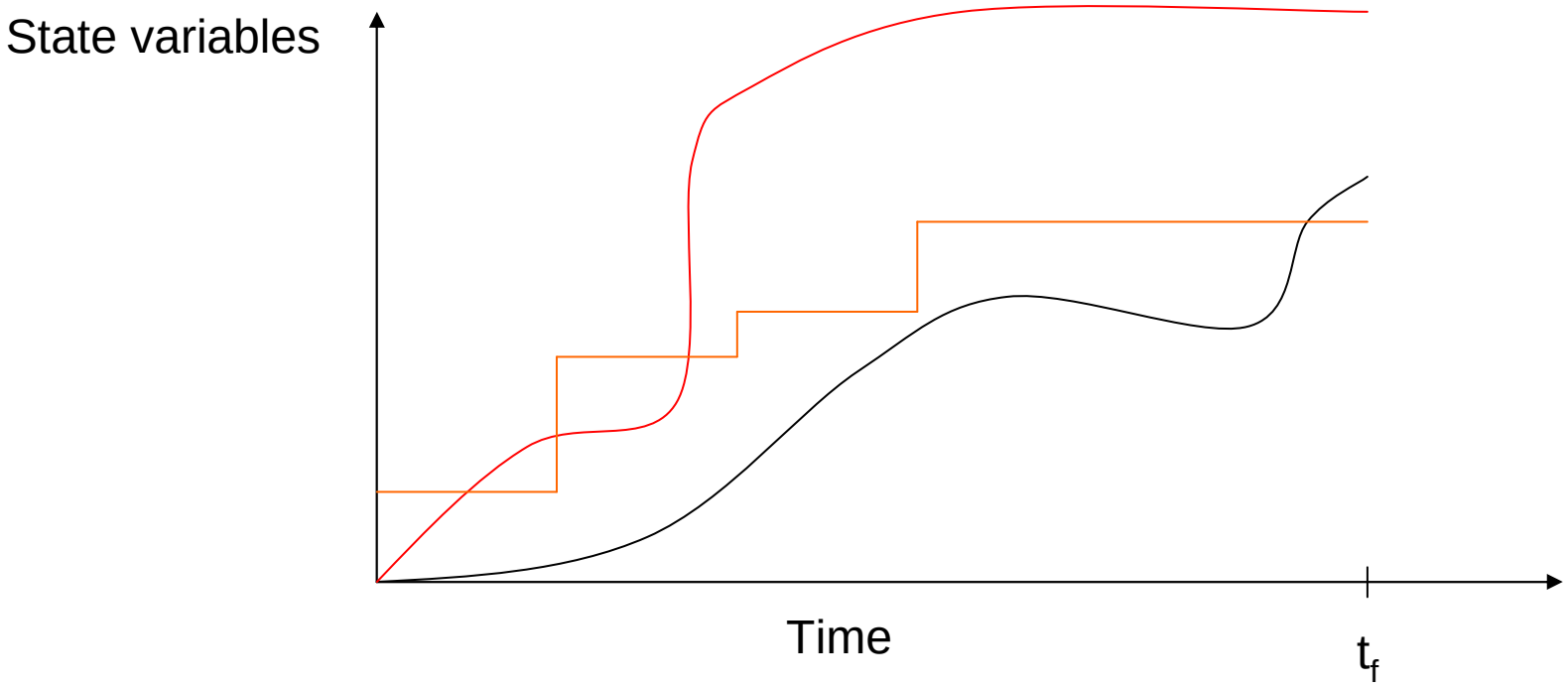
Outline

1) Different types of dynamic system models

2) Examples in the field of agronomy and epidemiology

3) Conclusion

What is a dynamic system model?



2 types of formalism to represent changes of a system over time

- Discrete time:
    - difference equations (constant time step)
    - compartment models (constant or variable time step)

- Continuous time:
    - continuous functions
    - differential equations (analytically or numerically solvable)

2) Discret time (difference equations)

$$Y(t+\Delta t) = Y(t) + f\left(Y\left(t\right), X\left(t\right), \theta\right)\Delta t$$

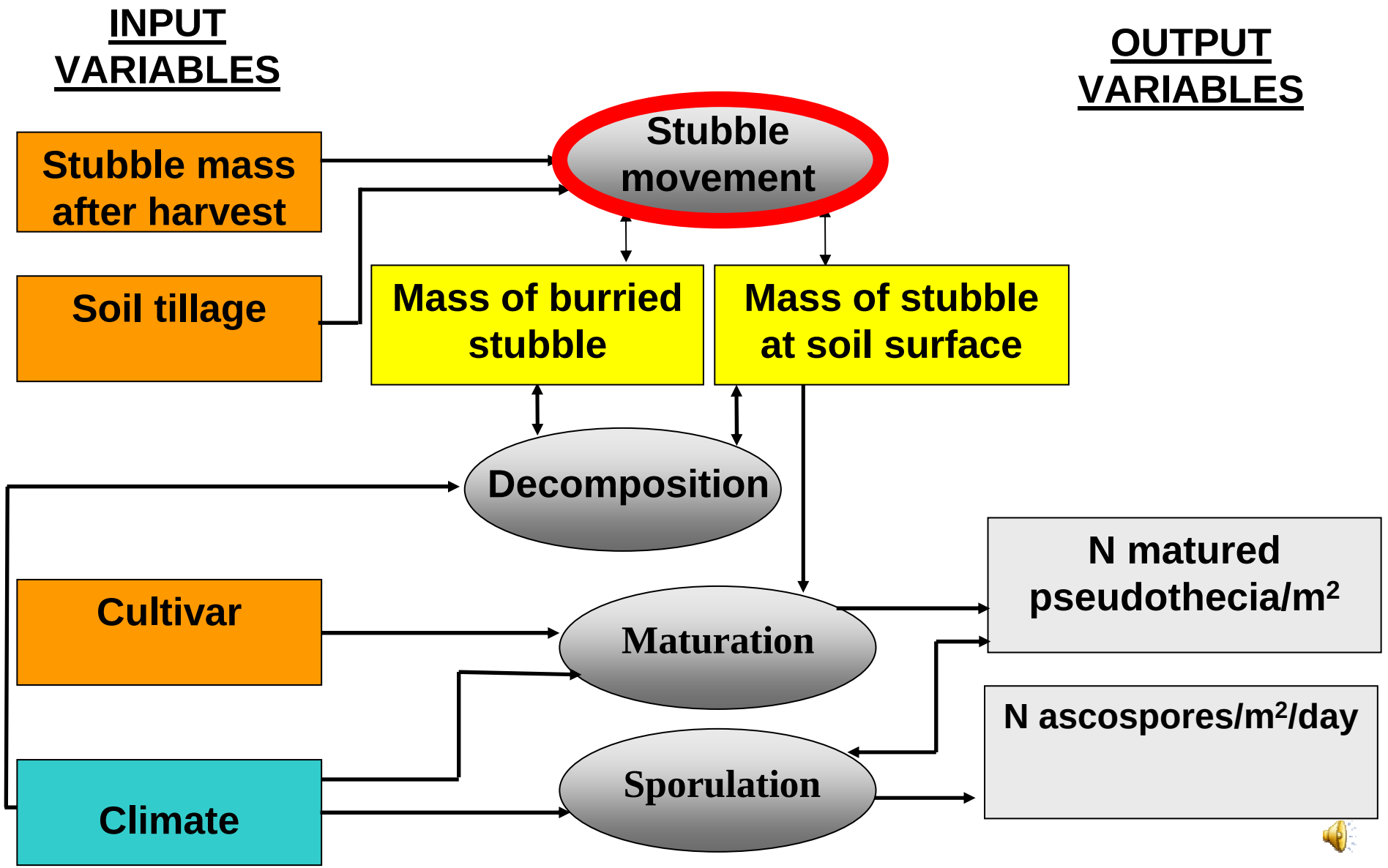
Examples:

- Predator prey system (Daniel's presentation)
- WHEATPEST (tomorrow)

2) Discret time (compartment model)

Example: SimInoc (Schneider et al., 2006)

Process chart of SimInoc



Parameterisation of matrices that simulate the vertical movement of stubble

$$\begin{pmatrix} X_{11} & X_{12} & X_{13} & X_{14} \\ X_{21} & X_{22} & X_{23} & X_{24} \\ X_{31} & X_{32} & X_{33} & X_{34} \\ X_{41} & X_{42} & X_{43} & X_{44} \end{pmatrix} \times \begin{pmatrix} n_1 i \\ n_2 i \\ n_3 i \\ n_4 i \end{pmatrix} = \begin{pmatrix} n_1 f \\ n_2 f \\ n_3 f \\ n_4 f \end{pmatrix}$$

Tillage matrix | **Initial state** | **Final state**

Reminder:

$$n_{1f} = x_{11}n_{1i} + x_{12}n_{2i} + x_{13}n_{3i} + x_{14}n_{4i}$$

$\vdots$

Experiment to quantify the effects of different tillage operations on the vertical movement of stubble

Studied tools:

- **Mouldboard plough**
- **Rotary harrow**
- **Cover crop**
- **Chisel**
- **Seeder**

Dziękuję Gosia!

Mouldboard ploughing

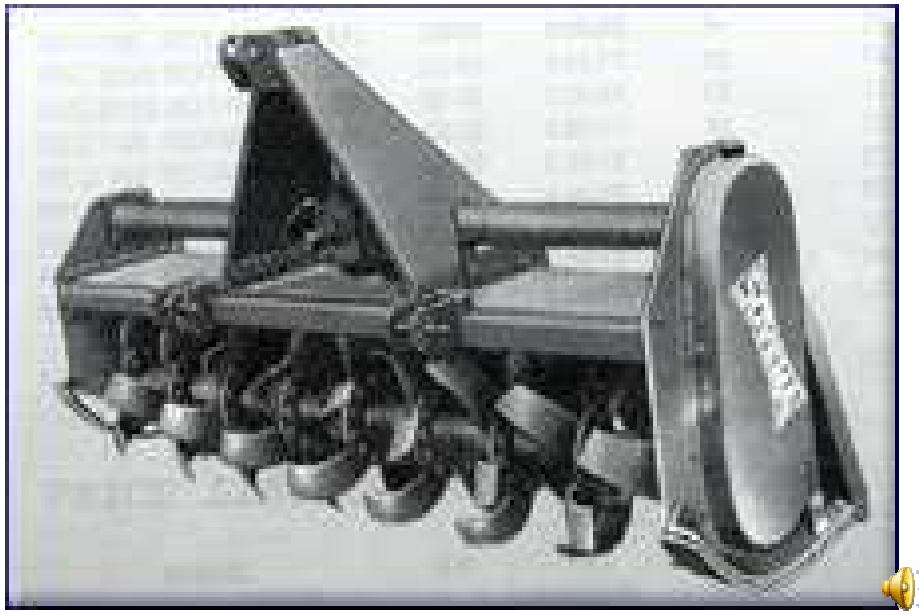
Orka z zastosowaniem odkładnicy (pługa)

