Bringing everything together into a simple functional-structural plant (FSP) model

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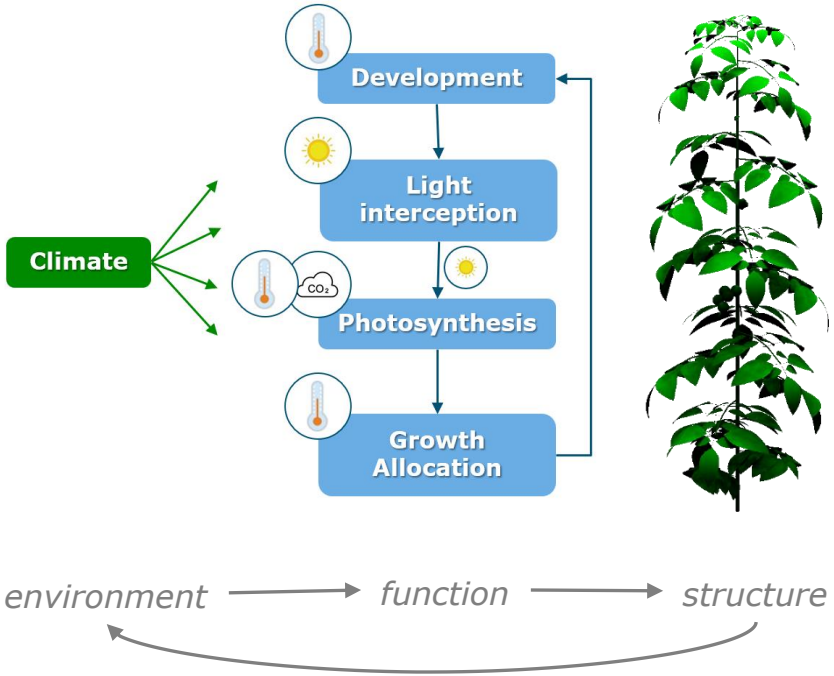
PIFI SUMMER WORKSHOP ON SYSTEMS MODELING OF
PLANT FACTORY FOR EXCELLENT YOUNG SCIENTISTS

FSP model: Combines function (F) and structure (S)



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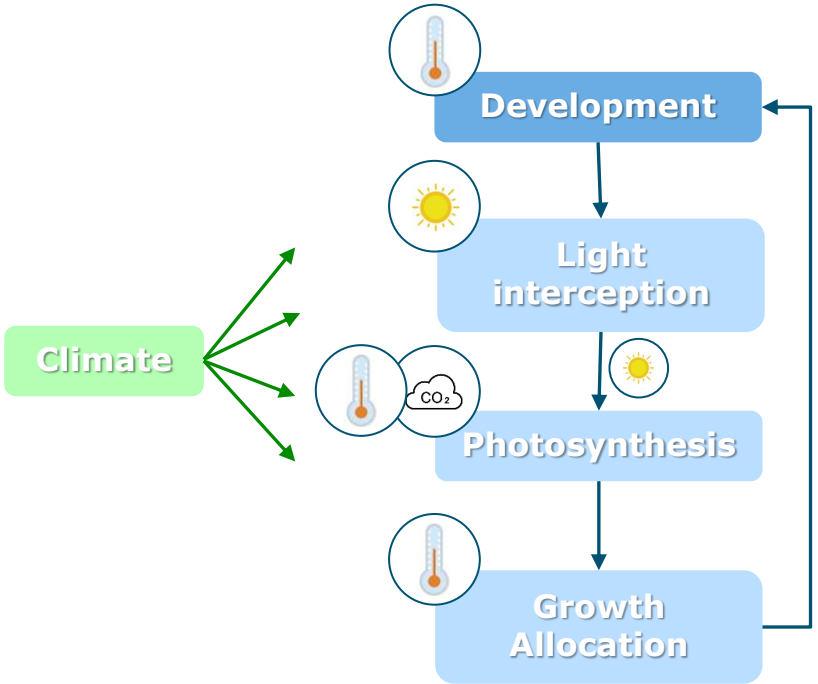
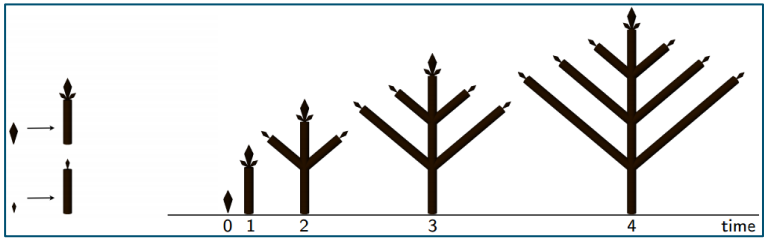


L-systems



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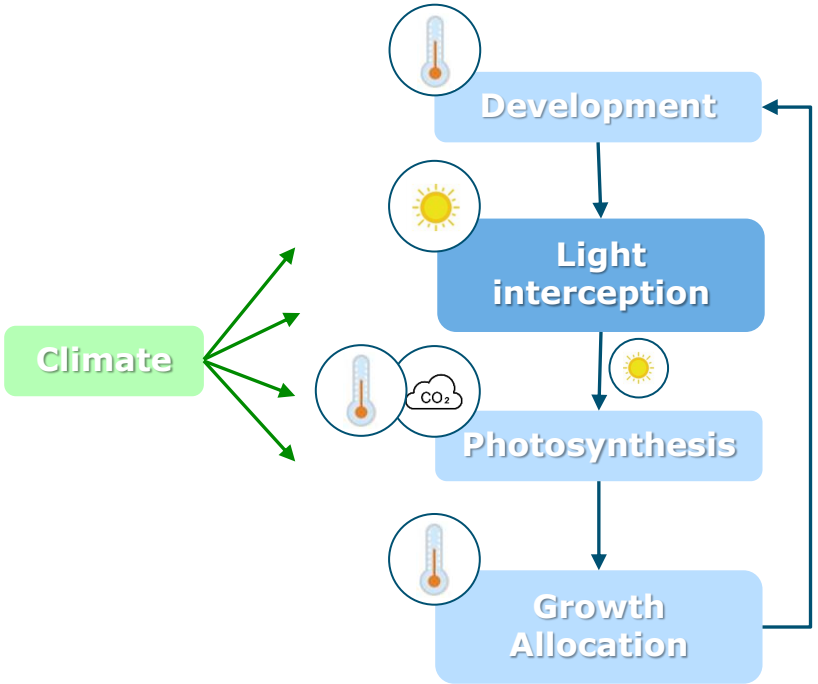

