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IWAS

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A stochastic simulation-optimization approach for estimating highly reliable soil tension threshold values in sensor-based deficit irrigation

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

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Background

Water scarcity in arid and semi-arid regions: irrigation necessary
Challenges: variable and severely limited water supply
→ Need for efficient management of available water resources

For agriculture in general:

- growing demand for food
- soil degradation (excessive irrigation, heavy use of synthetic fertilizer, etc.)

→ Strategies needed that:

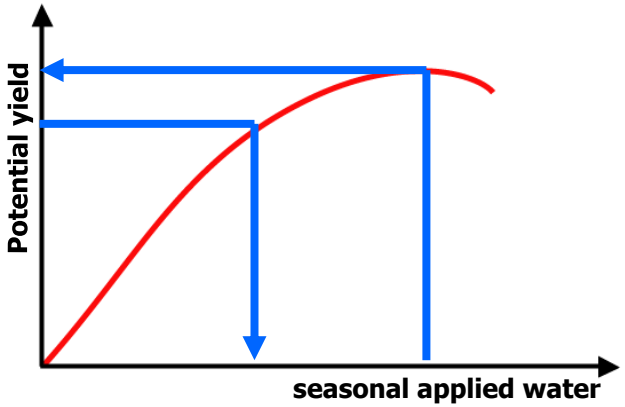
- Improve crop growth
- Make irrigation efficient and sustainable
- Preserve farmland through better cultivation practices

Strategy: increase water productivity (WP)

$$= \frac{\text{gain}}{\text{its expenses}} = \frac{\text{assimilated carbon, yield, biomass}}{\text{irrigation water, transpiration sum, evapotranspiration}}$$

Strategy

One option: controlled deficit irrigation (CDI), sensor-based



Realization through soil tension

- advantageous: less sensitive to different soils

For CDI, irrigation control of utmost importance
Problem: threshold for control difficult to determine (trial and error, arbitrary)

→ Stochastic simulation-optimization approach that determines reliable tension threshold values

Stochastic Simulation-Optimization Approach

Weather generator LARS-WG (Semenov et al. 1998)

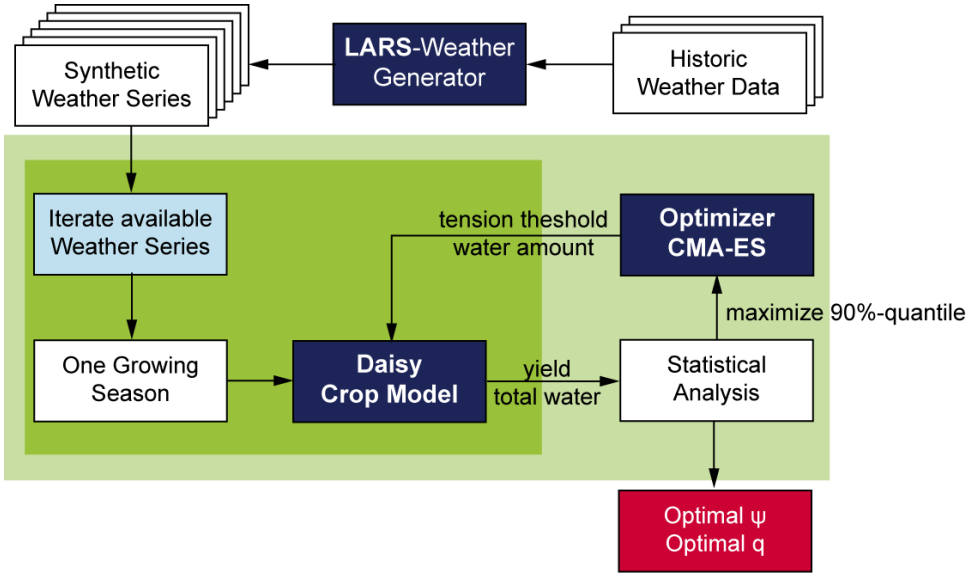
- Provides synthetic weather data for statistical significance

Optimization algorithm CMA-ES (Hansen 2006)

