Phytoplankton blooms localized by Sentinel-2 images and hydrodynamic modelling – Sulejów Reservoir, Pilica River, Poland

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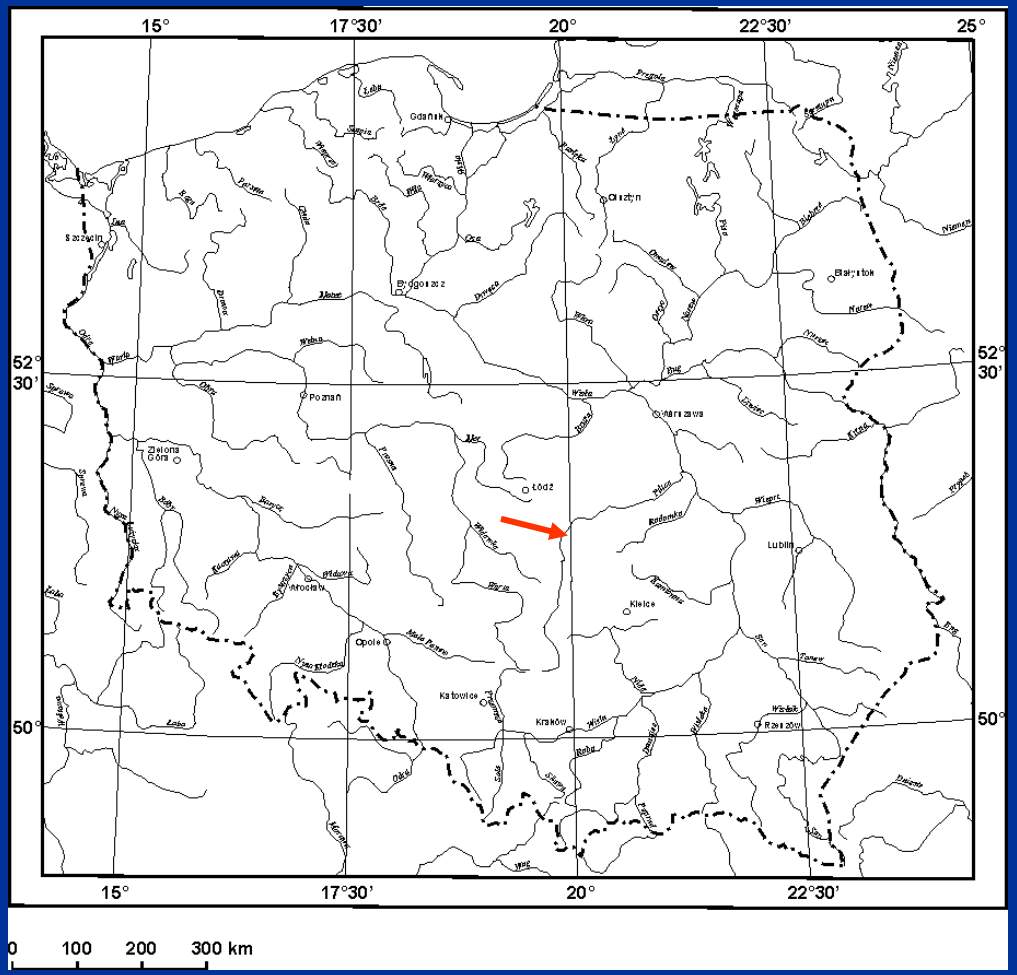
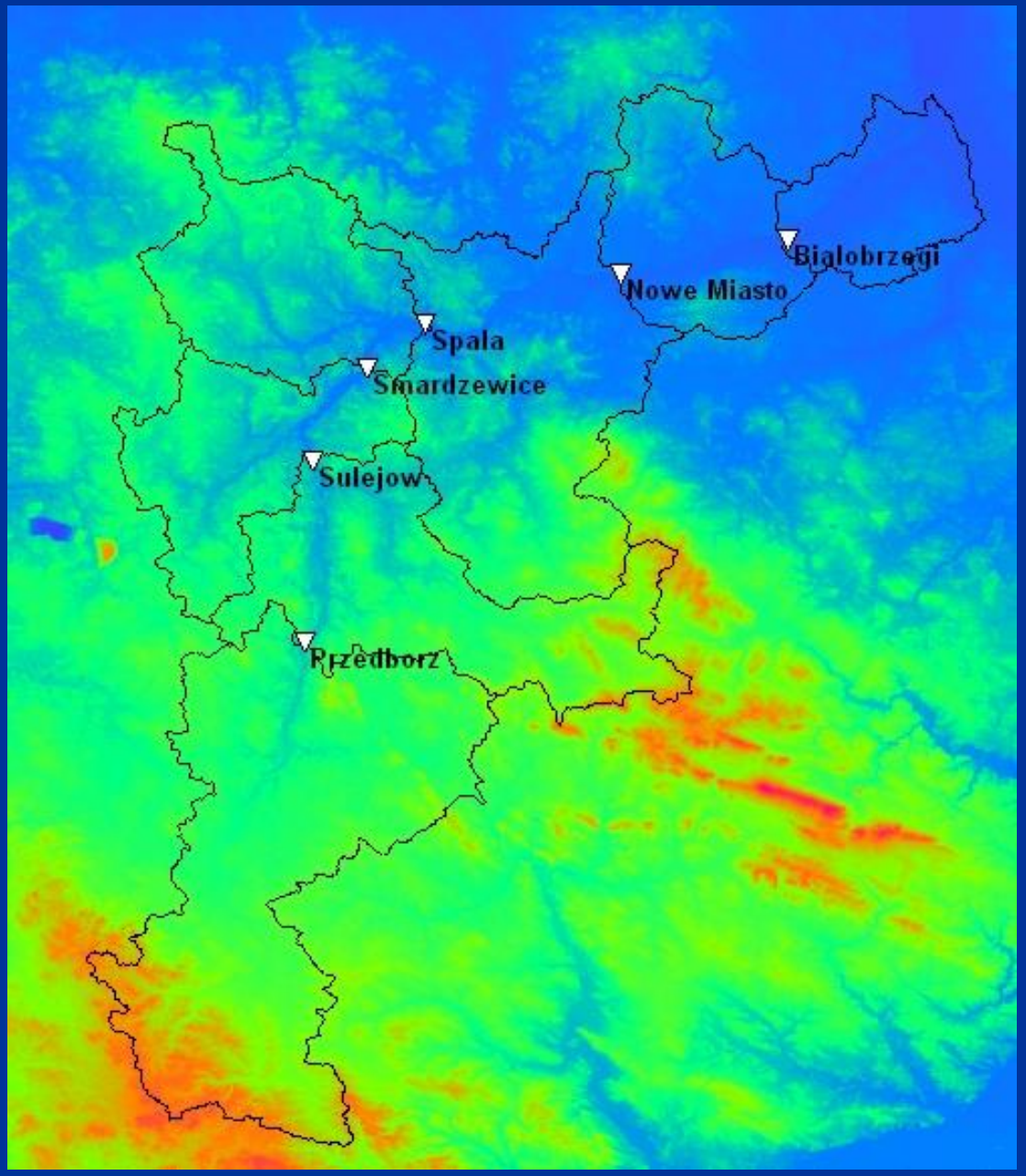
Location of the Pilica river and study area

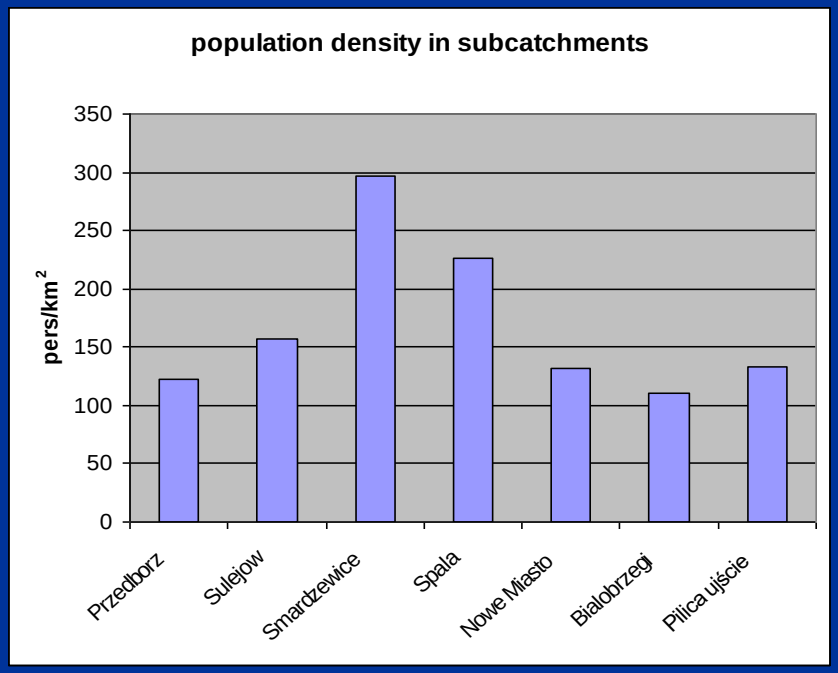
Pilica River is a right side tributary of the Vistula river, it has a length of 342 km and catchment area of 9,258 km^2.



