TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

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The value of information for the management of deficit irrigation systems

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Key messages

- the value of information about irrigation control strategies, future climate development, soil characteristics, and initial moisture conditions is evaluated for an arid and a semi-arid irrigation site
- as a stochastic framework the Deficit Irrigation Toolbox (DIT) is used
- value of information ≙ costs for compensation of uncertainty in units of additional water requirements
- results are:
  - costs of climate uncertainty (variability) are higher for the semi-arid site
  - costs of soil uncertainty (variability) are higher for the arid site, and even higher for wet initial conditions
  - costs of soil uncertainty (variability) can be reduced by proper soil analysis
  - **but highest added value of information have: knowledge about the proper deficit irrigation strategy and information about initial conditions**

Outline

Introduction
- Controlled deficit irrigation
- DIT modeling framework

Application to different climate regions

Results
- Impact of climate and soil variability
- Impact of deficit irrigation strategy

Conclusions and Outlook

Introduction

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Controlled deficit irrigation

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Impact of climate and soil variability

Impact of deficit irrigation strategy

Conclusions and Outlook

Focus on controlled deficit irrigation (CDI) for improving water productivity

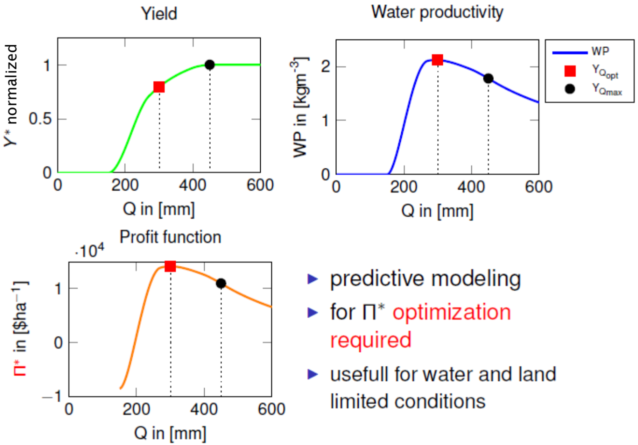
- More crop per drop: Improvement of Water Productivity (WP)
  - Improvement of crop growth
  - Efficient and sustainable irrigation
  - Preservation of farmland through better cultivation practices
- WP = gain over expenses
  - (Marketable) yield over total irrigation amount or evapotranspiration
- Typical ranges of WP_{ET}

Maize:
0.3 – 1.7 kg m^{-3}

Wheat:
0.6 – 1.5 kg m^{-3}

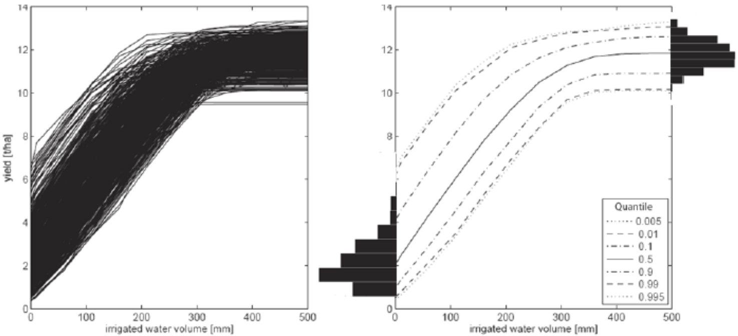
Rice:
0.4 – 1.4 kg m^{-3}

Theoretical framework of CDI:
The crop water production function (CWPF)



- predictive modeling
- for Π^* optimization required
- usefull for water and land limited conditions

What is unknown?
1) future weather development

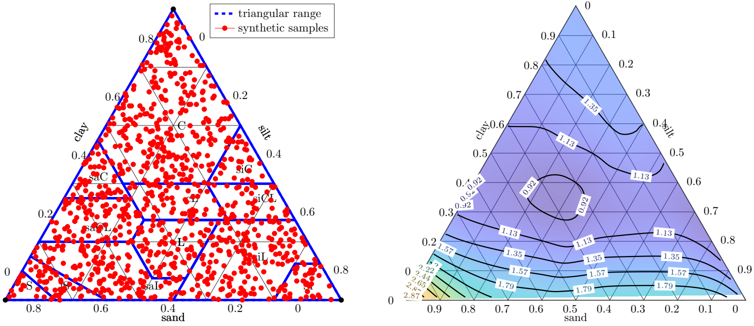


Variability in yield for rainfed, supplemental and full irrigation for maize (Montpellier, France)

If the site is known:
optimized simulations of 500 possible growing seasons for different irrigation water amounts available.