Chiselling

Głęboszowanie

Rotary harrowing

Bronowanie z zastosowaniem brony rotacyjnej



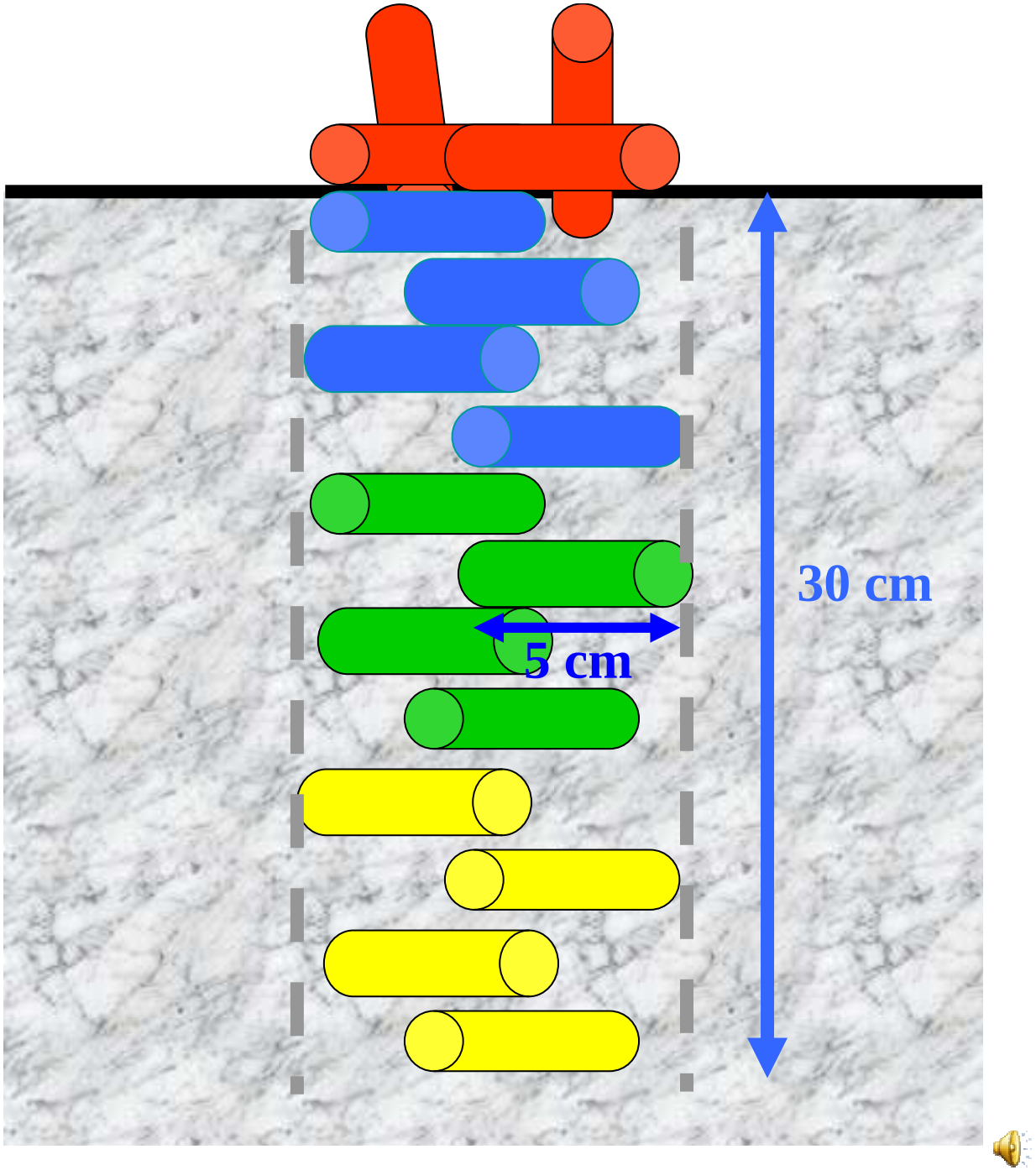
Stubble disking

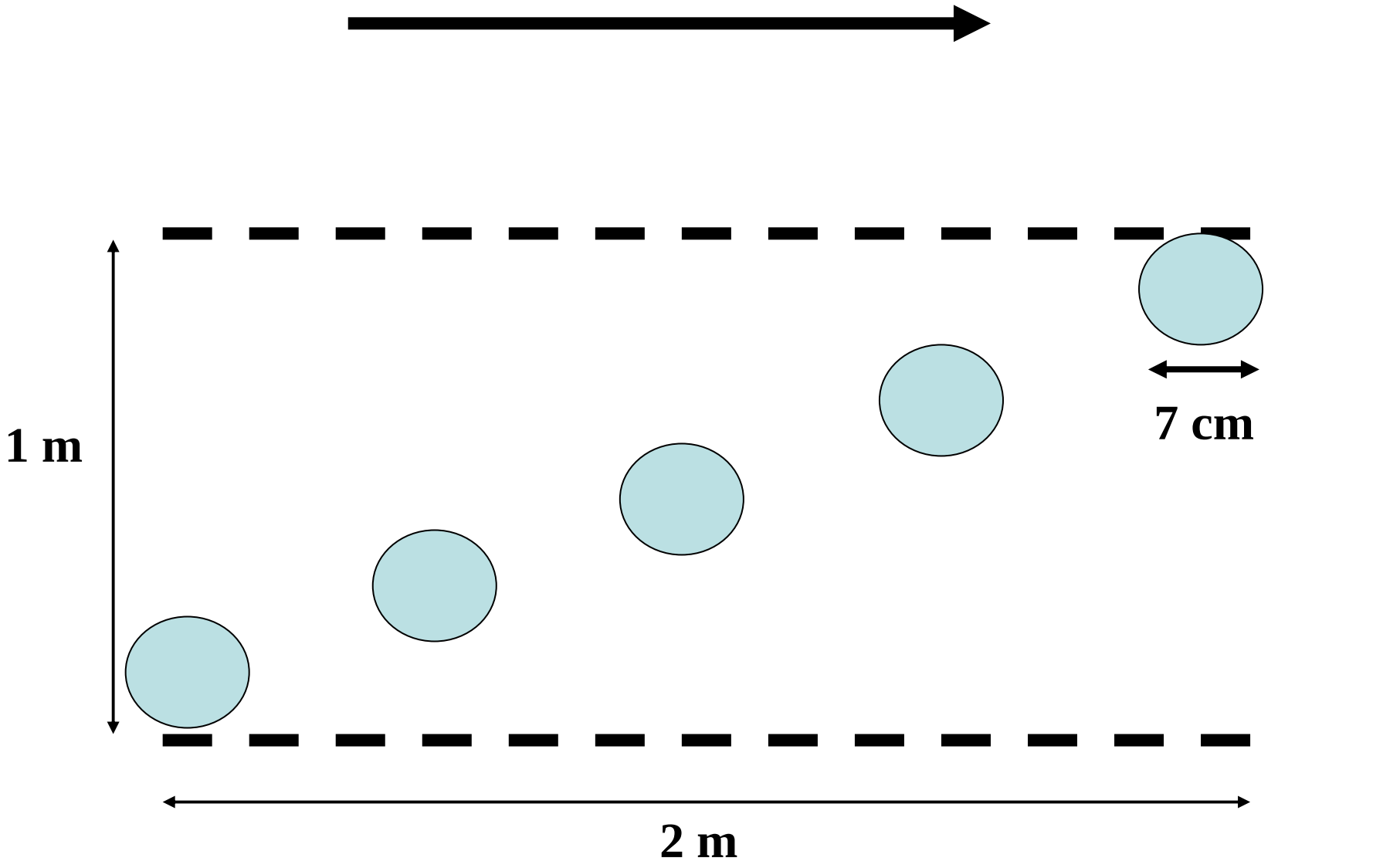
Talerzowanie ścierniska

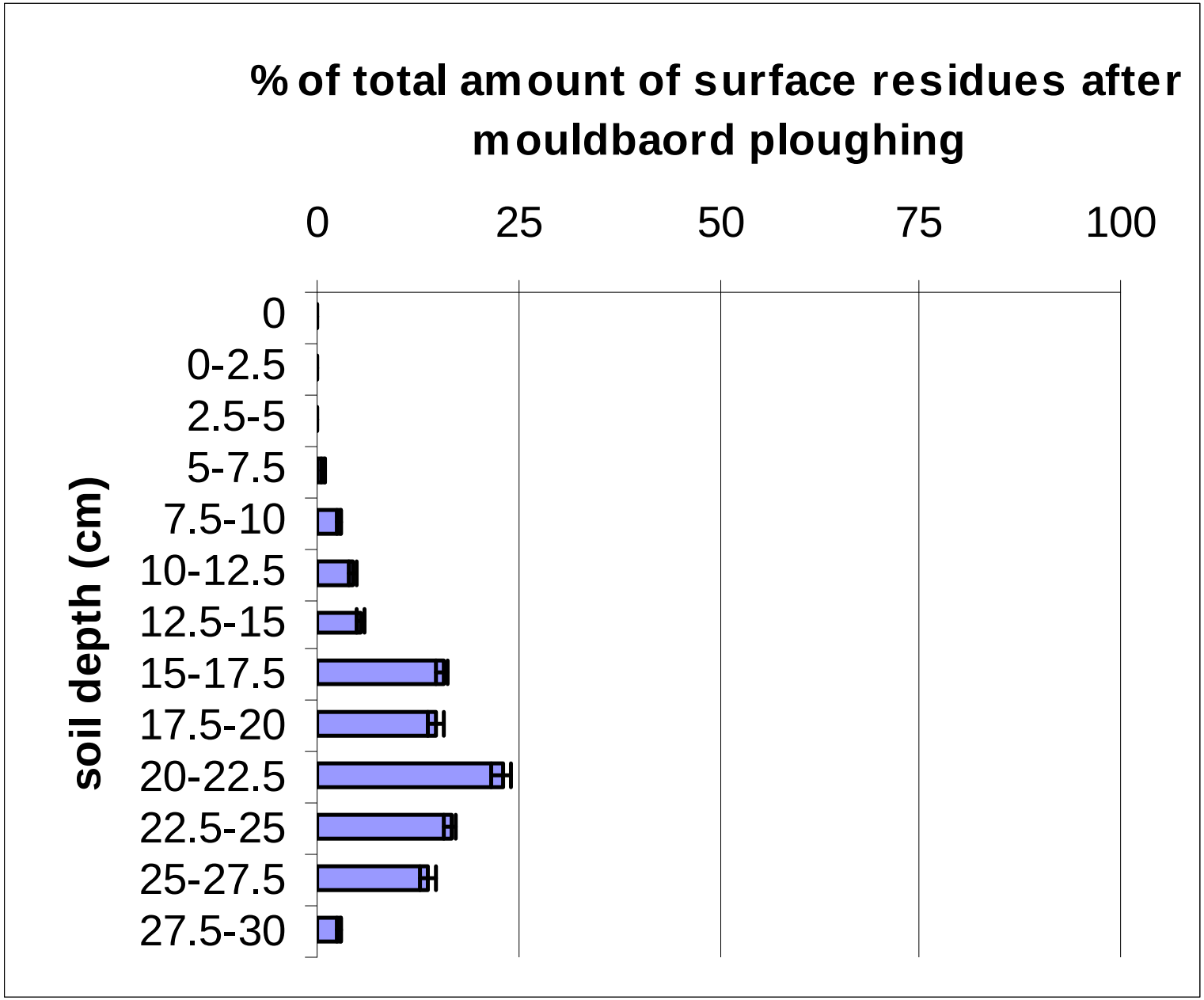
Sowing

Siew

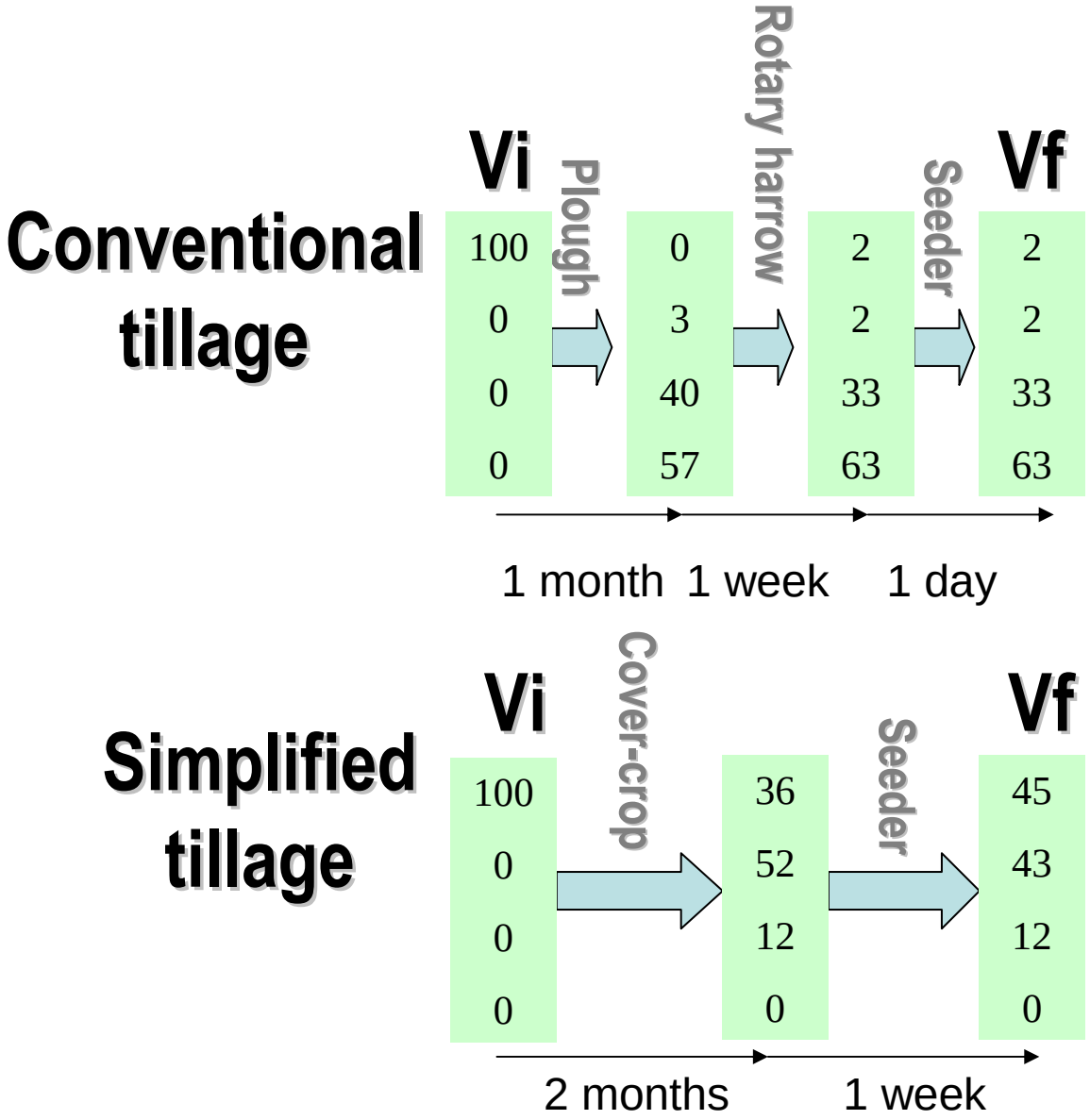
Method:




1 m
7 cm
2 m


% of total amount of surface residues after mouldbaord ploughing
0
25
50
75
100
soil depth (cm)
0
0-2.5
2.5-5
5-7.5
7.5-10
10-12.5
12.5-15
15-17.5
17.5-20
20-22.5
22.5-25
25-27.5
27.5-30

Examples of simulated tillage operations



2) Continuous time (differential equations)

$$\frac{dY}{dt} = f\left(Y(t), X(t), \theta\right)$$

$$\vdots$$

- Example:
  Epidemiological model for take-all on wheat
(Brasset, 1988 et al.; Colbach et al, 1997)

Modelling take-all on wheat

On a given soil surface:

n plants and p primary inoculum units

Let's denote :

- i, the number of infected plants

- k_1, infection rate of a healthy plant by a primary inoculum unit during an infinitesimal thermal time unit dt

