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# Remote Sensing as a Tool to Monitor Drought at the Watershed Scale

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Abstract

Drought occurs due to the accumulative effect of certain climatological and hydrological variables over a certain period. As droughts are becoming a frequent phenomenon also in regions generally not affected by them, they are becoming a significant research topic, also thanks to the development of advanced monitoring methods and models. Focusing on the Vistula basin in Poland, the present work investigates changes in drought indexes and connected metrics by analysing satellite data. The use of satellite information allows for deriving trends at the watershed scale, therefore providing spatially-distributed medium/long-term changes. The present analysis takes advantage of the potentiality of Google Earth Engine and its freely-available datasets, showing that nowadays drought is a major concern also for a region that used to be wetter in the past.

**Keywords:** drought, Google Earth Engine, Poland, remote sensing.

## 1. INTRODUCTION

The observed increase in the frequency of droughts and heatwaves over the Northern Hemisphere in the 21st century poses socio-economic threats affecting the well-being of the people by triggering negative effects (Rakovec et al. 2022). These adverse hydro-meteorological conditions can lead to agricultural and ecological impacts, poor water quality conditions, wildfires even threatening existing infrastructure (Kreibich et al. 2022).

Like many other countries in Central Europe, also Poland recently faced more severe droughts, as depicted in the present study. To address changes at the sub-basin scale, drought indices are here computed using Google Earth Engine (GEE), an online cloud-based platform (Gorelick et al. 2017) that runs on python/java API and is largely used for manipulating and performing operations on image or image collections (Khan and Gilani 2021; Boothroyd et al. 2021). GEE has a massive catalogue of datasets available for users and allows for efficient algorithm development, processing of the datasets, and crowdsourcing (Xiong et al. 2017).

## 2. MATERIALS AND METHODS

### 2.1 Study area

The study focuses on the Vistula River basin, which has a total drainage basin area of 193,960 km$^2$, of which 87% (169,000 km$^2$) lies within Poland. The remaining part of the basin is located in Belarus, Ukraine, and Slovakia (Fig. 1). The land use structure is dominated by arable land (66%), while forests and semi-natural ecosystems cover 29%, and only 3% are classified as urban areas. The Polish climate is generally cold, without a dry season and with a warm summer. In the south, cold, no dry seasons, and cold summers are also present, while the highest mountains can show tundra-like characteristics (Karamuz and Romanowicz 2021).

