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EXTENDED ABSTRACT

Adaptive Evaluation of SPI, RDI, and SPEI indices in Analyzing the Trend of Intensity, Duration, and Frequency of Drought in Arid and Semi-Arid Regions of Iran

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Introduction

Drought is one of the most important weather-induced phenomena which may have severe impacts on different areas, such as agriculture, economy, energy production, and society. From a meteorological point of view, drought can be induced by lack of precipitation, hot temperatures, and enhanced evapotranspiration. The efficiency of the drought monitoring system depends on the index which is selected based on the drought and climate conditions of the region. Precipitation-based drought indices, including the Standardized Precipitation Index (SPI) (McKee et al., 1993), China Z Index (CZI), (Percent of Normal Index) PNI, and others cannot identify the role of the temperature increase in the drought condition and in addressing the consequences of climate change. Recently, two new standardized drought indices have been proposed for drought analysis on multiple time scales: the Reconnaissance Drought Index (RDI) (Tsakiris and Vangelis, 2005) and the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente Serrano et al., 2011). The objective of this study is to evaluate the characteristics of drought, according to SPEI, SPI, and RDI. In addition, this study evaluates trends in meteorological drought frequency, duration, and severity during the study period through a multi-indicator approach and at low rainfall regions of Iran, providing a complete picture of the areas that suffered frequent and severe droughts in the past periods. Moreover, this might push towards the development of better frameworks for drought assessment, adaptation, and mitigation, in a possibly drier future.

Materials and Methods

We computed all three indicators at monthly scales of 3, 6, 9, 12, 24, and 48, from 1996 to 2014. We fitted the cumulated precipitation by gamma distribution for the SPI, the cumulated difference P-PET by log-logistic distribution, and the cumulated ratio P/PET by log-normal distribution for the RDI, following the authors' approaches who originally presented such indicators. All the available data in the period 1996–2014 have been used to fit the distributions. Three indices of SPI (precipitation), RDI (precipitation and temperature), and SPEI (precipitation and temperature) have been used in this research to analyze the trend of intensity, duration, and frequency of the drought in

the arid and semi-arid regions of Iran. Twenty-five synoptic stations in the mentioned climate were selected and their drought characteristics (intensity, duration, and frequency) were estimated in each of the 8 sub-climates. Also, we analyzed the trend using the Mann-Kendall trend test. The MK test is a statistical non-parametric test that is used for trend analysis. The MK statistics take positive or negative values which lead to increasing or decreasing trend, respectively. The null hypothesis assumes that the ranked data are independently and identically distributed while the alternative hypothesis assumes.

Results and discussion

The Agreement Index (AI) between drought indices showed the highest and lowest agreement between SPI-RDI and SPI-SPEI. So, the Agreement Index was observed in extra-arid, extra-warm and extra-arid, extra-cold climates at 48-month scale with values of 1 and 0.14, respectively. In general, in all sub-mates, the agreement index increases with the rise in time scale from three to 48 months. Based on the results, drought trends in cold and dry climates are decreasing in both short (3-month) and long (48-month) time scales and are increasing in the warm and dry climates. The highest and lowest agreement indices (0.99 and 0.14) were observed between SPI-RDI and SPI-SPEI, respectively, in extremely warm, extremely dry and extremely cold, extremely dry climates. The relation of SPI-RDI and SPEI-RDI in the magnitude and duration of the drought in cold climates is mostly weak and negative, and in the warm climates (0.32 and -0.06), the highest correlation was observed in extremely warm, extremely dry climate (0.98). Exploring the correlation of indices in the estimation of the drought frequency revealed that the lowest correlation was observed between coupled indices of SPI-SPEI and SPEI-RDI in cold, extremely dry and cold, moderately dry climates (0.39 and 0.34, respectively) and the highest correlation (0.99) was observed between coupled indices of SPI-RDI. The trend of intensity, duration, and frequency of the drought using the Mann-Kendal test showed that the increasing trend of the drought is increasing in dry and warm climates and decreasing (more than -2.61) in cold and dry climates, and that the SPEI index estimated the trend with a more intensity (more than +2.61).

Conclusion

In this research possible similarities/differences among SPI, RDI, and SPEI meteorological drought indices were investigated by a rather comprehensive comparability analysis, using data from different climatic zones. The comparison of the results in the trend analysis of the drought showed the same trend, but the SPEI index compared to the other indicators, showed a quicker response to changes in arid-warm climates. While SPI-RDI variations showed similar values in cold climates. The SPEI is based on precipitation and temperature data, and it has the advantage of combining multi-scalar character with the capacity to include the effects of temperature variability in the drought assessment. Thus, we recommend SPEI, as a suitable index for studying and identifying the effect of climate change on drought conditions.

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