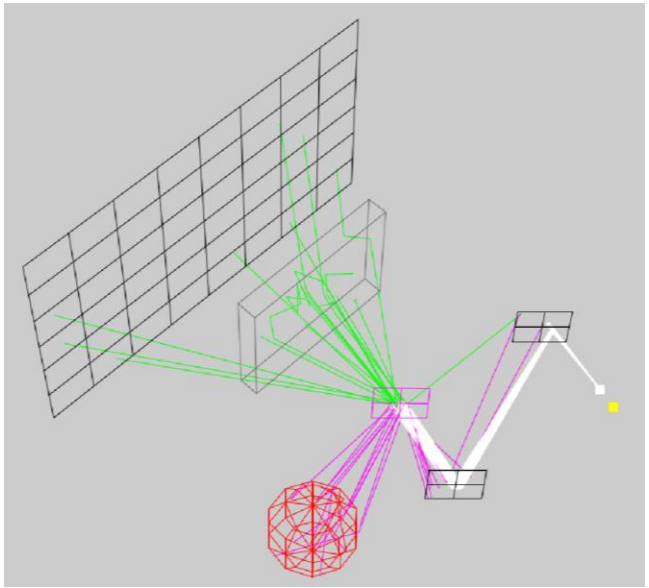

3D ray-tracing

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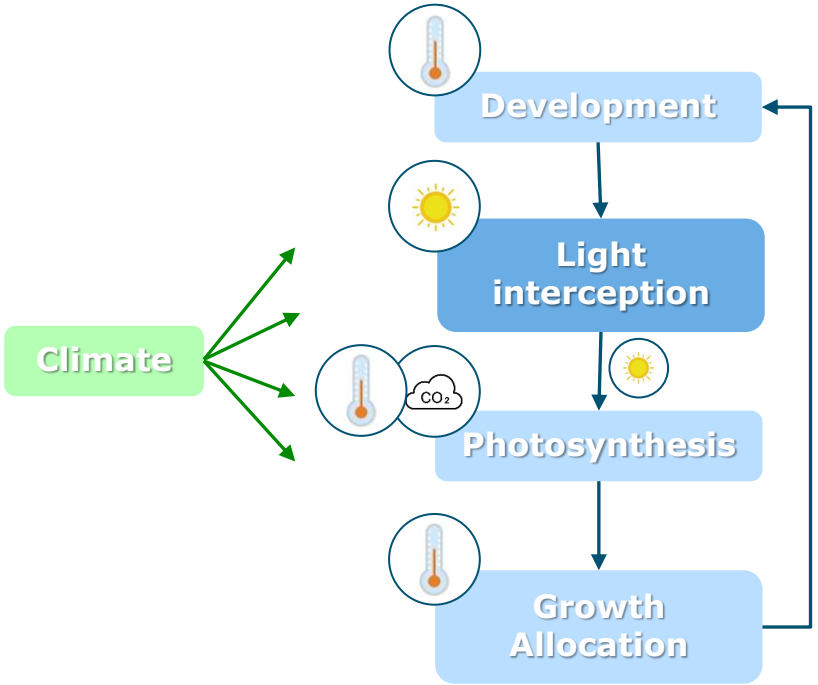
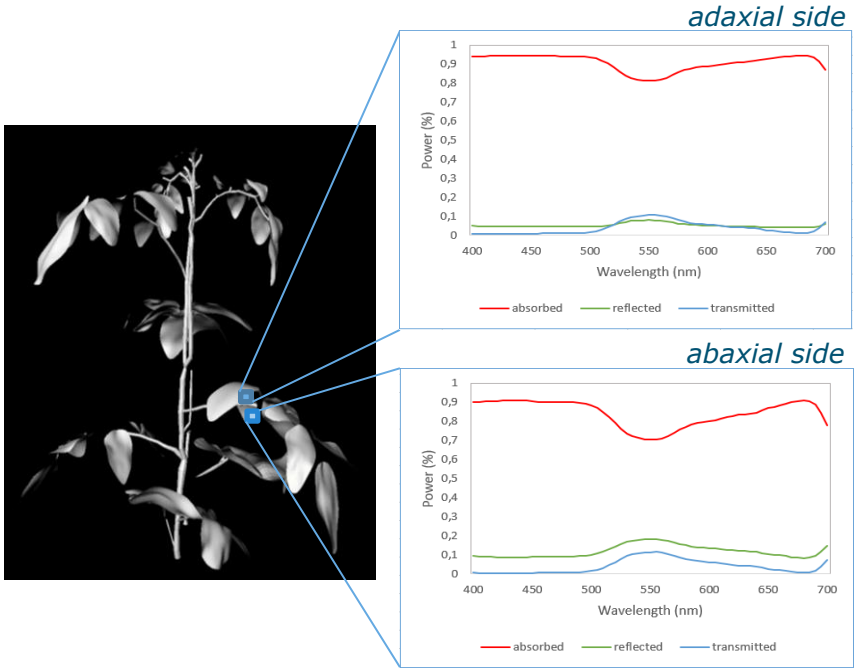
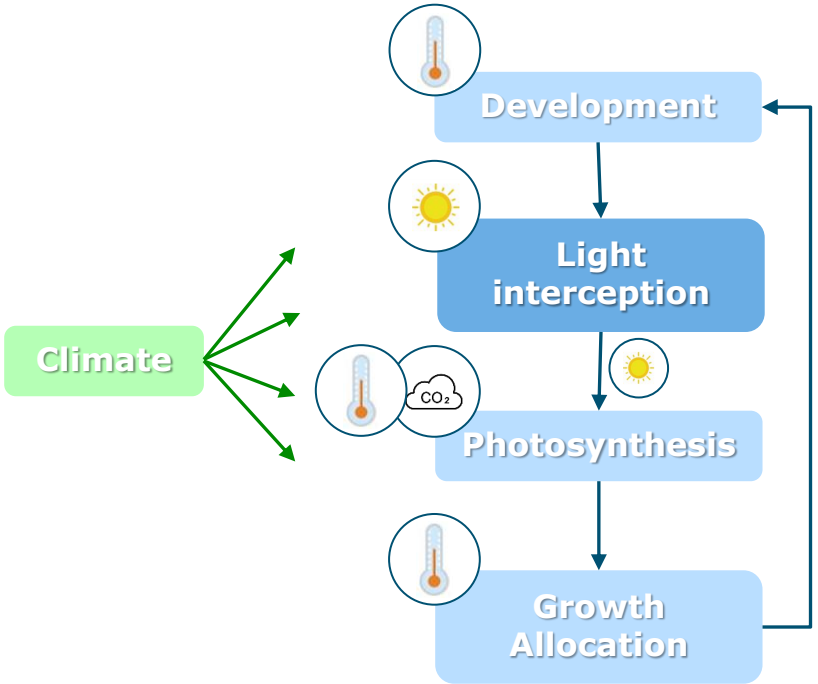
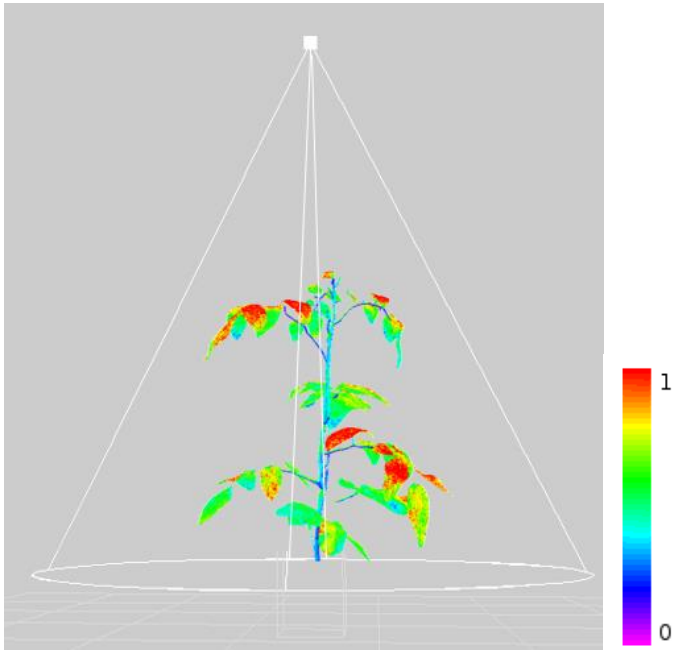




