# Modelling activities to support plant breeding

*Introducing a crop growth model for the use in phenotyping*

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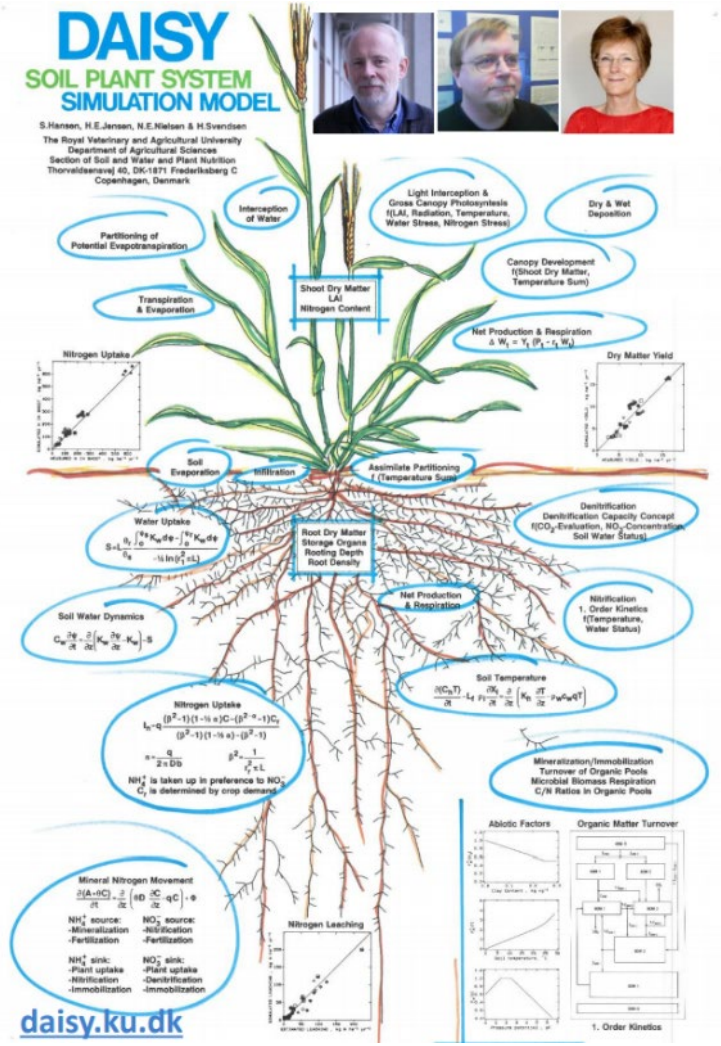
# DAISY: A mechanistic modelling tool




**The model concept**

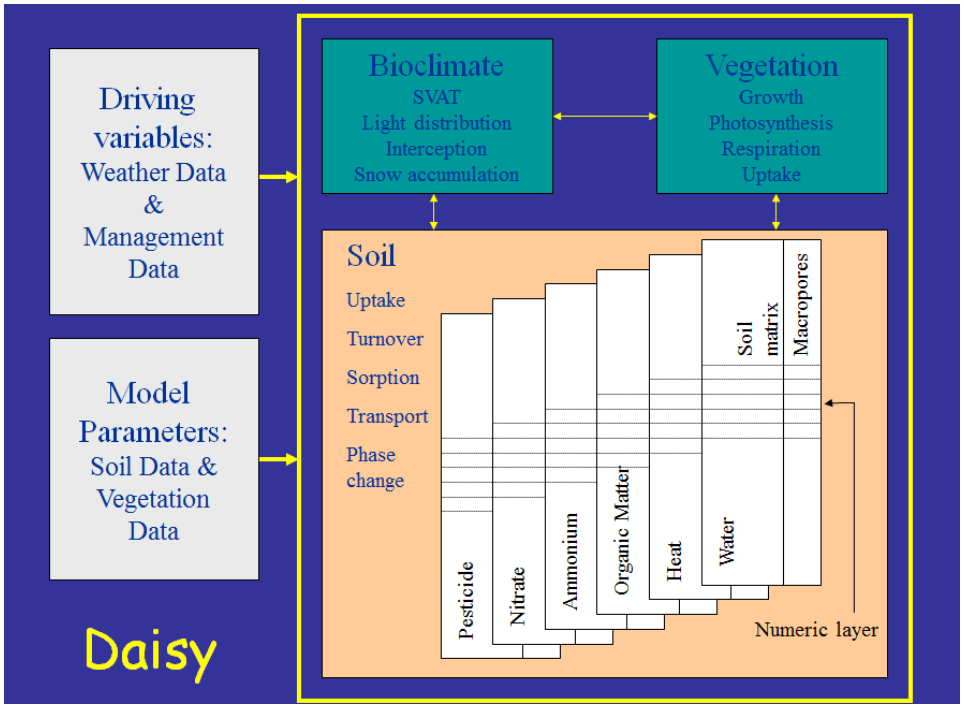
- Mathematical process descriptions
- Mass balances (Water, C and N)
- Complete description of plant production and losses of N to the environment

