2010 International SWAT conference

Comparison of the SWAT model versus the DAISY-MIKE SHE model for simulating the flow and nitrogen processes

Case study: Odense river basin, Denmark

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INTRODUCTION

The EU Water Framework Directive (WFD) has introduced a new approach in 2000 which has some significant changes:

- Address pollution problems at the river basin scale
- Establish water quality policies on water quality objectives (immision-based) rather than on emission limit value (emission-based)

Catchment modelling is a useful tool to estimate the pollutant loads from diffuse sources in the catchment to the river.

SWAT and MIKE-SHE are two catchment models with different approaches

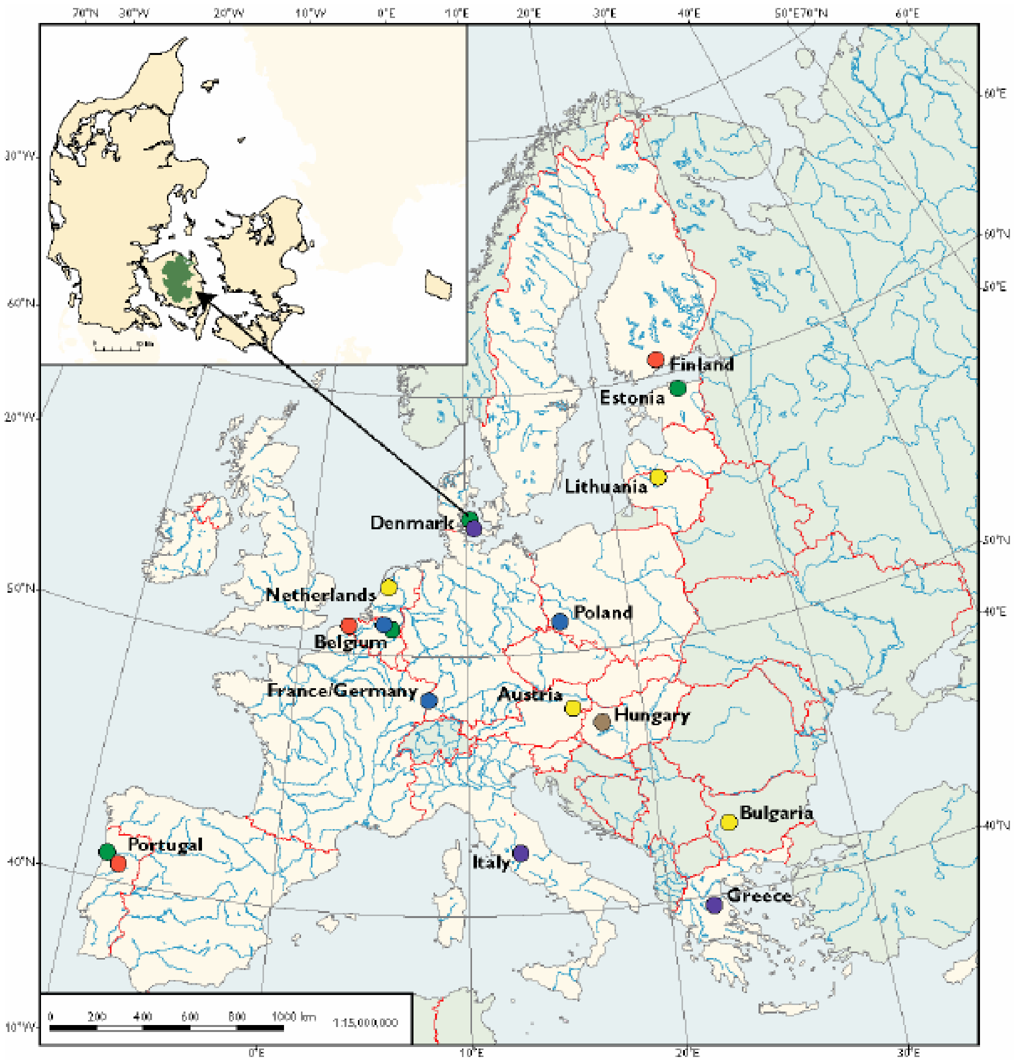
- SWAT is semi-distributed model in which all processes are lumped at hydrological response unit (HRU) level.
- MIKE-SHE is a fully distributed physically based hydrological catchment model which simulates all processes at grid level. MIKE-SHE is coupled with the crop model DAISY to simulate the crop yield and nitrogen cycle in the catchment.

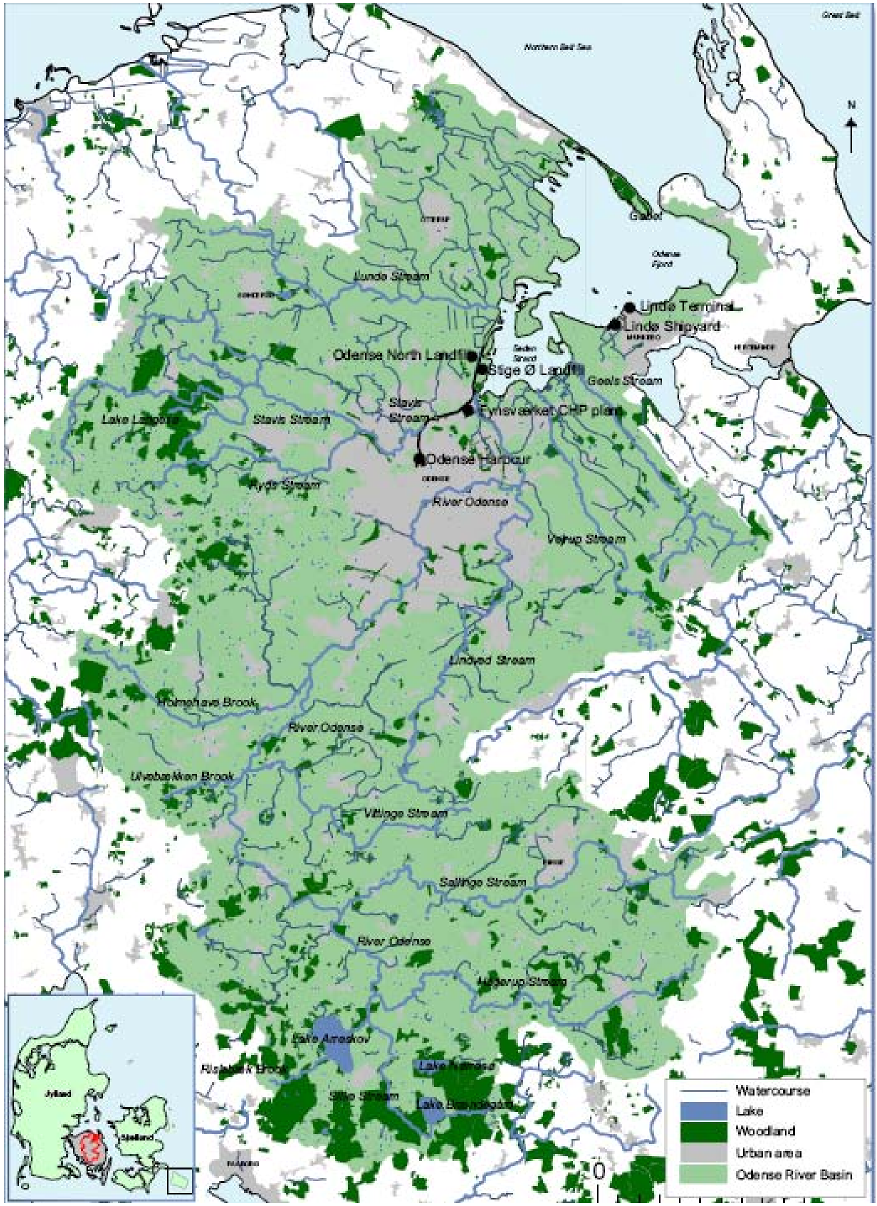
OBJECTIVES

1 Set up the SWAT model for the Odense river basin for simulating hydrology and nitrogen transport and transformation

2 Evaluate of the performance of SWAT in modelling water quantity and nitrogen by comparison to observations and previous DAISY-MIKE SHE model simulations.