- Determines threshold values under limiting water supply

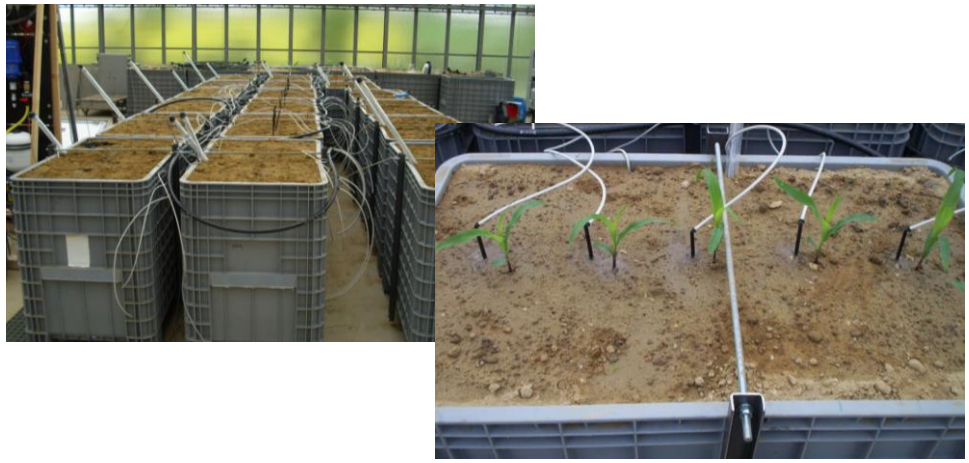
Crop growth model DAISY (Abrahamsen and Hansen 2000)

- Simulation of plant growth and water consumption



Experimental Outline

Vegetation hall near Munich, Germany
Hybrid maize
Each container with 5 plants (A=0.52m²)
Drip irrigation



Monitoring of soil moisture and tension

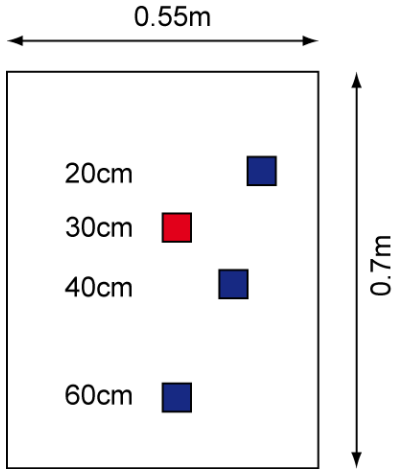
- Four heights
- TDR and pF-Meter

Irrigation control

- Tension-based
- Through pF-Meter

pF-Meter

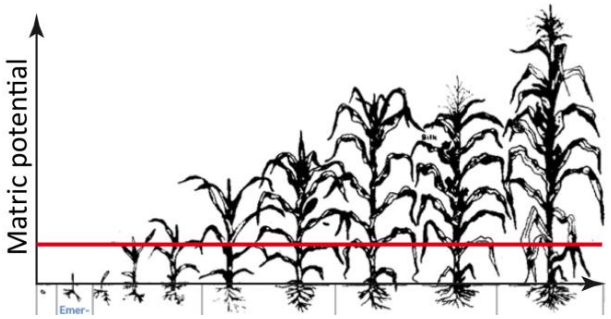
- Measurement principle: heat capacity
- Range: pF0…7, -40…+80°C
- Resolution: 0.01pF, 0.1°C



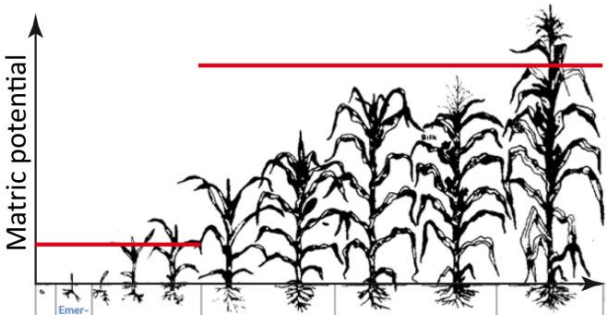
Soil Tension Thresholds

Treatment characteristics	Irrigation time	Redistribution time	Growth period	Tension threshold	Application amount	Target WP
Full irrigation	1h	3h		-130 cm	7.2 mm	2.4kg/m³
Constant threshold			Establishment	-130 cm -1250 cm	7.2 mm 6 mm	2.7kg/m³

