Quasi 3D modelling of water flow in the sandy soil

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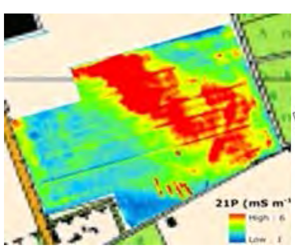
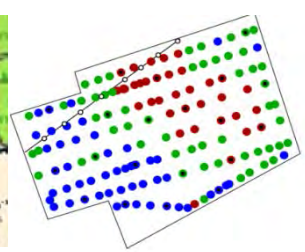
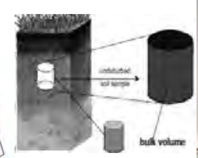


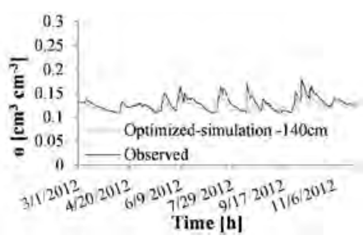

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❖ Introduction

- **How to improve *field scale irrigation* strategy?**

  Monitoring (modern technologies) and modeling tools

  - What needed in field scale modeling?

    Information about spatial variation of boundary condition e.g. GWL,
    topography e.g. FLD,
    hydraulic properties e.g. *Ks*
    …

    - How to characterize?

      measurements, proxy data e.g. ECa, DEM

- **Which modeling approach?** (from research to application)

  1, 2 or 3 D model (from research to application)?

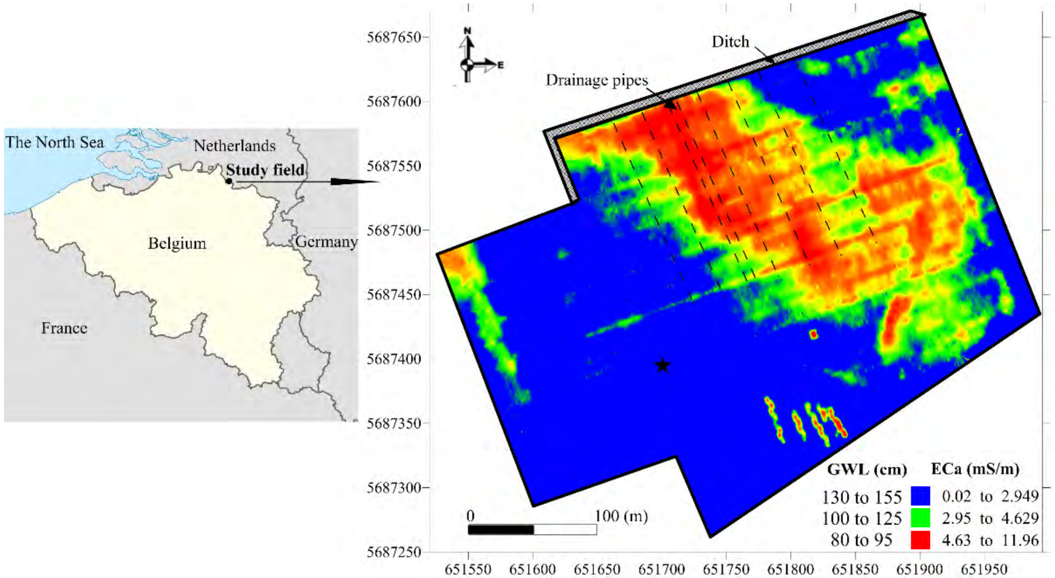
❖ Research aim and question

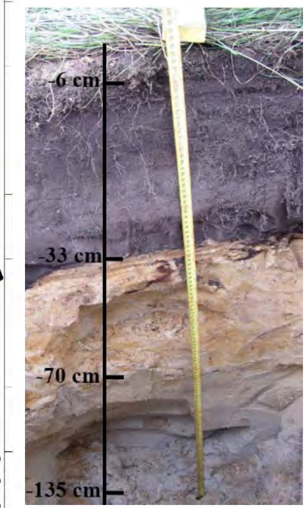
- How combined prior information with different resolutions can be used in water flow modeling for managing irrigation more effectively and practically?

1. Developing and evaluating the computational efficiency and uncertainty of our modeling approach/framework);

2. Assessing irrigation scenarios to find an optimized and cost-effective irrigation scheduling.

❖ Field site location and methods





- Grassland/potato field
- Typical sandy Podzol.
- Reel Sprinkler Gun irrigation

➢ First step: 1D modeling set-up/sensitivity analysis

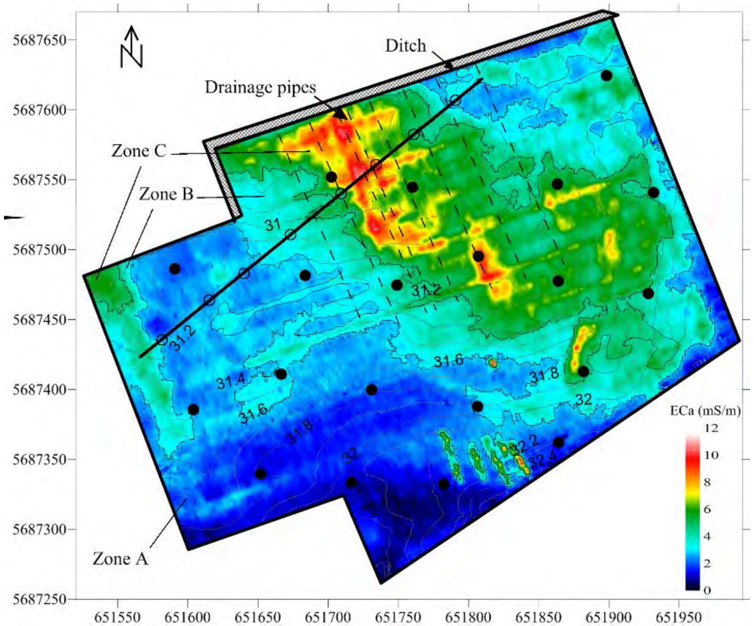
- Model: Hydrus-1D combined with crop growth model LINGRA-N
- Profile geometry: 200 cm with 2 layers
- Study period: growing season 2012 (wet year) and 2013 (dry year)
- Hydraulic model: MVG without air entry value and hysteresis
- Root water uptake model: Feddes model without solute stress
- Upper boundary condition: atmospheric (precipitation, LAI and ETp,)
- Bottom boundary condition: constant head (GWL)/free drainage
- Input hydraulic parameters: lab dataset

