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FORECASTING DROUGHT BASED ON THE STANDARDIZED PRECIPITATION INDEX (SPI) IN KÜÇÜK MENDERES BASIN, TURKEY

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Abstract

Drought, a natural disaster, slowly develops over time, and its effects are usually within a long time span. Benefiting from such temporal patterns, it is possible to reduce the most adverse effects of drought effectively, provided that they are monitored in time. Drought, often gives rise to environmental, social and economic problems Küçük Menderes Basin in Western Turkey, which accommodates significant agricultural land, is one of the regions suffering from occasional drought events. A systematic analysis of the drought pattern in such areas would help in identifying drought scenarios and will be considered to aid in drought management. In the presented study, observed monthly precipitation data covering the period 1972-2016 at a selected meteorological station in the basin was analysed and modelled based on the stochastic techniques. Genereted synthetic precipitation serie according to the model was then used to compute 6-month SPI values in order to quantify drought conditions. Constructed model is to examine probable drought events and to use its inputs as guidiance for drought management plans in Küçük Menderes Basin.

Keywords: Drought, forecast, SPI, stochastic modeling.

1 INTRODUCTION

Long-term shortages in the atmospheric, surface or ground water supplies, elevated pollution in water sources are the most encountered consequences from persistent drought events in most of the world and need ex-ante/-post assessments for orienting mitigative/adaptive efforts in coping with the associated negative outcomes (Onuşluel Gül et al., 2017). However, there is not any general definition of drought (Kallis, 2008; Mishra and Singh, 2010; Hao and Singh, 2015), which has been a setback in drought monitoring and analysis. The American Meteorological Society summarized several drought definitions into four categories: meteorological, agricultural, hydrological and socio-economic droughts (Society, 1997). These categories are related with various components of hydrologic cycle (Peters, 2003). Generally, precipitation is the main factor in the hydrologic cycle. The absence or reduction of precipitation produces meteorological drought. Subsequently, short-term dryness in the surface and sub-surface layers may result in agricultural drought. Finally, when precipitation deficits linger for a prolonged period, low recharge from soil to water features (lakes, groundwater, and rivers) causes a delayed hydrological drought (Zargar, 2011). The process from meteorological drought to hydrological drought is characterized in terms of pooling, time lag, attenuation, and lengthening (Eltahir and Yeh, 1999). That is to say, meteorological drought, which is defined as a lack of precipitation over region for a period of time, plays an important role in subsequent drought formation and propagation across different drought types (Zhou and Liu, 2016). In the presented study, observed precipitation data at the selected meteorological station in Küçük Menderes River Basin in Turkey was first statistically modelled and then by using the appropriate model projection was carried out by the year of 2050. After these steps, drought severity was analysed through the use of Standardized Precipitation Index (SPI) in order to evaluate the drought conditions for both the observed and projected period in the basin.

2 METHODS

2.1 Study area

Küçük Menderes River located in the west of Turkey flows into the Aegean Sea. Drainage area covers the size of about 3225 km² (Figure 1) and in the basin, the Mediterranean climate reigns. The basin has great significance in terms of agricultural activities in Küçük Menderes Plain covering large agricultural areas. The basin has 42% cultivated area and Ödemiş District has the biggest share in agricultural land use. In this study, Ödemiş meteorological gauging station was chosen to work with out of the 11 station within/nearby the basin.

