SWAT Soil & Water Assessment Tool

INSTITUTE OF METEOROLOGY AND WATER MANAGEMENT in Poland

National Research Institute

Topic : **Sediment, Nutrients, and Carbon**

Title : ***Seasonal variability of nutrients load discharged into the surface waters of Polish rivers***

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Seasonal variability of nutrients load discharged into the surface waters of Polish rivers

Objective

Variability analysis of total nitrogen (TN) loads, depending on the season and the stage of growing. Analysis takes into account the variability of the stream flow during a specified period.

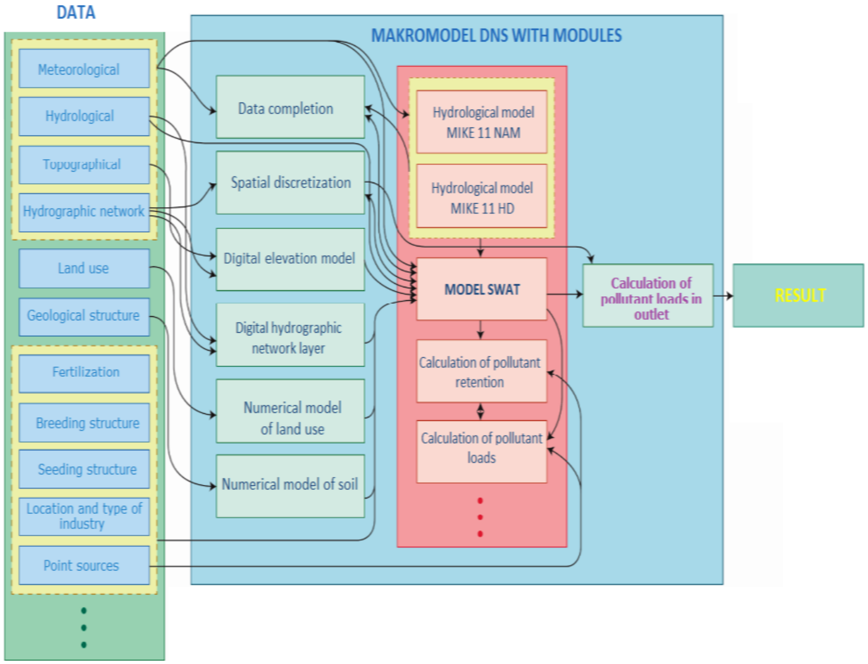
Analyses were performed for three pilot catchments using the Macromodel DNS/SWAT model (Soil and Water Assessment Tool)

Makromodel DNS: connection to coherent module systems describing:

- individual processes of nutrients,
- the spatial nature of land use,
- transport of nutrients in catchement (soil, rivers)

Makromodel DNS modules:

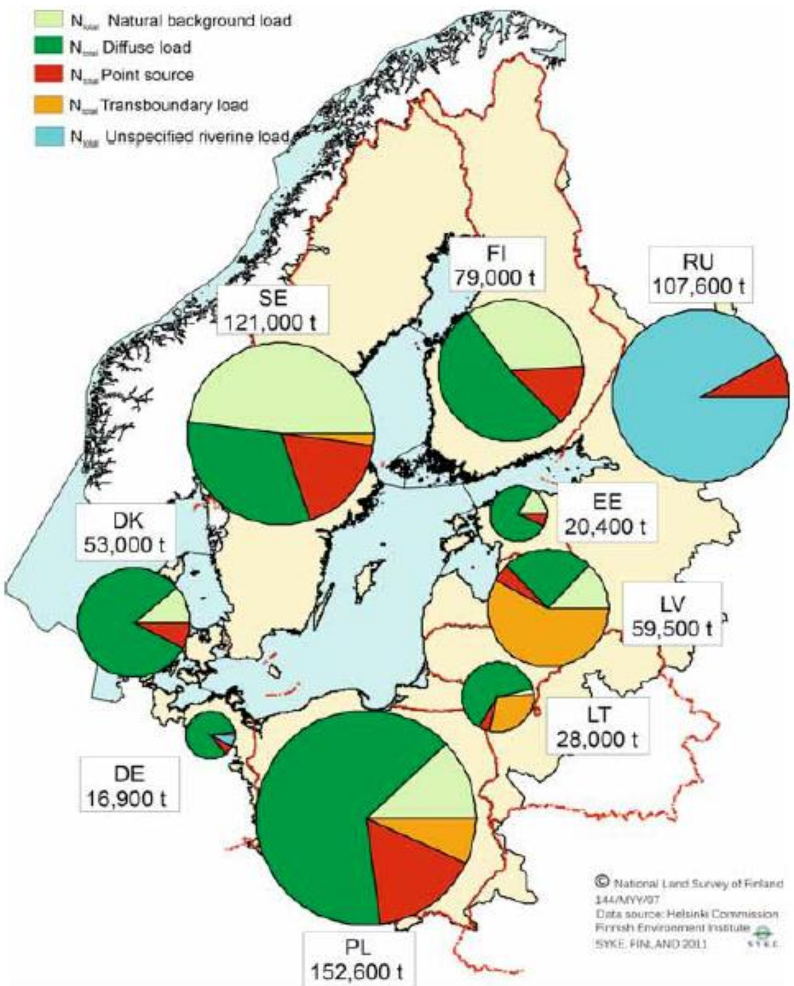
- Data completion modules
- Mathematical modeling modules
- Computational modules