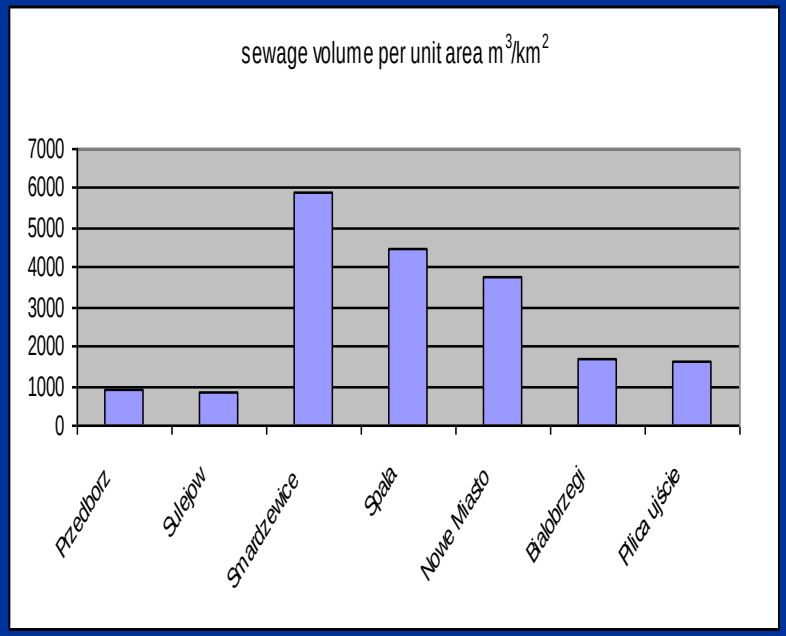


SRTM
Global Land Cover Facility,
Uniwersytet Maryland USA
(http://glcf.umiacs.umd.edu).

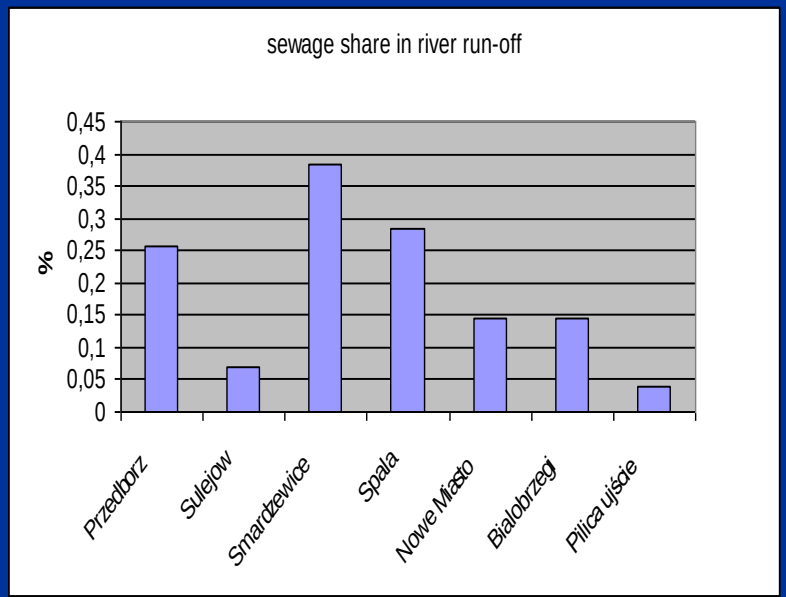
Population density pers/km^2



Sewage volume per unit area m^3/km^2



Sewage in river run-off (%)



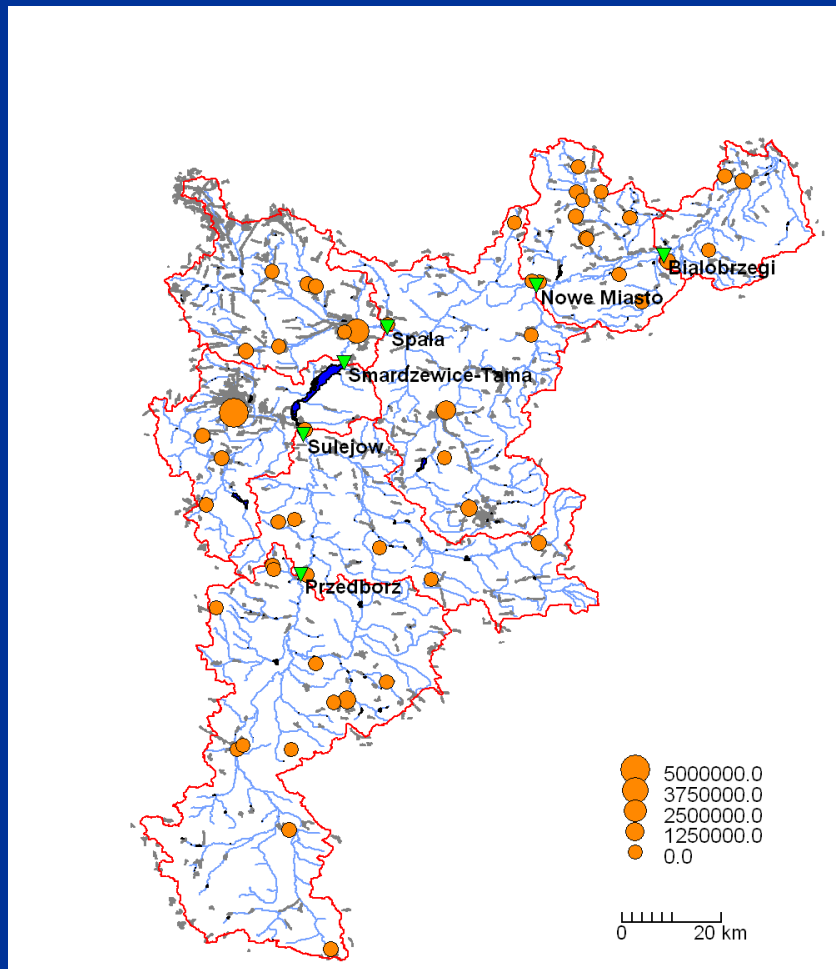


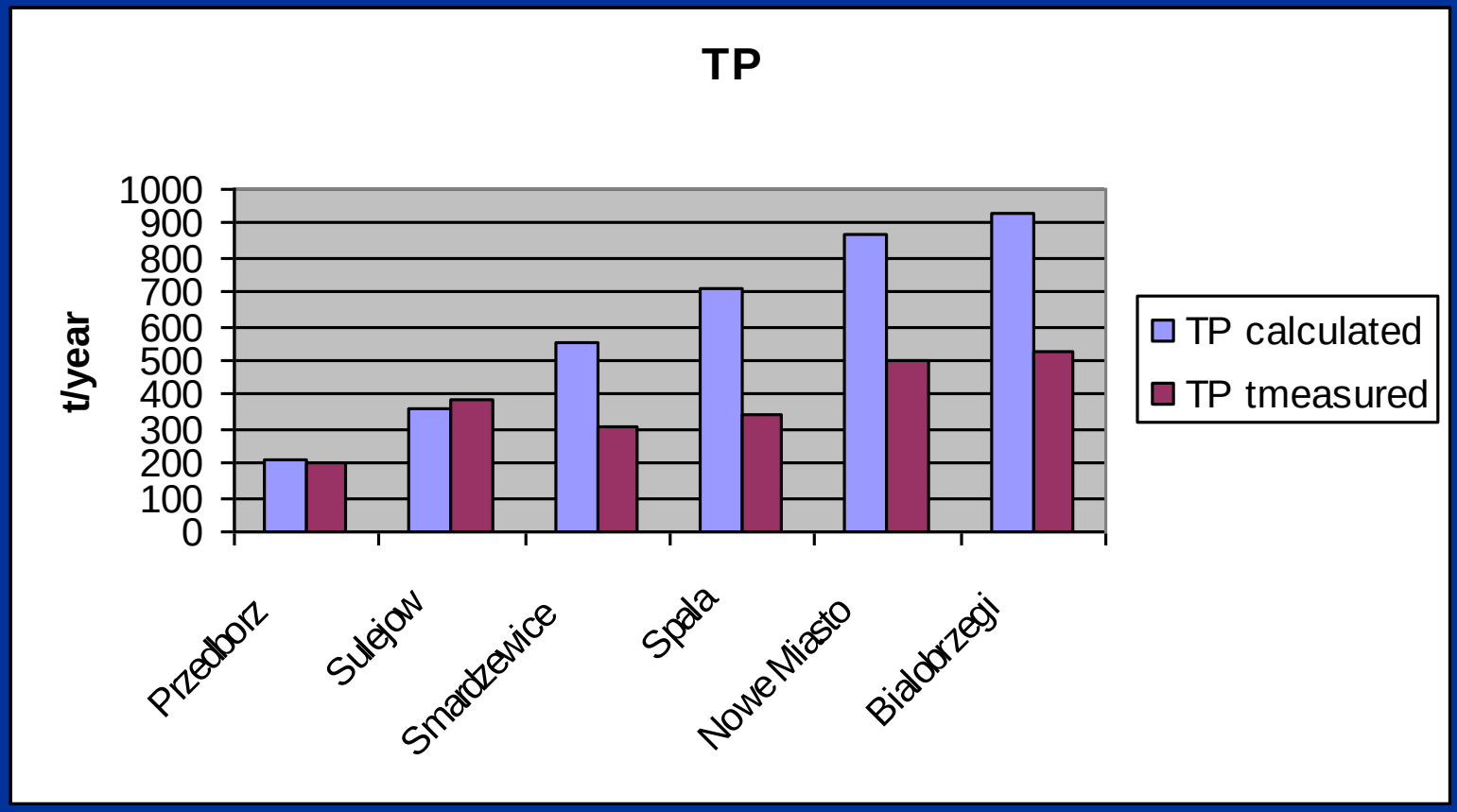
Table 1
Different nutrient flows from dwellings to the stream network