Full Irrigation



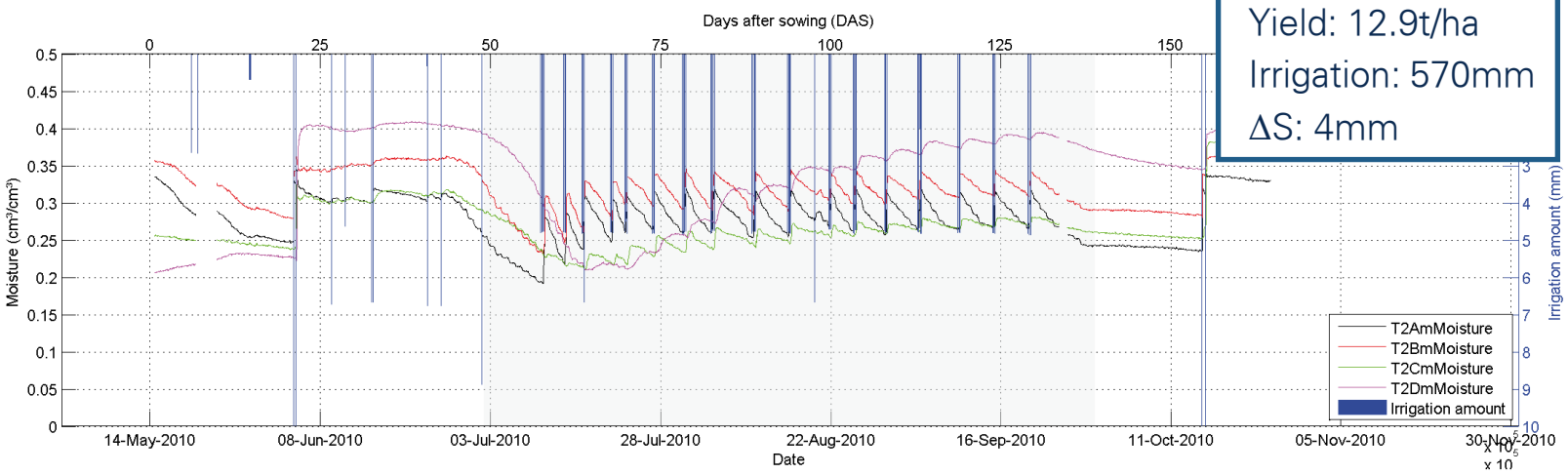
Constant threshold

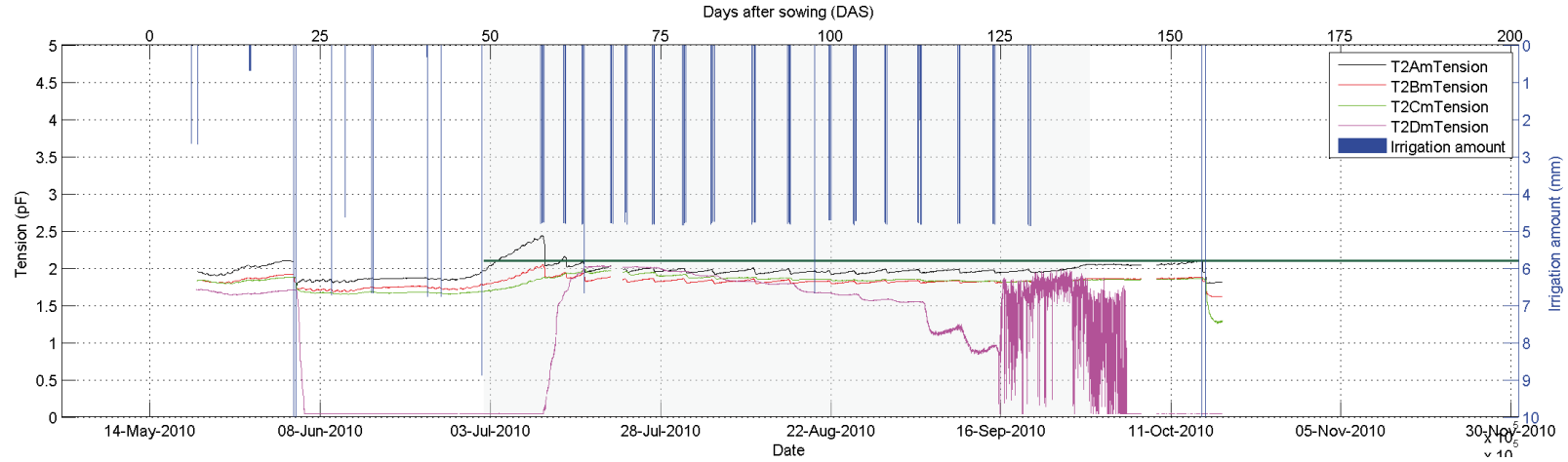