Introduction

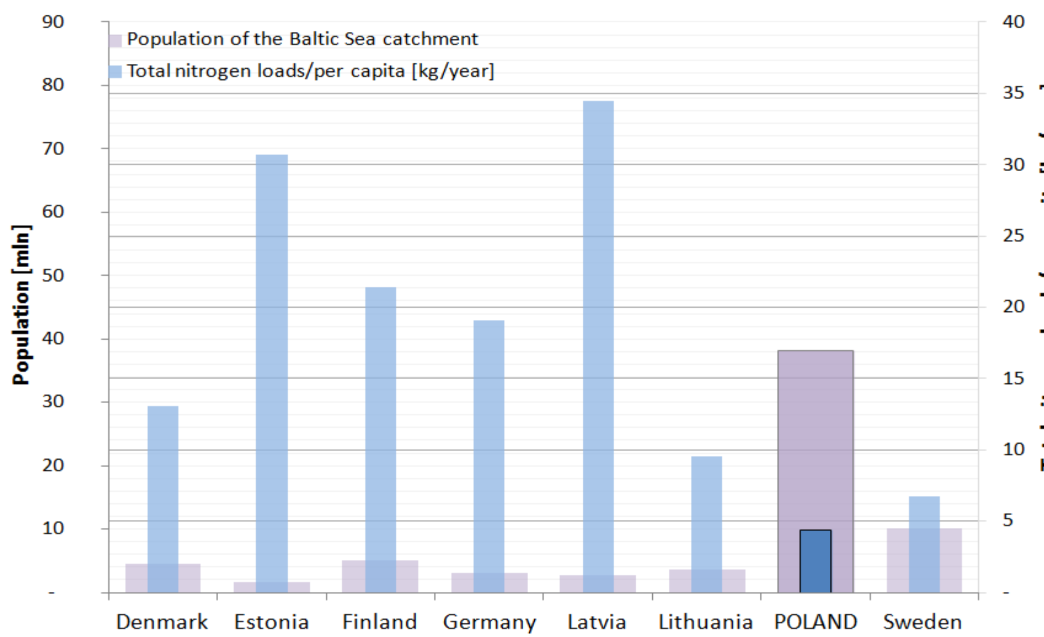
Polish participation in the pollution of the Baltic Sea loads of nutrients and progressive process of eutrophication

EUTROPHISATION (def.) – the process of enrichment of water with nutrients, resulting in an increase in the water's fertility and causing live disorders in organisms. Moreover, it contributes to the fundamental changes in the ecosystems energy, which brings a lot of negative changes in ecosystems



[HELCOM PLC-5]

The content of nitrogen compounds in the Baltic Sea waters has increased about 10-times in comparison to 19th century. In 2008, the total inflow to the Baltic Sea amounted to **859 600t N/year** of which the Polish contribution was **19%**, which places Poland in the first place in terms of volume of the loads



Dynamics of Nitrogen availability and Nitrogen uptake by plants

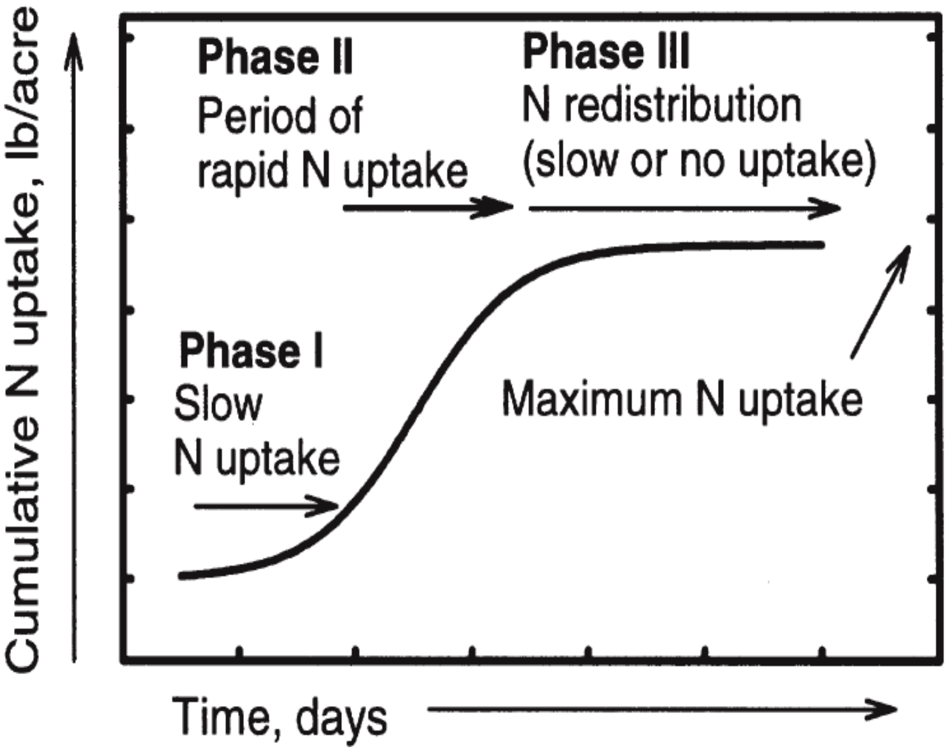
Studies have shown a significant impact of plants on the size of nitrogen compounds transfered from the catchment area to surface waters

Plants nitrogen uptake during the growing season is a three-phase process:

I. slow uptake of nutrients corresponding to the initial stage of growth

II. rapid consumption of the substance corresponding with increasing plant biomass

III. slowing down or stopping the process of collection of compounds

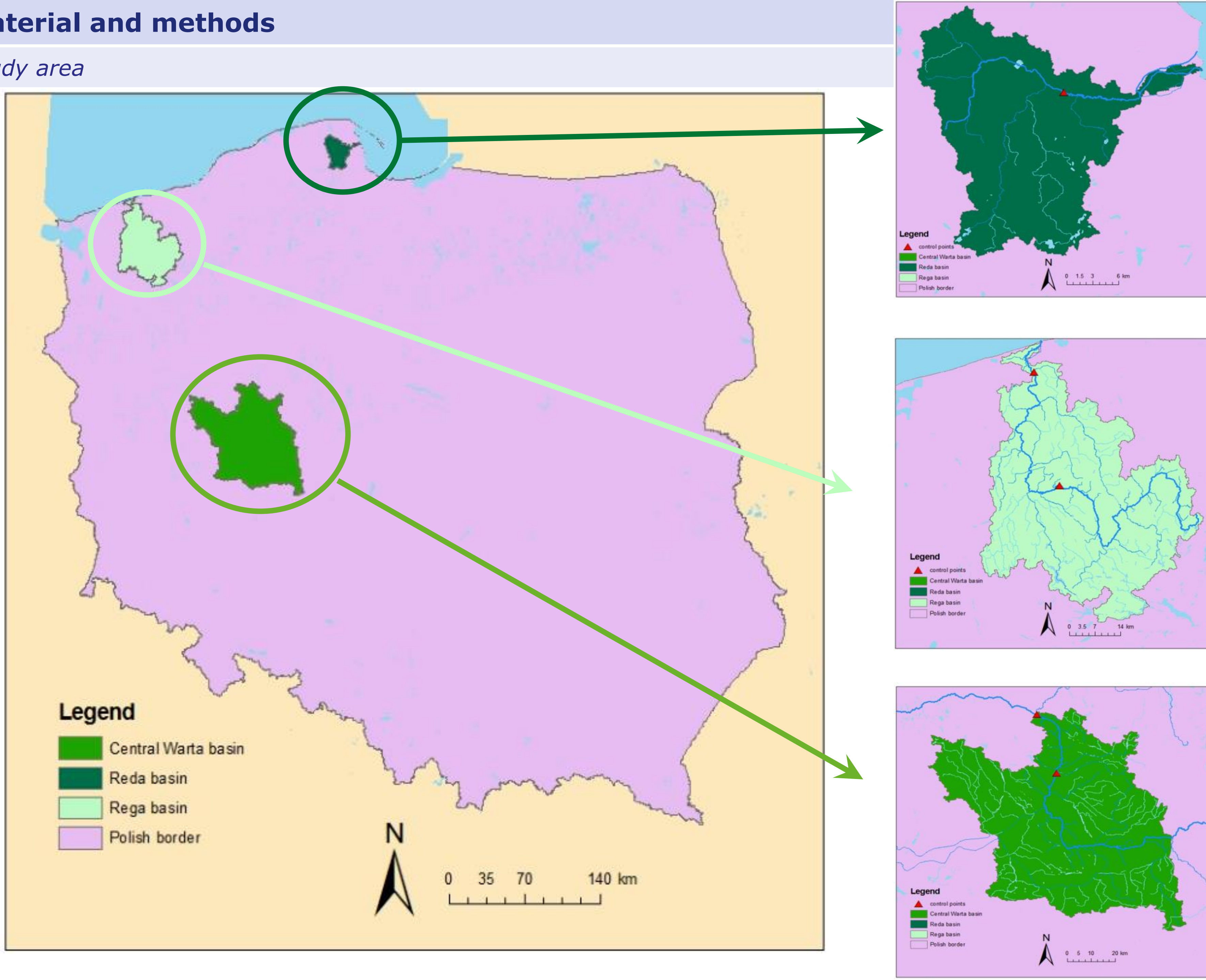


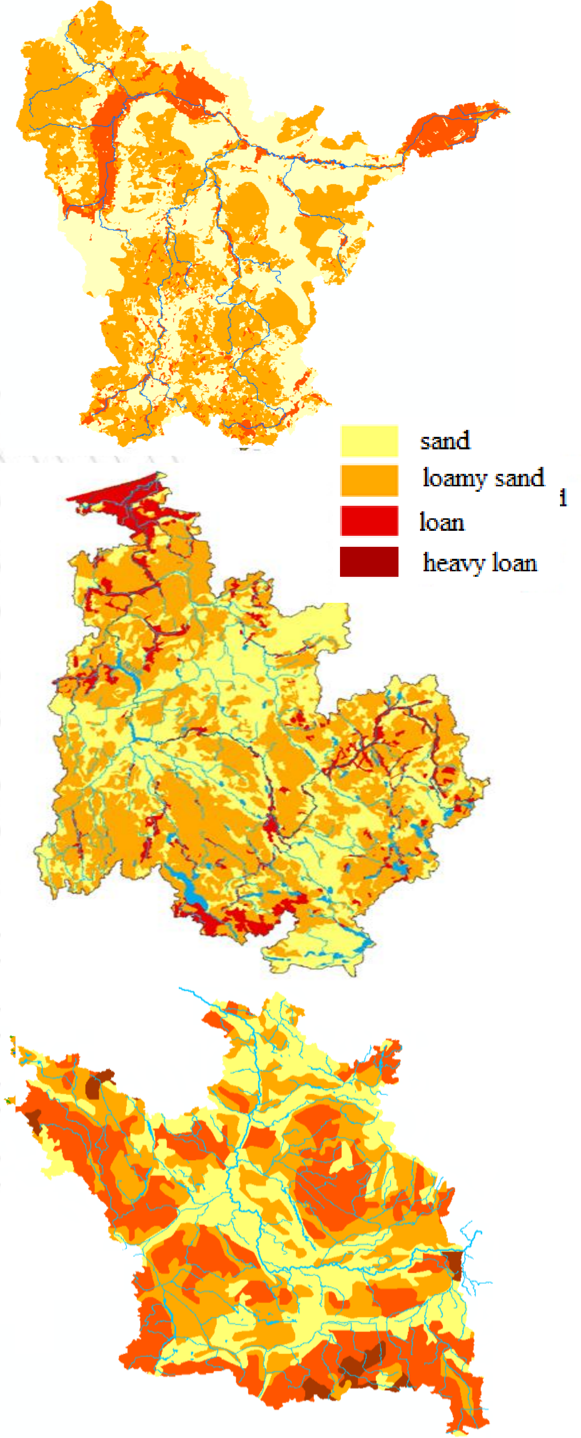
This regularities encourage to carry out an analysis regarding relationship between the processes in catchement area and nitrogen content in water depending on the phase of plant vegetation

Source: Lower Elkhorn, Nartural Resources District,
Sullivan D.M., Hart J.M., Christensen N.W.,Nitrogen Uptake and Utilization;
A Pacific Northwest Extension publication, Oregon, Idaho, Washington