Leaf optical properties

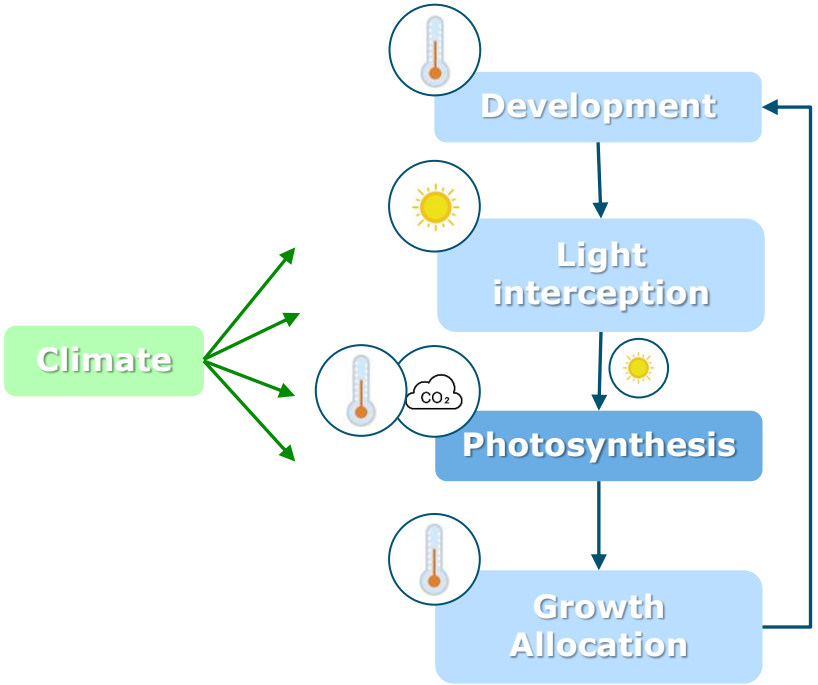
FSP model: Combines function (F) and structure (S)

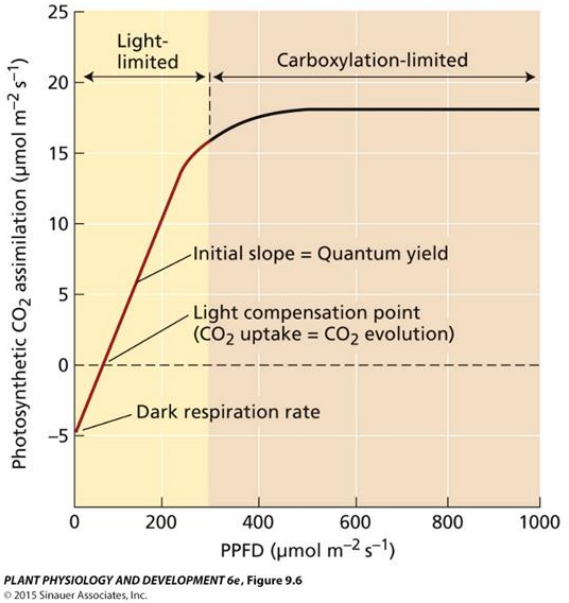




Light absorption

FSP model: Combines function (F) and structure (S)





