THE FORMATION AND DEVELOPMENT OF HYDROLOGICAL DROUGHT – KAMIENNA RIVER CASE STUDY

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INTRODUCTION

Drought is a widespread, naturally occurring phenomenon caused mainly by periodic decreases in precipitation over time. The origin and evolution of hydrological drought are quite dynamic and tends to be influenced by climate and human activities or a mixture of both variables. Precipitation and temperature are two main parameters among the various meteorological factors that mainly regulate the climate and the environment for the onset of hydrological drought (Liu et al., 2016). Tigkas et al. (2015) characterize drought as

- Meteorological drought;
- Hydrological drought;
- Agricultural drought; and
- Socio-economic drought.

Human activities affecting the hydrological processes in a river basin take many forms, and the influence of these activities on the propagation of drought in a river basin depends on the magnitude of the processes involved. The research presented focuses on the influence of reservoir and land use on drought dynamics. The main objective of the study is to analyze the influence of human activities on the development of hydrological droughts in the Kamienna River. This includes separating the impact of human activities (i.e. land-use change and reservoir operation) from climate change impacts and investigating the role of human activities in the propagation of hydrological droughts.

LOCATION OF THE STUDY AREA AND DATASETS

This study was carried out at the Kamienna River basin, the left tributary of the middle Vistula Basin, located in Poland (Figure 1).

Agriculture (50 percent) is the predominant form of land use, followed by forests and near-natural areas (42 percent).

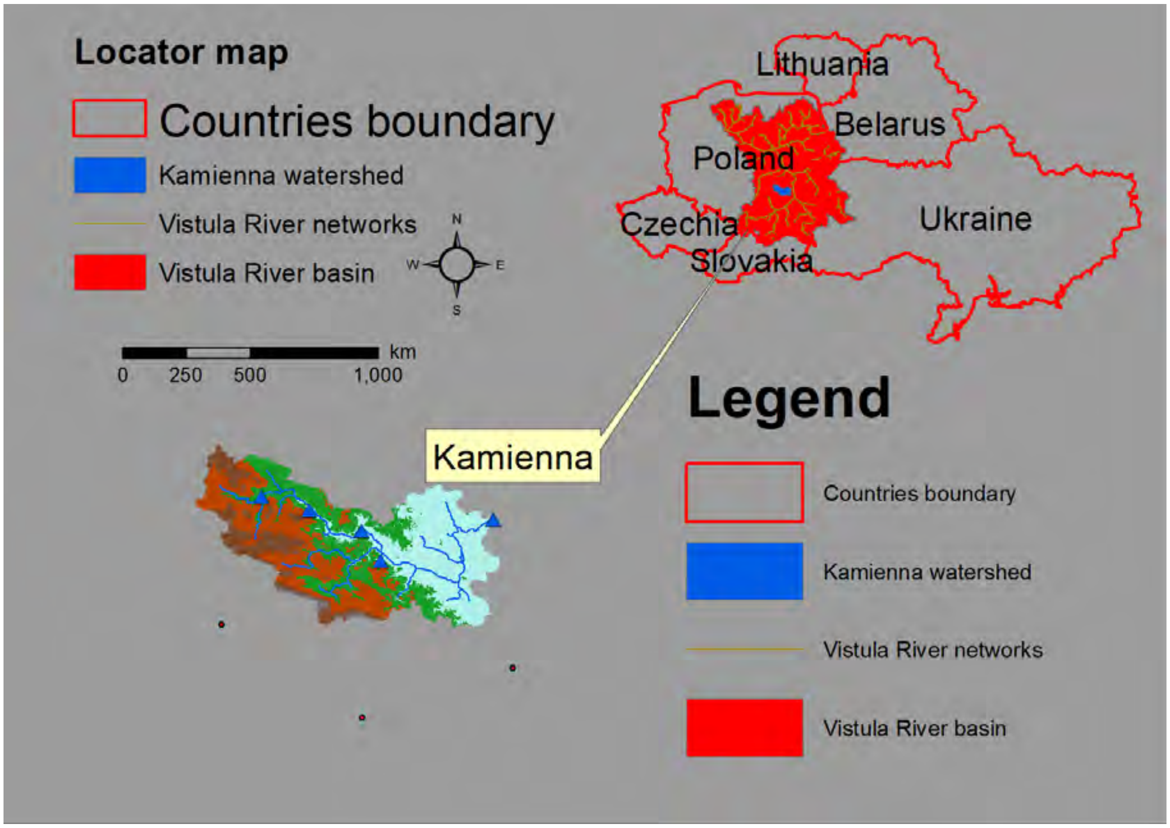


Figure 1: Location of the study area and hydrometeorological data.

