Modeling water resources in Black Sea Basin

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Major challenges

- Environmental degradation
- Water quality
- Water stresses
- Flood- droughts risks
- Transboundary effects
- High variability in precipitation and evaporative demand
- Agricultural productivity and water demands
Research questions
To assess:

- Black Sea data gaps

- Water resources of BSB on a fine spatial and temporal resolution

- Feasibility of running a time-consuming high-resolution hydrologic model on a PC & gridded network

- Potential impacts of climate change and landuse change on water quantity, water quality and crop yields
Research question 1: Data gaps in BSB
Data gap analysis and difficulties
Load $NO_3$ g/day
$T_{eff} = 0.8$ treatment efficiency
$N = 8.8$ g
$S_{rate} = \text{As presented in table 2..}$
$PE = 0.63$

$$Load_{NO_3} = POP_1 \times \left[ \left( 1 - S_{rate} \times \frac{N}{PE} \right) + \left( 1 - T_{Eff} \right) \right]$$
Data sets

**DEM:** Elevation, slope, drainage network
SRTM 90 m resolution

**River network:** Ecrine Rivers, 30 m resolution

**Landuse:** Modis Land cover, NASA, 500 m resolution

**Soil:** Hydro-pedological parameters.
FAO/UNESCO, Scale: 1:500 000

**Climate:** Daily precipitation, temperature and solar radiation for 1973-2006,
Climate Research Unit (CRU)

**Agricultural Management:** Crop types,
Harvested area, Crop calendar, crop Yields, Miraca 2000, 5 Arc min resolution

**Calibration & Evaluation:** Crop yields, river discharge, NO3

GEOSS: A Global, Coordinated, Comprehensive and Sustained System of Observing Systems
Research question 2:

High resolution water resources assessment in BSB
SWAT in the Black Sea Basin

Europe Basin

Sub- basin HRU
Complications
- Imprecise gauge location
Complications

- Dams, Reservoirs
- Highly agricultural areas and water abstractions
Complications

- Glaciers
- Disconnected rivers
Calibration, Evaluation & Uncertainty

Parameterisation → 500x simulation → Evaluation

Parameter updating

Diagram showing the process of calibration, evaluation, and parameter updating with a map and a scatter plot.
Calibration, Evaluation & Uncertainty

- Calibration and evaluation
  - 1973-2000 Calibration
  - 2000-2006 validation
  - Discharge (monthly, 79 stns)
  - NO3 (Monthly, 37 stns)

- Parameter selection based on sensitivity analysis → 26 Discharge, water quality and crop growth parameters

- Initial parameter ranges from physically meaningful limits at uniform probability distribution

- New ranges based on parameterisation with highest objective function for

  200 runs (Estimated run time in a single machine → 350 days!!)
parallel Sufi2 speed up & efficiency tested on different computers

More details:
Parallelization & Gridification

200 runs using the parallel processing and Grid infrastructure → 2 weeks!!

(4 blocks of 50 worker node)

More details:
River Discharge results

River Discharge (Q_2467, Prypiat River, drains to Dnieper, Belarus)

- p-factor = 0.8
- r-factor = 1.71
- $R^2 = 0.52$
- NS = 0.28

River Discharge (Q_6080, Prut River, Romania, Moldova, Ukraine)

- p-factor = 0.59
- r-factor = 0.92
- $R^2 = 0.58$
- NS = 0.47
NO3 loads in Reaches

**NO3 in reach (WQ_8176)**
- p-factor = 0.81
- r-factor = 2.13
- $R^2$ = 0.53
- NS = 0.25

**NO3 in reach (WQ_6883)**
- p-factor = 0.54
- r-factor = 1.8
- $R^2$ = 0.56
- NS = 0.23
Calibration efficiency
Danube Delta

NO3 in reach (WQ_9175)

NO3 in reach (WQ_10395)

NO3 in reach (WQ_8880)

Map showing locations of Siret, Bratul Splina, Arges, Dunarea, and Black Sea Basin.
Blue Water, Green Water Flow and Green Water Storage

Green Water Storage (34 yrs avg.) [mm yr⁻¹]
- < 30
- 30 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 150
- 150 - 200
- > 200

Green Water Flow (34 yrs avg.) [mm yr⁻¹]
- < 150
- 150 - 300
- 300 - 380
- 380 - 420
- 420 - 450
- 450 - 490
- 490 - 540
- > 540

Blue Water [mm yr⁻¹]
(34 yrs average)
- < 50
- 50 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 600
- 600 - 1000
- > 1000

CV Blue Water [%]
- 300 - 500
- 150 - 300
- 80 - 150
- 50 - 80
- 30 - 50
- 1 - 20
- Countries
Uncertainties
Internal renewable water resources, annual average (1970-2000)
Green Water Flow, Green Water Storage, Blue water (mm yr$^{-1}$)

Black Sea Countries Freshwater Availability (long term annual average)
Internal renewable water resources (Blue water) (m³ yr⁻¹)

Comparison of the computed 95PPU intervals for the annual average (1970-2000) of the internal renewable water resources (IRWR) for BSC countries with the results from the FAO assessment mm year⁻¹.
Blue Water Per capita, Water scarcity
Outlook

Research question 3:

- Potential impacts of climate change and land use change
Acknowledgements

Key references

- Arc SWAT 2009
- 12982 subbasins
- 89202 Hrus
- CRU data sets as weather data
- Modis land cover
- Agricultural management for wheat, Maize and Barely
- Et Calculation based on Hargreaves Method
- Daily step SWAT run and monthly output printing was selected
- 37 yrs of simulation, 3 yrs warm up period (1970-2006)
- Each run 42 hours on a super power machin
Hydrology eq

SCS curve number equation (SCS, 1972)

\[ Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \]

\( I_a \) is initial abstraction which include surface storage, interception and infiltration prior to runoff, mm H\(_2\)O

\( S \) in retention parameter mm H\(_2\)O. The retention parameter varies spatially due to changes in soil, landuse and management and slope and temporally due to changes in soil water content.

\[ S = 25.4 \left( \frac{1000}{CN} - 10 \right) \]

Where CN is the curve number of the day. 
\( I_a = 0.2 \times S \)

\[ Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \]

The SCS Curve number is a fraction of the soil permeability, land use and antecedent soil water conditions.
Water quality eq
Crop growth eq