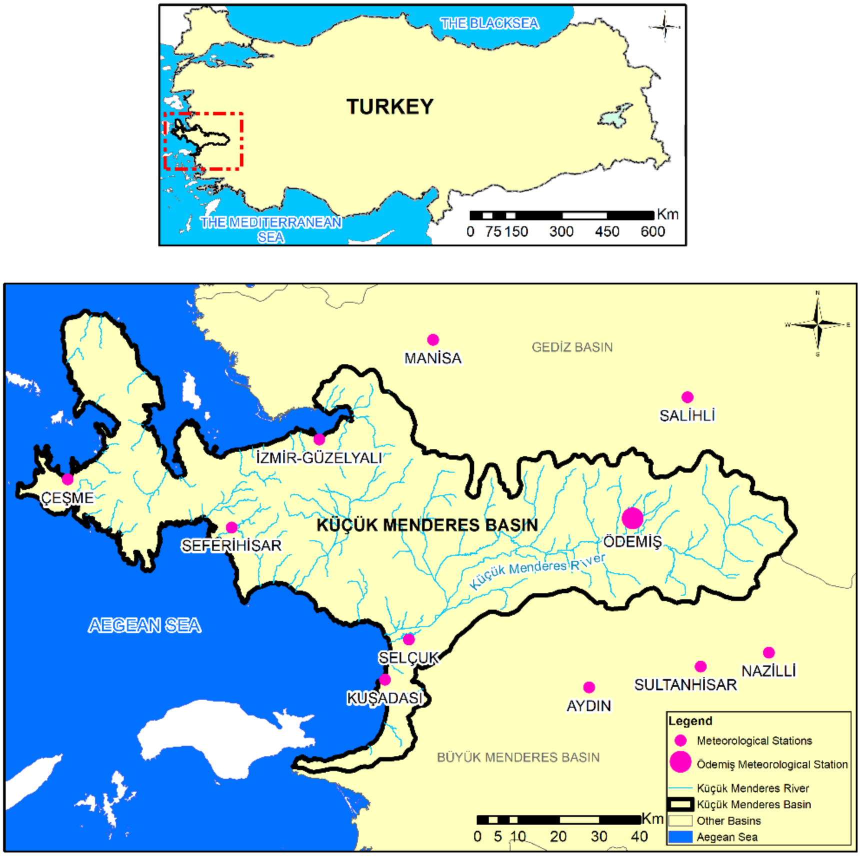

Figure 1. Küçük Menderes River Basin

2.2 Modeling the observed precipitation

Before the precipitation data is modelled, exploratory data analyses were conducted for estimating gaps in the data series, assessing homogeneity and performing trend analysis. Missing data analysis was carried out by using linear regression analyses with respective reference series in order to complete the precipitation time series. Homogeneity analysis was performed to secure that the data set used in the study have adequate quality. For this purpose, standard normal homogeneity test, Buishand range test and Pettitt test were performed on monthly precipitation time series. The results indicated that the data series is homogeneous. Trend analysis was then performed on precipitation data by using Mann-Kendal non parametric test (Buishand T.A., 1982; Pettitt, A. N., 1979; Mann, H.B., 1945).

Results of autocorrelation and partial autocorrelation analyses of the 1, 3 and 6- month precipitation data series showed that there were no significant inherent dependency. Because of the months with zero precipitation, eligible data transformation techniques and distribution families were narrowed down to a certain lot. The data has been fully-standardized by the sample mean and standard deviation. For the 6-month precipitation data, Normal distribution fitted the best to the among several distributions. Synthetic data then were generated by the year 2050 in order to calculate SPI values.

2.3 Computation of SPI

In the presented study, SPI was employed to analyse temporal variations of drought cases by using the data observed precipitation at Ödemiş station. SPI is explained as for a specified period over time with the division of precipitation difference from the mean by the standard deviation, which is statistically computed being based on probability distribution of precipitation variable adapted from representative historical records (McKee et al., 1993). Since SPI computation first requires fitting a probability density function to frequency distribution of total precipitation values in a selected period, gamma distribution function was designated in the study to represent the best-fit probability distribution. The rationale behind this selection was based on the knowledge that the gamma distribution, which is also commonly used by Turkish State Meteorological

Service, is mostly considered to be suitable with a positive-skewed character for use in arid regions where the average rainfall is low and the variability is high. Table 1 shows the SPI value range descriptions.

Table 1. SPI value ranges and their classifications

SPI Values	Classification
2.0	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-.99 to 0.99	Near normal
-1.00 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

The SPI values were computed by using the algorithms embedded in the Drought package developed for the R statistical software (Hao, 2016).As indicated by WMO and GWP (2016); from 1-month to 6-month SPI values can be used for evaluation of agricultural drought. Therefore 6-month SPI values were considered in this study.

3 RESULTS AND DISCUSSION

Figure 2 shows 6-month precipitation data observed at Ödemiş station between 1972-2016. Pre-processing stage shown that there were no trends in data. Since there were no inherent dependency in the data, it has been fully standardized by the observed mean and standard deviation and tested for several distributions by using MINITAB software.