METHODOLOGY

The new approach to determine the significant change point using the Pettitt test (Pettitt, 1979) based on the slope of the double mass curve as found in (Gao et al., 2017) was used in this study.

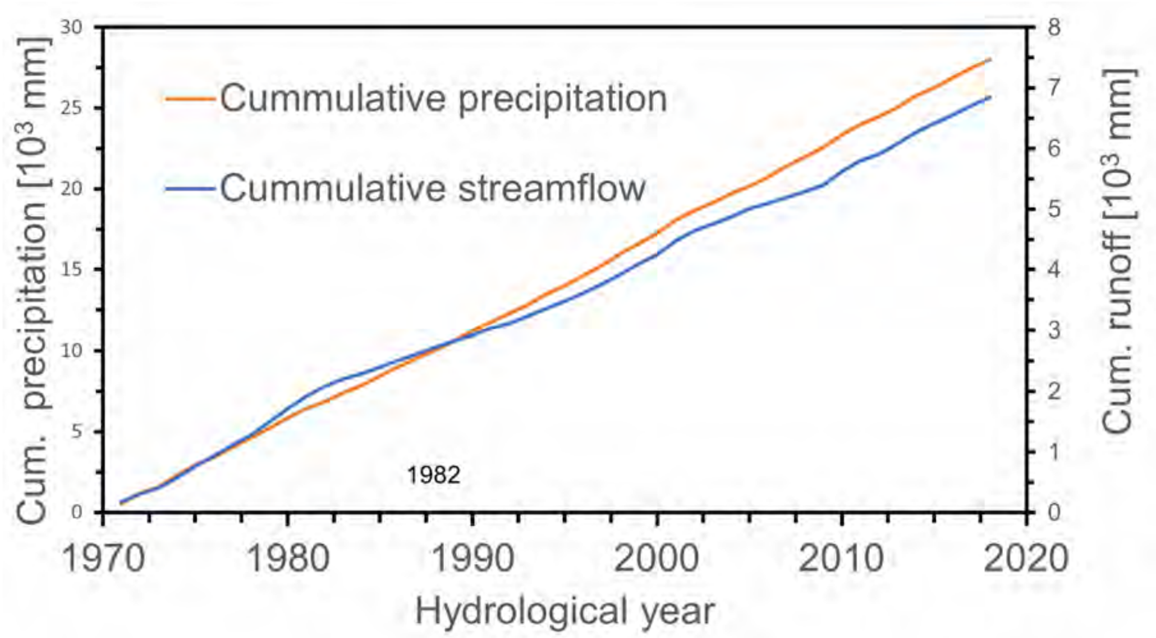


Figure 2: Double Mass Curve (DMC) of cumulative precipitation versus cumulative streamflow in the Kamienna River.

