SETOF Soil Erosion and TOrrential Flood Prevention: Curriculum Development at the Universities of Western Balkan Countries

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Mean Annual Sediment Yield Estimation

A case study of small catchment in Poland

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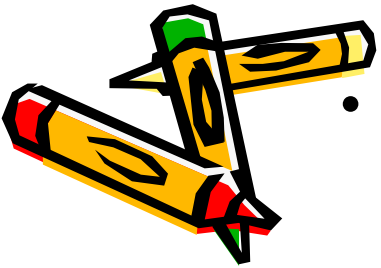
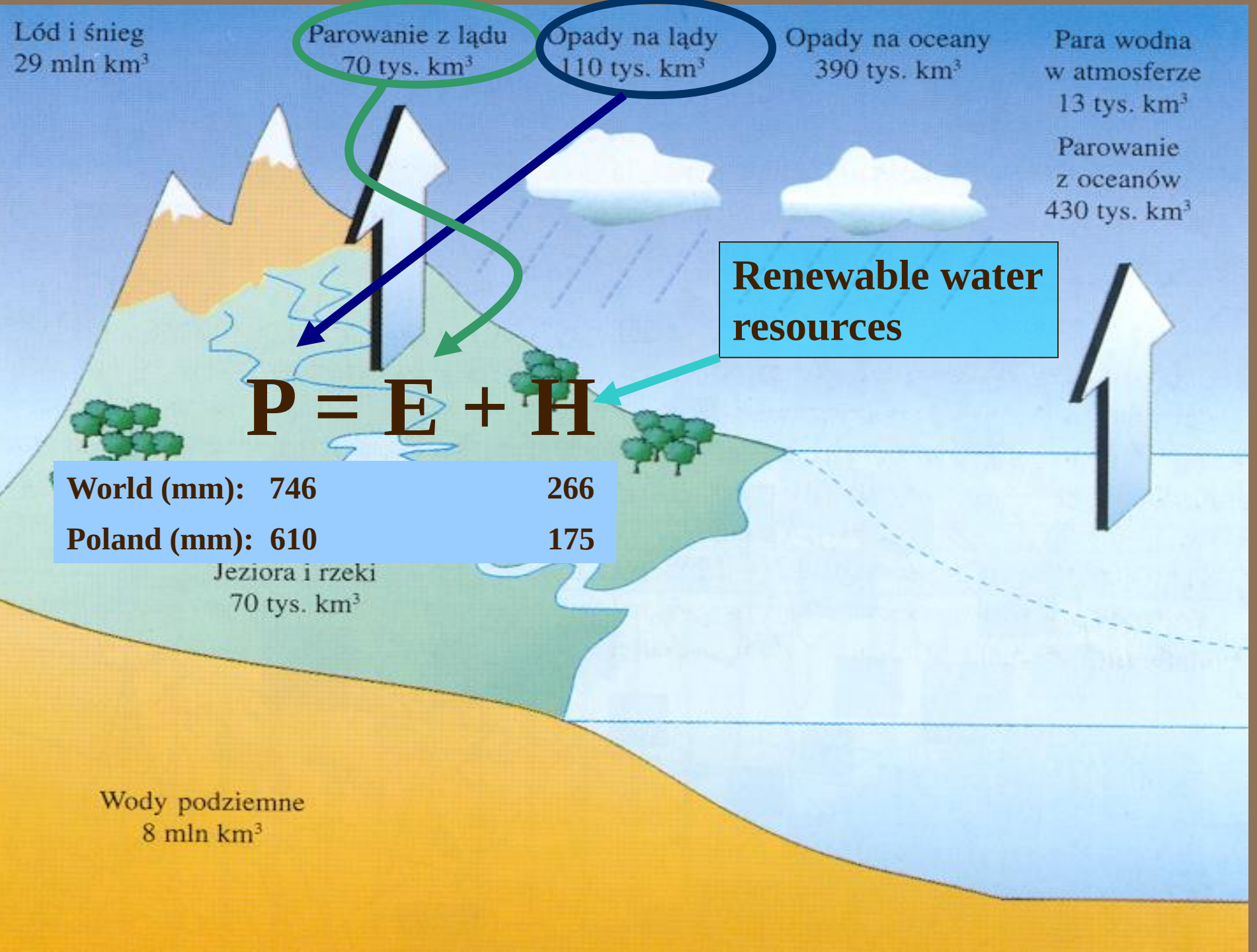
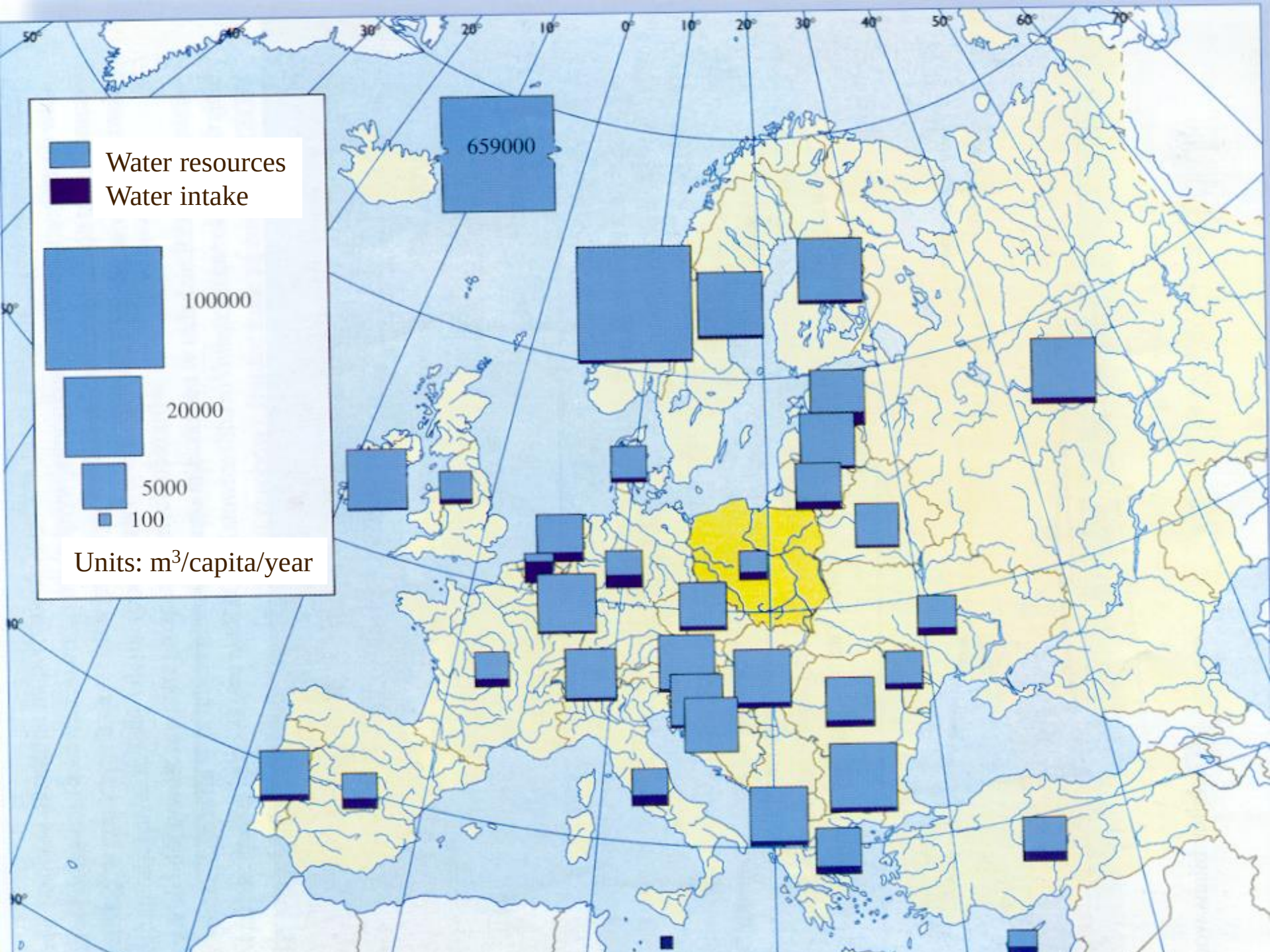
Scope of the presentation

