The European Commission's science and knowledge service

Joint Research Centre

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Water quality modelling at cross-continental-scale using the SWAT model

European Commission, Joint Research Centre

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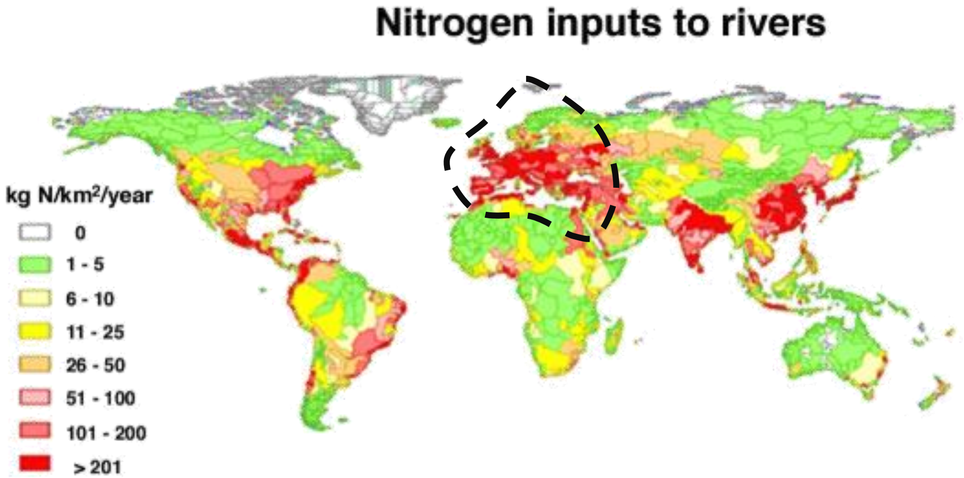
2019 Vienna SWAT Conference Agenda
17-19 July 2019

BOKU

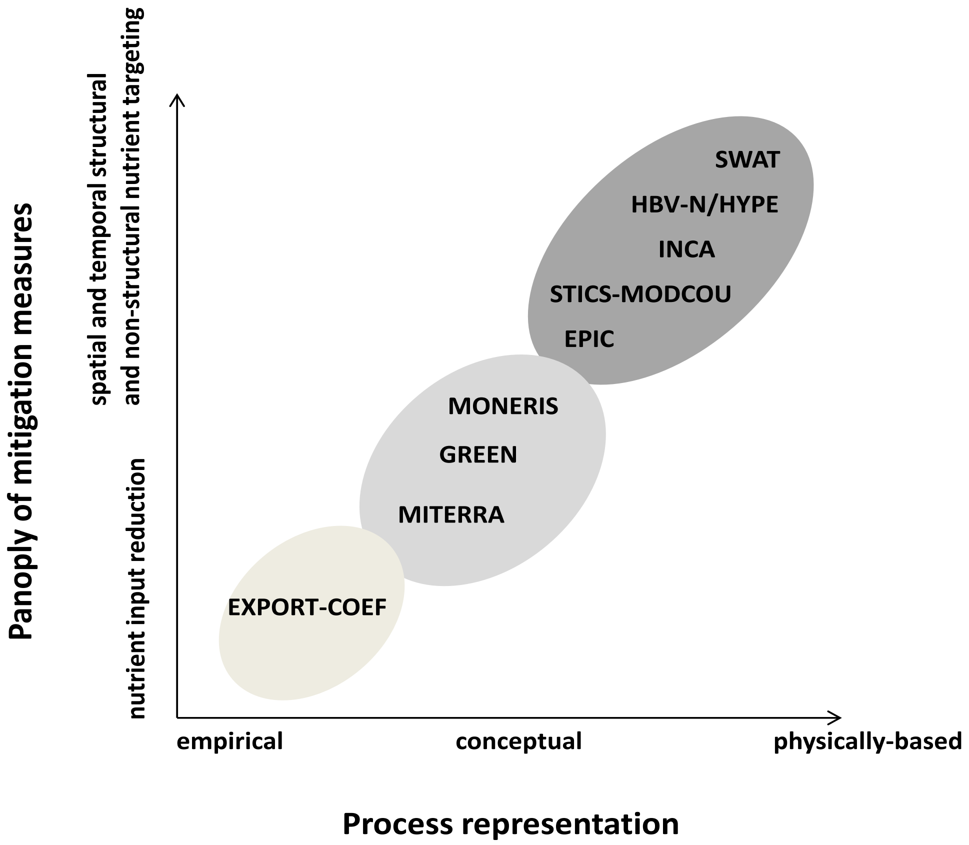
European Commission

Water resources are under increasing threaths

from a wide range of pollutants, resulting in **deteriorating water quality** in rivers, lakes, aquifers and seas worldwide



Strokal et al., 2019



Water quality modelling plays an important role in better understanding **the magnitude** and the impacts of anthropogenic activities and in **providing evidence for policy making** for implementing measures to mitigate water pollution

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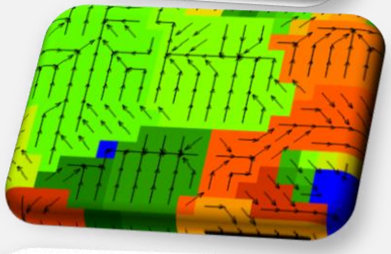
1. Develop a **cross-continental-scale** (across Europe, African Mediterranean basins, Black Sea basins and Middle East) application of the **SWAT model** at **grid-cell level** using the **latest and readily available global datasets** for preparation of inputs
2. Predict **annual crop yields** under different management, **monthly streamflow**, **nutrients** and **sediments concentrations** and **loads**
3. Quantify **nutrients losses from point and diffuse sources** to freshwater, aquifers and coastal waters
4. Identify the **major sources of nutrient pollution**
5. Evaluate the **effectiveness of measures to reduce nutrient pollution** and **sediment yield** from different sources

The structure

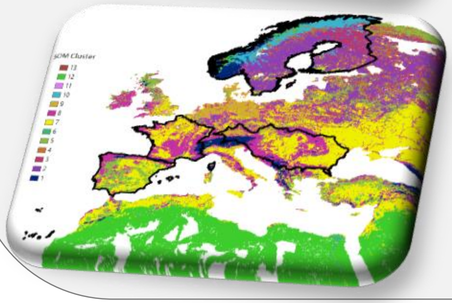
inputs
outputs
Scripts

SWAT inputs and parametrization

Global datasets



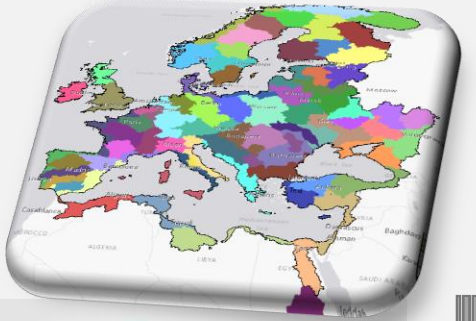
Grid cell discretization



Regionalized parameters

SWAT
Soil & Water Assessment Tool

Model Domain
Creation of PROJECTS



inputs
outputs
Scripts

Analysis of SWAT outputs and scenarios

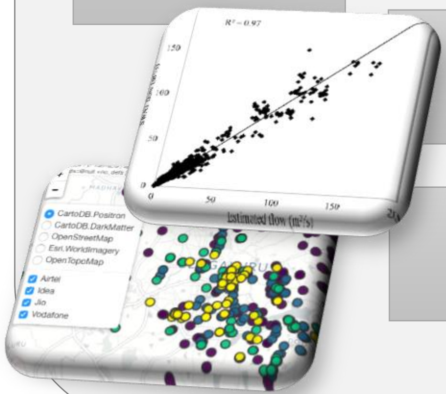
Unique
Output.rch
Output.hru

Specific analysis (Crop yield, WQ balances)

Plots of model performances and time series

Raster maps

Online iteractive maps



Technical characteristics

SWAT inputs and parametrization

inputs
outputs
Scripts

raster
data.table
ncdf4
sqldf
foreach
snow
sf
dplyr
tidyr
ROBDC

Model Platform
Creation of PROJECTS

SWAT2012 rev. 664

NO SUPER PC!
3.70 GHz
RAM 32/64 GB
2TB of space

Analysis of SWAT outputs and scenarios

inputs
outputs
Scripts

raster
sf
data.table
sqldf
foreach
rasterVis
snow
HydroGOF
dplyr
ggplot2
mapview
sp

The Global Datasets

Malagò et al., Journal of Hydrology: Regional Studies 22 (2019) 100592
Malagò et al., Water (2019) , 11, 1030; doi:10.3390/w11051030

DEM
GTOPO30
30 arc seconds

SOIL
FAO Harmonized
World Soil Database

16,328 soils

LUSE
GLOBCOVER 2009
and SPAM2005

9 land covers
168 SPAM crops
keeping H,I,L,S type for each crop

CLIMATE
MSWEP (pcp)
ERA-Interim (others)
1979/2012

177,575 equally distributed stations

LAKES
Hydrolakes

112,348 lakes

Reclassify rasters 100 x 100 m

MANAGEMENT
“PACKAGE" approach

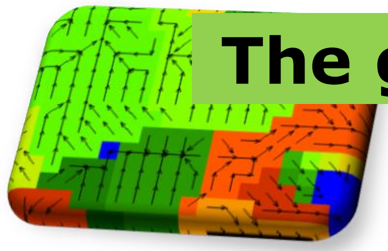
MIRCA crop calenders	N,P mineral and manure fertilizers
Irrigation	Tillage