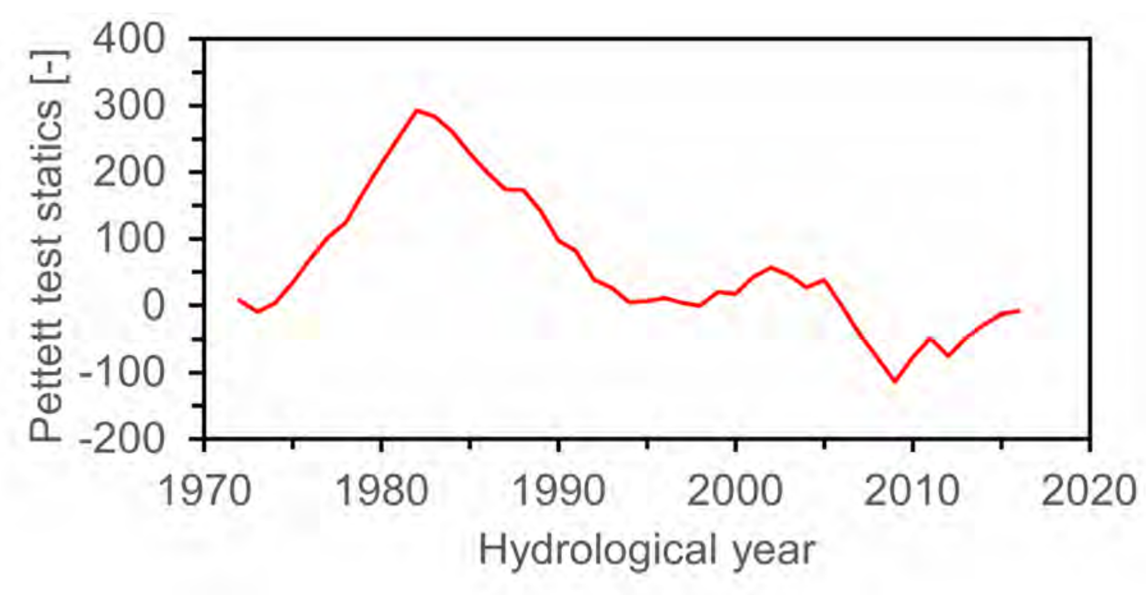


Figure 3. Detection of major change that took place with the basin using the Pettitt test method.

The period from 1971 to 1982 is taken as a reference, based on the result of the Pettitt test. The selected hydrological models (SWAT, HBV, and TOPMODEL) were calibrated and validated in the years 1971-1976 and 1977-1982 respectively.

The Nash-Sutcliffe efficiency (NSE) and Kling-Gupta efficiency (KGE) were used as objective functions to evaluate model performance. The models performed well to very well.

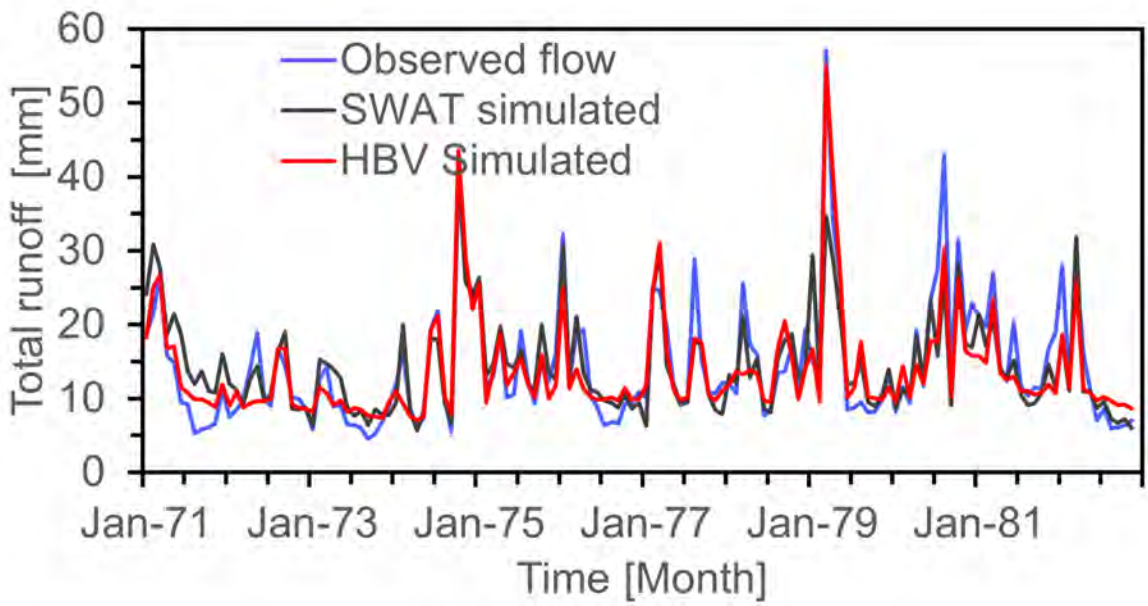


Figure 4: Observed flow, the SWAT and the HBV models simulated the flow during the calibration and validation.