Methods of treatment	TN (kg N person^{-1} yr^{-1})	TP (kg P person^{-1} yr^{-1})
Dwellings with septic tanks		
Rhine 1990–1995 (de Wit, 1999)	1.18	0.29
Elbe 1990–1995 (de Wit, 1999)	1.22	0.24
Applied in this study	1.20	0.27
Dwellings delivering effluent directly to the river network		
Rhine 1990–1995 (de Wit, 1999)	4.38	0.63
Elbe 1990–1995 (de Wit, 1999)	4.06	0.72
Applied in this study	4.10	0.67

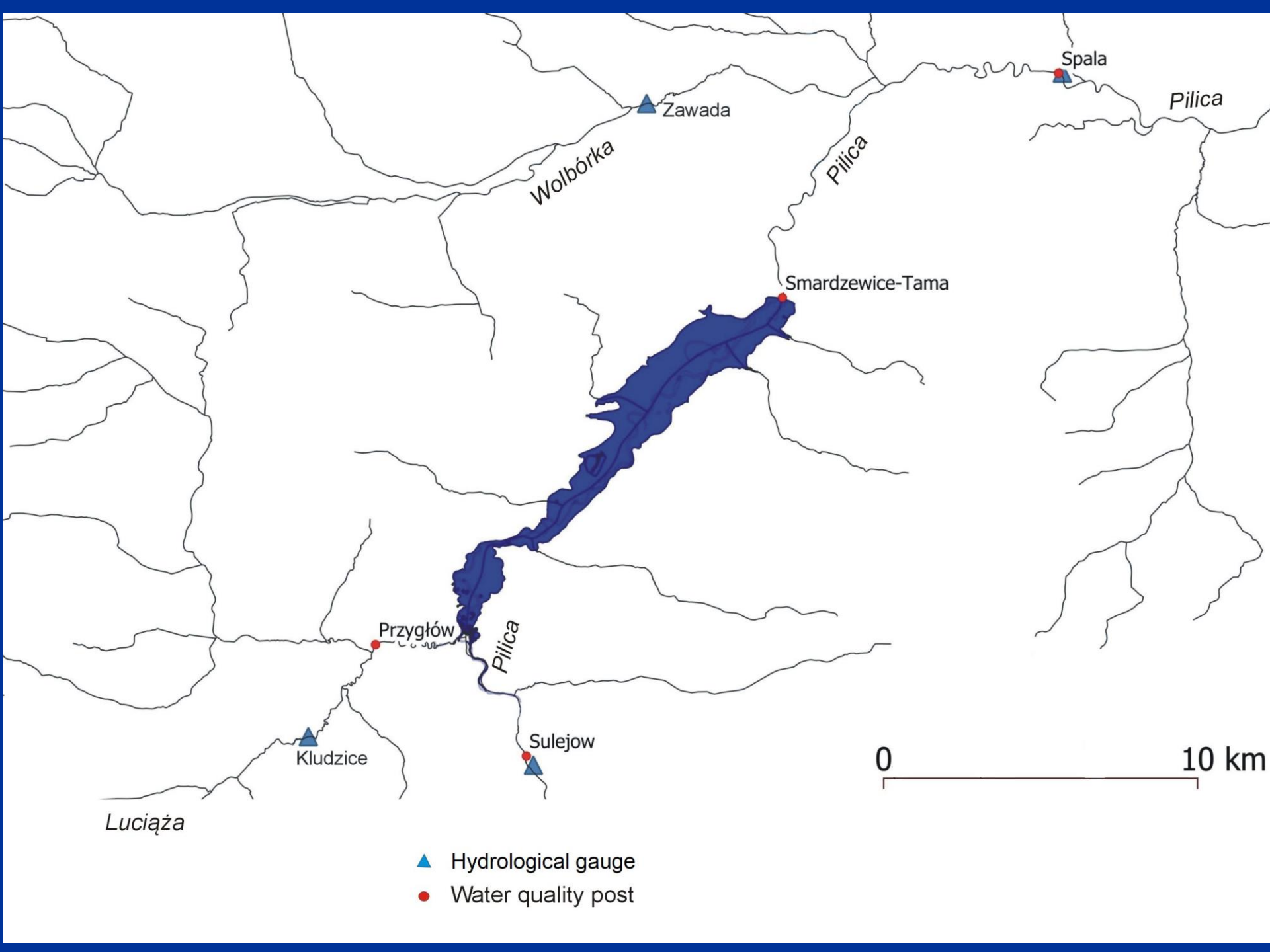
Pieterse N.M., Bleuten W. Jørgensen S.E., 2003, Contribution of point sources and diffuse sources to nitrogen and phosphorus loads in lowland river tributaries. Journal of Hydrology 271(2003) 213–225.

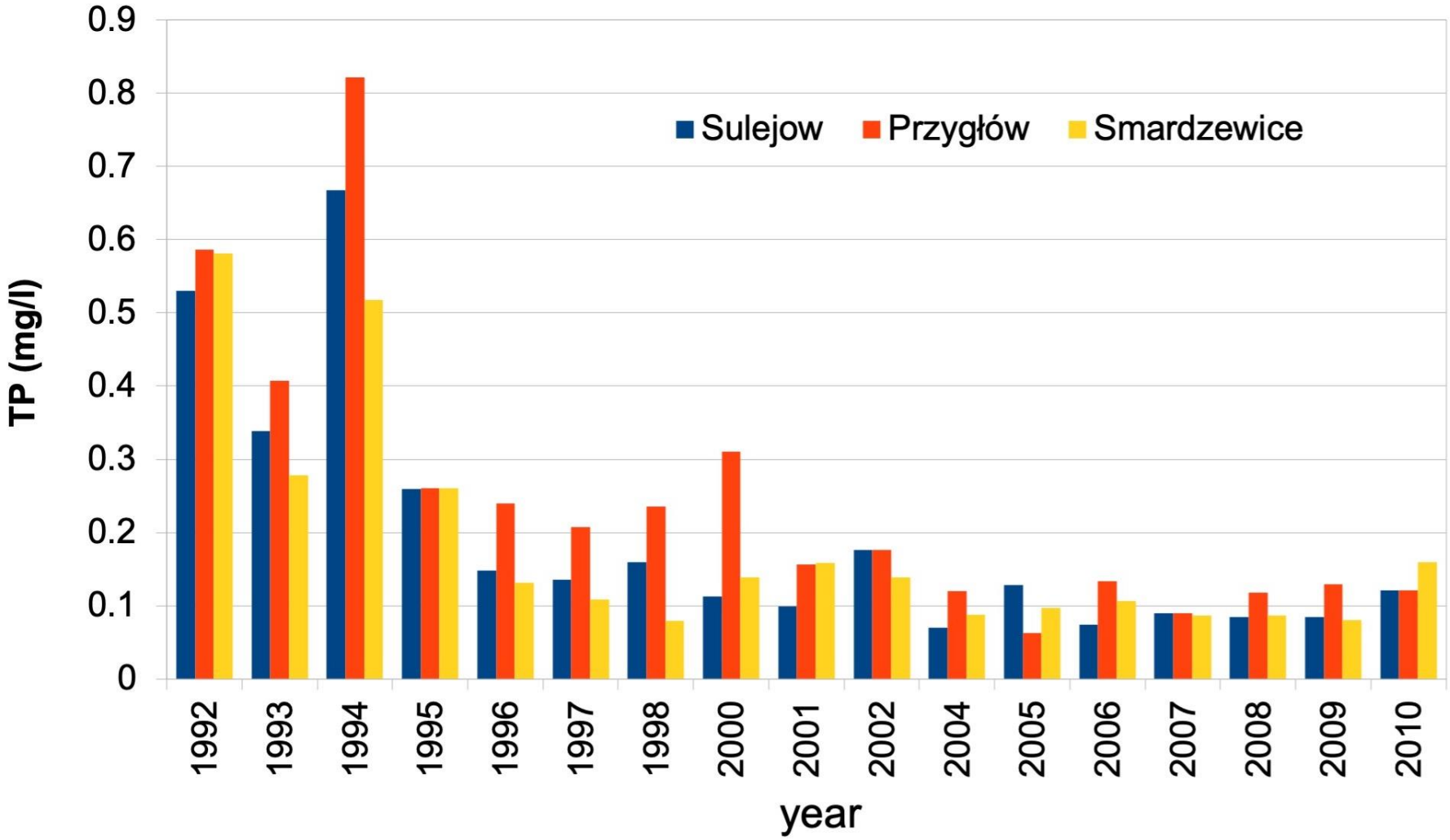
TP load measured versus calculated

Sulejów Reservoir retained 80.4 t of TP load during the study period 19 May 2010 - 19 May 2011 (Kiedrzyńska et all., 2012)



Measured data from Kiedrzyńska et all., 2012


Spala
Pilica
Zawada
Wolbórka
Pilica
Smardzewice-Tama
Przygłów
Pilica
Sulejow
Kludzice
Luciąża
0
10 km
Hydrological gauge
Water quality post