STUDY AREA: Odense river basin

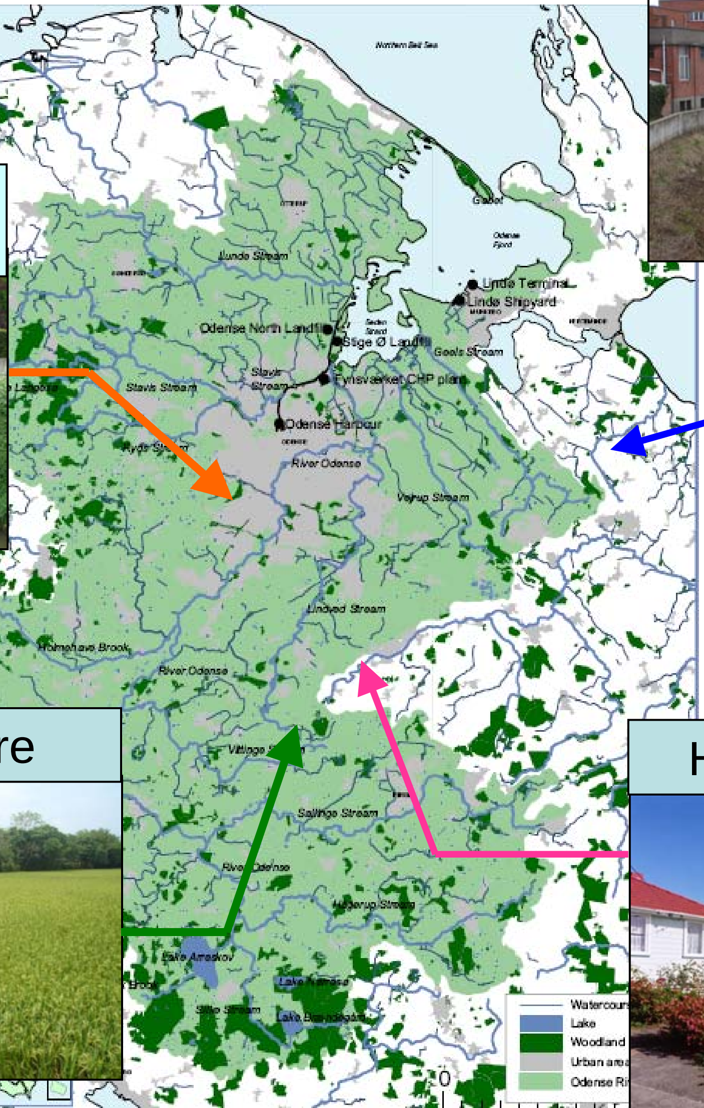




STUDY AREA: Odense river basin

Pressure on water quality

- ✓25 WWTPs
- ✓489 stormwater outfalls, 204 from combined and 285 from separate sewerage system



WWTPs and stormwater outfalls

Industry

- ✓1870 registered farms in 2000
- ✓960 is livestock holdings
- ✓Livestock density: 0.9 unit/ha

Agriculture

Households

SWAT model set up for Odense river

SWAT MODEL SET UP FOR ODENSE RIVER

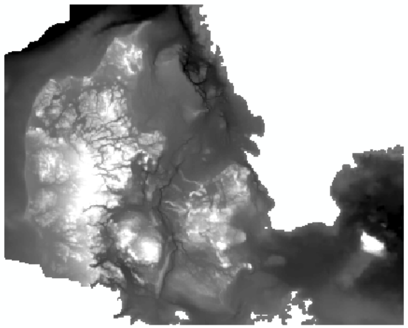
1. Data collection

No.	Data	Purpose
1	Catchment data (topology, geology, land use, soil map)	Build catchment models
2	Meteorological data	Input for catchment models
3	Hydrological data (discharge)	Calibrate hydrological models
4	Water quality data	Calibrate water quality models
5	Pollutant loadings from point sources (households, industries, WWTPs, etc)	Inputs for water quality models
6	Diffuse source data (Agriculture and farming data)	Inputs for water quality models

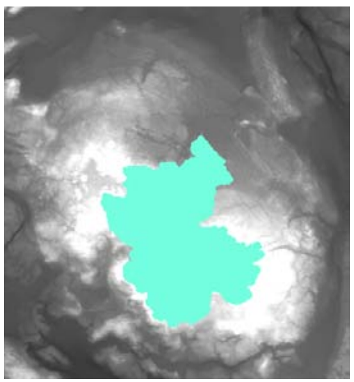
SWAT MODEL SET UP FOR ODENSE RIVER

2. Watershed delineation

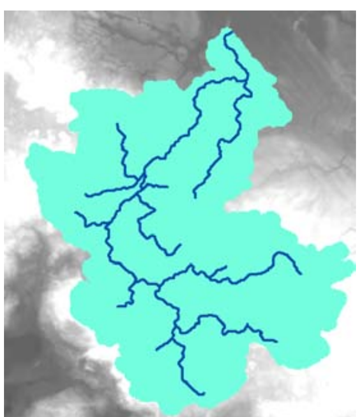
DEM

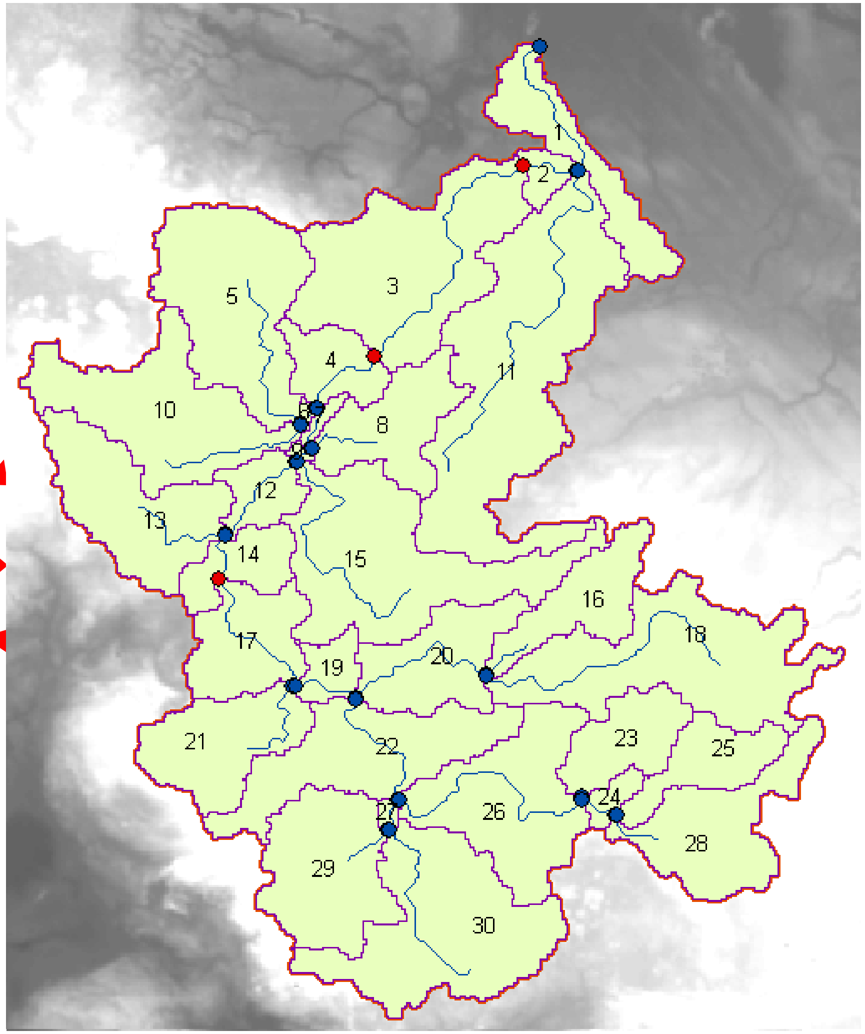


Mask



Burn_in river





-30 subbasins

-30 outlets in which 3 correspond to gauging stations

-1 point source/ subbasin

SWAT MODEL SET UP FOR ODENSE RIVER

3. HRU definition

Soil map

Horizon A
- Raster map of % sand
- Raster map of % silt
- Raster map of % clay

→ Convert to vector maps → Overlay, Classify to JB → JB map for horizon A

Horizon B → JB map for horizon B

Horizon C → JB map for horizon C

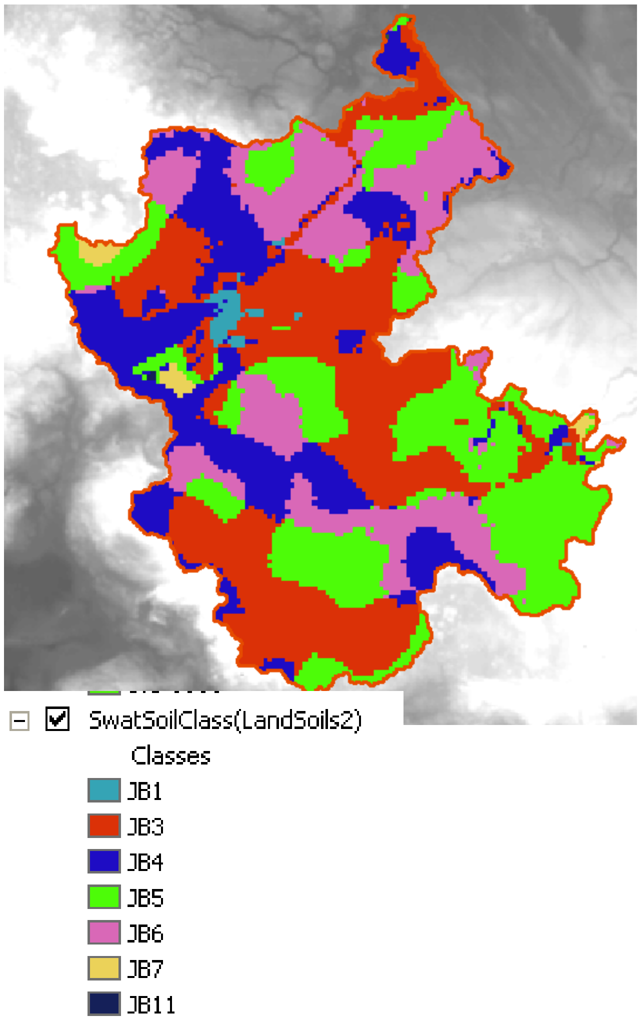
The number of soil profiles when overlay the 3 maps is too big

Assume that JB map for horizon B and C is the same as horizon A.