RESULTS

Human activities

During the disturbed period (1983-2018) considered in the study, the average reduction in runoff due to both climate change and human interference was 23.8%, as shown in Figure 6.

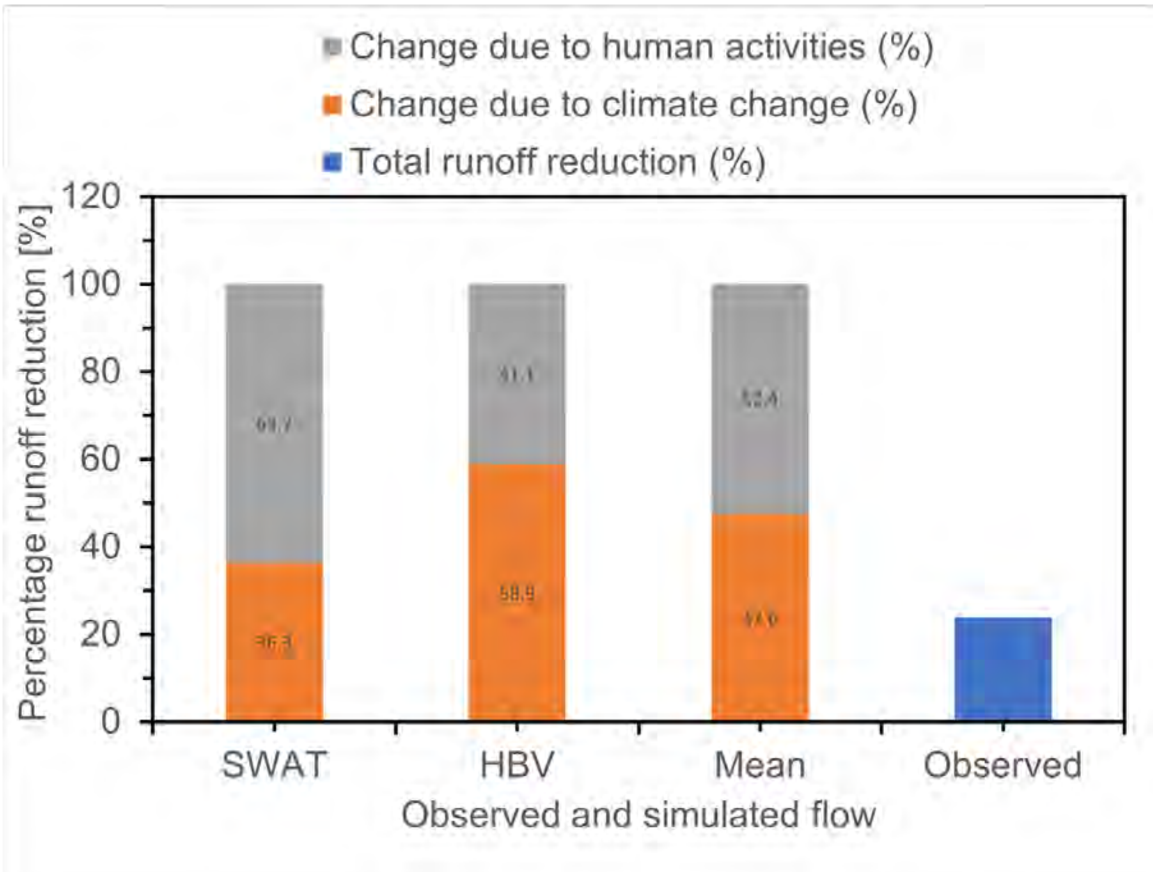


Figure 5: Historical impacts of climate and human activities on the Kamienna River basin.