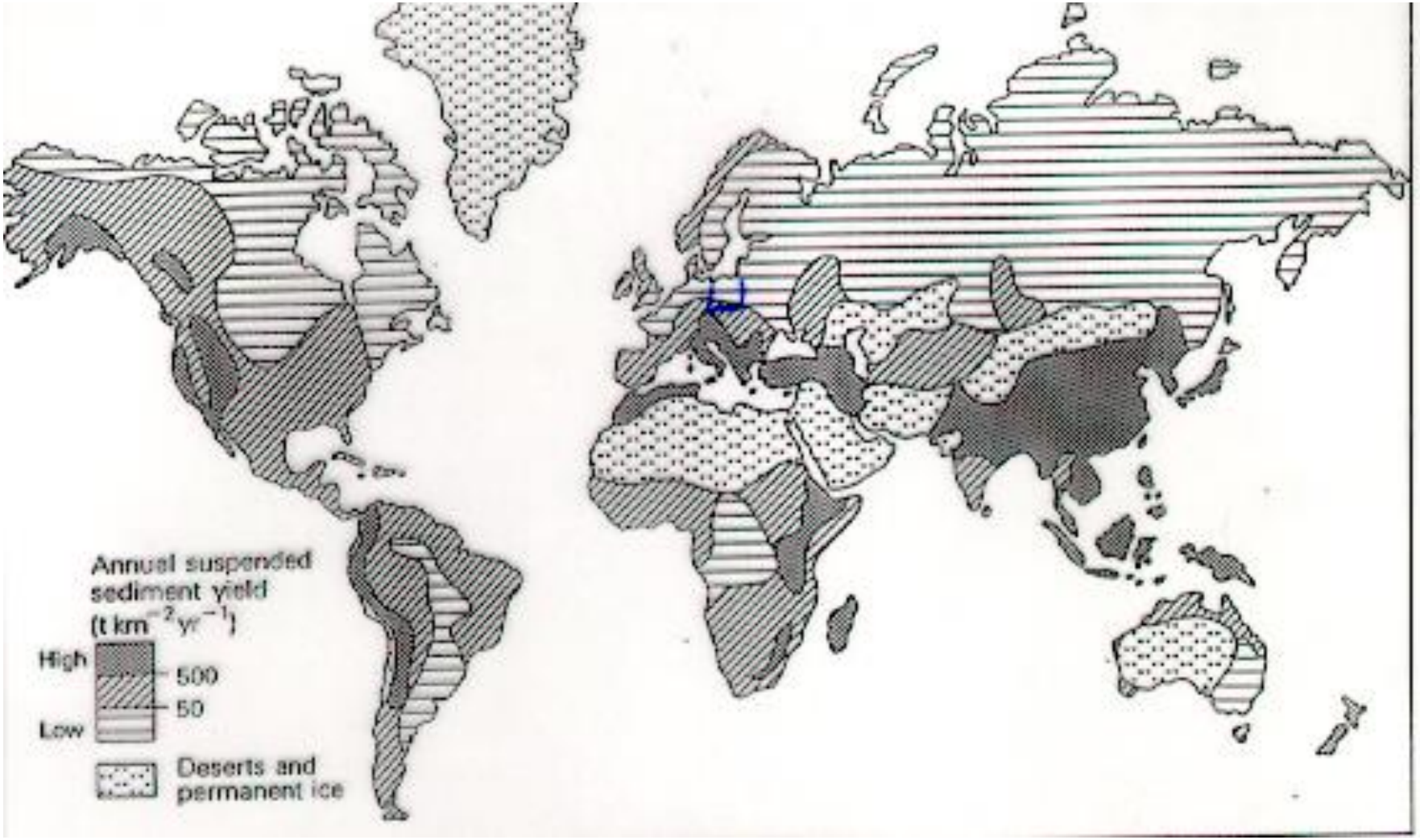
- **Introduction:**
  - Renewable water resources of Poland
  - Specific suspended sediment yield in Poland
- **Case study of a small catchment located in the middle of the country**
  - Catchment and reservoir characteristics
  - Sediment deposits in the period 1980-2020
  - Suspended sediment yield based on USLE application
  - Sediment delivered to the reservoir (suspended+bed load) vs deposited
- **Concluding remarks**



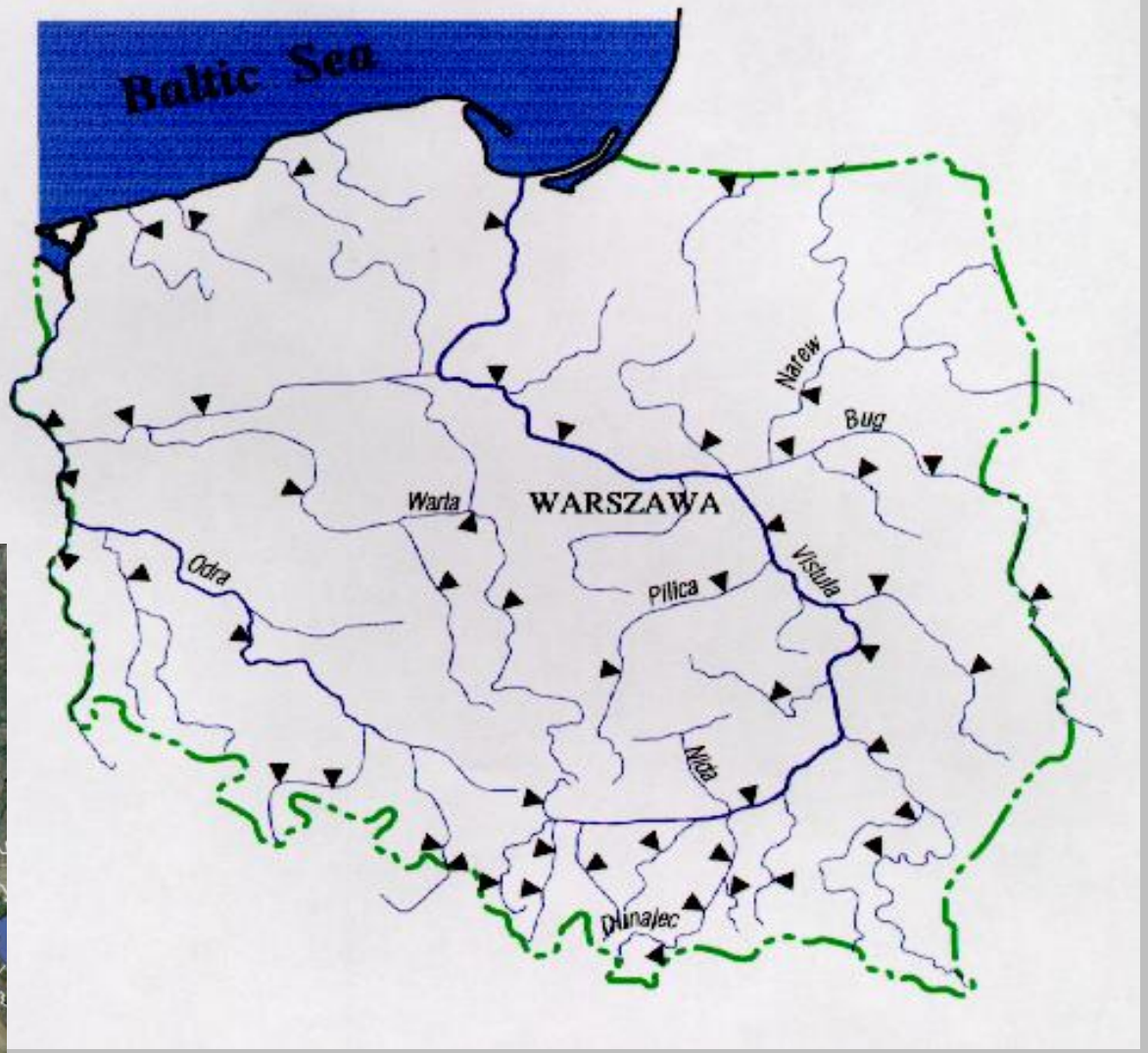

Lód i śnieg
29 mln km³
Parowanie z lądu
70 tys. km³
Opady na lądy
110 tys. km³
Opady na oceany
390 tys. km³
Para wodna
w atmosferze
13 tys. km³
Parowanie
z oceanów
430 tys. km³
Renewable water resources
P = E + H
World (mm): 746 266
Poland (mm): 610 175
Jeziora i rzeki
70 tys. km³
Wody podziemne
8 mln km³