(Rezaei et al, 2016a)

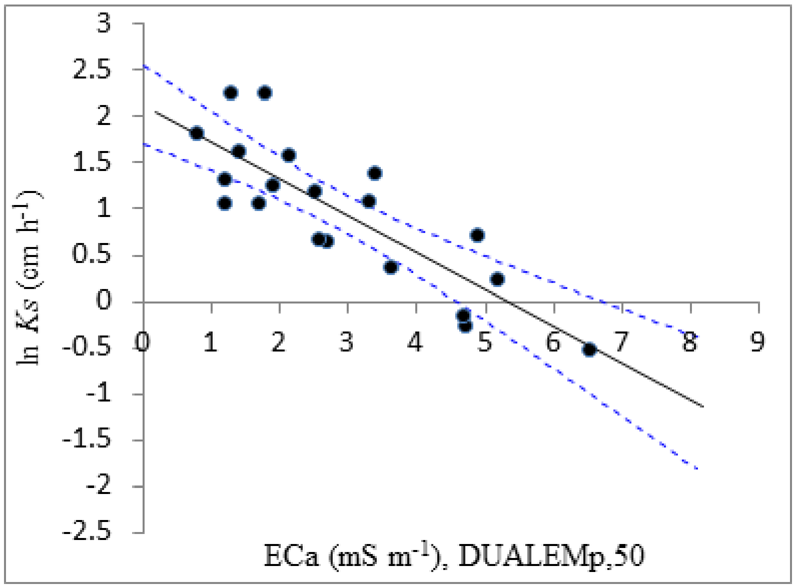
➢Second step: modeling parametrization at field scale

➢ ECa data (DUALEM-21S, DOE: 0-50)

- ➢ **Soil sampling strategy** (Fuzzme(Minasny and McBratney 2002), ESAP (Lesch 2006))
- ➢ **Soil samples analysis** (Ks, pF, texture, ECsat)



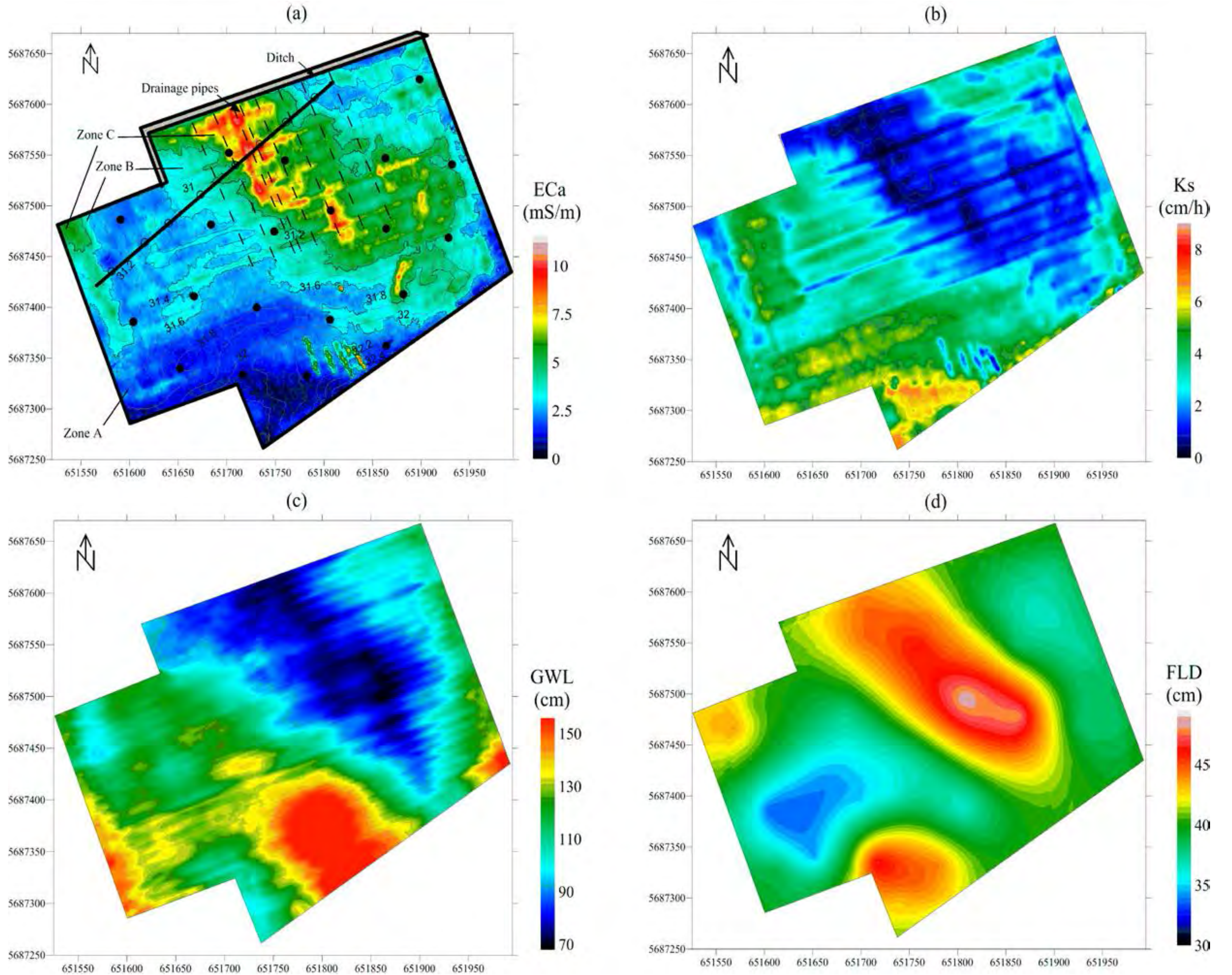
$$\ln Ks = -0.398\,ECa_{p.50} + 2.13 \qquad r^2 = 0.694$$



➢ Bottom boundary condition and profile geometry

- ➢ **Groundwater layer (GWL)**
- ➢ **Thicknesses of layers, e.g. First layer depts. (FLD)**
  - ➢ Measurements by augering at 28 locations
  - ➢ Using detailed digital elevation data and Surface Software

