Smart sensing: combining sensors and intelligence

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24/04/2024

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Future trends in Horticulture

- Fossil free: Energy saving, sustainable energy sources
- Emission free: Water saving, no nutrient losses
- Pesticide free: No chemicals
- Vertical farming, plant factories

- Digital growing: Sensors, AI, phenotyping
- Robotics, automation, labour saving, “labour free”

→ full control in Advanced Production Systems

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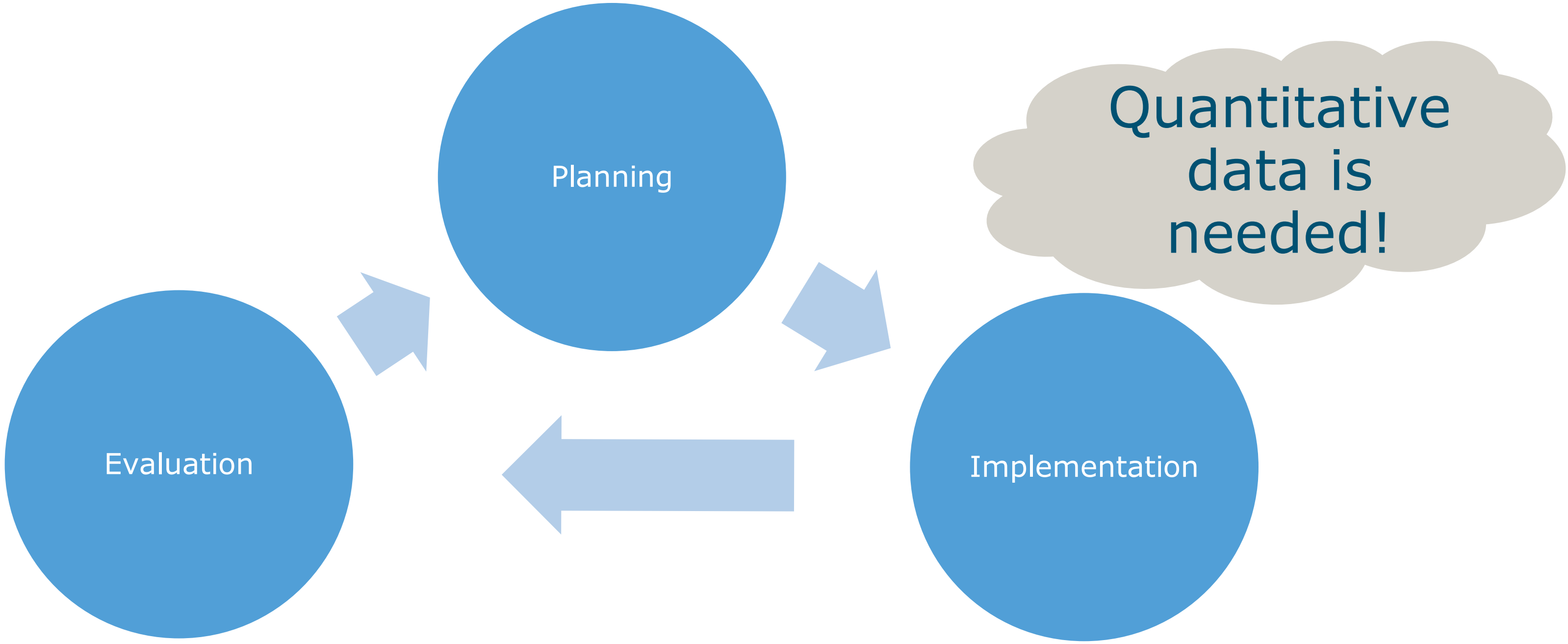
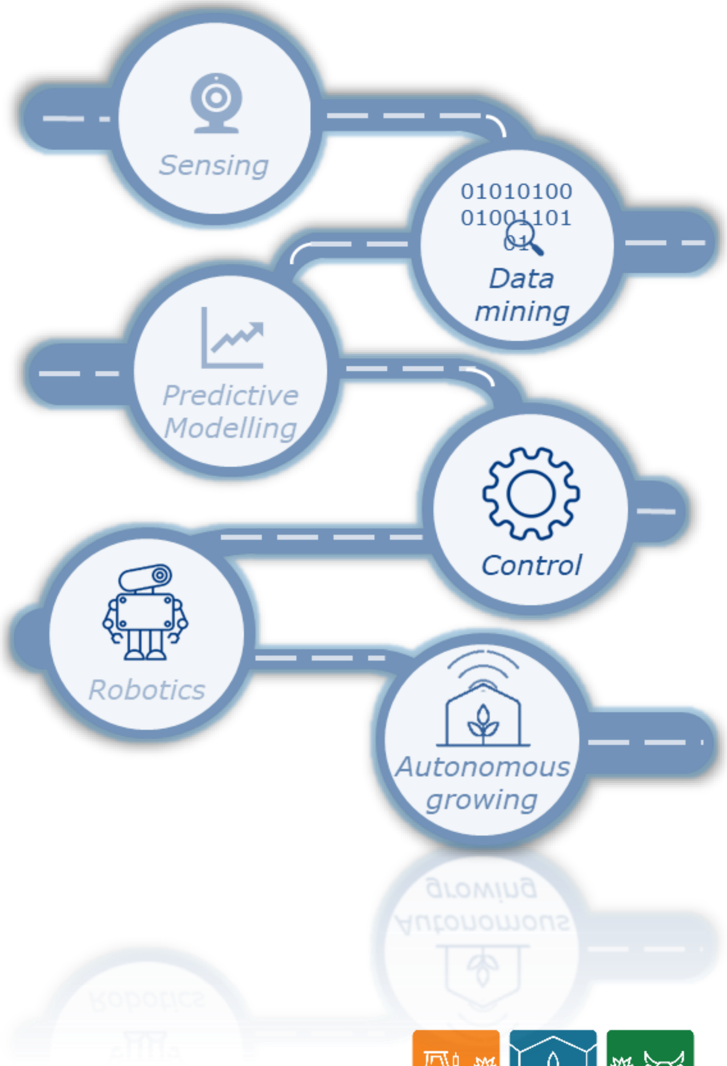
Goal of Greenhouse control