Point Sources

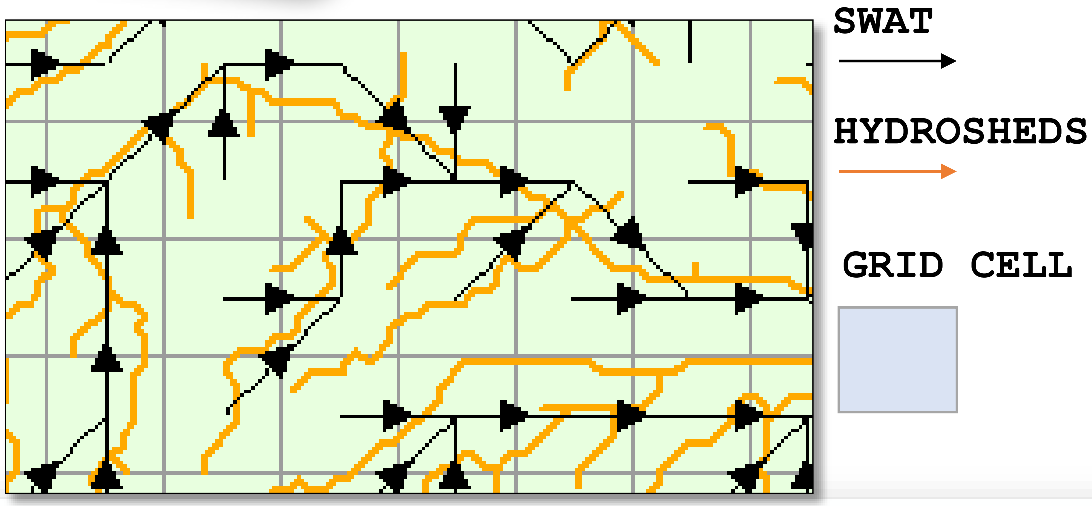
Domestic water abstractions

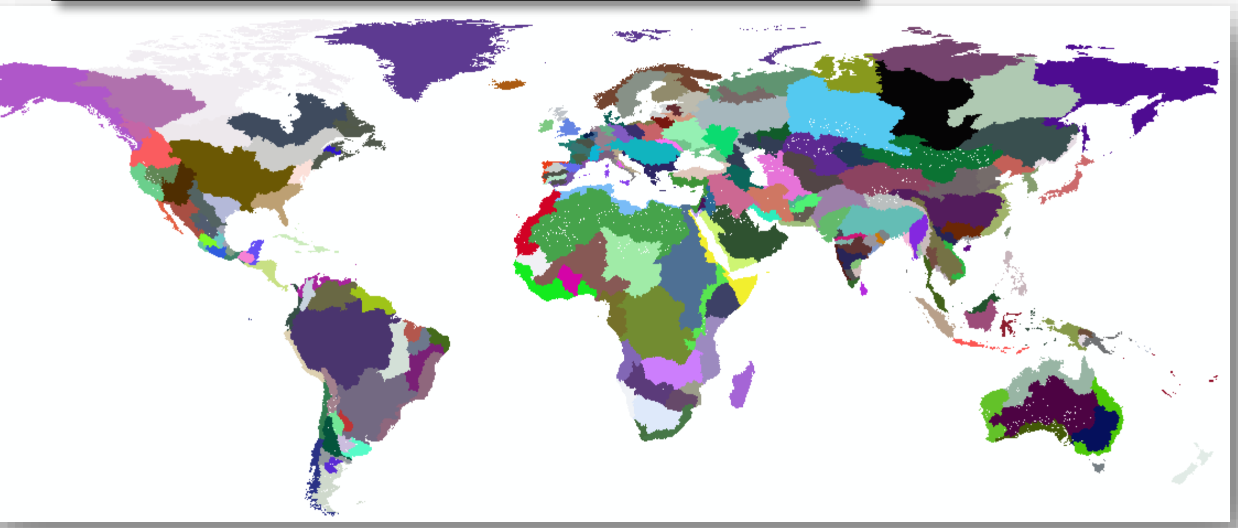
Atmospheric dep.

NO3 into aquifer



The grid cell discretization





SWAT was forced to use a predefined delineation of streams and watershed using **a regular grid-cell** and a **river network of 5 arc-minutes of resolution** (about 60 km^2 of grid cell area in the Mediterranean area)

2,158,178 grid cells
82,792 river basins with outlet to the sea

Malagò et al., Water (2019), 11, 1030; doi:10.3390/w11051030

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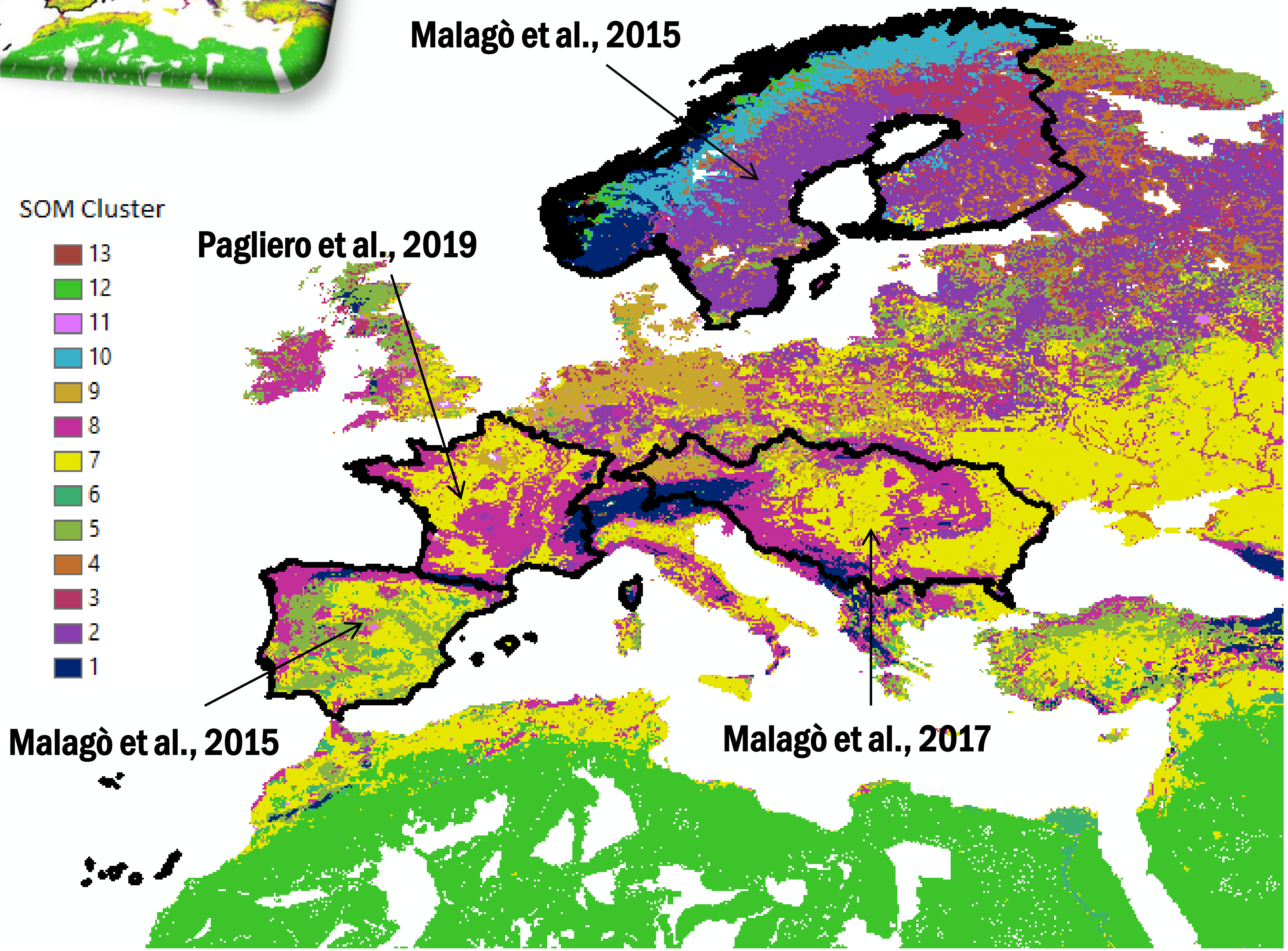
The Regionalization of calibrated parameters

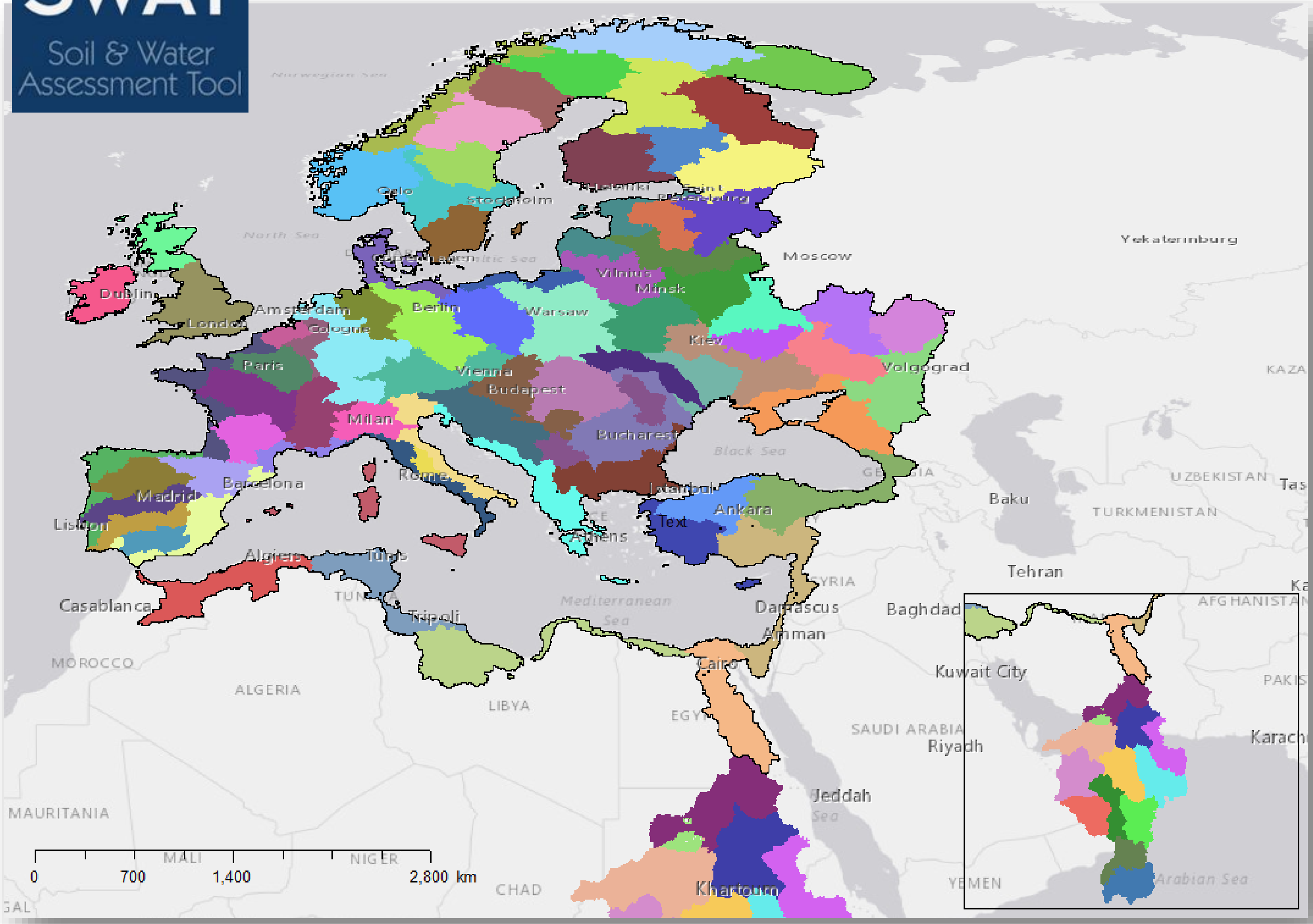


The **groundwater parameters** were estimated by regionalizing values calibrated in previous large-scale applications in Europe