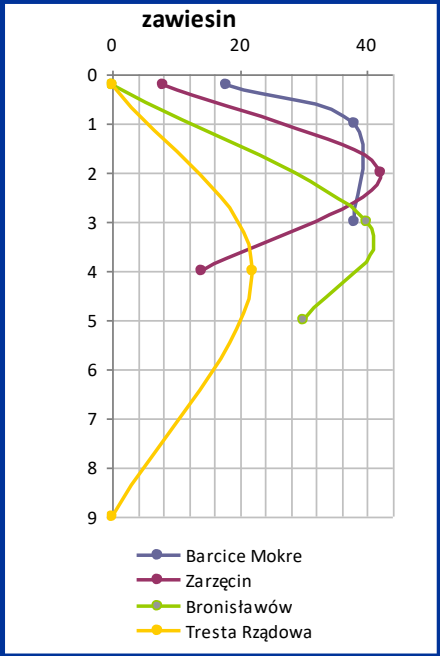


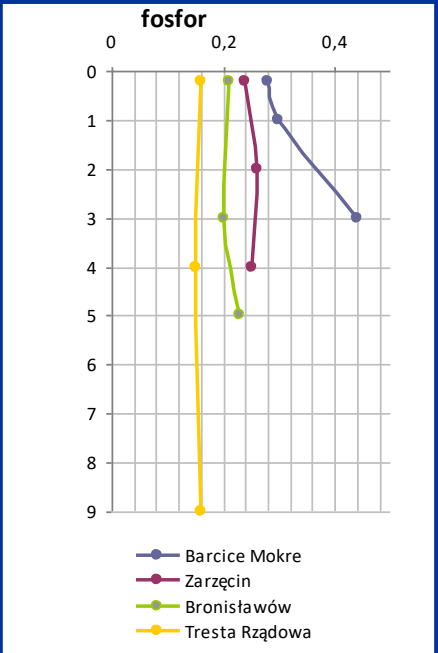
Average annual concentrations of TP in the monitoring stations at the Sulejów Reservoir backwater: Pilica River – Sulejów; Luciąża River – Przygłów; and below the Pilica dam – Smardzewice. The data for TP concentration was not made for years 1999 and 2003.