- Achieve maximum quality and optimum quantity of crop production with the most efficient and sustainable use of the available resources
- Maximize profit
- Stable production



Autonomous greenhouses

- Autonomous decision support systems (climate, irrigation, crop management)
- Intelligent sensing of cultivation parameters (climate, crop, irrigation, fertigation, pest, diseases)
- Automated handling of activities with robotics (harvesting, spraying)



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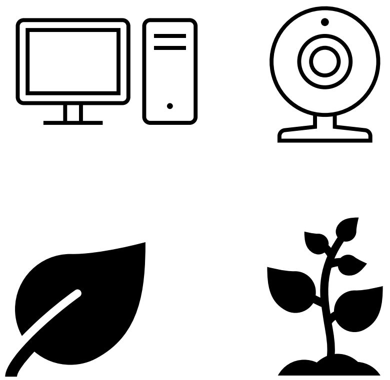
Data collection in autonomous greenhouse control

WHY?

- ✓ Input for control
- ✓ Maintain agreement between reality and model computations
- ✓ Detect non-optimal situations



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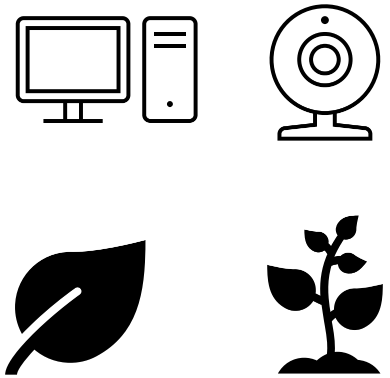
Data collection in autonomous greenhouse control

WHAT?

- ✓ Climate data
- ✓ Equipment use
- ✓ Crop parameters



Data collection in autonomous greenhouse control

HOW?