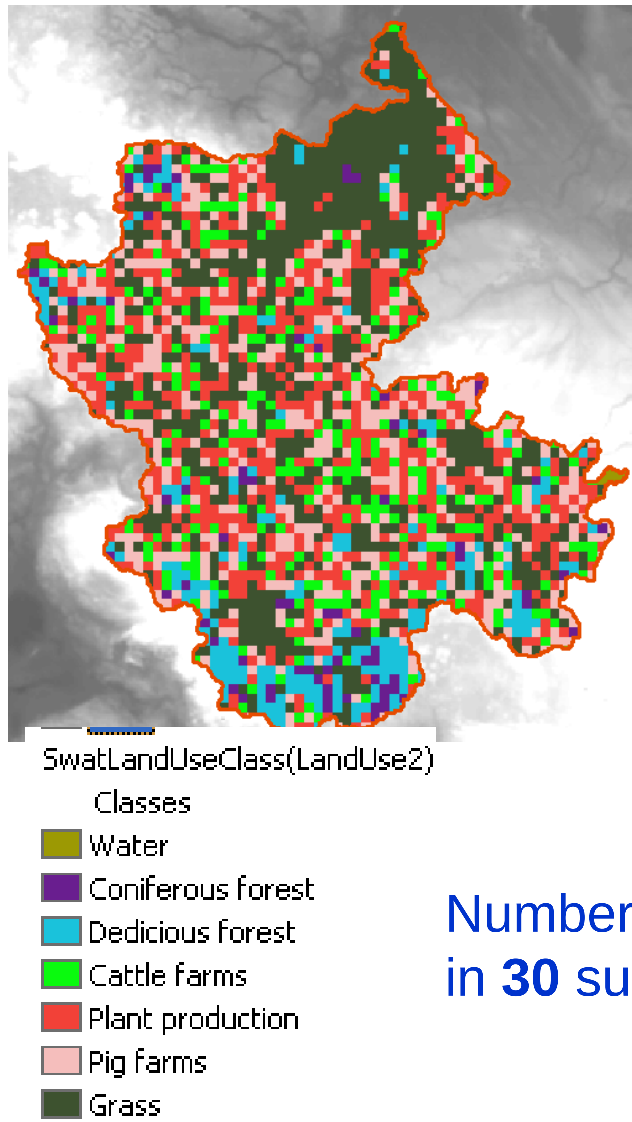
SWAT MODEL SET UP FOR ODENSE RIVER

3. HRU definition

Soil



Land use



Slope

Divided in 2 class:

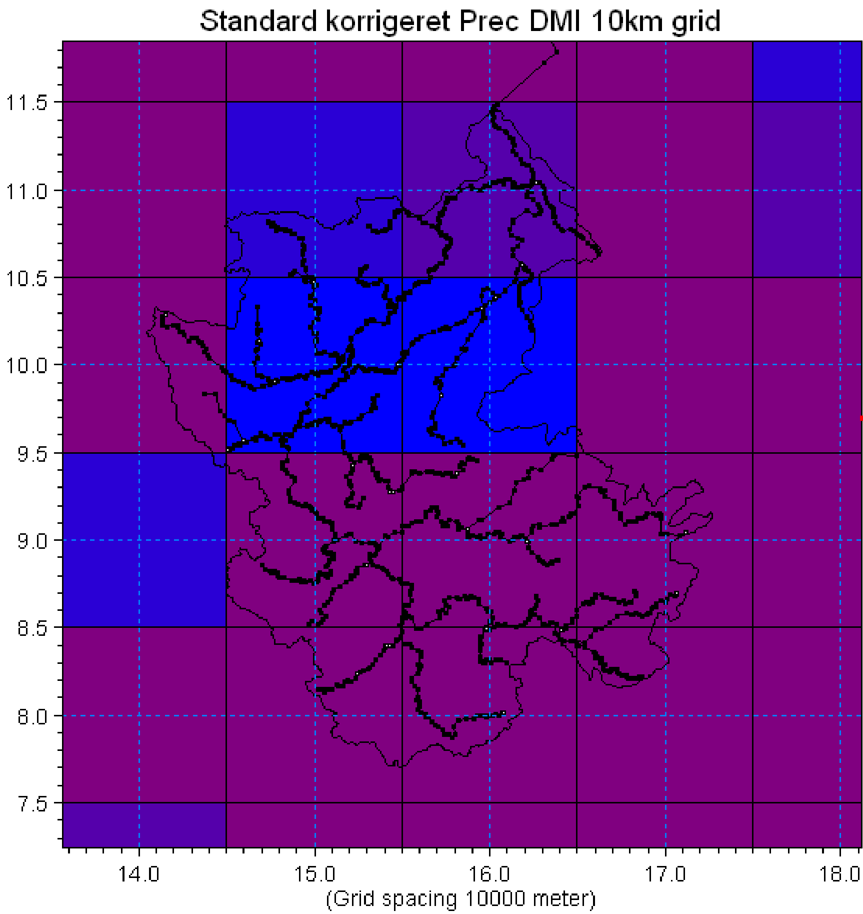
0-0.3

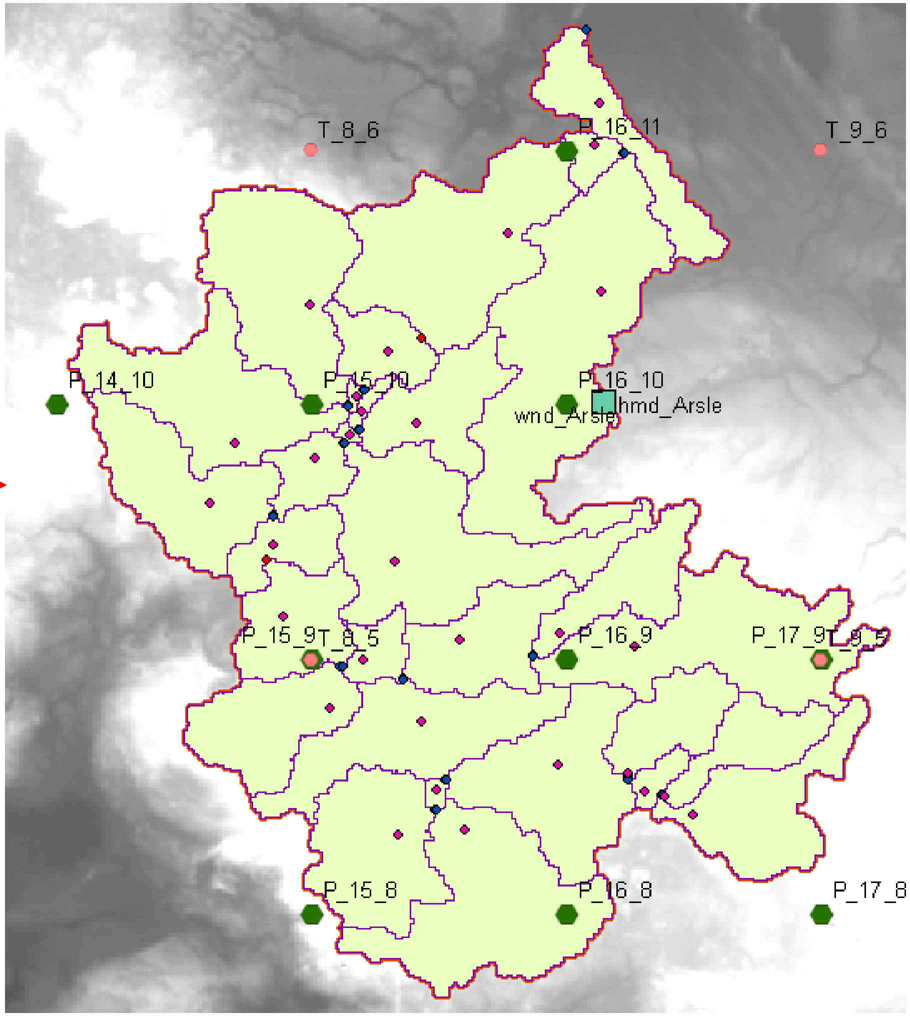
0.3-1999

Number of HRUs created : **654** in **30** subbasins

SWAT MODEL SET UP FOR ODENSE RIVER

4. Define weather stations





11 stations for precipitation

4 stations for temperature

1 station for Solar radiation, wind, humidity

SWAT MODEL SET UP FOR ODENSE RIVER

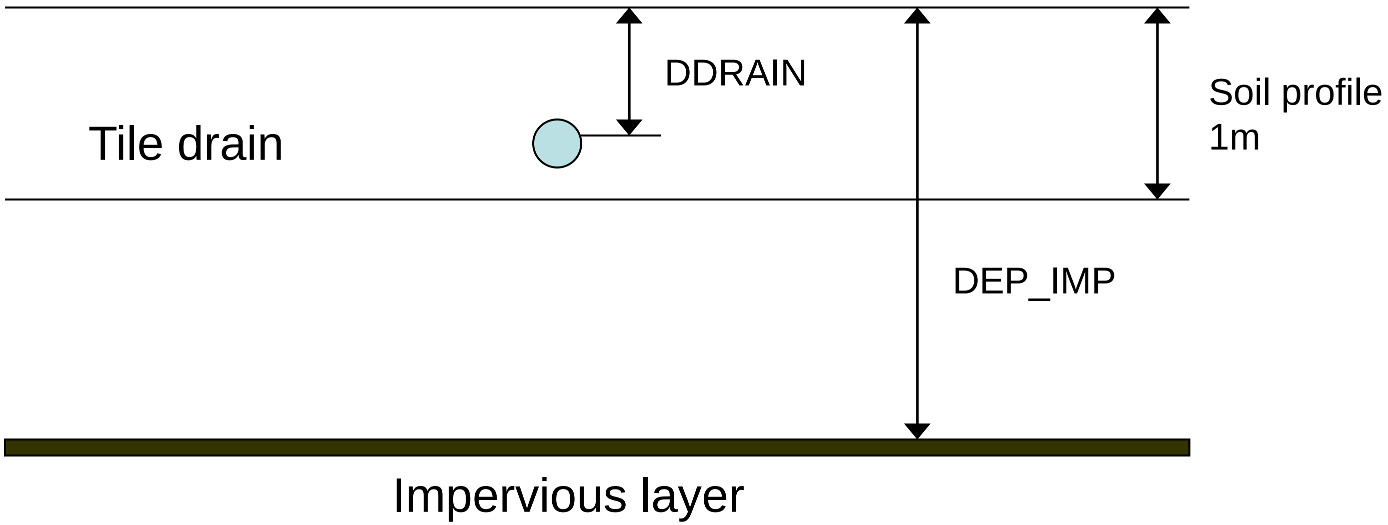
5. Tile drainage

The model was built in 2 versions: with and without tile drainage

Drainage was handled using the tile drainage option in management files in SWAT.