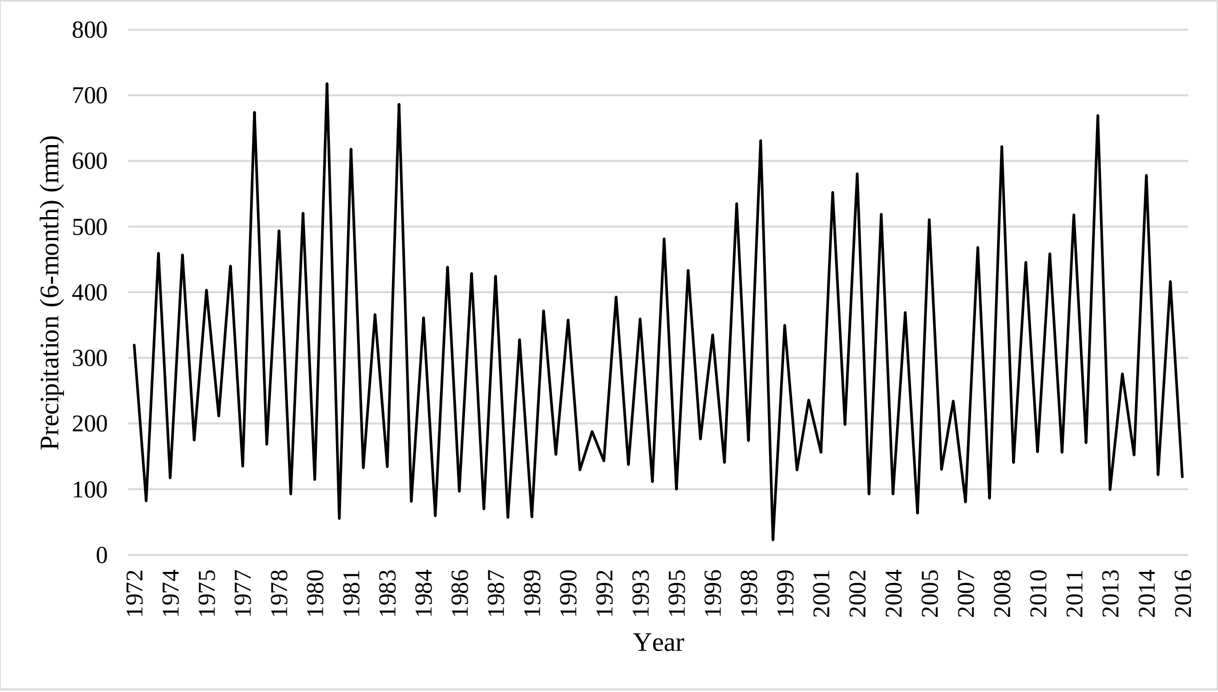

Figure 2. Observed total precipitation (6-month) data at Ödemiş Meteorological Station

"Individual Distribution Identification" tool was used in order to determine best fitting distribution. Out of the 9 distributions tested by the tool (normal, 3-parameter lognormal, 2-parameter exponential, 3-parameter Weibull, smallest extreme value, largest extreme value, 3-parameter gamma, logistic and 3-parameter loglogistic) results of the MINITAB software depicted that the normal distribution was the best alternative according to Anderson-Darling and Kolmogorov-Smirnov tests for the observed precipitation data. Figure 3 shows the probability plot of the data series.