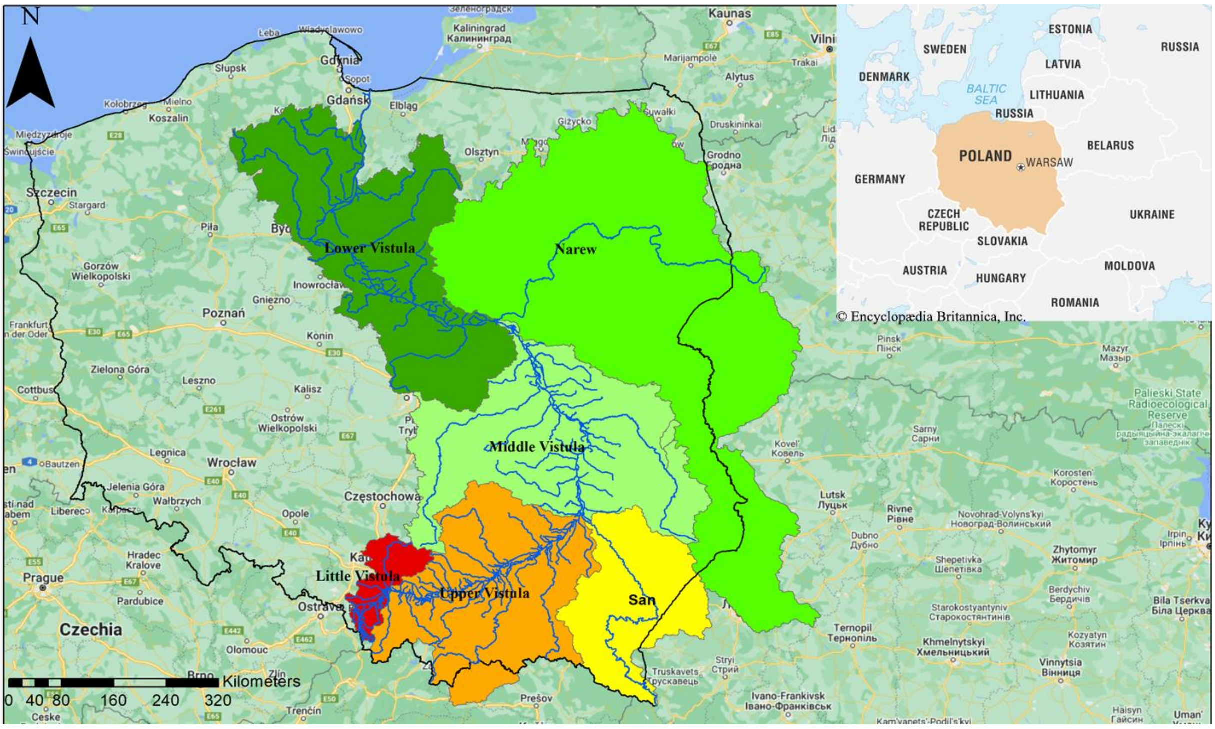


Fig. 1. Vistula basin and sub-basins.

### 2.2 GEE Datasets and data processing

The analysis took advantage of multiple datasets freely available via GEE, as detailed in Table 1. In particular, results extrapolated from TerraClimate are shown here.

The Palmer Drought Severity Index (PDSI), computed and released by the University of Idaho (Abatzoglou et al. 2018), uses readily available temperature and precipitation data to estimate relative dryness. In fact, it is derived by combining temperature with a physical water balance model, and therefore it can capture the basic effect of global warming on drought through changes in potential evapotranspiration.

Table 1
Used data and main information

| Used data | Earth Engine Snippet | Used data range | Spatial resolution | Temporal resolution | Data reduction method |
|---|---|---|---|---|---|
| PDSI (Palmer Drought Severity Index | IDAHO_EPSCOR/ TERRACLIMATE | 1958-01-01–2021-12-01 | 1/24° | Monthly | Monthly per basin |
| AET (Actual evapotranspiration) | IDAHO_EPSCOR/ TERRACLIMATE | 1958-01-01–2021-12-01 | 1/24° | Monthly | Monthly per basin |
| PR (Precipitation accumulation) | IDAHO_EPSCOR/ TERRACLIMATE | 1958-01-01–2021-12-01 | 1/24° | Monthly | Monthly per basin |
| RO (Runoff) | IDAHO_EPSCOR/ TERRACLIMATE | 1958-01-01–2021-12-01 | 1/24° | Monthly | Monthly per basin |
| NDVI | MODIS/061/MOD13A1 | 2001-01-01–2021-12-01 | 500 m | 16 days | Monthly mean per basin |
| EVI | MODIS/061/MOD13A1 | 2001-01-01–2021-12-02 | 500 m | 16 days | Monthly mean per basin |
| AVERAGE, MININUM, MAXIMUM LST (Daytime Land Surface Temperature) | MODIS/061/MOD11A1 | 2001-01-01–2021-12-02 | 1000 m | Daily | Monthly mean, minimum, maximum per basin |
| Soil moisture (10–40 cm underground), Soil moisture (100–200 cm underground) | NASA/FLDAS/NOAH01/ C/GL/M/V001 | 1982-01-01–2021-12-01 | 1/10° | Monthly | Monthly per basin |
| Population density | CIESIN/GPWv411/ GPW_Population_Density | 2000-01-01–2020-01-01 | 30″ | Every 5th year | Every 5th year per basin |

The PDSI is a standardized index that generally spans –10 (dry) to +10 (wet), and has been reasonably successful at quantifying long-term drought, while it has some drawbacks in quantifying sub-monthly changes, if compared with other drought indexes. As the focus of the present study is investigating long-term changes in drought-related parameters, the PDSI is assumed as a reliable proxy.

## 3. FIRST RESULTS

The analysis of the GEE datasets pointed out that, basin-wide, a clear increase in the drought state is visible, both in terms of severity and duration of dry conditions.