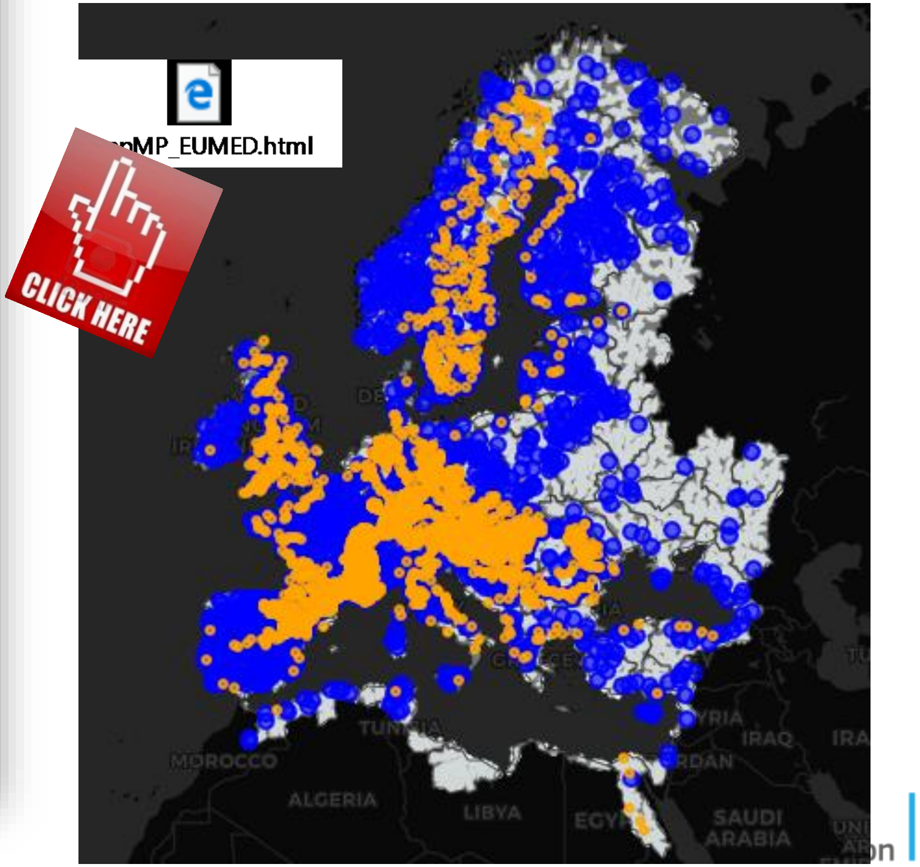
Cluster analysis performed using the **Self Organized Map (SOM)** and a **similarity approach** to transpose the calibrated parameters (61,439 grid cells) to all uncalibrated grid cells