(Rezaei et al, 2016b)


(a)
(b)
(c)
(d)
Ditch
Drainage pipes
Zone C
Zone B
Zone A
ECa
(mS/m)
Ks
(cm/h)
GWL
(cm)
FLD
(cm)

➢Third step: a quasi 3D modelling approach

➢ **Model implementation**

The field is represented as a collection of 1D columns

Each column parameterized using (*Ks*, GWL, FLD)

Resolutions: ranging from 5 x 5 m to 400 x 400 m

Step 1. Initialization

Initialize coupled hydrologic-crop growth models
Programmed scripts/routines in Python
Prepare input text file i.e., GWL, FLD and *Ks* file in the same resolution

Step 2. Checkup programing

Read and check all files and model routines
Build coupled hydrologic-crop growth model in the desire directory/path
Pre-test of scripts by running the program
Replacement and set of input data for each run of location

Step 3. Pre-processing

Run the coupled model in a desire resolution
Save the initial results

Step 4. Post-processing

Reload and read the output files
Analyzing the results
Compute field scale soil-water stress and storage, infiltration and yield
Visualize the results and interpret

Model output

- Crop yield reduction due to water shortage (Doorenbos and Kassam, 1979)

$$1-\frac{Y_a}{Y_m}=K_y\,(1-\frac{ET_a}{ET_p})$$

- Soil-water stress (Jarvis, 1989)

$$\mathrm{WS}=\frac{T_a}{T_p}=\int_{Lr} w(h)R(x)dx$$

- Soil-water storage (20 cm)

Uncertainty and efficiency of simulation

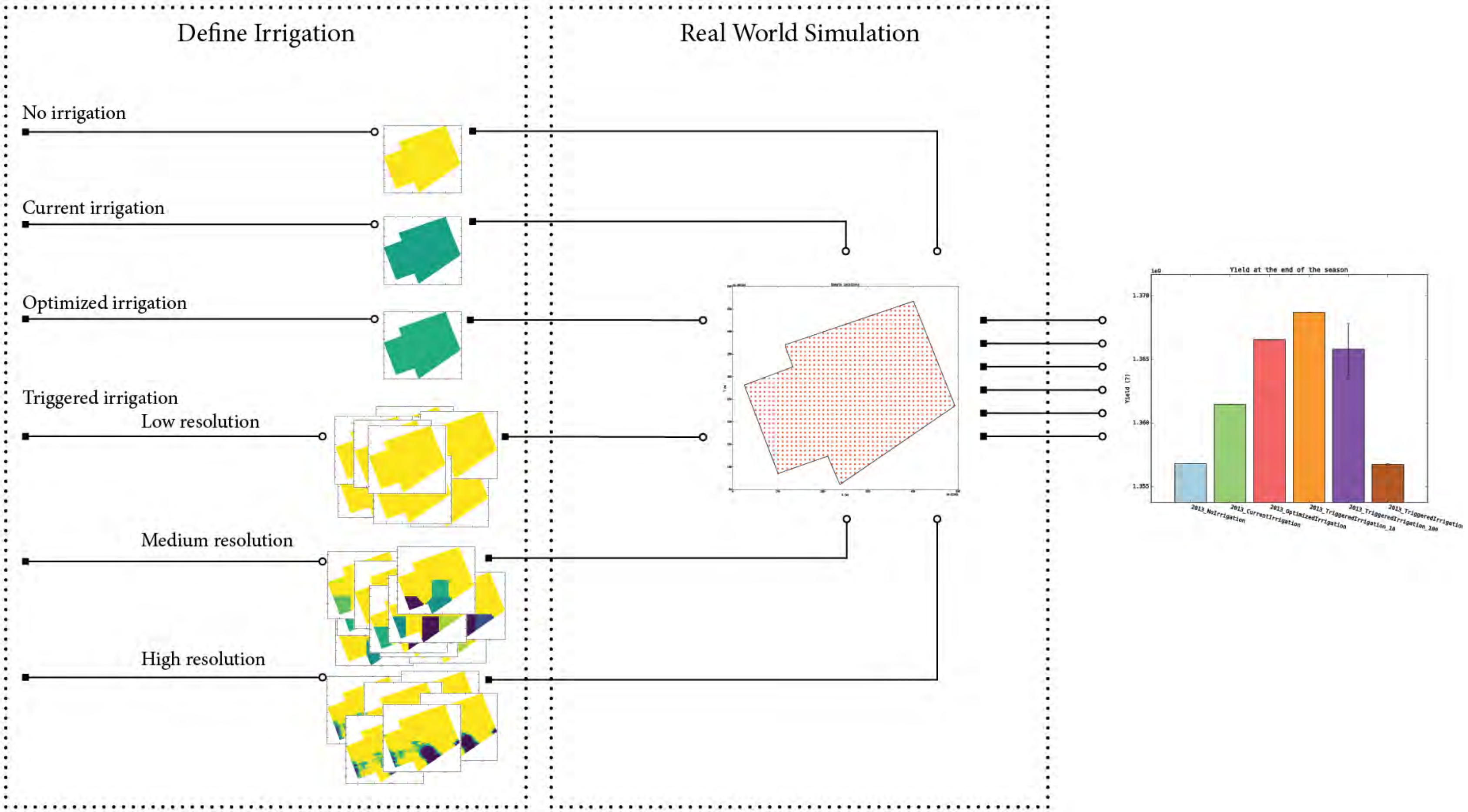
- The efficiency of the modeling approach
  Evaluating computational time of pre and post processing

- Effect of the data resolution on the uncertainty of model output
  5 x 5 m (4490 runs), …, 10 x 10 m (1212 runs), ….and 400 x 400 m (1 run)

- Uncertainty of irrigation management
  Three different resolutions i.e., 10 x 10 m, 100 x 100 m and 400 x 400 in trigged irrigation scenario

