



# Satellite-based monitoring of drought at the watershed scale

## Satellite-based monitoring of drought at the watershed scale

**Abstract**

Drought is a complex and multi-scale phenomenon influenced by diverse physical and hydrological processes, as they derive from the accumulation effects of climatological and hydrological variables over a certain period. Nevertheless, droughts are becoming a very frequent phenomenon also in regions traditionally not affected by them, such as Poland. To tackle this phenomenon and investigate its drivers, multiple approaches are being developed, based both on in-situ data and satellite-based observations, also thanks to recent advancements in statistical modeling and spatial-temporal resolution of satellite data.

Focusing on the Vistula River basin in Poland, the present research aims to detect drought indices to infer spatial-temporal changes of drought over the last few decades. The opportunity to use freely available satellite observations provided with Google Earth Engine, allows for drought trends at the watershed scale, providing spatially-distributed indices to long-term changes. The present methods allow that, sometimes, drought is a common occurrence also for a country that used to be not at all dry.

**Study Area & Dataset**

The study focuses on the Vistula River basin, characterized by an area of 131,000 km<sup>2</sup>, of which 67% (107,000 km<sup>2</sup>) lies within Poland. The land use is mainly dominated by arable land (48%), while forests and some natural reserves cover 25%, excluding 27% of the built-up urban area.

The hydro climate is generally cold, without a dry season and with a warm summer. In the north, cold, dry winters and mild summers are also present, while the highest temperatures are above water bodies (Kucenas & Romanowski, 2021).

Year	2013 (Spring-September)	2014	2015 (Summer)	2016 (Summer)
Area	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000
Area	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000
Area	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000
Area	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000
Area	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000	100,000,000,000,000,000,000

**Trends**

- To investigate drought conditions over the Vistula River catchment, the Palmer Drought Severity Index (PDSI) was calculated. It uses monthly available temperature and precipitation data to estimate relative humidity (Mishra et al., 2015). As a derivative from a combination of temperature with a physical water balance model, PDSI not only captures the local effect of global warming on drought through changes in potential evapotranspiration. The PDSI is a standardized index that generally spans from -4 (very dry) to +4 (very wet), and describes the balance between water supply and atmospheric evaporative demand on a monthly scale.
- PDSI can be used as a proxy for long-term drought trends, while soil-moisture anomalies derived from such an index can be best compared to other (Mishra et al., 2015). Therefore, the following analysis was performed on a yearly scale.
- Monthly yearly values PDSI conditions were investigated at the monthly scale, showing that PDSI in the last years is generally below zero, meaning that periodic, while at the beginning of the observation period (1980s-1990s), the catchment was characterized by more conditions to experience more annual changes, prolonged dry periods are characterizing the recent period, while only seasonal wet periods are seen in the past.
- Together with a decrease in precipitation, rising temperatures can lead to an increase in evapotranspiration, and subsequent drier conditions. The average maximum temperature has shown a significant increase for all the sub-basins, reaching in the last years values around 2.5 °C higher than in the 1980s.
- The population already increased over time, even if more expansion is recognizable, meaning the need for more resources for agricultural purposes, forest and livestock management, and industrial and energy uses (Kucenas & Romanowski, 2021).
- The example of the Vistula River basin drought has a bigger picture, as shown in an open access article related to drought impacts for monitoring and implementing a pan-European drought prevention approach, to mitigate indirect drought management policies and addressing the adaptive impact on human or water use vulnerability aspects.

**Conclusions**

- Satellite datasets can be used for monitoring to determine the evolution of long-term droughts at the basin scale, providing monitoring and water management with an additional tool for tracking regions where more detailed analyses are needed, or specific actions should be performed.
- The combination of increasing human pressure and climate change is negatively affecting the basin, with more frequent and prolonged droughts.
- The Vistula River basin, a region that used to be not so dry in the past, is now moving towards drier conditions with a rather stable period, mainly because of an increase in temperature and water evapotranspiration without precipitation.
- Such results should be used as a basis for future investigations, as evidenced by the dry drivers of drought and capturing effective adaptation strategies.

