BIOLOGICKÉ CENTRUM AV ČR, v. v. i.

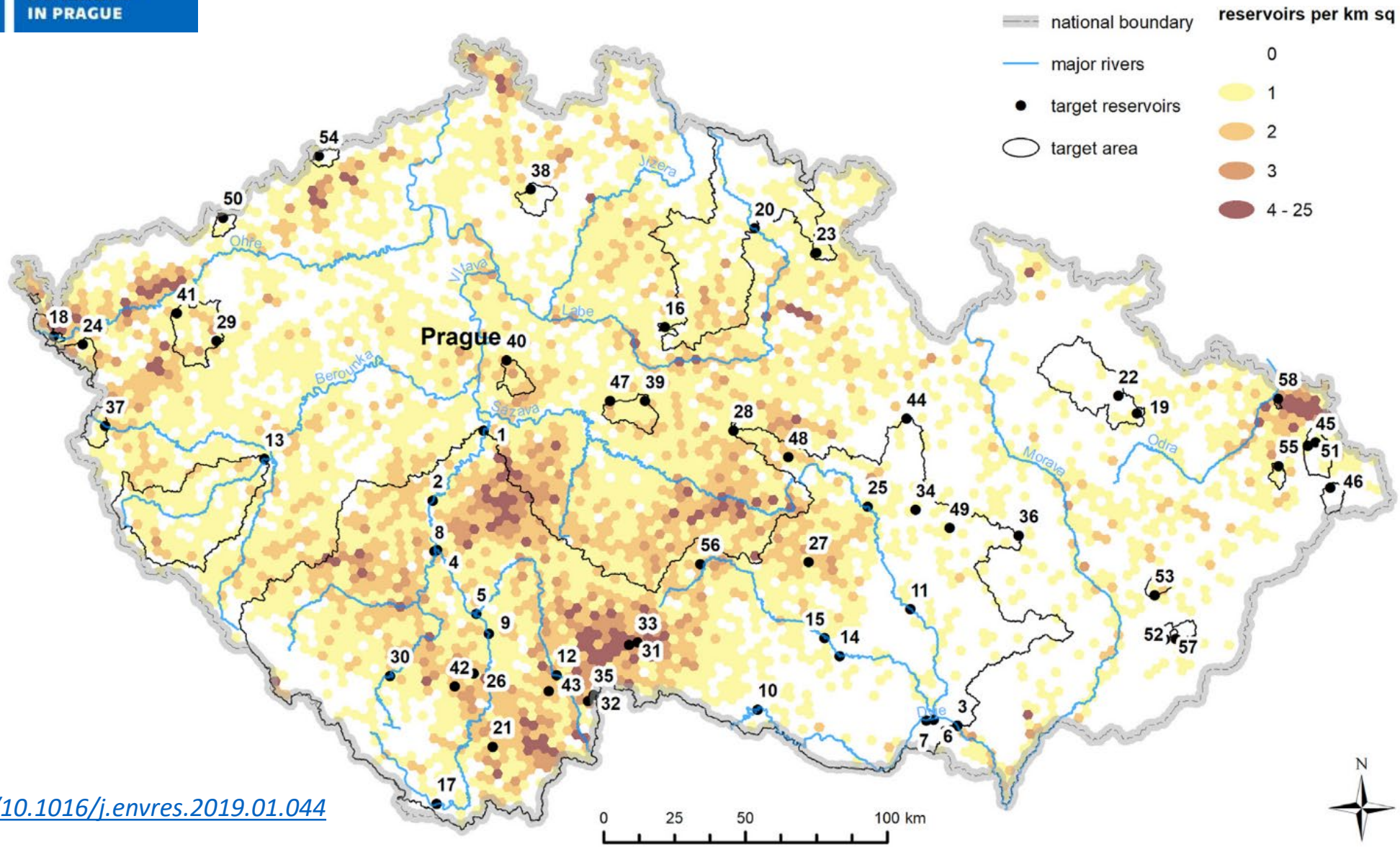
FAKULTA STAVEBNÍ ČVUT V PRAZE

Assessment of the Share of Sediments in the Eutrophication of Reservoirs: **Case Study from the Czech Republic**

Josef Krása[1], Jakub Borovec[2], Jiří Jan[2], Barbora Jáchymová[1], Jan Devátý[1]

1 Czech Technical University in Prague, Czech Republic
2 CAS Biology Centre, Czech Republic
In cooperation with reservoir managers: Morava River Basin, Vltava River Basin, Elbe River Basin,Ohře River Basin Authority, state enterprises

Czech Republic has about 75 000 water bodies (20 477 water bodies > 0.25 ha).

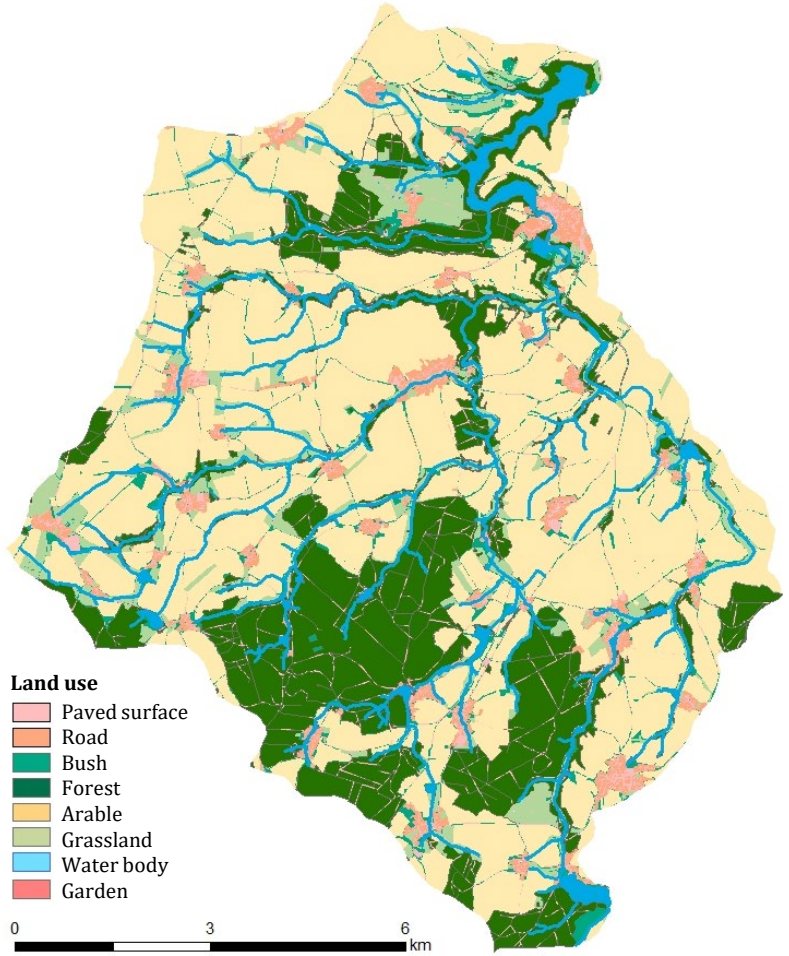


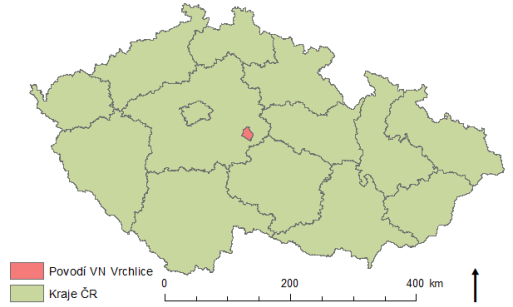
https://doi.org/10.1016/j.envres.2019.01.044

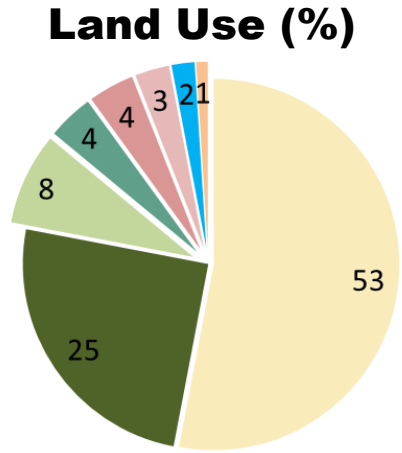
Czech Republic has about 75 000 water bodies
- example → Vrchlice watershed

Introduction to the landuse

- **Vrchlice Watershed**
  - Middle Bohemia, Elbe tributary, Kutná Hora town
  - Area 98 km^2
  - Ca 150 reservoirs and fish ponds
- Vrchlice Reservoir
  - Arch dam
  - Storage capacity ca 8 million m^3
  - Drinking water for ca 50 000 inhabitants
- Soil erosion by water
  - Release, transport, deposition
  - Connectivity issues – silting of streams and reservoirs in the area








March 2021


June 2021


September 2021


Prosík pond 2008
ČÚZK
0.3 km


Prosík pond 1953
0.3 km

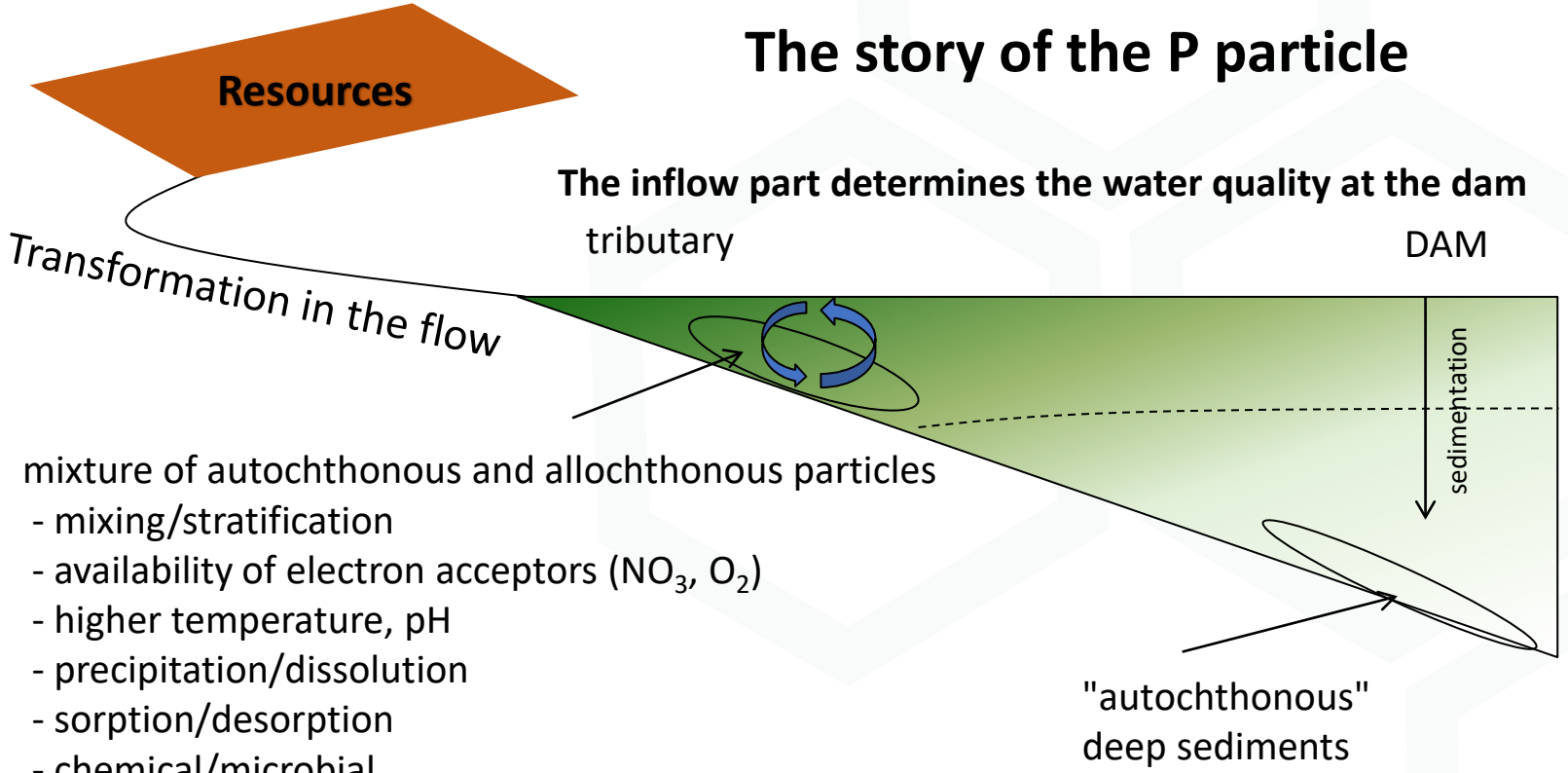
GOALS

Determine significance of the impact of sediments deposited in tributary parts of reservoirs on water quality