Material and methods

Study area



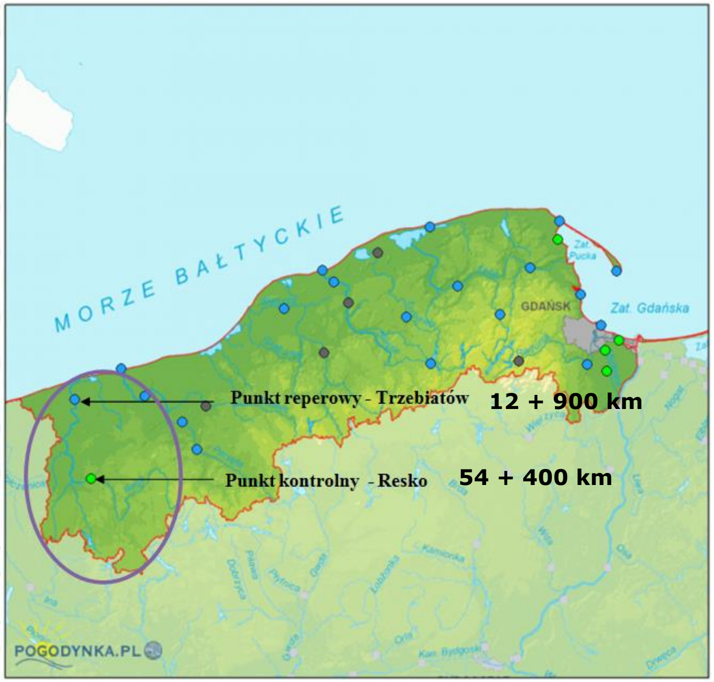


Area	Reda - 485,55 km2
Period and time step	01.01.2002 – 31.12.2005, daily time step
Elevation	0-234 m
Land use	Agriculture: 37%, Forest:40%,
Soil type	Loamy sand: 42,7%, sand: 45,3%, loam: 12%
Climate	2000-2005, Precipitation: 810.4 mm
Monitoring	Wejcherowo:Daily flow, daily TN,TP

Area	Rega - 2766,8 km2
Period and time step	01.01.1995– 31.12.2009 , daily time step
Elevation	0-199 m
Land use	Agriculture: 54,5% Forest: 32%
Soil type	Loamy sand: 50,7%, sand: 39%, loam: 10,2%
Climate	1995-2009, Precipitation: 739.1 mm
Monitoring	Trzebiatów, Resko Daily flow, daily TN,TP

Area	Middle Warta - 6039 km^2
Period and time step	01.01.2002 – 31.12.2009, daily time step
Elevation	0-166 m
Land use	Agriculture: 72.82% Forest: 20.04 %
Soil type	Loamy sand: 30,5%, sand: 33,6%, loam: 33,6% heavy loam: 2.2%
Climate	2002-2009, Precipitation: 544.5 mm
Monitoring	Most Rocha, Oborniki : Daily flow, daily TN,TP

Obtaining reliable modeling results requires comparing them with the monitoring data by the step of:



I. Calibration – parameterization with a view to obtain the greatest convergence of simulations and observations

II. Verification – checking whether the model is a good enough representation of reality – on independent data

III. Validation – the final step - performed at a different point than the calibration step

Material and methods

Evaluation methods of models

EVALUATION STATISTICS

Coefficient of determination (R^2)

Matching compability between observed and simulated data

$$R^2 = \frac{\left(\sum_i (y_i^{obs} - y_{sr}^{obs})(y_i^{sim} - y_{sr}^{sim})\right)^2}{\left(\sum_i (y_i^{obs} - y_{sr}^{obs})^2\right)\left(\sum_i (y_i^{sim} - y_{sr}^{sim})^2\right)}$$

Nash–Sutcliffe efficiency coefficient (NSE)

Data variability assessment between observed and simulated data

$$NSE = 1 - \frac{\sum_i (y_i^{obs} - y_i^{sim})^2}{\sum_i (y_i^{obs} - y_{sr}^{obs})^2}$$

Bias coefficient (PBIAS)

Percentage of overestimation and underestimation of variables

$$PBIAS = \frac{\sum_i (y_i^{obs} - y_i^{sim})}{\sum_i y_i^{obs}} 100\%$$

Even a single error, seen as a deviation of simulation from observation, should not result in signifficant statistical errors in the results and final conclusions

In statistical analysis **mean winsorized** was applied

Robust *(Hubert):* insensitivity to small deviations from the assumptions - achieving relative insensitivity of robust estimator to:

- *a small number of observations of large deviations suspected of being erroneous observations*
- *a large number of relatively small deviations in observations – e.g as a results of rounding data in a sample*

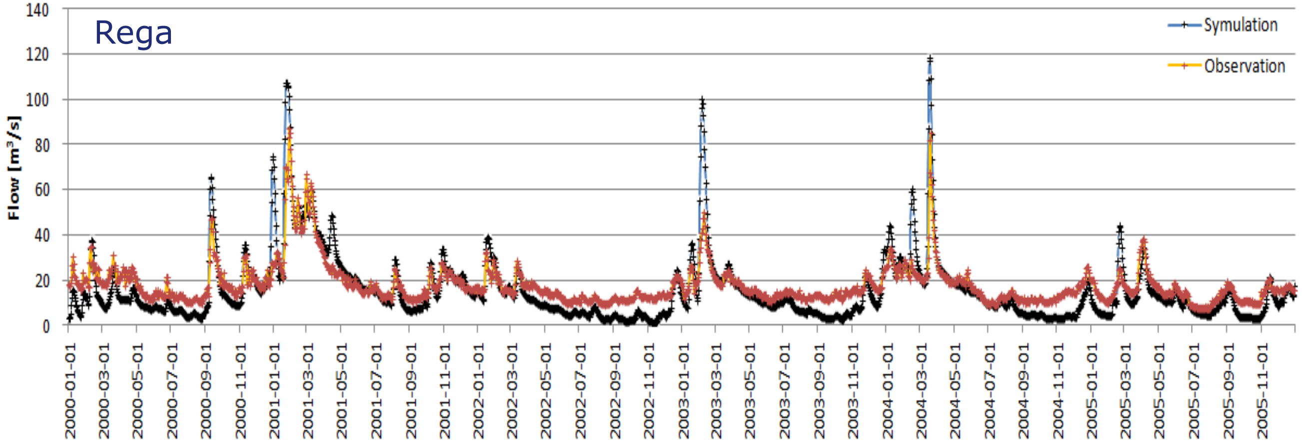
$$W_\alpha = \frac{1}{n}\left((g+1)X_{(g+1)} + \sum_{i=g+2}^{n-g-1} X_{(i)} + (g+1)X_{(g+1)} \right) = \frac{1}{n}\sum_{i=g+2}^{n-g-1} X'_{(i)}$$