The depth from soil surface to tile drainages (DDRAIN) was set at 0.5 m in every HRU.

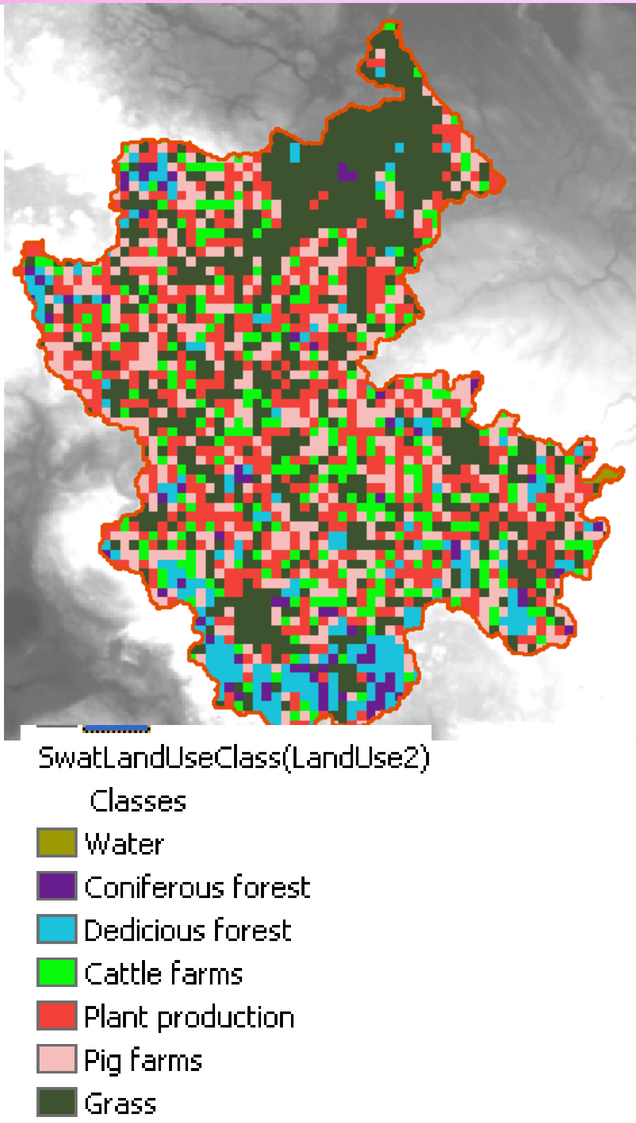
The depth to impervious layer DEP_IMP was set at 3000 mm for the whole basin to allow the rising of perched water table which generate tile flow. If groundwater table height exceeds the height of tile drains above the impervious zone, tile drainage will occur.



SWAT MODEL SET UP FOR ODENSE RIVER

6. Crop rotation

No.	Type of landuse	% of area	Crop rotation
1	Cattle farms	11.5	Spring Barley (year 1), Grass (year 2), Winter wheat (year 3), Maize (year 4)
2	Plant production	25.2	Spring Barley (year 1), Grass (year 2), Winter wheat (year 3 + year 4)
3	Pig farms	19.8	Spring Barley (year 1), Grass (year 2), Winter wheat (year 3), Winter barley (year 4)
4	Grass	32.0	Grass (year 1-4)
5	Coniferous forest	3	
6	Dedicious forest	8.5	



SWAT MODEL SET UP FOR ODENSE RIVER

7. Write input files

Input data is written based on input data and default values

8. Run SWAT

Time step: 1 day

Simulation period: 1990-2003

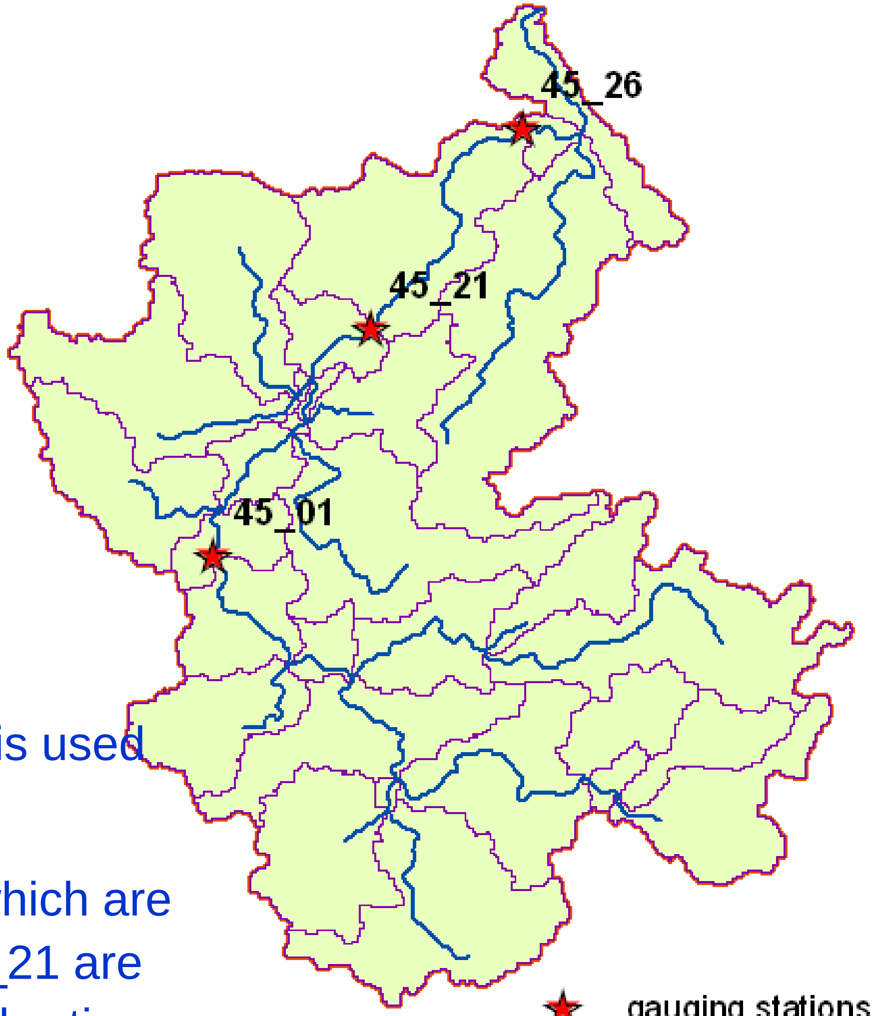
1990-1993: warming-up period

1994-1998: calibration period

1999-2000: validation period

Result from the outlet of subbasin 3 which is corresponding to the gauging station 45_26 is used for flow calibration.

Results from outlets of subbasin 4 and 17 which are corresponding to gauging station 45_01, 45_21 are also compared with measured data after calibration



SWAT MODEL SET UP FOR ODENSE RIVER

8. Evaluation

To evaluate SWAT performance for the simulated discharge and nitrogen flux, the following criteria were used:

- ✓ $R^2_{Q,\text{ daily or annual}}$: the model efficiency calculated on the basis of observed and simulated daily or annual discharge values (Nash and Sutcliffe, 1970).
- ✓ $R^2_{N,\text{ daily or annual}}$: the model efficiency calculated on the basis of observed and simulated daily or annual total nitrogen flux (Nash and Sutcliffe, 1970).
- ✓ $r_{Q,\text{ daily or annual}}$: the correlation coefficients between simulated and observed daily or annual discharge.
- ✓ $r_{N,\text{ daily or annual}}$: the correlation coefficients between simulated and observed daily or annual total nitrogen flux.