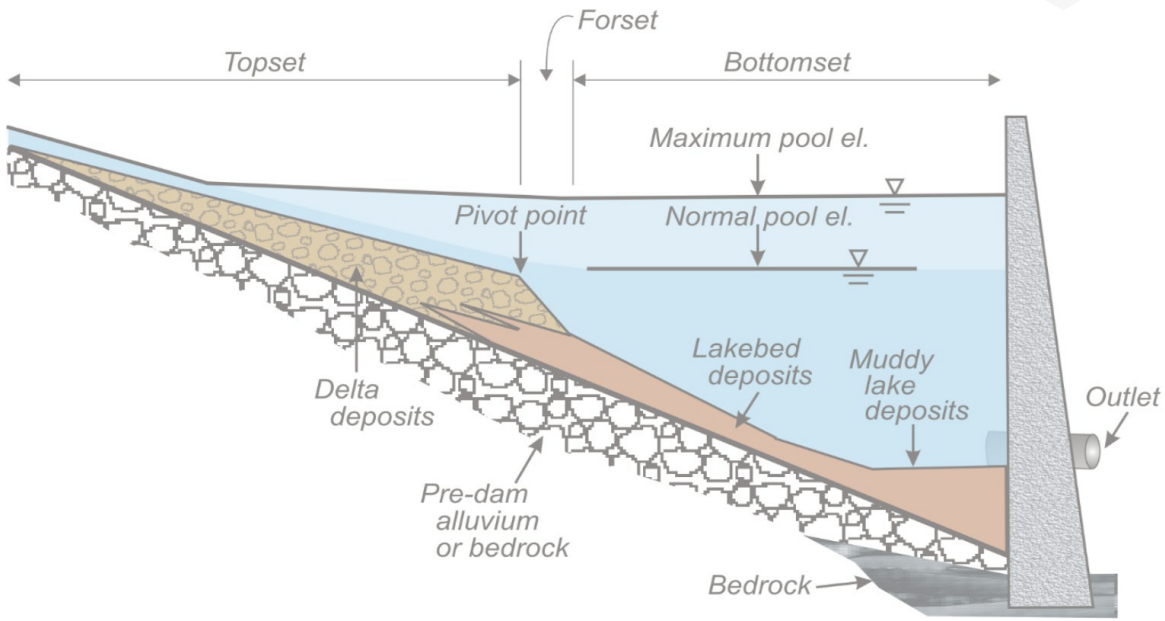
- Description of the current situation
- Generalization of the information obtained on the assumed gradient of reservoirs
- Remediation proposal and outline of scenarios of possible behavior

RESERVOIRS

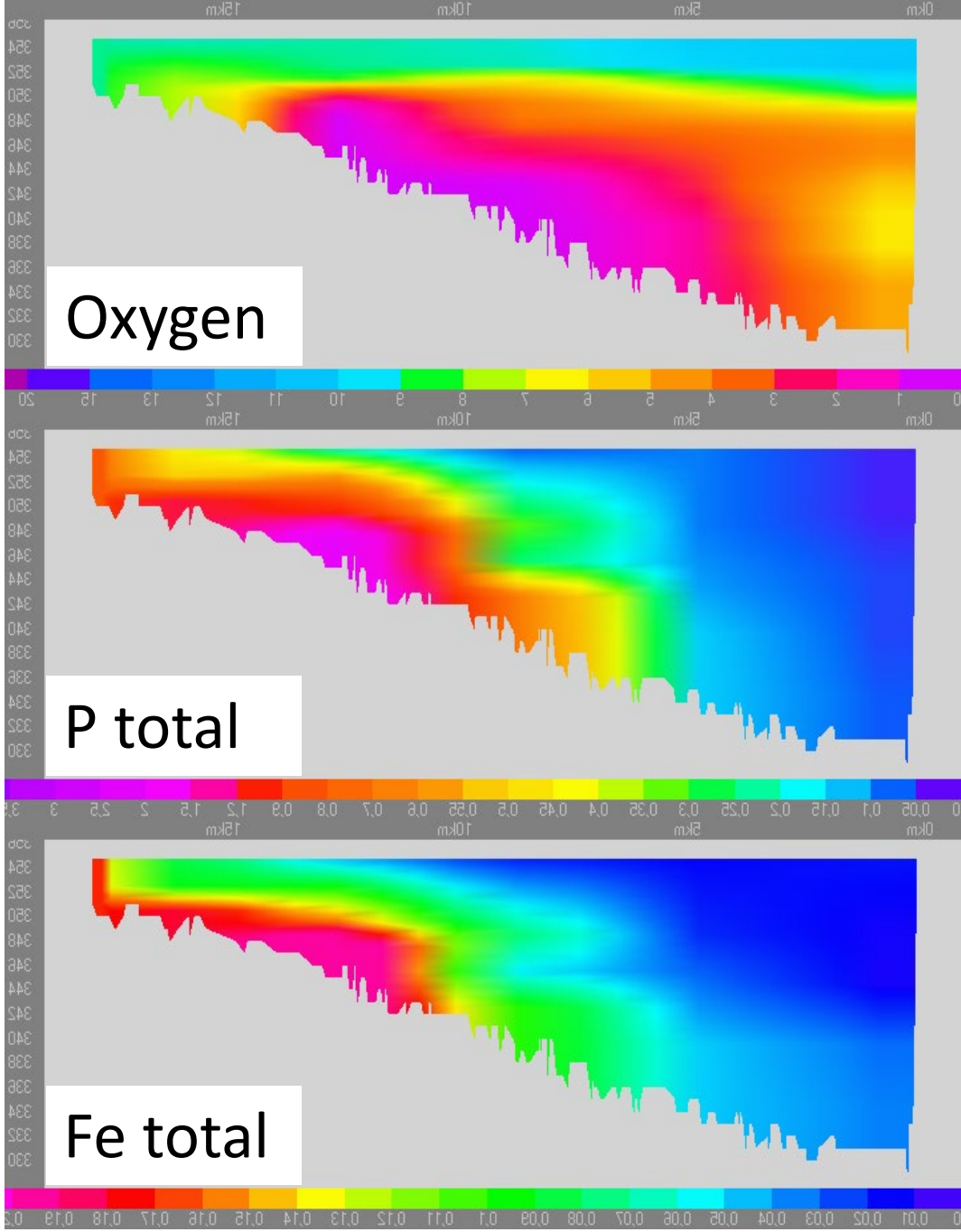
The story of the P particle



Model example of the Hracholusky reservoir
Longitudinal profile, June 2015



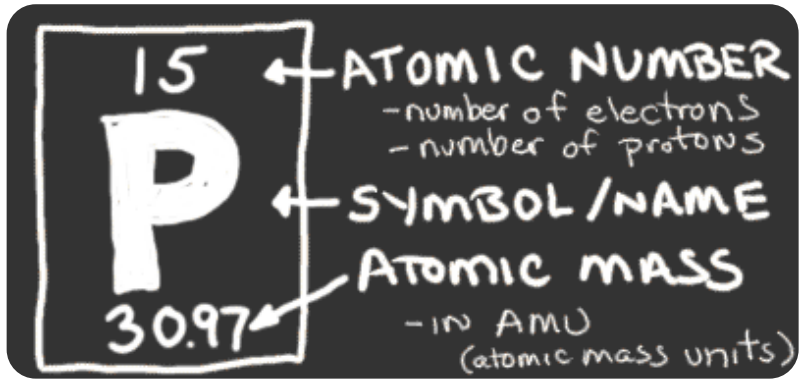
Randle and Bountry (2017)