Water resources
Water intake
659000
100000
20000
5000
100
Units: m3/capita/year

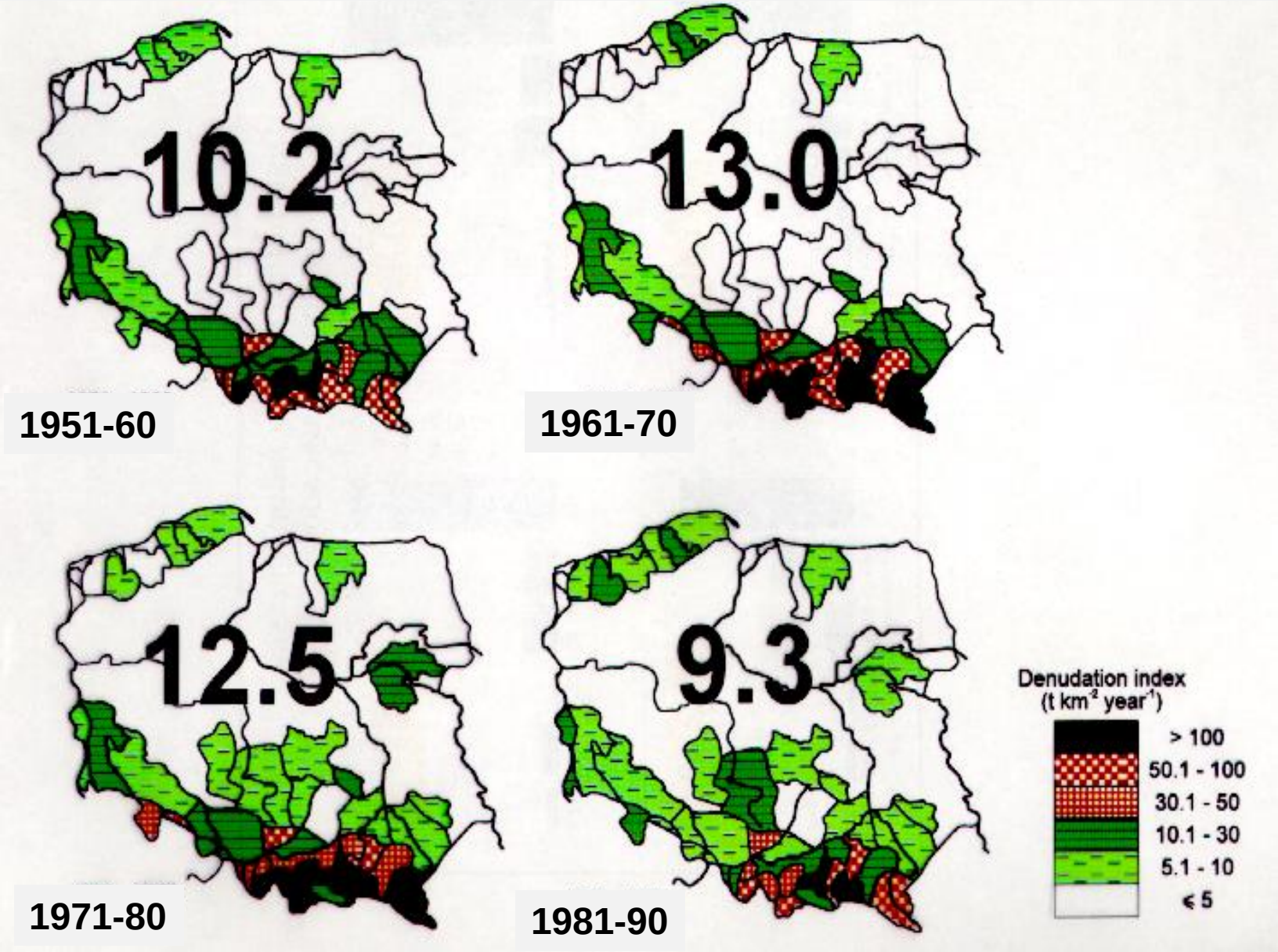
A generalized map of global specific suspended sediment yields (Walling 1988)



Location of gauging stations in Poland for monitoring discharge and suspended sediment concentration (by IMWM)

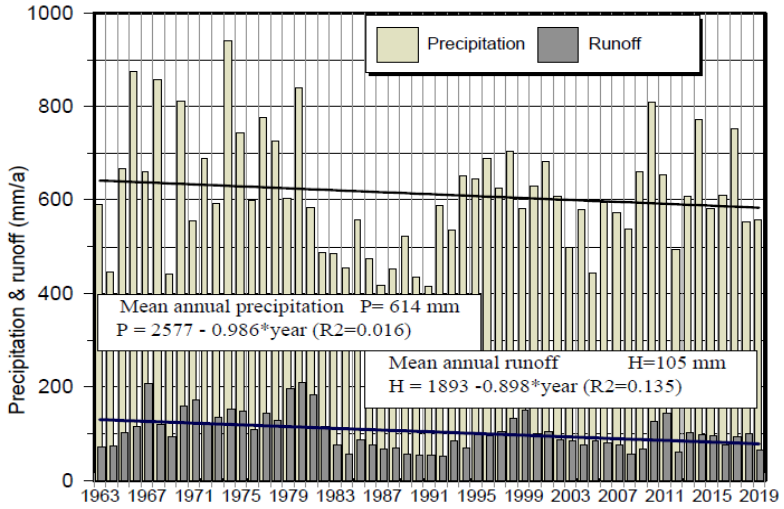


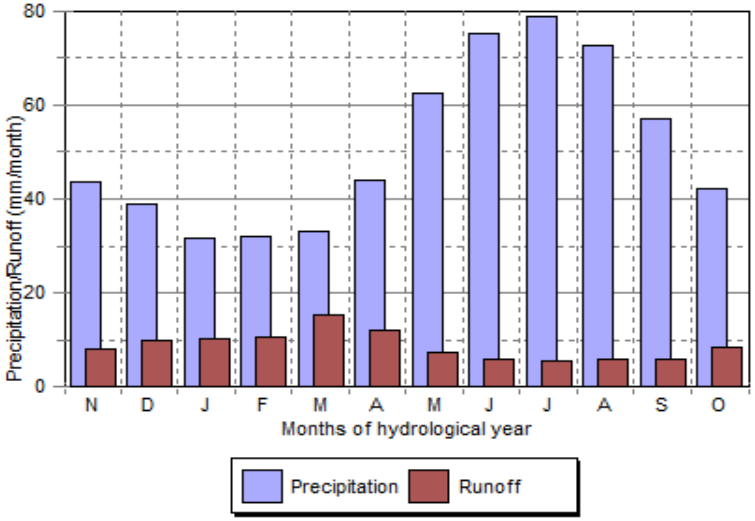
Mean annual specific suspended sediment yield [t km^{-2} year^{-1}] (Brański & Banasik, 1996)