The Modelling domain

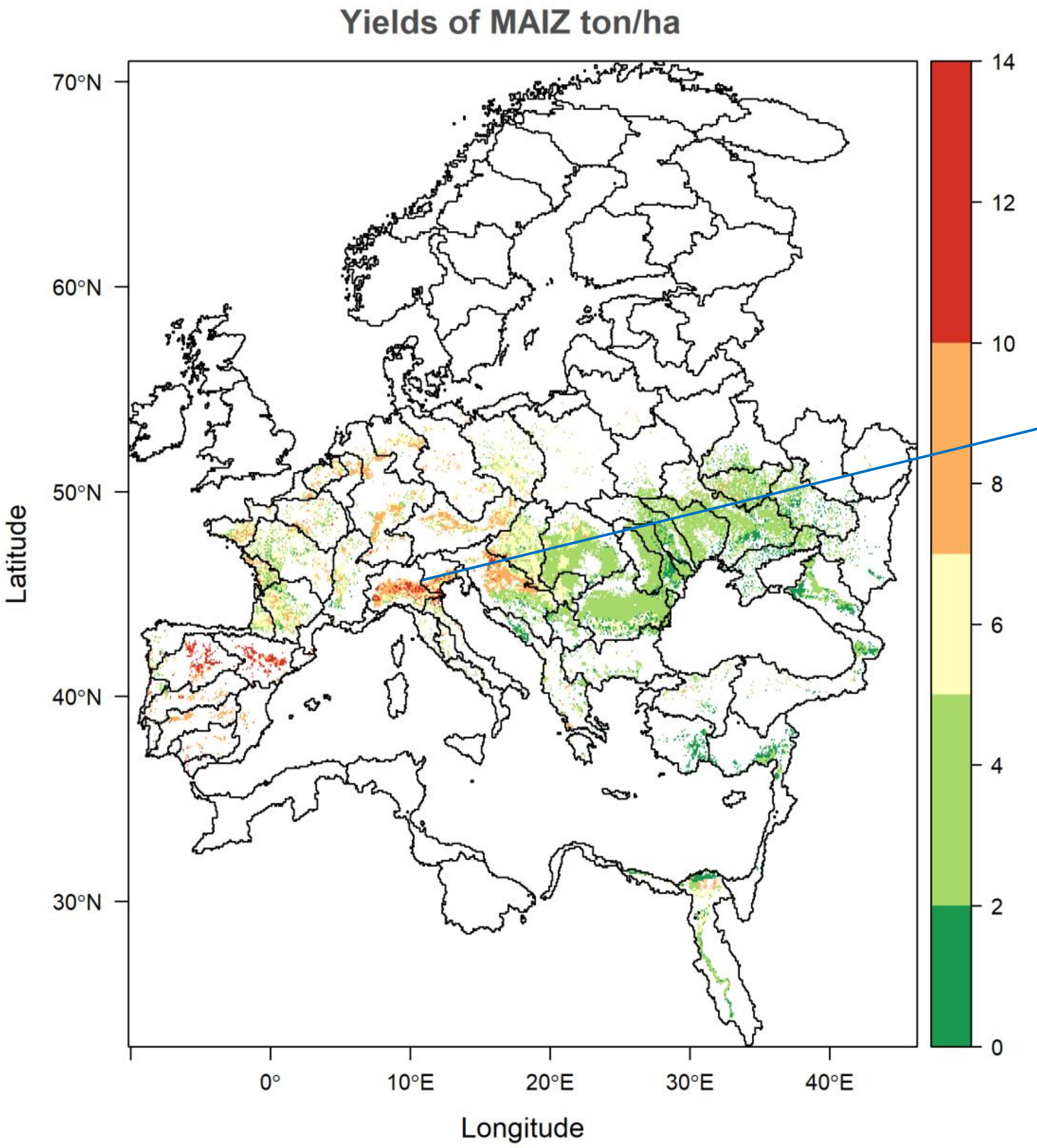
SWAT Soil & Water Assessment Tool

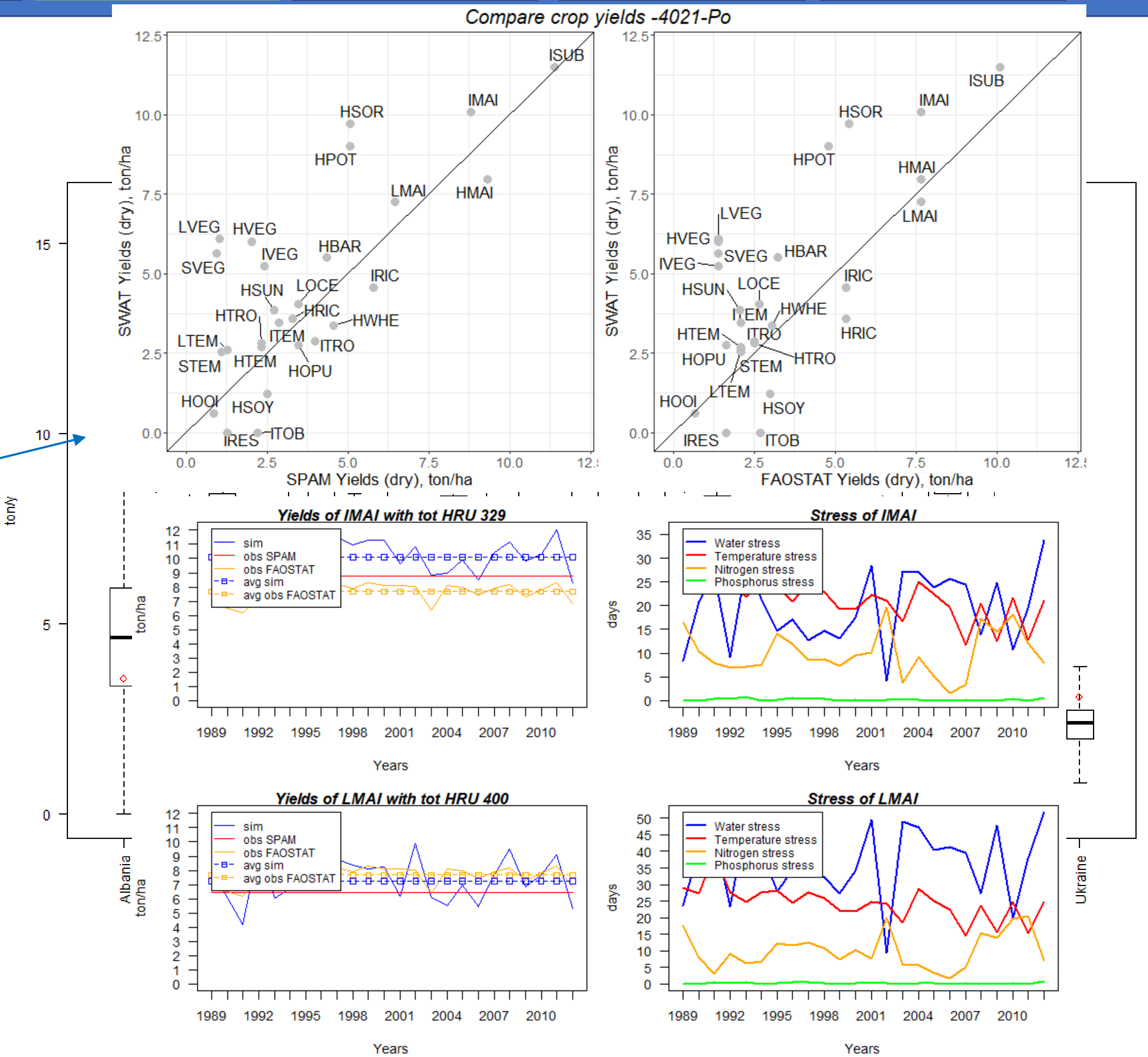


- # SWAT projects **78**
- # grid cells **149,907**
- # HRUs **644,321**
- # Streamflow stations **2919**
- # Water quality stations **2630**