J. Duras (Unpublished data)

PHOSPHORUS

Key nutrient

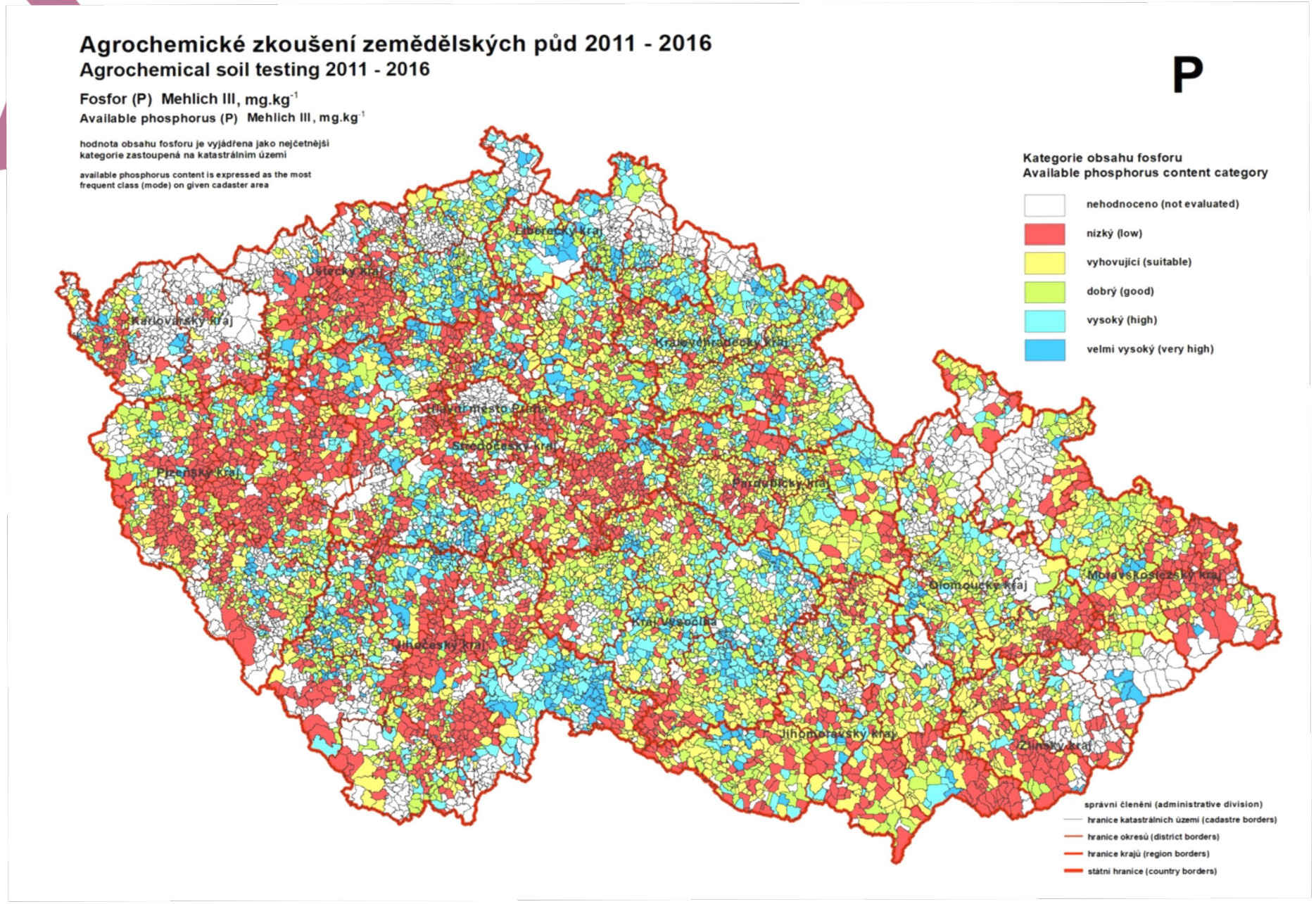


We need to connect the theory of P chemistry with real conditions in different types of reservoirs
P – Fe – Al – Ca – organic matter, molar ratios, properties of compounds, microbial utilization, lability

We have to connect different variables – geology, land use, point sources, reservoir morphology, seasonal influences...

We need to uniformly describe the risk assessment of the release of P from the sediment into the water

P M3



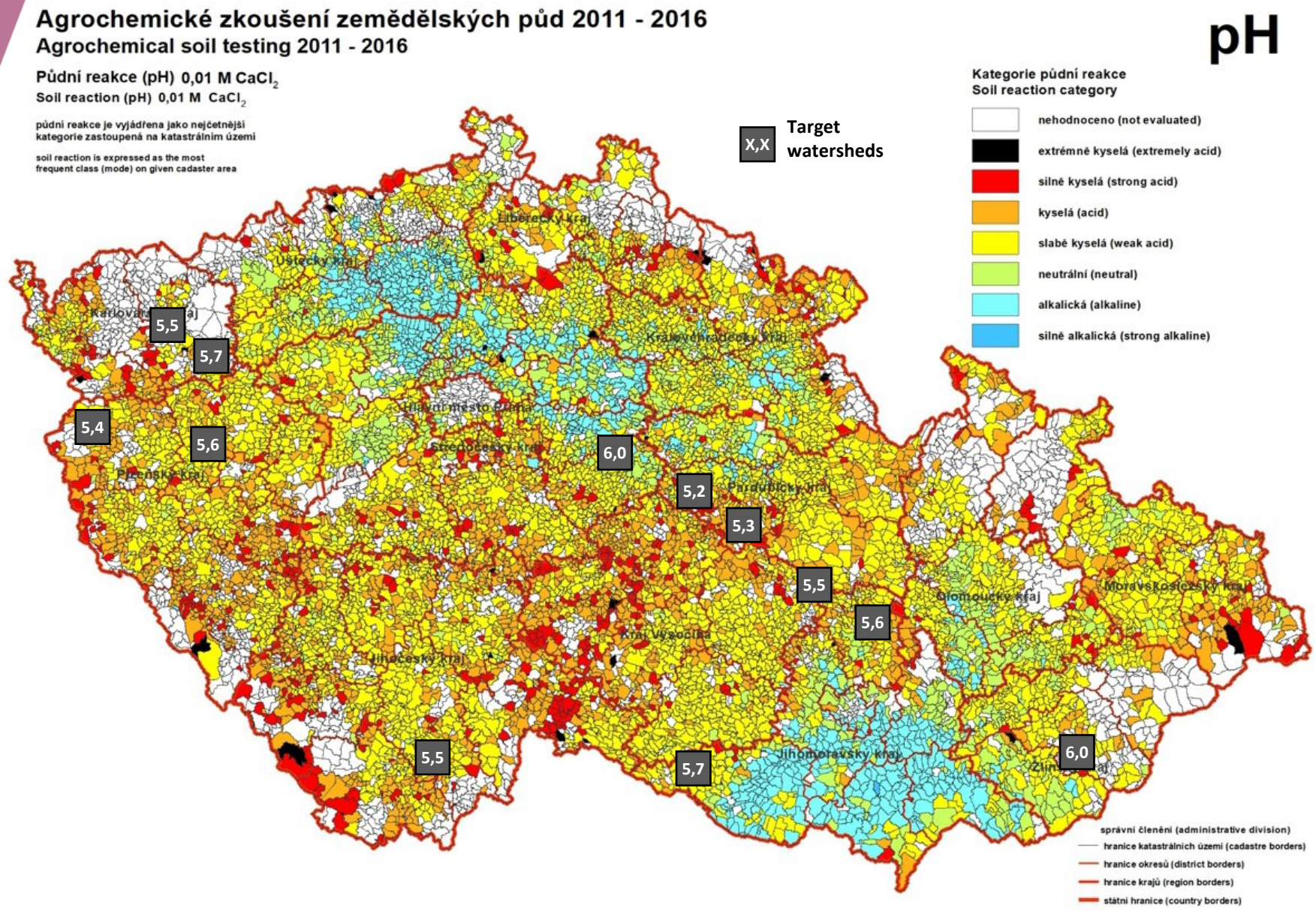
ÚKZUZ - Institute for Supervising and Testing in Agriculture, Agrochemical testing of agricultural soils in the period 2011-2016
https://eagri.cz/public/web/ukzuz/portal/dokumenty-a-publikace/hnojiva-a-puda/agroch-zkouseni-zemedelskych-pud/

RESERVOIRS

Heterogenity

Reservoir	pH	Ca	Altitude	Theoretical residence time
		ug/g	masl	year
Seč I	5,2	1393	487	0,21
Hamry	5,3	1275	580	0,06
Lučina	5,4	1520	533	0,13
Stanovice	5,5	1588	513	0,24
Vír I	5,5	1606	465	0,42
Římov	5,5	1498	471	0,23
Boskovice	5,6	1758	430	0,63
Hracholusky	5,6	1599	354	0,14
Vranov	5,7	1773	349	0,42
Žlutice	5,7	1840	507	0,29
Vrchlice	6,0	1928	324	0,59
Ludkovice	6,0	1977	284	0,31

pH



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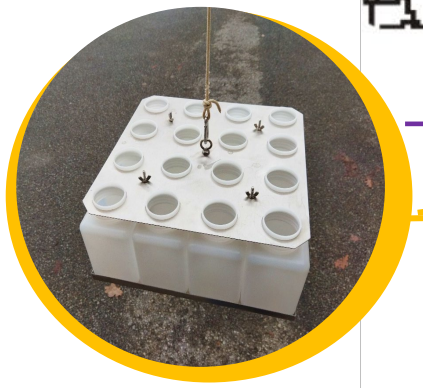
Quality of flowing particles
Phillips traps

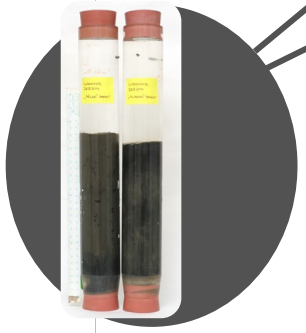
Quantity of sedimenting particles
Quantitative traps

Zone 1

Zone 2



Quality of sedimenting particles
„Over trapping“ traps



Sediment quality – analyses + incubation

Localities on the reservoir
– Zone 1: no stratification
– Zone 2: stratified water column

*** Sonar survey of sediments + site inspection (multiple samples)**

1

Change in particle composition in time/space gradient

SOURCE / Field → TRANSFORMATION / river → SEATING / tank

2

Changes in the vertical profile of sediments

PARTICLE
PORE WATER

3

Incubation experiments of intact corres

release/consumption RATES
SIMULATION of possible situations

4

Importance of source areas of erosion particles

IDENTIFICATION
QUANTIFICATION

1 Change in particle composition in time/space gradient

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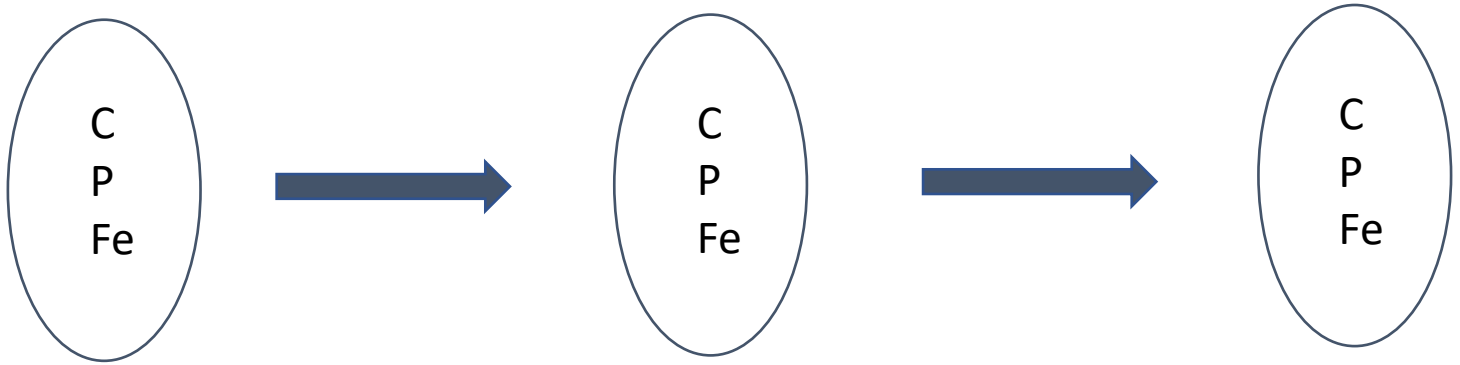


Water/Particle Composition
ICP-MS: Fe, P, Ca, ...
IC: NH4-N
TOC-L: DOC
extraction – aqueous, reducing, sequential
- sorption properties for P

Fluorescence Spectroscopy of Organic Compounds (OL)
Excitation: 250 – 550 nm / Emission: 250 – 280 nm
Peaks: ratio of excitation maximum/emission maximum at specific wavelengths
A, M, C – peaks of organic substances such as humic substances
B, T – protein peaks, microbial decomposition processes
HIX – humification index, OL aromaticity
BIX – OL Biological Index

UV-VIS Spectroscopy
- $SUVA_{280}$
- Sr („slope ratio“)