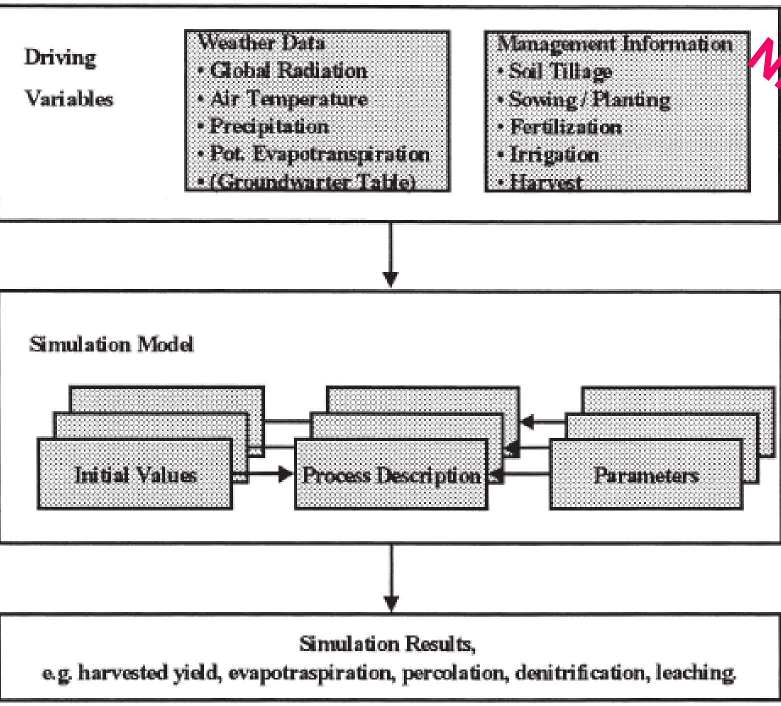
DAISY-MIKE SHE MODEL

DAISY

DAISY is a one-dimensional crop model that simulates crop production and crop yield, water dynamics, soil temperature, the carbon and nitrogen cycle of the root zone (Abrahamsen and Hansen, 2000; Hansen et al., 1991).

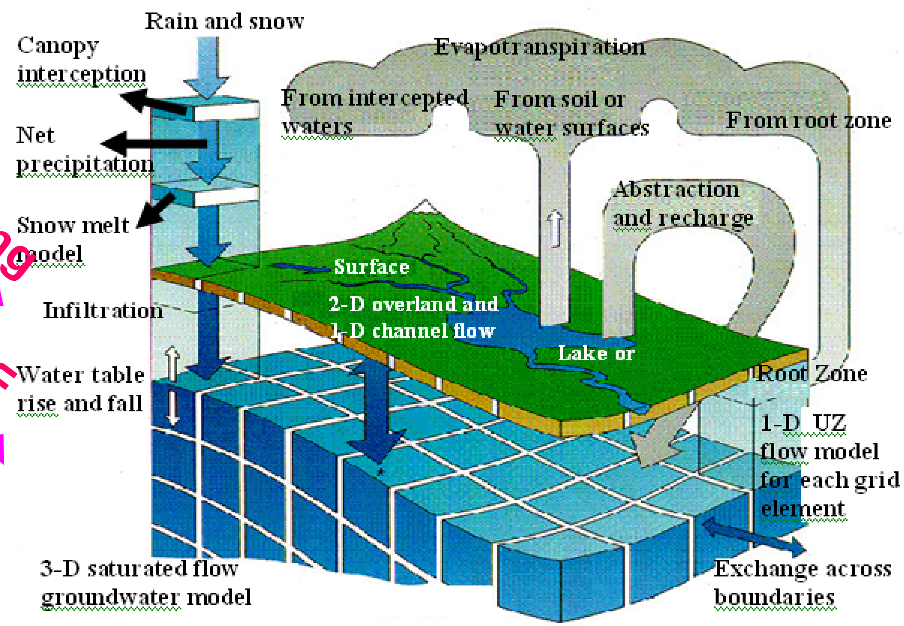
MIKE SHE

MIKE-SHE is a fully distributed physically based hydrological catchment model which can simulate all hydrological domains within the land phase of the hydrological cycle (Refsgaard and Storm, 1995).



Nitrate leaching

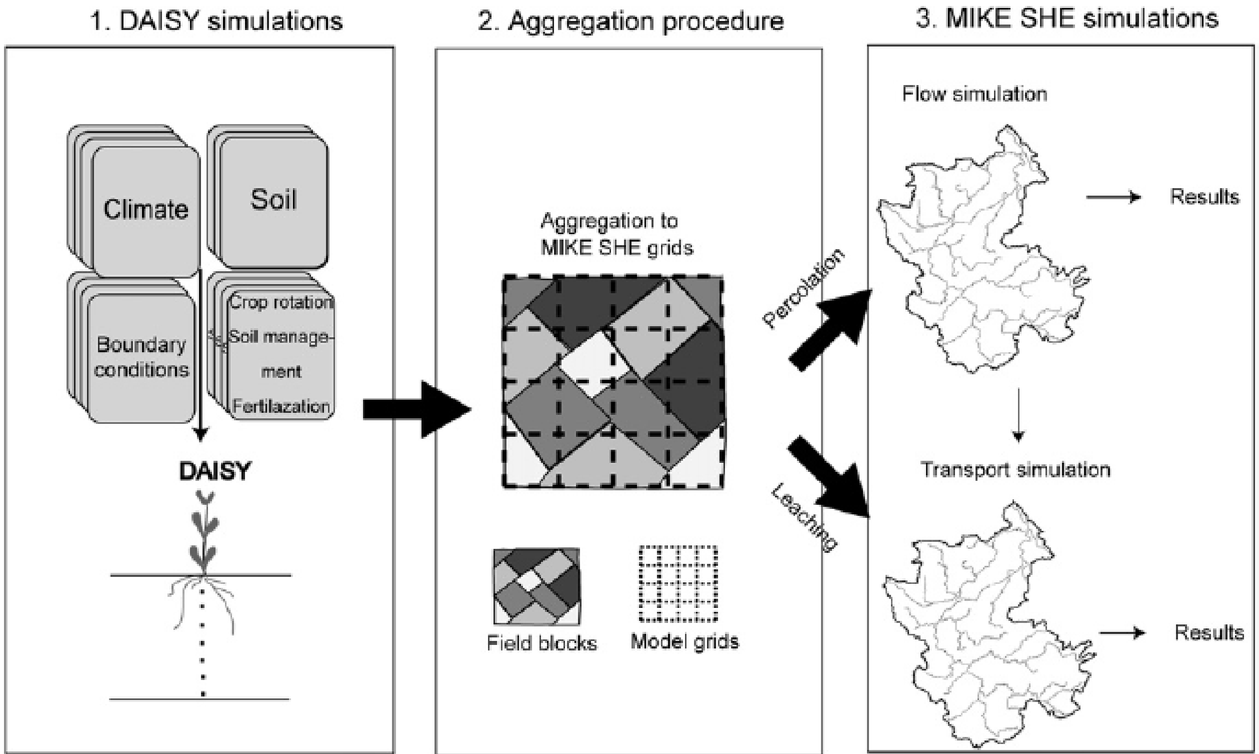
Water percolation



DAISY-MIKE SHE MODEL

Coupling of DAISY and MIKE SHE models

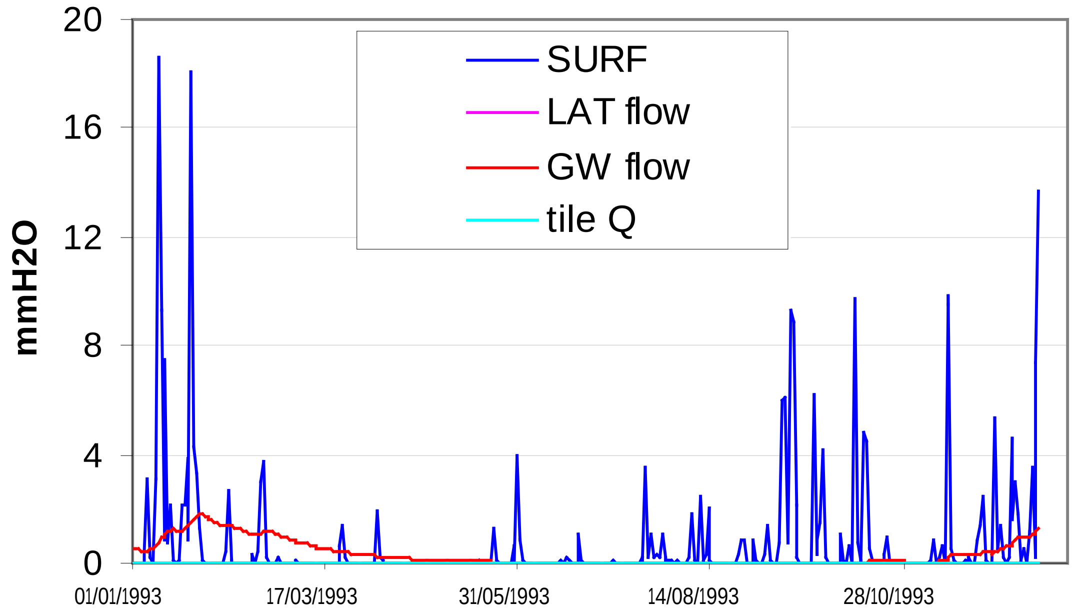
- ✓ DAISY substitutes the unsaturated zone of MIKE SHE.
- ✓ DAISY and MIKE SHE are coupled sequentially without any feedback from the groundwater and river to the rootzone.
- ✓ DAISY used groundwater level as boundary condition while MIKE SHE also simulates it in the saturated zone. Drain pipe is applied in DAISY as one of the boundary conditions and drainage was simulated in DAISY while drain flow also was simulated in the saturated zone in MIKE SHE.