- All in one model
  - Crop model (Shoot+Root)
  - Soil hydraulic processes (Richard equation)
  - Soil organic matter turnover
  - Bioclimate processes (Farquhar model)

- The Daisy model was developed in 1990 and have been constantly improved. >150 scientific paper

- The model is open source written in C++
  http://daisy.ku.dk/
  https://github.com/perabrahamsen/daisy-model

# DAISY: A mechanistic modelling tool




- Builds on system description – not a "black box" model
- The processes in the model are calibrated based on field trials. Knowledge is recycled.

**The model requires:**

- Weather data
- Management information
- Description of soil hydraulic properties
- A crop model (Can be cultivar specific)

**The model simulates:**

- Bioclimatic-variables
- Plant growth
- Water, Carbon and Nitrogen dynamics in different soil horizons
- Gaseous losses of N.

# Scope: DAISY to support plant breeding

## Main hypotheses

- "The use of modelling will improve the understanding of relationships between crop "traits" and environment"
- "The environmental information for different yield test site will improve the description of "E" and "M" in GxExM relationship and therefore improve estimation of G"

**Limitations:**
DAISY models environmental effects related to limitation of water and nitrogen only. Thus the model are not able to model the negative impact of plant diseases, lodging or other nutrients deficiencies (e.g. P and K)

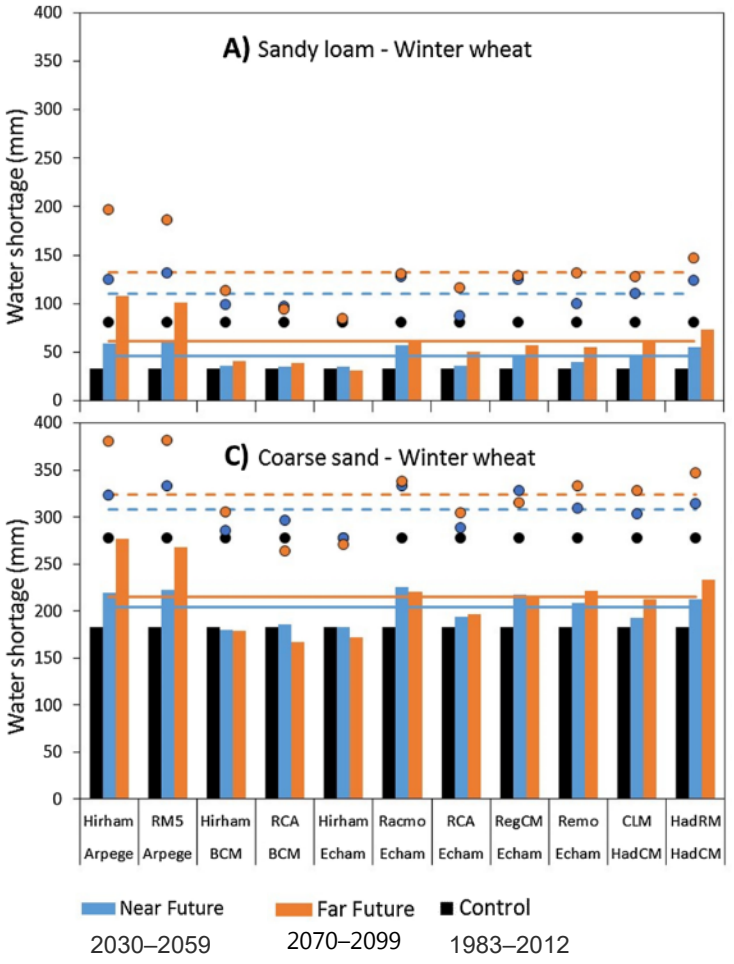
# Scenario testing

## Scenario testing of crop performance

- Identify growth limitation caused by climate change
- Ideotype testing (e.g., phenology, root development)