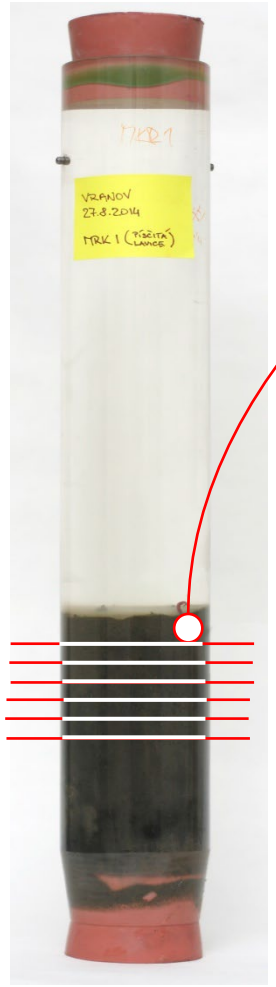
Aromaticity
Molecular Weight

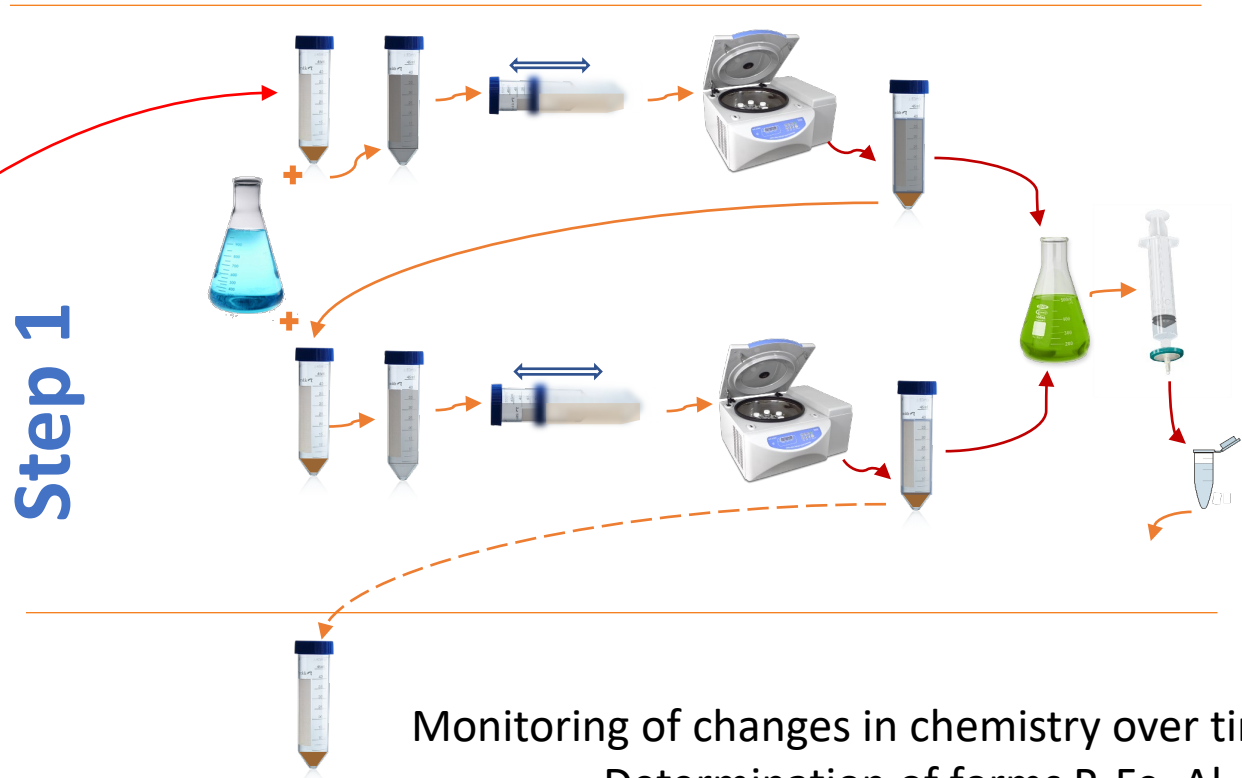
2

Changes in the vertical profile of sediments

PARTICLE
PORE WATER

Sequential 6 step extraction (fractionation)





P
Fe
Al
DOC
FTIR
UV/VIS

C
P
Fe

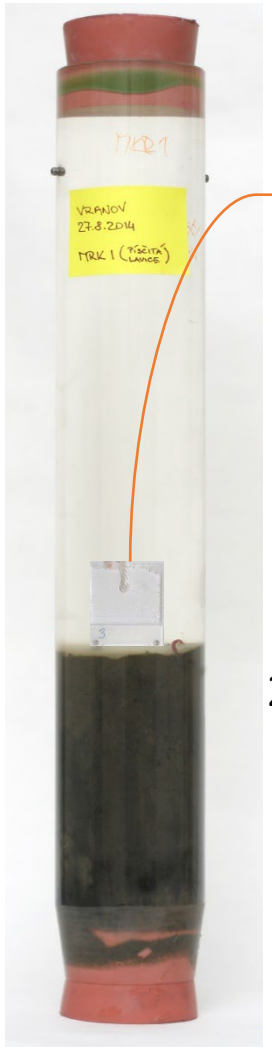
Monitoring of changes in chemistry over time – release of P from sediment

Determination of forms P, Fe, Al + mutual molar ratios

Quality contained org. masses

P-release potential under certain environmental conditions

Pore Water Analysis (DET)



24h

gel

O_2

H_2O

24h

P, Fe, NO_3^-, SO_4^{2-}, NH_4^+...

C
P
Fe

24h

0,1M
HNO_3

P, Fe, Al, ...

H_2O – Simulation of oxygenation of pore water - precipitation formation

Calculation of the diffusion release rate P at a given moment
Availability of electron acceptors, decomposition processes

3

Incubation experiments of intact corres

release/consumption RATES

SIMULATION of possible situations

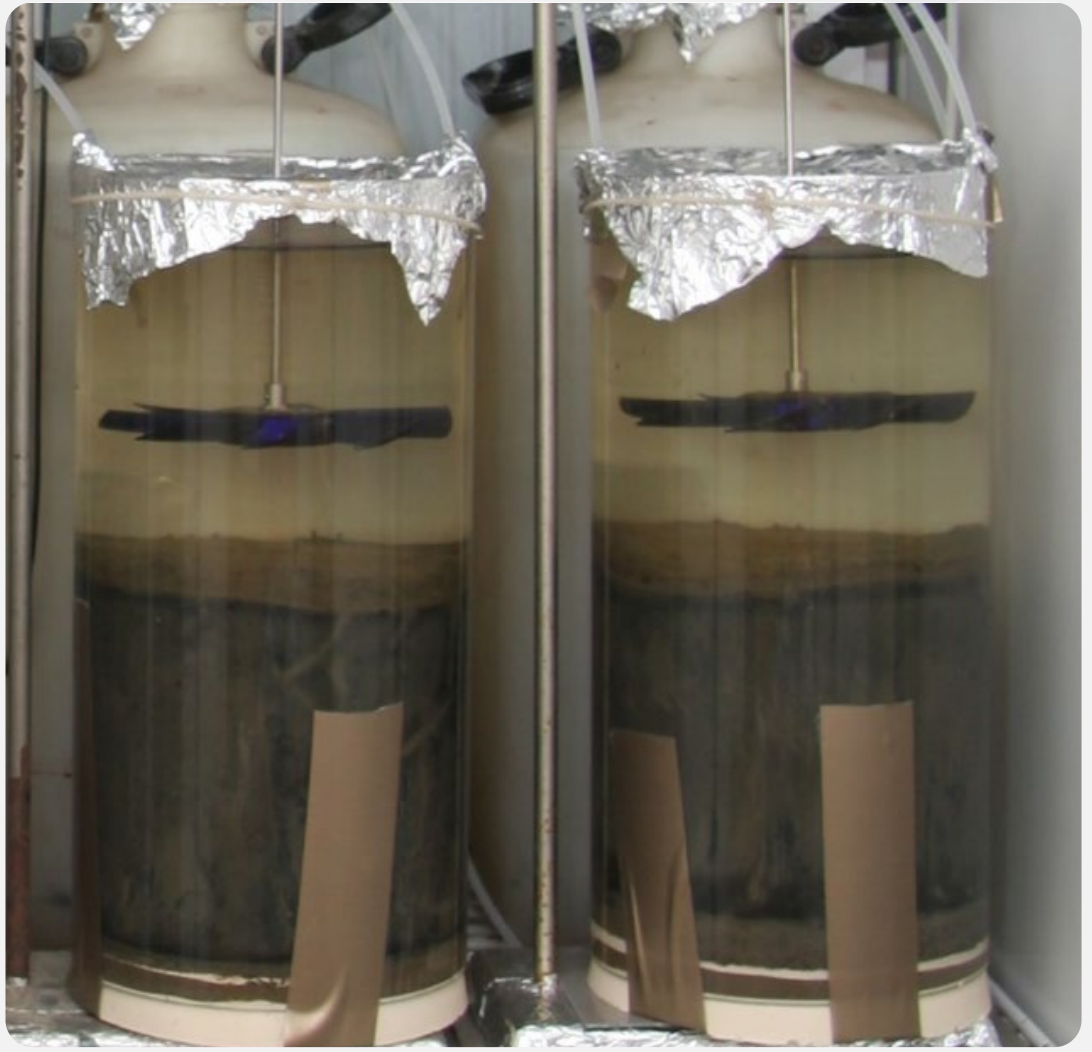
Incubation of intact sediment cores

C
P
Fe

Determination of the rate of release/consumption of substances (in-situ conditions)
Changes in concentrations of substances above sediment + DET

Manipulative experiments
3rd year of the project
- oxygen/nitrate depletion
- desiccation
- proposal to increase P retention and sediment stability (Fe input, electron acceptors)

Sediment selection
- sediments with the highest enrichment P compared to soils
- sediments with a predominance of aliphatic OM bound to Fe



4

Importance of source areas of erosion particles

IDENTIFICATION
QUANTIFICATION

Foto: J. Krása

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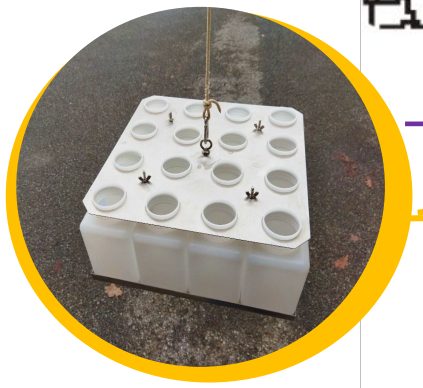

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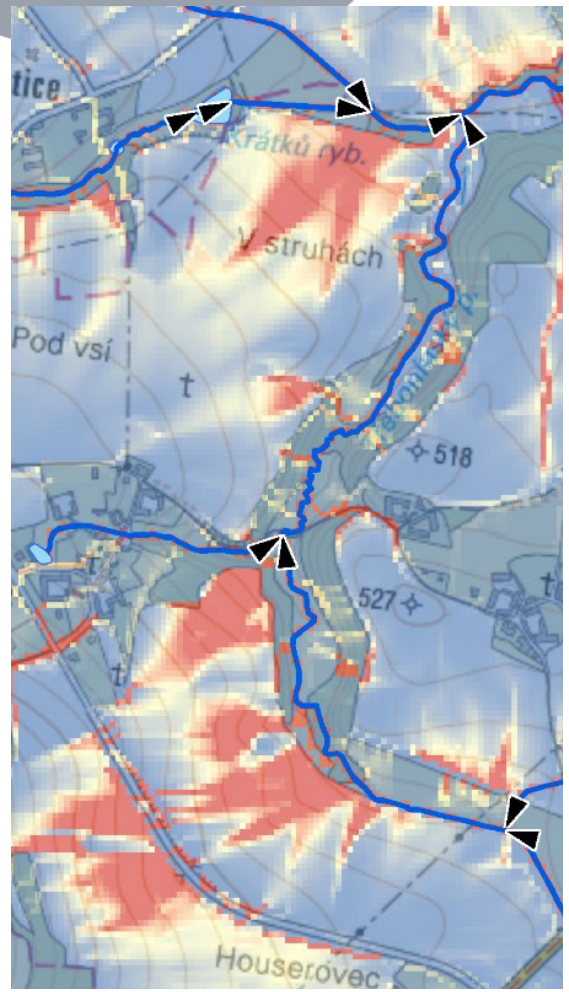
*** Sonar survey of sediments + site inspection (multiple samples)**

