SWAT vs. SWAT-MODFLOW in lowland catchments:

Comparison of performance and simulation of groundwater abstraction scenarios

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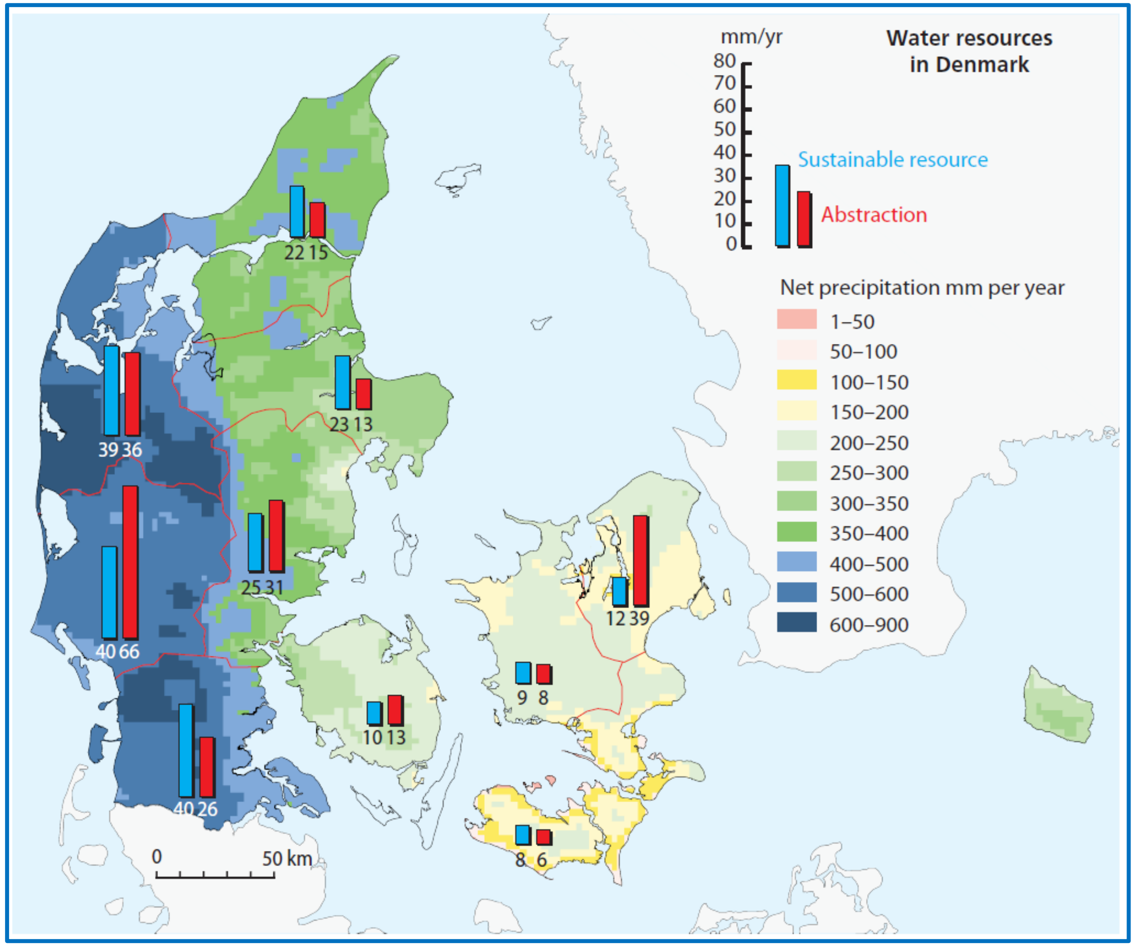
INTRODUCTION



GEUS (2008)

Danish drinking water supply: based entirely on groundwater

Additional abstraction for agricultural and industrial purposes

Some areas: groundwater exploitation above sustainable yield

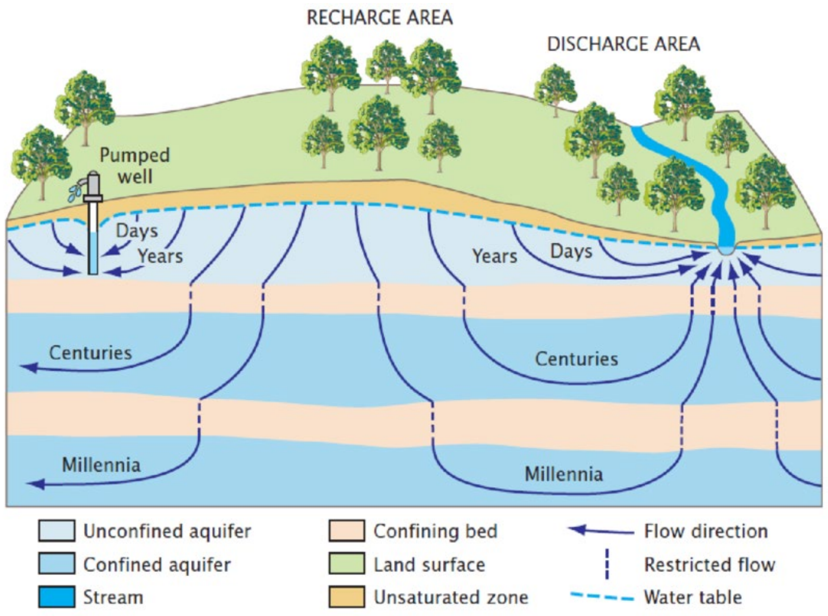
Average GW contribution to streamflow:
- 76% continent
- 59% islands

Vital importance of good understanding of GW processes and the GW-SW interactions

INTRODUCTION

Soil & Water Assessment Tool | SWAT

Simple approach to represent groundwater processes



Walker & Mallants (2014)