SS

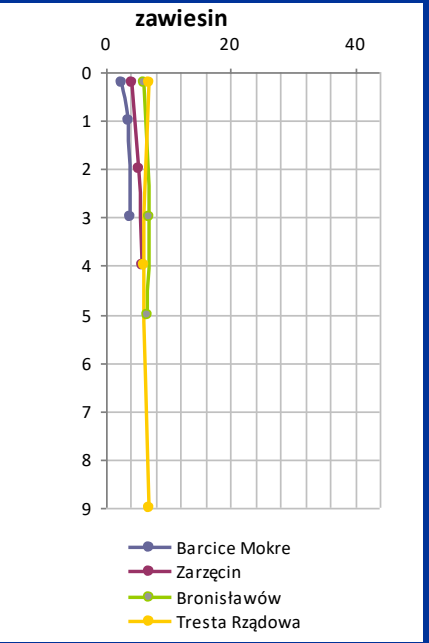
TP

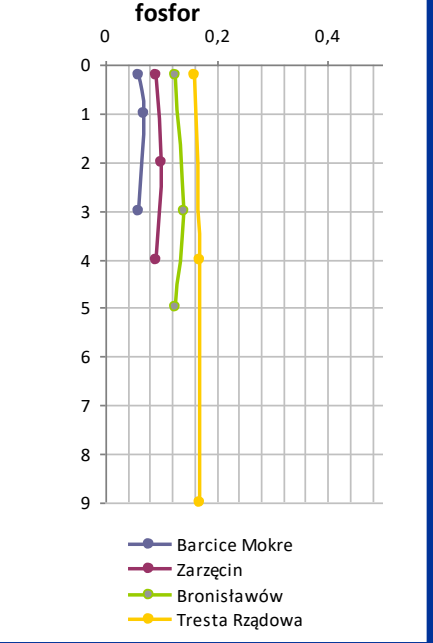
WQ=208

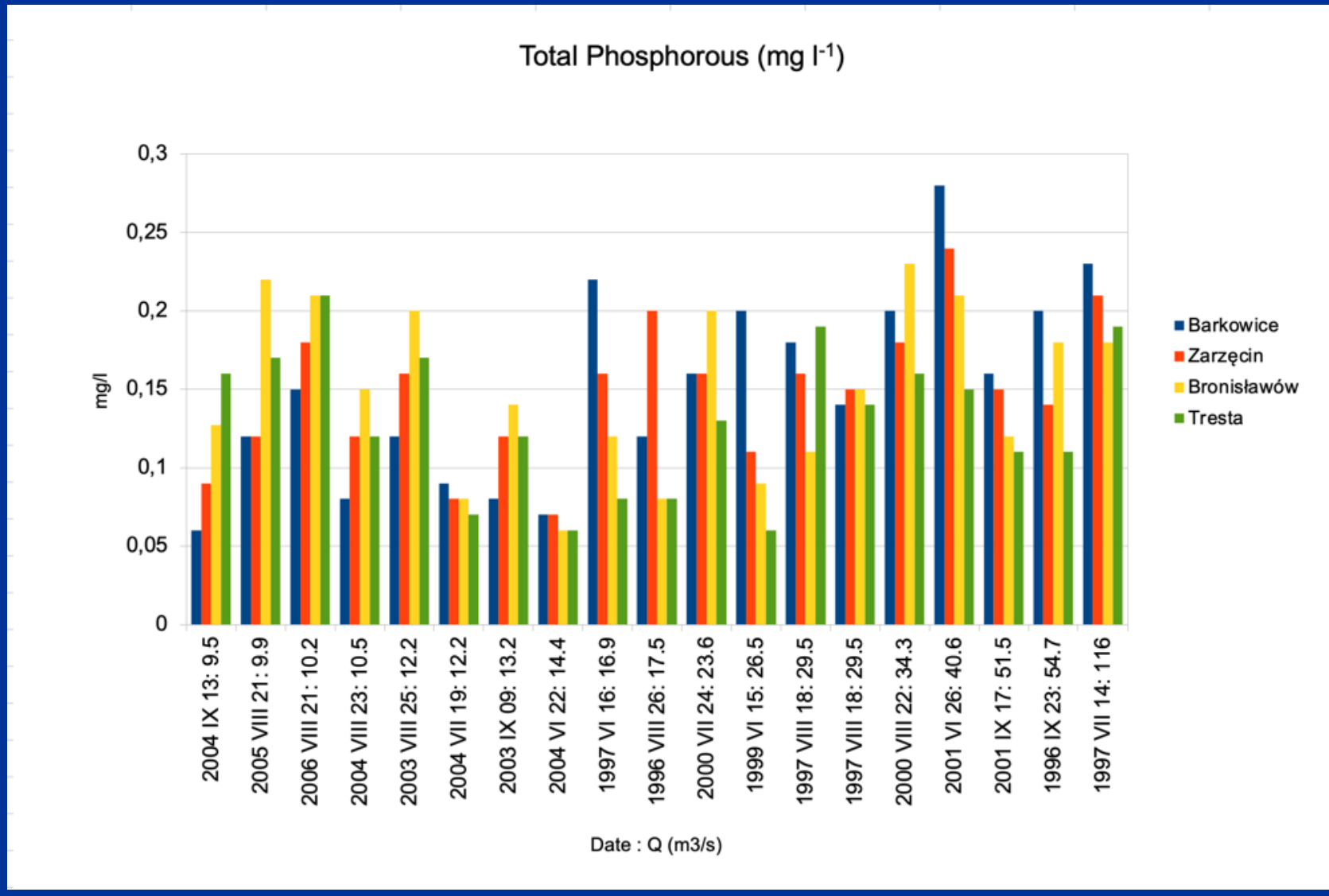


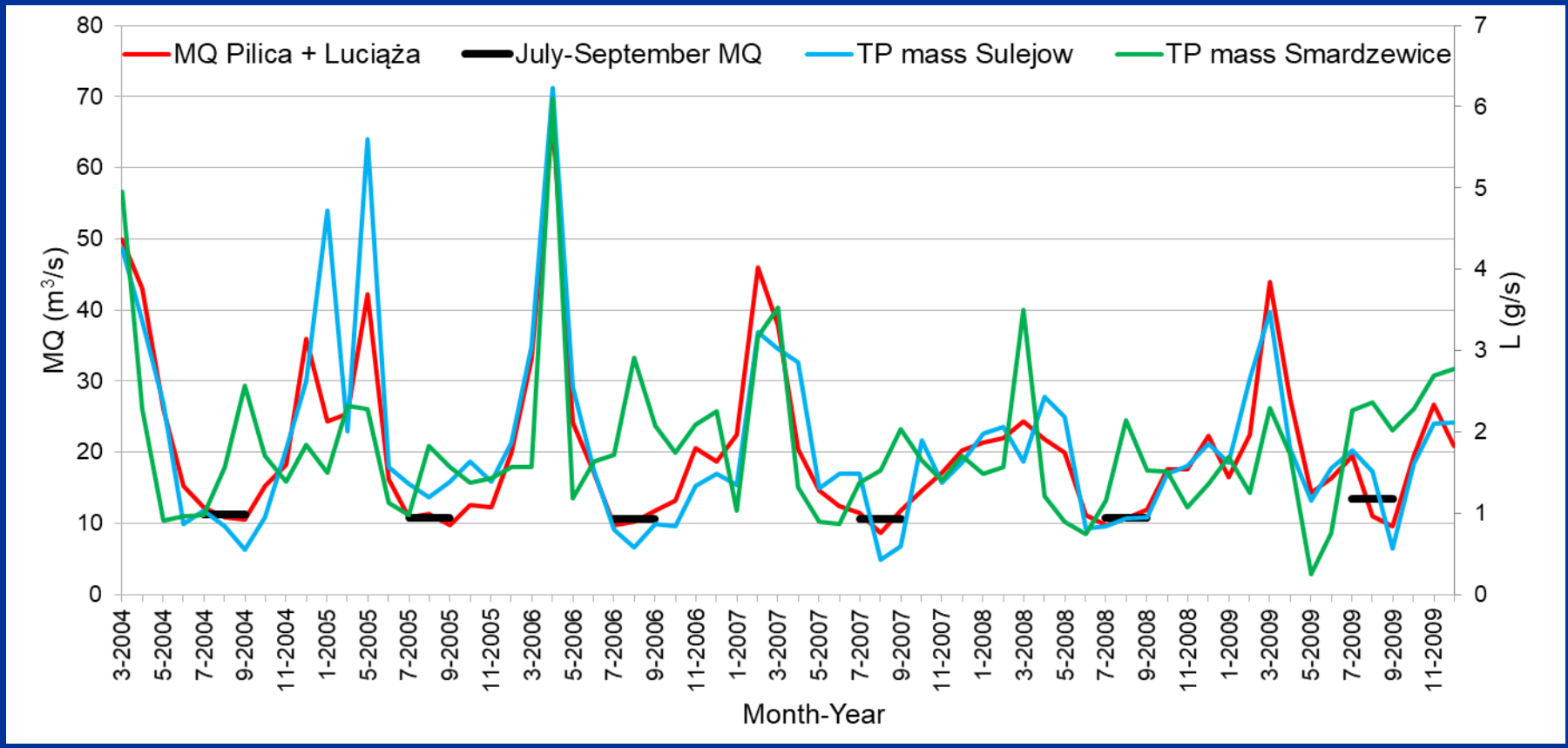


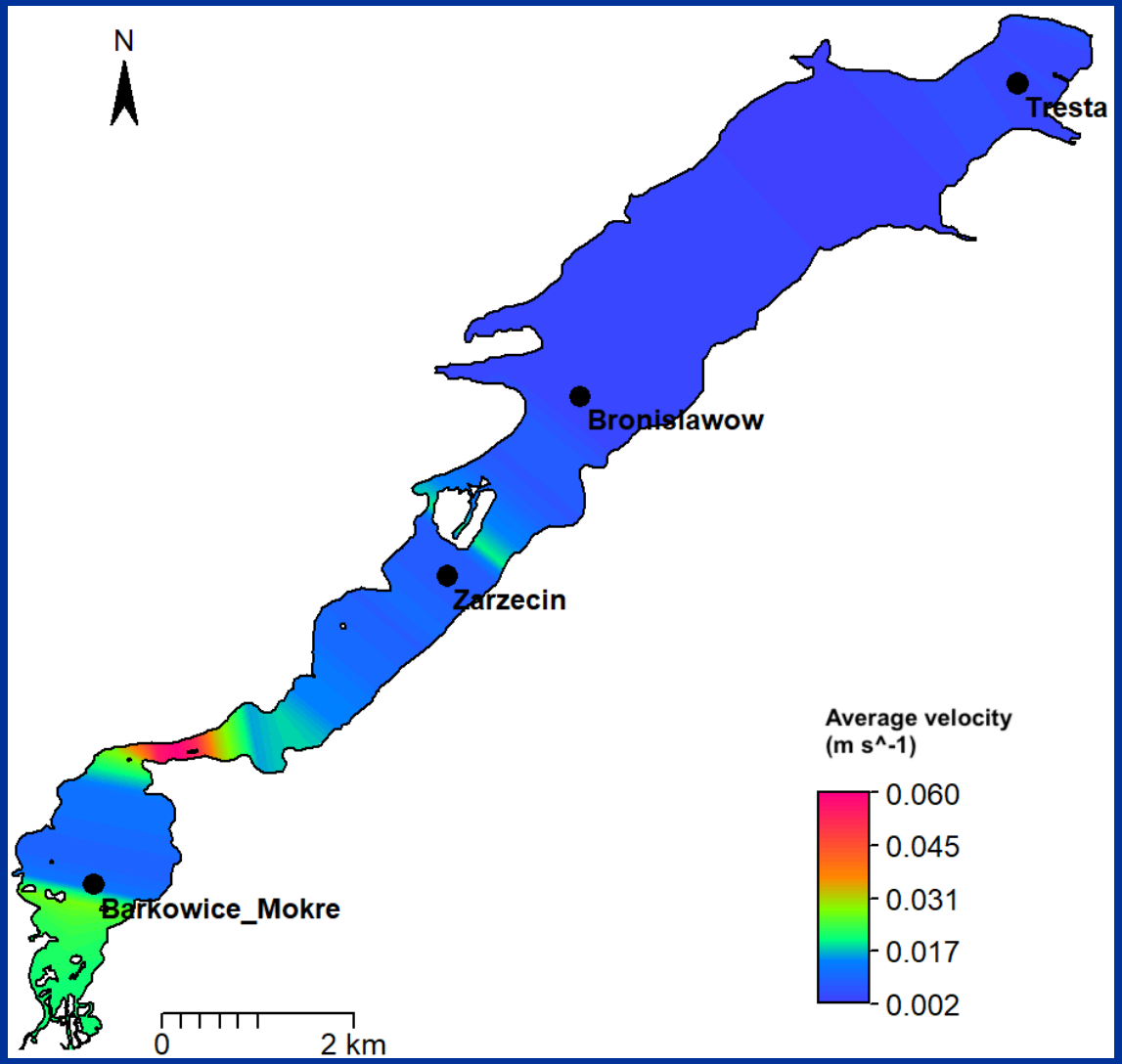
NQ=10



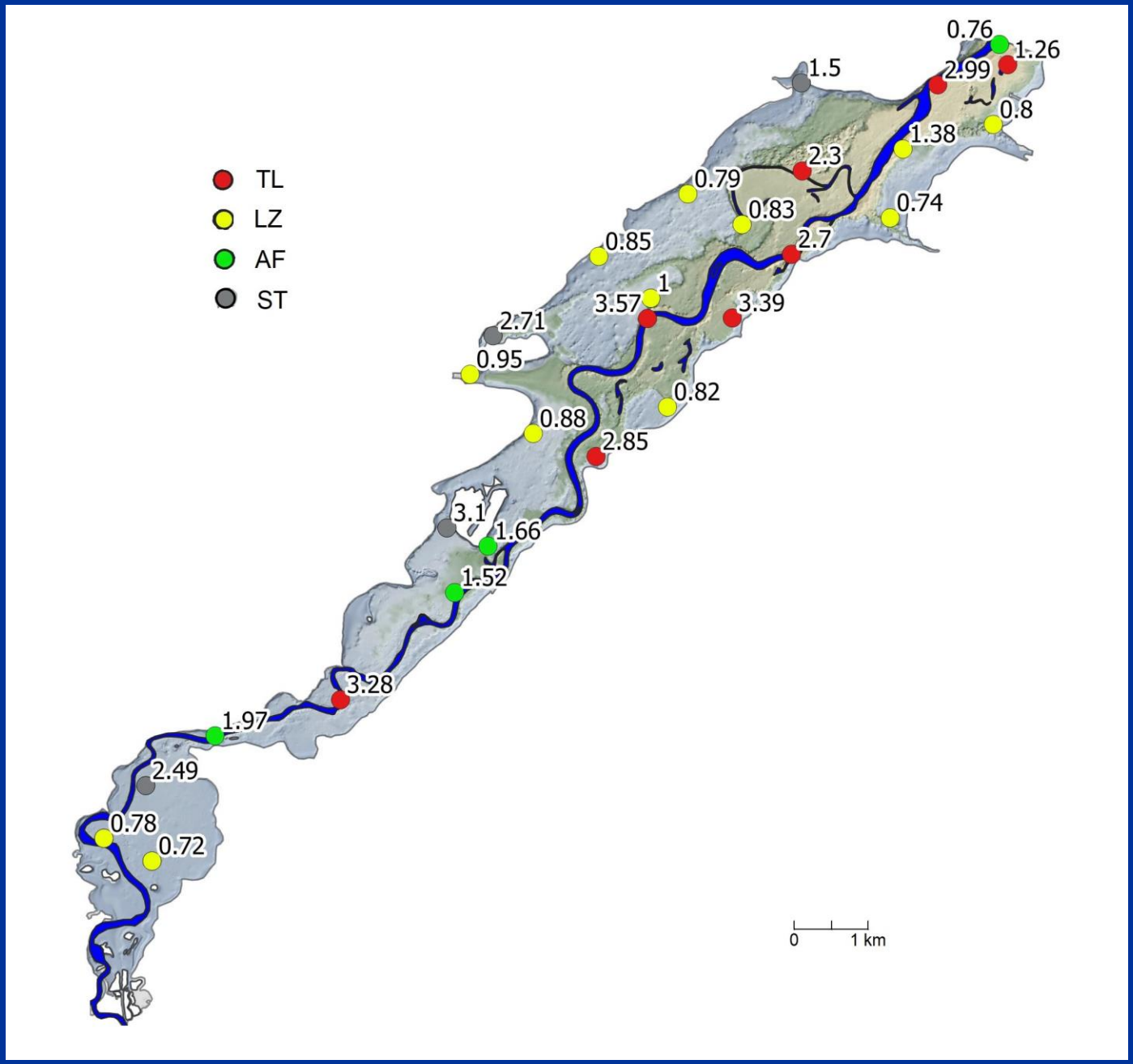



Total Phosphorous (mg l-1)
0,3
0,25
0,2
0,15
0,1
0,05
0
mg/l
2004 IX 13: 9.5
2005 VIII 21: 9.9
2006 VIII 21: 10.2
2004 VIII 23: 10.5
2003 VIII 25: 12.2
2004 VII 19: 12.2
2003 IX 09: 13.2
2004 VI 22: 14.4
1997 VI 16: 16.9
1996 VIII 26: 17.5
2000 VII 24: 23.6
1999 VI 15: 26.5
1997 VIII 18: 29.5
1997 VIII 18: 29.5
2000 VIII 22: 34.3
2001 VI 26: 40.6
2001 IX 17: 51.5
1996 IX 23: 54.7
1997 VII 14: 116
Date : Q (m3/s)
Barkowice
Zarzęcin
Bronisławów
Tresta