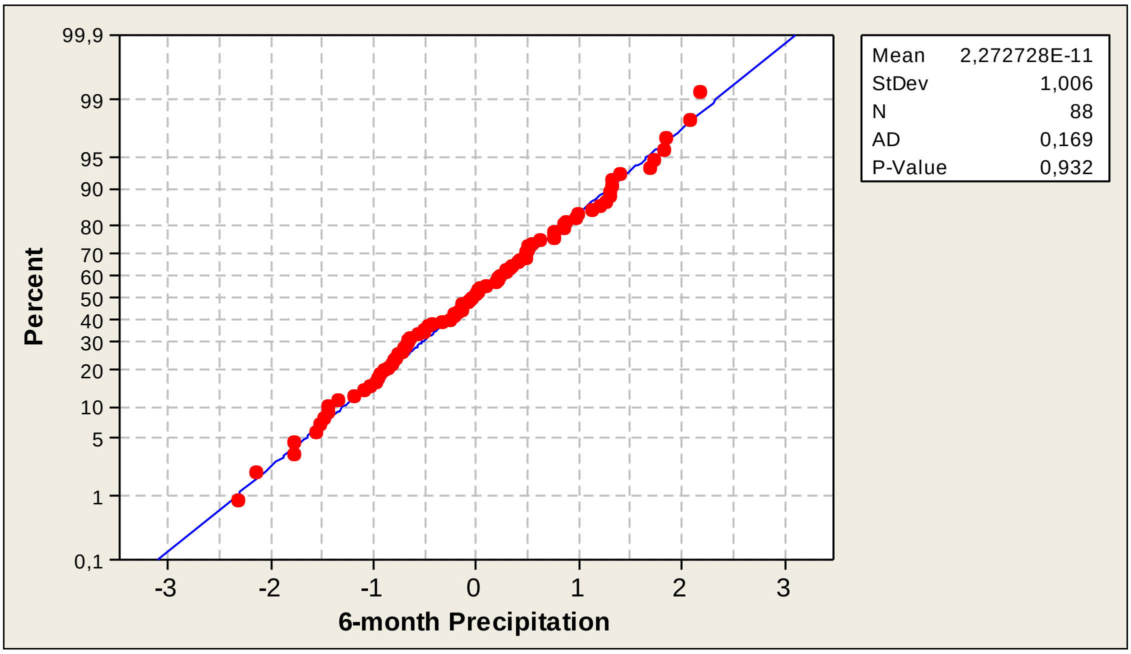

Figure 3. Probability plot of 6-month total precipitation data

In order to validate the fitted model, observed data period was divided into two parts. By using the model parameters obtained for the first part (1972-1992), second part of the observation period was generated (1992-2016). Figure 4 shows the relationship between the observed and generated data while the Table 2 displays the goodness of fit indicators between the two data strips.

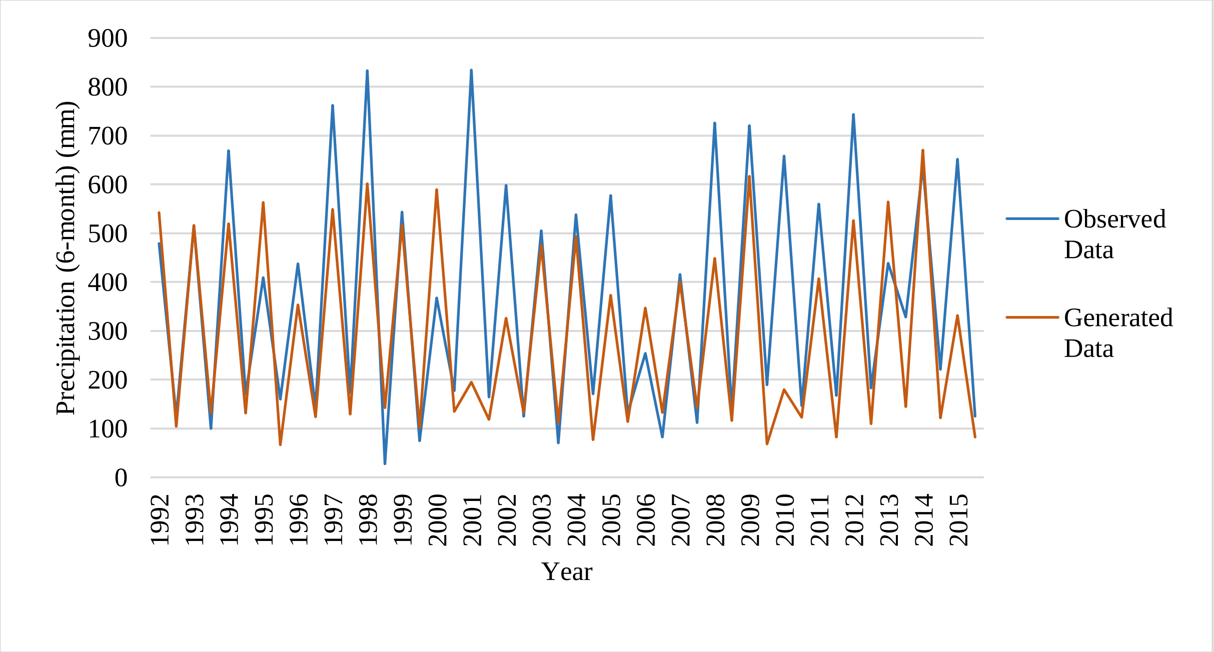

Figure 4. Observed and generated precipitation (6-month) data of the second observation period

Table 2. Goodness of fit indicators between model and observations

Parameter	**Legend**	**Value**
NSE	Nash-Sutcliffe efficiency	0.52
r	Pearson product-moment correlation coefficient	0.78

After validation of the model, precipitation was projected by the year of 2050 to calculate SPI values for forecasting the future droughts. Figure 5 shows the projected precipitation (6-month) data and Figure 6 shows the calculated 6-month SPI values. Projected SPI values indicate that there will be more frequent and severe droughts in the future.