- k_2, infection rate of a healthy plant by an infected plant during an infinitesimal thermal time unit dt

$$\frac{di}{dt} = k_1 p(n - i) + k_2 i(n - i)$$

Let’s denote:

- $y=\frac{i}{n}$, the disease incidence

- $C_1=k_1p$, infection rate of a healthy plant by the primary inoculum during an infinitesimal thermal time dt

- $C_2=k_2n$, maximum infection rate of a healthy plant by the infected plants during an infinitesimal thermal time dt

Analytical integration:

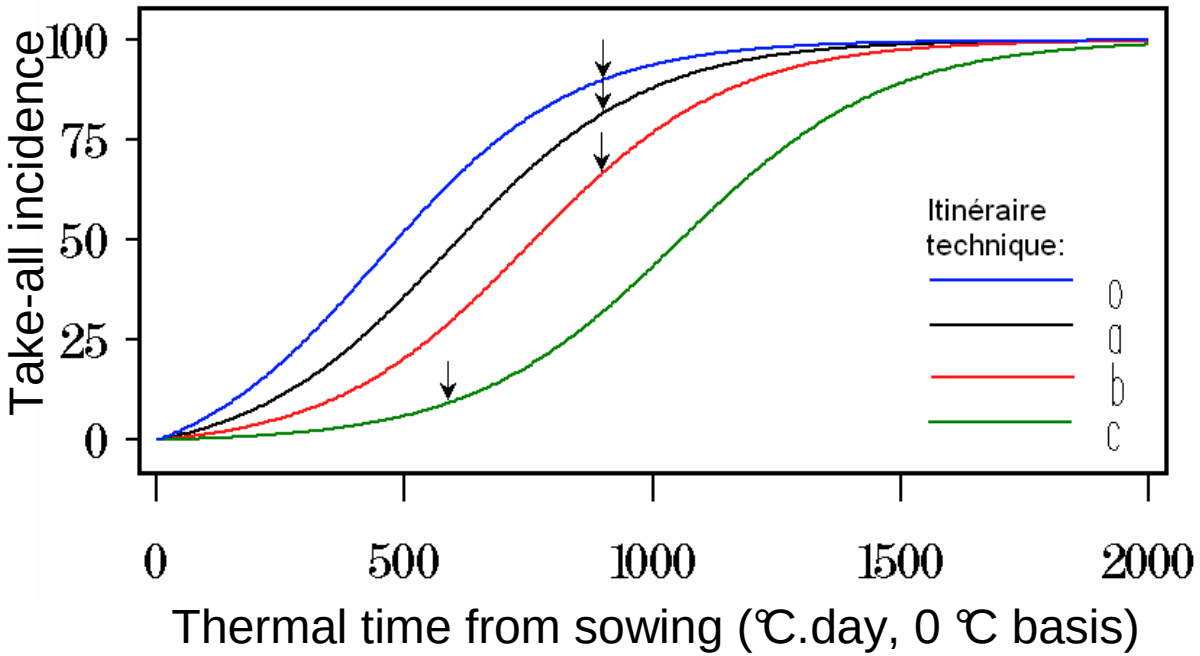
$$y=\frac{1-e^{-(c_1+c_2)t}}{1+\frac{c_2}{c_1}e^{-(c_1+c_2)t}}$$

Using experimental datasets, the variables C_1 and C_2 are expressed as a function of cultural practices

Simulations: effect of contrasted crop management

on take-all epidemics

	O	a	b	c
SD	10/10	10/10	10/10	10/11
Density (m^{-2})	350	240	225	225
N (kg/ha)	300	270	225	225



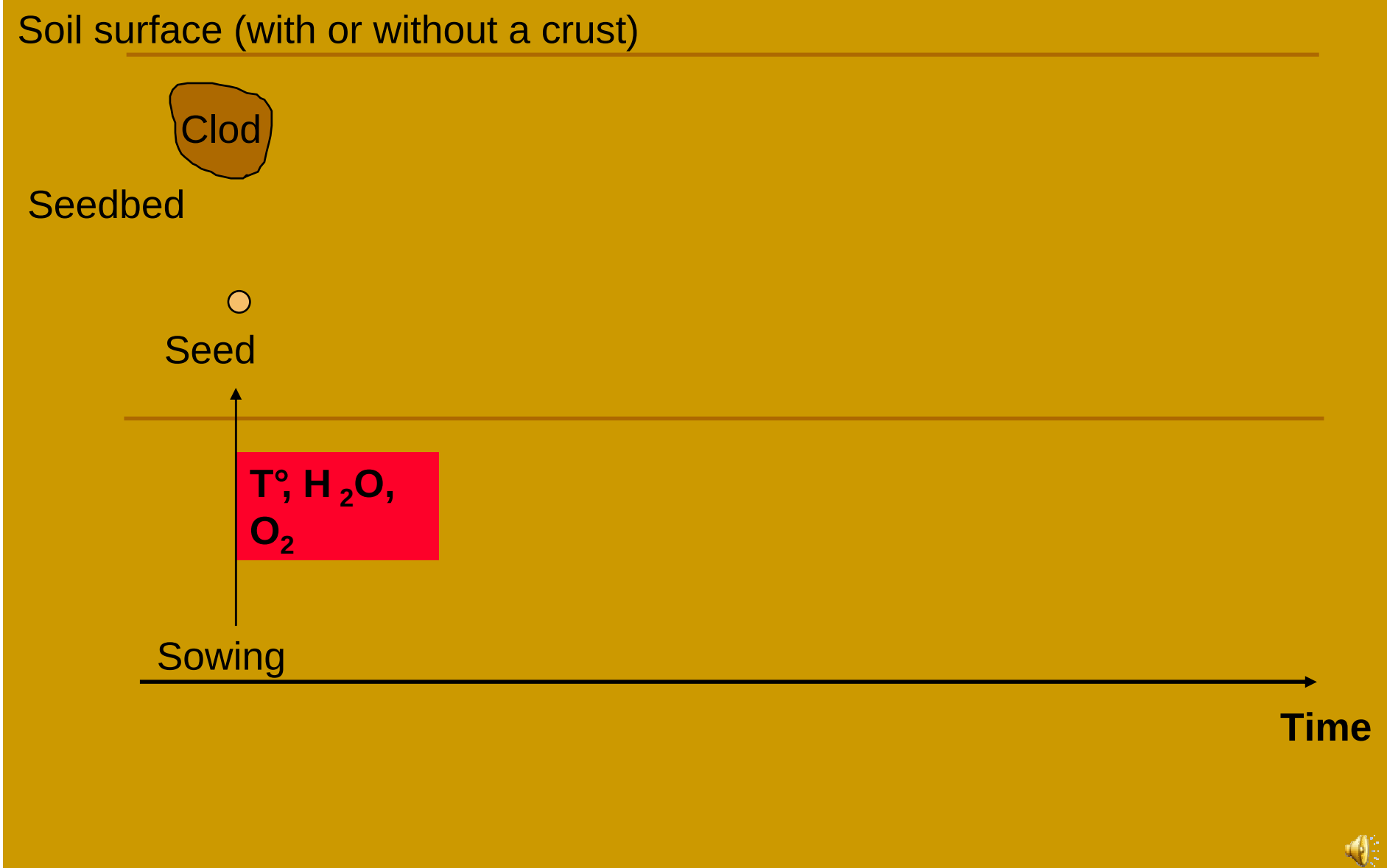
2) Continuous time (continuous functions)