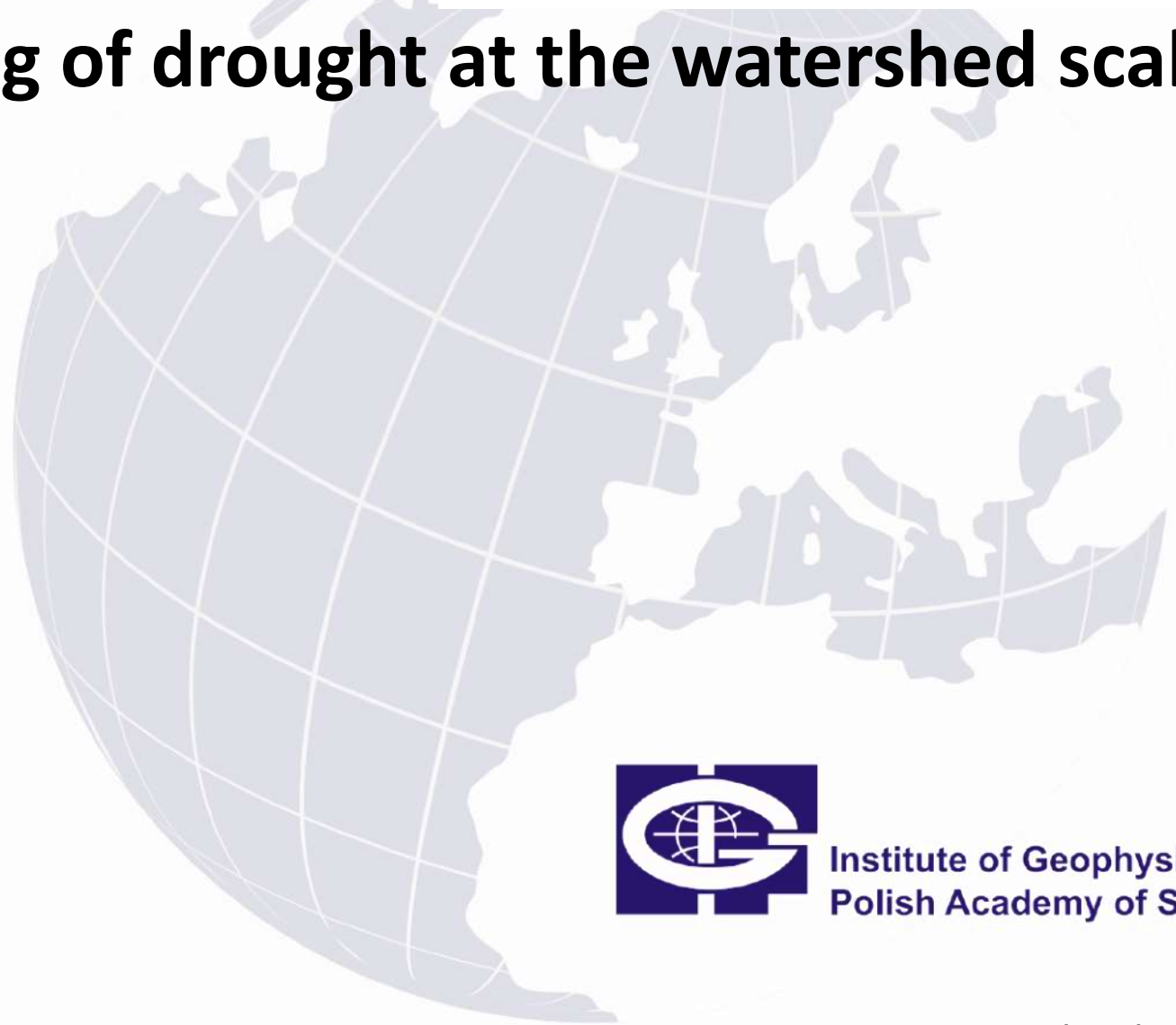
**References & Code availability**

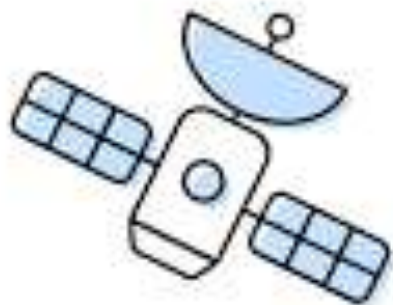
Mishra, S., & Romanowski, J. (2021). Drought trends in the Vistula River basin: a multi-scale analysis of monthly changes and climate variability over 1980-2017. *Hydrology*, 10(12), 1827.