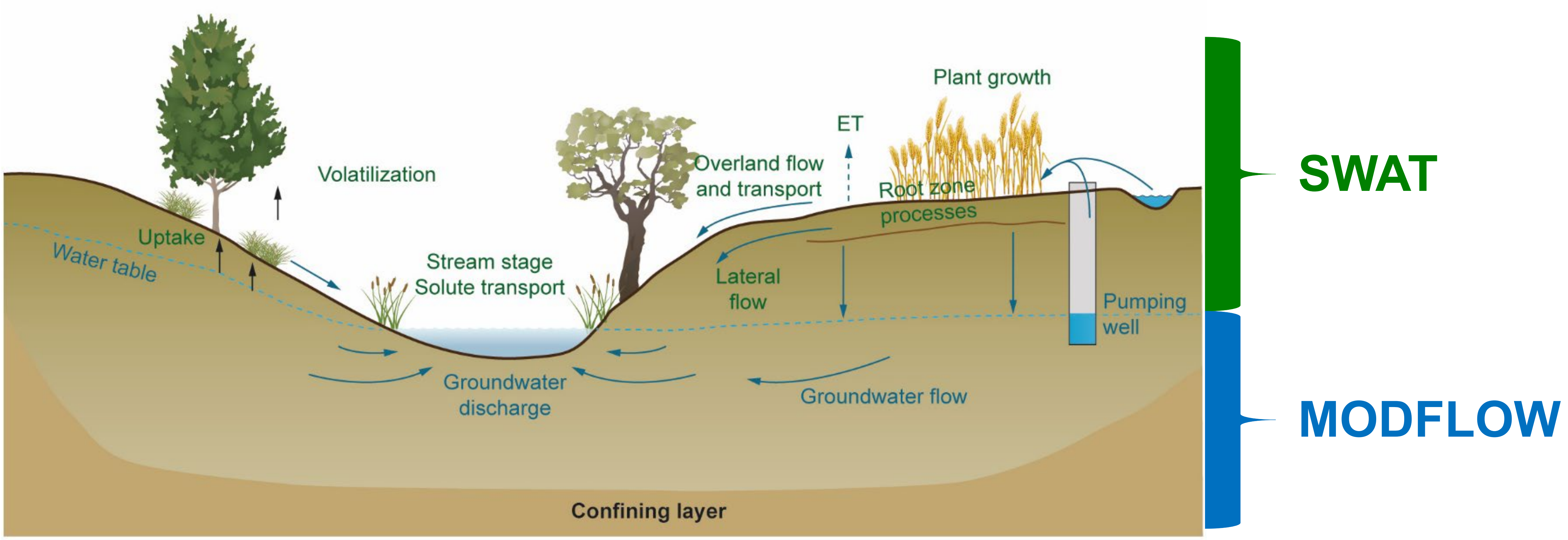
Accurate representation of GW processes is desirable.

- To know well how is the **interaction with surface water**

- To assess the impacts of **groundwater abstraction**

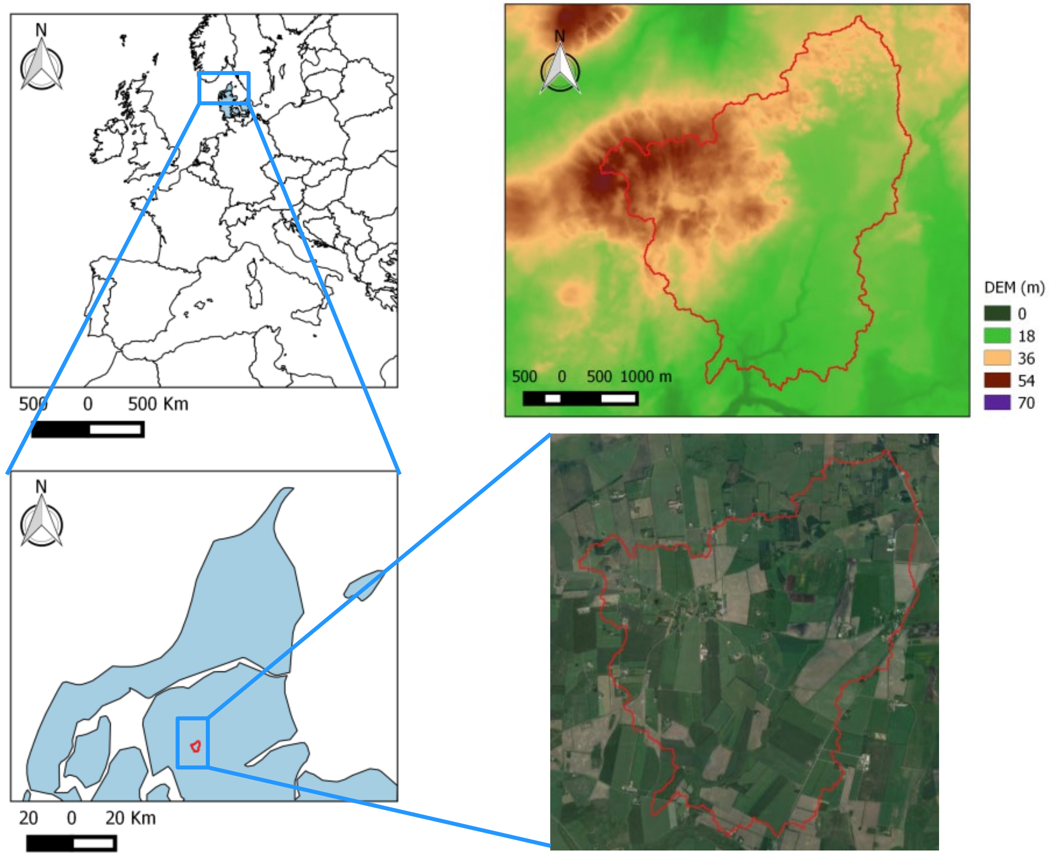
How to achieve it:
Coupling SWAT with a more detailed groundwater model

INTRODUCTION: SWAT-MODFLOW



Modified from Bailey et al (2017)

STUDY AREA: ODDERBÆK CATCHMENT



MAIN CHARACTERISTICS:

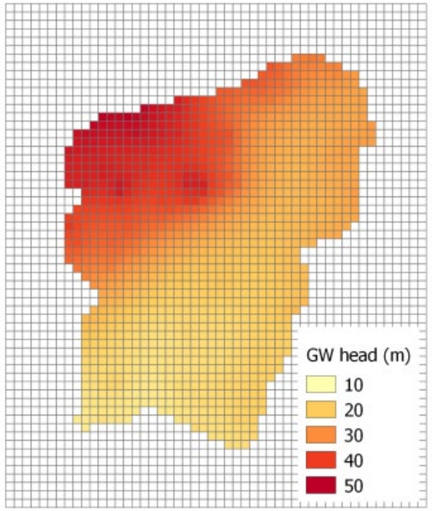
- **Area:** 1142 ha
- **Elevation range:** 11 m – 58 m
- **Main land use:** Agriculture (85%)
- **Climate:** Oceanic (warm temperate, fully humid)
    - Average P (2000-2015): 871 mm.
    - Average T (2000-2015): 12.3 ºC max, 5.4 ºC min

Gislum church

GOALS

Soil & Water Assessment Tool SWAT

Set-up a new SWAT model
with the latest version of Q-SWAT



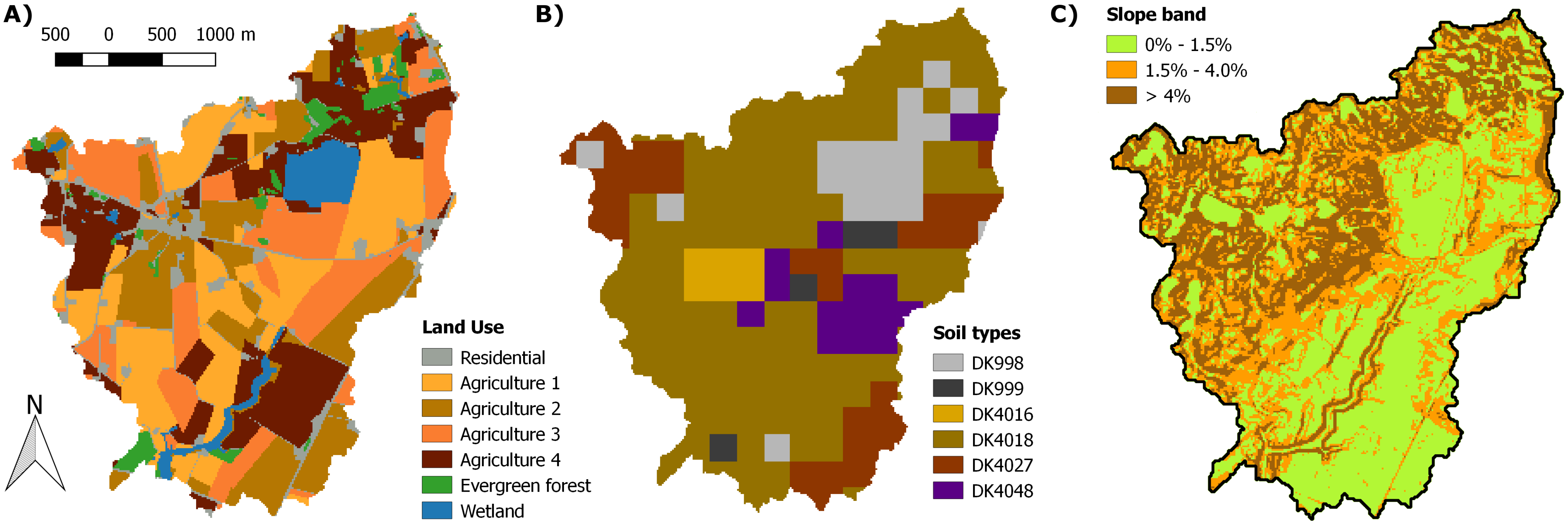
Couple the SWAT
model with a
MODFLOW model
provided by NIRAS
(SWAT-MODFLOW)

Calibrate both models
(SWAT and SWAT-MODFLOW)
using SWAT-CUP

Compare their
performances

Evaluate models
when simulating
abstraction
scenarios

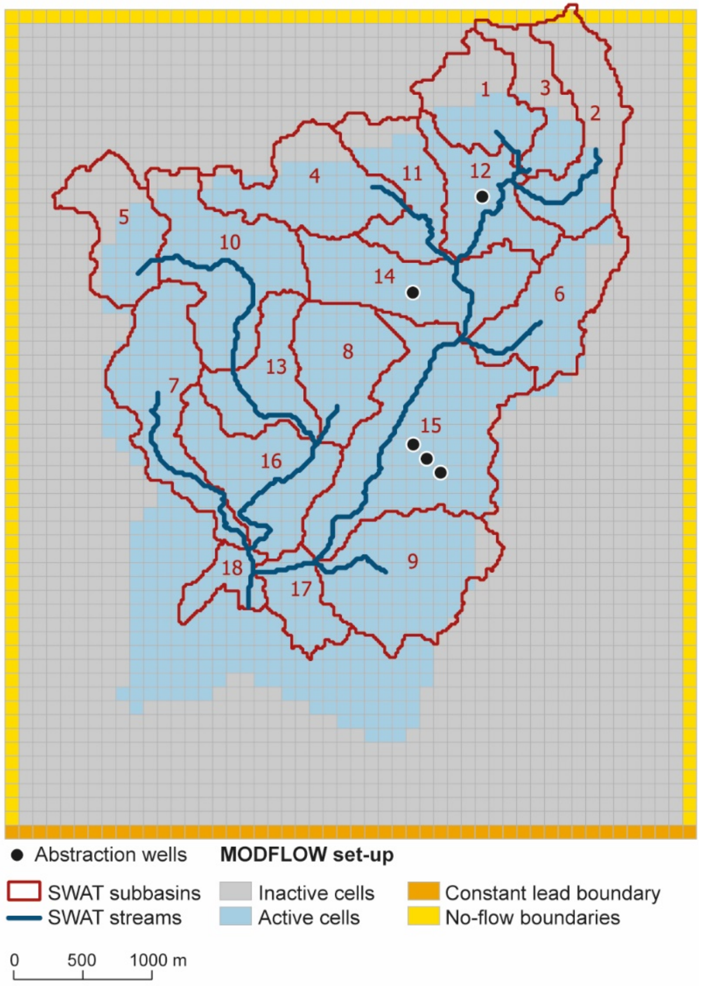
MODELS SET-UP: Q-SWAT



Pasture (0.68%) → Agriculture
Water (0.14%) → Wetlands
Roads = Residential

DK4037 (0.54%) → DK4027
DK4047 (0.54%) → DK4027

MODELS SET-UP: SWAT-MODFLOW COUPLING



MODFLOW MODEL (NIRAS)