$$Y(t) = f\left(X(t), \theta\right)$$

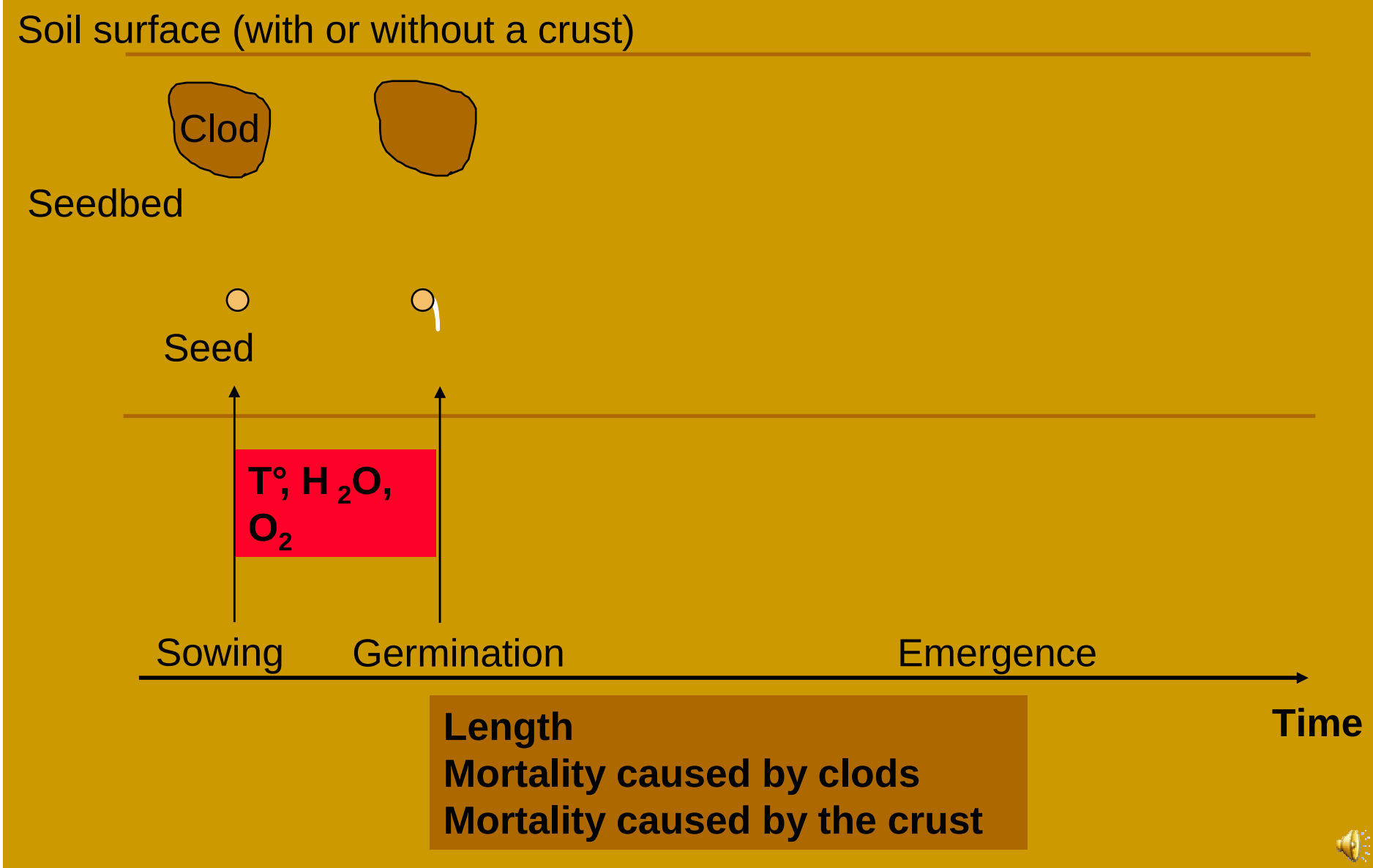
$$\vdots$$

- Example:
  SIMPLE (Durr et al., 2001)

Crop establishment (sugar beet)



Crop establishment (sugar beet)



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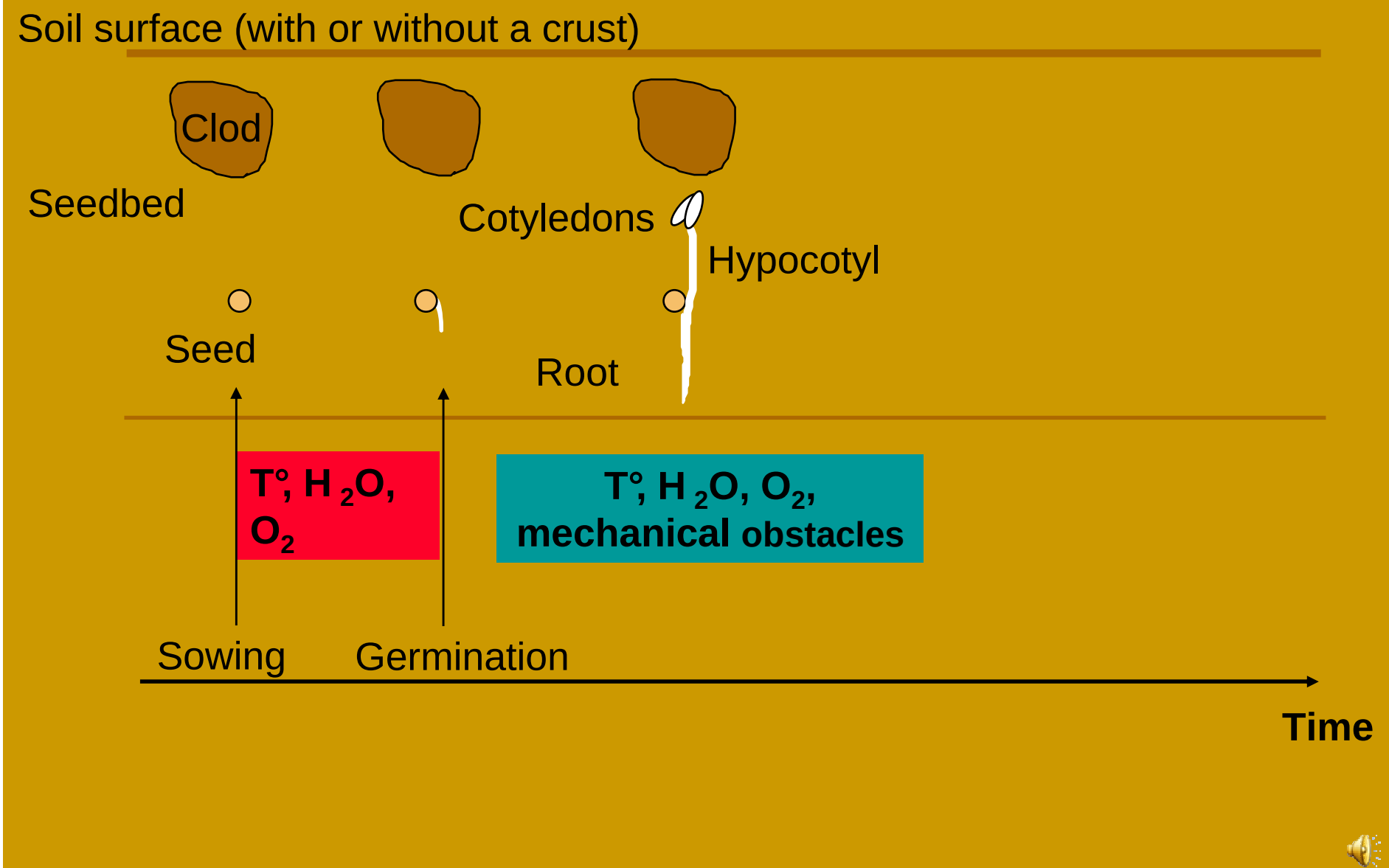

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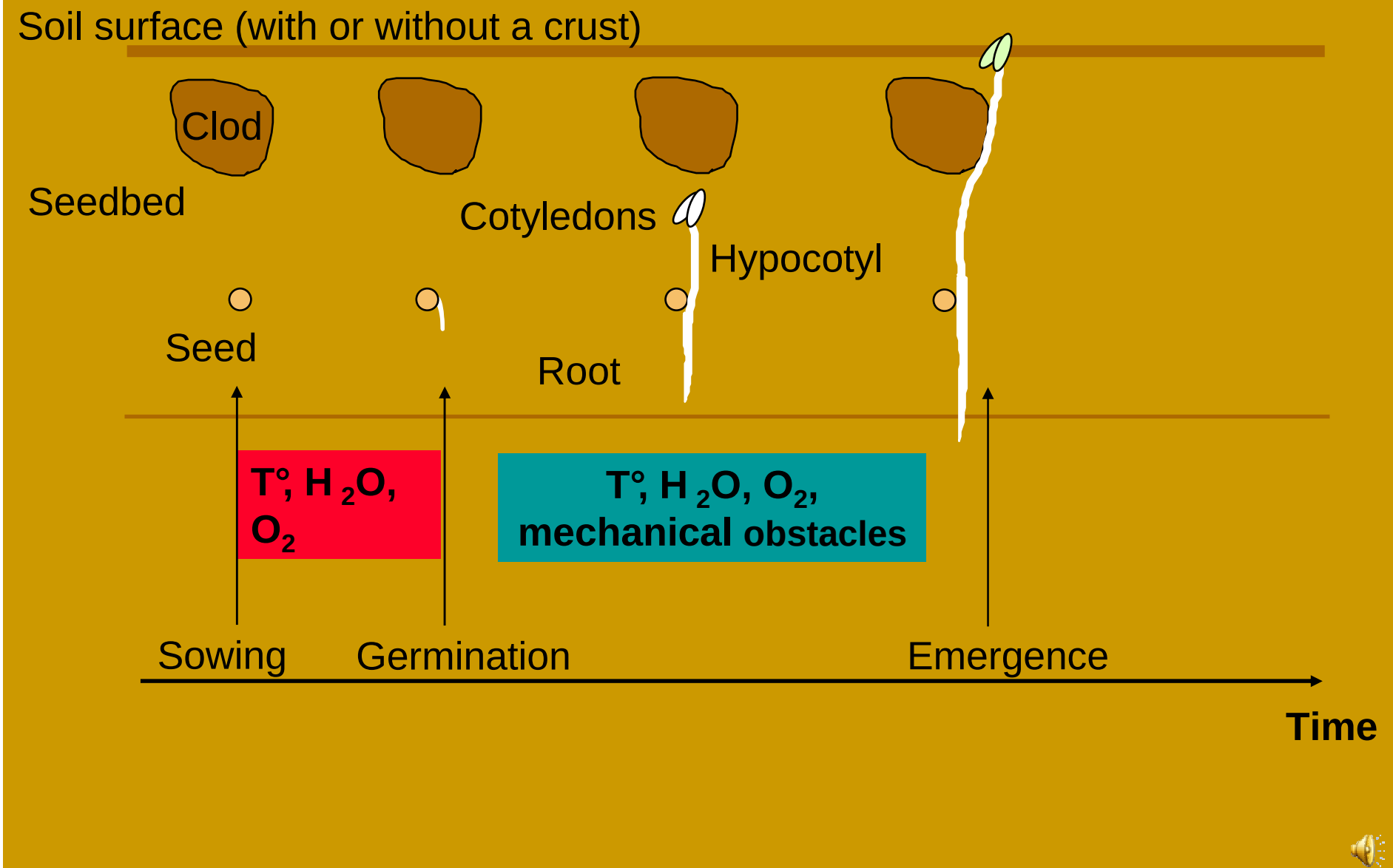