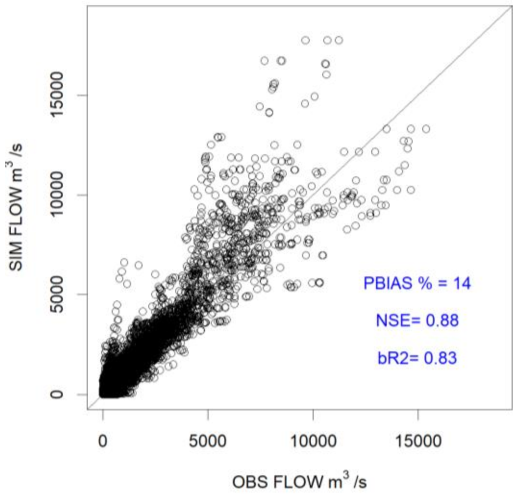


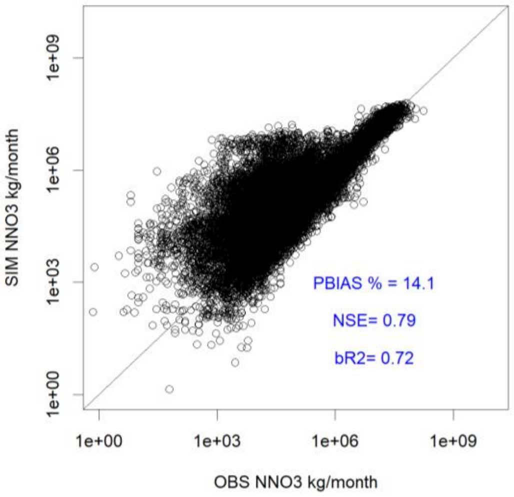
Crop yield simulation

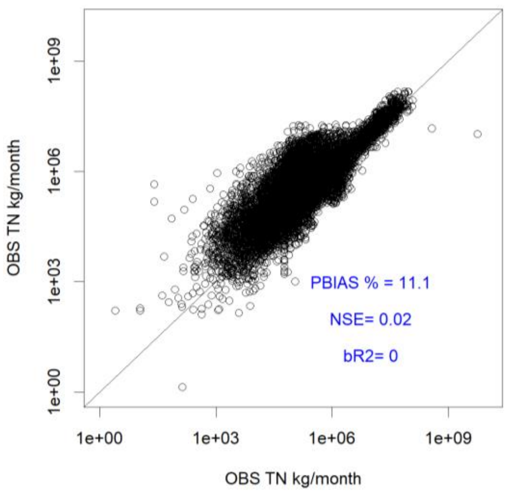


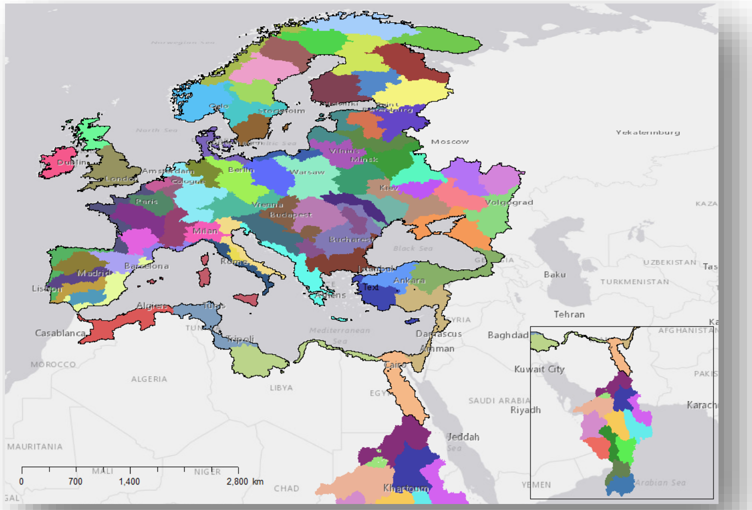


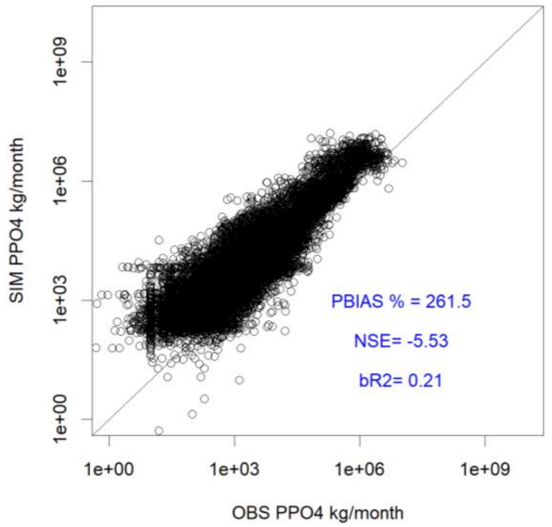
The model performances

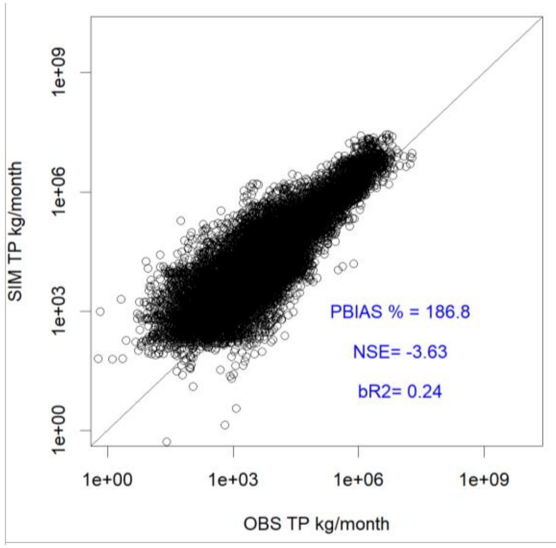


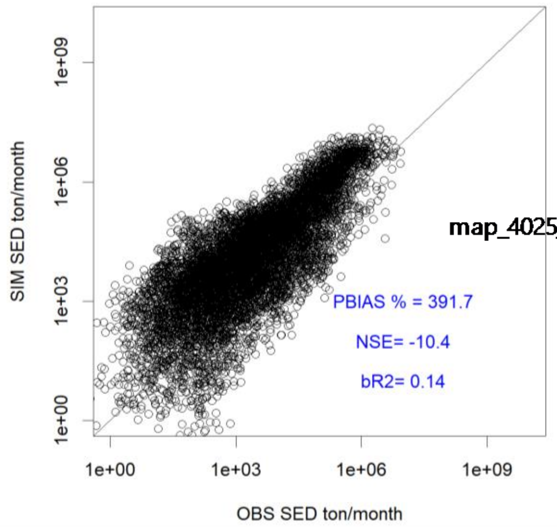












PJ4012 FLOW NSE
map_401… FLOW.html
CLICK HERE

PJ4012 FLOW bR2
map_401… FLOW.html
CLICK HERE

PJ4025 NNO3 BIAS
map_4025_P… NO3mgl.html
CLICK HERE

PJ4010 FLOW bR2
map_401… FLOW.html
CLICK HERE

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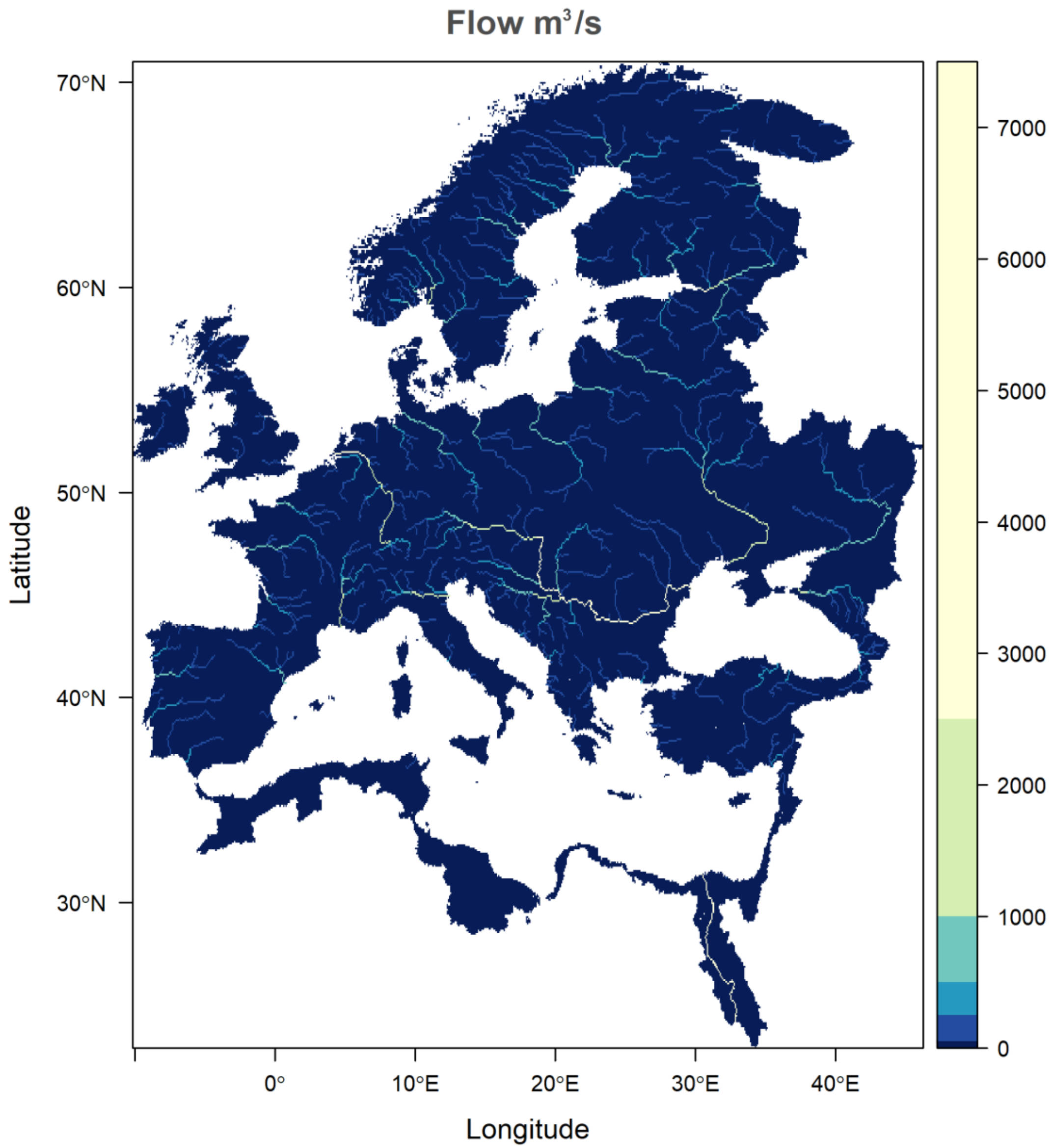
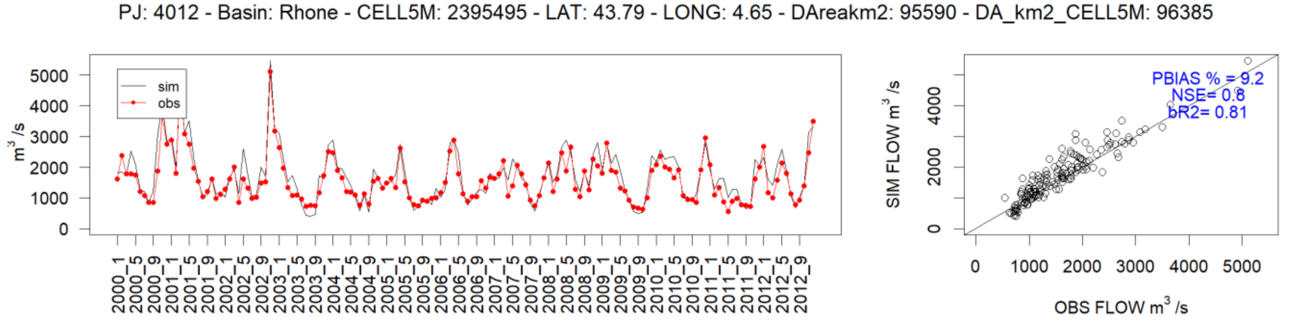
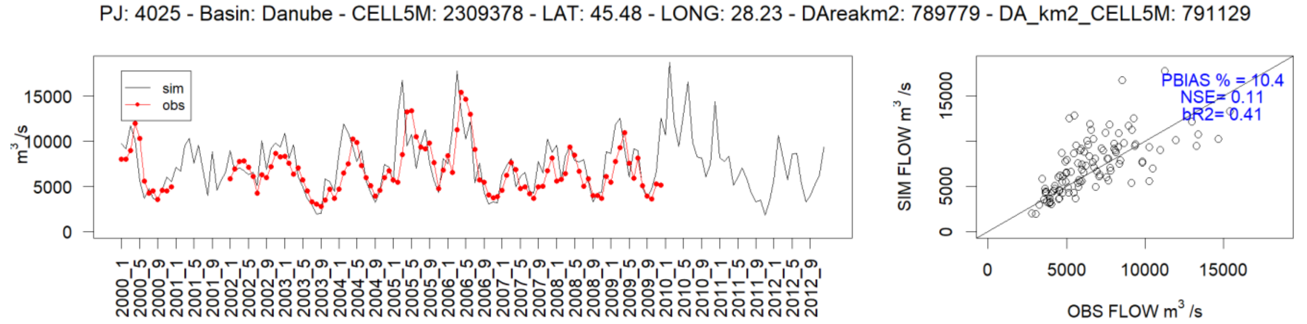
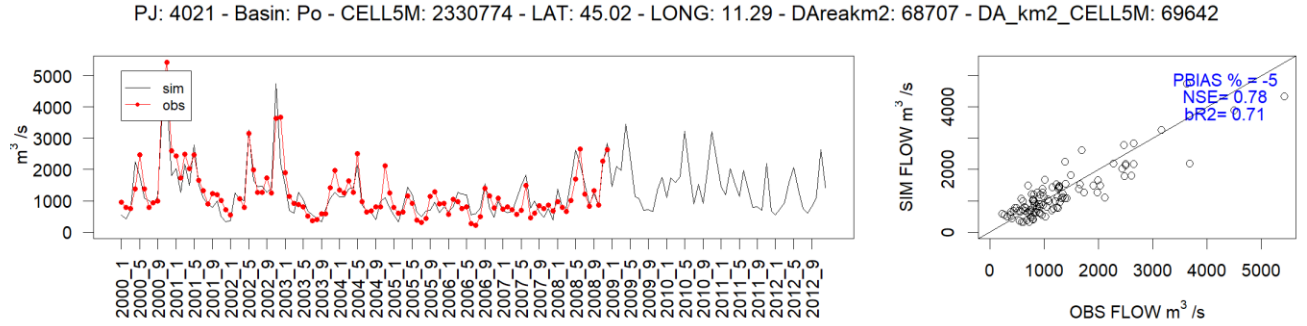
The prediction at annual and monthly time scales