What is unknown?

2) soil variability and / or 3) initial soil moisture



soil texture

$log\,(K_s)$

If nothing about the soil is known:
sampling of 500 texture realizations and translated saturated conductivity values by the ROSETTA-PTF.

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Evaluation of the value of information using:

The Deficit irrigation toolbox (DIT) – http://bit.ly/TUD-DIT

Crop models

- Cropwat (FAO)
- Aquacrop OS* (FAO)
- Daisy
- Apsim
- . . .

Irrigation strategies (full and deficit)

- no irrigation
- full irrigation
- open-loop control (fixed)
- closed-loop (feedback) control
- open-loop control (calendar)
- . . .

DIT uncertainty framework:
parameters, initial and boundary conditions

Climate variability

using a weather generator, e.g. LARS-WG

- based on climate stations, e.g. NOAA
- generates realisations of historic and future growing seasons
- and meteorological forecasts

Soil variability

- using a soil texture generator

Initial conditions

- $\theta_0 = PWP$
- $\theta_0 = FC$
- $\theta_0 = PWP \ldots \theta_s$

DIT modeling framework v1.0

Features

- probabilistic framework (SCWPF)
- parallel computation (works on HPC)
- visualization tools for performance analysis
- manual, examples, tutorial

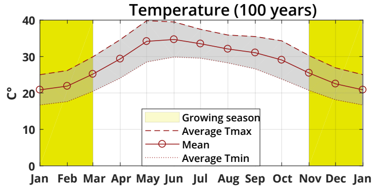
Software development

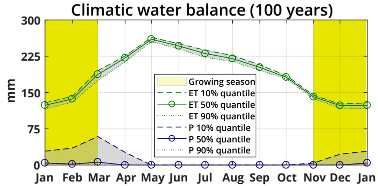
- uses software engineering tools
  - Unit tests
  - FusionForge
  - Code revision control
- provided as open source
  - `http://bit.ly/TUD-DIT`

Application to different climate regions

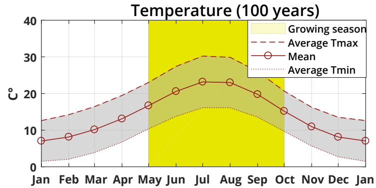
Considered climate regions

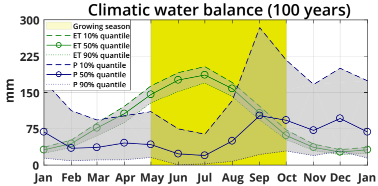
Arid site: Seeb, Oman





Semi-arid site: Montpellier, France





Experimental setup:
32 combinations of varying levels of information in

Climate variability

2 levels of information

from 2 climate stations: Seeb, Montpellier

- climate series of 100 generated years
- average year (perfect knowledge)

Soil variability

2 levels of information from

2 texture samplings:

soil triangle,
USDA class: sandy loam

- 100 soil samples
- cendroid of each sample (perfect knowledge)

Initial conditions

2 cases of initial condition:

- dry: $\theta_0 = PWP$
- wet: $\theta_0 = FC$

Experimental setup:
32 combinations of varying levels of information in

Climate variability

2 levels of information

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Seeb, Montpellier

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Initial conditions

2 cases of initial condition:

- dry: θ_0 = *PWP*
- wet: θ_0 = *FC*

Experimental setup:
varying knowledge / information about 5 irrigation strategies

Crop model

- Aquacrop OS* (FAO)

Irrigation strategies

- no irrigation
- full irrigation
- closed-loop control (decision table)
- open-loop control (long term calendar)
- open-loop control (perfect knowledge)