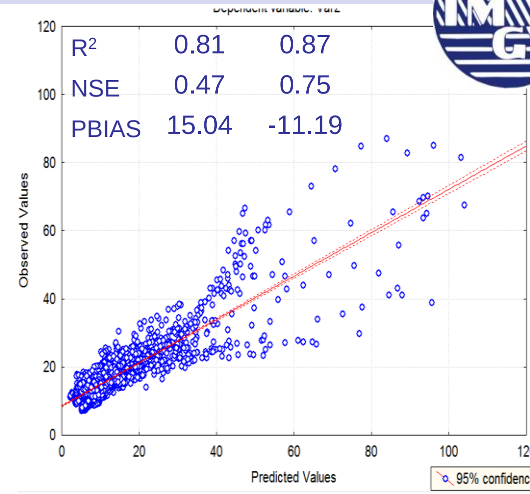
where:

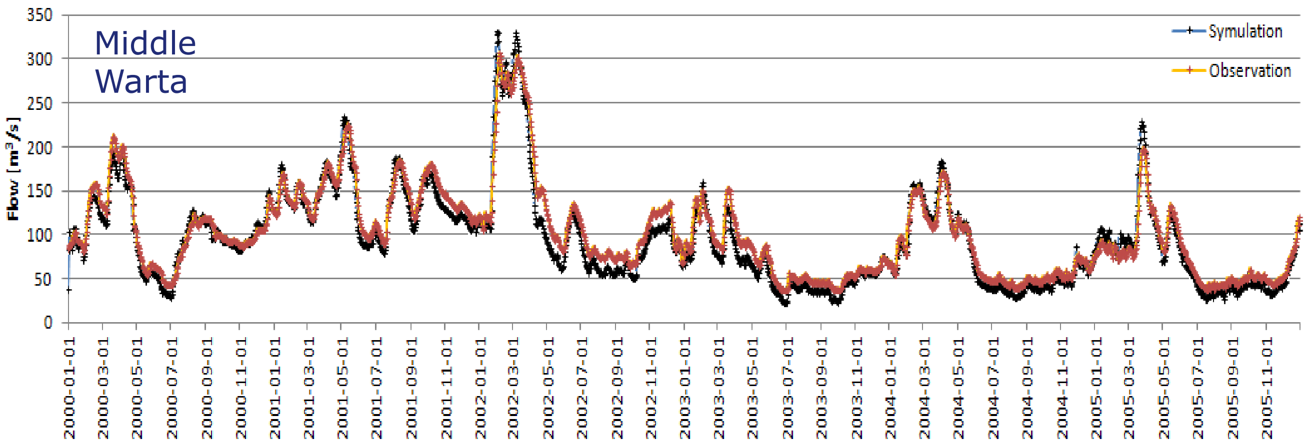
$$X'_{(i)} = \begin{cases} X_{(i)} & dla \quad g+1 \leq i \leq n-g \\ X_{(g)} & dla \quad i \leq n \\ X_{(n-g-1)} & dla \quad i \geq n-g+1 \end{cases}$$

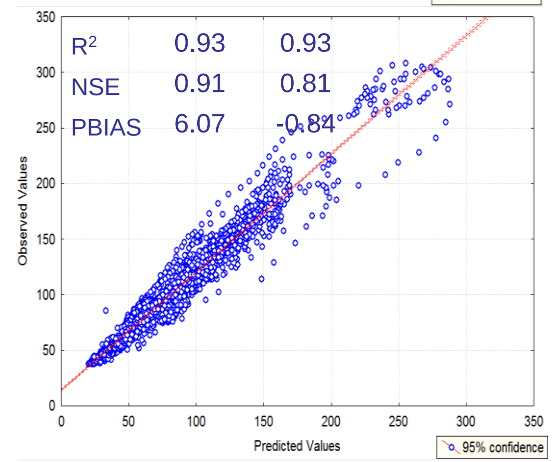
Calculations are based on the calculation of the relevant statistical measures of the modified value sets

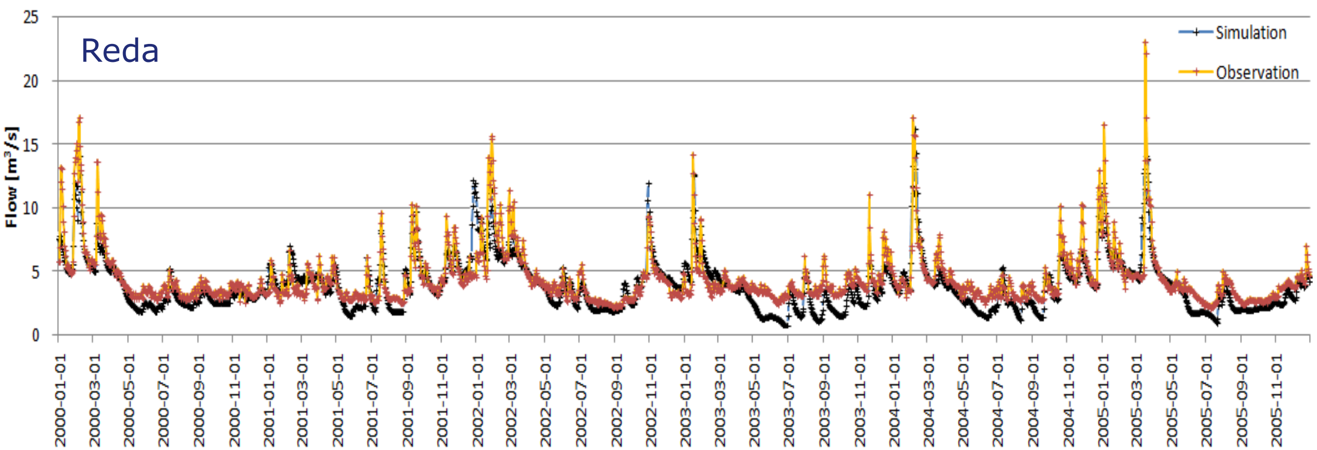
Results: *Calibration, Verification – Stream flow*