- **100 m discretization**
- **Two aquifers with a clay layer in-between**
- **Pre-calibrated** (Sørensen and Jensen, 2009)

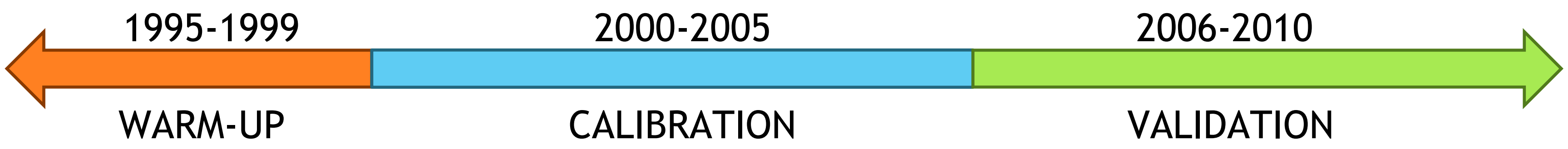
COUPLING PROCEDURE:

FIRST: Disaggregate HRUs into DHRUs (individual polygons)

SECOND: LINKAGES

- **SWAT DHRUs ↔ MODFLOW grid cells**
- **SWAT SUBBASINS ↔ MODFLOW river cells**
- **Done through GIS routines** (Bailey et al., 2016, 2017)

CALIBRATION AND VALIDATION



Flow data

SWAT: 24 parameters
S-M: 17 parameters

Expert knowledge

Molina-Navarro *et al.* (2017)
Environmental Modelling & Software

ADDITIONALLY IN SWAT-MODFLOW

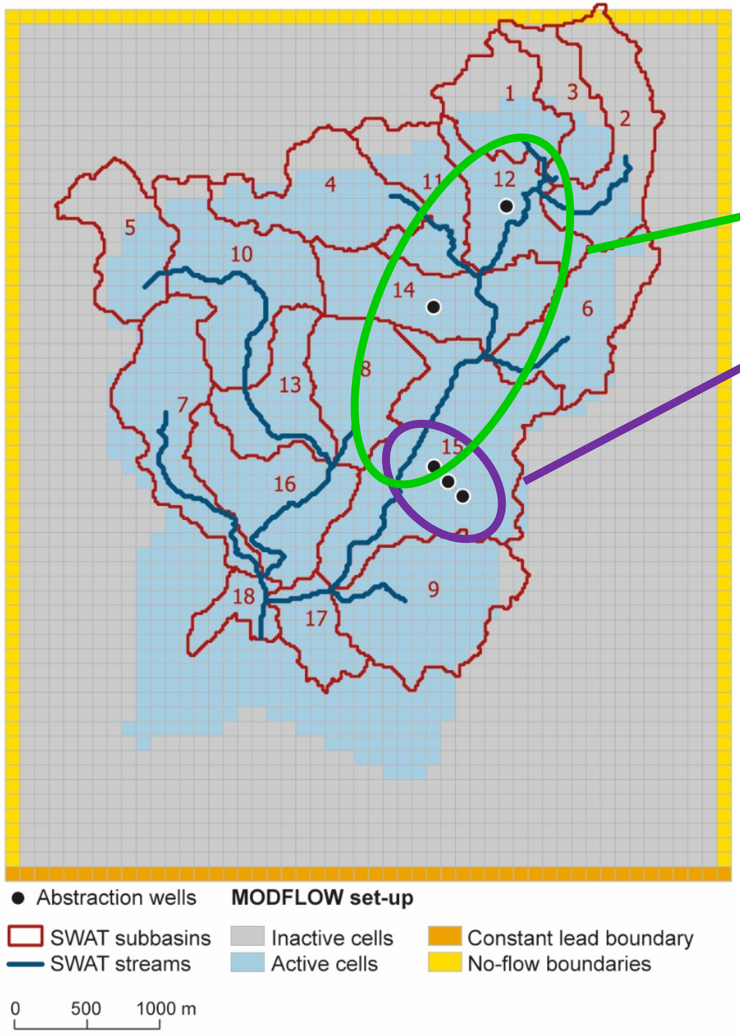
BEFORE SWAT-CUP:

- Preliminary iteration of 300 simulations
- OAT manual sensitivity analysis of MODFLOW´s River Package parameters
- Manual calibration of River Package parameters.
- SWAT parameters calibration

AFTER SWAT-CUP:

- Fine-tunning of sensitive parameters in the River Package

SCENARIOS SIMULATION



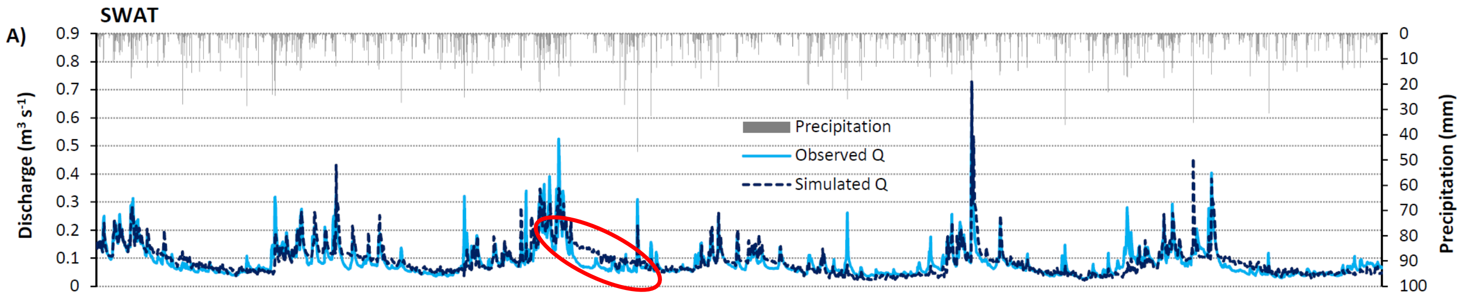
3 abstraction wells, one each in subbasins 12, 14 and 15