Various photosynthesis models

(non-rectangular hyperbola, FvCB, Kim-Lieth)

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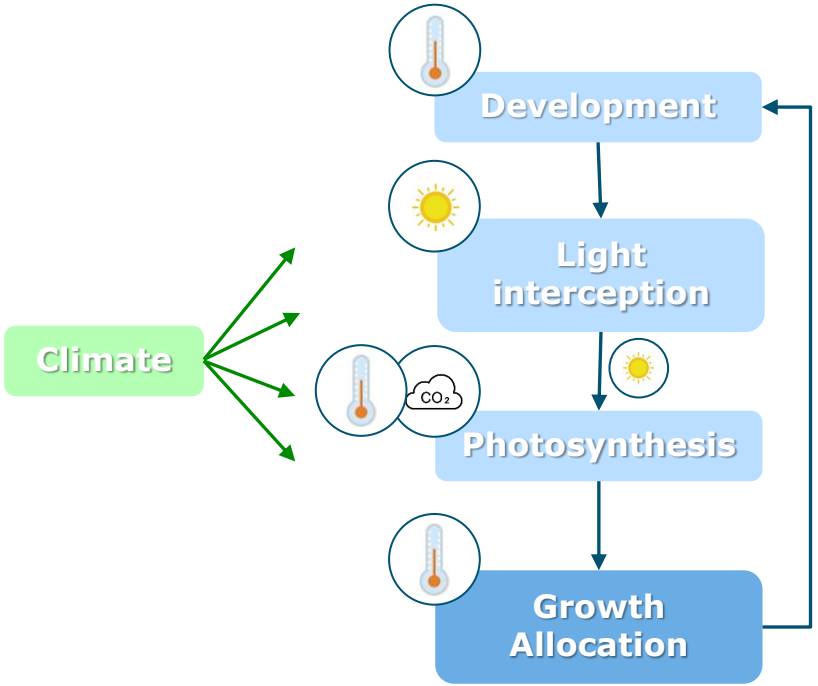
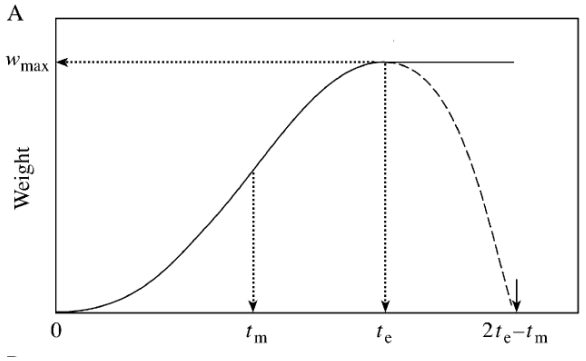
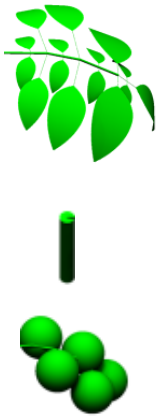