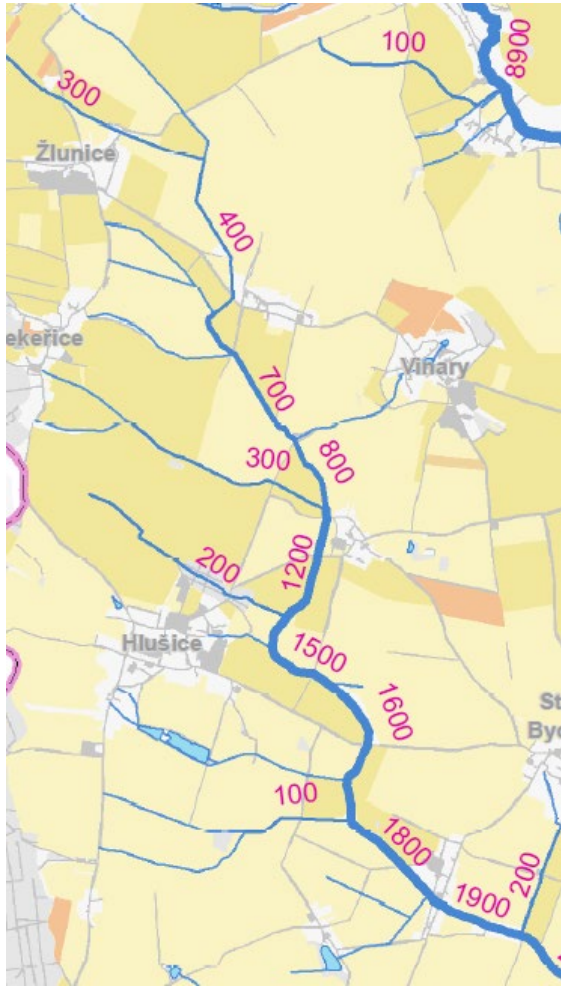
SOURCES

WATEM/SEDEM model: erosion x deposition for each element (10x10 m, 5x5 m) – **Long-term average inputs** **- sediment**
- Total P

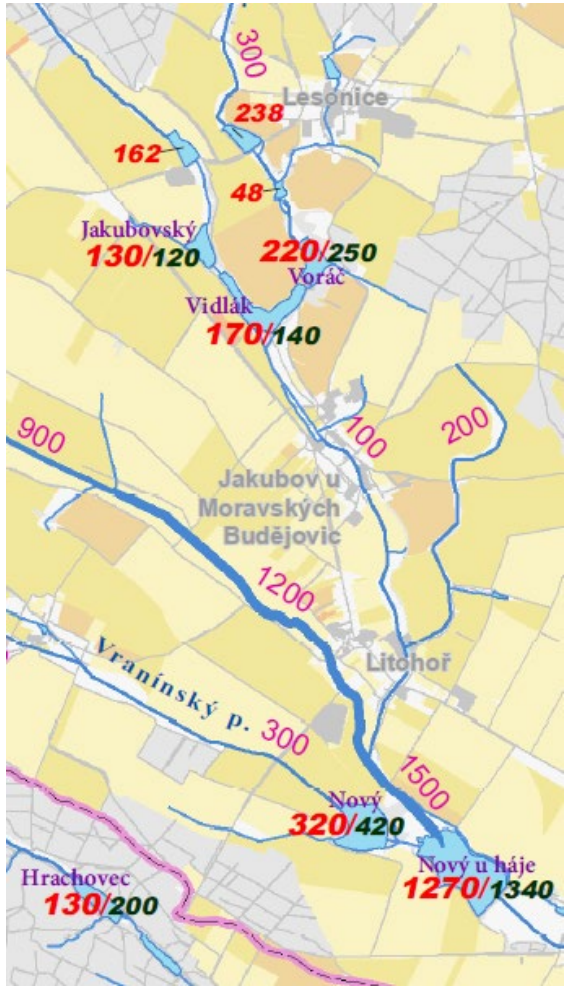
1. Parcel based source



2. River transport



3. Reservoir trapping



https://doi.org/10.1016/j.envres.2019.01.044

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WATEM/SEDEM model uncertainty – reservoir trap efficiency

https://doi.org/10.1016/j.envres.2019.01.044

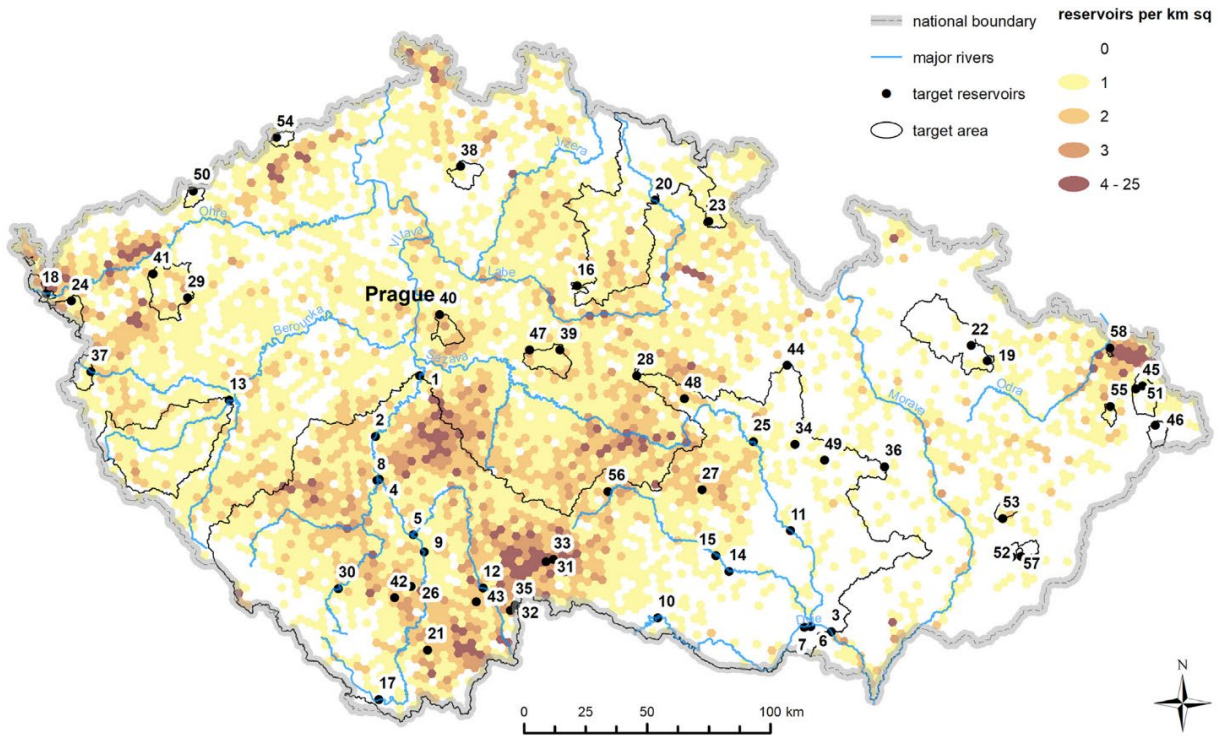

Fig. 1. Variability in reservoir density in the Czech Republic, the study area and the target reservoirs of the study.

Czech Republic has about 75 000 water bodies (20 477 water bodies > 0.25 ha). When we tried to find only reservoir volume data – 11.4% accessible. Outlet types, flow rates – generally not accessible at all.

	Reservoirs in evidence	Information on volume		Can be spatially linked		errors
DIBAVOD	20 477	200	1,0%	200	1,0%	2
Dop. ch. DIBAVOD	186	186	0,9%	186	0,9%	5
ISVS voda	9999	330	1,6%	37	0,2%	0
Povodí Vltavy	1681	1681	8,2%	1681	8,2%	25
TBD, a.s.	2048	1581	7,7%	743	3,6%	2
VHM 1 : 50 000	4761	1508	7,3%	1238	6,0%	**

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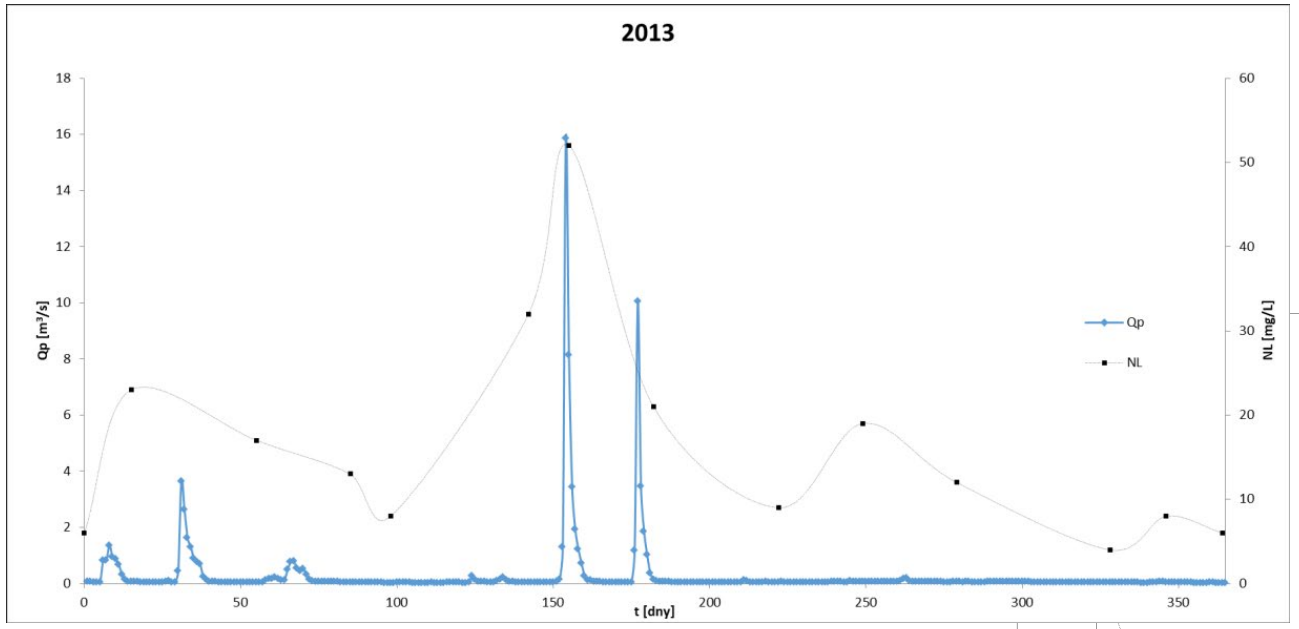
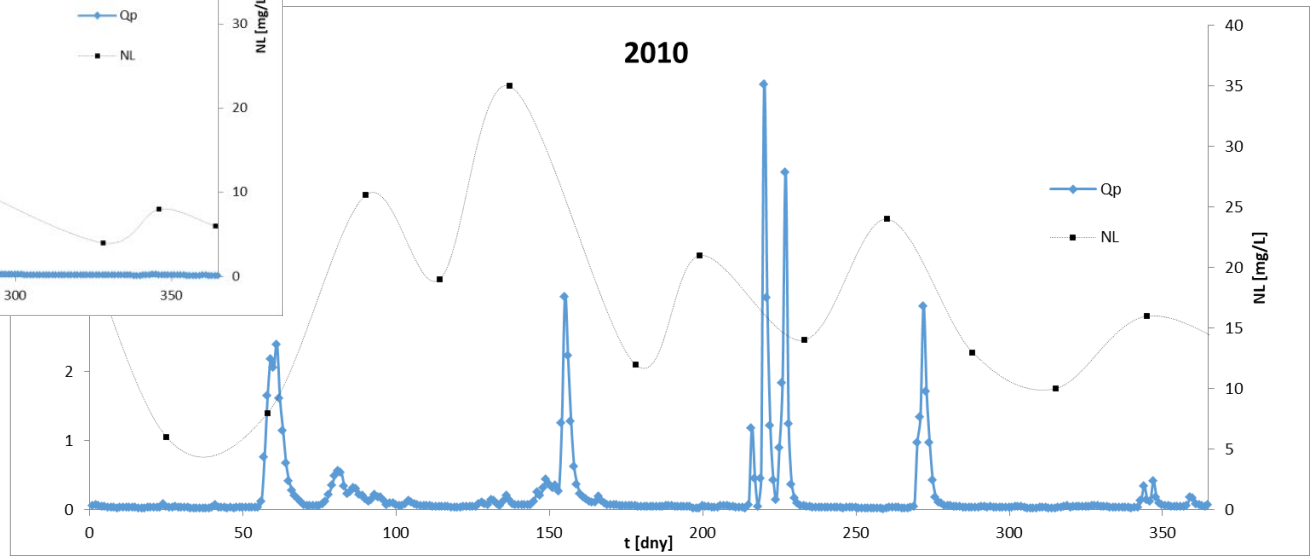
WATEM/SEDEM model uncertainty – input data accuracy (Czech Republic)