Hydrological drought

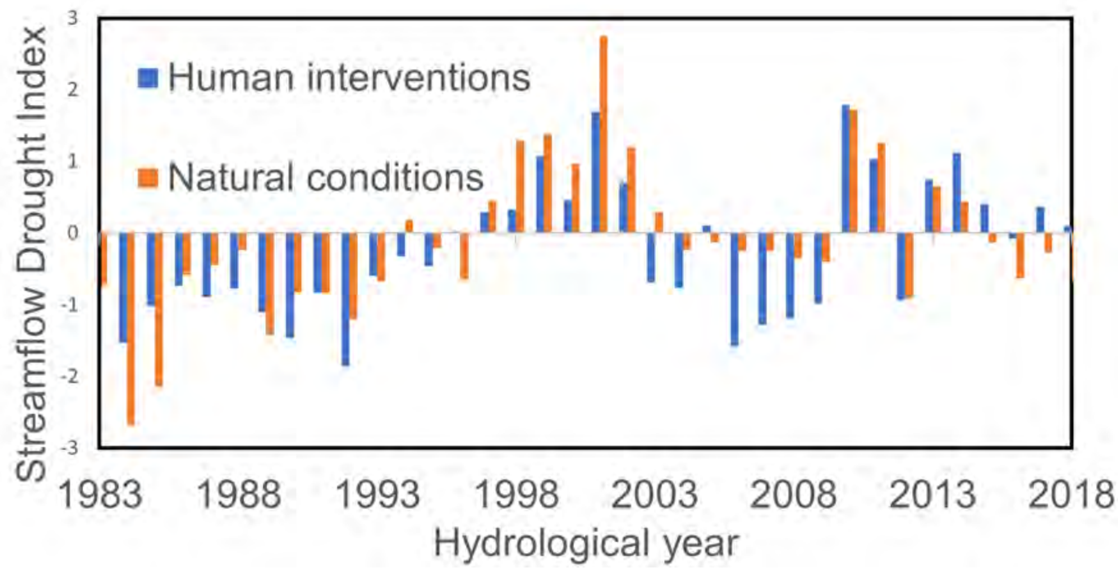
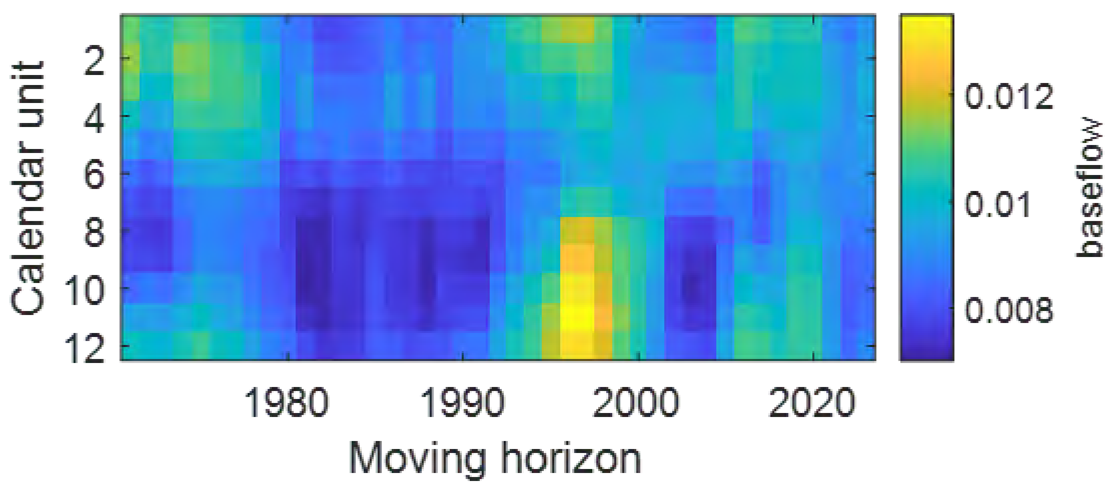


Figure 6: The developments of hydrological droughts with significant human intervention (blue) and under natural conditions (red) during 1983-2018 in the Kamienna river basin.