RESULT AND DISCUSSION

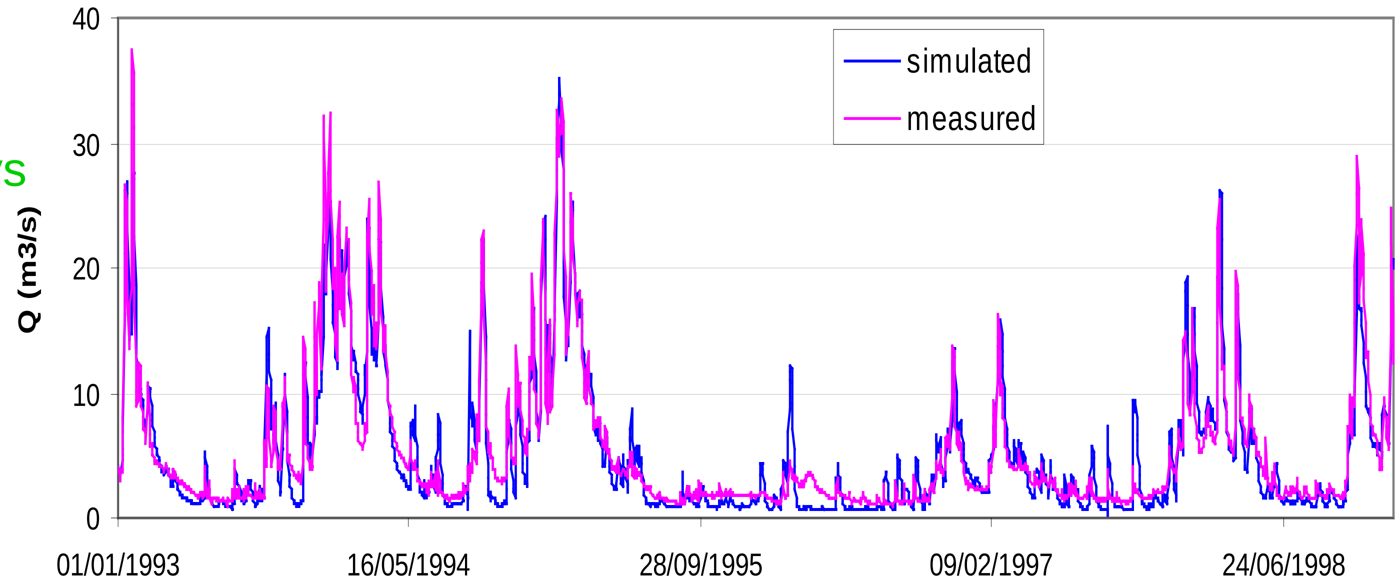
Performance of SWAT model in flow simulation

Flow composition



WITHOUT TILE DRAINS

Simulated vs measured data

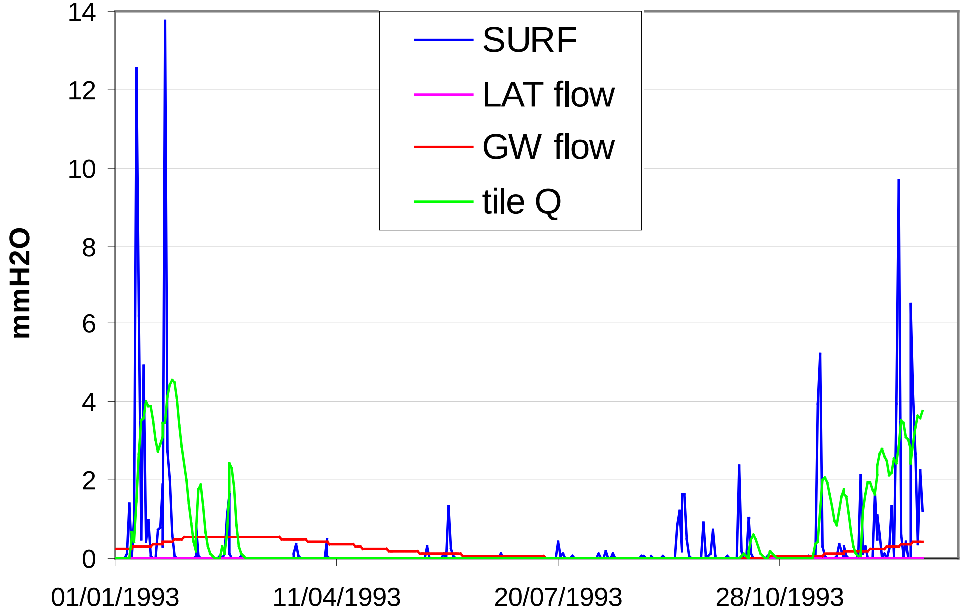


$R^2_{Q,daily}$ =0.88

$r_{Q,\ daily}$ = 0.94

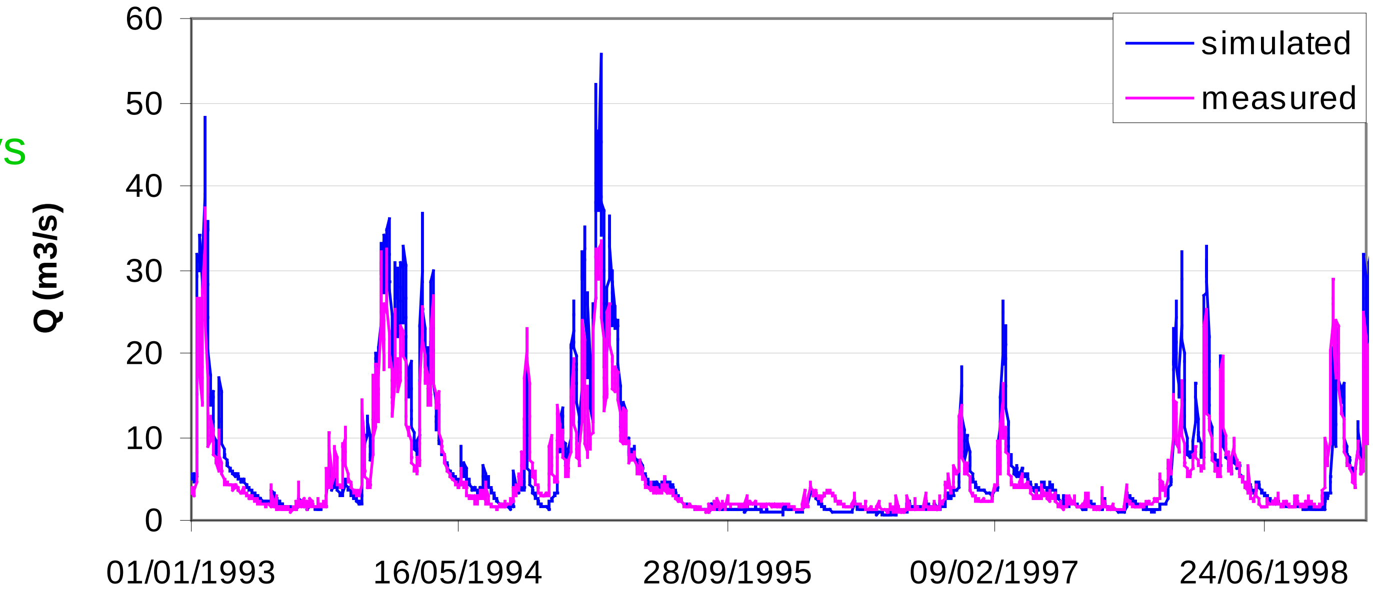
Performance of SWAT model in flow simulation