Calibrations to suspended solids measured within watercourses usually do not provide sufficiently dense time series of measured concentrations.



Therefore, we usually rely on measured **sediment in reservoirs**

SOURCES

WATEM/SEDEM model: erosion x deposition for each element (10x10 m, 5x5 m) – **Long-term average inputs - sediment - Total P**

Preparation of the "C factor" data layer based on data on cultivated crops and catch crops in 2020 and 2021

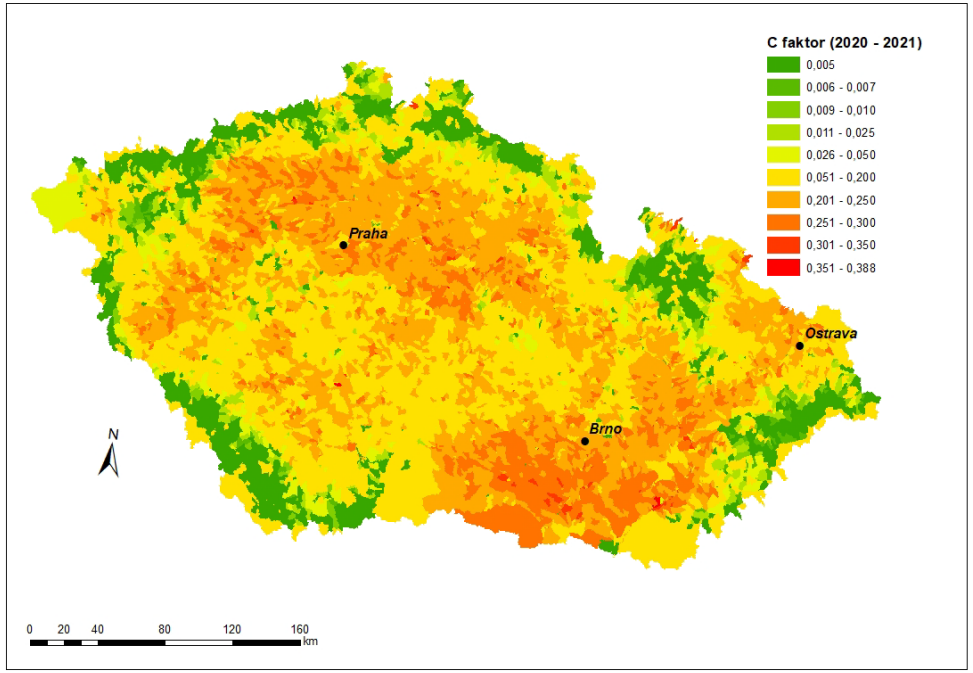
These are separate shp datasets containing polygons of cultivated crops, catch crops. Data on crops and catch crops were provided to the RIRV for 2020 and 2021. These data were analysed in order to find the most common "crop rotations" or biannual crop sequences. On the basis of nationwide statistics (for individual districts of the Czech Republic) it was found that 95% of the LPIS area is covered by 8 crops according to the following distribution:

Plodina	ČR
Sugar beet	2%
barley	10%
maize	10%
Oil rape	11%
wheat	24%
ray	2%
Fodder	6%
grass	31%
ON THE WHOLE	95%
other	5%

It was also found that about 71% of the inter- crop area is covered by 3 crops according to the following distribution:

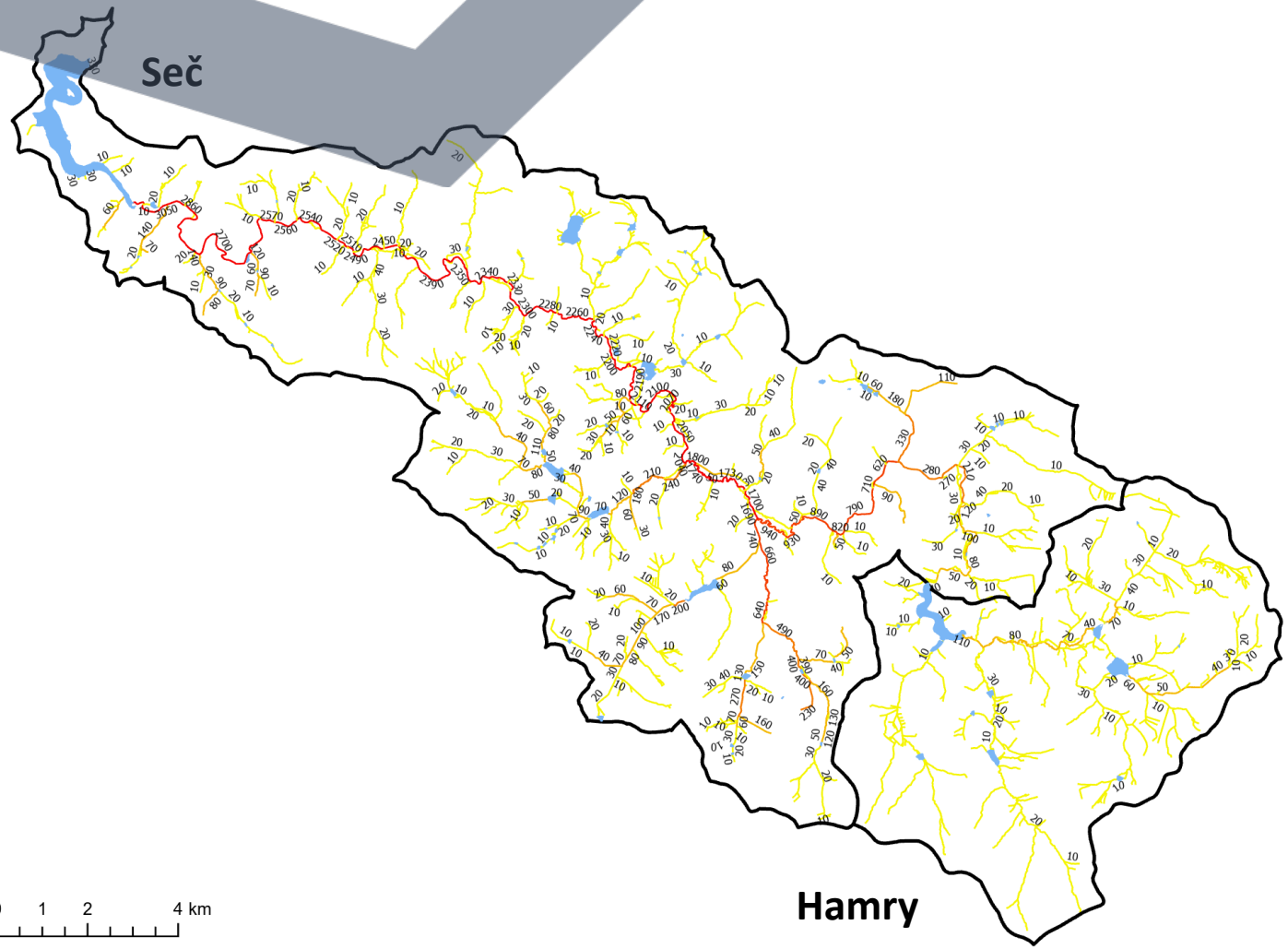
Inter-crop	ČR
Spring barley	8.78%
Winter wheat	53.52%
oilseed rape	8.30%
ON THE WHOLE	70.60%
other	29.40%

On the basis of statistical processing, 20 "crop rotations" (crop rotation in two consecutive years) were found, covering a total of 79% of the LPIS area. These crop rotations were assigned C factor values.