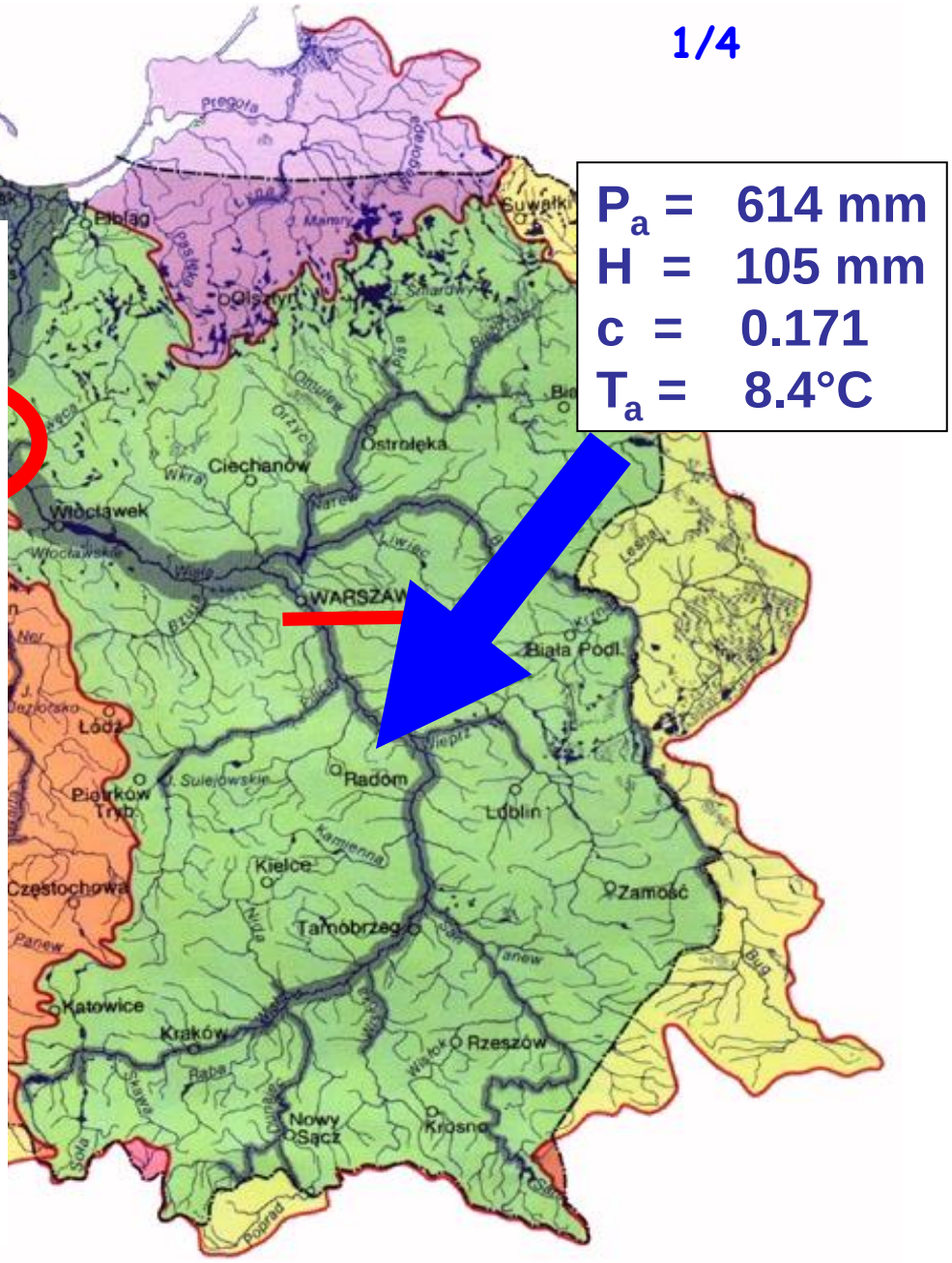
Catchment info

Baltic Sea



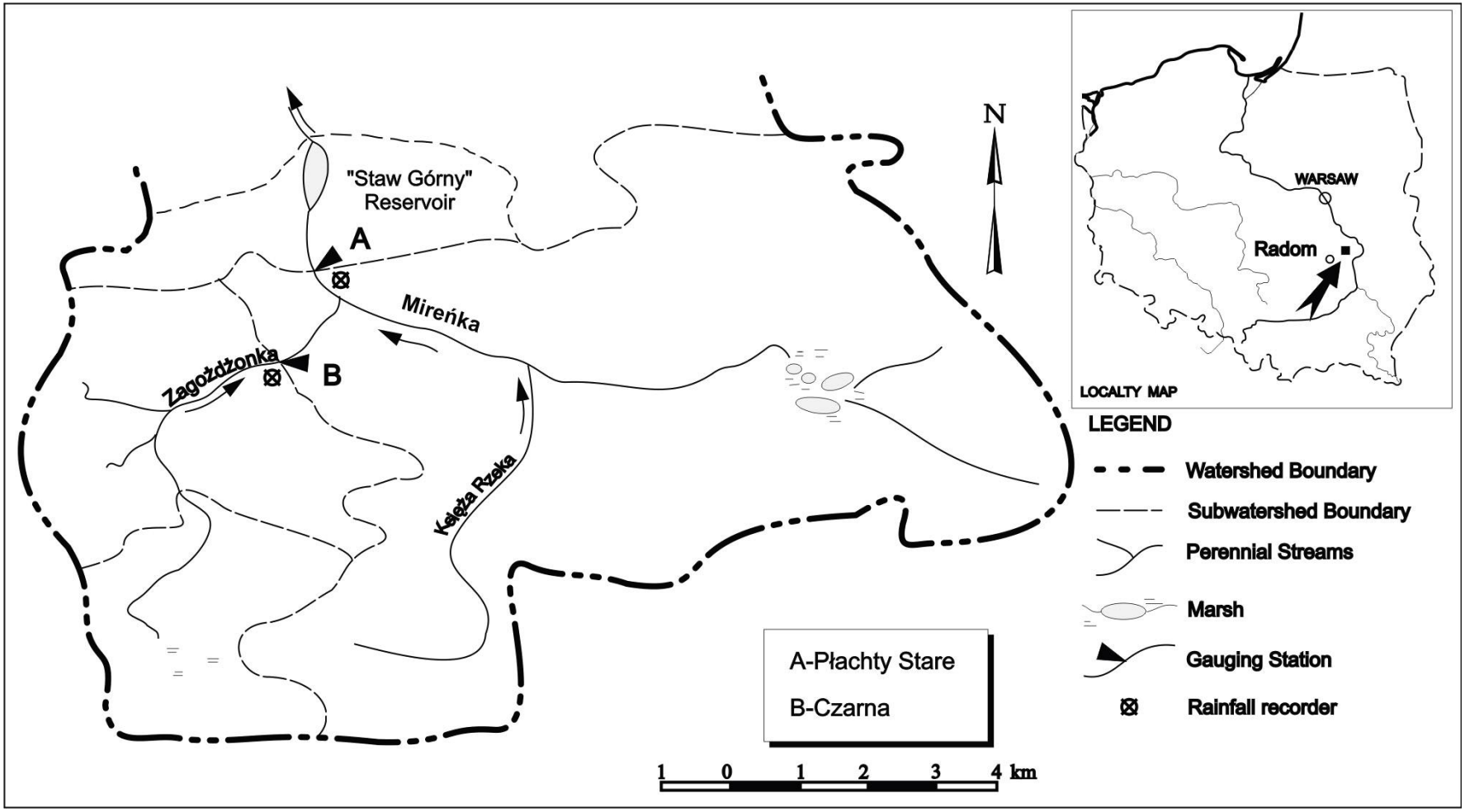


P_a = 614 mm
H = 105 mm
c = 0.171
T_a = 8.4°C



Research catchment

with gauging stations and reservoir

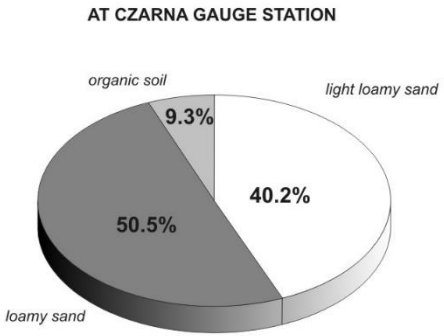


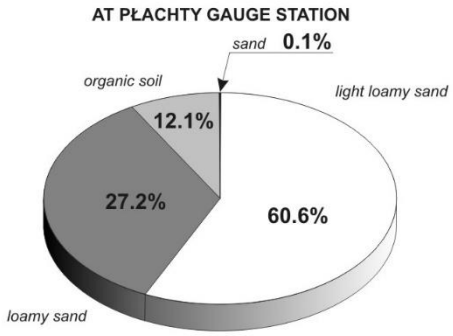
Research catchment info

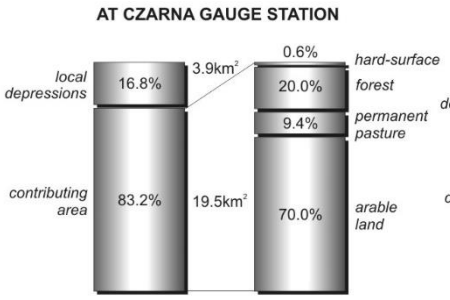
- The Zagożdżonka catchment (left tributary of Vistula River) is a small lowland agro-forested catchment, located in central Poland, about 100 km south of Warsaw.
- Hydrological investigations of the Zagożdżonka River at Płachty (N51°26′43.8″; E21°27′35.6″), have been carried out by the Department of River Engineering of Warsaw University of Life Science (WULS) since 1962.
- The catchment area is 82.4 km^2 at the Płachty gauging station, whereas the catchment area above the dam of the “Staw Górny” Reservoir is 91.4 km^2.