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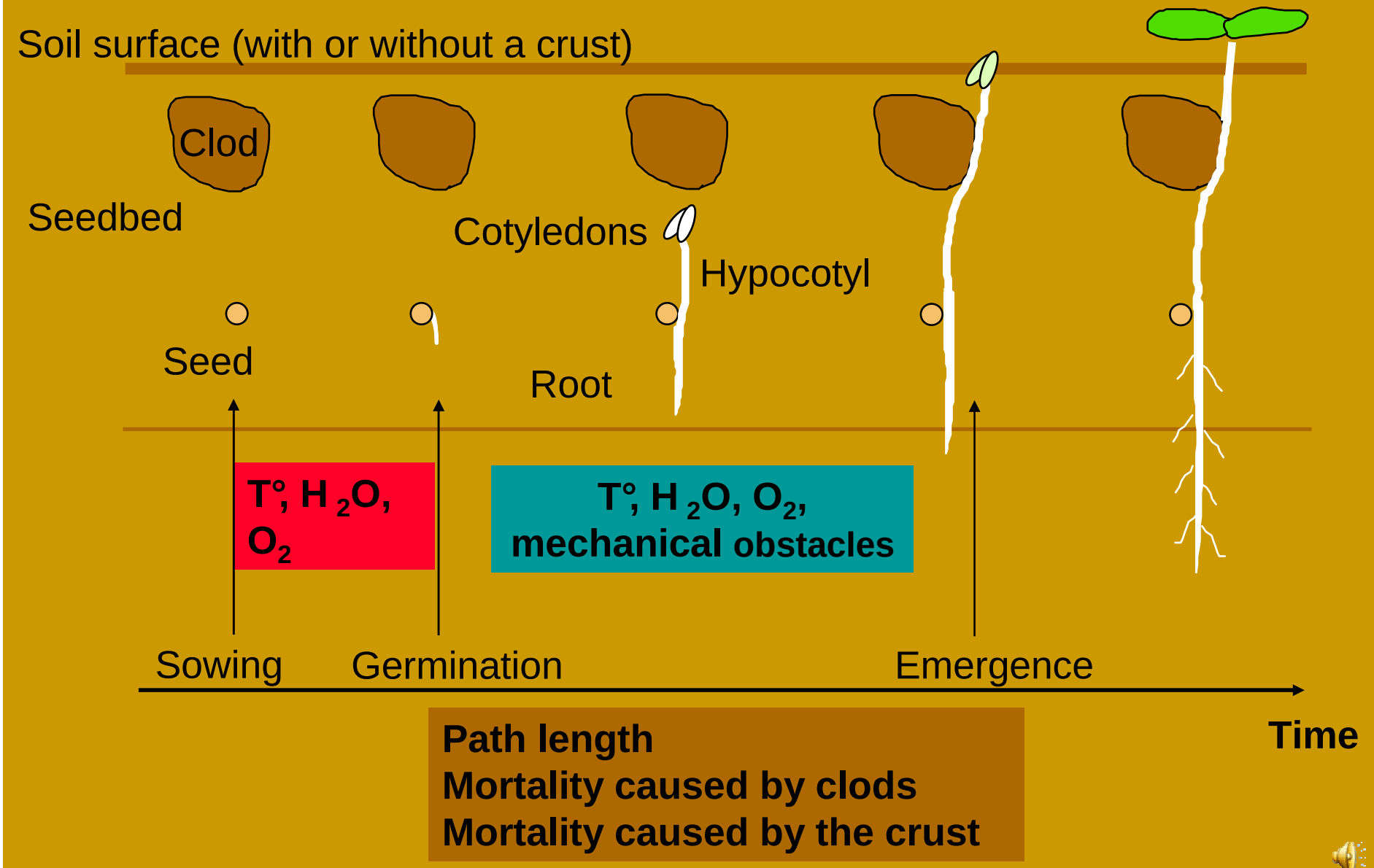
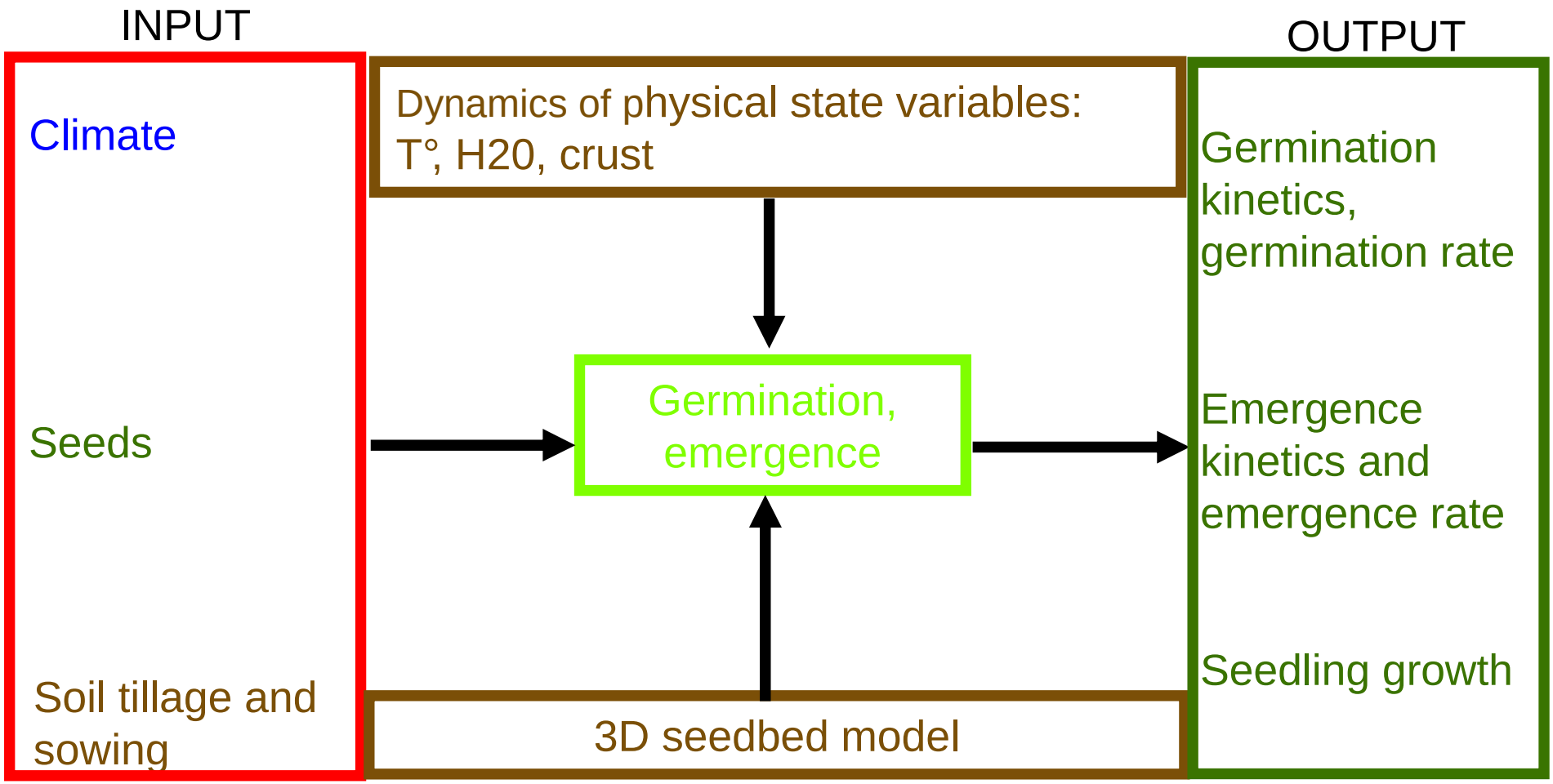


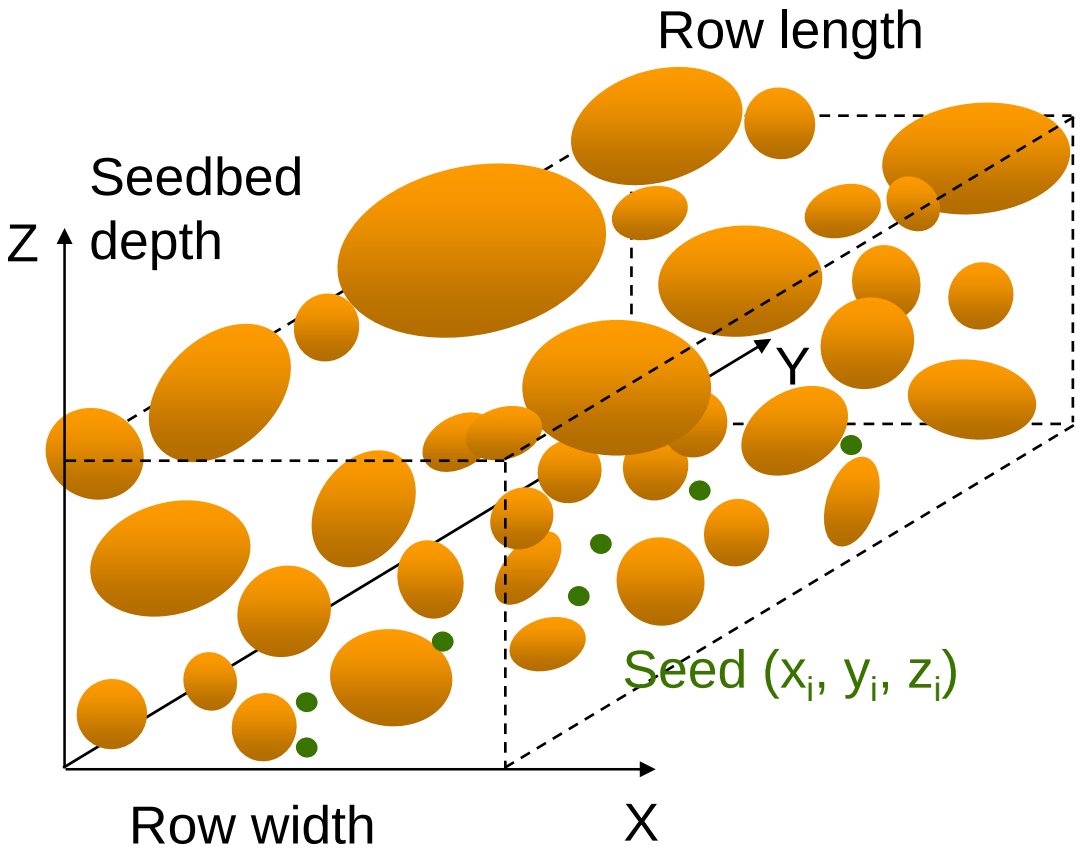
Flow chart of SIMPLE



3D seedbed model

Input variables

- Diameters, aspect ratios
- Size distribution
- Spatial distribution rules



Free demo!

2) Continuous time: SIMPLE

$$L(t) = L\max\left(1 - \exp\left(-bt\right)^{c}\right)$$

Dimensionless parameter

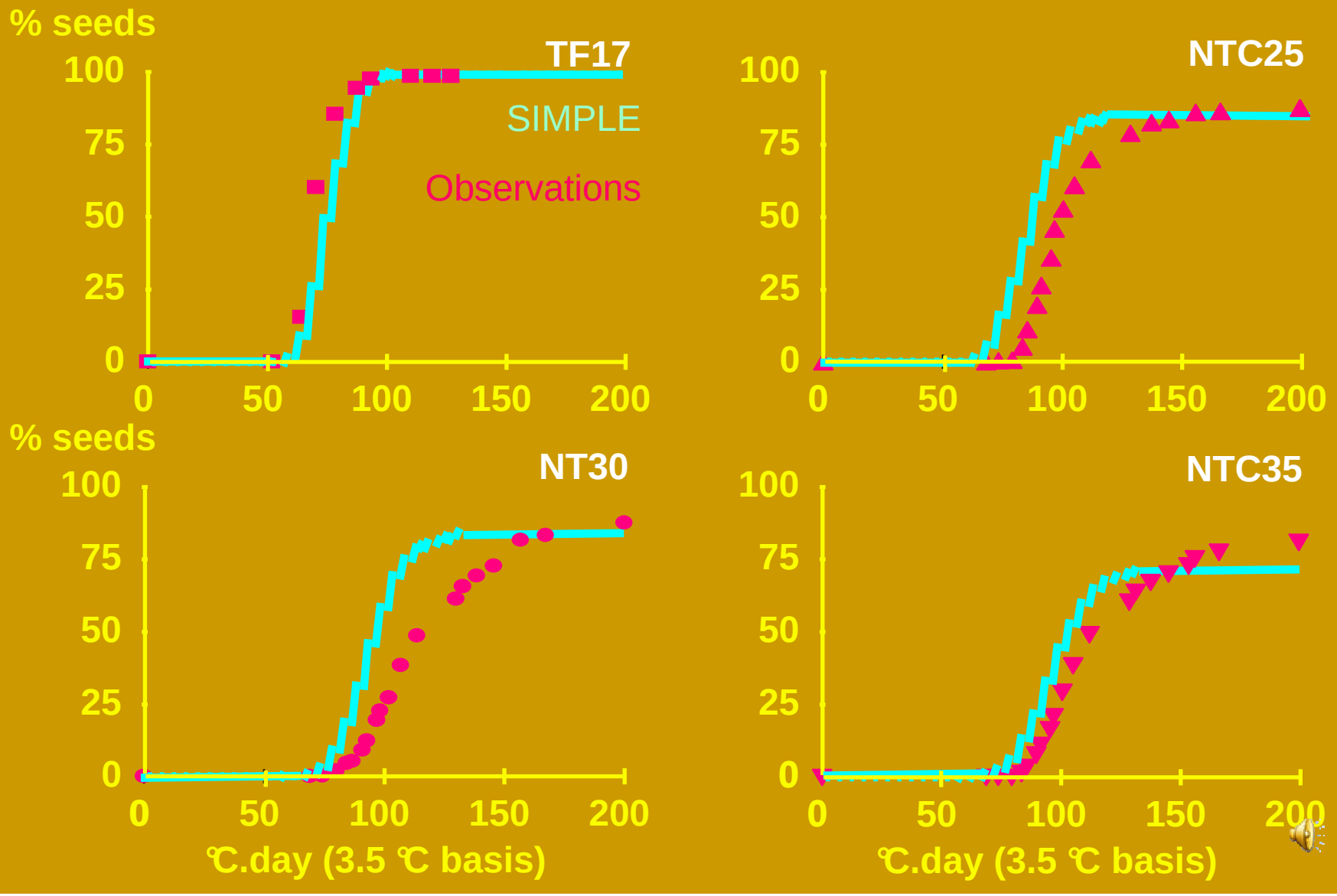
Hypocotyl length

Maximum hypocotyl length (parameter)

