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Long term changes in groundwater dynamics in the Vistula Catchment

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Abstract

Assessment of groundwater changes from a long term perspective is a challenging task. This is mainly due to scarcity of groundwater measurement, incomplete and short data series, and large heterogeneity of hydrogeological conditions. Baseflow (estimated based on streamflow data) can be treated as a proxy measure of groundwater storage and outflow on the catchment scale and used to quantify groundwater dynamics over a longer time horizon. This study uses different recession analysis and recession extraction methods to isolate baseflow in a selected sub-basins in the Vistula catchment. Mann-Kendall statistical test was applied to identify long term trends in annual and seasonal baseflow index (BFI) values. Preliminary results showed increased BFI values for most of the study sub-basins, indicating an increased pressure on groundwater in the Vistula catchment.

Introduction

Baseflow is a portion of streamflow that is not directly generated from the excess rainfall during a storm event. Estimation of baseflow and direct runoff is useful to understand the catchment hydrology, including interaction of surface and sub-surface water, role of urbanization on runoff generation and the health of aquatic habitat within a stream. Baseflow is the most important component of river flow in Poland. Proper quantitative assessment of baseflow is important for conducting efficient water management.

The magnitude of baseflow and its part in the total river flow is a function of climate, land cover, hydrogeological conditions, river morphology and anthropogenic factors.

MOTIVATION:

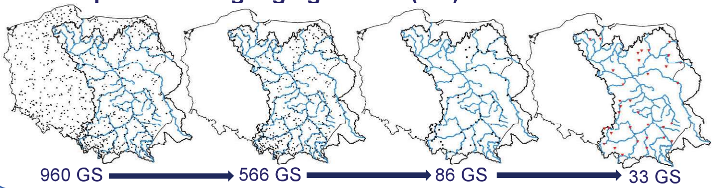
- In Poland there is a lack of complementary studies on quantification of baseflow and its spatio-temporal variability
- Baseflow can be treated as a proxy measure of groundwater storage and outflow on the catchment scale and used to quantify groundwater dynamics over a longer time horizon.

AIM OF THE STUDY:

- Quantification of baseflow of the Vistula catchment in the long time horizon (1951-2020);
- Determination of the baseflow index (BFI);
- Analysis of changes in baseflow in time;
- Analysis of trends in baseflow.

Materials and methods

Data acquistion and gauging station (GS) selection



Gauging station (GS) selection criteria:

- **maximum longest daily flow data (86 GS) – 70 years (1951-2020)**
- **data without gaps**
- **not influenced by any dams (33 GS)**

Baseflow index calculation

- Recession Analysis Methods

Method	Storage - discharge relationship	Recession curve equation
Maillet (1905)	$S=Q/\alpha$	$Q_t=Q_0\,e^{-at}$
Boussinesq (1905)	$S=\int f(Q)dt$	$Q_t=Q_0(1+n\,t)^{-2}$
Coutange (1978)	$dQ/dt=-aQ^b$	$Q_t=[Q_0^{1-b}-(1-b)at]^{1/1-b}$
Wittenberg (1999)	$S=cQ^d$	$Q_t=Q_0[1+((1-d)Q_0^{1-d}/cd)\,t]^{1/d-1}$

- Recession Extraction Methods

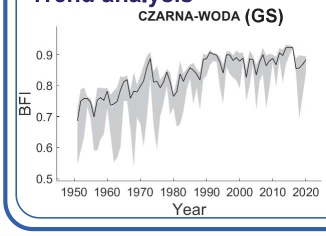
Method	Criterion	Minimum duration (days)	Filter criterion (removed days)	Exclusion of anomalous recession decline
Vogel and Kroll (1992)	Decreasing 3-day moving average	10	First 30 %	$Q_t-Q_{t+1}/Q_{t+1}>30\%$
Brutsaert and Nieber (1977)	$dQ/dt<0$	6-7	First 3-4, last 2	$dQ_{t+1}/dt>dQt/dt$
Aksoy and Wittenberg (2011)	$dQ/dt<0$	5	First 2	$CV>0.20$