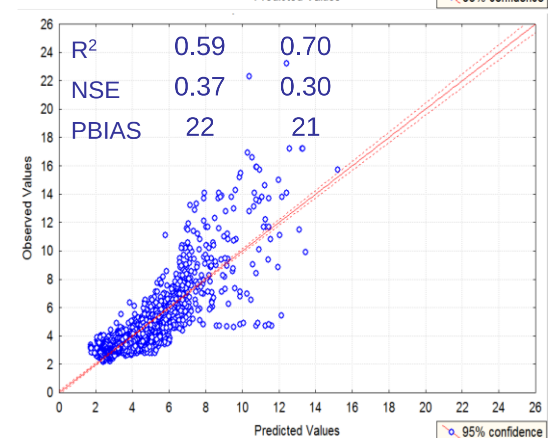






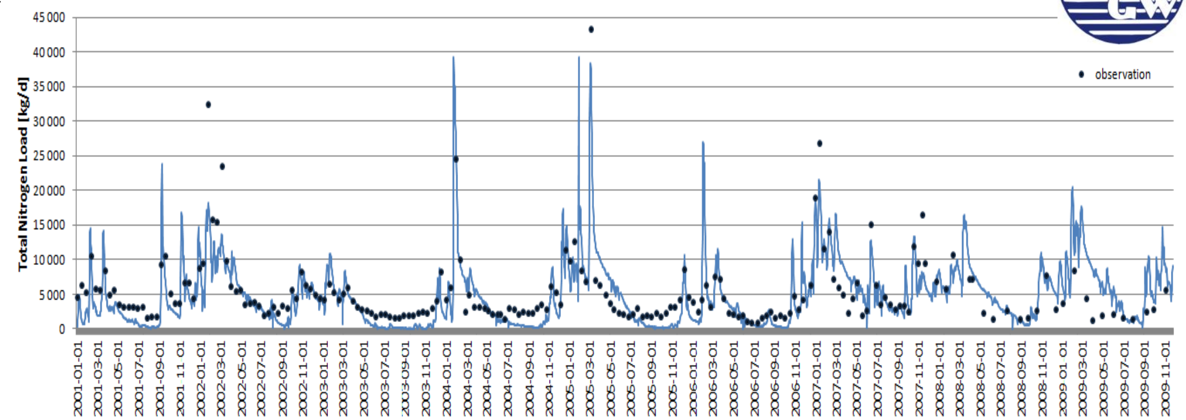


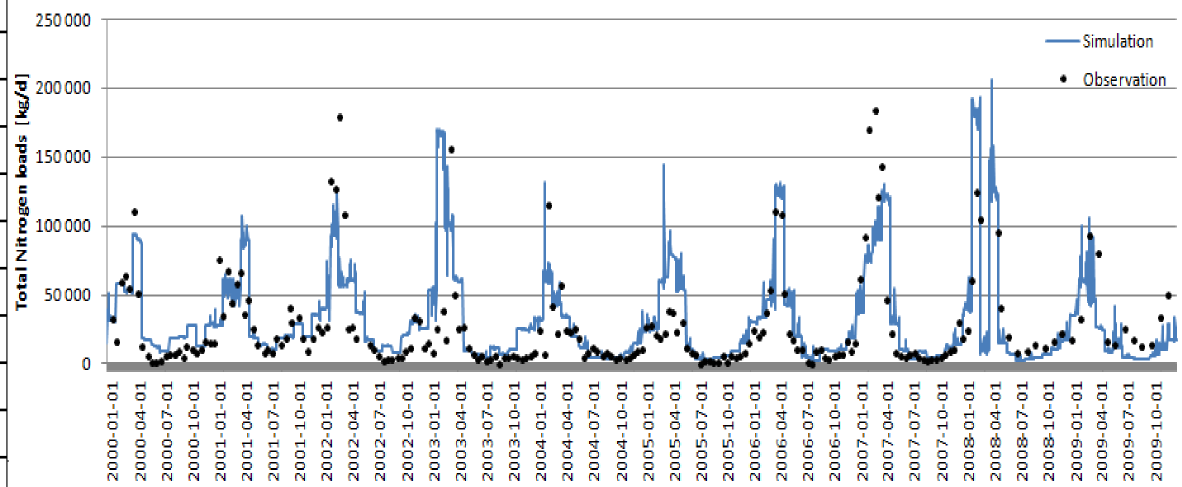


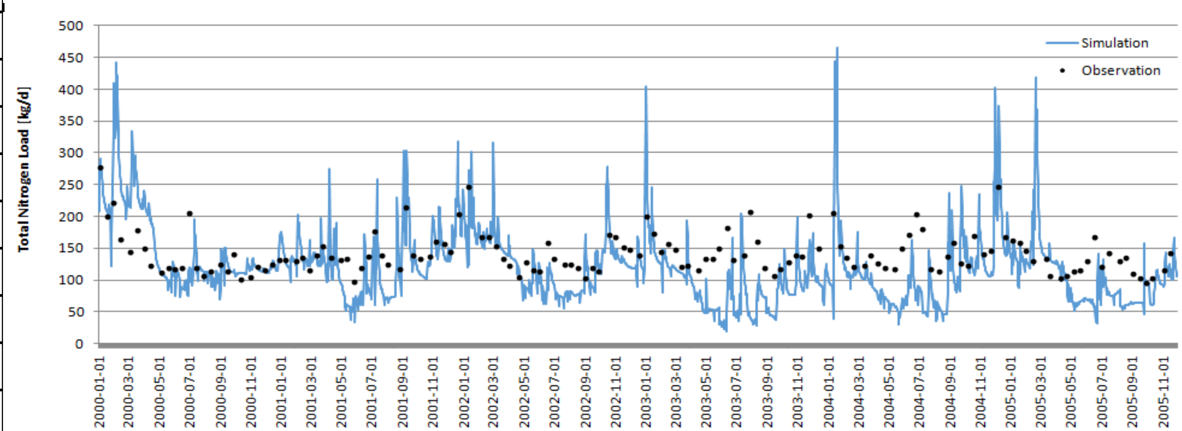


Results: *Calibration, Verification – Total Nitrogen*

Catch.	Stage	Statistical measures	Stream flow	TN
Rega	Calibr.	R^2	0.81	0.50
		NSE	0.47	0.00
		PBIAS	15.00	23.32
	Verif.	R^2	0.87	0.55
		NSE	0.75	0.47
		PBIAS	-11.19	-13.06
	Valid.	R^2	0.69	0.57
		NSE	0.00	0.38
		PBIAS	2.53	28.39
Middle Warta	Calibr.	R^2	0.93	0.65
		NSE	0.91	0.59
		PBIAS	6.07	-0.44
	Verif.	R^2	0.93	0.81
		NSE	0.81	0.57
		PBIAS	-0.84	0.14
	Valid.	R^2	0.94	0.47
		NSE	0.85	0.06
		PBIAS	14.51	-0.58
Reda	Calibr.	R^2	0.59	0.40
		NSE	0.37	-1.13
		PBIAS	22	12
	Verif.	R^2	0.70	0.30
		NSE	0.30	-2.37
		PBIAS	21	23
	Valid.	R^2	-	-
		NSE	-	-
		PBIAS	-	-