➢ Cost-effective irrigation scenarios

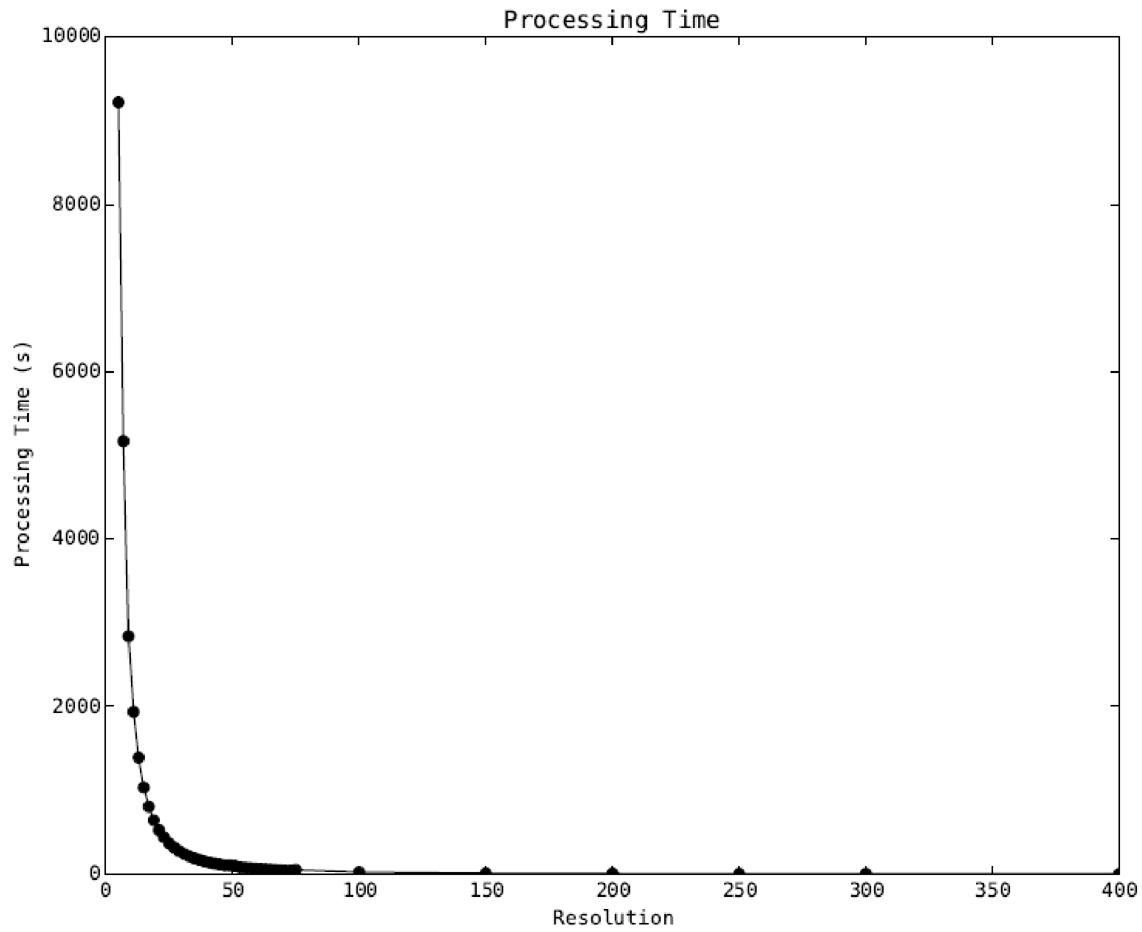
a) current irrigation
b) no irrigation
c) trial and error (optimized based on one spot)
d) triggered irrigation (2.5 cm water at pressure head above -300 cm within 2 hours)