As an example, focusing on the Middle Vistula sub-basin (Fig. 2), one can notice that the PDSI observed for the last years is generally below zero, meaning drier periods, while at the beginning of the observation period (1960s and 1970s), the sub-basin was characterized by wetter conditions. Moreover, also looking at the inter-annual variations, it is possible to observe prolonged dry periods, generally not visible in the past.

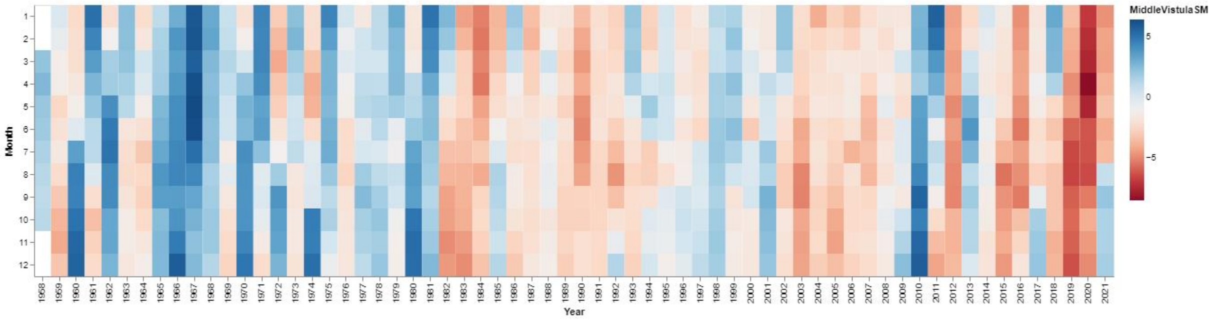


Fig. 2. Variation of the Palmer Drought Severity Index in the Middle Vistula sub-basin (derived from TerraClimate Dataset).

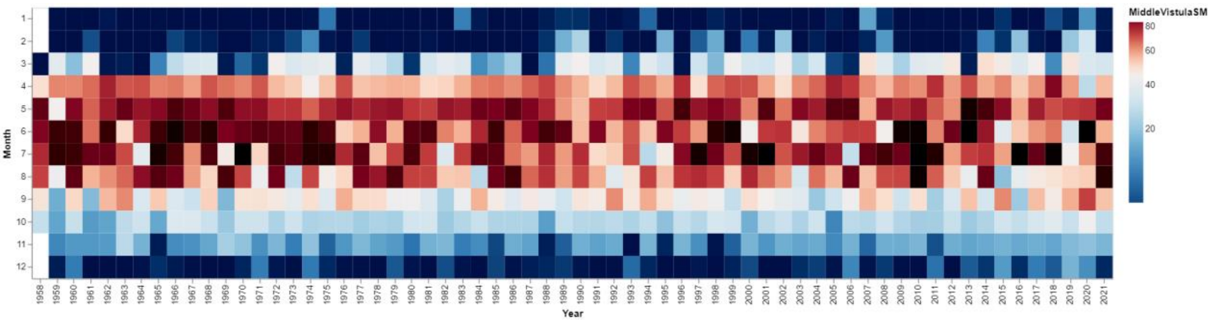


Fig. 3. Variation of actual evapotranspiration in the Middle Vistula sub-basin (derived from TerraClimate Dataset).

Looking at the actual evapotranspiration (Fig. 3) over the same sub-basin, longer periods characterized by higher evapotranspiration are observable for the last decade (see November and December). However, the dynamics observed for the PDSI are less clear in this case, suggesting that, in this case, the evapotranspiration parameter alone is not able to capture the drought phenomenon adequately.

## 4. CONCLUSIONS AND FUTURE PERSPECTIVES

The preliminary results presented here proved that satellite information can be used for retrieving information on drought at the basin scale, eventually providing researchers and water managers with an additional tool for locating areas where more detailed analyses are needed.

Besides analyzing past records, future investigations should be focused on understanding the drivers of the recent drought phenomena observed in the Vistula basin, via a combination of remotely acquired data with field and office information.

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*Code availability*: The code is available at:

https://colab.research.google.com/drive/1vCaO7z5TKRSzmQfo5WWGgQZ3D2lczDnJ

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