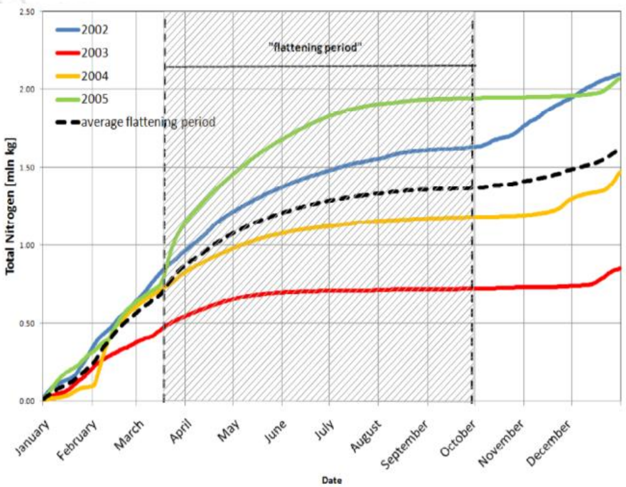




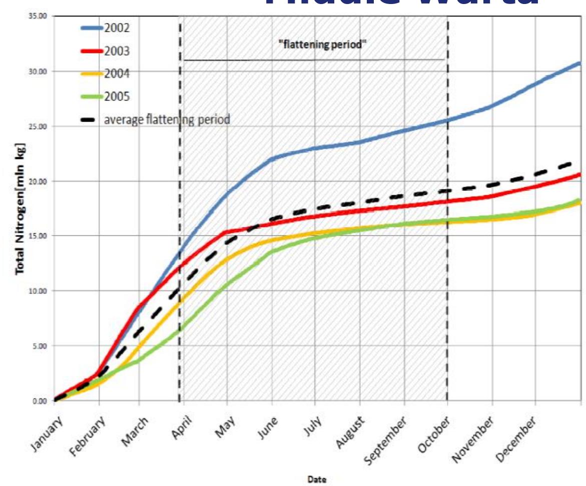
Contribution of total nitrogen in the outflow of the area was analyzed on the basis of :

I. **Cumulative N curve** of total nitrogen loads was created for the period 01.01.2002 – 31.12.2005 r. for pilot rivers catchements

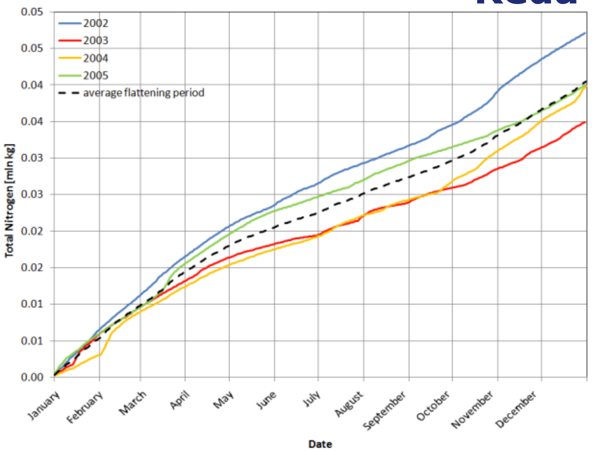
Rega



Middle Warta



Reda

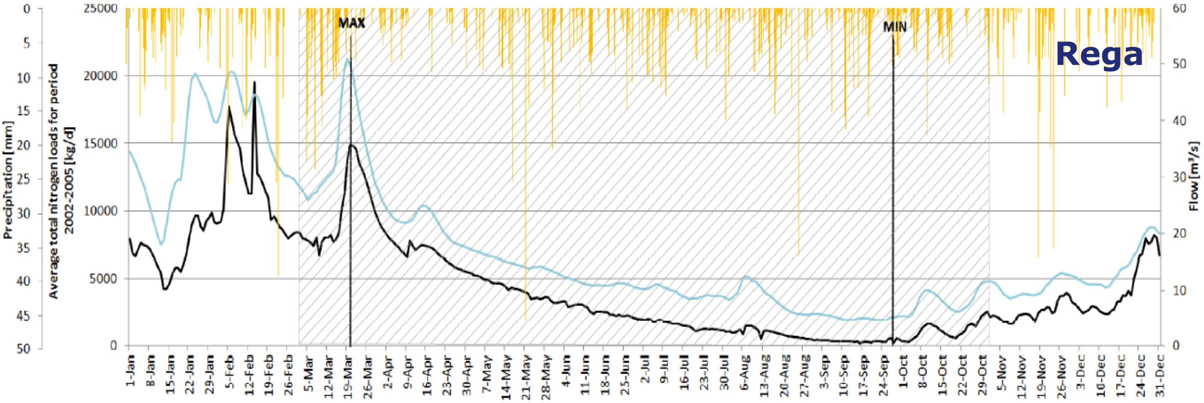


The amount of total nitrogen loads in the outflow profiles for the Rega and the Middle Warta catchements is stabilizing in the months from April to October. This coincides with the growing season

