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Identification of Hydrological Drought Trends in the Lake Urmia Basin

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1- Introduction

Climate change has been a very important issue in recent decades. Recently, frequent climatic events such as storms, floods, and droughts have been reported around the world (Habeeb et al., 2015). These extreme events will have devastating effects on ecosystems, society, and the economy (Hallegatte et al., 2013). Among these extreme events, drought plays a more prominent role due to its direct impact on socio-economic development and environmental degradation. Therefore, understanding drought phenomena is important for proper planning and management of water resources (Yilmaz, 2019). So far, various indicators have been proposed to monitor the drought. Undoubtedly the most well-known drought monitoring index is SPI proposed by McKee et al. The World Meteorological Organization has recommended this index as the main indicator of meteorological drought. It is also important to analyze the SPI trend, which provides scientific information for better modeling as well as the prediction of the phenomenon (Golian et al., 2015).

A review of research conducted worldwide and in Iran shows that drought trend analysis has been mainly done using parametric tests such as linear regression and non-parametric tests like Mann-Kendall, Spearman, Sen's estimator, and modified Mann-Kendall. These methods require a set of assumption validity such as serial correlation structure, probability distribution functions, and seasonal trends. For this reason, Şen (2012) proposed the Innovative Trend Analysis (ITA) method, which does not require any assumptions and analyzes the trend of time series based on a comparison of two ascendingly ordered halves. This method has found wide applications in hydro-climatic research and has been considered and used by many researchers.

This study aimed to identify drought-prone areas in the Lake Urmia basin using SPI time series and the innovative trend analysis (ITA). For this purpose, SPI values in 12 and 24-month time scales were calculated based on 32-year-long precipitation data (1986-2017) in 8 synoptic stations in the Lake Urmia basin. Then the trend of the SPI series was investigated using the ITA method. Finally, the results of this method were compared with the results of the Mann-Kendall test.

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2- Methodology

2-1- Standardized precipitation index (SPI)

Among the quantitative indicators in drought analysis, SPI is acceptable as a suitable index for drought analysis due to the simplicity of calculations, the use of available rainfall data, and the ability to calculate for different time scales as well as different spatial scales. SPI can show the impact of drought on water resources. In a general classification, it is possible to use the 1 to 3-month SPI for meteorological drought, 3 to 6-month SPI for agricultural drought, and 12 to 24-month SPI for hydrological drought analyses and applications (Bonaccorso et al., 2003).

2-2- Innovative Trend Analysis (ITA)

This method has been proposed by Şen (2012). In this index, time series are divided into two equal parts, which are separately sorted in ascending order. Then, the first and the second half of the time series are located on the x-axis and y-axis, respectively, of a Cartesian coordinate system. If the data are collected on the 1:1 straight line (45°), there is no trend in the time series (Fig. 1). If data are located on the upper triangular area of the ideal line, an increasing trend in the time series exists. If the data pile up in the lower (upper) triangular area of the 1:1 line, there is a decreasing (increasing) trend in the time series (Şen, 2014).

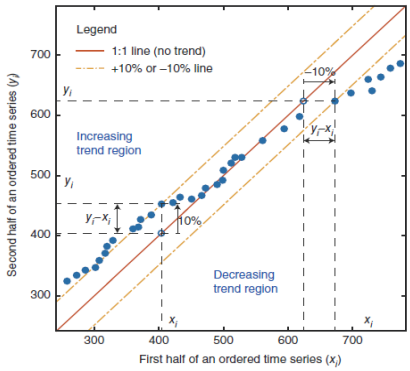

Fig (1): ITA method

The statistical significance test of the ITA method has been also proposed by Şen (2017). This test is performed based on the construction of confidence intervals and considering the difference between the two population means. If the slope value (s) is

between the upper and lower confidence limits, the null hypothesis (H0) is confirmed; otherwise, the alternative hypothesis (H1) is accepted. The type of trend depends on the slope sign. The slope value can be positive or negative; this means that there is an increasing (+) or decreasing (-) trend in the time series (Şen, 2017).

2-3- Mann-Kendall test (MK)

The non-parametric Mann-Kendall test is one of the most widely used methods for trend detection in time series. One of the main advantages of nonparametric methods is that the presence of outgoing data affects the result of the data process less than parametric methods. Besides, it is more suitable for data series having a short length and not normal statistical distribution or having missed data (Partal and Kahya, 2006). The positive and negative Z values indicate the increasing and decreasing trend in the series, respectively.

3- Results and Discussion

To detect the drought trend in the stations of the Lake Urmia basin, the ITA method was used for the 12 and 24-month SPI series. All SPI series were divided into two 16-year sub-series: from 1986 to 2001, and from 2002 to 2017. To identify the possible trend of the drought as well as normal and wet conditions easily and better, two vertical lines have been added to the diagrams. The red line indicated the drought limit and the green line indicated the limitations of the wet conditions and the area between the two lines representing the normal conditions. According to the figures, the 1:1 line shows the neutral line (no trend) and in the case of no trend, the center point falls on the 1:1 line.

The results of the trend analysis of 12-month SPI values showed that the drought and normal periods in Urmia, Saghez, and Mahabad had an increasing trend, but the wet conditions followed a decreasing trend. In Tabriz, an increasing trend was seen in normal and moderately drought periods, and a mild decreasing trend was seen in wet periods. In Takab, wet periods showed a sharp decreasing trend, and a slightly increasing trend could be seen in Sarab. In Sahand and Maragheh, there has been a declining trend in all SPI values, leading to more severe drought and weaker wet periods. The significance analysis of ITA and the Mann-Kendall test showed that in the 12-month SPI time series and based on the ITA method, all stations showed a significant trend, which was increasing in Tabriz and Sarab, and in other stations, it was decreasing. While the Man-Kendall method did not have a significant trend in Urmia, Tabriz, and Sarab, it showed a significant decreasing trend in other stations .

In the trend analysis of 24-month SPI values by the ITA method, almost the same results were obtained. However, it should be noted that there was an increase in the

slope of the trend for all stations. Another important point is that there were no significant increases in wet conditions. Similar to the results of 12-month SPI and based on two methods, the significance analysis of the ITA and Mann-Kendall test showed that Takab, Saqez, Sahand, Maragheh, and Mahabad had a significant decreasing trend and the difference was only observed in the higher ITA slope as well as the higher Z values in these stations. While in Urmia, Tabriz, and Sarab, there was no correspondence between the two methods.

4- Conclusions

In this study, the ITA and Mann-Kendall trend tests were used for the 12 and 24-month SPI time series, determined for the 1970-2017 period, in order to demonstrate the hydrological drought trends in the Urmia Lake`s basin. The results of ITA and Mann-Kendall tests showed that Maragheh, Sahand, Saqez, Takab, and Mahabad had a significant decreasing trend in the 12 and 24-month SPI series. In Urmia, Tabriz, and Sarab, the Mann-Kendall test did not show any significant trends; while the ITA method showed significant decreasing and increasing trends in these stations. The results of this study can be used to manage water resources and understand the characteristics of climate change in the studied area.

Keywords: Hydrological Drought, Trend Analysis, Innovative Trend Analysis (ITA), Man-Kendall, Lake Urmia Basin.

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