(FAO,2011)

Full Irrigation 2010

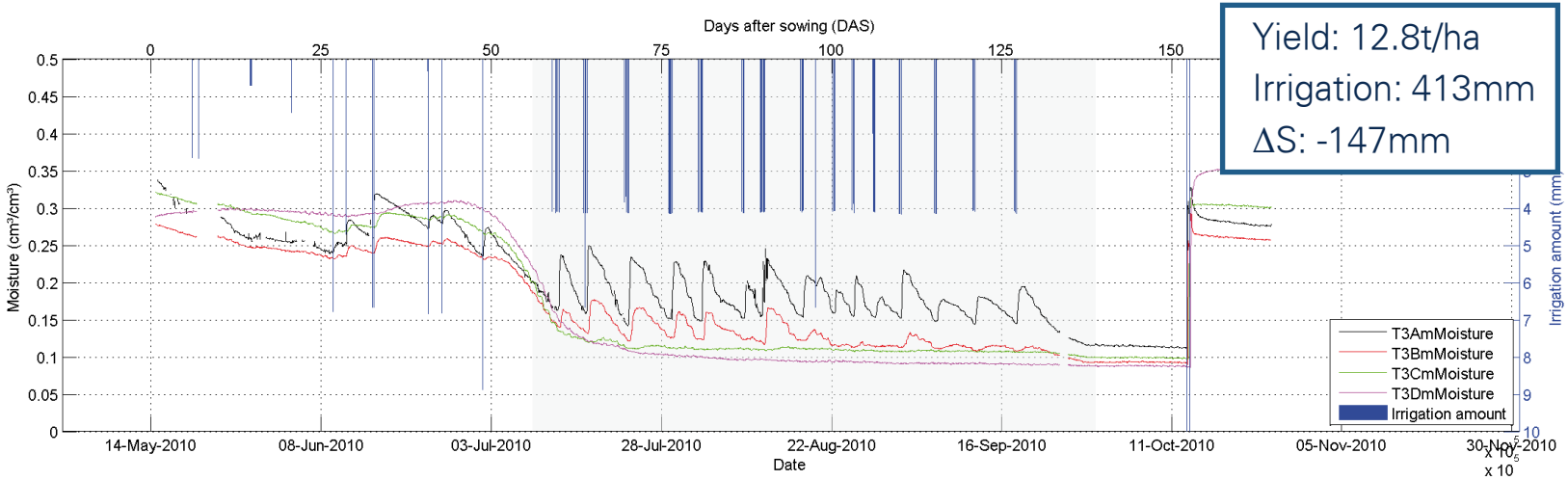
Yield: 12.9t/ha
Irrigation: 570mm
ΔS: 4mm