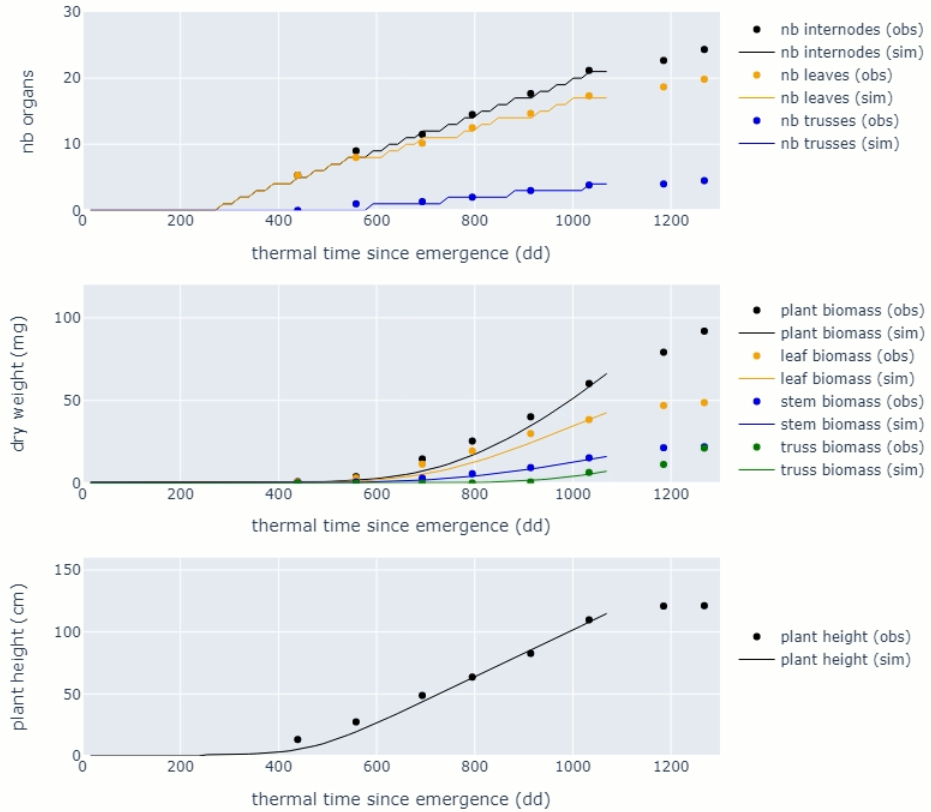
Yin et al., 2003, AoB

Sigmoid function of growth

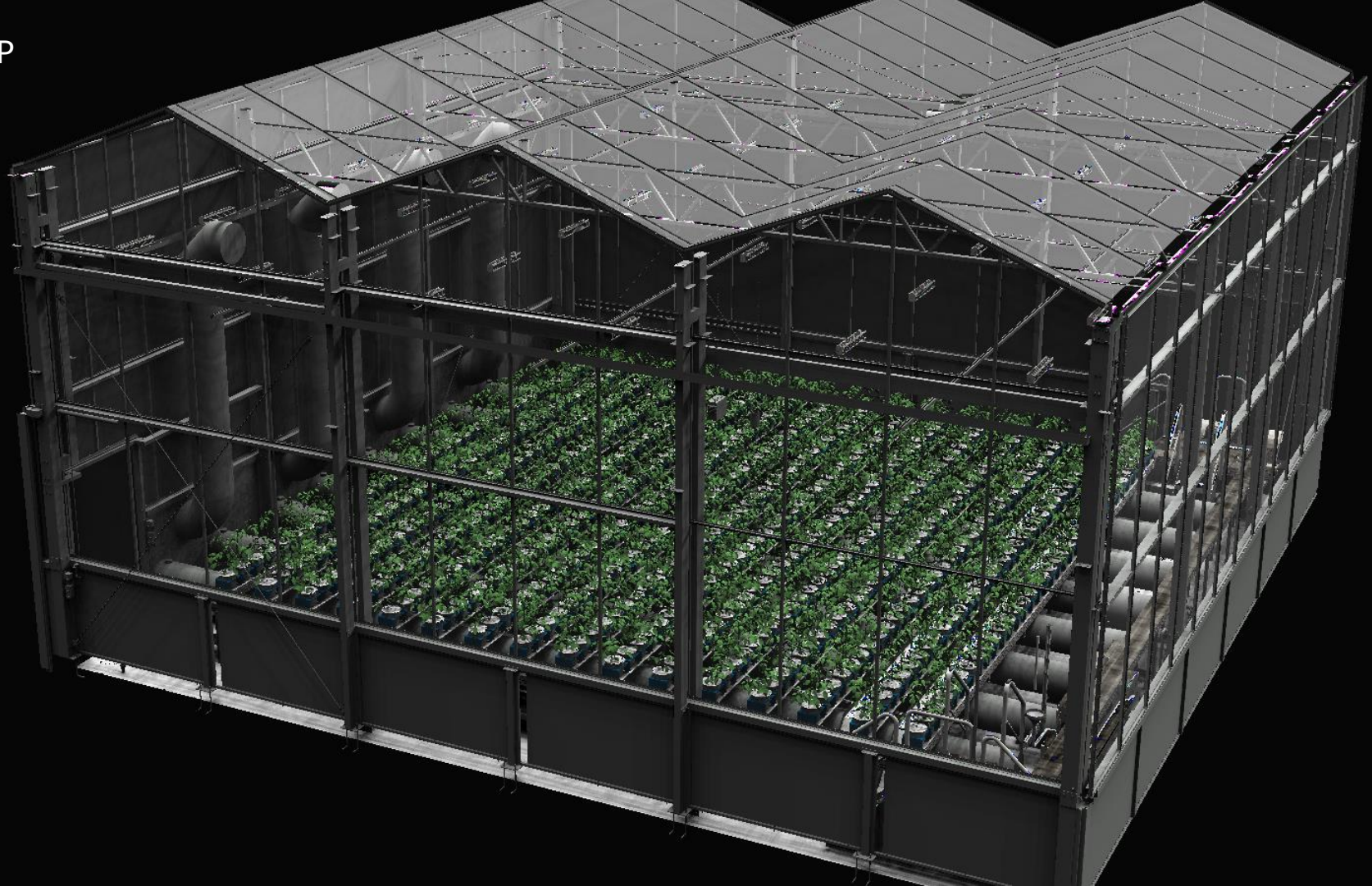


Dynamic tomato FSP model

Cultivar: Merlice



GroIMP

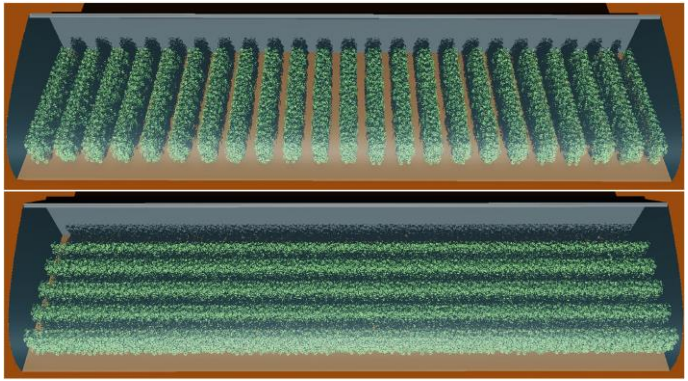


Why an FSP model?

- Architecture -> Environment -> Function (feedback loop)
- Find: Planting layout, leaf pruning strategies

  Better plant traits (plant ideotypes)