Flow composition



WITH TILE DRAINS

Simulated vs measured data

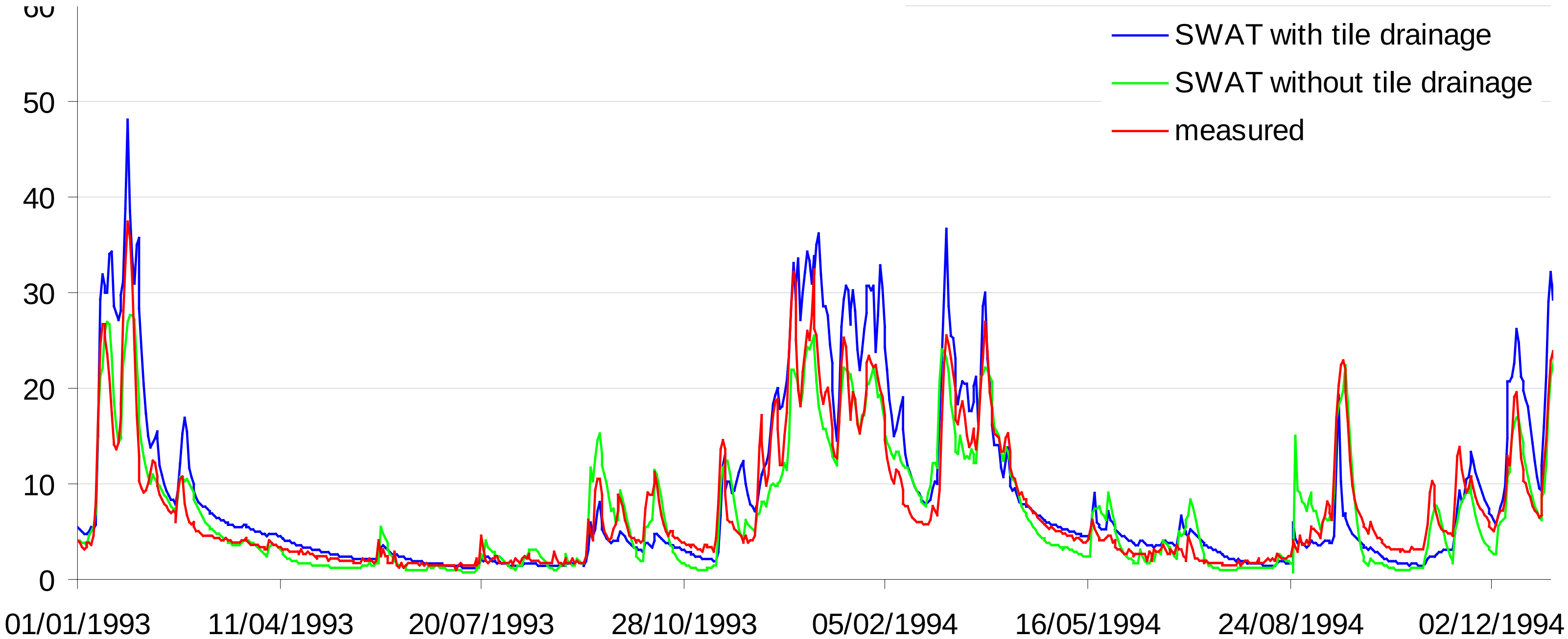


$R^2_{Q,daily} = 0.82$

$r_{Q,\ daily} = 0.92$

Performance of SWAT model in flow simulation

Comparison with measured data



Period		SWAT model without tile drainage			SWAT model with tile drainage		
	Station/ Criteria	45_26	45_21	45_01	45_26	45_21	45_01
Calibration	$R^2_{Q,daily}$	0.88	0.88	0.85	0.82	0.77	0.80
	$r_{Q,\ daily}$	0.94	0.94	0.93	0.92	0.92	0.91
Validation	$R^2_{Q,daily}$	0.85	0.87	0.85	0.80	0.75	0.80
	$r_{Q,\ daily}$	0.94	0.94	0.95	0.90	0.90	0.92

Performance of SWAT model in flow simulation

Comparison with measured data

✓ The model without tile drainage fits very well with the measured data ($R^2_{Q,daily}$=0.88). However, the model generates very high amount of surface runoff which is not realistic in Denmark.

✓ The model with tile drainage decreases surface runoff and generates tile drainage ($R^2_{Q,daily}$=0.82). The model overestimated discharge in flood period and could not catch the small variation very well in the dry period.

✓ The assignment of DEP_IMP at the same value for every HRU causes the overestimation of the model in flood period when tile drainage is generated in every HRU. DEP_IMP should be different in different elevation which is not considered in HRU.

✓ There are many ways to get a good hydrograph and obtain a good flow simulation in a hydrological model if we do not care where the water come from.

Performance of SWAT model in flow simulation

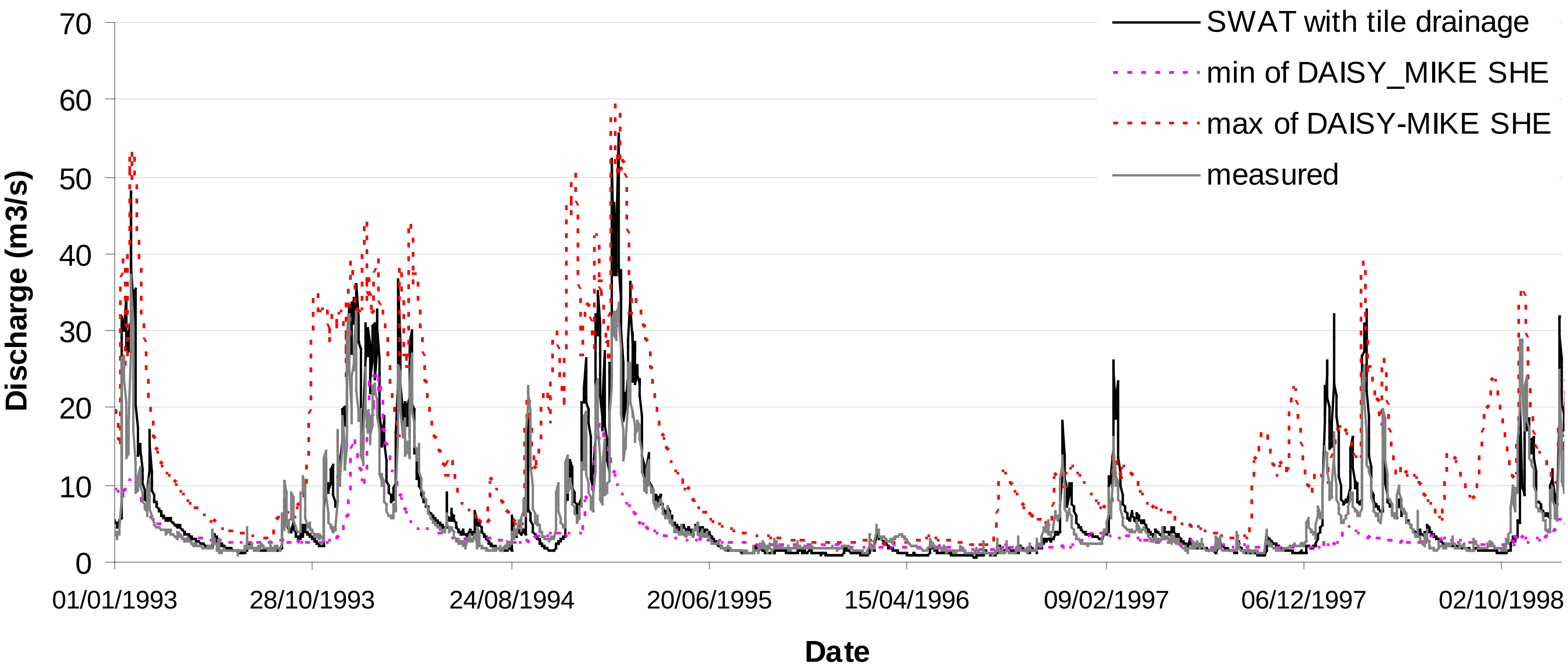
Compared with DAISY-MIKE SHE

	SWAT without tile drainage (mm)	SWAT with tile drainage (mm)	DAISY-MIKE SHE (mm)
Precipitation	875	875	883
Surface runoff	248	107	50
Lateral flow	1	3	
Tile drainage	0	123	183
Groundwater flow	130	105	72
Revaporation	1	2	
Evaporation	490	531	594

Performance of SWAT model in flow simulation

Compared with DAISY-MIKE SHE

SWAT model is compared with DAISY-MIKE SHE model taking into account the uncertainty of soil hydraulic properties and slurry amounts (Van der Keur et al. , 2008)

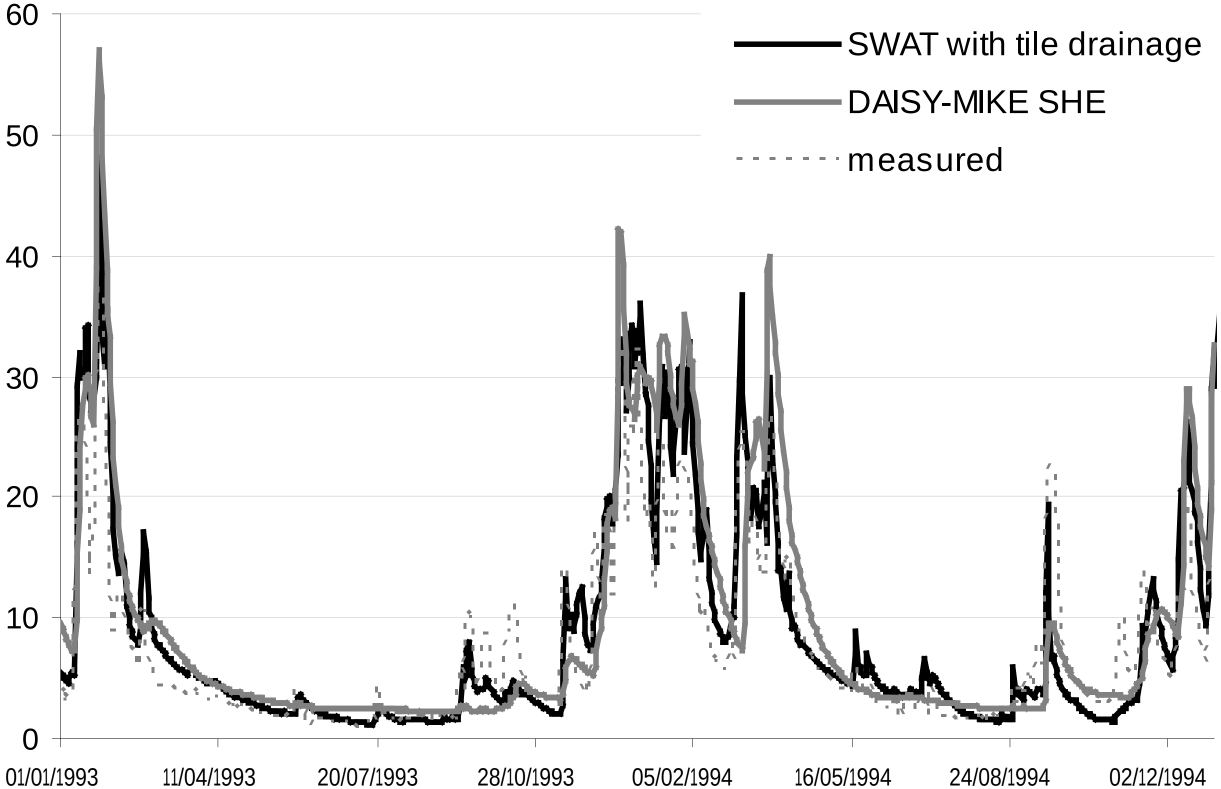


- ✓ SWAT results fit quite well inside the range of DAISY- MIKE SHE values.
- ✓ In the flood period, almost all the SWAT values are within the range.
- ✓ In dry period SWAT result is lower than the range, however, the difference is small