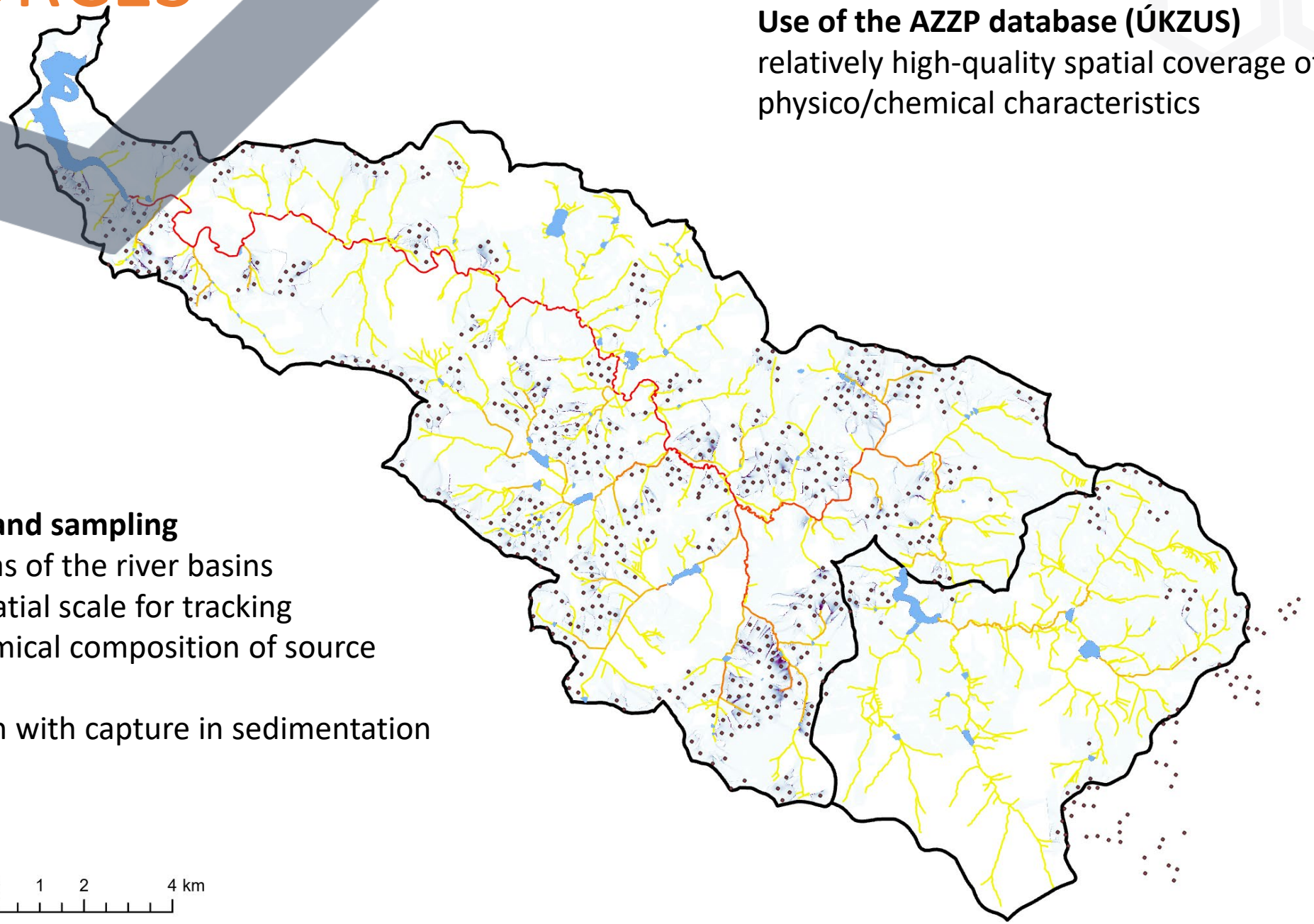
SOURCES

WATEM/SEDEM model: erosion x deposition for each element
- The problem of different scales of individual catchments
- Necessity of distinguishing between "normal" and "significant" erosion episodes



SOURCES

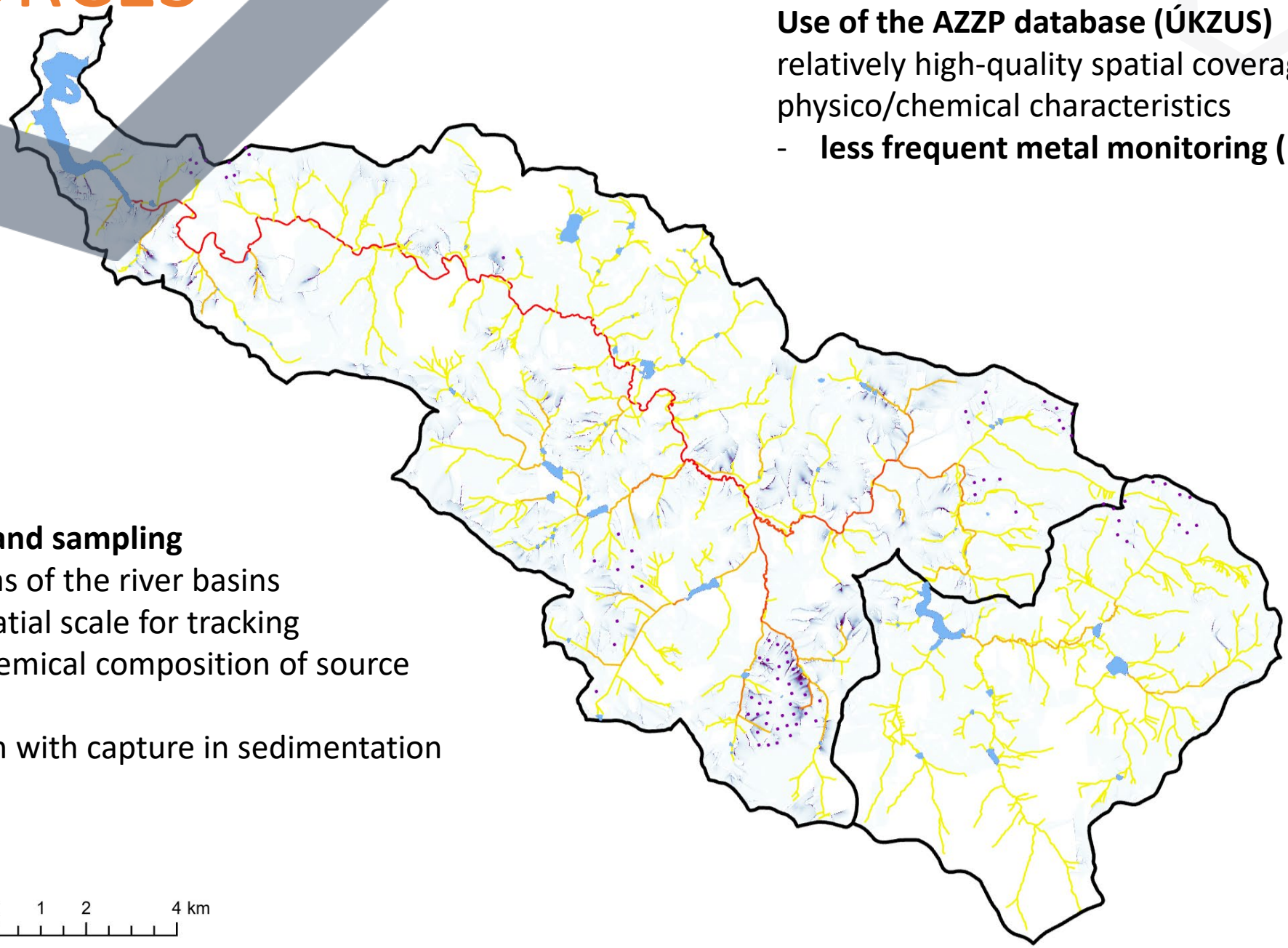
Use of the AZZP database (ÚKZUS)
relatively high-quality spatial coverage of most physico/chemical characteristics



Monitoring and sampling
- Source areas of the river basins
- Suitable spatial scale for tracking physico/chemical composition of source surfaces
- Comparison with capture in sedimentation traps

SOURCES

Use of the AZZP database (ÚKZUS)
relatively high-quality spatial coverage of most physico/chemical characteristics
- **less frequent metal monitoring (Fe, Al, Mn)**



Monitoring and sampling
- Source areas of the river basins
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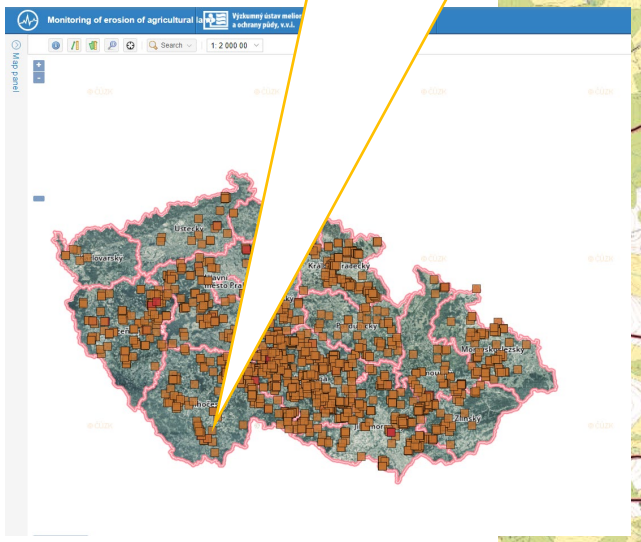
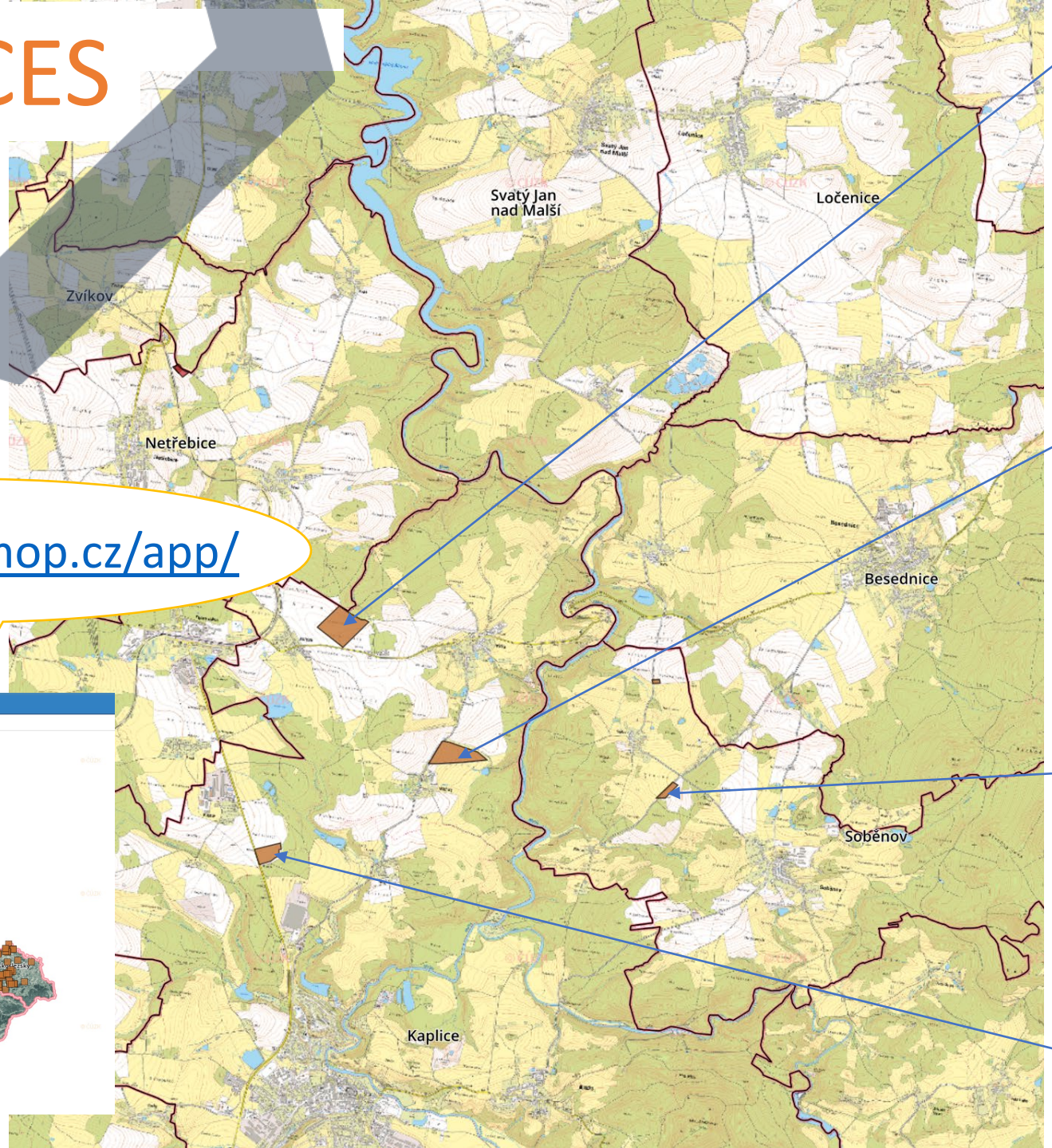
0 1 2 4 km

SOURCES

https://me.vumop.cz/app/





Typ eroze: rýhová - na hraně pozemku
Akumulace sedimentů: na hraně pozemku [0 cm]
Akcelerátory eroze: *neuvedeno*
Hlášení: 19.07.2021
Okres: Český Krumlov
KÚ: Pořešín
Vznik od: 18.7.2021 03:30
do: 18.7.2021 04:00
Plocha nákresu: 9,32 ha
Místní název: k.ú. Pořešín- Vodárna

Komentář:
Vlivem intenzivních srážek v časných ranních hodinách došlo ke vzniku erozní události na poli osázeném kukuřicí. Na poli vznikly erozní rýhy a došlo ke smyvu ornice k patě svahu. Žádné materiální škody nevznikly.