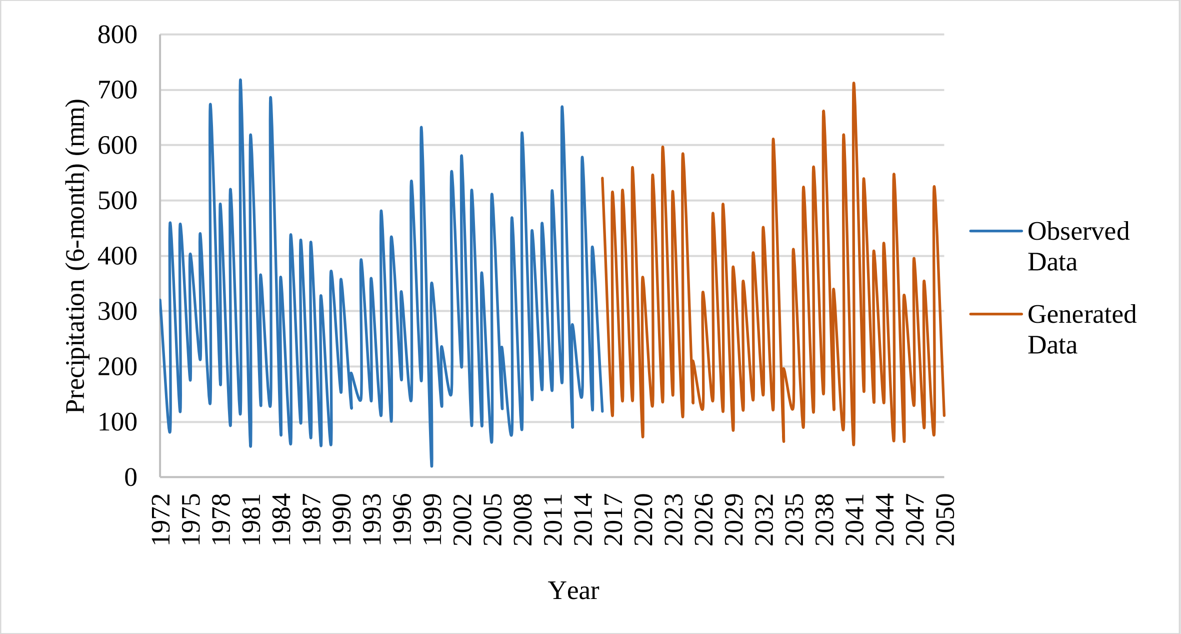

Figure 5. Observed and generated preicipitation (6-month) data of Ödemiş Meteorological Station