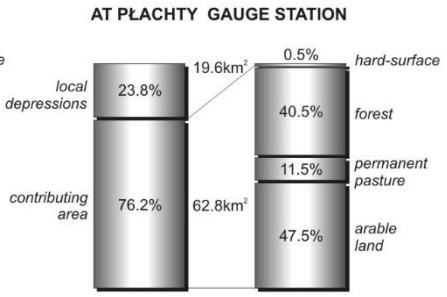
Catchment info

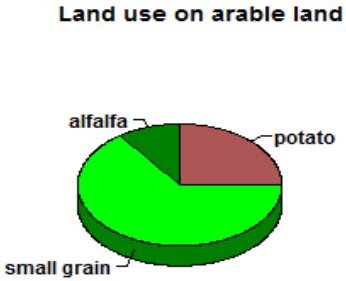
Soil types & land use





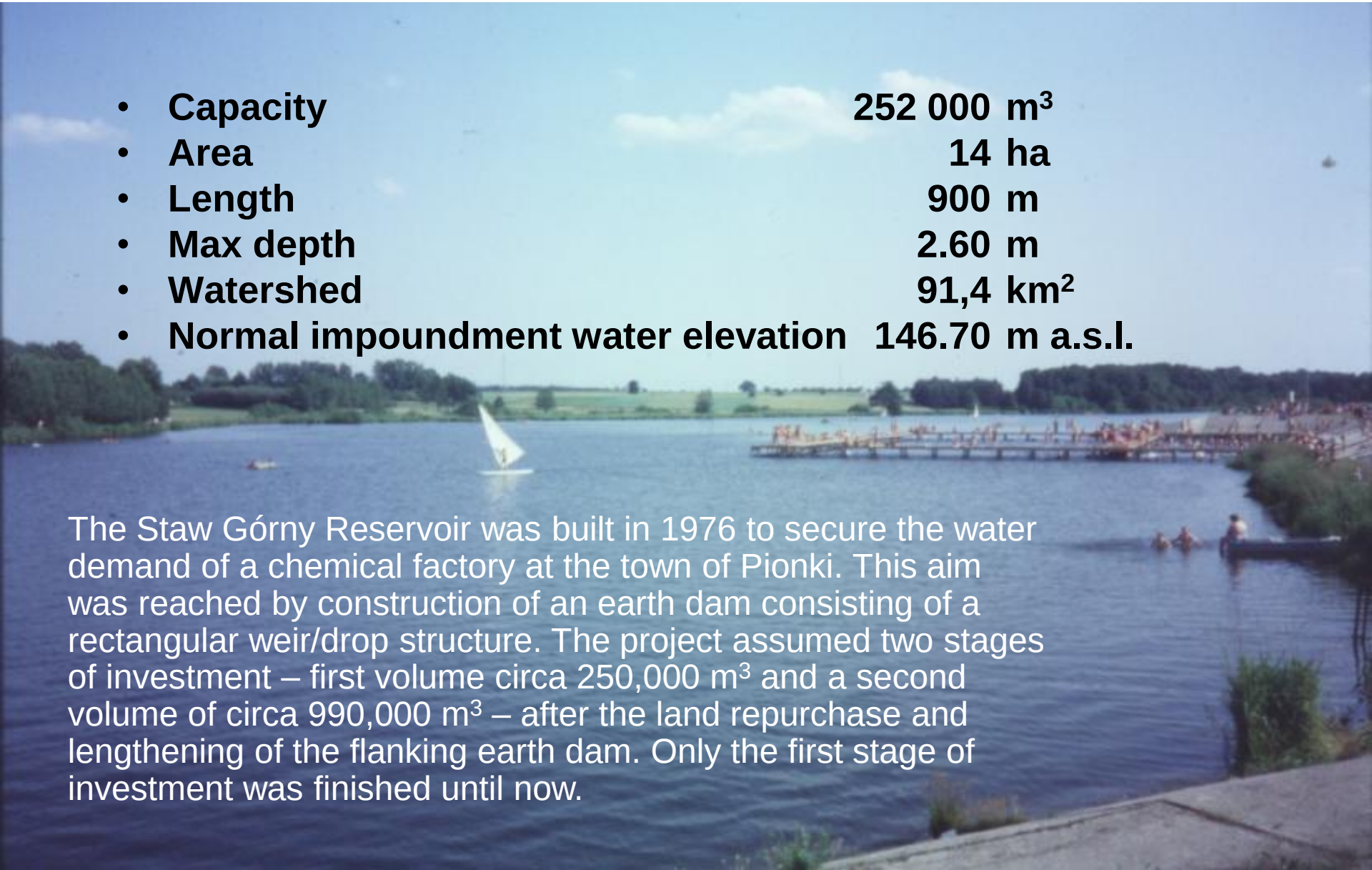






Catchment info

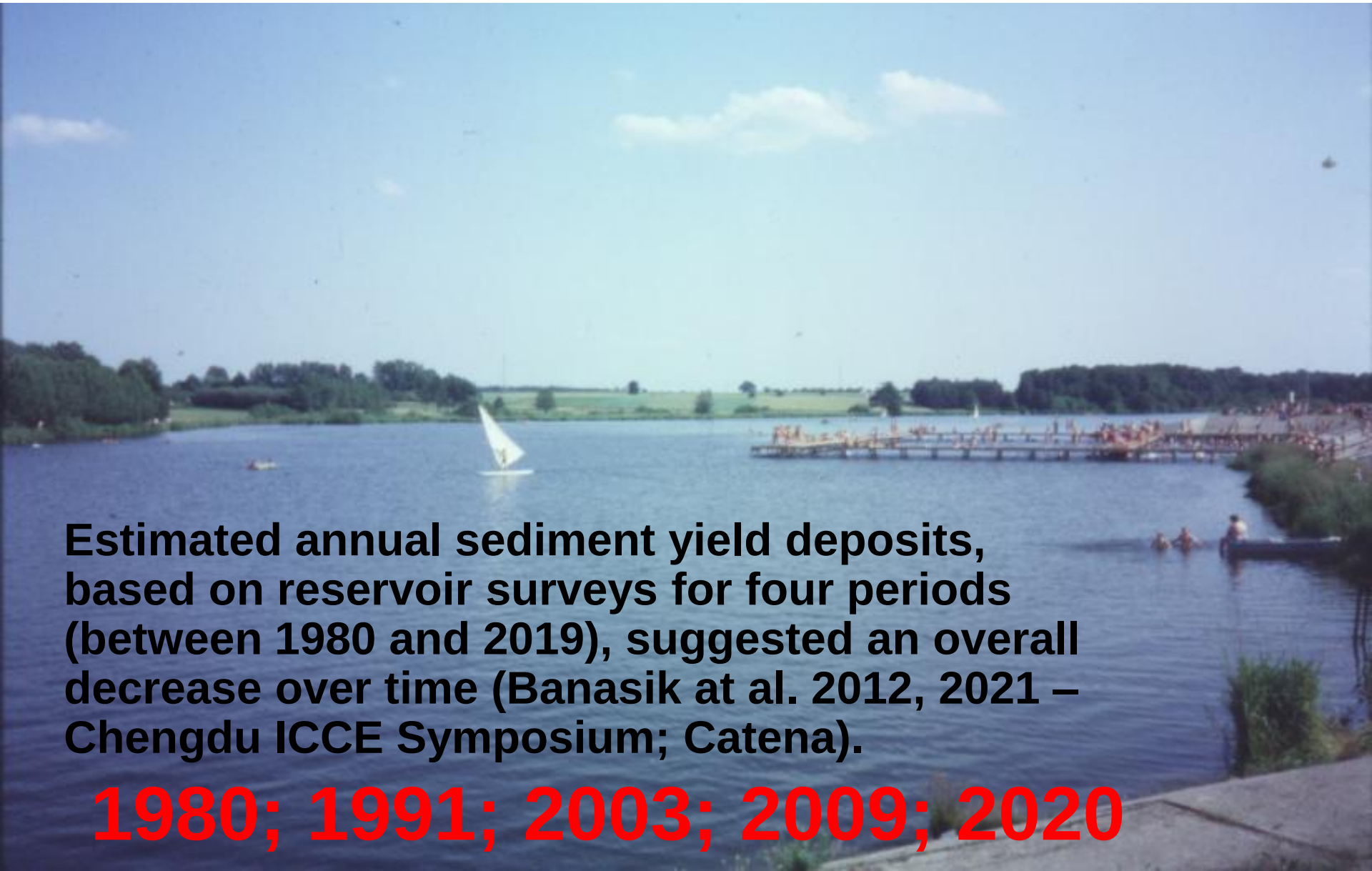
„Staw Górny" reservoir



- **Capacity** **252 000 m^3**
- **Area** **14 ha**
- **Length** **900 m**
- **Max depth** **2.60 m**
- **Watershed** **91,4 km^2**
- **Normal impoundment water elevation** **146.70 m a.s.l.**

The Staw Górny Reservoir was built in 1976 to secure the water demand of a chemical factory at the town of Pionki. This aim was reached by construction of an earth dam consisting of a rectangular weir/drop structure. The project assumed two stages of investment – first volume circa 250,000 m^3 and a second volume of circa 990,000 m^3 – after the land repurchase and lengthening of the flanking earth dam. Only the first stage of investment was finished until now.