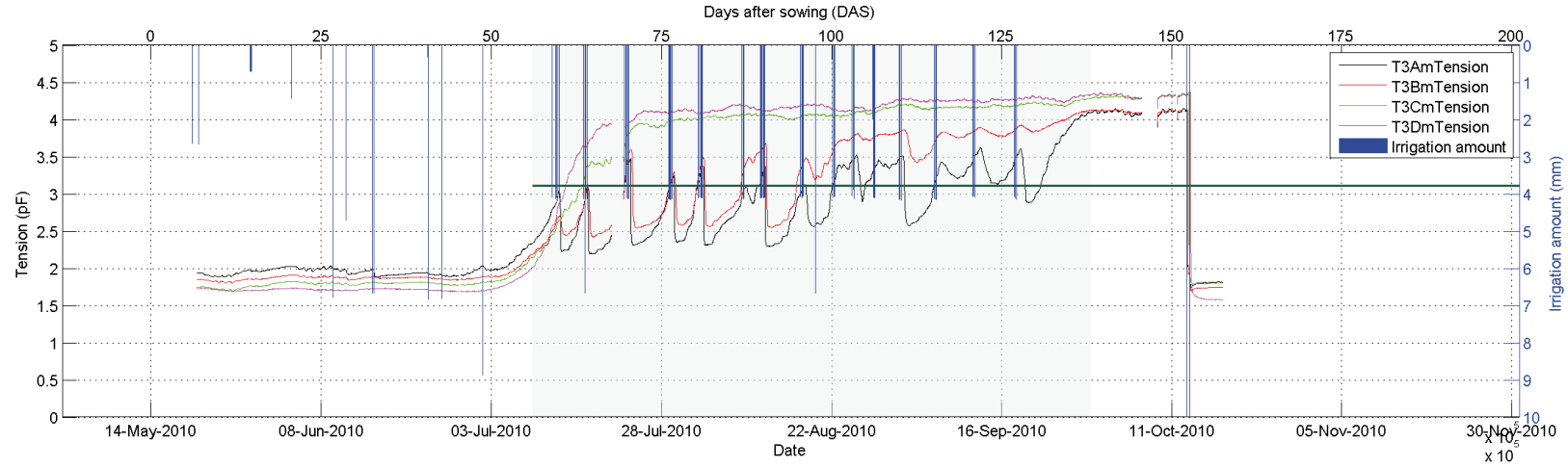




Constant Threshold 2010

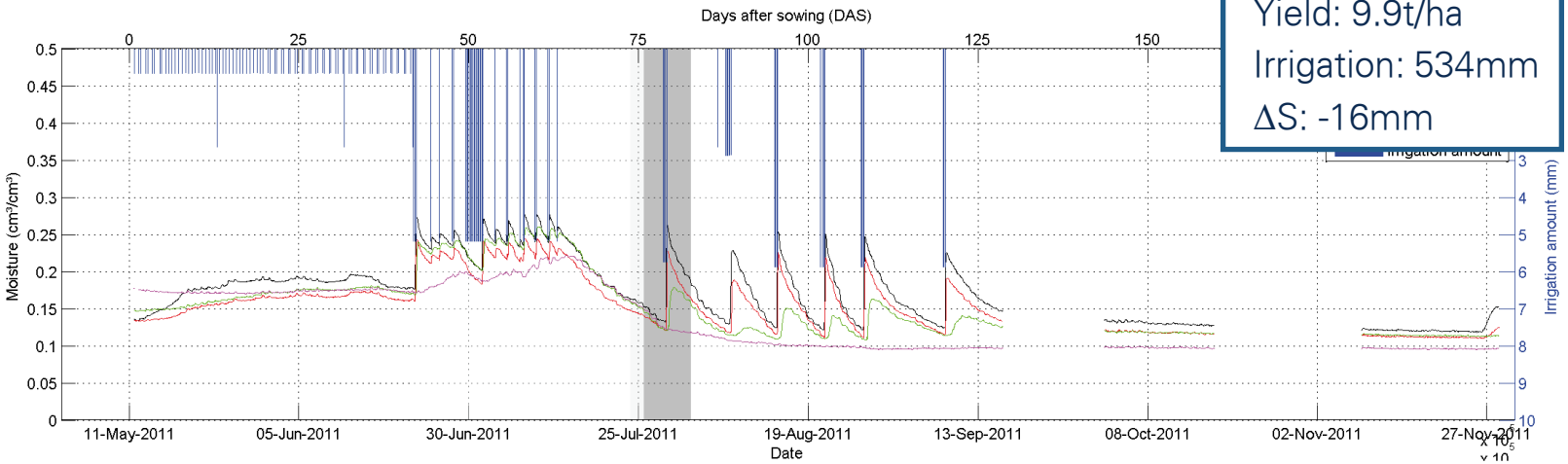
Yield: 12.8t/ha
Irrigation: 413mm
ΔS: -147mm