MQ Pilica + Luciąża
July-September MQ
TP mass Sulejow
TP mass Smardzewice
MQ (m3/s)
L (g/s)
Month-Year
0
10
20
30
40
50
60
70
80
0
1
2
3
4
5
6
7
3-2004
5-2004
7-2004
9-2004
11-2004
1-2005
5-2005
7-2005
9-2005
11-2005
3-2006
5-2006
7-2006
9-2006
11-2006
1-2007
3-2007
5-2007
7-2007
9-2007
11-2007
1-2008
3-2008
5-2008
7-2008
9-2008
11-2008
1-2009
3-2009
5-2009
7-2009
9-2009
11-2009



Simulated HEC-RAS 1D result of Sulejow reservoir


TL
LZ
AF
ST
0.76
1.26
1.5
2.99
0.8
1.38
2.3
0.79
0.83
0.74
0.85
2.7
1
3.57
3.39
2.71
0.95
0.82
0.88
2.85
3.1
1.66
1.52
3.28
1.97
2.49
0.78
0.72
0
1 km

TP

ESA Sentinel 2

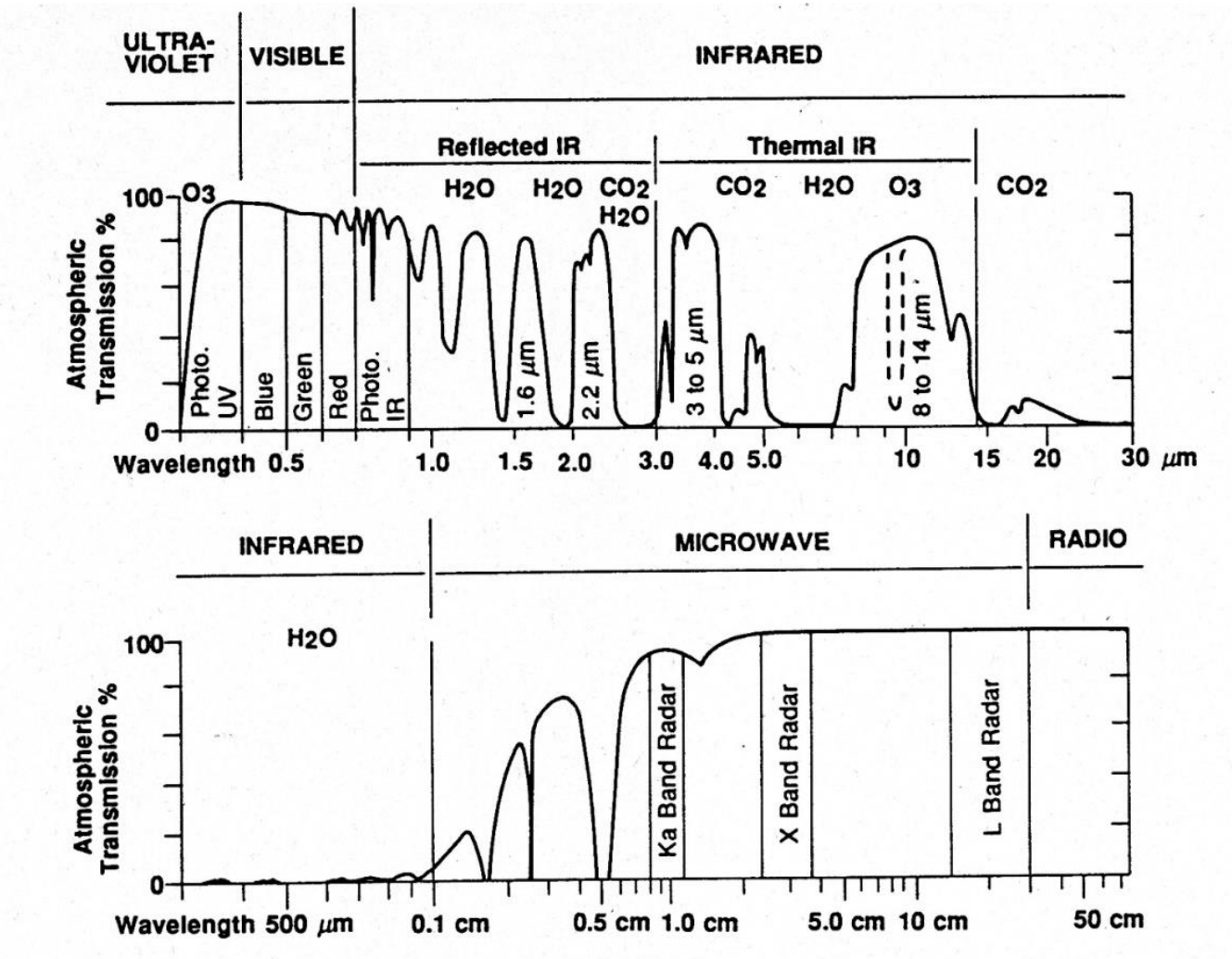
Circumpolar orbit

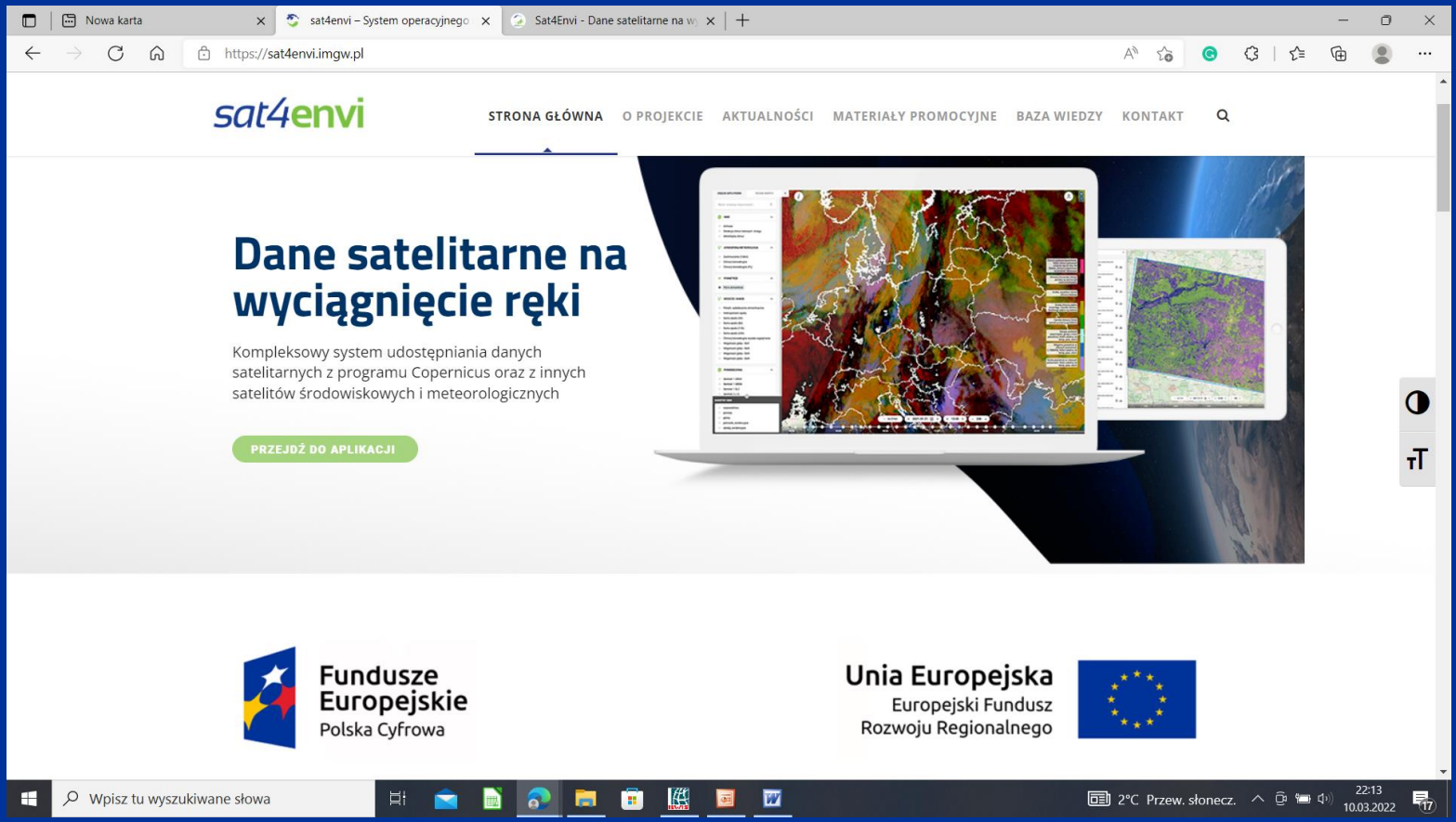
Revisit time 5 days

13 spectral bands

high resolution (10-60 m)