Mishra, S., & Romanowski, J. (2021). Evapotranspiration trends and their impact on drought conditions in a river catchment in the Vistula River basin (1980-2017). *Hydrology*, 10(12), 1827.

The code is available at <https://doi.org/10.1002/hydro.2414>

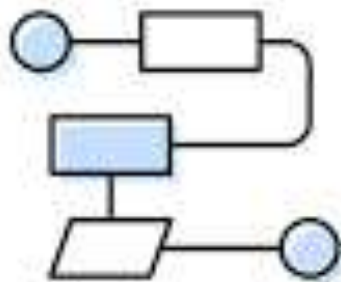
**Project website:** <https://journal.xl.edu.pl/>





Satellite imagery

+

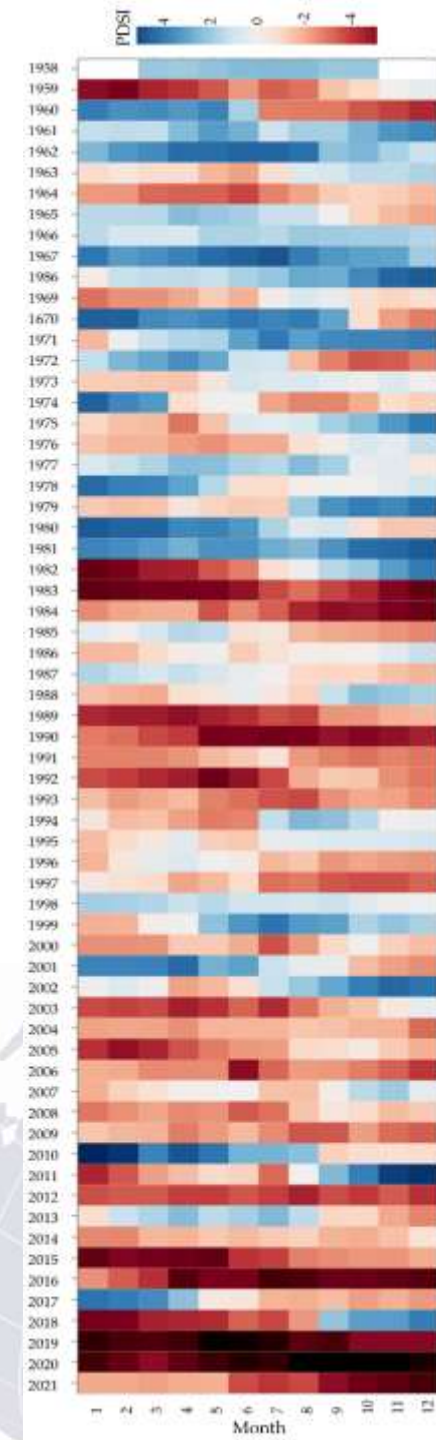


Existing datasets

+



Drought Vistula River basin



Data	Earth Engine Snippet	Range	Spatial Resolution	Temporal Resolution
PDSI	IDAHO_EPSCOR/TERRACLIMATE	1958-2021	1/24°	monthly
AET	IDAHO_EPSCOR/TERRACLIMATE	1958-2021	1/24°	monthly
PR	IDAHO_EPSCOR/TERRACLIMATE	1958-2021	1/24°	monthly
Tmax	IDAHO_EPSCOR/TERRACLIMATE	1958-2021	1/24°	monthly
Population	CIESIN/GPWv411/GPW_Population_Density	2000-2020	30"	5 year