Performance of SWAT model in flow simulation

Compared with DAISY-MIKE SHE

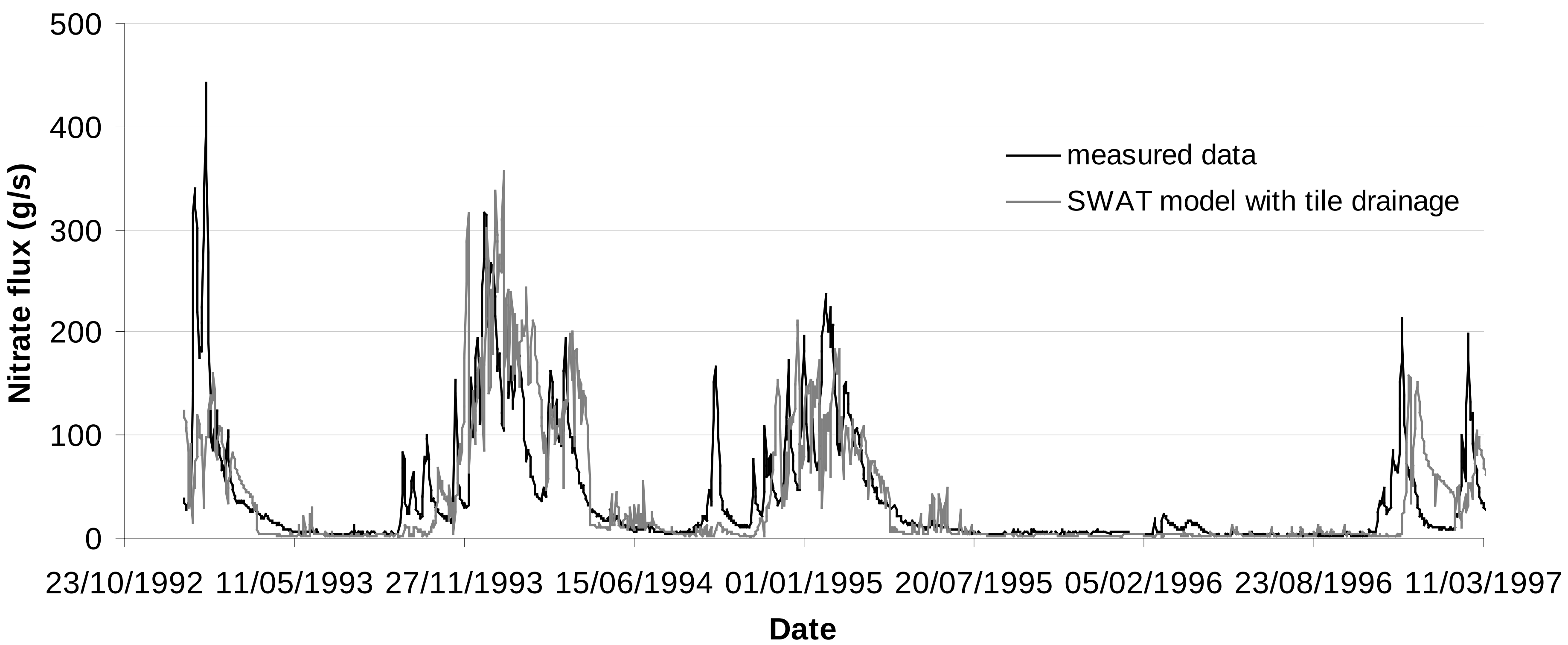
The hydrograph of the SWAT model was also compared with the 50th percentile (median) ranked DAISY-MIKE SHE output from outputs of 25 simulations.



	SWAT model without tile drainage	DAISY-MIKE SHE
$R^2_{Q,daily}$	0.82	0.72
$r_{Q,\ daily}$	0.92	0.87

Performance of SWAT model in nitrogen simulation

Compared with measured data



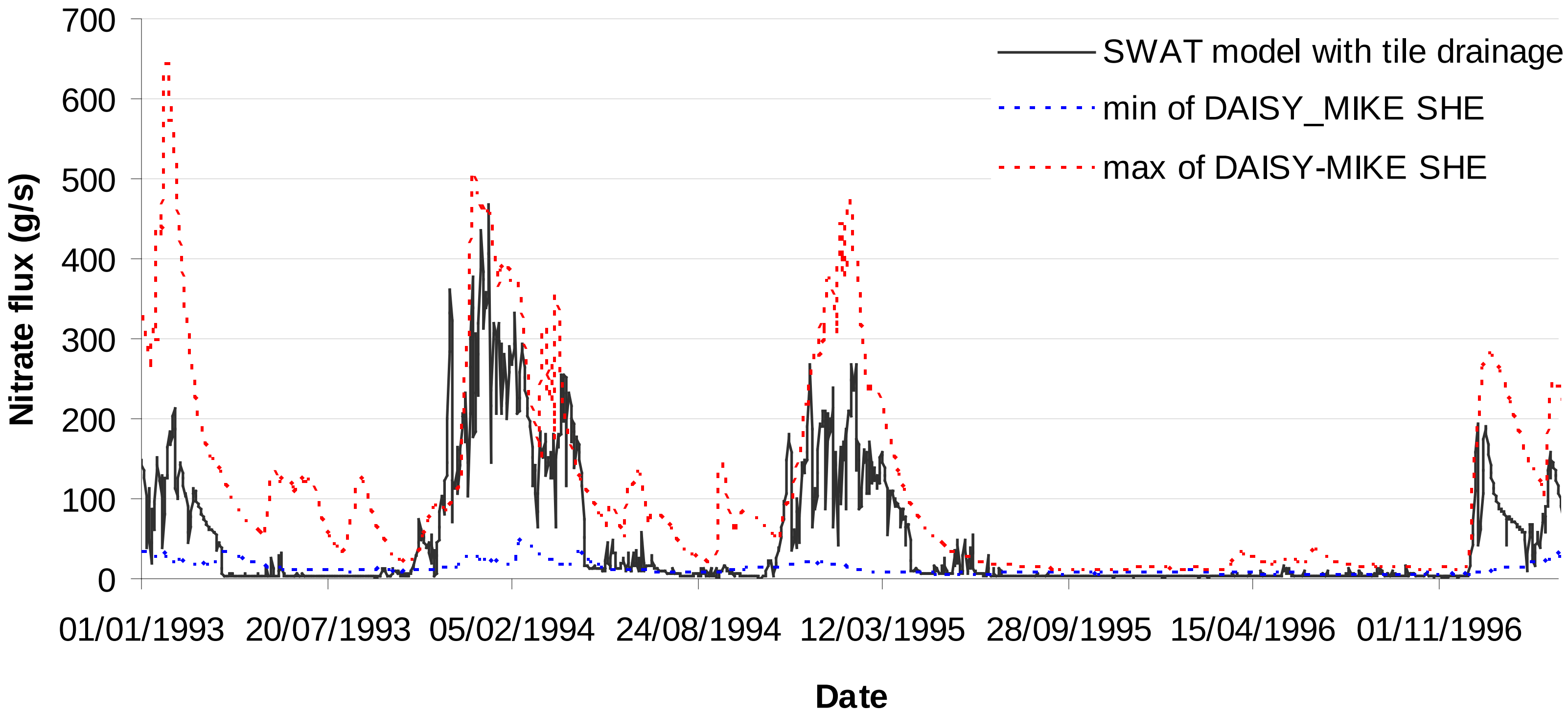
- ✓ The magnitude and the trend of nitrogen flux from SWAT model are quite similar to the measured data.

- ✓ SWAT model does not capture very well the measured values in each time step especially the flood period ($R^2_{N,daily}$=0.36). The possible reason is that the permutation of crops is not implemented.

Performance of SWAT model in nitrogen simulation

Compared with DAISY-MIKE SHE

SWAT model is compared with DAISY-MIKE SHE model taking into account the uncertainty of soil hydraulic properties and slurry amounts (Van der Keur et al. , 2008)



✓ SWAT results fit quite well inside the range between maximum and minimum values from DAISY-MIKE SHE in flood period.

✓ 42% of the values from SWAT are smaller than the minimum value from DAISY-MIKE SHE and most of them happen in the dry period because the flow simulated in SWAT is smaller than DAISY-MIKE SHE and the instream water quality is not considered

Conclusion

- The SWAT model for Odense river basin was built with and without the tile drainage in this paper.

- The model without tile drainage resulted in a better hydrograph than the model where tile drainage was included. However, the model gave very high surface runoff which is not realistic in Denmark and this can affect the result for estimating soil erosion or nitrogen loads if fertilizer is applied near the soil surface.

- Both models give reasonable result and have high correlation with the measured data.

- From the set up of the two models in different ways, it can be concluded that there are many ways to get a good hydrograph and obtain a good flow simulation in a hydrological model if we do not care where the water come from. However, depending on the purpose of modelling, it must be careful to choose the model.

- The magnitude and trend in nitrate flux was comparable with the measured data, however, the value in each time step does not capture the measured data very well because permutation was not applied in the scope of this paper.

- Compared with the DAISY-MIKE SHE model in which the uncertainty of soil hydraulic properties and slurry amount, SWAT result fitted quite well in the range of value for both flow and nitrate flux in the flood period while SWAT gave lower result than the range in dry period, however, the difference was very small.


THANK YOU FOR
YOUR ATTENTION