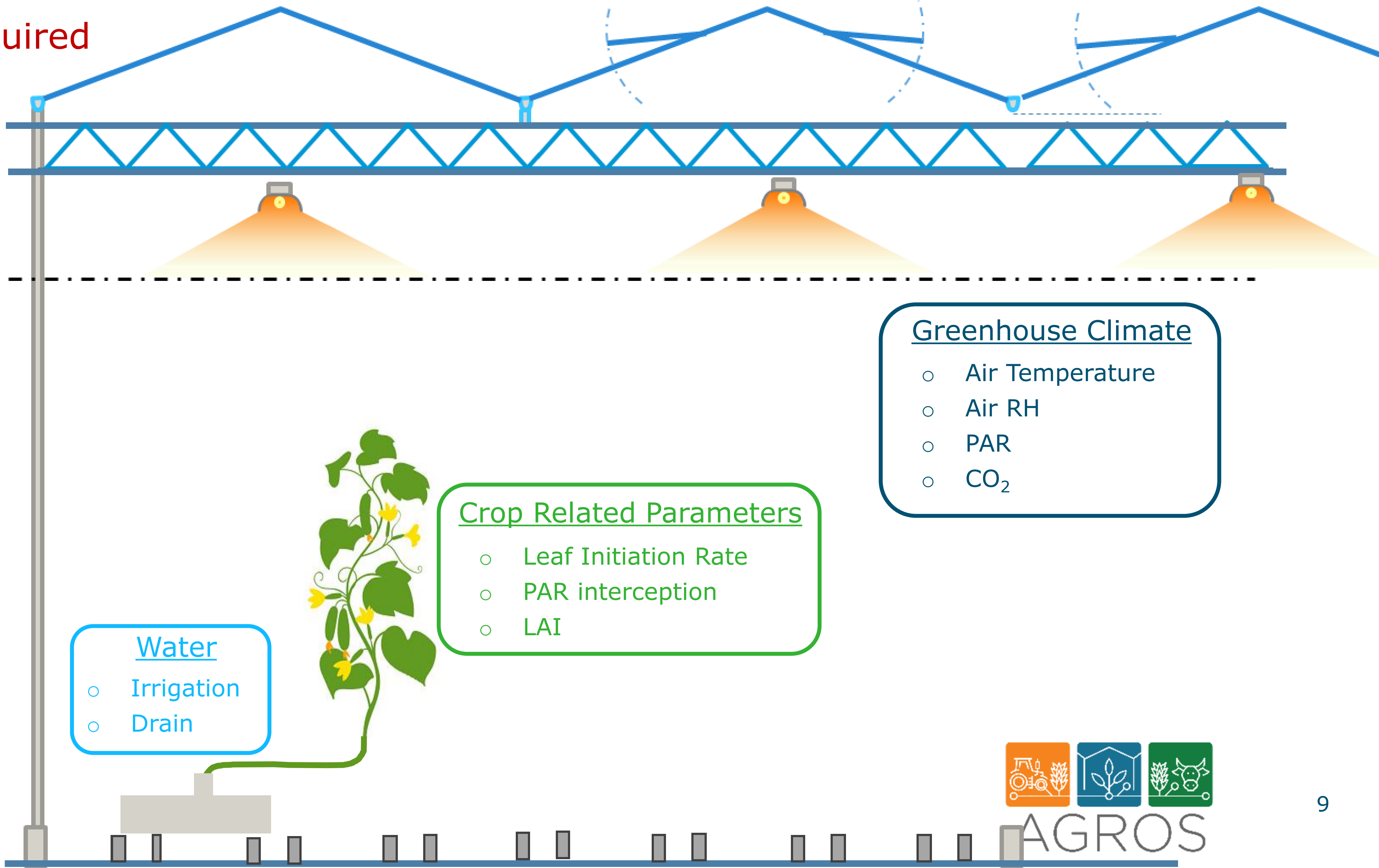
- ✓ SENSORS
  - ✓ Direct measurement of desired parameter
  - ✓ Soft sensors (use of algorithm to compute desired parameter)
- ✓ Manual Measurements

What did we measure?

✓ Measurements required as model input

Actual Weather and Weather Forecast

- Air Temperature
- Air RH
- Global Radiation
- PAR
- Outgoing Longwave Radiation
- Wind