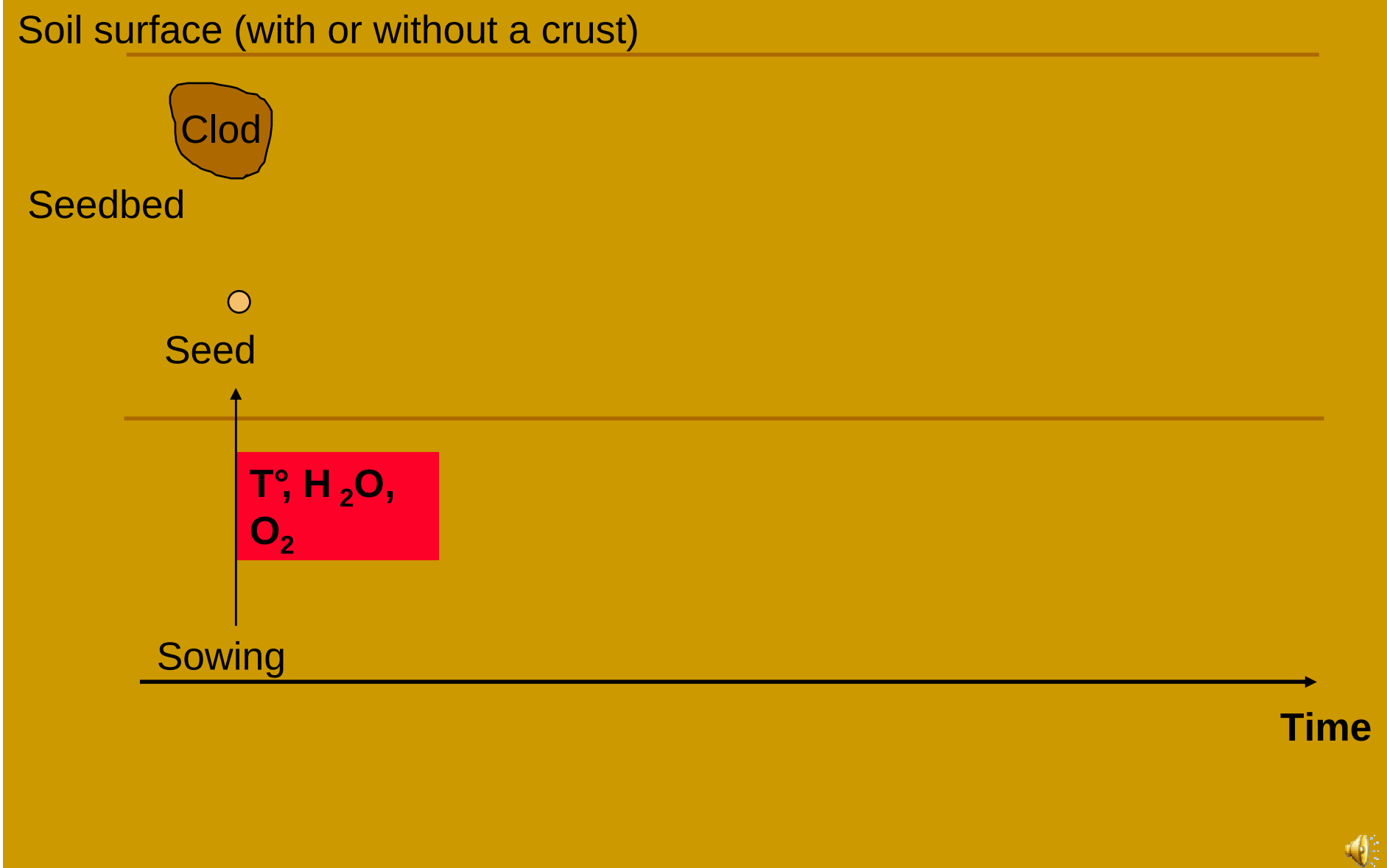
parameter

Thermal time from sowing

Evaluation of the predictive quality of SIMPLE



Crop establishment (sugar beet)



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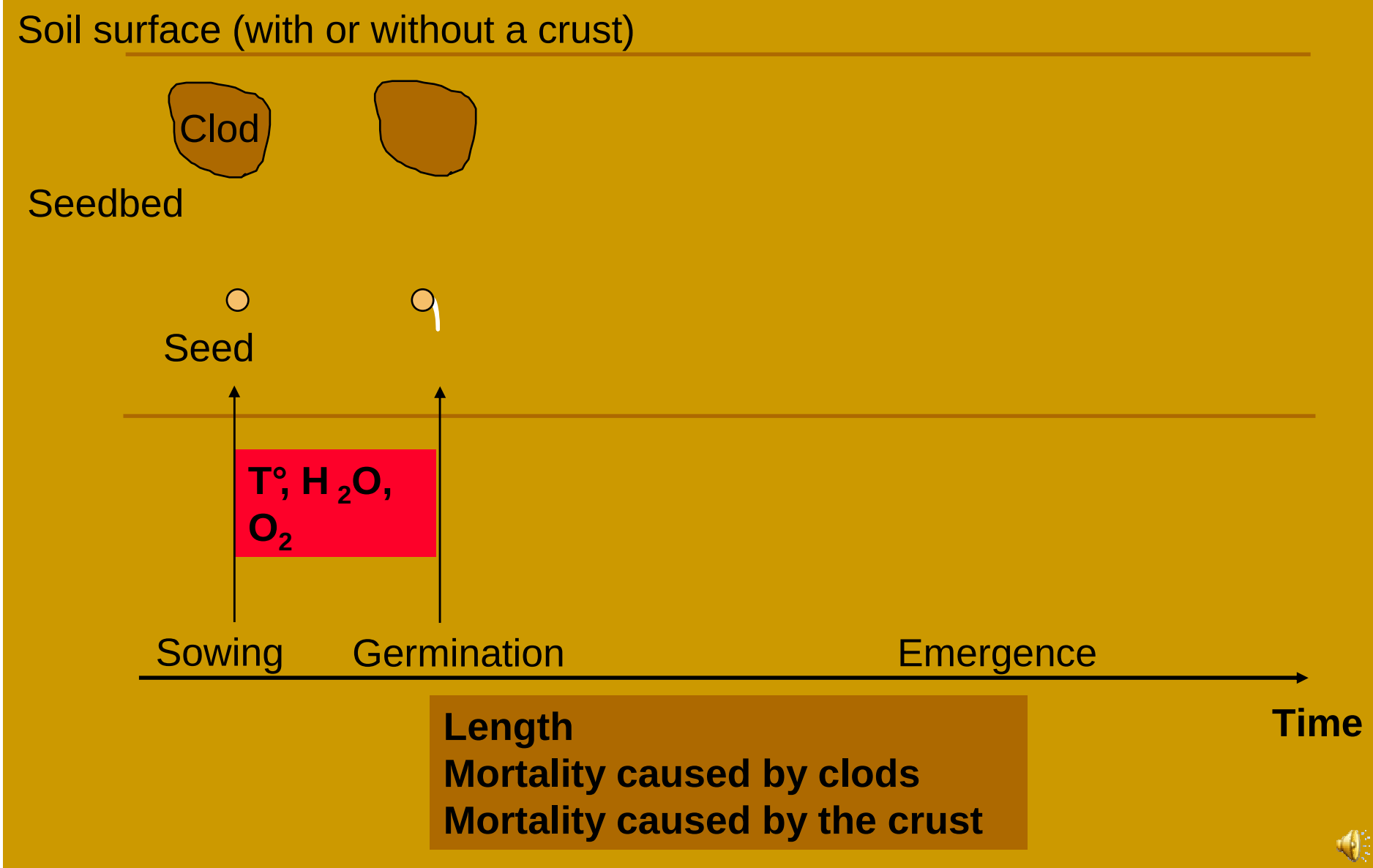

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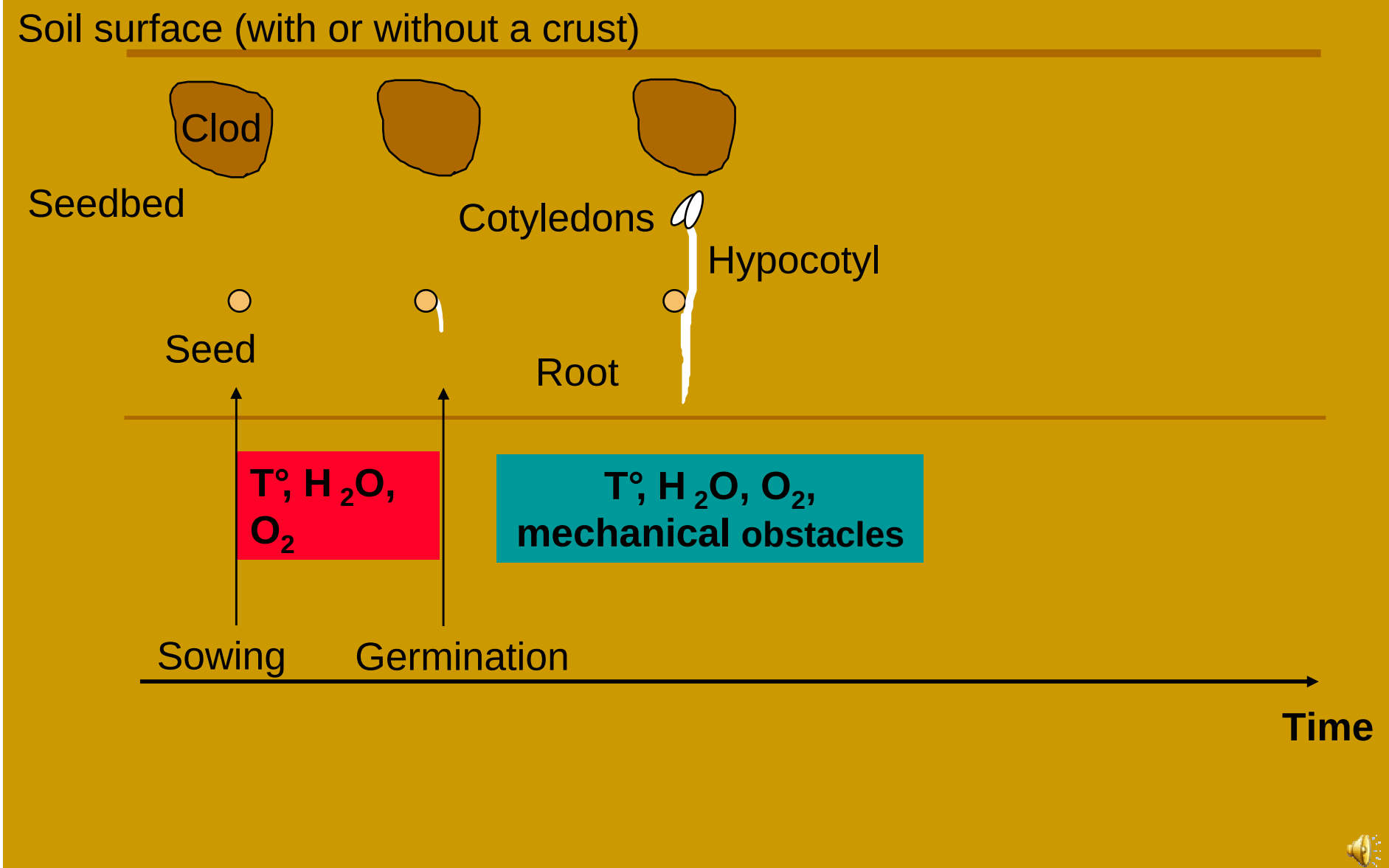