FLOW Regime



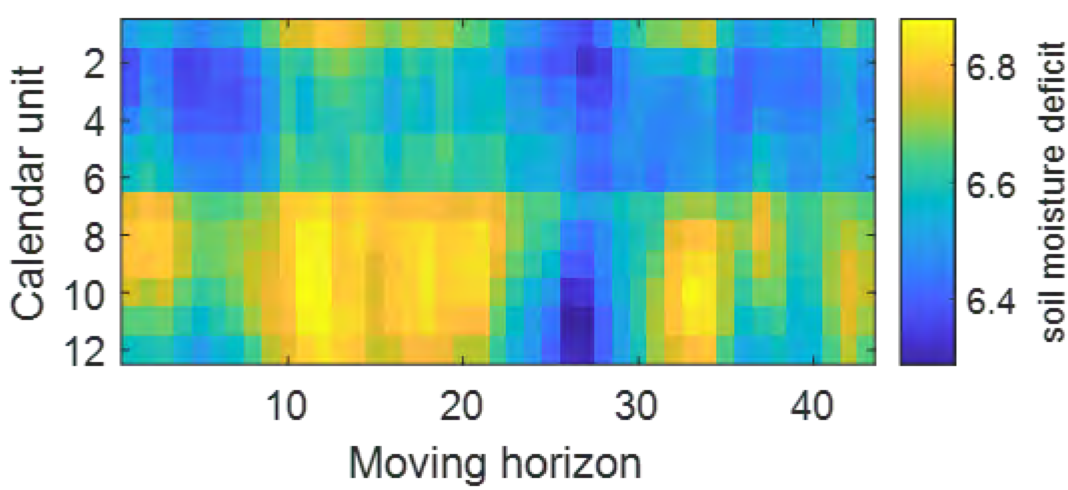


Figure 7: Upper panel: baseflow simulated by the TOPMODEL; lower panel: soil moisture deficit simulated by the TOPMODEL.

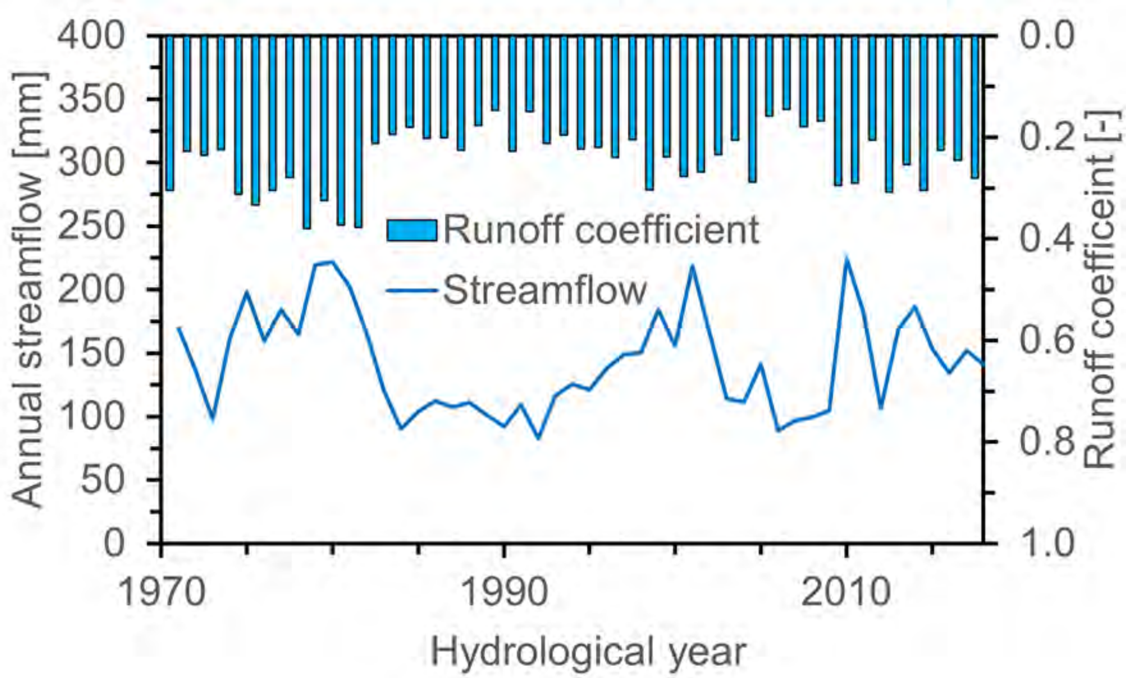


Figure 8: Temporal evolution of streamflow and runoff coefficient over the Kamienna River basin.