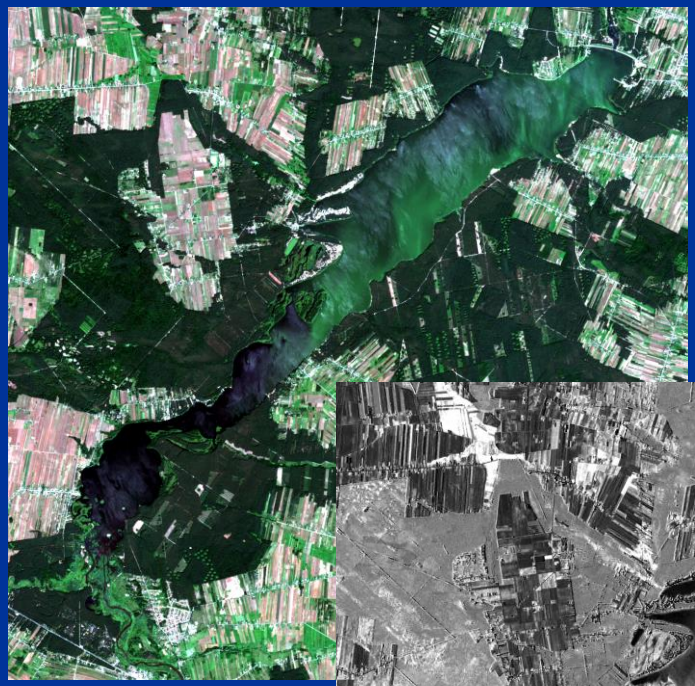
Sentinel-2A, 23 June 2015
Sentinel-2B, 7 March 2017

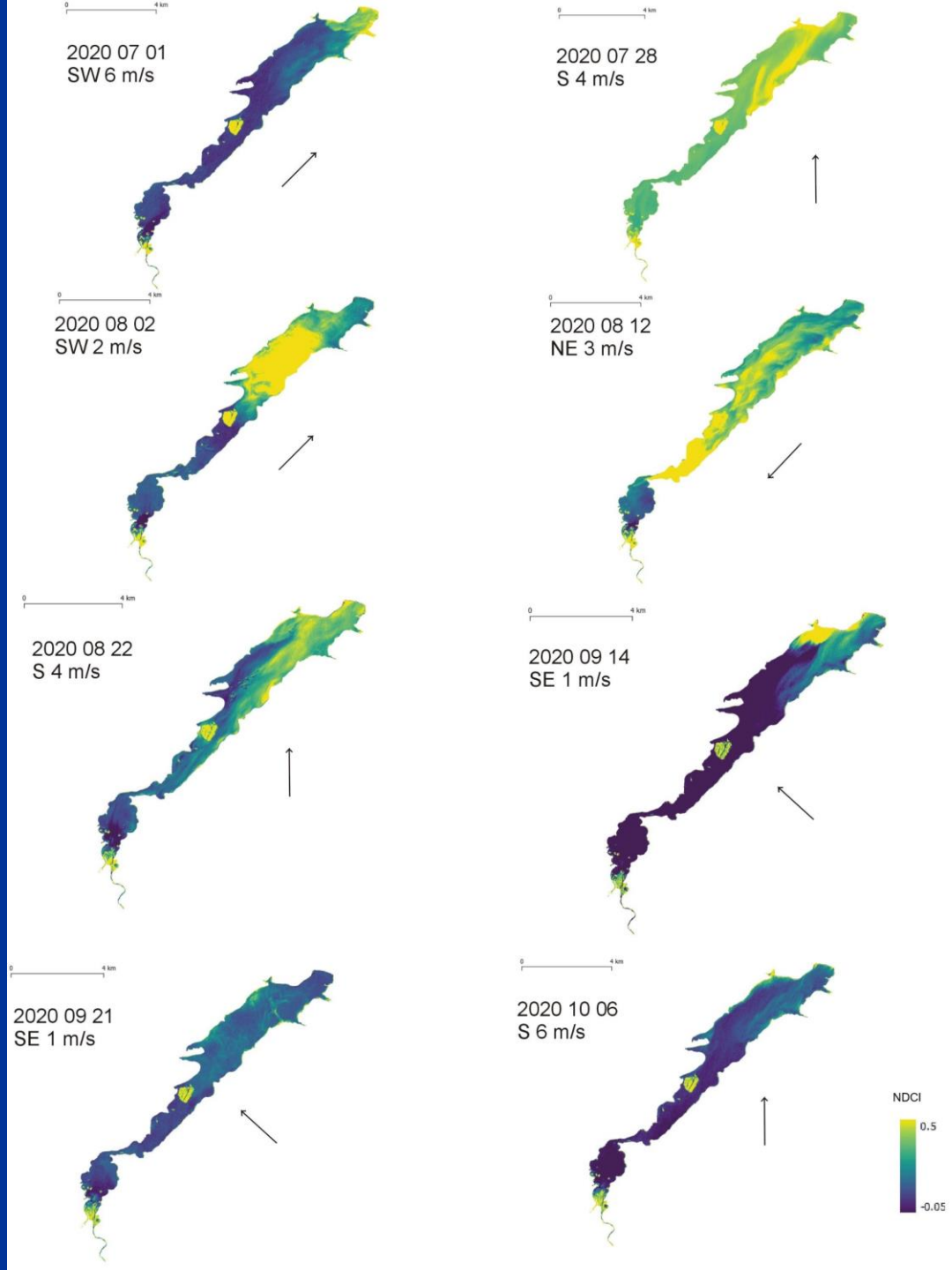

ULTRA-VIOLET
VISIBLE
INFRARED
Reflected IR
Thermal IR
O3
H2O
H2O
CO2
H2O
CO2
H2O
O3
CO2
100
0
Atmospheric Transmission %
Photo. UV
Blue
Green
Red
Photo. IR
1.6 μm
2.2 μm
3 to 5 μm
8 to 14 μm
Wavelength 0.5
1.0
1.5
2.0
3.0
4.0
5.0
10
15
20
30 μm
INFRARED
MICROWAVE
RADIO
H2O
100
0
Atmospheric Transmission %
Ka Band Radar
X Band Radar
L Band Radar
Wavelength 500 μm
0.1 cm
0.5 cm
1.0 cm
5.0 cm
10 cm
50 cm



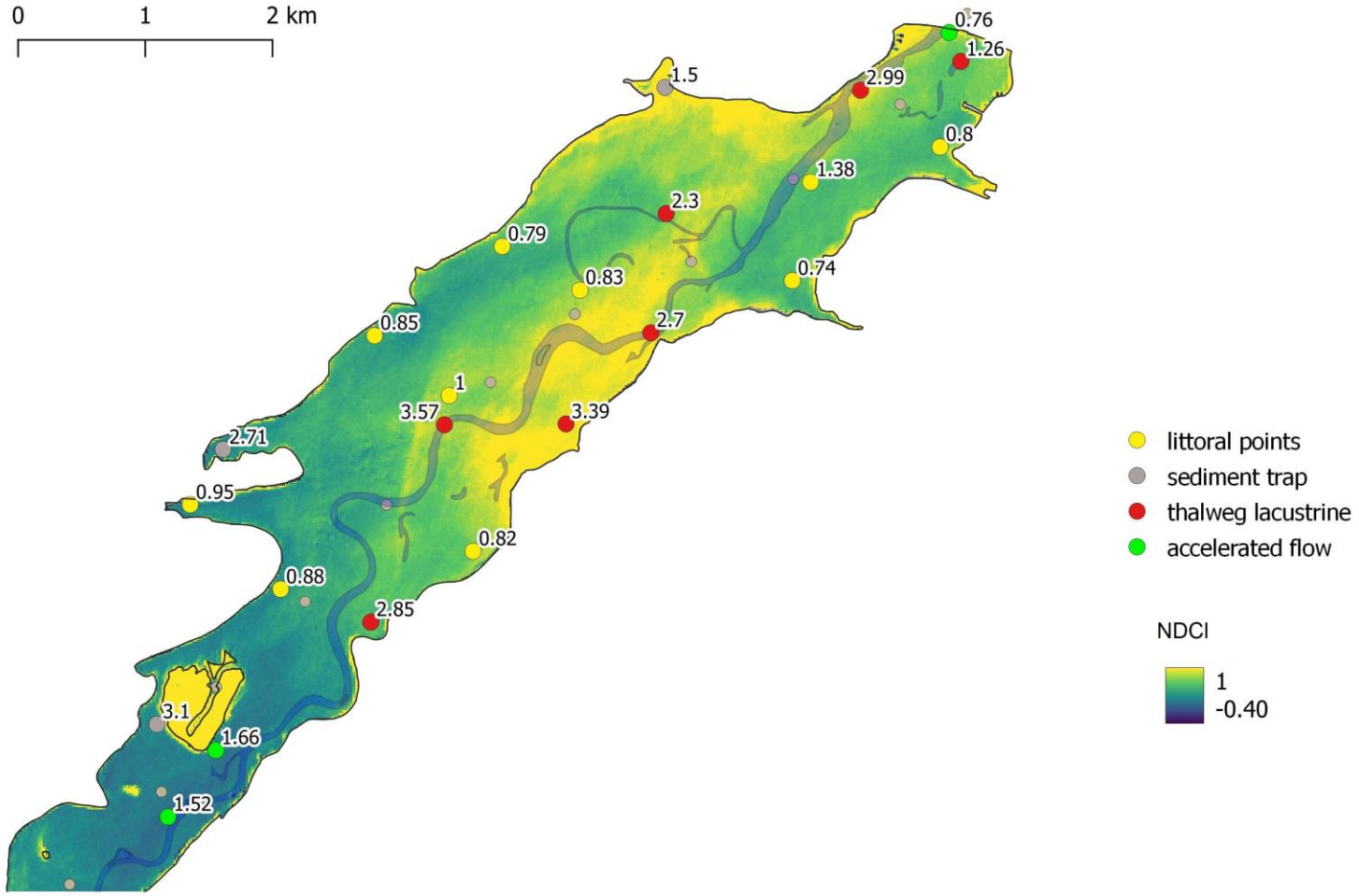
SNAP Sentinel Toolbox Application

NDcl
(B5-B4)/(B5+B4),
where B5 (705 nm) and B4 (665 nm) .