  Lighting setup, greenhouse construction

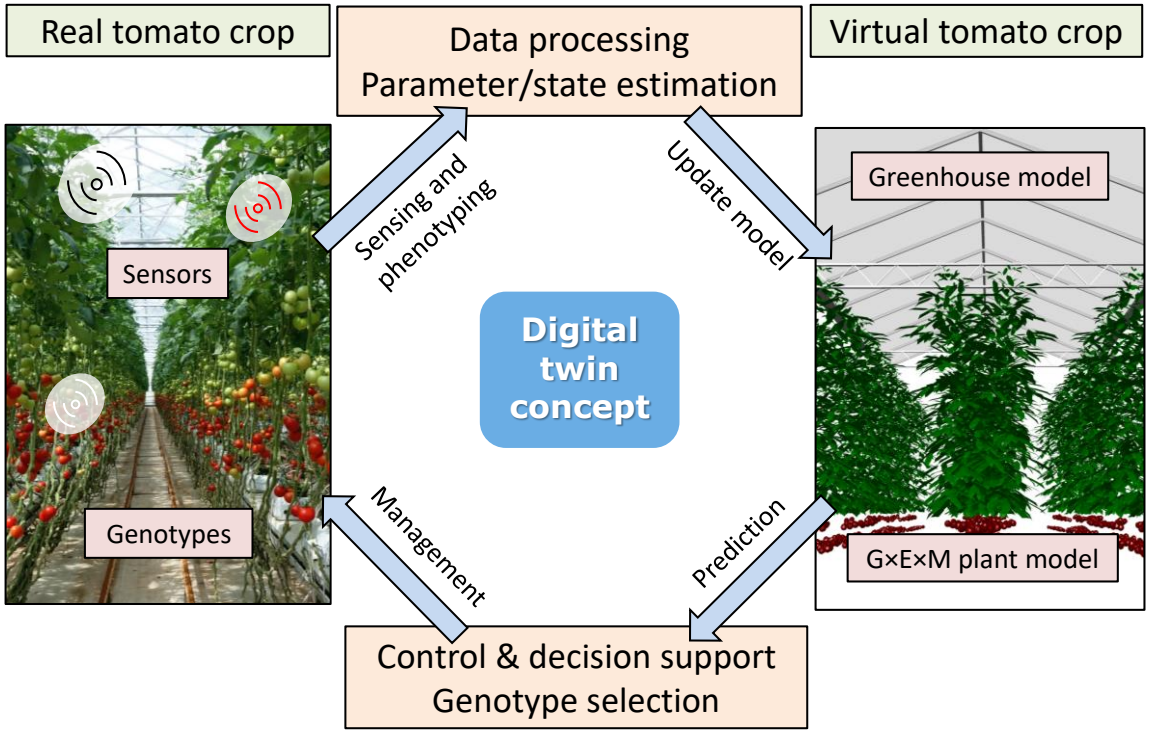


Zhang et al., 2022, Frontiers in PS

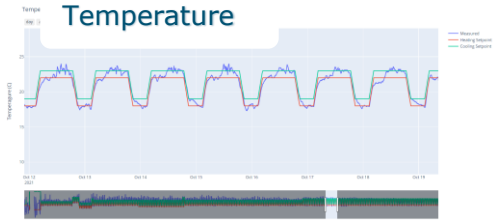
Digital twin with an FSP model

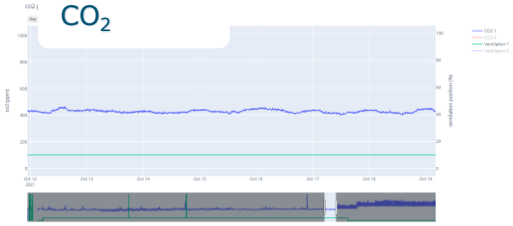
- Mirroring behaviour of a **real crop** – updated using (real-time) climate data and (high-throughput) phenotyping data
- Predict crop yield and resource use efficiency (light, water, nitrogen, energy)
- Decision support

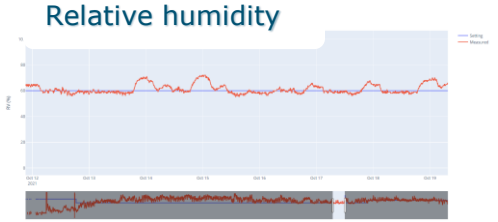
“Traditional” data collection for FSP models

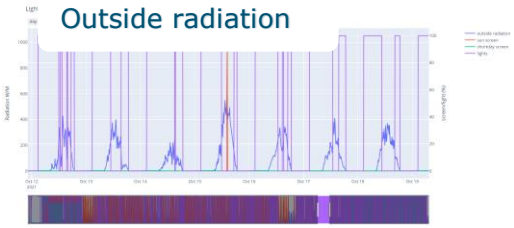

Real tomato crop
Data processing
Parameter/state estimation
Virtual tomato crop
Sensors
Genotypes
Sensing and phenotyping
Update model
Greenhouse model
Digital twin concept
Management
Prediction
G×E×M plant model
Control & decision support
Genotype selection

Evolving dataset for model updating









Graphs visualise one week of climate data

RGB side view images

3D point clouds

Climate model and plant model

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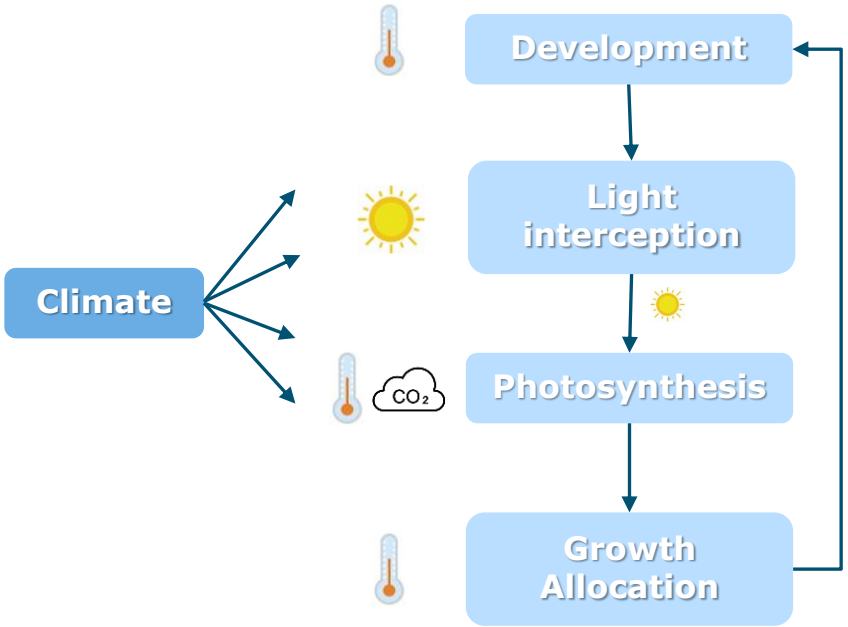
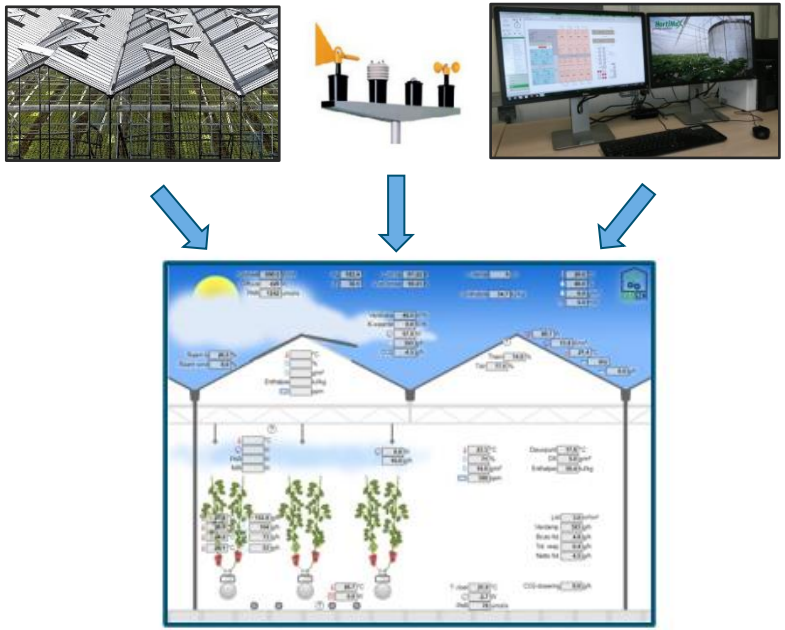
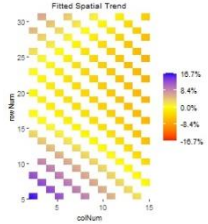
Predicting indoor climate