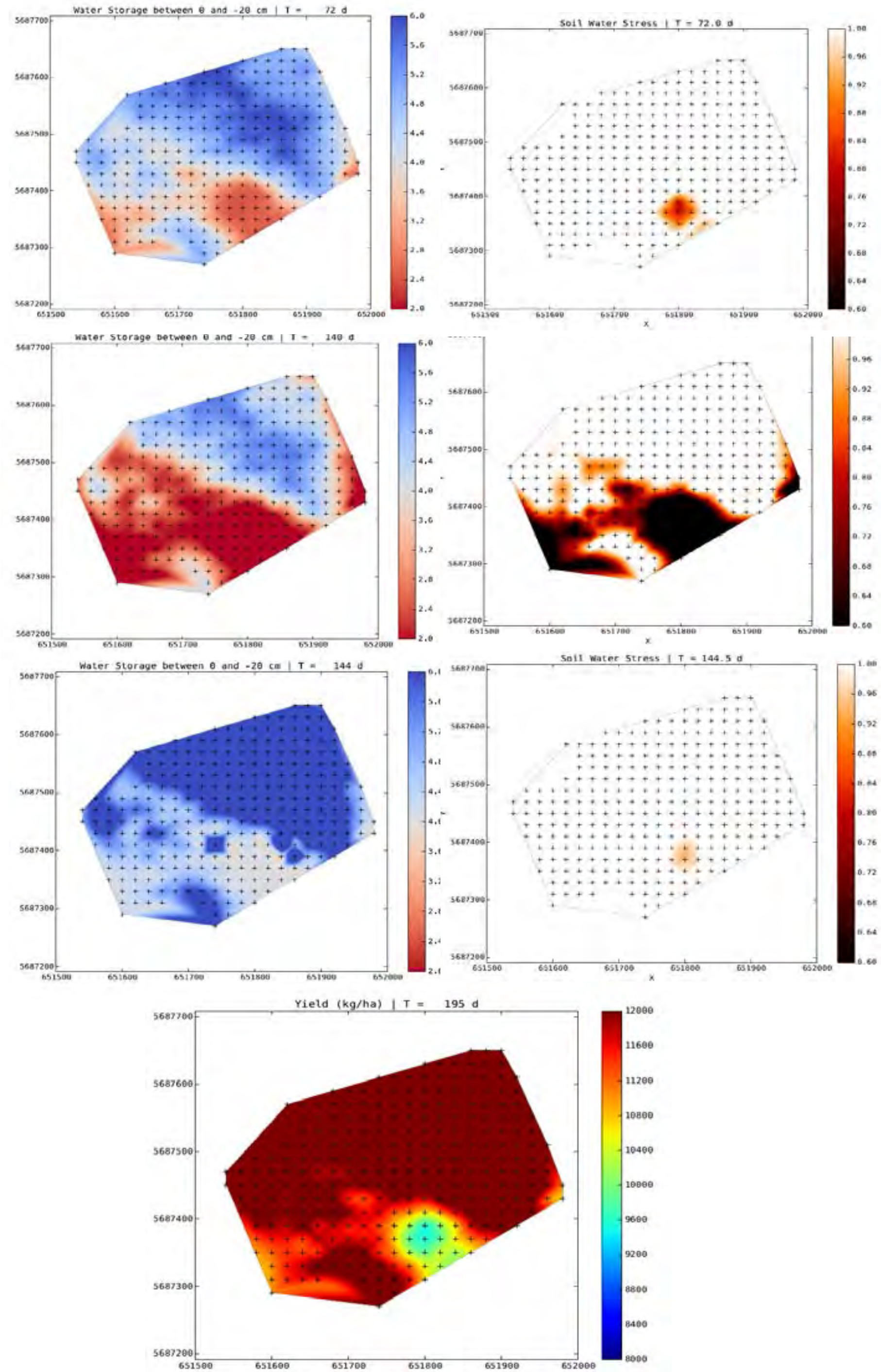
❖ Results and discussion

➢ Modeling approach evaluation

- 1950 s for 10 x 10 m resolution
- More than 250 maps and graphs (Stress, Storage, Yield)
- Less time performance and expensive (computational burden)

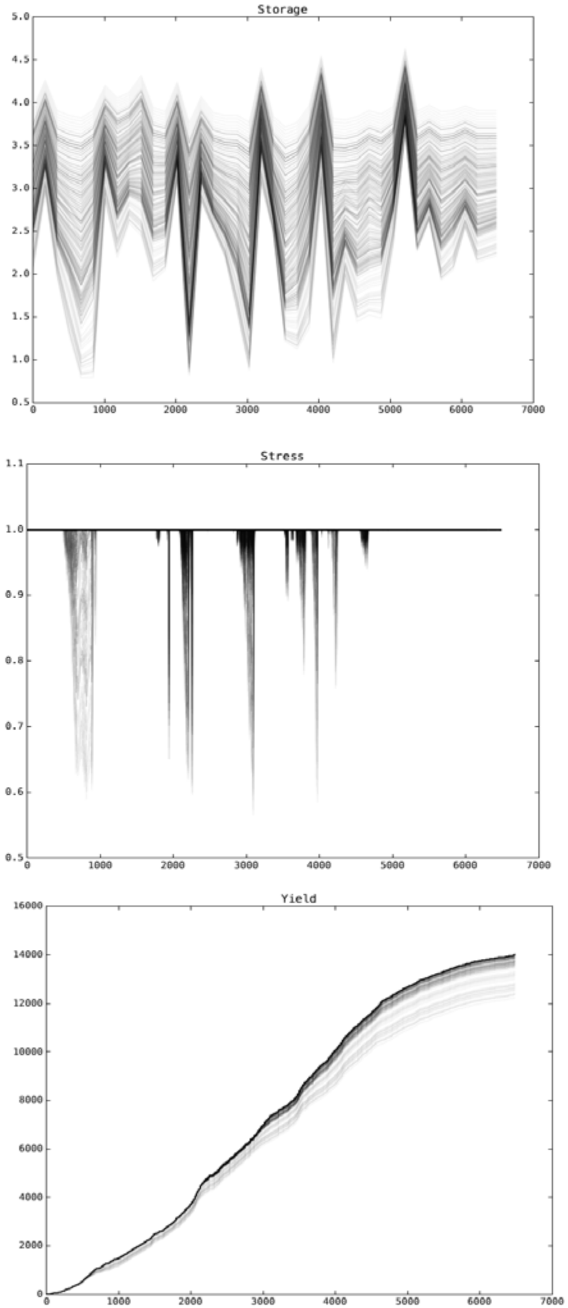


What matters only are the expenses (the labor and analysis cost) associated with measuring/determining the needed input data

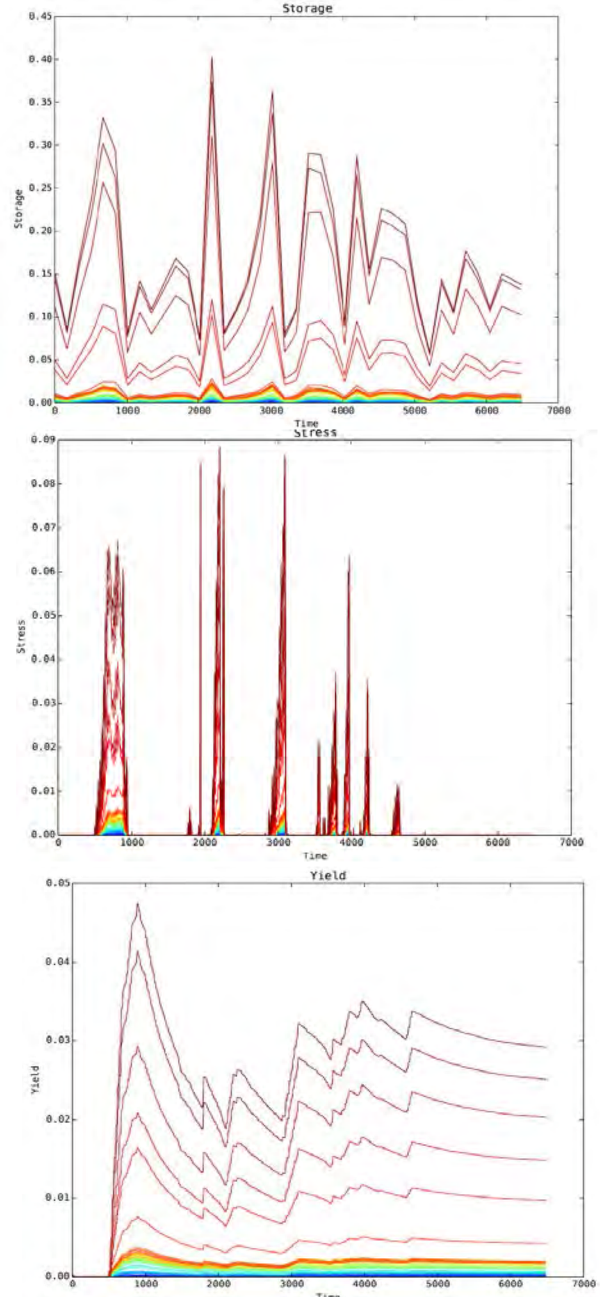


Water Storage between 0 and -20 cm | T = 72 d
Soil Water Stress | T = 72.0 d
Water Storage between 0 and -20 cm | T = 140 d
Water Storage between 0 and -20 cm | T = 144 d
Soil Water Stress | T = 144.5 d
Yield (kg/ha) | T = 195 d

