TECHNISCHE UNIVERSITÄT DRESDEN

IWAS

Faculty of Forest, Geo and Hydro Sciences – Institute of Hydrology and Meteorology

Sebastian Kloss, Niels Schütze, Sabine Walser, Jens Grundmann

Comparison of Different Model-Based Deficit Irrigation Strategies to Maximize Water Productivity of Corn

EGU
General Assembly 2011
Vienna, 05.04.2011

Overview

1. Background
2. Basics
3. Experimental outline
4. Results



Background – Current Situation

Agriculture

Soil degradation and soil depletion through:
- Extensive farming
- Excessive irrigation
- Heavy use of synthetic fertilizers

→ Soils lost for agriculture

WWF

Population growth
- Still 852 million people are chronically hungry and
- 2 billion people lack food security due to poverty (FAO 2003)
- Food security is becoming increasingly difficult to maintain

Current agricultural yields are insufficient to feed the growing populations (USAID)

→ Addressing agriculture and population growth to reduce food insecurity

→ For agriculture, strategies are needed that:
- Improve crop growth
- Make irrigation efficient and sustainable
- Preserve farmland through better cultivation practices

Strategies

- Improving water use efficiency (WUE) or water productivity (WP)

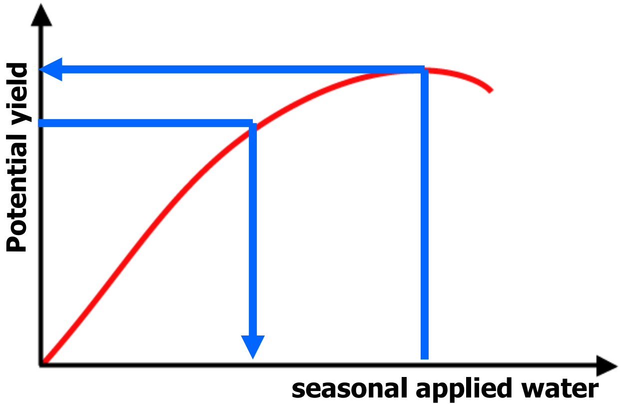
$$= \frac{\text{gain}}{\text{its expenses}} = \frac{\text{assimilated carbon, yield, biomass}}{\text{irrigation water, transpiration sum, evapotranspiration}}$$

- by controlled deficit irrigation (CDI)

  Deliberate deprivation of irrigation water during crop growth

  → Reduced water consumption and reduced yields

  → Increases WP to a certain point



2 commonly used approaches for CDI:

- Field experiments
- Simulation-based studies

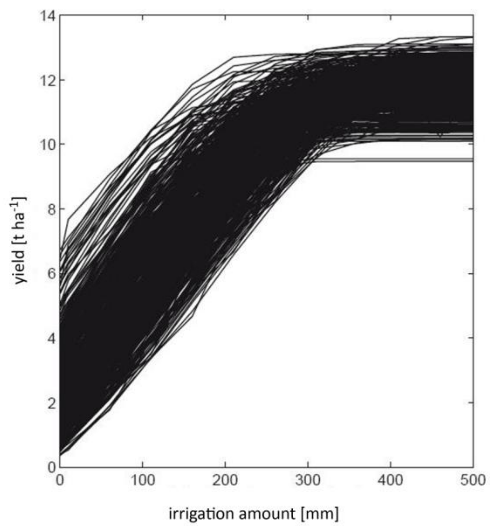
Stochastic Simulation-Based Approach

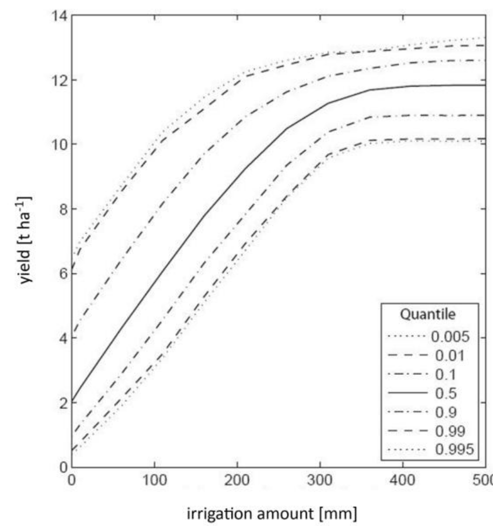
- Allows for consideration of climate variability (soil variability or salinity also possible)
- Application of the stochastic planning tool for Optimal Climate Change Adaption Strategies for Irrigation (OCCASION)