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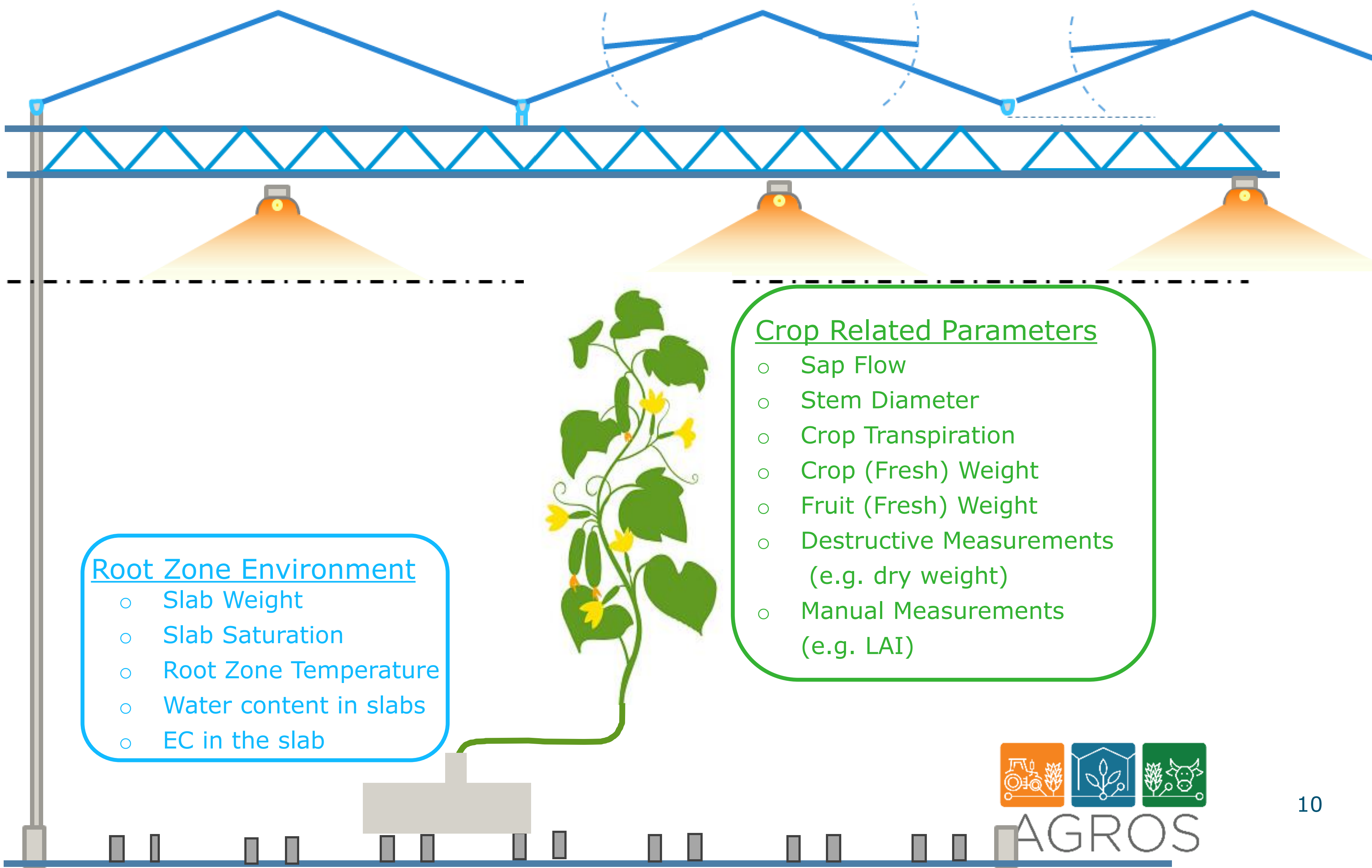
What did we measure?