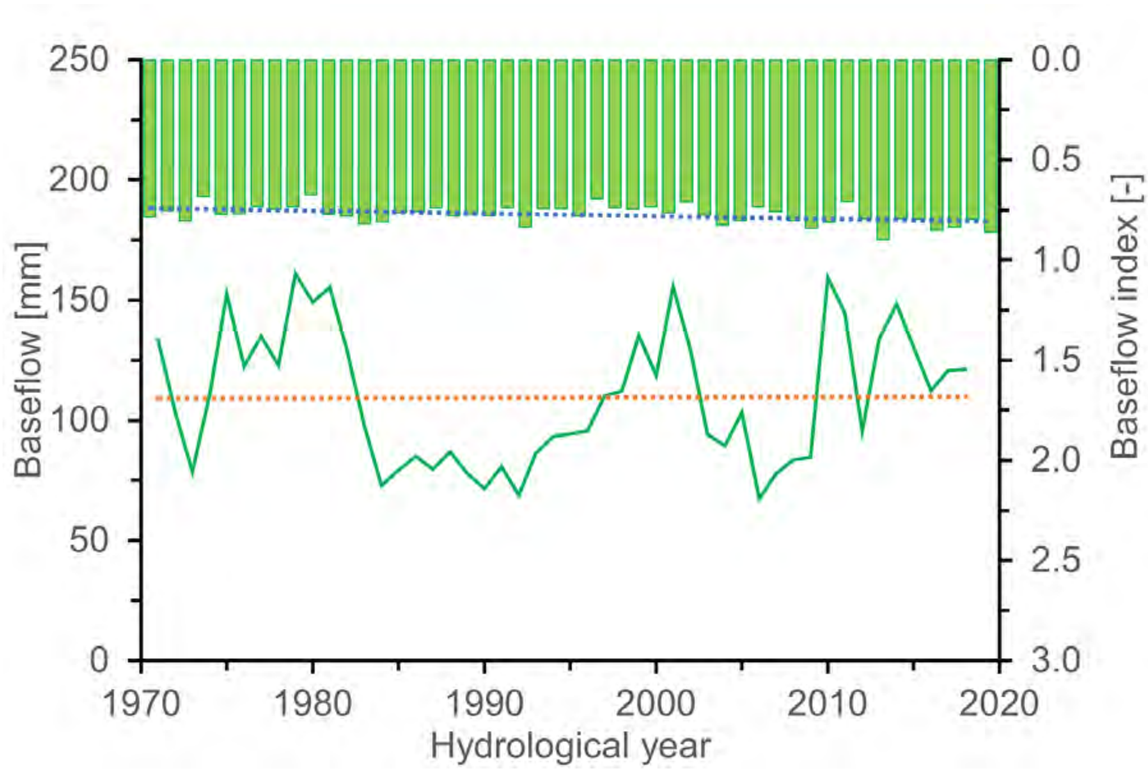


Figure 9: Historical variations of the baseflow and baseflow index over the basin.

CONCLUSIONS

By applying the Pettitt test on double Mass Curve slopes to estimate time with or without human intervention, the significant transition in the basin began in 1982. Thus, the period from 1971 to 1982 without significant human intervention is referred to as the reference period, and the period from 1983 to 2018 with significant human intervention is considered as the disturbed period.

Human activities (52.4%) contributed more than climate change (47.6%) to reducing river flows, and thus indicate that human activities dominated the decrease in runoff over the Kamienna River.

Of the four decades considered in this study, the first (the 1980s) and the third (2000s) are the two severe decades that suffer successive periods of drought, while in the 1990s there are fewer hydrological droughts.

Human intervention such as the construction of reservoirs, land-use changes, mining, etc. has led to a more severe hydrological drought than under natural conditions, with a significant difference between the two conditions, particularly in the 2000s (2001-2010).

The temporal variations in runoff coefficient decline while that of baseflow index increases during the disturbed period.

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