3 abstraction wells, all in subbasin 15

- High abstraction rate (water supply, deep)
- Low abstraction rate (irrigation, shallow)

3 SCENARIOS ➔ Impacts on streamflow

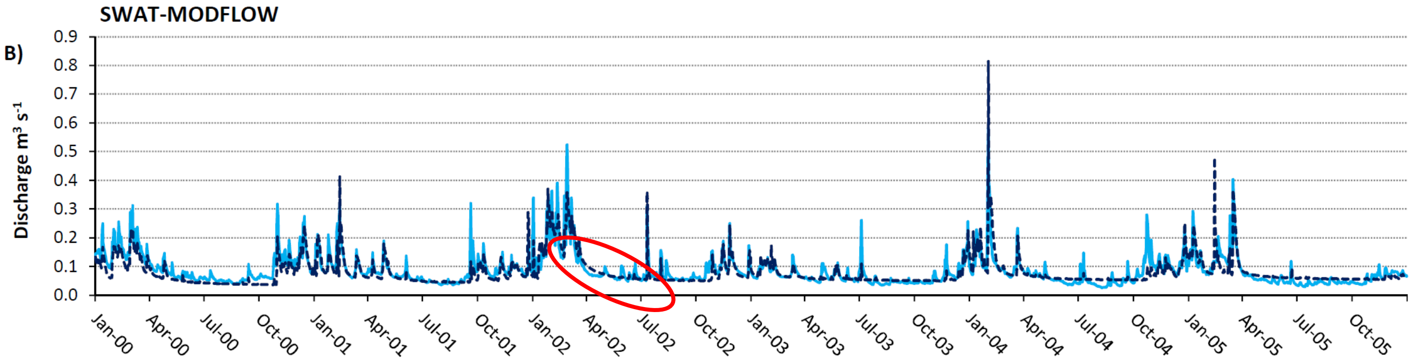
RESULTS: CALIBRATION



SWAT:

R^2=0.69
NSE=0.64
PBIAS=-4.4

P (mm)	875
SUR Q (mm)	8
LAT Q (mm)	8
TILE Q (mm)	37
GW Q (mm)	200
ET (mm)	574
PET (mm)	669

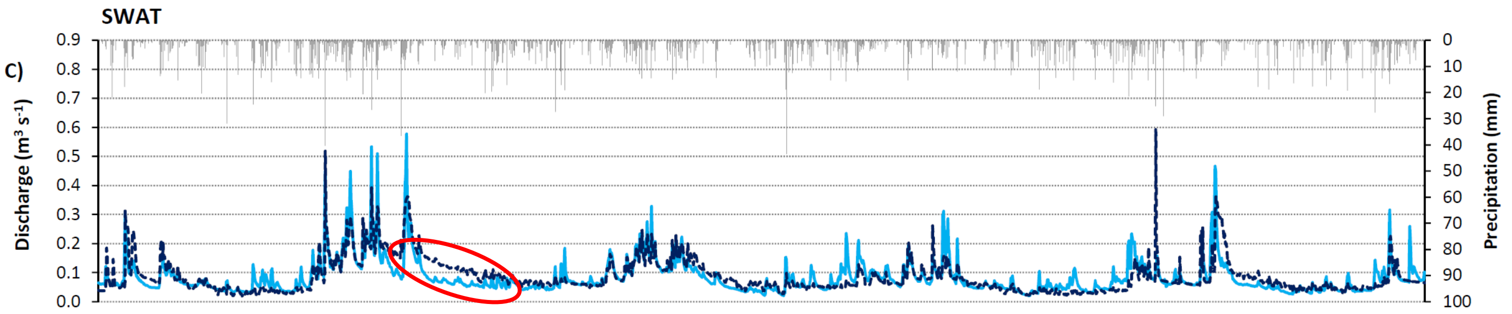


SWAT-MODFLOW:

R^2 = 0.71
NSE = 0.69
PBIAS = 7.0

P (mm)	875
SUR Q (mm)	12
LAT Q (mm)	1
TILE Q (mm)	38
GW Q (mm)	174
ET (mm)	570
PET (mm)	669

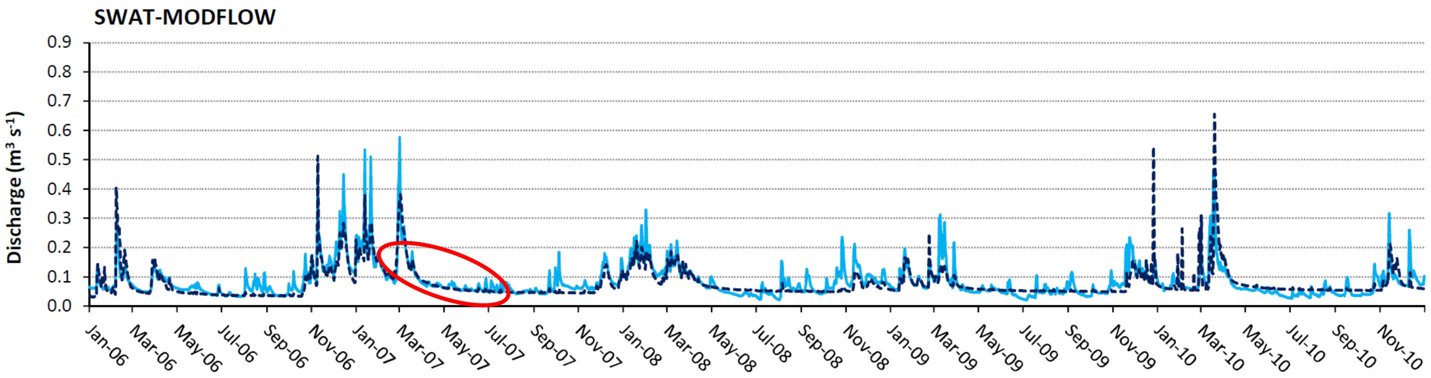
RESULTS: VALIDATION



SWAT:

R^2=0.64
NSE=0.59
PBIAS=-2.6

P (mm)	889
SUR Q (mm)	8
LAT Q (mm)	8
TILE Q (mm)	39
GW Q (mm)	185
ET (mm)	565
PET (mm)	690



SWAT-MODFLOW:

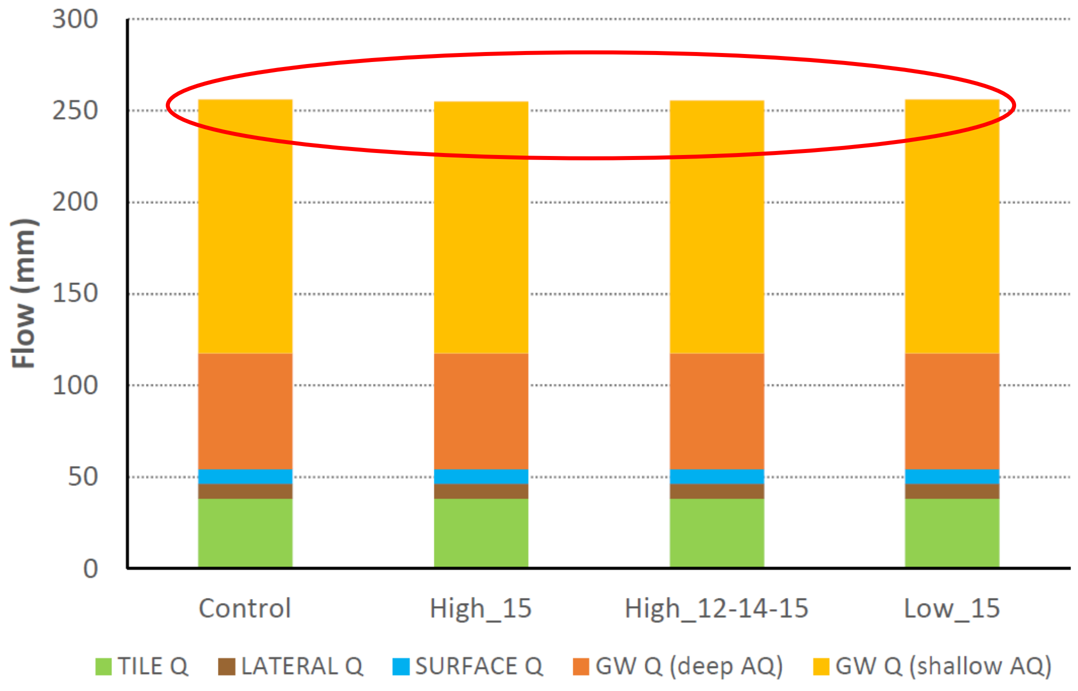
R^2 = 0.68
NSE = 0.65
PBIAS = 7.6

P (mm)	889
SUR Q (mm)	13
LAT Q (mm)	1
TILE Q (mm)	40
GW Q (mm)	162
ET (mm)	562
PET (mm)	691

RESULTS: ABSTRACTION SCENARIOS

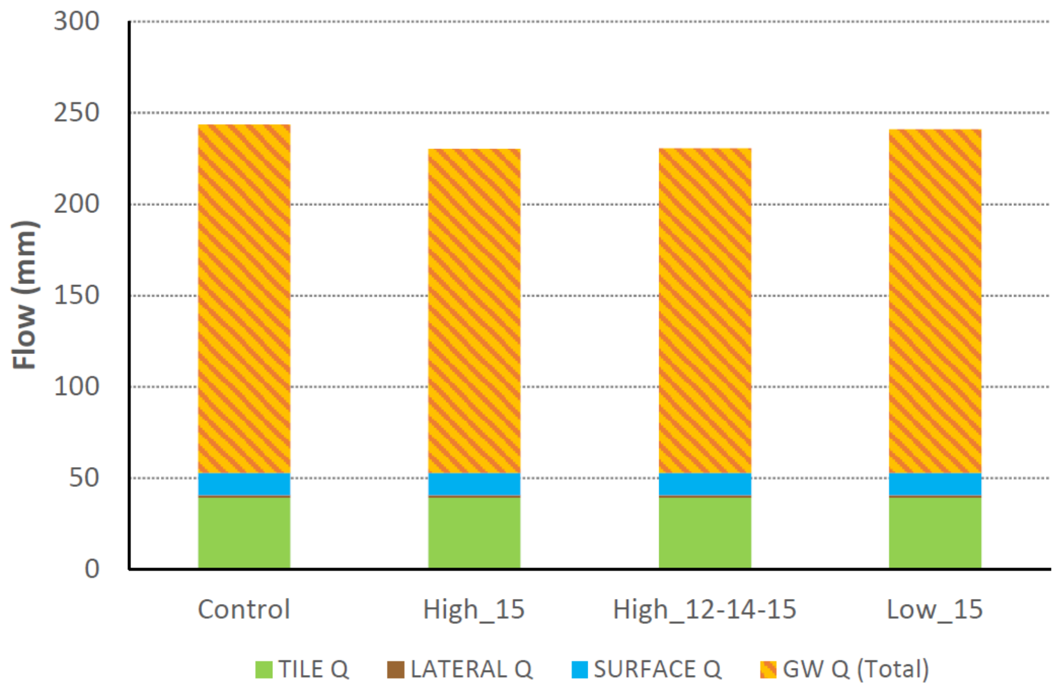
SWAT

A)