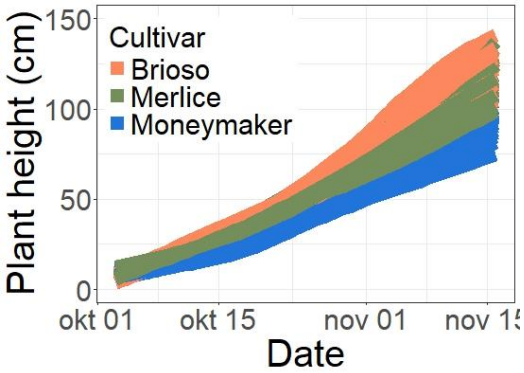


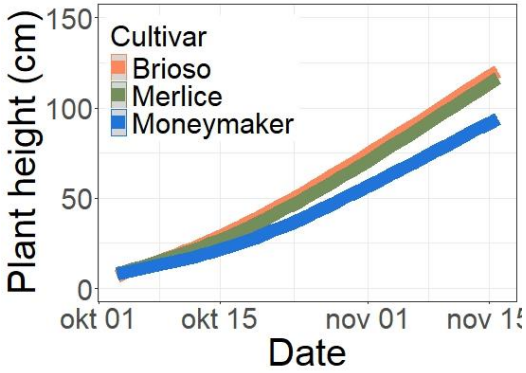


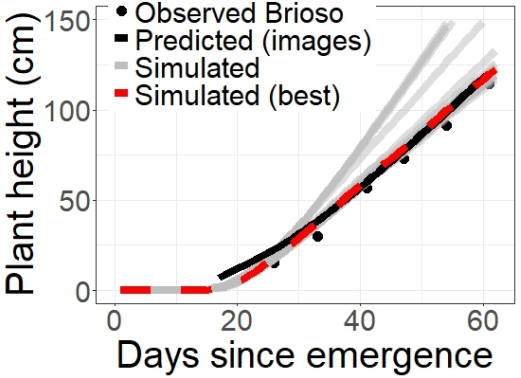
Climate model (KASPRO)

Model updating pipeline (images)