**Manschadi et al. 2010:** modelling drought-adaptive root architectural traits in wheat

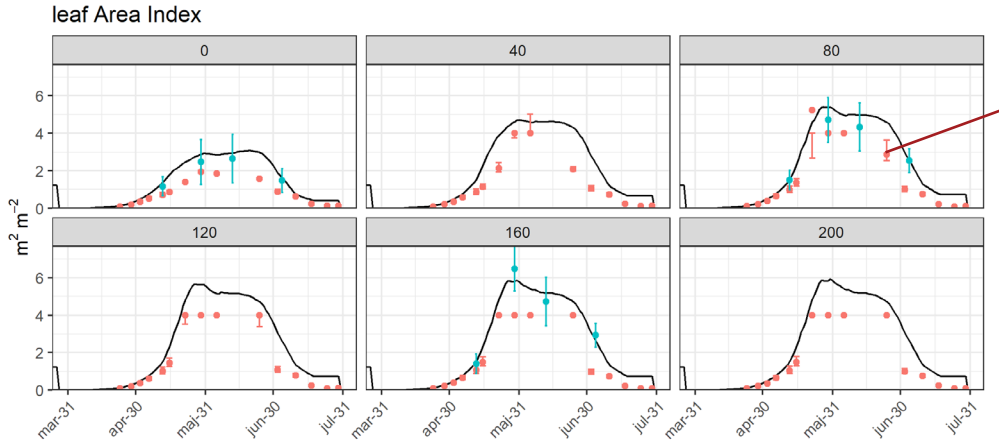
**Sinclair et al. 2016:** Limited-transpiration trait for soybean.



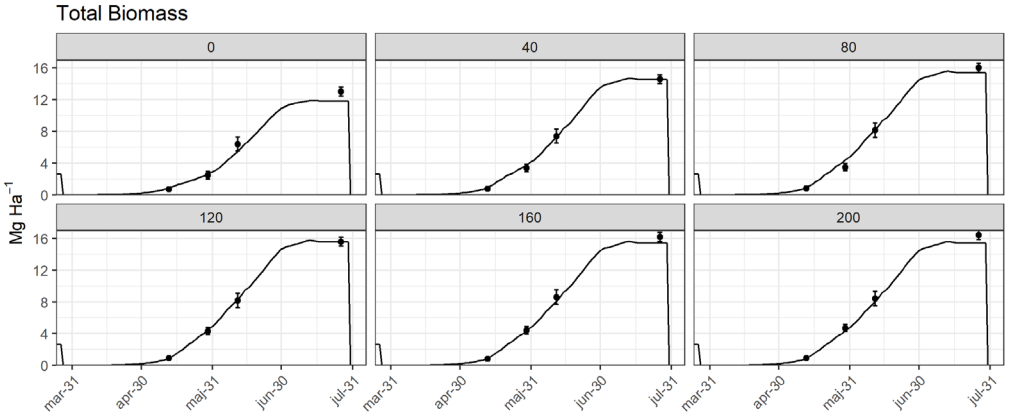

Rasmussen et al. 2018

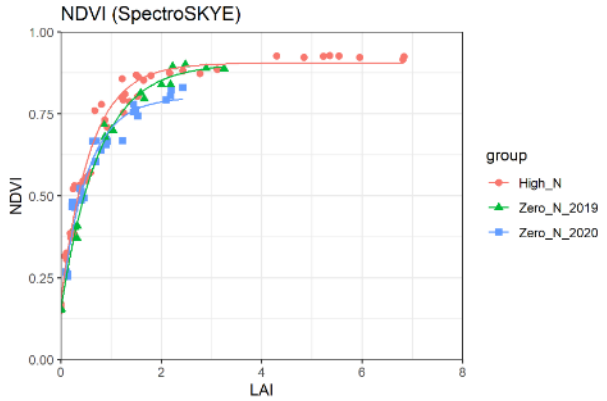
# Mechanistic modelling using phenotyping data

- The DAISY platform offers and opportunity to couple environmental sensor data (Locale weather data or soil sensors) with UAV data.