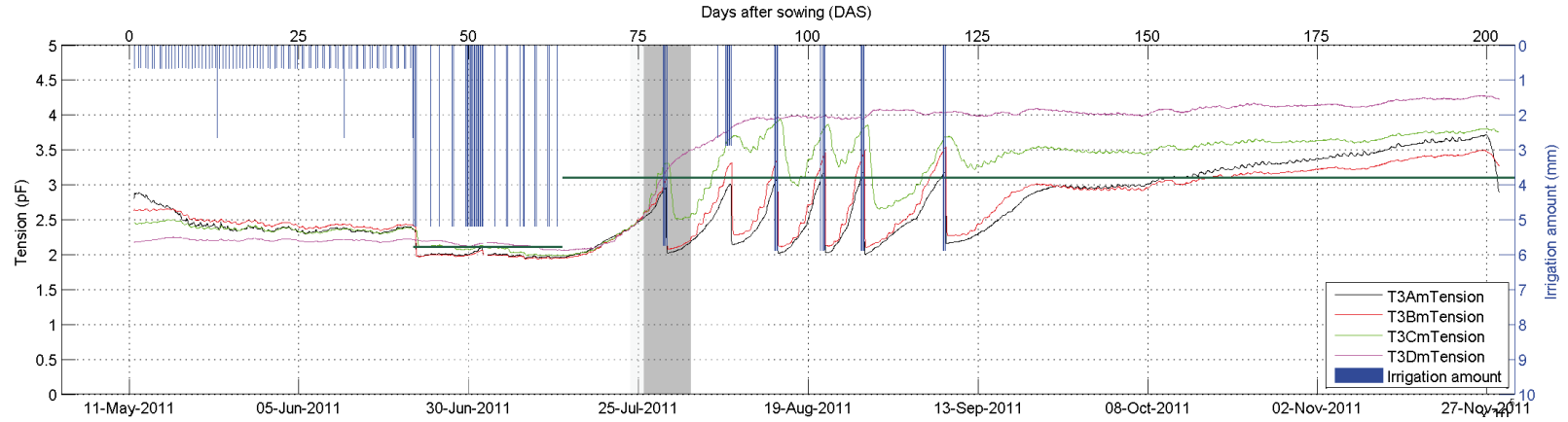




Constant Threshold 2011

Yield: 9.9t/ha
Irrigation: 534mm
ΔS: -16mm





Experiments

	Yield	Irrigation	ΔS	WP (without ΔS)	WP (with ΔS)
Full Irrigation 2010	12.9t/ha	570mm	4mm	2.26kg/m³	2.28kg/m³
Full Irrigation 2011	13.3t/ha	599mm	5mm	2.22kg/m³	2.24kg/m³
Constant Threshold 2010	12.8t/ha	413mm	-147mm	3.10kg/m³	2.29kg/m³
Constant Threshold 2011	9.9t/ha	534mm	-16mm	1.85kg/m³	1.80kg/m³

Constant Threshold 2010

- High initial soil moisture

→ Example for Southern France

Constant Threshold 2011

- Low initial soil moisture

→ Example for Arabian Peninsula

Full Irrigation

- No percolation due to container

Recalculation of Full Irrigation 2010

	Yield	**Irrigation**	ΔS	**WP (without ΔS)**	**WP (with ΔS)**
Full Irrigation 2010	12.9t/ha	570mm	4mm	2.26kg/m³	2.28kg/m³
FI 2010 recalculated	12.7t/ha	581mm	-9mm	2.19kg/m³	2.15kg/m³

- Free drainage lower boundary condition
- Threshold: 300cm (vs. 130cm before)

FI 2010 free drainage	12.7t/ha	617	-77mm	2.06kg/m³	1.83kg/m³

- Percolation of 108mm

Conclusion

Achieved WPs lie in good agreement with predicted outcome

- High WPs achieved
- Values from literature: 0.65 - 2.92 kg/m^3 (Zwart 2004)

Constant Threshold treatments:

- WPs in the range of full irrigation WPs
- Increase in WP possible with pF-Meter, if initial moisture is high
  - → Impossible with tensiometers: soil tensions beyond measurement range
  - → Legitimate to disregard soil water depletion: replenished during winter
- when considering percolation for full irrigation treatments, further drop in WP

Approach successfully applied to determine tension thresholds
pF-Meter applicable for irrigation control

Other CDI strategies possible

- Plant growth adapted tension threshold
- Different irrigation intervals, different control depths

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Thank you for your attention!