➢ **soil-water storage, water stress and yield for 10 x 10 m**



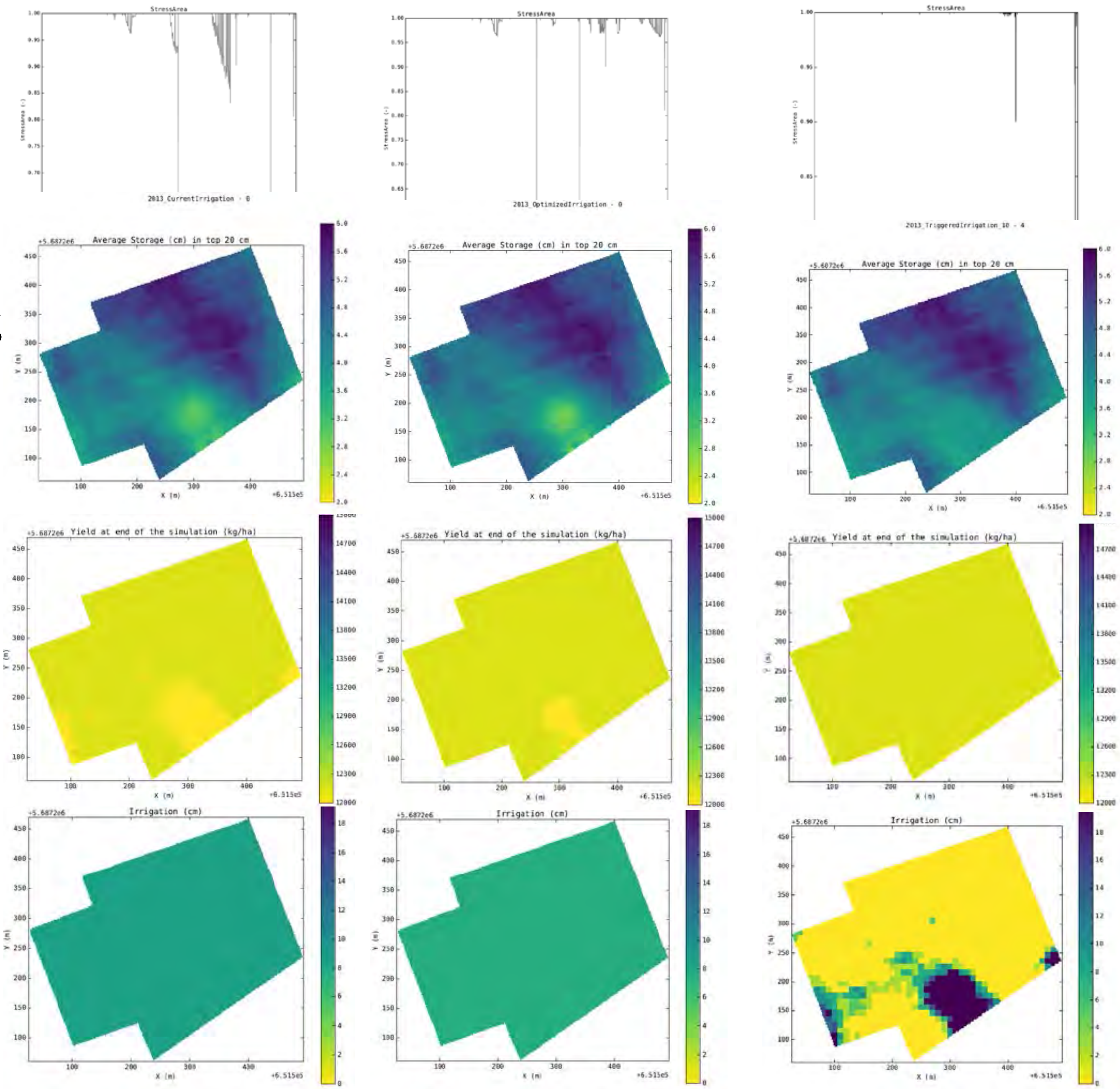
➢ **Output uncertainty of different resolutions**