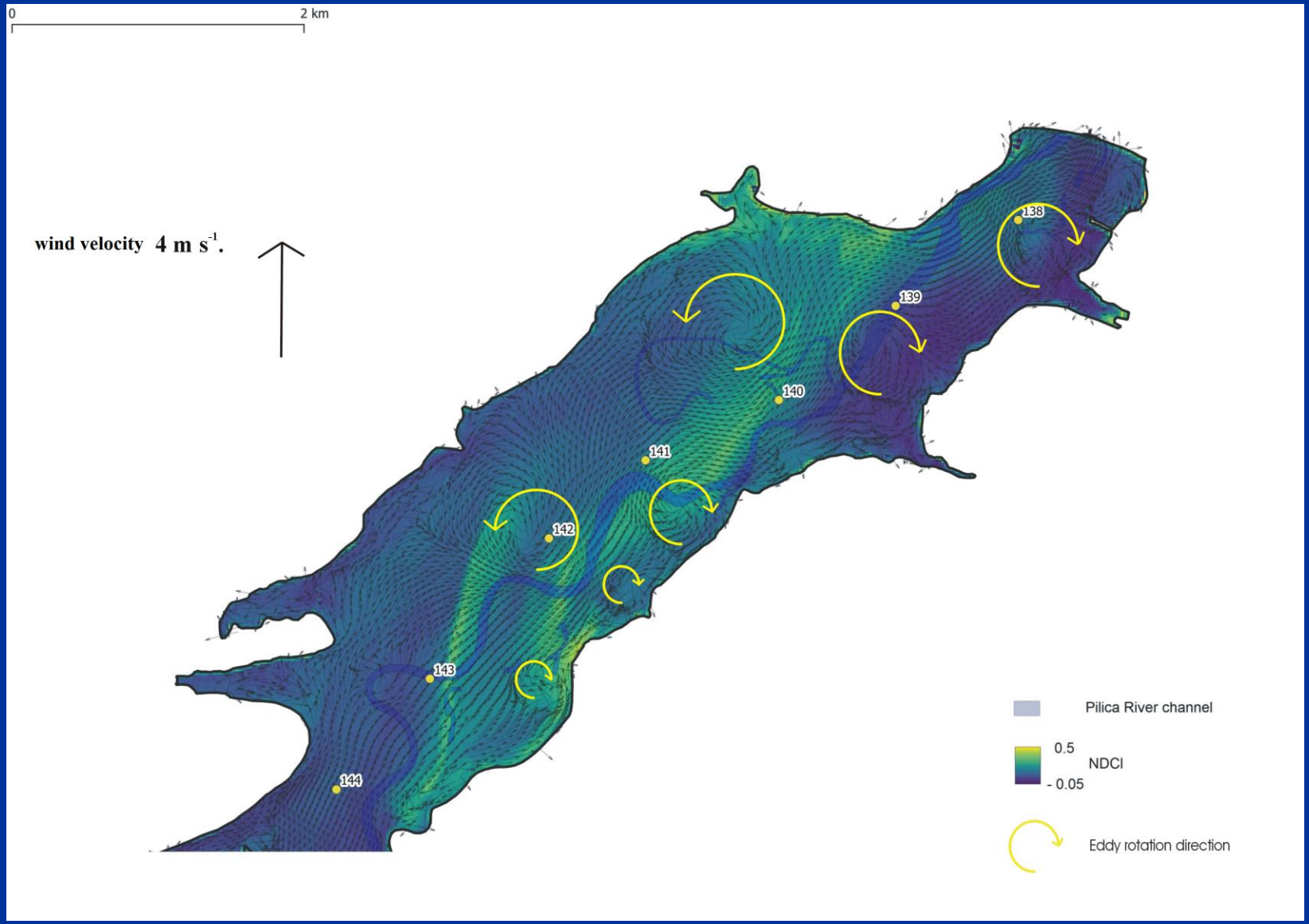




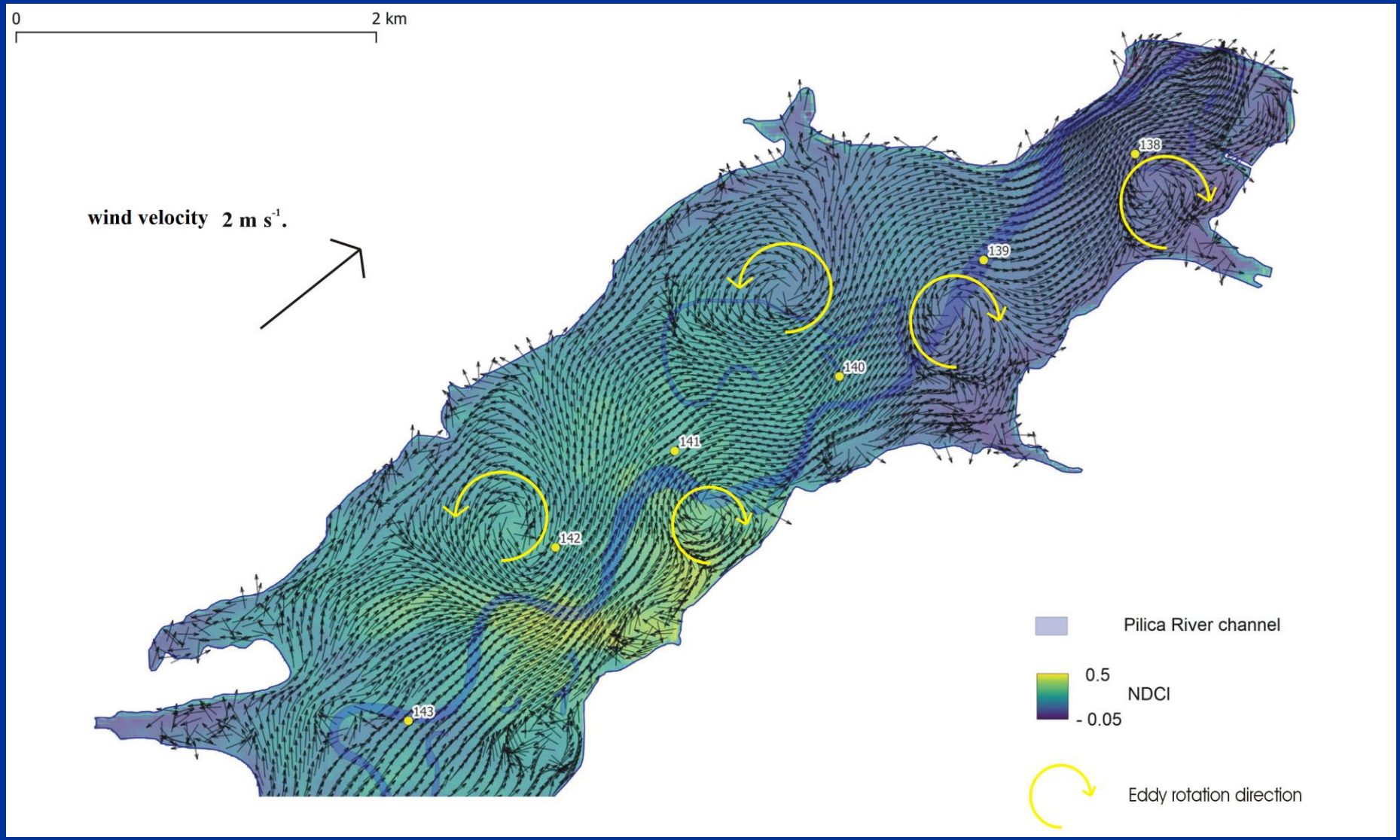
Year	No. of images
2016	1
2017	3
2018	6
2019	5
2020	8
2021	4
2022	5
2023*	6
2024	6



The Sulejów Reservoir lacustrine zone; summarized NDCl index,
and concentration of TP in bottom sediments (mg l^{-3}) with different sedimentation conditions.



The Sulejów Reservoir lacustrine zone; summarized NDCl index; the result of a simulation shown as a pattern of surface currents caused by S wind velocity 4 m s-^{1} and NDCl index on 2020/07/28.



Lacustrine part of the Sulejów Reservoir – NDCl index, calculated from Sentinel-2 image from 2020/08/02;
and velocity field of surface currents, calculated using the CCHE2D model at wind direction SW and velocity 2 m s^{-1}.

Conclusions

- Artificial reservoir disturbs the river continuity and nutrients transport

- The calculation of TP load has shown that under low-flow conditions during the summer months (July-September), the reservoir can act as a source, supplying the lower reach of the Pilica River with TP due to the high concentration of the organic form of phosphorus enclosed in phytoplankton blooms in the Lacustrine part of the reservoir.

- Hydrodynamic modeling and Remote Sensing can be used to trace the phytoplankton