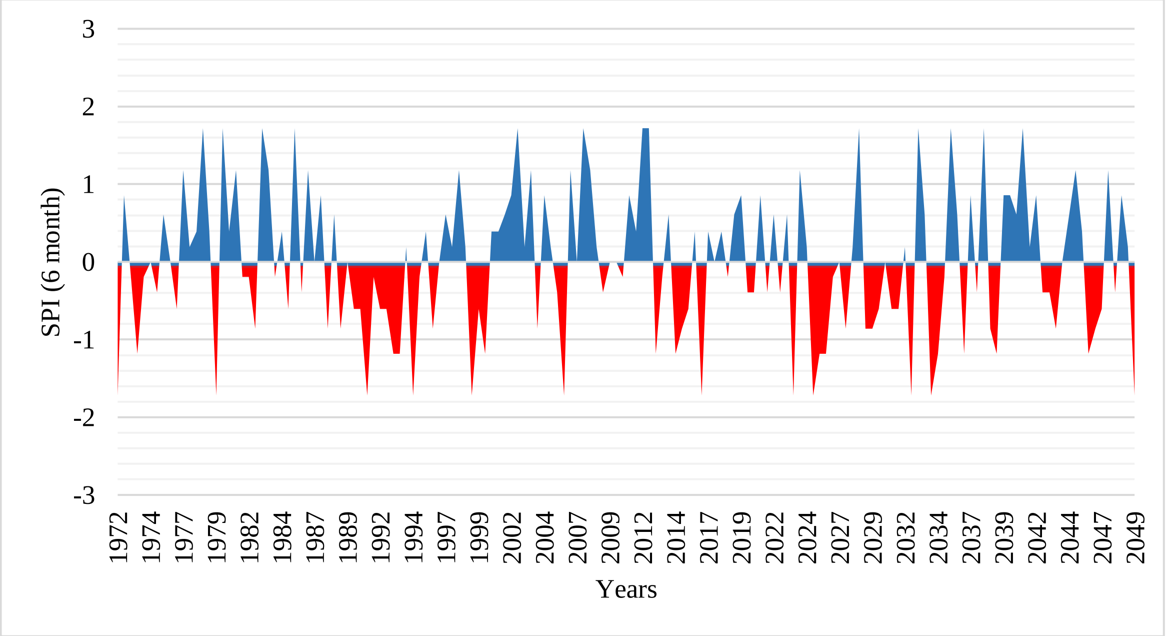

Figure 6. 6-month SPI values of Ödemiş Meteorological Station

Finally, Mann-Kendall test was implemented for detecting any possible trend over the computed SPI values. The results showed that there was no significant trend for 6-month SPI values

4 CONCLUSION

In this paper, drought analysis based on Ödemiş meteorological station in Küçük Menderes River Basin, Turkey was carried out by modeling and projecting the observed data and determining the corresponding SPI values in order to observe possible future meteorological drought phenomena in the basin.. Such studies can be considered as tools for drought management strategies and plans, which would benefit fight against droughts in vulnerable basins. Results of this paper suggest that wet periods will be shorter and dry periods will be more frequent and more severe in the future. This outcome indicates that many socio-economic activities will be more vulnerable and exposed to the conditions of the future water resources. Since Küçük Menderes Basin is mostly associated with a major agricultural sector, future droughts drawbacks on agriculture on the basin will not only affect the basin by sector-wise but rather as a whole. Repeating the same modeling, projection and SPI calculation processes to as many as possible meteorological stations in the basin would produce a spatial and temporal understanding of the future drought cases. Further studies which would include climate and land use change and water resources policies will improve drought management plans.

REFERENCES

Buishand, T.A. (1982). Some methods for testing the homogeneity of rainfall records. *J Hydrol.,* 58(1–2):11–27.

Eltahir, E.A.B., Yeh, P.J.F. (1999). On the asymmetric response of aquifer water level to floods and droughts in illinois. *Water Resour. Res.*, 35, 1199–1217.

Hao, Z.C., Singh, V.P. (2015). Drought characterization from a multivariate perspective: A review. *J. Hydrol.,* 527, 668–678.

Kallis, G. (2008). Droughts. *Annu. Rev. Environ. Resour*., 33, 85–118.

Mann, H.B. (1945). Non-parametric tests against trend, *Econometrica,* 13:163-171.

Mishra, A.K., Singh, V.P. (2010). A review of drought concepts. *J. Hydrol*., 391, 202–216.

Onuşluel Gül, G., Gül, A., Kuzucu, A. (2017). Analysis of drought in küçük menderes river basin using SPI and SPEI drought indices, *STAHY 2017 Workshop*.

Peters, E. (2003). Propagation of Drought through Groundwater Systems: Illustrated in the Pang (UK) and Upper-guadiana (es) Catchments. *Ph.D. Thesis,Wageningen University,Wageningen, The Netherlands*.

Zargar, A., Sadiq, R., Naser, B., Khan, F.I. (2011). A review of drought indices. *Environ. Rev.*, 19, 333–349.

Pettitt, A.N. (1979). A non-parametric approach to the change point problem. *Journal of the Royal Statistical Society Series C,* Applied Statistics 28, 126-135.

Society, A.M. (1997). Policy statement: Meteorological drought. *Bull. Am. Meteorol. Soc.*, 78, 847–849.

WMO (World Meteorological Organization) and GWP (Global Water Partnership): Handbook of Drought Indicators and Indices (M. Svoboda and B.A. Fuchs). Integrated Drought Management Programme (IDMP), Integrated Drought Management Tools and Guidelines Series 2. Geneva, 2016.

Zhou, H., Liu, Y. (2016). SPI Based Meteorological Drought Assessment over a Humid Basin: Effects of Processing Schemes. *Water,* 8(9), 373.