❖ Irrigation scenarios

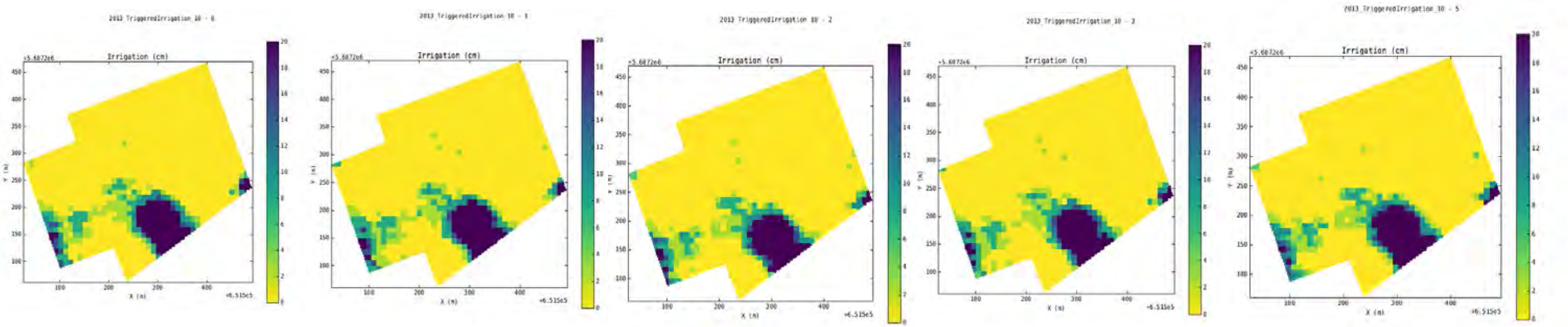
Current | Trial and error | Triggered

- Water stress
- Water storag
- Yield
- Irrigation

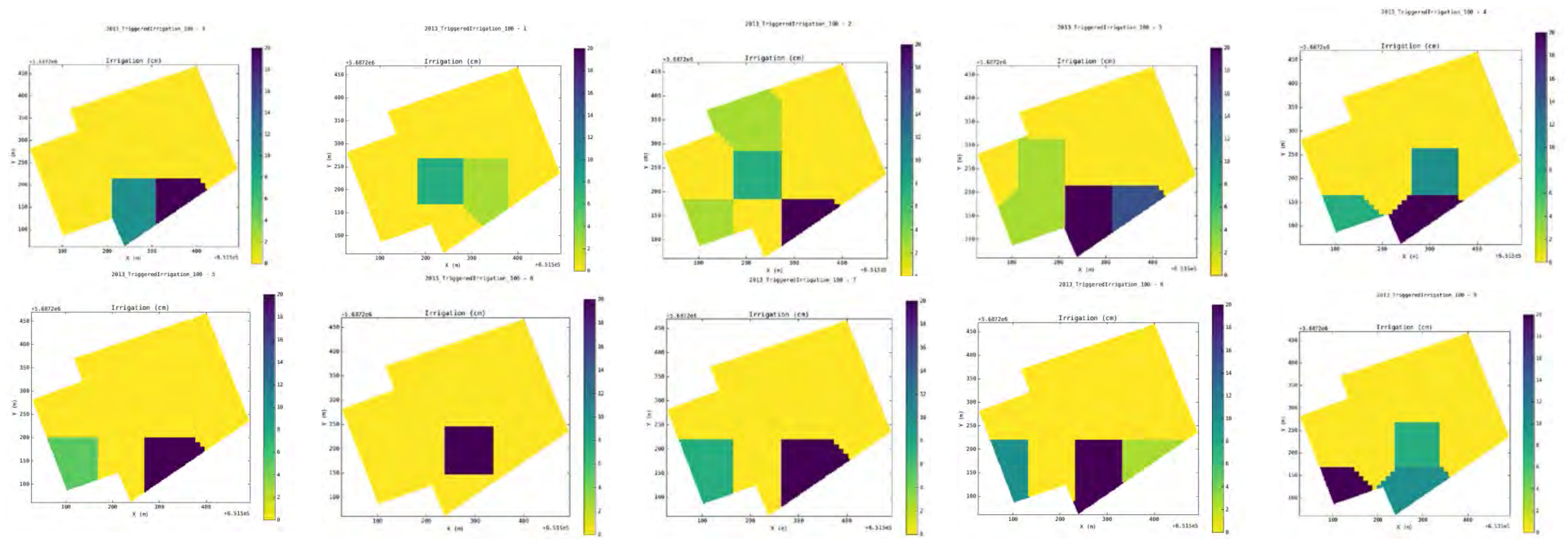


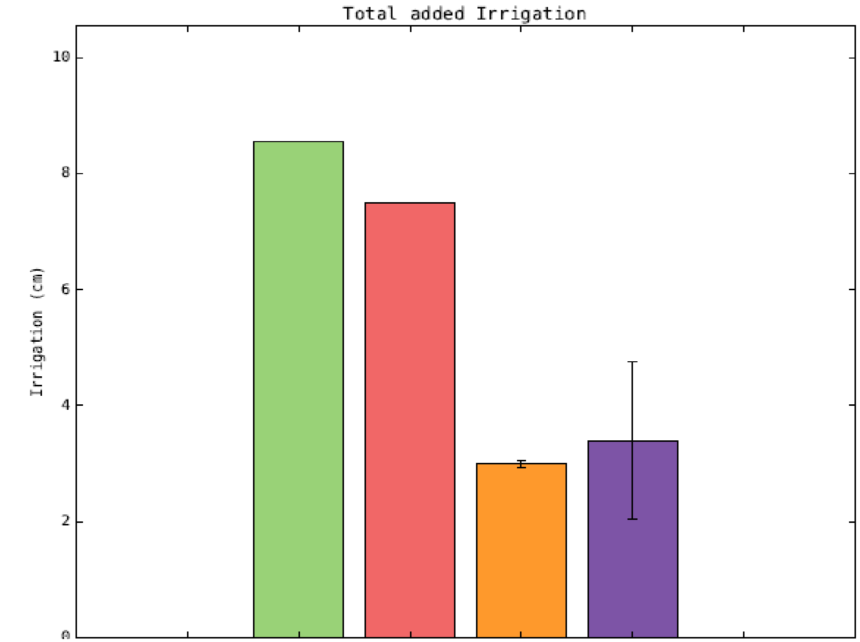
➢ Irrigation uncertainty using different resolutions