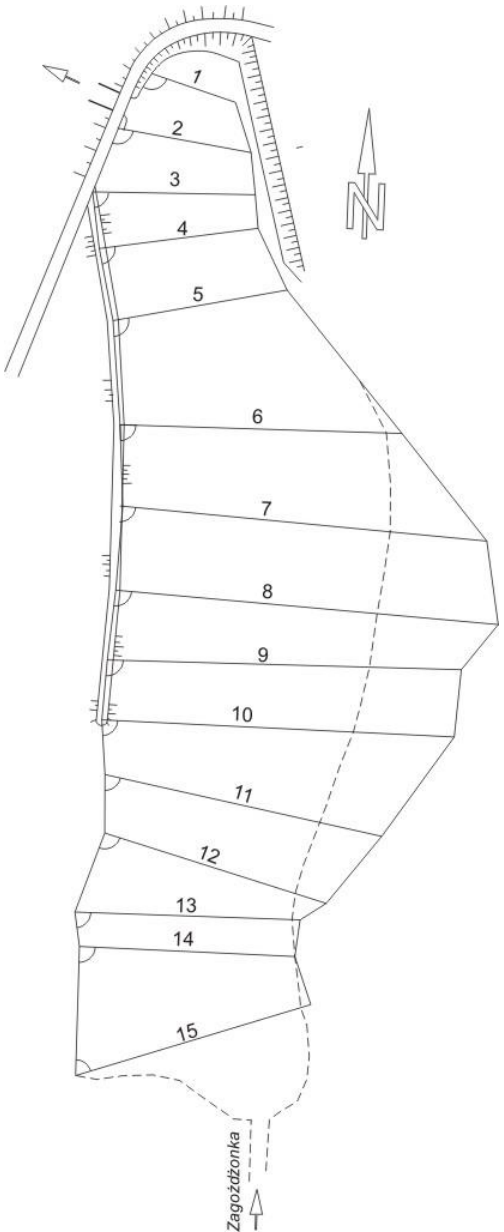
„Staw Górny” reservoir



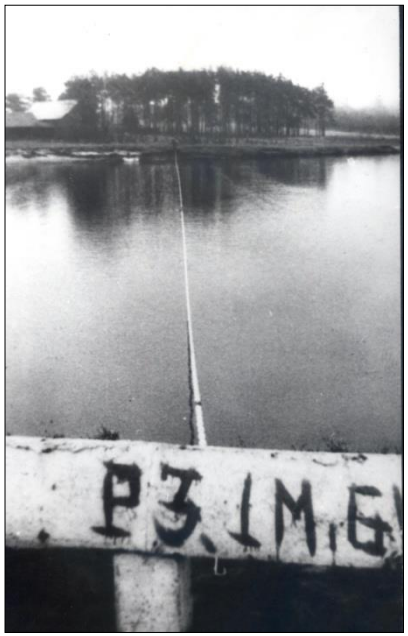
Estimated annual sediment yield deposits, based on reservoir surveys for four periods (between 1980 and 2019), suggested an overall decrease over time (Banasik at al. 2012, 2021 – Chengdu ICCE Symposium; Catena).

1980; 1991; 2003; 2009; 2020

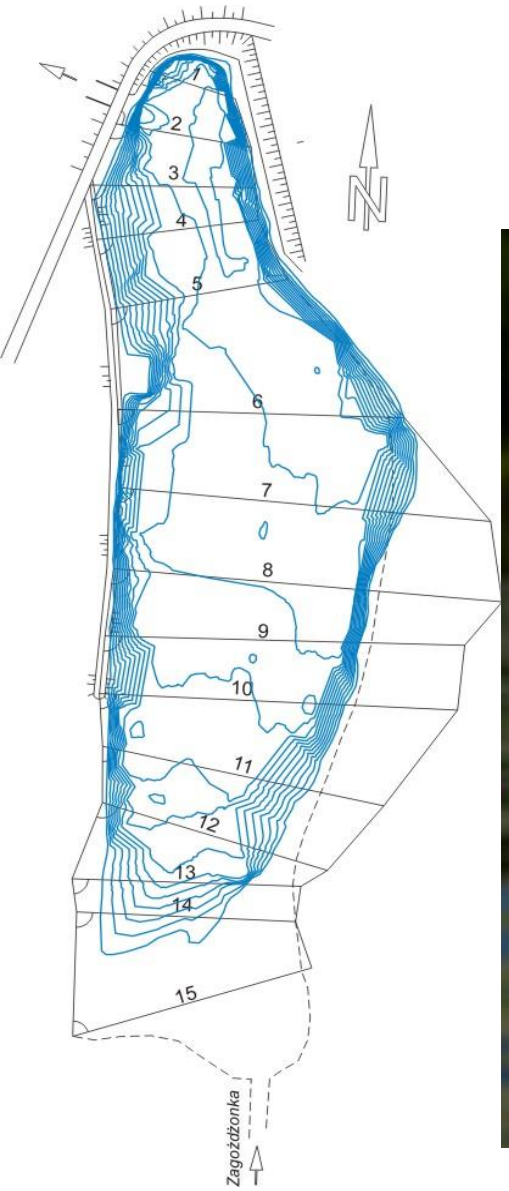
Reservoir bathymetry survey 1/2



The **first bed survey** of the Staw Górny Reservoir was conducted during the period **Nov. 1979-Feb. 1980**, using the range line method. A base line was established by fixing permanent markers along the left side of the reservoir and cross-sections were referenced by distance and direction angles to the base line as shown on Figure (left).



Reservoir survey



The echo-sounder unit and a Global Positioning System (GPS) receiver.

Sediment deposits in the reservoir (1980-2019)

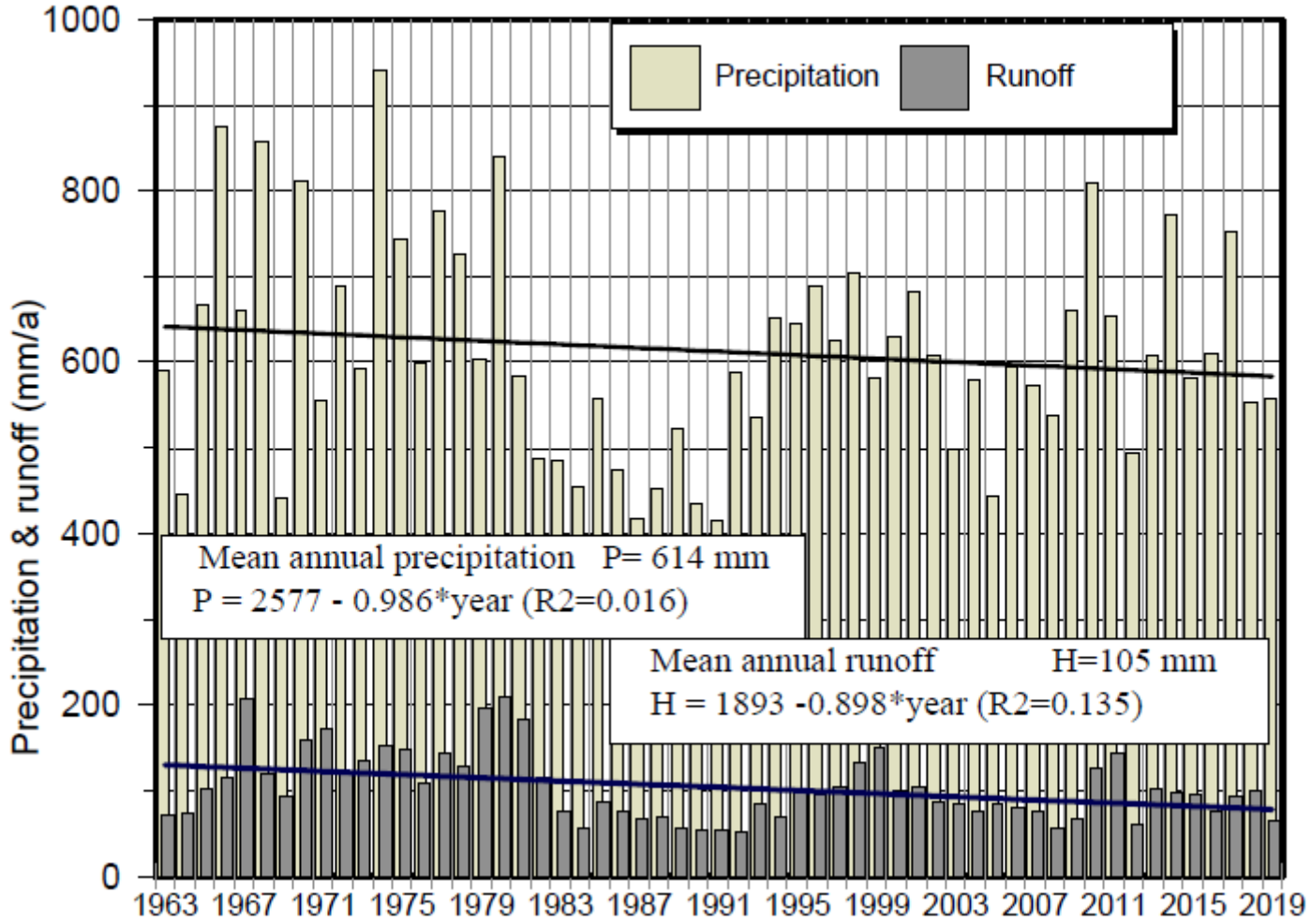
Period	Annual volume of sediment deposited in the reservoir (m^3/year)
I: 1980-1991 (12 years)	1 330
II: 1991-2003 (12 years)	970
III: 2003-2009 (6 years)	820
IV: 2009-2019 (10 years)	740
Average (1980-2019)	**1000**