  consists of:

  i. weather generator for a statistically sound number of climate time series
  ii. problem specific algorithm for optimal irrigation scheduling
  iii. crop model for simulating plant growth and water consumption
- Results are crop water production functions (CWPFs) → statistical analysis → stochastic crop water production function (SCWPF)

Optimized (potential) CWPFs





SCWPF

- *Quantiles as probability of exceedance*
- *WP function as derivative*

Experimental Outline

Investigation of different water deficit strategies in an irrigation experiment

Silage maize grown in a vegetation hall

- Variety Pioneer PR35Y65

Setup comprised of 9 containers (A=0.52m², 5 plants)

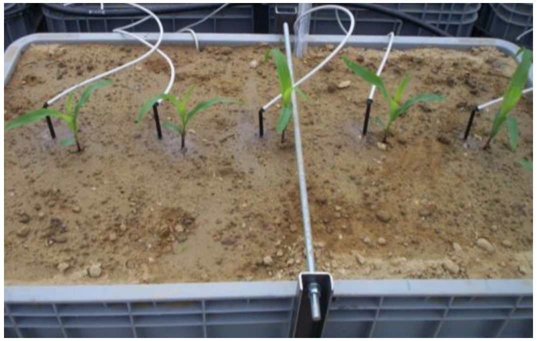
- Each container represents one treatment
- 3 different treatments, 3 replicates
- Alignment of plants resembles field condition
- Application of irrigation water by drip lines

Monitoring of soil moisture and tension

- In different heights
- TDR and pF-Meter

Irrigation control

- Tension-based
- Through pF-Meter
  (advantage over tensiometer)



Measurement principle: Heat capacity
Range: pF 0…pF 7, -40…+80°C
Resolution: 0.01 pF, 0.1°C

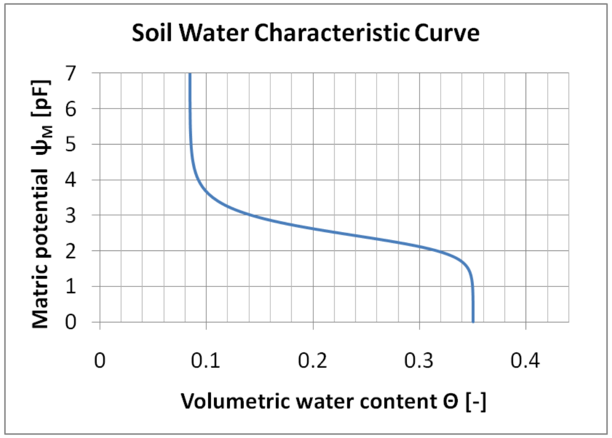
Treatment Setup

Determined prior to the experiment with OCCASION

- Simulation with crop model Daisy
- Objective: maximizing the 90%-quantile of WP