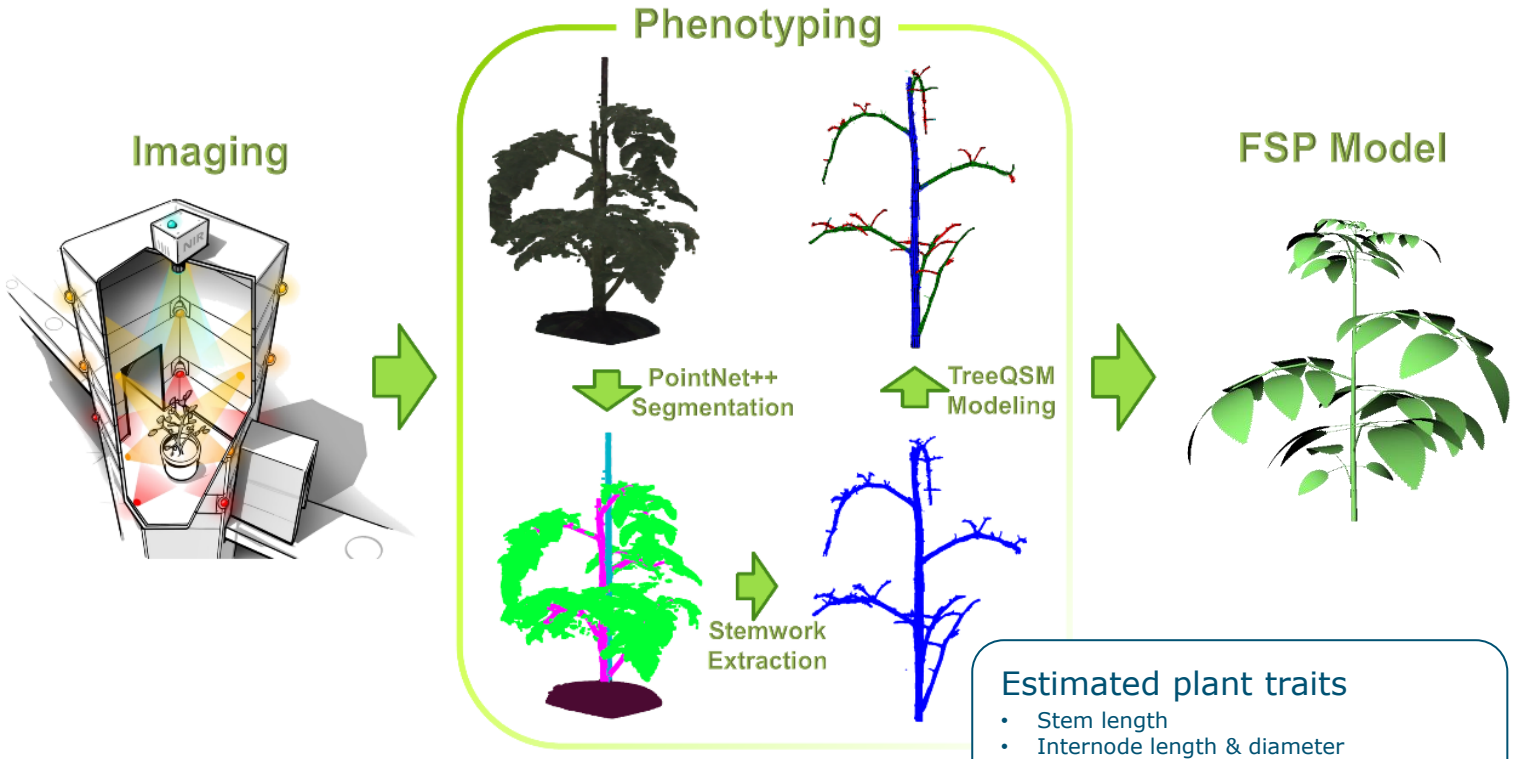




Plant height extraction from 2D images → Plant height estimation per cultivar → Model optimisation

Smolenova et al., subm.

3D phenotyping pipeline



Xin et al., 2024, COMPAG

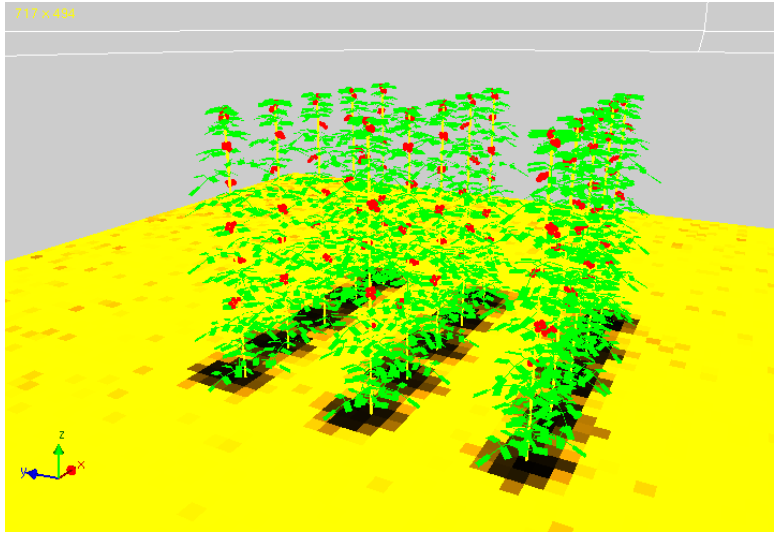
Estimated plant traits

- Stem length
- Internode length & diameter
- Leaf angle
- Phyllotactic angle

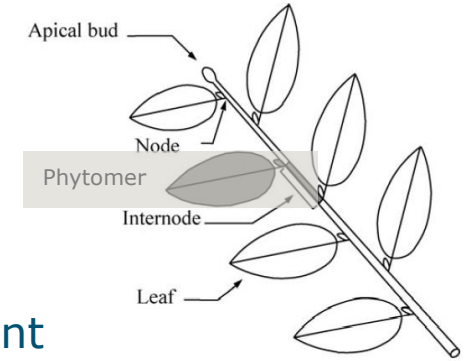
Hands-on examples

- Improving our simple tomato model
  - Organ extension modelling
  - Light modelling
  - Photosynthesis modelling
  - Plotting simulated outputs

- Running scenarios
  - Aim: increased production



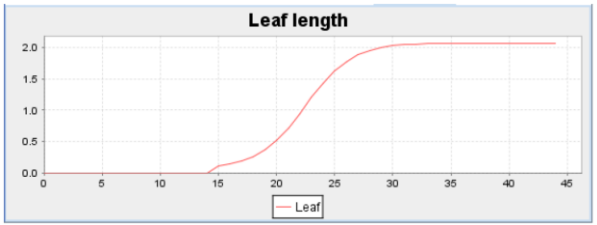
New concepts

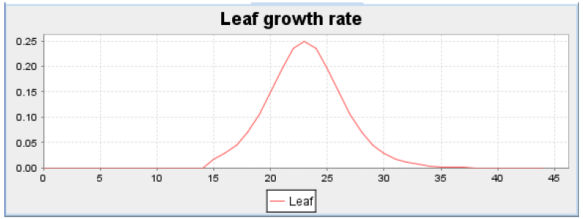


(acc. Barthélémy & Caraglio, 2007)

- **Phyllochron** - time span between the appearance of new phytomers -> more precise timing of development

- **Organ extension** – gradual increase in size as a function of age; described e.g. by a logistic curve





$$\frac{dW}{dt} = \frac{kW_{max}e^{(-k(t-tm))}}{(e^{(-k(t-tm))}+1)^2}$$

Try yourself

- **Materials**: wiki.grogra.de > Workshops https://wiki.grogra.de/doku.php?id=workshops:summer_school_sh_25
- Simple tomato plant

  -> go through the added model steps (organ extension, light & photosynthesis)

  -> extended to a simple canopy
- Model scenarios

  -> modify model parameters of your choice

  (planting density, leaf angle, internode length, etc.)

  -> which model settings lead to increased assimilate production?

wiki.grogra.de

fspm.discourse.group