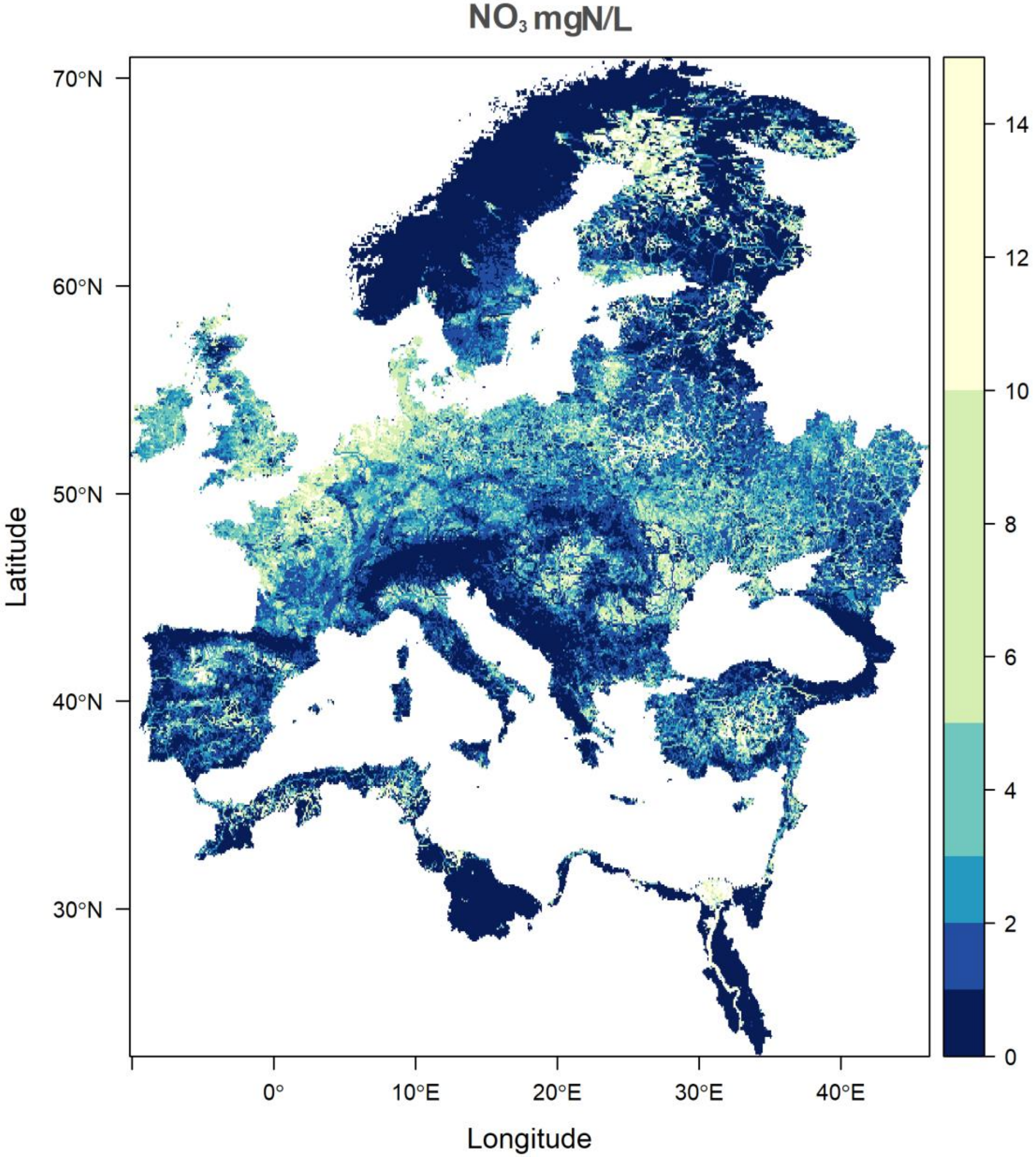


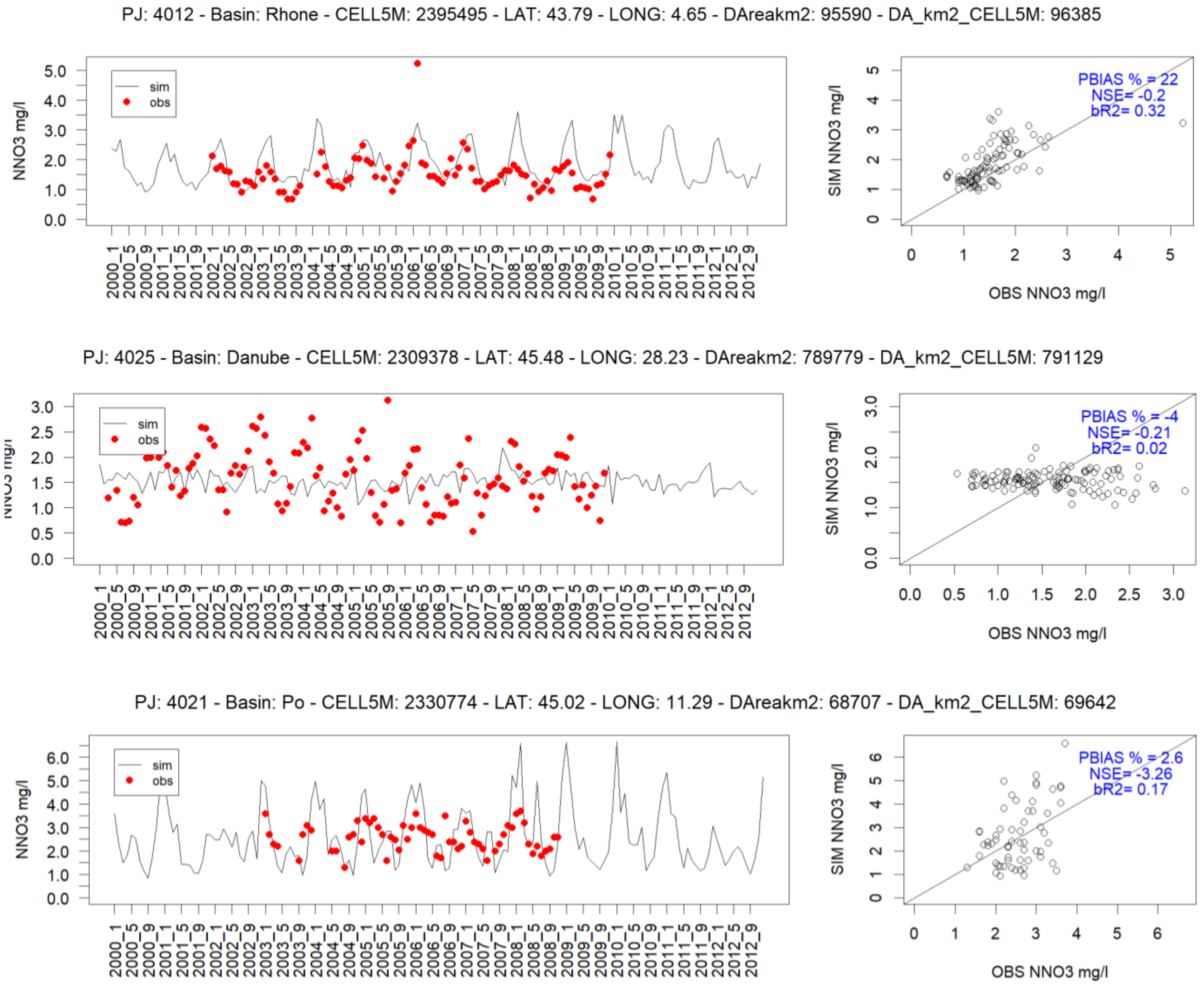




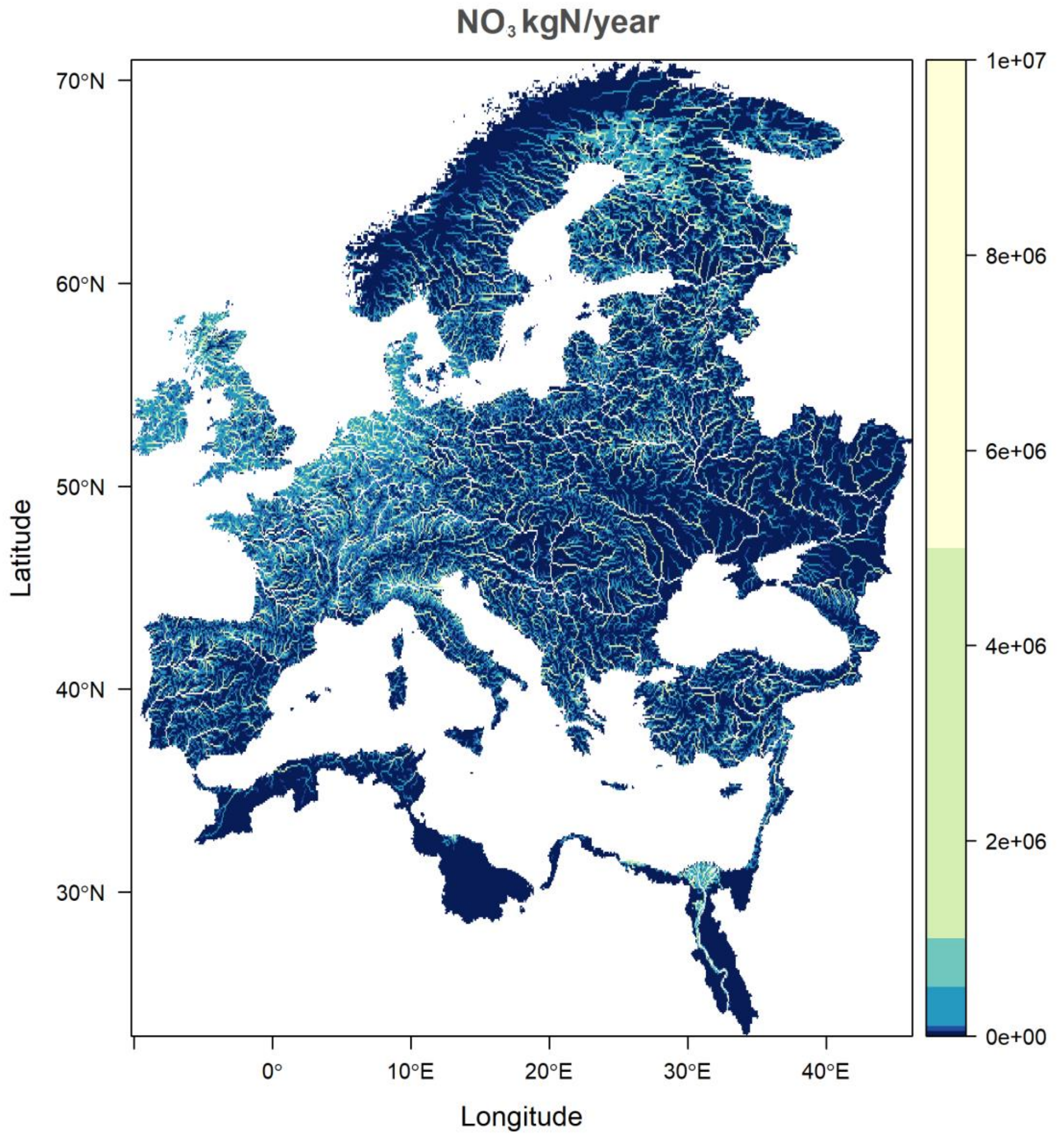


The prediction at annual and monthly time scales

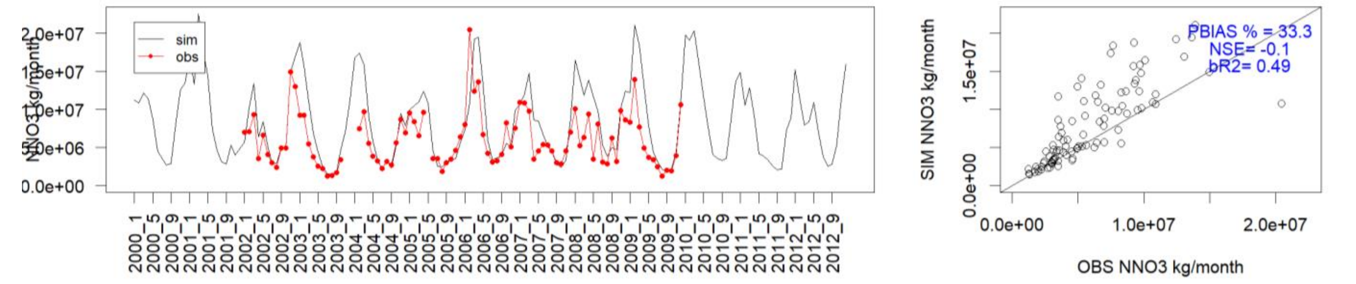




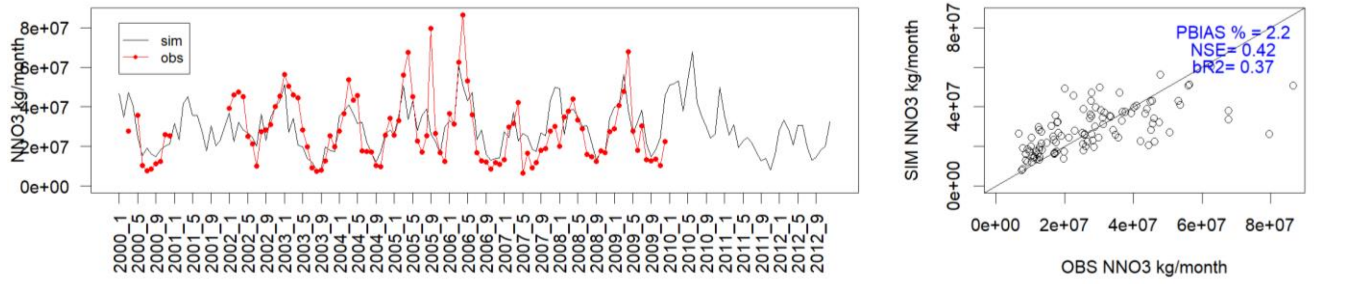
The prediction at annual and monthly time scales