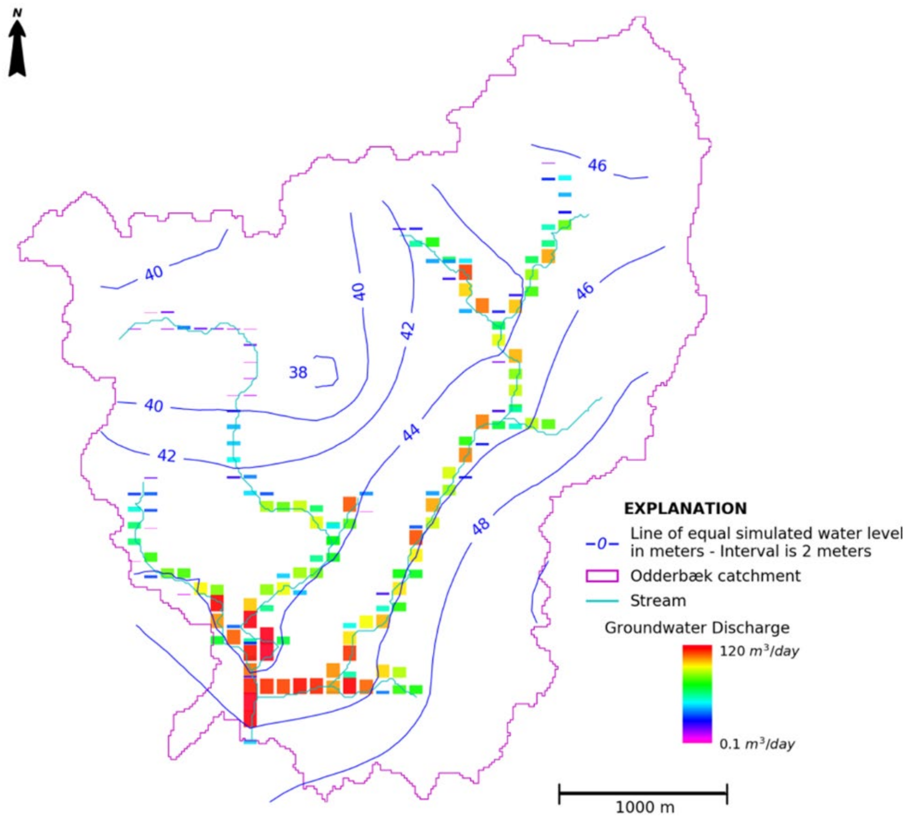
SWAT-MODFLOW

B)

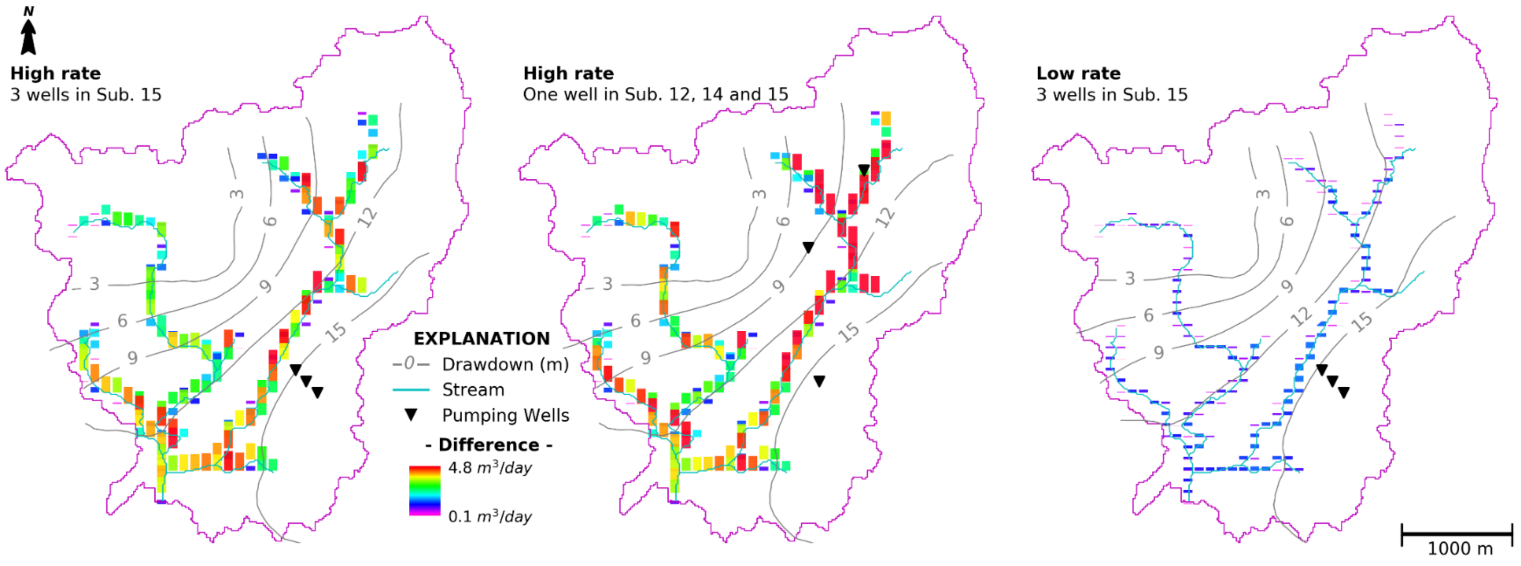


ADDITIONAL SWAT-MODFLOW OUTPUTS

Average daily rate of stream-aquifer water exchange (control)