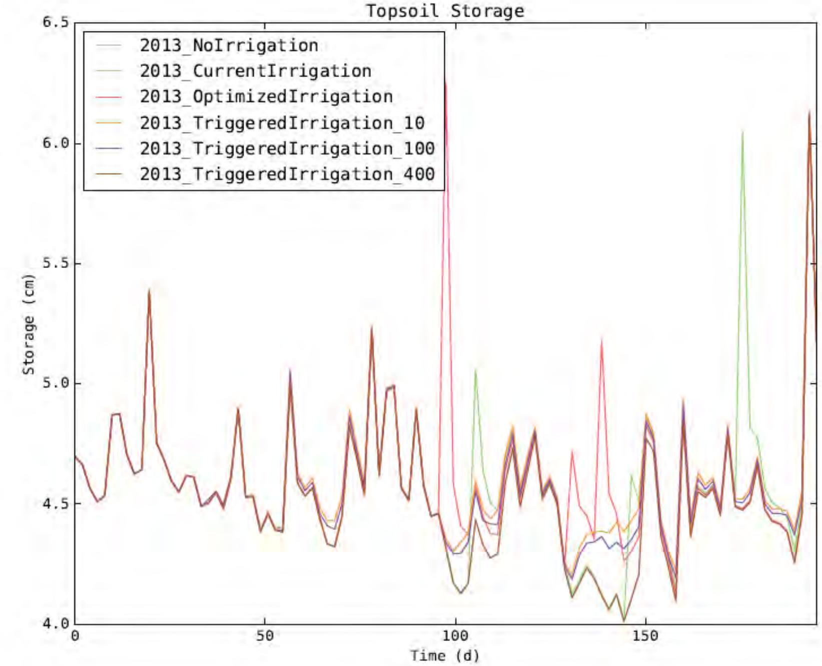
10 x 10 m

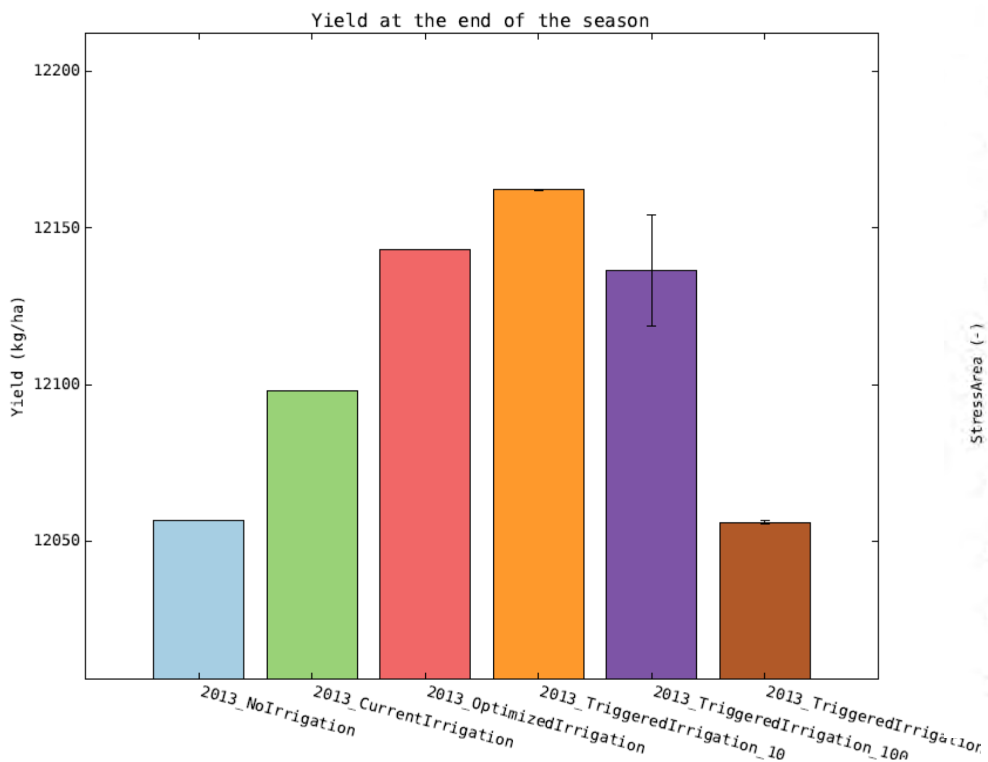


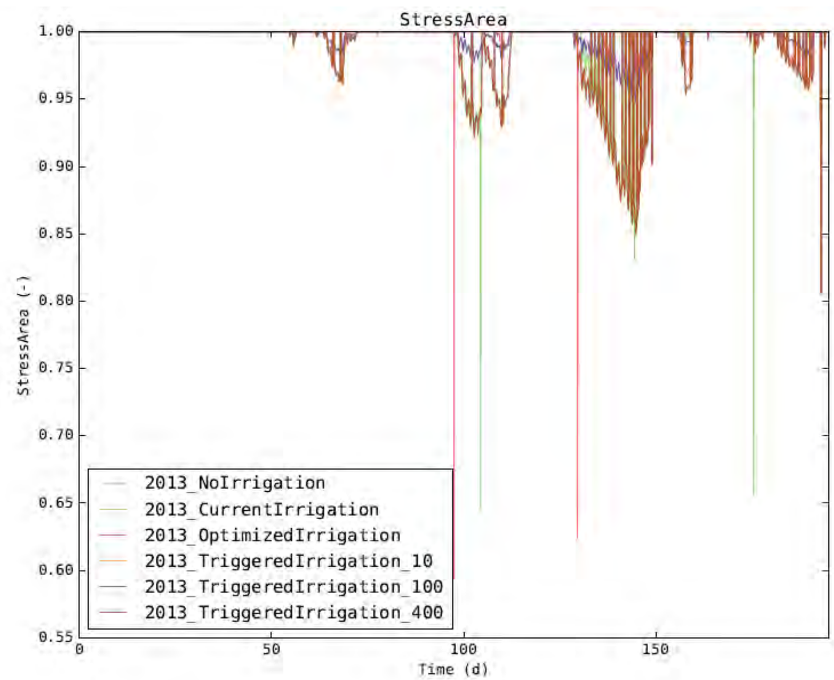
100 x 100 m




Total added Irrigation
Irrigation (cm)
0
2
4
6
8
10


Topsoil Storage
Storage (cm)
Time (d)
4.0
4.5
5.0
5.5
6.0
6.5
0
50
100
150
2013_NoIrrigation
2013_CurrentIrrigation
2013_OptimizedIrrigation
2013_TriggeredIrrigation_10
2013_TriggeredIrrigation_100
2013_TriggeredIrrigation_400


Yield at the end of the season
Yield (kg/ha)
12050
12100
12150
12200
2013_NoIrrigation
2013_CurrentIrrigation
2013_OptimizedIrrigation
2013_TriggeredIrrigation_10
2013_TriggeredIrrigation_100


StressArea
StressArea (-)
Time (d)
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
0
50
100
150
2013_NoIrrigation
2013_CurrentIrrigation
2013_OptimizedIrrigation
2013_TriggeredIrrigation_10
2013_TriggeredIrrigation_100
2013_TriggeredIrrigation_400

❖ Conclusion

❖ Our developed quasi 3D modeling approach was able to reproduce high resolution spatial patterns of soil water stress, water storage and crop yield more effectively which can help to optimize irrigation strategy adequately and practically.

a) A quick performance of the approach.

b) Higher resolution reduce the uncertainty of simulations.

c) uniform distribution of water is not an efficient approach.

d) Optimal irrigation scheduling reducing the water consumption up to 30% with respect to common irrigation practice -ensuring water productivity.

e) Economic benefit →up to 2570-3100 euro per year.

Acknowledgments

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- ✓ Gent University
- ✓ Flemish Institute for Technological Research (VITO)
- ✓ The farmer and field owner Jacob Van Den Borne

- ✓ Thanks you for your attention…

Further reading

- Rezaei, et al, 2016. Journal of Applied Geophysics, 126: 35-41.
- Rezaei, et al, 2016. Hydrology and Earth System Sciences, 20(1): 487-503.
- Rezaei, et al, 2016. Journal of Hydrology, 534: 251-265.