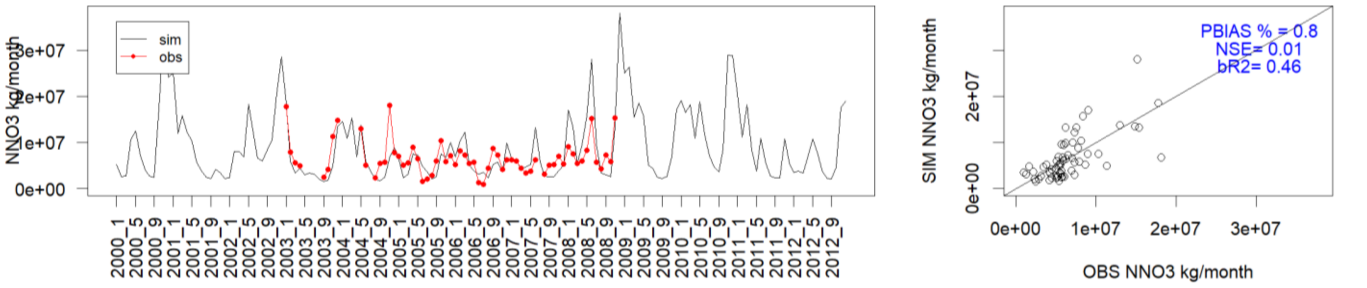
PJ: 4012 - Basin: Rhone - CELL5M: 2395495 - LAT: 43.79 - LONG: 4.65 - DAreakm2: 95590 - DA_km2_CELL5M: 96385



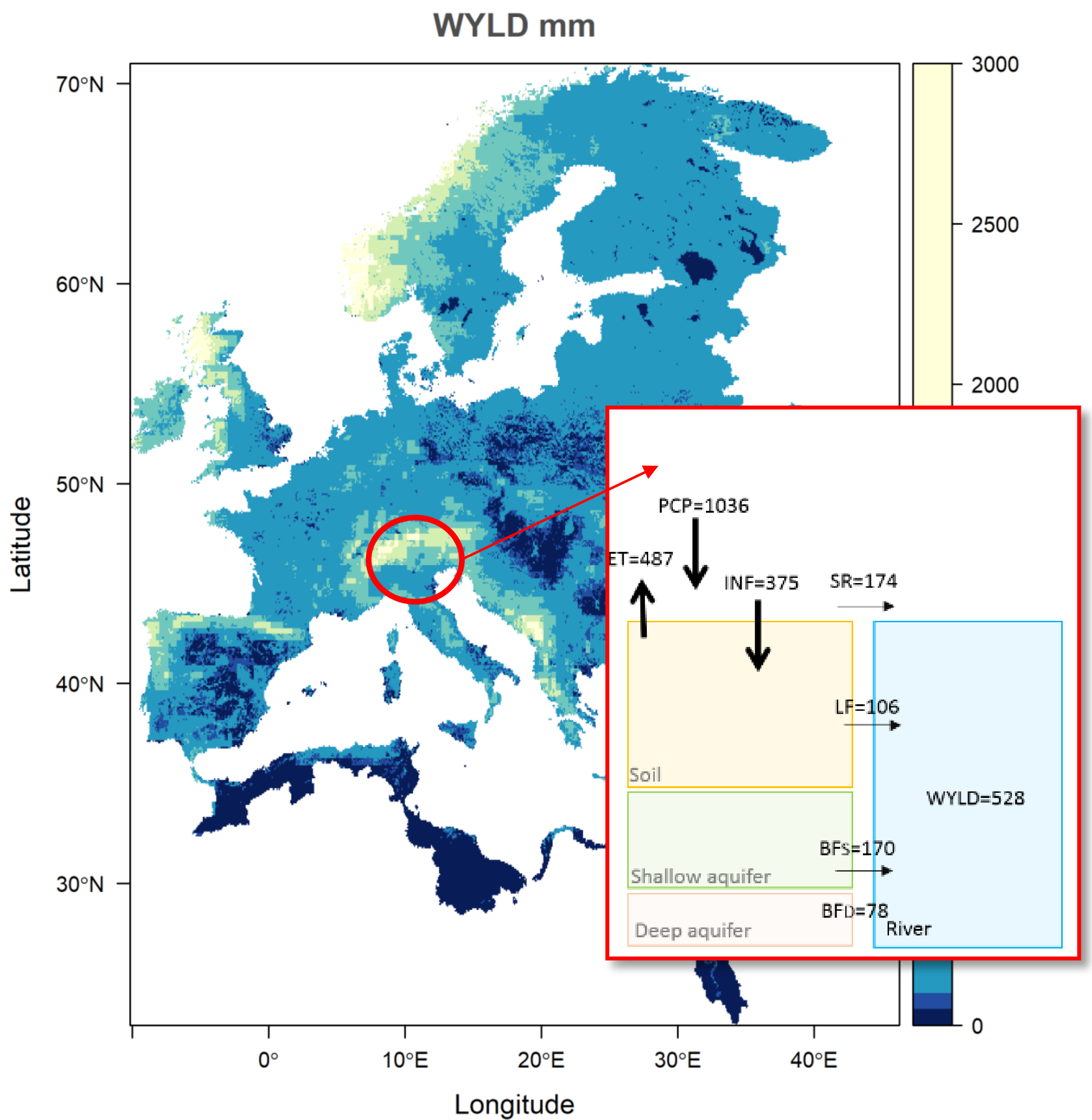
PJ: 4025 - Basin: Danube - CELL5M: 2309378 - LAT: 45.48 - LONG: 28.23 - DAreakm2: 789779 - DA_km2_CELL5M: 791129

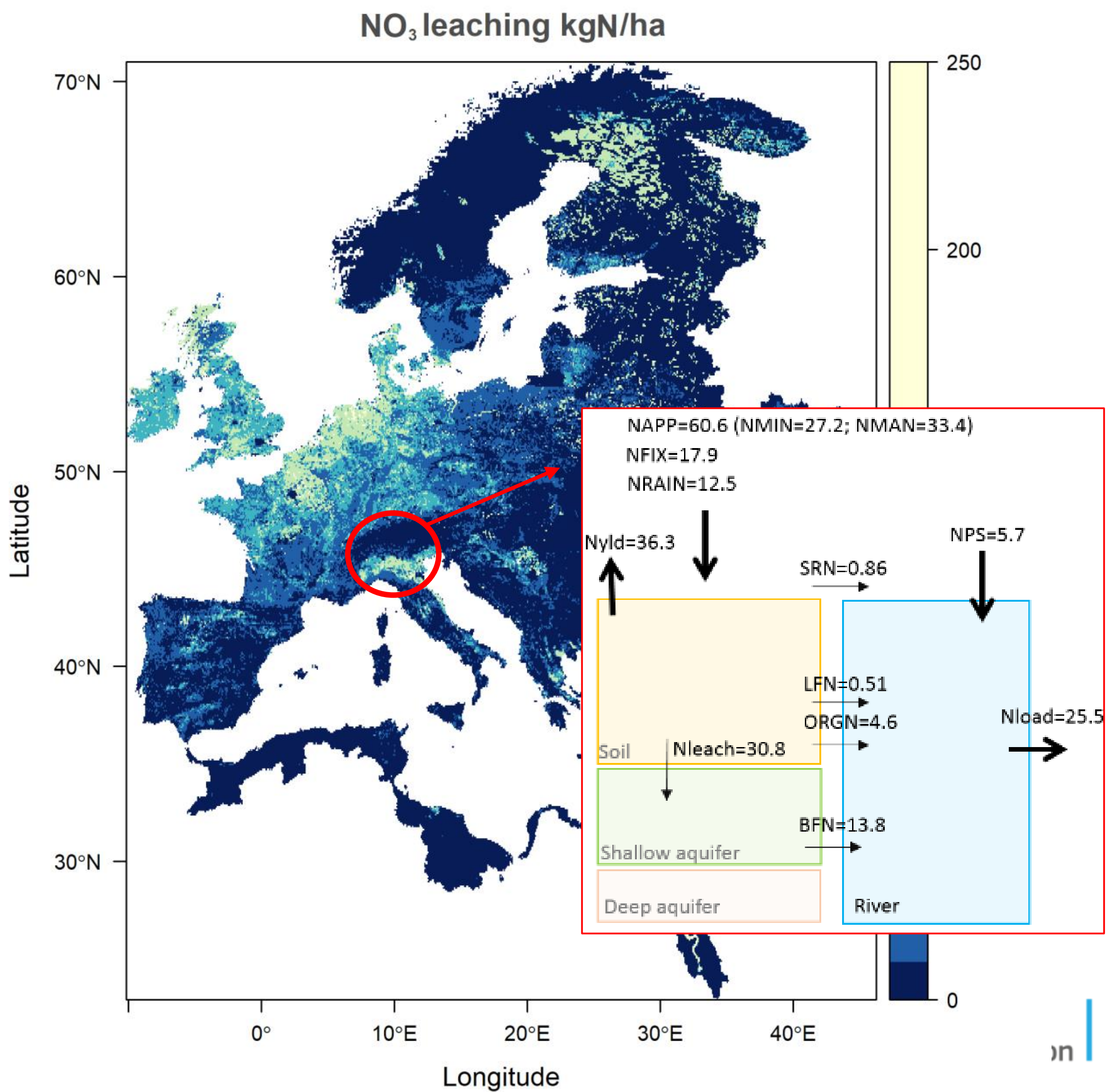


PJ: 4021 - Basin: Po - CELL5M: 2330774 - LAT: 45.02 - LONG: 11.29 - DAreakm2: 68707 - DA_km2_CELL5M: 69642