Input data

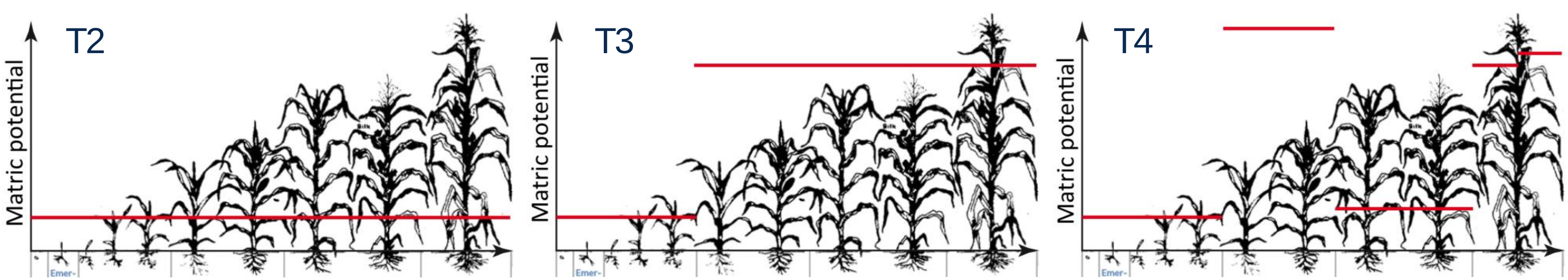
- Climate:
  - Global radiation and temperature from adjacent climate station (20-year time series)
  - 100 realizations created
- Crop parameterization:
  - Parameterization from an open land experiment
- Soil parameterization
  - Infiltration experiment
  - Inverse soil hydraulic parameter estimation (Hydrus 2D)
  - Soil properties:
    - Loamy sand
    - Clay 3.3%, silt 17.5%, sand 79.2%



Treatments

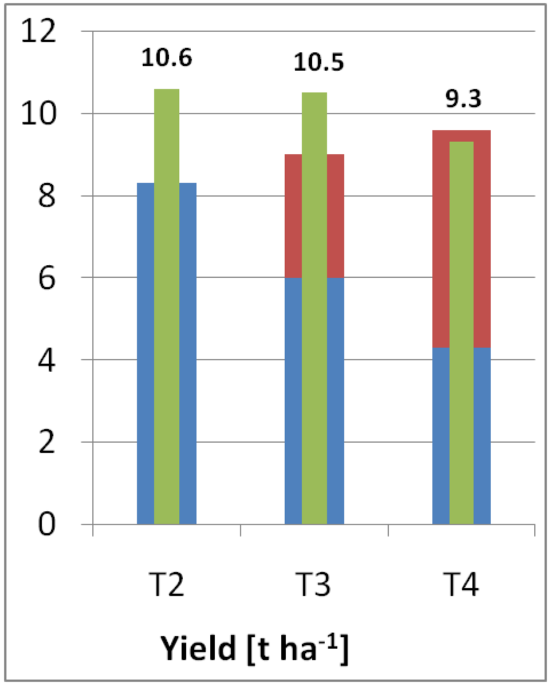
Soil tension-based irrigation schedules with different threshold levels

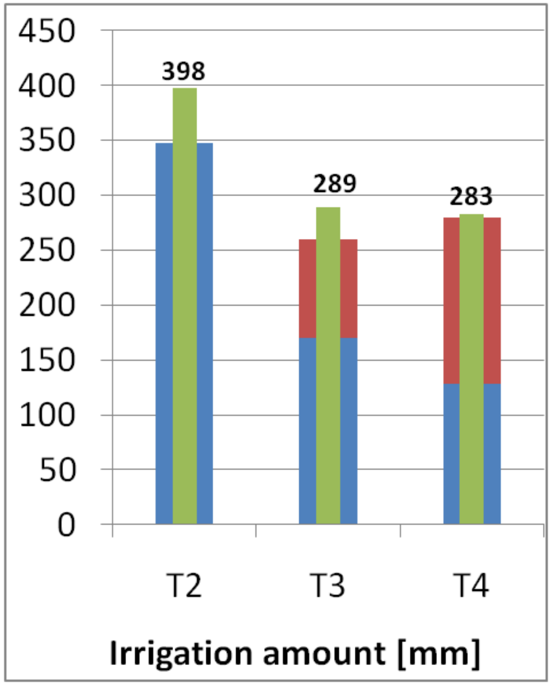
	Treatment characteristics	Irrigation time	Redistribution time	Growth period	Tension threshold	Application amount
T2	Full irrigation				-130 cm	7.2 mm
T3	Constant threshold			Establishment	-130 cm -1250 cm	7.2 mm 6 mm
T4	Growth period adapted threshold	1h	3h	Establishment Vegetative Flowering Yield formation Ripening	-130 cm -1400 cm -150 cm -1250 cm -1300 cm	7.2 mm 6.0 mm 2.9 mm 11.6 mm 2.2 mm