- ✓ Additional Measurements

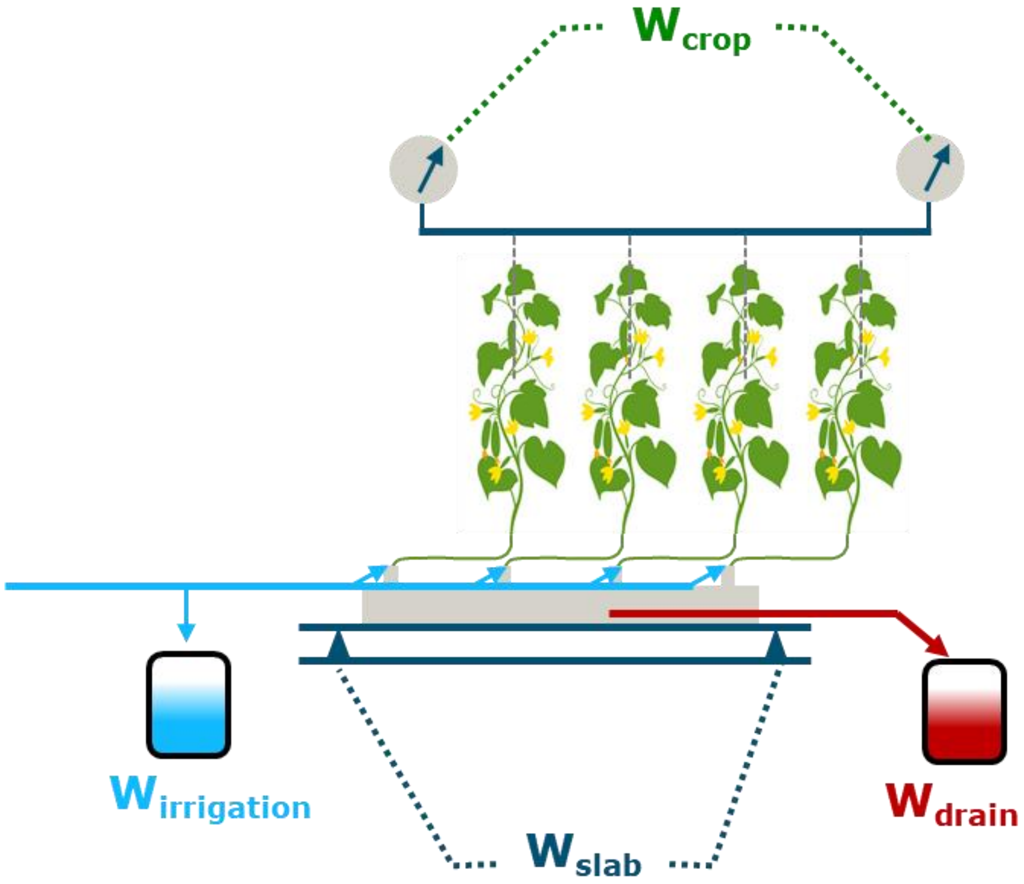


Crop/Gutter weighing system

Measures:

- Irrigation
- Drain
- Slab weight and saturation
- Crop weight
- Transpiration

$$W_{irrigation} = \Delta W_{slab} + \Delta W_{crop} + W_{drain} + W_{transpiration}$$



A virtual greenhouse system (with a crop) that reacts to environmental changes and climate control actions on the exact same way as the “physical” system.

The crop reacts (growth and production) on the exact same way as the physical too.

Digital Twin

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Sensing Applications – crop/gutter weighing system

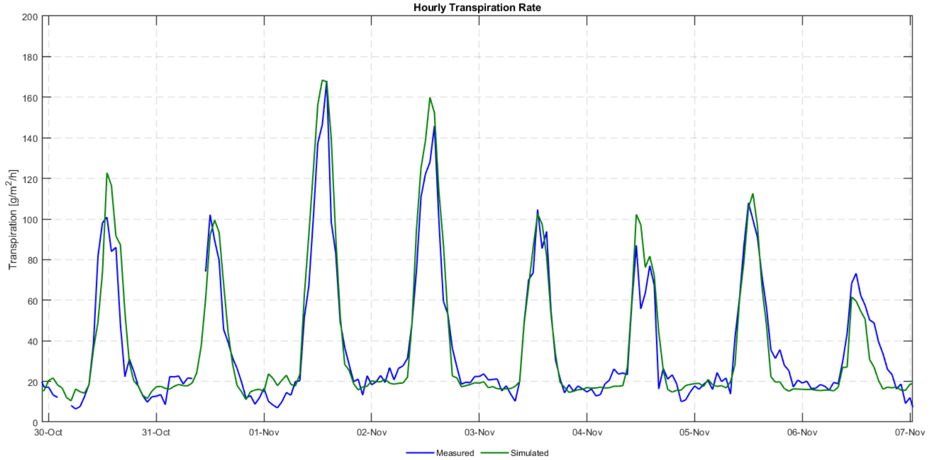
Real-time validation/calibration of Digital Twin with measured data

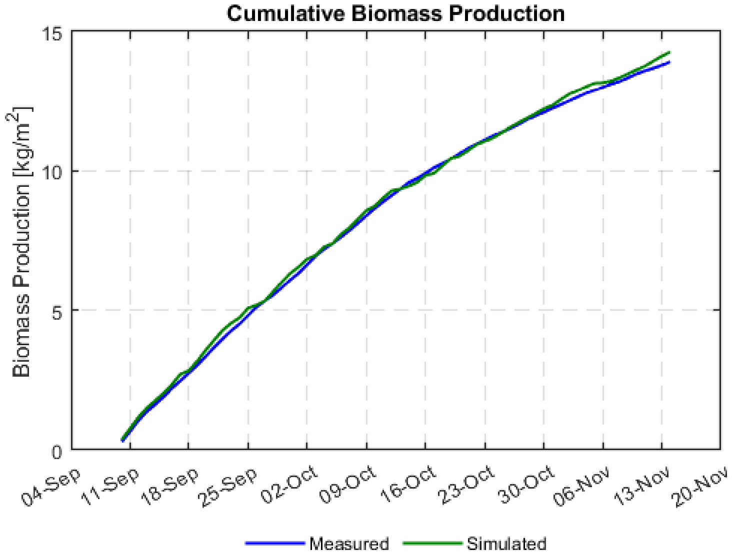
Accurate computations of:

- ✓ Indoor climate
- ✓ Transpiration
- ✓ Crop growth

Allow the use of the Digital Twin for

- ➢ Estimation of yield → compute cost and benefits of climate control actions
- ➢ Estimation of water requirements → Autonomous irrigation scheduling





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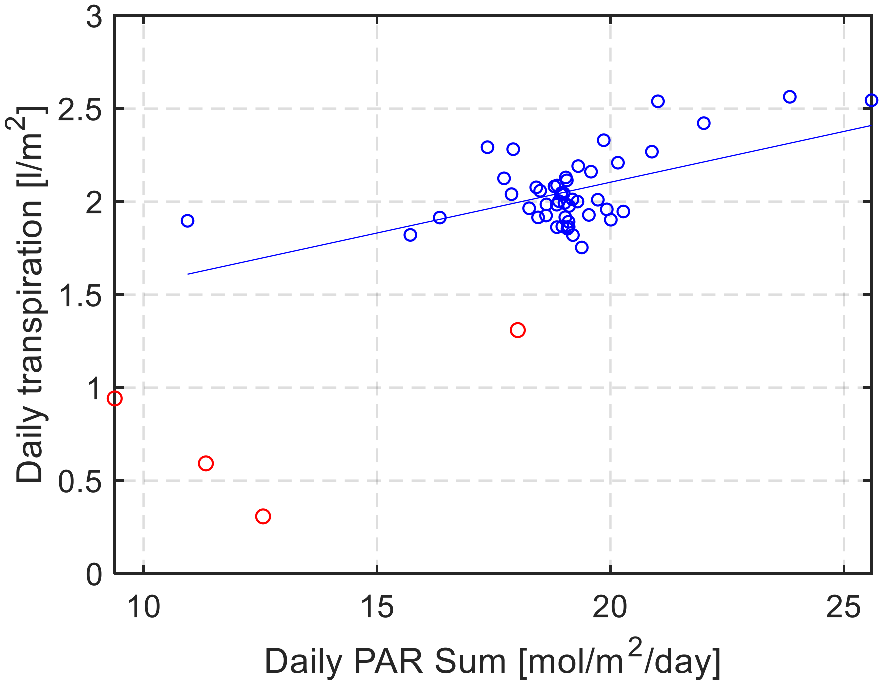
Water Balances

Water Stress Test: Weighing gutters

- Compasiron of exoectation and measurement or measurement and model output for stress or abnormalities detection



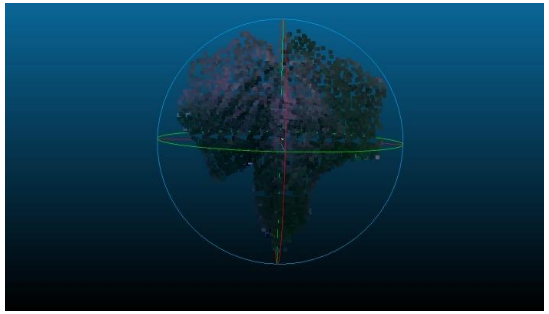
- Reduced irrigation can clearly be seen in the reduced transpiration

Sensing applications – LAI estimation

- LAI was estimated with fair accuracy (15% and 6%)!