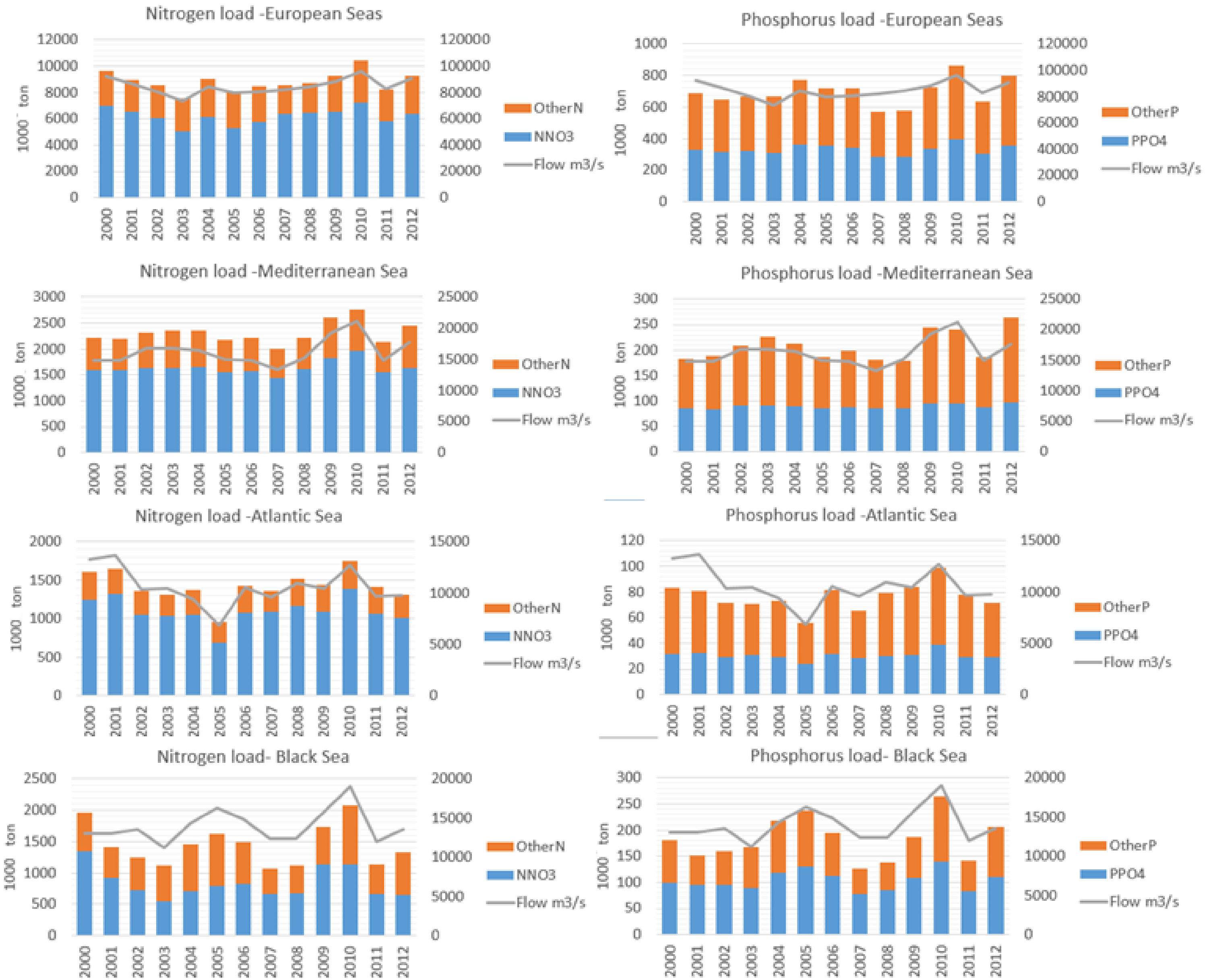


The annual water and nutrient balance and the use of soft data

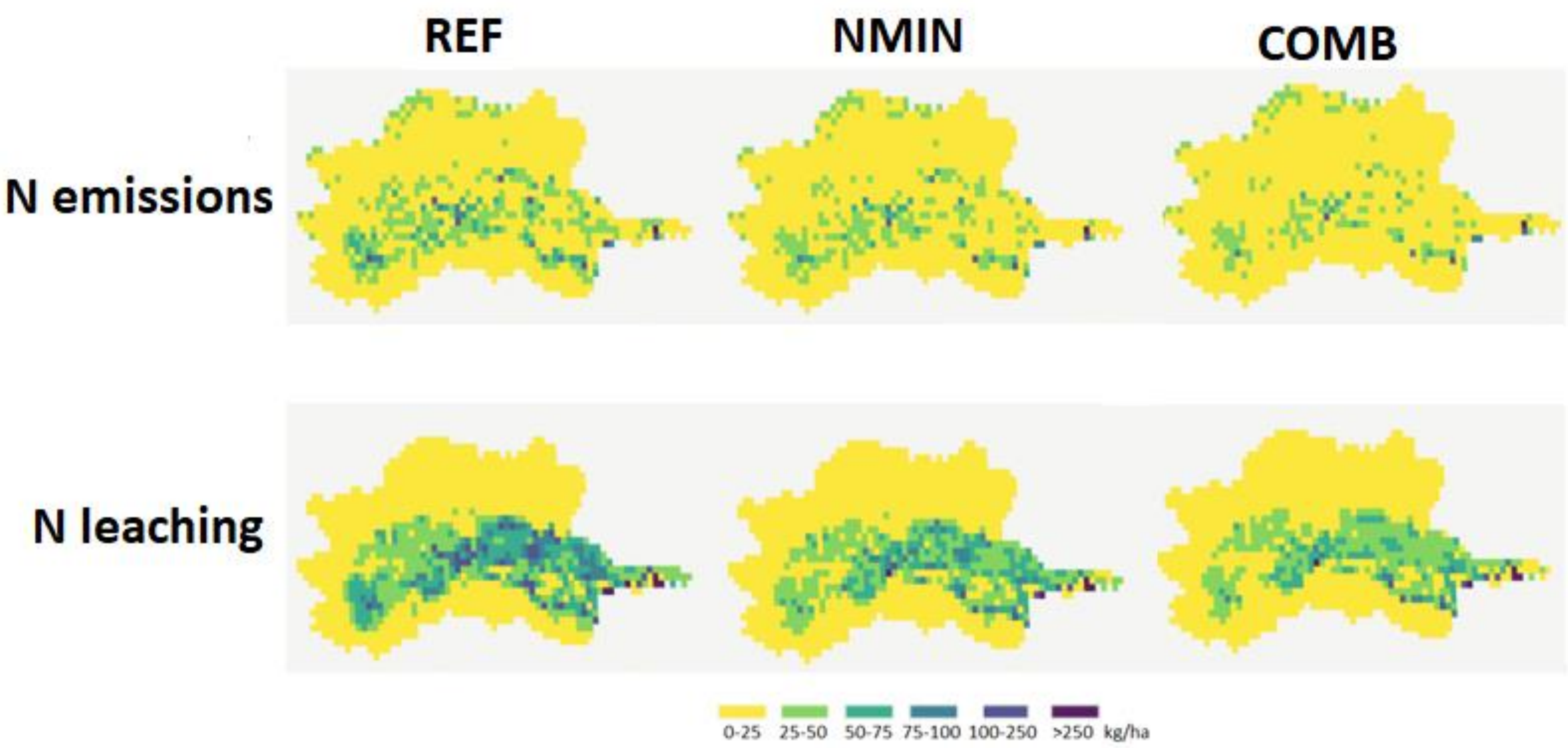




FLOW, N, P discharged to the sea



Scenarios of reduction of nitrogen emissions and leaching



Po river basin, Italy

NMIN > Strategic reduction of N mineral fertilizer application in each HRU limiting the change in annual crop yield from baseline below 5%

COMB > Combination of scenario NMIN, restriction of manure application to maximum 170 kg N/ha/y and planting red clover as cover crop after harvesting corn

Lesson learnt

1. The use of the latest and readily available global datasets provides a more homogeneous information around the world. As a consequence, different applications of SWAT can be easily compared, avoiding the uncertainty related to the use of different inputs
2. Using directly grid-cells decreases the risk of loss of information due to data transformation from a simple grid geometry to irregular polygons
3. Combining R environment programming and SWAT we are able to develop cross-continental-scale model without the use of super PC
4. The regionalization of parameters has allowed constraining SWAT model parameters decreasing the computational burden of sophisticated calibration. However, to improve the model performances in specific areas the cross-continental-scale model requires a step-wise calibration and the use of soft data

Conclusions

1. The cross-continental-scale model has a very high spatial resolution with 149,907 grid cells, 644,321 HRUs and a detailed crop management
2. The model was successfully implemented providing robust spatial and temporal predictions of streamflow and water quality
3. The model is extremely efficient in identifying the types of measures to be implemented depending on the local conditions
4. The cross-continental-scale model platform is being expanded in other areas of the world. Currently: Senegal river basin and whole Nile

Main issue with SWAT2012

5. Split big basins in several parts e.g. the Danube in 6 parts and the Nile in 13

Future work

1. Improve model performances using the step-wise calibration and soft data (Malagò et al. 2017)
2. Improve modelling of hydrologically altered basins including lakes/dams operations
3. Improve crop yields simulation and the crop management
4. Extend climate data until 2018
5. Implement interactive maps on a web platform

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Thank you for your attention

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