Typ eroze: rýhová - na hraně pozemku
Akumulace sedimentů: na hraně pozemku [0 cm]
Akcelerátory eroze: *neuvedeno*
Hlášení: 21.07.2021
Okres: Český Krumlov
KÚ: Pořešín
Vznik od: 18.7.2021 03:30
do: 18.7.2021 04:00
Plocha nákresu: 6,90 ha
Místní název: Pořešínec

Komentář:
Vlivem intenzivních srážek v časných ranních hodinách došlo ke vzniku erozní události na poli s kukuřicí. Na poli vznikly erozní rýhy a došlo ke smyvu ornice k patě svahu. Žádné materiální škody nevznikly.

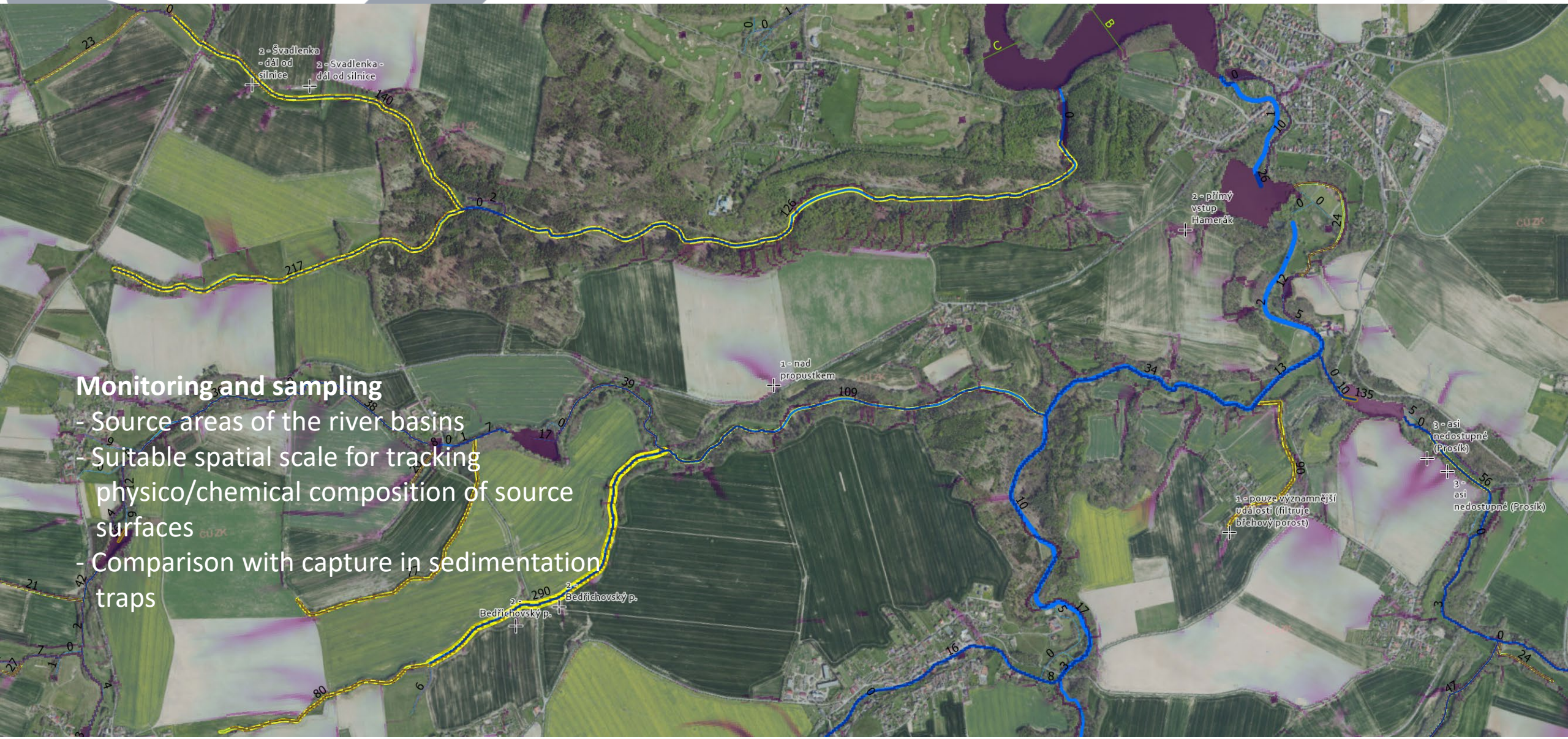
Typ eroze: plošná - na hlavní ploše
Akumulace sedimentů: *neuvedeno*
Akcelerátory eroze: *neuvedeno*
Hlášení: 02.07.2021
Okres: Český Krumlov
Vznik od: 29.6.2021 20:00
Plocha nákresu: 1,10 ha

Komentář:
Vlivem extrémních srážkových
škodám nedošlo.

Typ eroze: rýžková - na hraně pozemku
Akumulace sedimentů: na hraně pozemku [5 cm]
Akcelerátory eroze: *neuvedeno*
Hlášení: 04.07.2022
Okres: Český Krumlov
KÚ: Kaplice, Žďár u Kaplice
Vznik od: 27.6.2022 00:00
do: 1.7.2022 19:00
Plocha nákresu: 3,21 ha
Místní název: Žďár u Kaplice

Komentář:
Erozní událost byla zjištěna v souvislosti s několika opakujícími se silnými přívalovými dešti od 27.6 do 1.7.2022. Na poli byla zjištěna plošná a rýžková eroze, na krajích pole byly zjištěny naplaveniny erodované ornice.

SOURCES



Monitoring and sampling

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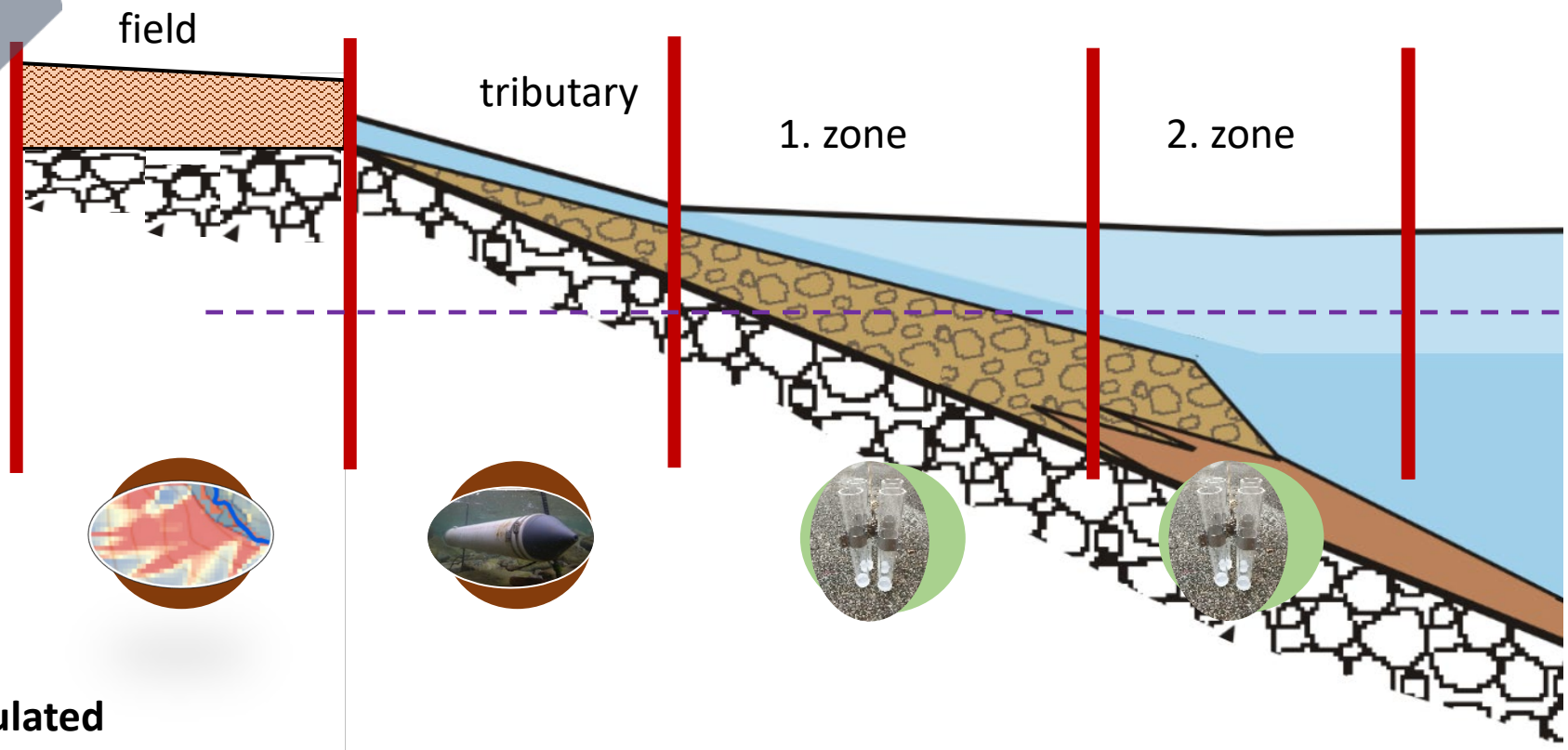
- Suitable spatial scale for tracking physico/chemical composition of source surfaces
- Comparison with capture in sedimentation traps

RESULTS



Only preliminary results can be formulated

- The sediment significantly changes characteristics from field to tributary and the reservoir
- It is hard to predict sorption/desorption capacities based on original soil sampling
- Wastewater has high potential to change sediment enrichment by phosphorus and make it potential P-sink
- Sediment further interacts with nutrients dynamically

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FAKULTA STAVEBNÍ ČVUT V PRAZE

Thank you for your attention!

Assessment of the Share of Sediments in the Eutrophication of Reservoirs: Case Study from the Czech Republic

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