Challenge!
Image acquisition (different angles, moving cameras or many cameras)

Segmentation



Point cloud filtering and down sampling

Combining multiple view points

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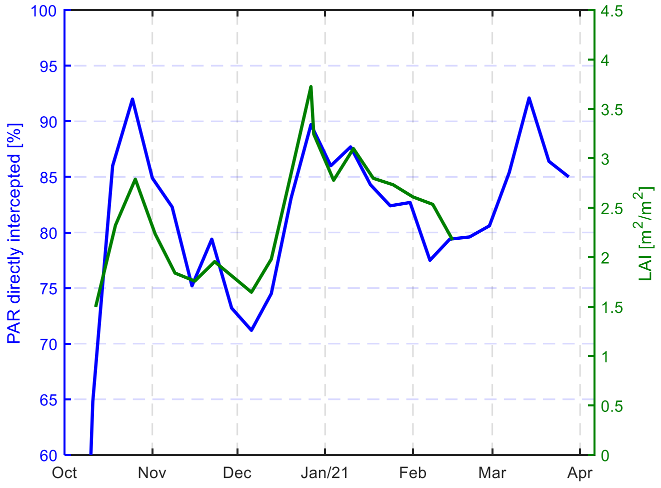
Sensing applications – LAI estimation

- Replacing labour intensive measurements
- Plant in the spotlight of decision making
- Accurate, continuous, automated



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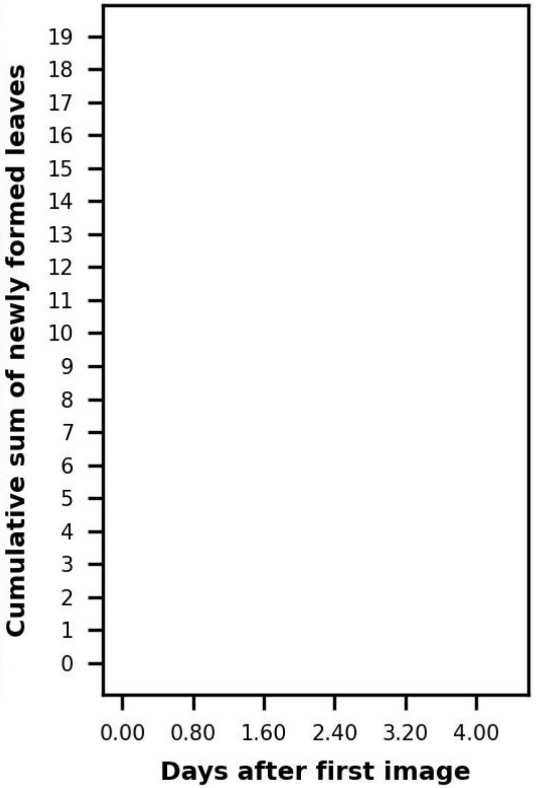
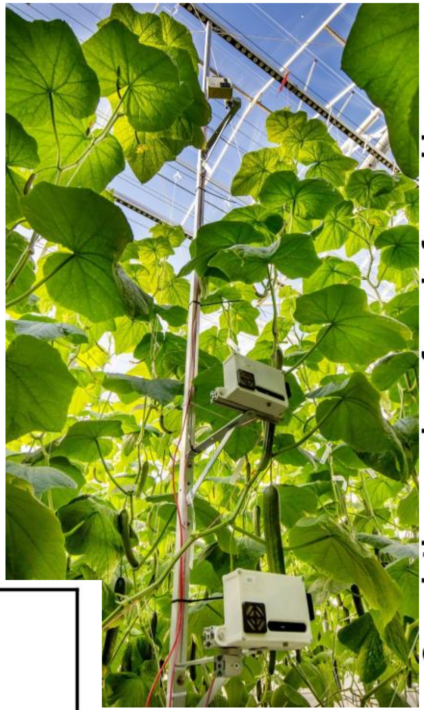
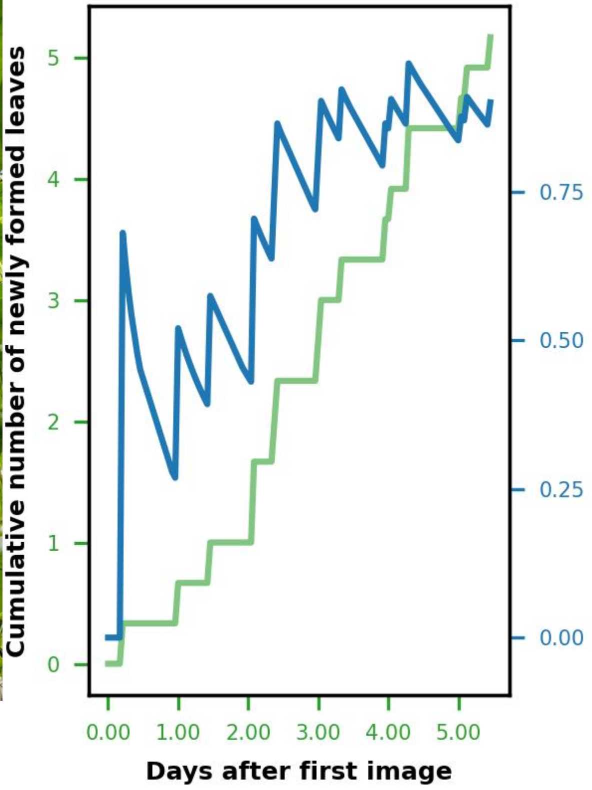
Sensing applications – Leaf initiation rate