Aim of the analysis:

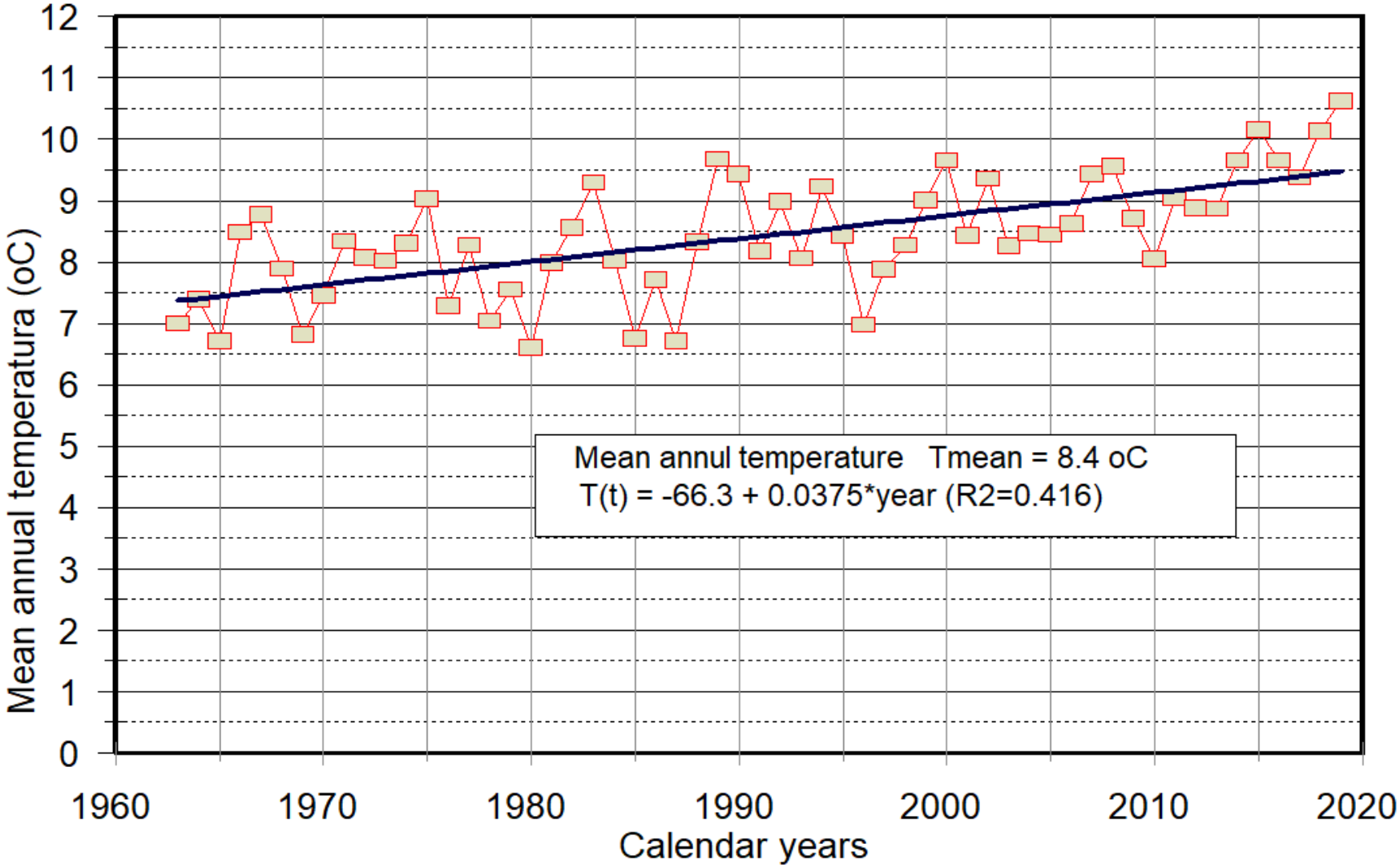
- Could we confirm the amount of the sediment deposits in reservoir by catchment hydrological characteristics ?
- Is the sediment delivery to the reservoir (and deposits) changing (decreasing) with time (based on hydr-meteorological parameters)?

Are the erosive factors (R_r, EI_{max} & n-day rainfall) changing in time?

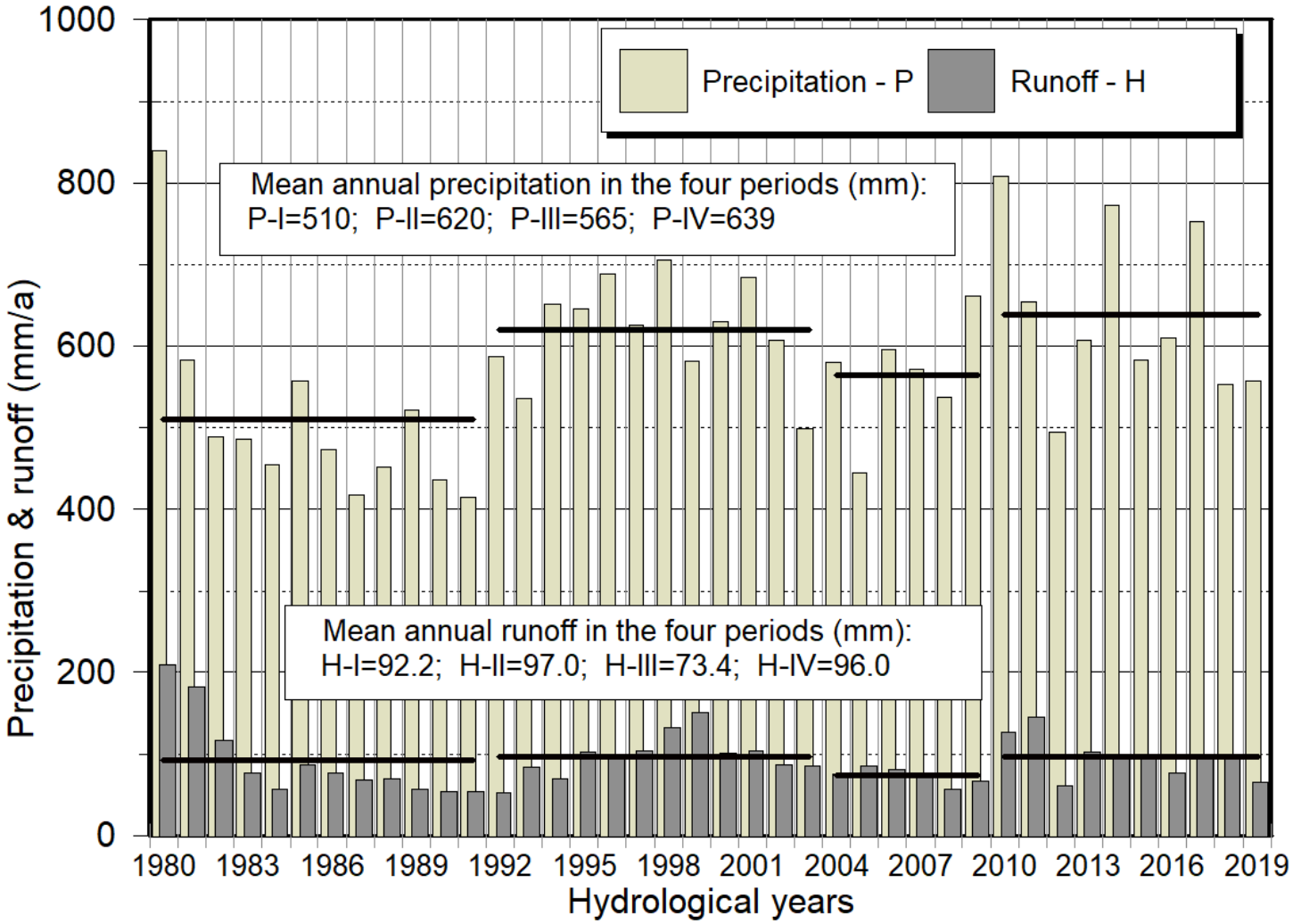
Mean annual precipitation and discharge for Zagożdżonka (1963-2019)



Mean annual temperature at Puławy
(1963-2019 – data of IMWM)



Annual precipitation and runoff
for the four periods between reservoir surveying



Sediment delivery to the reservoir for the a.m. three periods

- USLE – SDR (acc. to Vanoni or Roehl)
- Reservoir trap efficiency (Łopatin)