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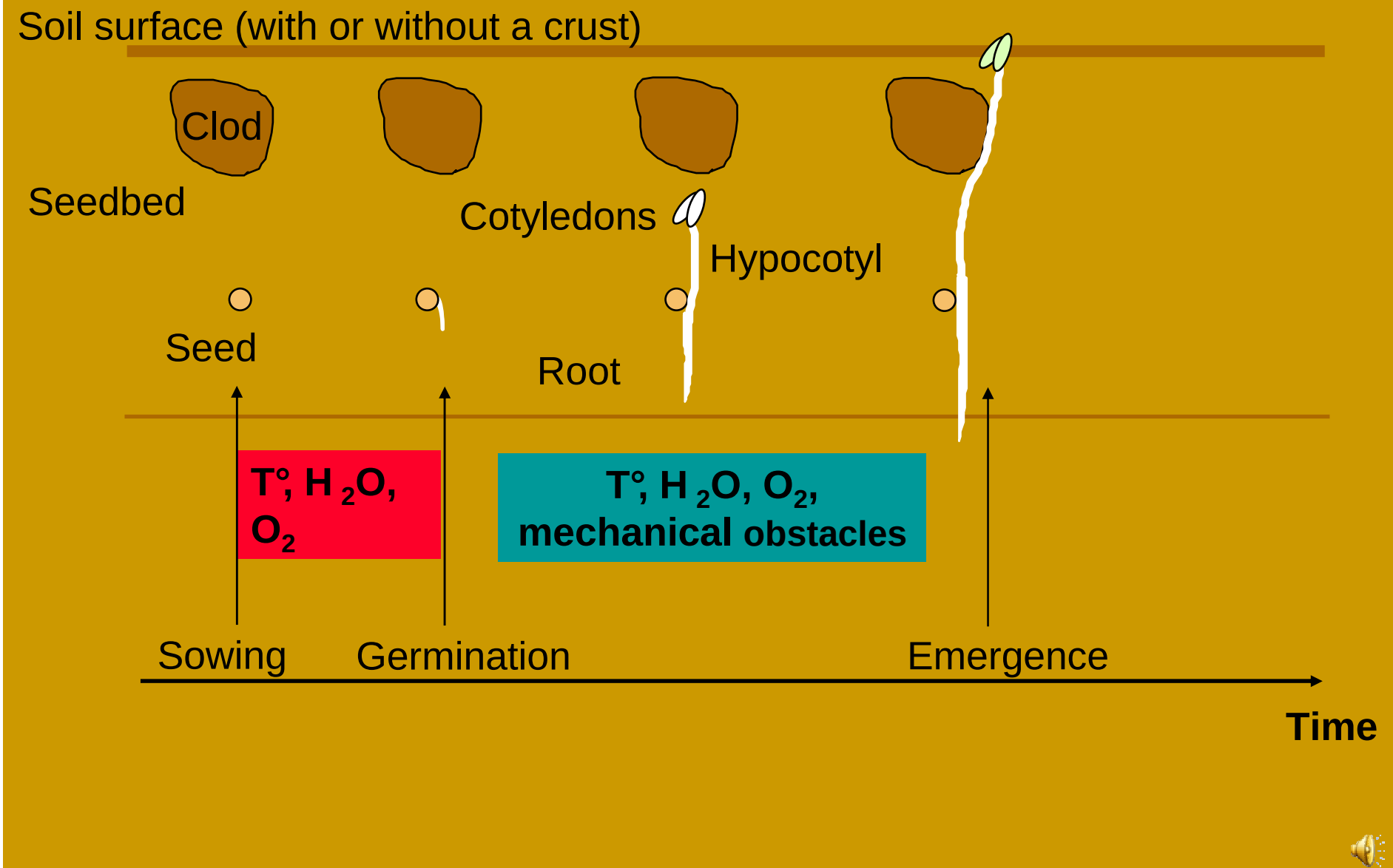

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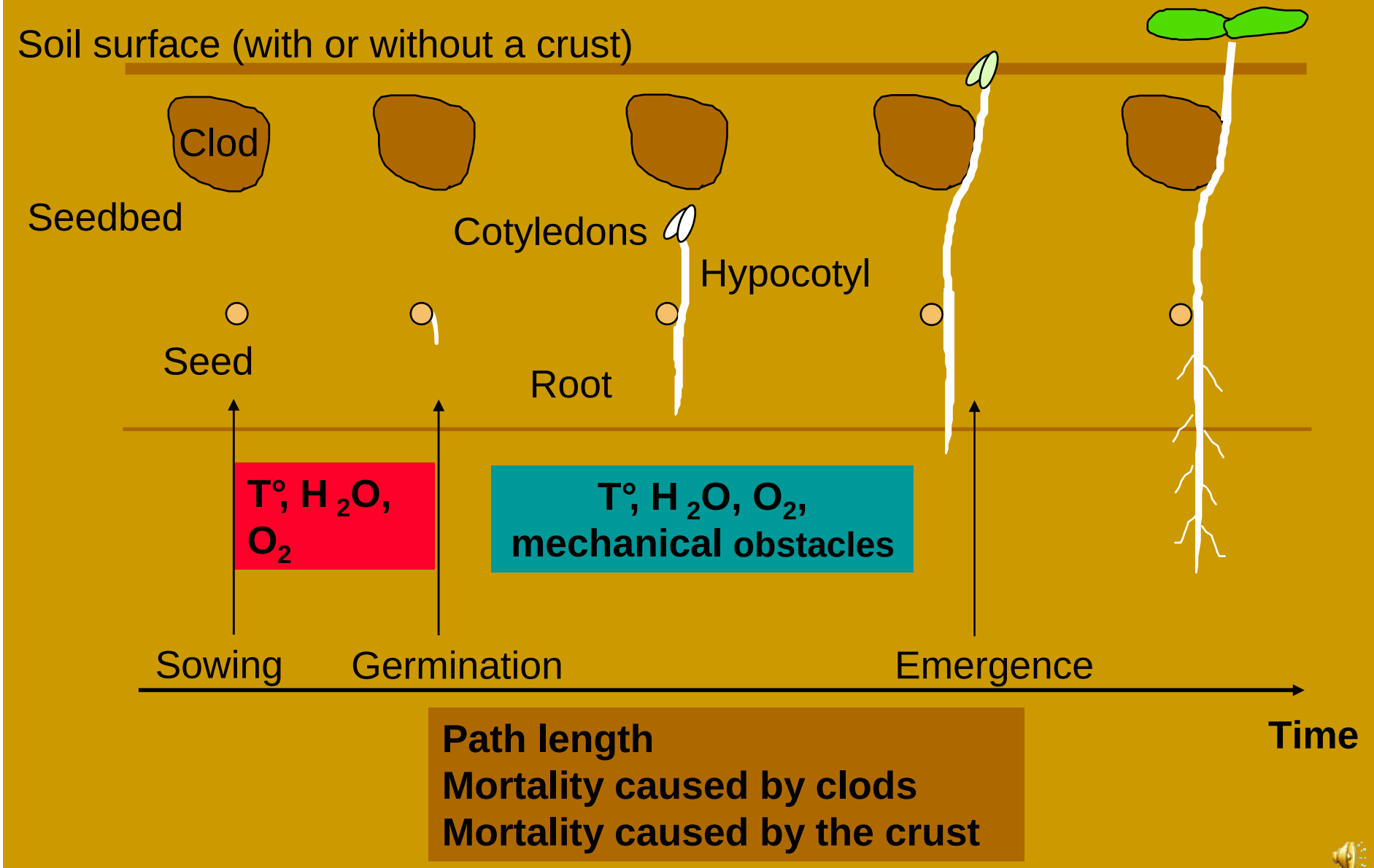
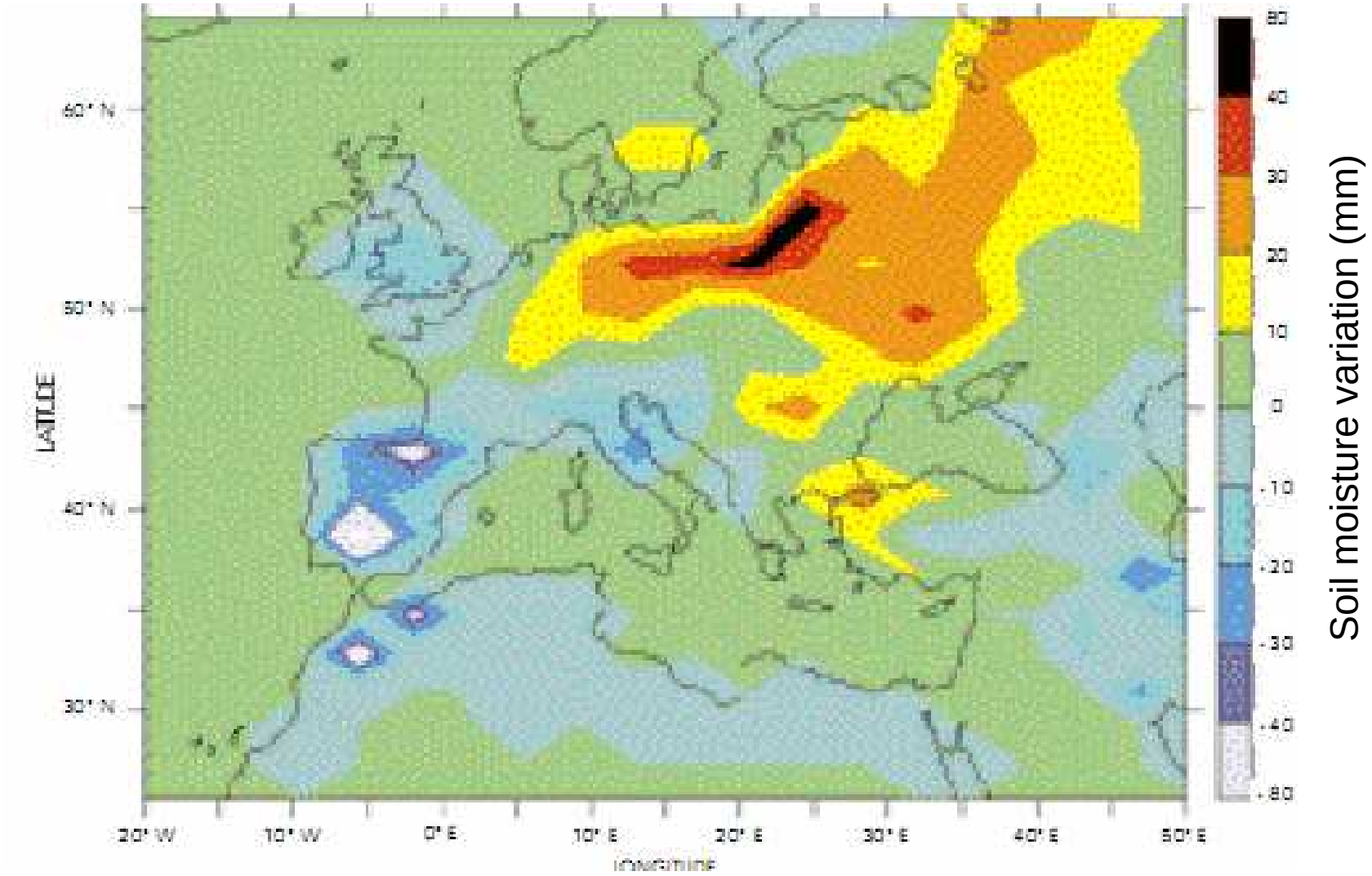