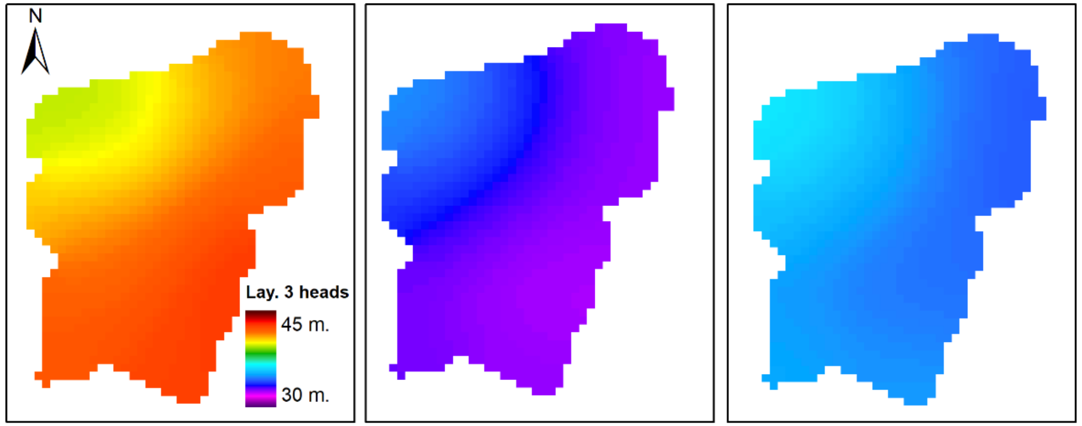
Difference in average stream-aquifer water exchange vs. control



SWAT-MODFLOW allows to explore the **spatial variability** of groundwater discharge at a cell level, evaluating the impacts of the scenarios

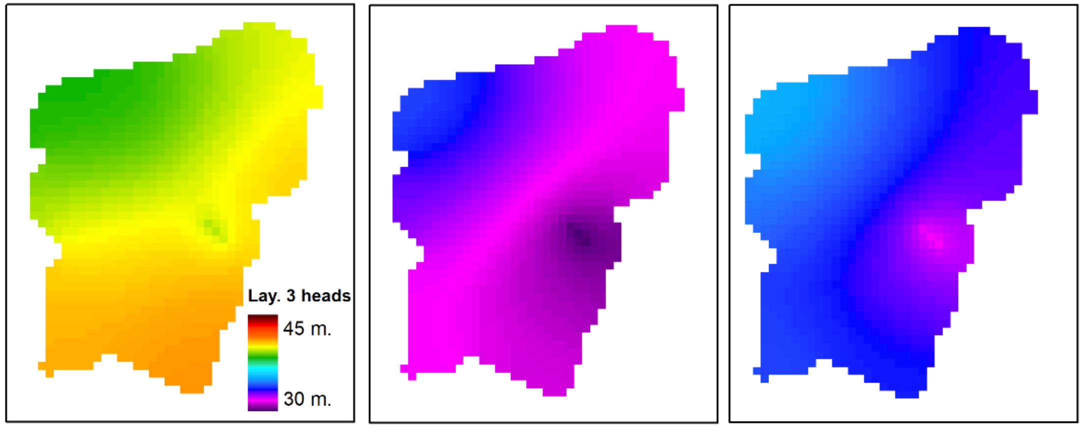
ADDITIONAL SWAT-MODFLOW OUTPUTS

CONTROL SCENARIO

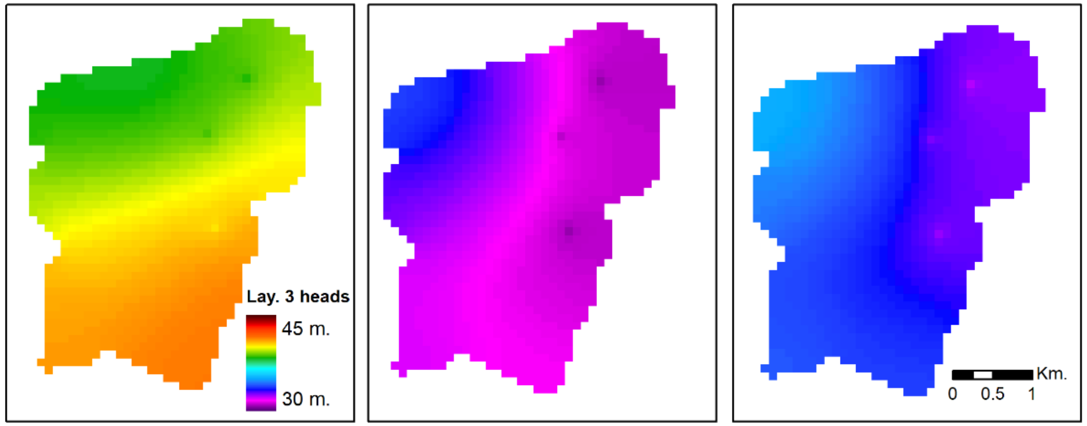


START (01/01/2000) MID (31/12/2005) END (31/12/2010)

THREE WELLS IN SUB-BASIN 15



ONE WELL IN SUB-BASINS 12, 14 and 15



START (01/01/2000) MID (31/12/2005) END (31/12/2010)

SWAT-MODFLOW allows to explore the impacts of the scenarios in the **water table elevation**

CONCLUSIONS

MODEL PERFORMANCE

- ✓ **Both models showed a good statistical performance** (first time this version of SWAT-MODFLOW is successfully applied in a catchment of this characteristics).
- ✓ **SWAT-MODFLOW** performs better during periods of **hydrograph recession**.

ABSTRACTION SCENARIOS SIMULATION

- ✓ **SWAT-MODFLOW** yielded **more realistic** results than SWAT, simulating a decrease in streamflow close to the abstracted water volume.
- ✓ In **SWAT**, groundwater in the **"deep aquifer"** was **not affected**, besides being numerical input limitations.
- ✓ **SWAT-MODFLOW allows wider possibilities** for groundwater analysis, e.g. spatial distribution of stream-aquifer exchange or water table elevations.

RESULTS SUPPORT THE USE OF SWAT-MODFLOW INSTEAD OF SWAT IN CATCHMENTS WHEREIN GROUNDWATER IS A DOMINANT COMPONENT OF STREAM FLOW

THANKS FOR YOUR ATTENTION

Questions?

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