- Bed load formula (acc. to Skibiński or M-P,M) and daily flow frequency data

Sediment delivery to the reservoir

I. Suspended sediment input:

acc. to USLE-SDR, i.e.:

$$E = R\ K\ L\ S\ C\ P$$

where:

E – soil loss
R – rainfall-runoff erosivity
K – soil erodibility
L - slop length factor
S - slop steepness factor
C - crop management factor
P - erosion protection factor

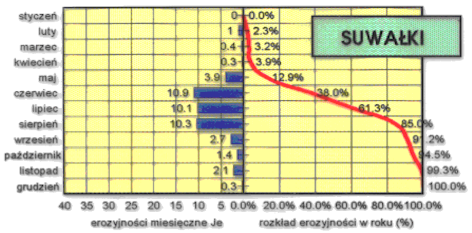
$$Y_r = SDR\ E\ A_E$$

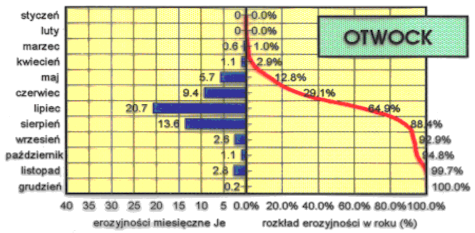
Y_r - annual sediment yield; SDR – sediment delivery ration acc. to Roehl, A_E – active area of the catchment

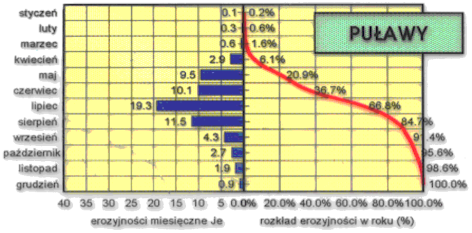
Sediment delivery to the reservoir

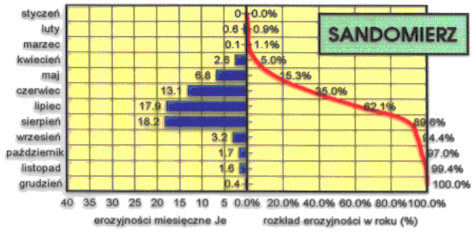
I. Suspended sediment input:

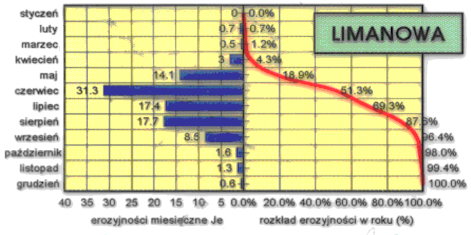
R (= R_r+R_s) rainfall-runoff erosivity in Poland (Banasik & Górski 1993; Banasik et al. 2001):

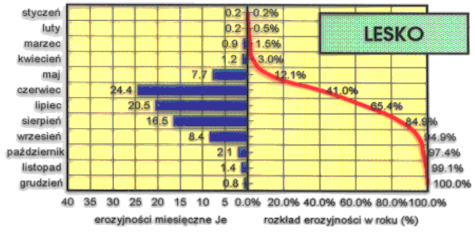












R-erosivity, Land use, C-crop managment factor

Period	R	Arable land; forest (%)	C
I: 1980-1991	745	54; 33	0.077
II: 1991-2003	761	47; 41	0.071
III: 2003-2009	690	42; 46	0.054
IV: 2009-2019	751	36; 52	0.047
Average (1980-2019)	**690-761** (93%-102%)	**54-36; 33-52**	**0.077-0.047** (62%)

Sediment delivery to the reservoir

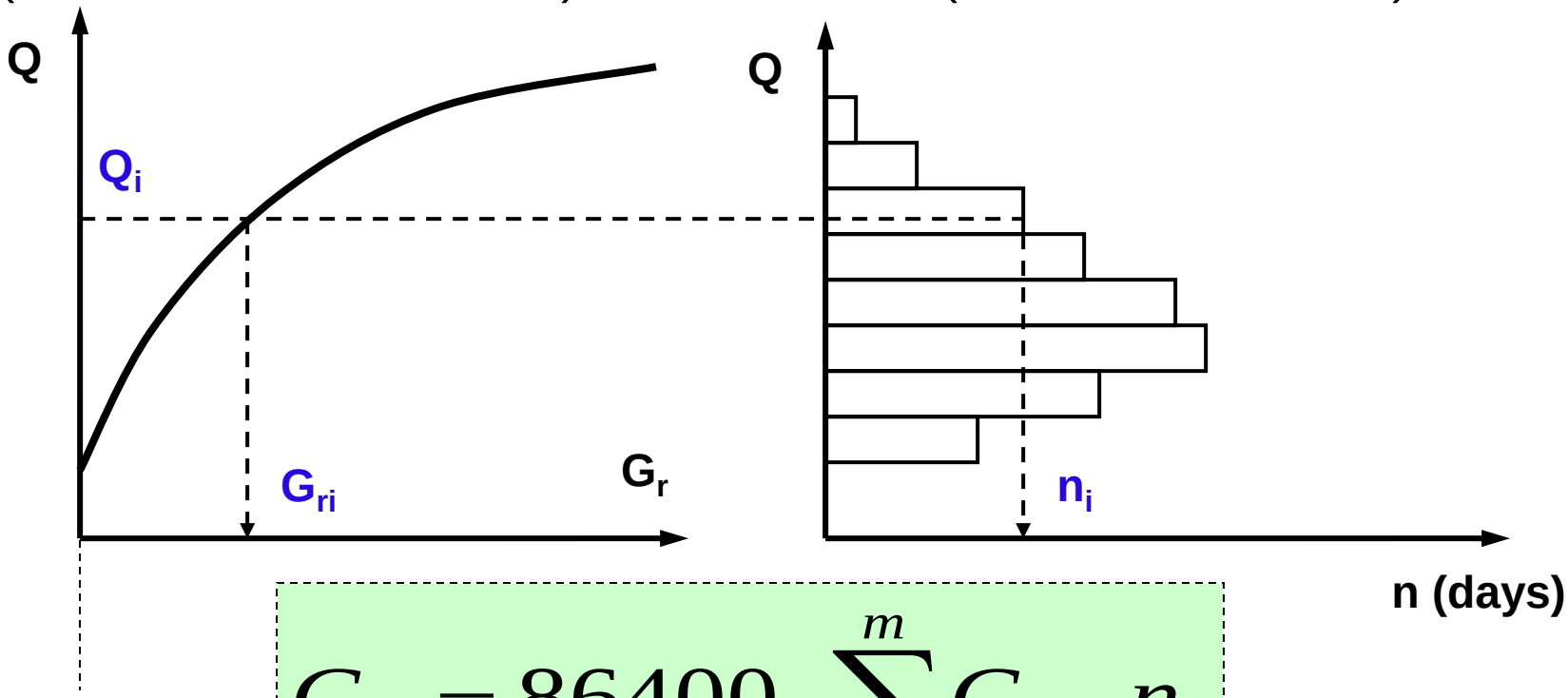
II. Bed load input:

a) bed load rating curve

(acc. formula of Skibinski)

b) flow frequency graph

(FDC for 1980-2019)



$$G_R = 86400 \cdot \sum_{i=1}^{m} G_{ri} \cdot n_i$$

The amount of sediment deliverd to, and deposited in the reservoir

Period	Suspended sediment (Mg)	Bed load (m^3)	Deposits (m^3)
I: 1980-1991	998	305	1 093
II: 1991-2003	948	322	1 055
III: 2003-2009	648	242	767
IV: 2009-2019	614	496	969
Average (1980-2019)	**832**	**348**	**1 002**

The amount of sediment deliverd to, and deposited in the reservoir

Period	Annual volume of sediment deposited in the reservoir (m^3/year)	Deposits (m^3)
I: 1980-1991 (12 years)	1 330	1 093
II: 1991-2003 (12 years)	970	1 055
III: 2003-2009 (6 years)	820	767
IV: 2009-2019 (10 years)	740	969
Average (1980-2019)	**1000**	**1 002**

Concluding remarks:

- There was good agreement between the mean annual quantity of sediment deposits estimated on based on catchment characteristics with the USLE & SDR (acc. to Vanoni) [& with sediment trap efficiency acc. to Łopatin] and the local bed load formula (acc. to Skibiński) with the measured value.

- The average annual SSSY in the catchment of the reservoir (9.1 Mg/km2) is significantly higher then that provided by the general maps.

- From the amonut deposits in the reservoir (1000m3/year) arounf 35% is bed load and 65% is suspended load.

Thank you for your attention!

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The intensity of siltation of a small reservoir in Poland and its relationship to environmental changes

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