- Computer vision for tracking leaf initiation rate
- Replacing labour intensive measurements
- Used for model validation/ calibration

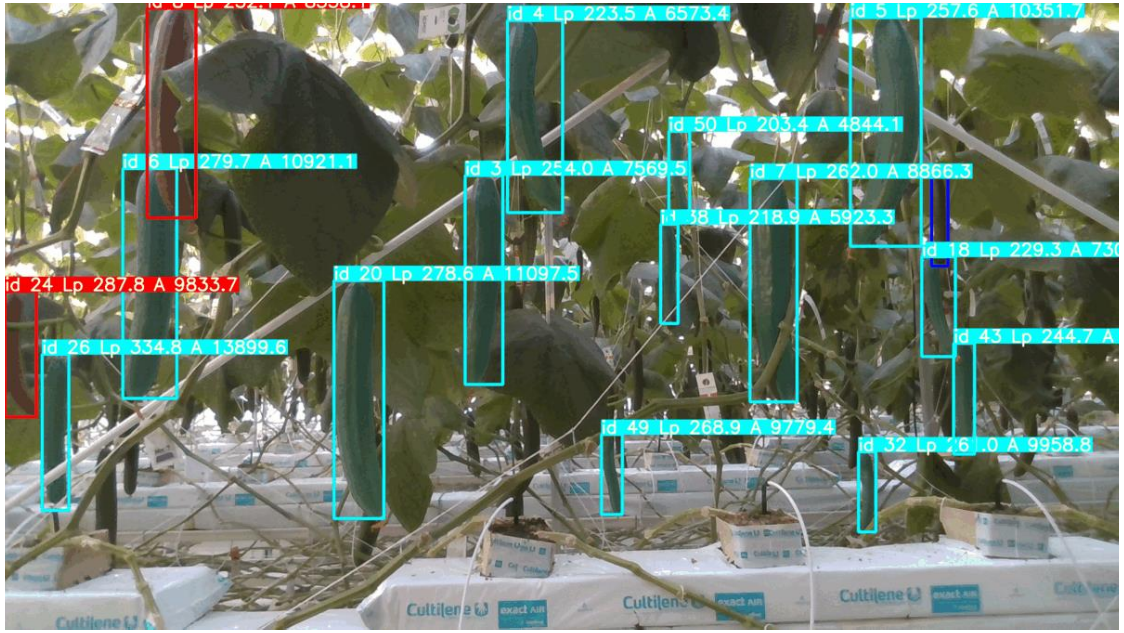


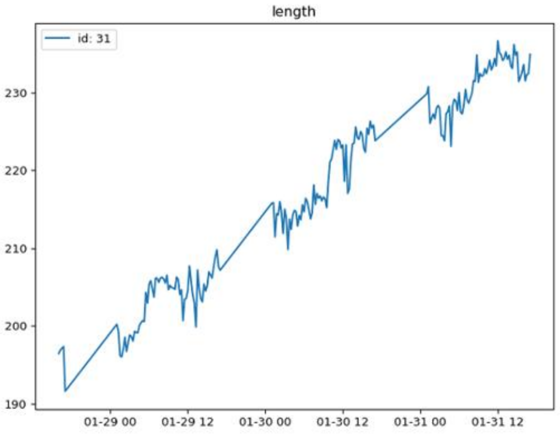




Computer vision for fruit growth

- One functional model
  - Detect and segment cucumbers
  - Determine length and width
  - Estimate weight over time
- Comparison with manual measurements





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Take home messages

- Sensing is essential in autonomous greenhouse control
- A minimum set of sensors is required for operation
- Additional sensors can replace manual tasks
- Sensors can be used to maintain high accuracy of simulation data
- Additional sensors can provide insight in crop functions and allow control optimisation

Thank you for your attention!

For more information:
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