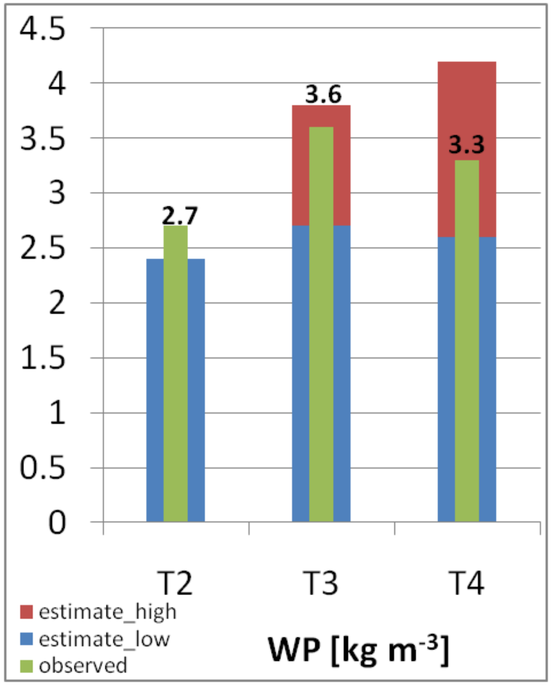


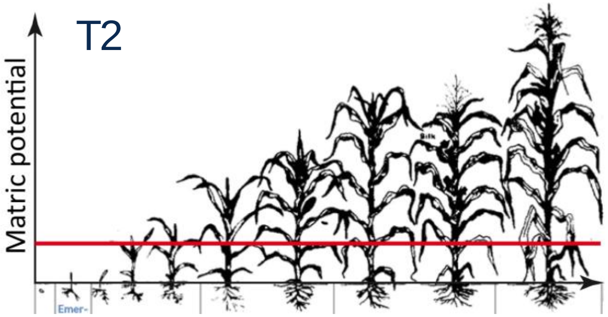
(FAO,2011)

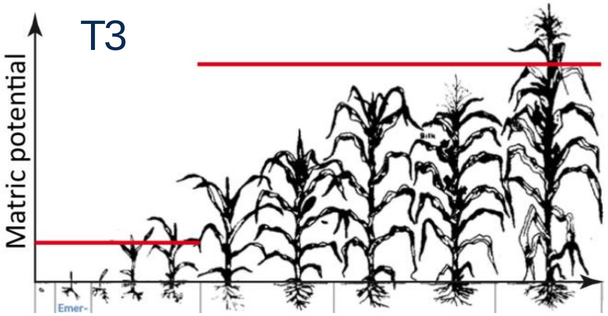
Overview

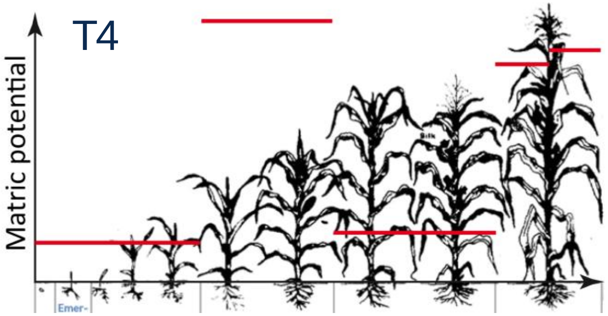












(FAO,2011)

Summary

Achieved WPs lie in good agreement with predicted outcome

- High WPs achieved (2.7 - 3.6 kg m^{-3})
- Values from literature: 0.65 - 2.92 kg m^{-3} (Zwart 2004)

Determination of the tension thresholds prior to the experimental run combined with pF-meters for irrigation control successfully applied

Improvements to be implemented:

- Due to the wide range of yields and irrigation amounts
  → Extending the objective of maximizing WP by including a minimum target yield
- Volume-based irrigation schedule
  → Application of weekly amounts of irrigation water

Outlook:

Simulation of all experiments → Recalibration and reoptimization of the model

Second series of experiments