NDVI Green-LAI estimate



# Improving genomic prediction accuracy

A mechanistic crop models such as DAISY could potentially capture variation caused by location specific limitation of water and nitrogen

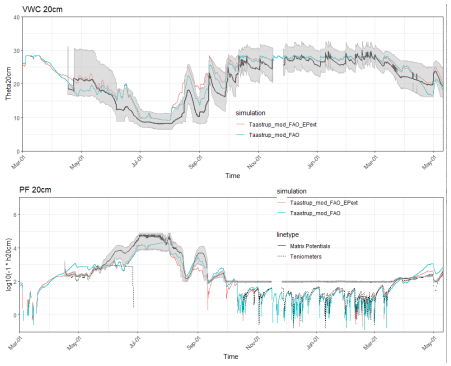
- *"The potential to add significant value to the rapid advances in plant breeding technologies associated with statistical whole-genome prediction methods is a new frontier for crop physiology and modelling*" **Hammer et al. 2019**
- Combining Crop Growth Modeling and Statistical Genetic Modeling to Evaluate Phenotyping Strategies. **Bustos-Korts et al. 2019**
- Combined crop model and genome-wide association model approach improve prediction accuracy in rice. **Toda et al. 2020**

# Idea for 6P-3 collaboration

- Test experiment preferably with the same model crop (Spring barley) and subset of cultivars grown at different field sites used for yield selections
- A detailed site characterisation are made by the Agrohydrology-Group
- Collection of UAV data to generate growth curves (green-LAI estimates)
- Measurements of final grain yield and grain nitrogen content
- Daisy model description for all sites will be made by the DAISY group
- A comparison of the different sites will be made. Identify potential growth limitations caused by lack of water or nitrogen.
- Incorporate model output in the statistical models. (Fred van Eeuwijk talk!)

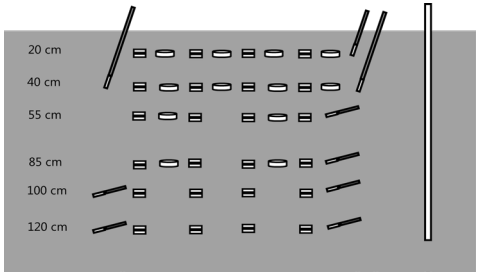

# Idea for 6P-3 collaboration

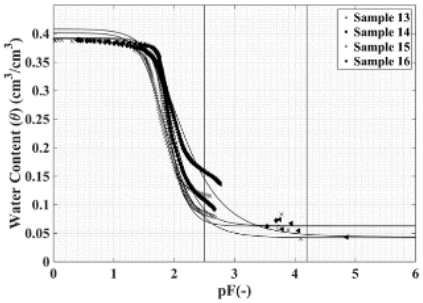
- **The model requires:**
- Locale weather station
  Temperature, RH, wind, precipitation, solar radiation
- Management information
  Sowing date, plant number, N-fertilisation strategy, soil cultivation…
- Soil hydraulic properties
  Soil profile description, depth of soil layers, retention curve, hydraulic conductivity, groundwater level, root restricting layers



# Site characterisation

- A small trench will be excavated at a “representative” area at each site (if allowed)
- Soil horizons will be identified and mapped
- Soil samples will be collected for lab analysis (water retention and hydraulic conductivity)
- Preferably a soil sensor system should be installed for soil column calibration and to capture root growth dynamics.




# Outcome for plant breeders

- Detailed site characterisation for DAISY modelling “or other crop models”
- Physical understanding of phenotyping data. Dissecting growth curves in terms of yield formation. (e.g. when was the crop water stressed or nitrogen limited)
- Scenario testing for future climate conditions.
- Using the “knowledge” of the mechanistic crop growth model in statistical models