- 5 irrigation strategies x 32 scenarios → 160 combinations of information

Results

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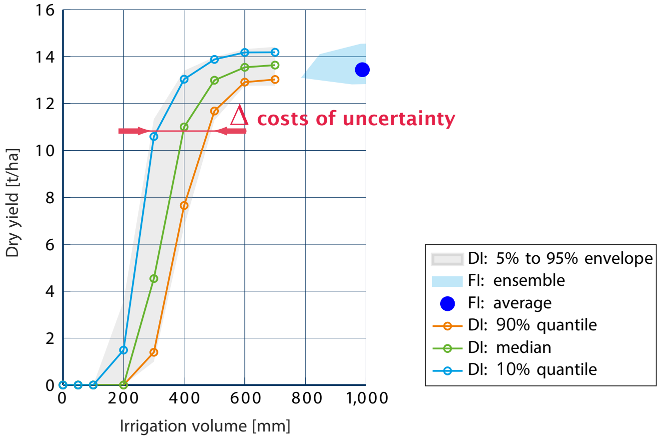
Example plot:

costs of uncertainty (additional water requirements) ≙ value of information

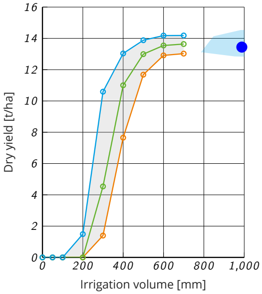


Climate variability

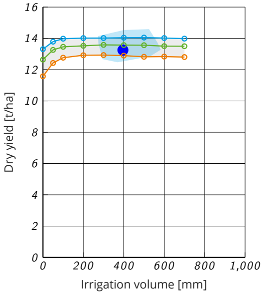
Each season optimized (perfect knowledge of soil characteristics)

Montpellier (semi-arid)

dry

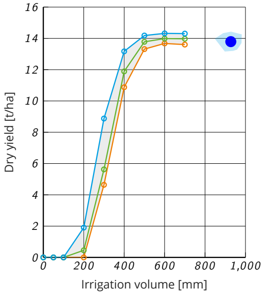


wet

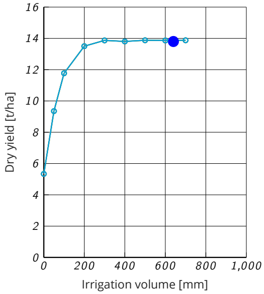


Seeb (arid)

dry

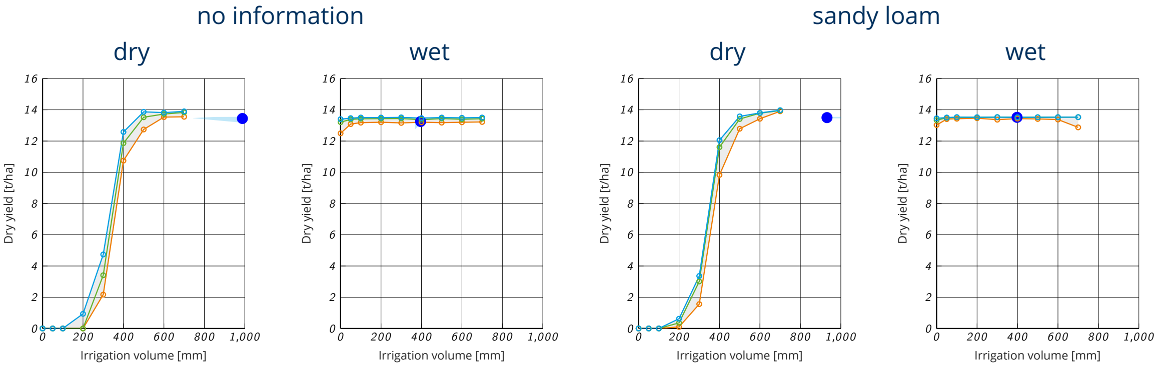


wet



Soil variability: Montpellier (semi-arid)

Each season optimized (perfect knowledge of weather development)

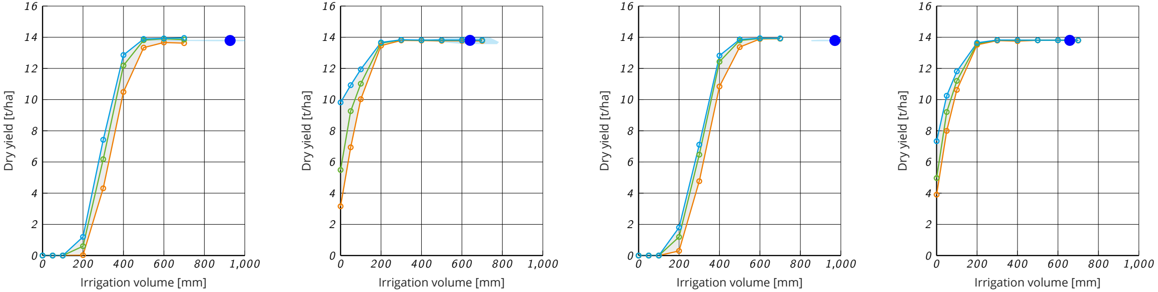


Soil variability: Seeb (arid)