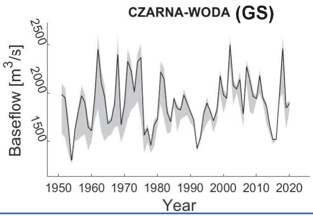
- Parameter estimation technique
  - Least squares
  - Linear regression
  - Lower envelope
  - Data Binning

- **20 baseflow** for each station

- 20 combinations based on different recession analysis, extraction methods and parameter estimation techniques

Trend analysis



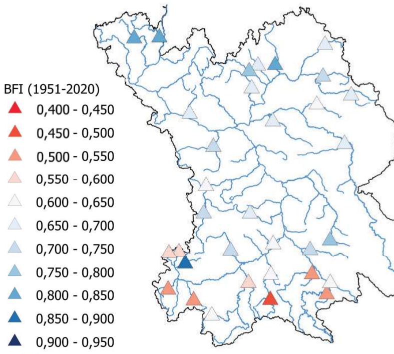


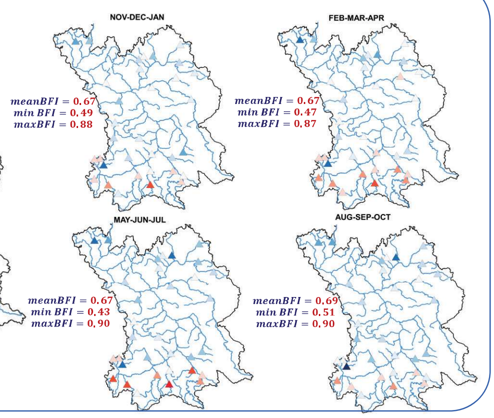
- Avarage baseflow and BFI of 20 combinations (black line)
- Shaded area indicates the range of variation for the 20 considered combinations
- Trend analysis was performed for avarage BFI of 20 considered combinations using **Modified Mann Kendall test**

Results

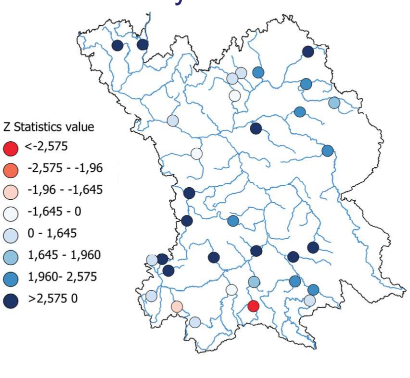
BFI quantification

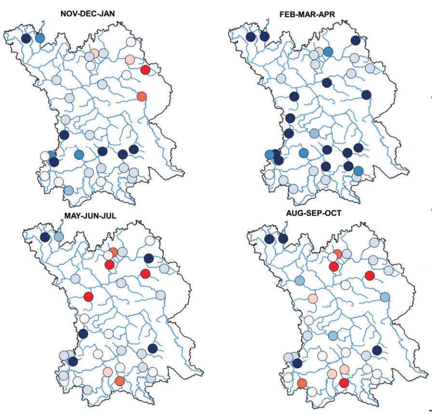
- Baseflow index
  - $BFI = \frac{Baseflow}{Total\ flow}$
- $meanBFI_{Vistula} = 0.67$
- $min\ BFI_{Vistula} = 0.48$
- $maxBFI_{Vistula} = 0.89$





BFI trend analysis





- 28 GS – BFI increasing
  - 19 GS - statistically significant
- 5 GS - BFI decreasing
  - 1 GS - statistically significant

Conclusions

- Baseflow component in the Vistula catchment is increasing;
- The average share of the baseflow component of river flow in the Vistula catchment is 0.67;
- For 20 (out of 33) analysed gauging stations, statistically significant trends of changes in BFI were found;
- It seems that the causes of changes in baseflow should be sought in cumulative interactions of anthropopression and climate.

Acknowledgements

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