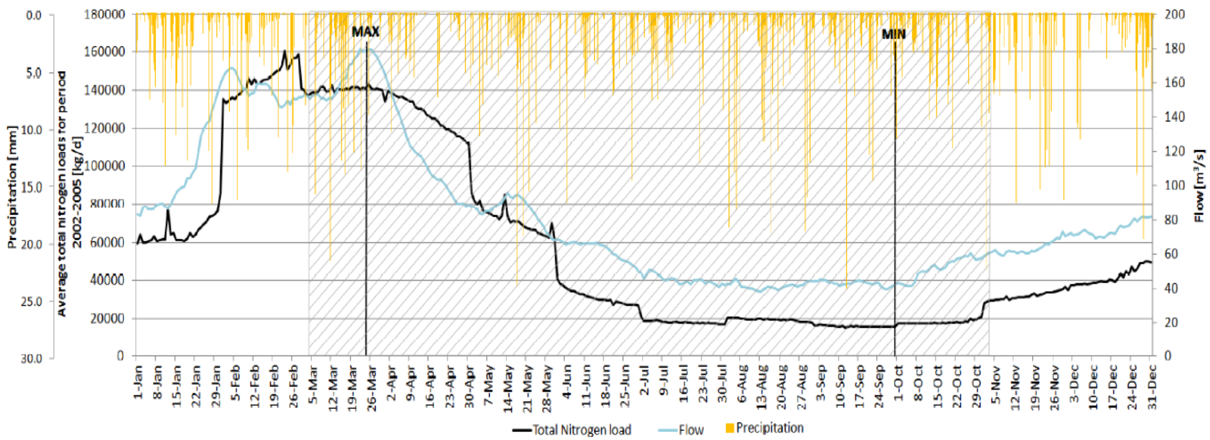
„Flattening period” - this phenomenon is defined as a period of stabilization of nitrogen loads in outflow profiles in catchments

Results

Total Nitrogen loads for the Rega and the Middle Warta catchments



Period (dd-mm)	20.03(MAX)-28.09 (MIN)*	29.09 – 19.03	2002-2005
Precip [mm]	363.75	345.22	**Sum:** 708.97
Stream flow [m^3/s]	13.40	46.11	**Average:** 17.45
TN load [kg/d]	3389.00	11781.38	**Average:** 4425.27



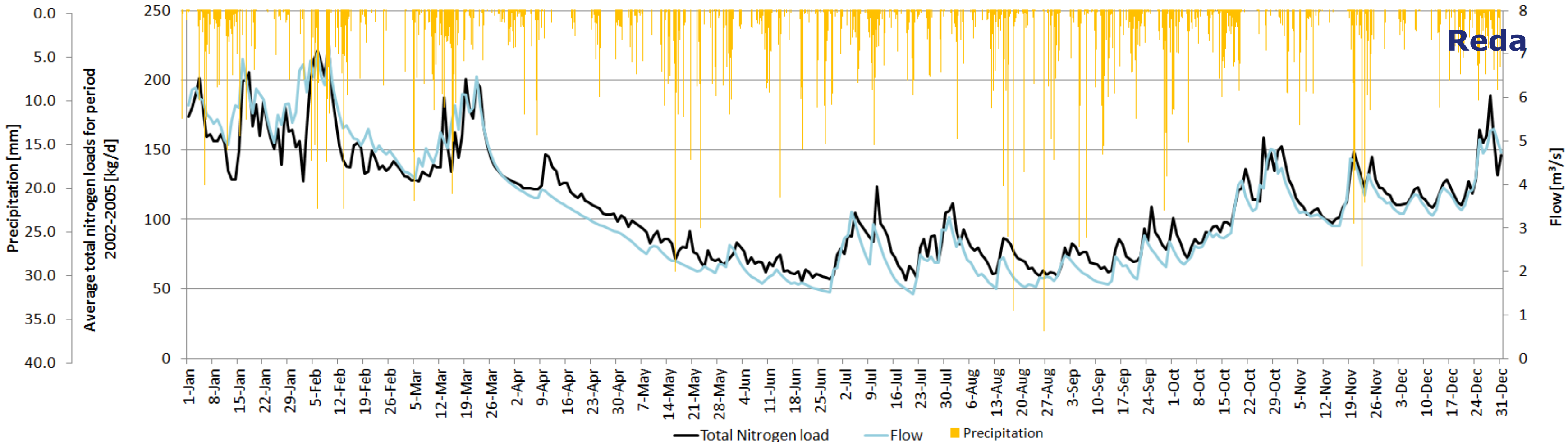
Period (dd-mm)	25.03(MAX)-29.09(MIN)*	30.09 - 24.03	2002-2005
Precip [mm]	294.25	262.37	**Sum:** 556.62
Stream flow [m3/s]	72.06	198.72	**Average:** 83.31
TN load [kg/d]	53176.20	142691.13	**Average:** 59934.47

1. Retention increases in growing season → higher loads of total nitrogen are observed in winter months than in summertime
2. Total precipitation during average flattening periods is higher than in winter periods
3. Streamflows during average flattening periods are lower

This confirms significant contribution of plants within the basin, including arable crops, in the retention of water and nitrogen compounds

Results

Total Nitrogen loads for the Reda catchments



Lack of noticeable retention of total nitrogen in the analysed periods

This may be due to:

- many uncontroled years of excessive soil fertilization in the area – this could cause the percolation of nitrogen compounds through the deeper layers of soil. Though subsurface runoffs are rather evenly washed into the river,
- subsurface runoffs are not as dynamic as the surface runoffs and are dependent on the season and the growing season

Soil profile	Average for Poland		REDA	
	The mineral nitrogen contents Nmin (NO3-N + NH4-N) [mg/kg]			
	spring	autumn	spring	autumn
0-30	9.0	11.6	16.7	19.4
30-60	6.7	6.9	8.2	11.6
60-90	5.8	5.1	8.9	10.2

Conclusions:

- Retention of water coming from rainfall by plants in the catchment is important from the point of view of reducing the total nitrogen loads in surface waters,

- After the end of the growing season and the collection of crops from the catchment area, there comes a period of an increase of total nitrogen loads in waters caused by increase of surface runoffs,

- Even short-term retention is a desirable phenomenon in the environment. Storing water from rainfall in the soil and thus reducing surface runoffs of nitrogen compounds coming from fertilizers, allows a better use of fertilizers by plants,

- The phenomenon of „flattening” is not always present and depends very often on the amount of nitrogen compounds available in the soil and procesess of leaching to waters,

- The size of the „flattening” phenomenon allows to detemine the relations between the amount of exported nitrogen compounds into water, depending on the season, extreme weather phenomena and the periods of increasing nitrogen uptakes by plants.

Thank you for your attention!

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