Each season optimized (perfect knowledge of weather development)

no information — dry | wet

sandy loam — dry | wet



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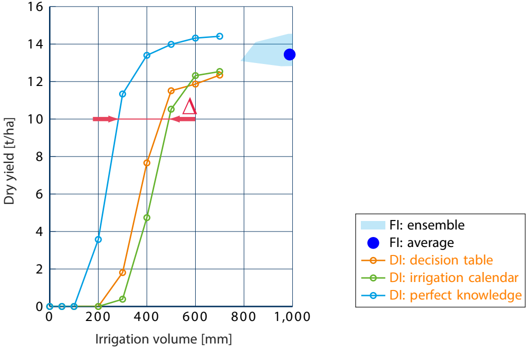
Example plot

Different irrigation strategies and costs of uncertainty in [mm] for 0.9 quantile



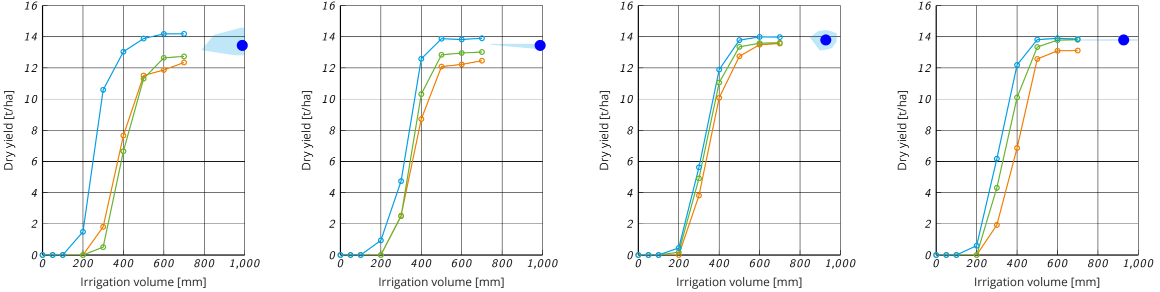
	decision table	irrigation calendar
Costs in [mm]:	178	208

Yield for maize for a semi-arid site: France

Costs for dry conditions in [mm]

Montpellier (semi-arid) | Seeb (arid)

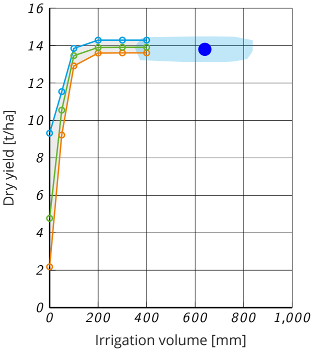
climate variability | soil variability | climate variability | soil variability



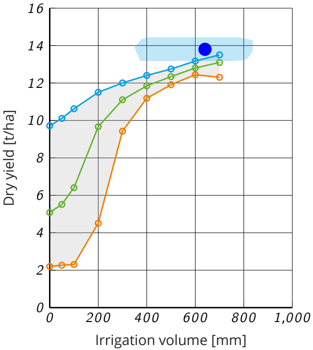
178	180	76	43	30	10	88	40

An Example for Seeb for mixed variability

Stochastic Crop Water Production Function for wet conditions



irrigation calendar



simple deficit irrigation

Conclusions and Outlook

Conclusions

- value of information ≙ costs for compensation of uncertainty in units of additional water requirements
- costs of climate uncertainty (variability) are higher for the semi-arid site compared to arid climate conditions
- costs of soil uncertainty (variability) are higher for the arid site, and even higher for wet initial conditions
- costs of soil uncertainty (variability) can be reduced by proper soil analysis
- **but highest added value of information have: knowledge about deficit irrigation strategy and information about initial conditions**