3) CONCLUSION

- Dynamic models are used in practically all scientific disciplines

Impact of a doubled CO_2 scenario on soil moisture content



K Laval, J Polcher (LMD, ENS, France)

CERN : European Organization for Nuclear Research

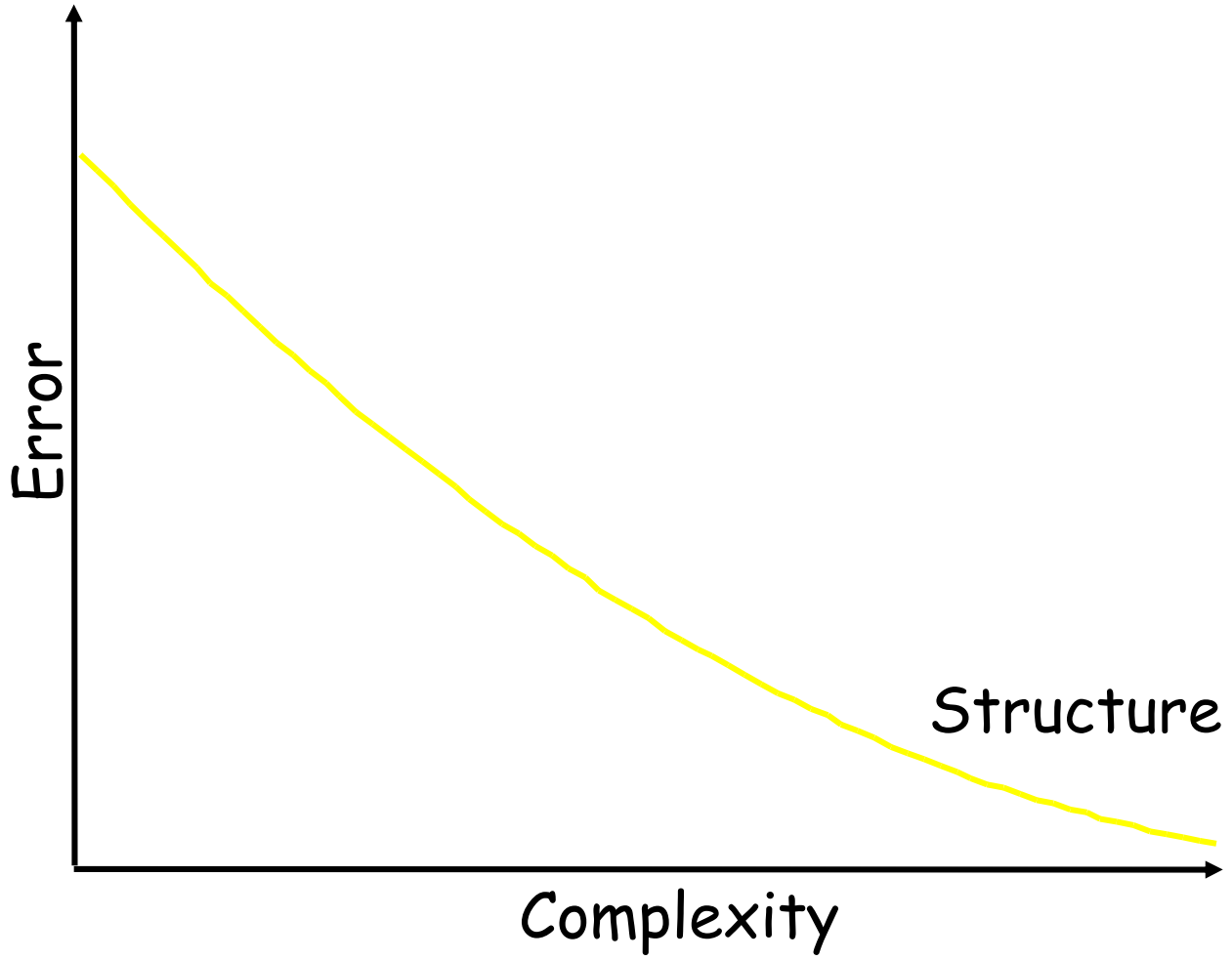
3) CONCLUSION

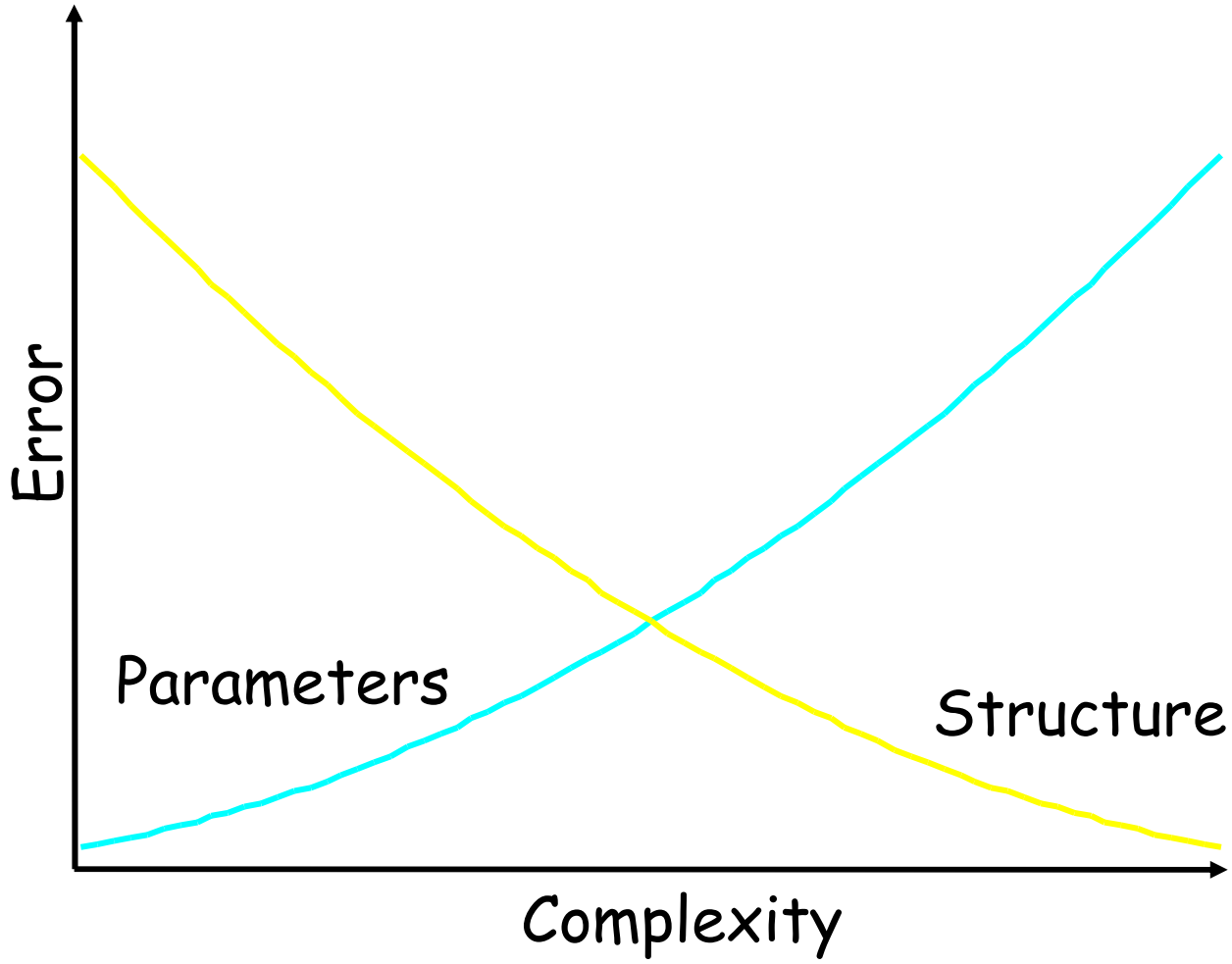
- Dynamic models are used in practically all scientific disciplines

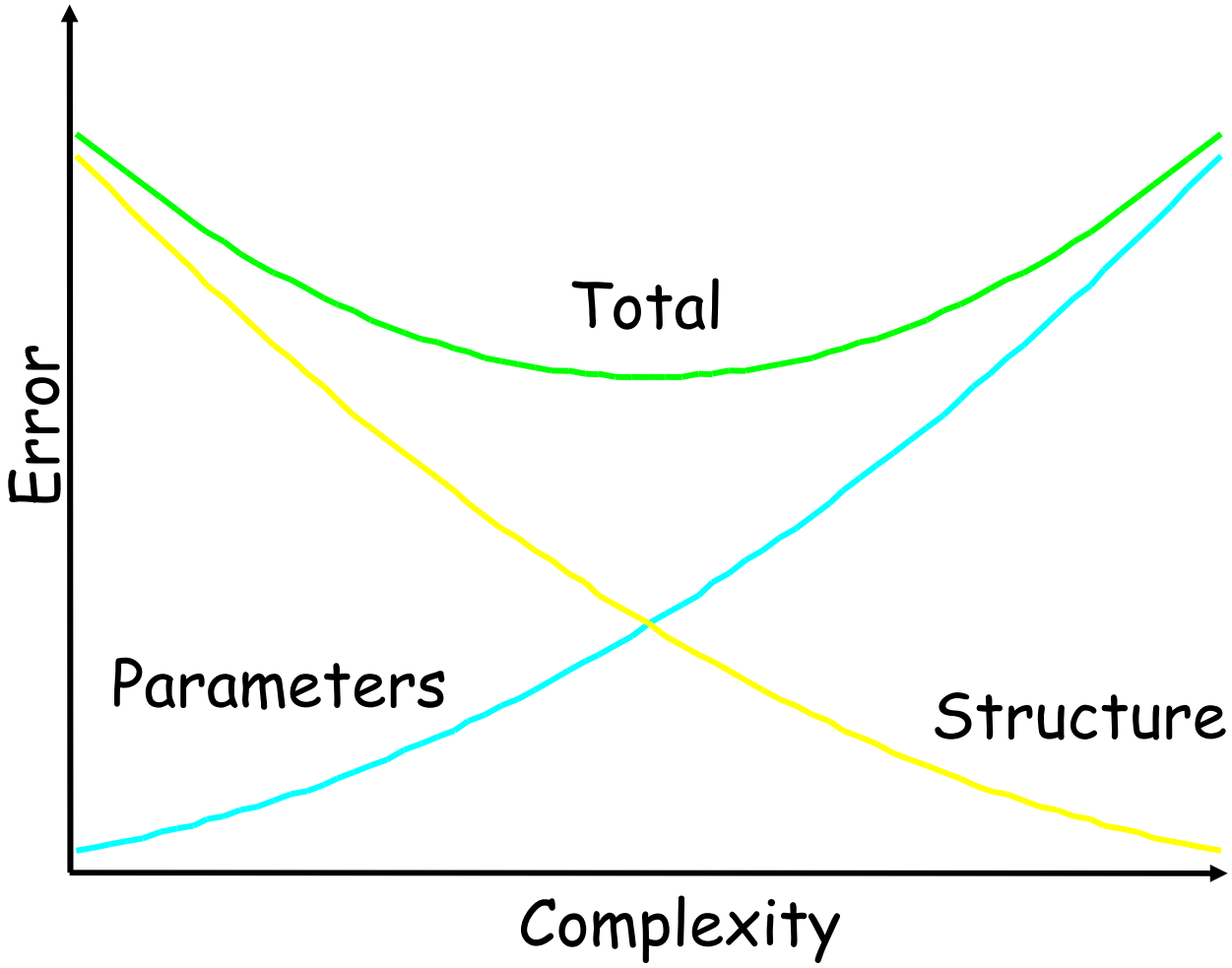
- The choice of the mathematical formalism depends on the knowledge on the represented system

- Outputs can be dynamics or final values

- Balance between complexity and simplicity


Error
Structure
Complexity


Error
Parameters
Structure
Complexity



Passioura, 1996

References

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