EXTENDED ABSTRACT

Comparison of Inherent Performance of Seven Drought Indices in Drought Mitigation Using a Monte Carlo Simulation Approach

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1. Introduction

Drought indices as important tools for drought monitoring are used to evaluate the performance of water resource systems in most parts of the world [1]. A lot of drought indices are developed at particular geographic and climate condition and given objectives. Consequently, the application of such indices is generally involved with considerable uncertainty in accurate and complete drought characteristic analysis in different places due to inherent complexity of the drought phenomenon and local climate condition.

A few studies have been published to evaluate and compare the performance and capability of drought indices. Such studies are often based on historical data record with short length, e.g. 20-30 years, and have been also concentrated on particular aspect. On the other hand, a historical data record is an example of thousands probable samples which may occur in future and can not introduce complete universal statistic characteristics. As a result, the application of a stochastic procedure to generate large samples of synthetic time series will be indeed essential and useful for drought events analysis.

2. Methodology

2.1. Study area and data analysis

The rainfall data records used in this analysis consists of annual and monthly time series from eleven synoptic stations located in northwest of Iran. The data records are 50 years long (1961-2010) and were checked using a number of statistical tests as described by Adeloye and Montaseri [2] to examine their suitability for the stochastic drought events analysis. The tests were applied to investigate the statistical qualities of randomness and stationarity in data records. The non-parametric Run Test and Rank Order Correlation Coefficient Test were applied to check for randomness and trend of the historical rainfall data records [3]. The results of tests indicate that the tests statistic of randomness and stationarity of historical data lie between the critical points for all the stations.

2.2. Monte Carlo simulation

In this study, Monte Carlo simulation method was used for monitoring drought. Hence rather than generating monthly rainfalls directly, annual rainfall were first generated with AR (1) model and later disaggregated to monthly rainfalls using the Valencia–Schaake approach [4]. For each of the eleven synoptic stations, 1000 possible sequences of annual and monthly rainfalls were generated using AR (1) and desegregation approach, respectively, where each replicate had the same length as the length of historic data record. Each of the 1000 sequences (annual and monthly) was then routed for drought monitoring through a Stochastic Drought Simulation Model (SDSM) and seven drought indices such as RAI, DI, Nitzche, PNPL, SPL, Z-Score and SPIo.

Also, a common quantitative classification has been used with seven classes such as extremely wet, severely wet, moderately wet, normal, moderately dry, severely dry and extremely dry, to simply evaluate and compare the performance of mentioned drought indices. The results of study have been illustrated on five parts as follow:

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a- Probability density function of drought indices time series,
b- Correlation between of drought indices time series,
c- Probability distribution of three main drought characteristics i.e. duration, intensity and interarrival time,
d- Transition probabilities matrix of drought events,
e- Effects of different months on annually drought.

3. Results and discussion

3.1. The probability distribution of wet and dry periods

The results indicated that drought indices based on the characteristics of the drought phenomenon can be divided into three groups: i- SPI, Nitzche and SPIo, ii- Z-Score, DI and RAI, iii- PNPI. Despite significant differences between indices in each group, indices of any group have a similar behavior in drought monitoring.

In the first above indices group, probability density function of SPI values fitted exactly with normal density function, but there were slight differences for Nitzche and SPIo values due to few number of drought events classifications (Nitzche) and non-transformation of data to normal distribution, respectively. Probability density function of the second and third groups index values were completely different from normal density function. Thus, the performances of first group indices for drought monitoring are very realistic and accurate because drought characteristic as expected events from a natural process would be consistent with normal distribution.

Probability distributions of wet and dry periods with PNPI index as only index of the third group, for different stations in the study area were very different and was a function of the average rainfall in each station. Therefore, behavior and performance of this index in drought mitigation are not independent of spatial, and relying on results of this index in forecasting drought are highly uncertain and will be unreliable. For example, maximum, average and minimum probability distributions of wet and dry periods of SPI, RAI and PNPI indices for all stations are presented in Fig. 1.

![Fig. 1. Maximum, average and minimum probability distribution of wet and dry periods of SPI, RAI and PNPI indices for all stations](image)

3.2. Probability of drought duration

Comparison of the probability of drought duration based on the first and second group indices indicated that the obtained values of second group indices are significantly higher than the obtained values of first group indices. The reason is that the probability of normal state based on the first and second group indices were 68% and 40%, respectively and also the probability of wet and dry events for second group indices were twice the values for the first group.

3.3. Transition probability matrix

Results for the conditional probabilities of wet and dry events showed similar behavior of indices in three groups and conditional probabilities i.e. DD, WW, DW and WD for all indices are a function of rainfall auto-correlation lag-1 coefficient. Therefore, auto-correlation lag-1 parameter has an important role in conditional probabilities of drought monitoring. In Fig. 2, maximum, average and minimum steady-state conditions of regional stations with different drought indices are presented.
3.4. Convergence of annual drought with different months of the year

Results based on the first group indices showed that highly rainy months have a major impact to classify drought class at an annual level but there were not similar results for the second group indices. Thus, using second group indices, forecasting long-term drought events based on short-term drought events analysis or vice versa would be associated with highly fault. For example, the convergence of annual drought with different months of the year for SPI and RAI indices are presented in Fig. 3.

4. Conclusions

The results of this study indicate that using SPI and SPIo indices are a great advantage for a more comprehensive analysis and Nitzche index would be very useful for primary analysis. Using the second group indices for drought phenomenon will be significant deviations from events expected from natural processes and its results may not be reliable for forecasting the drought. PNPI index is inefficient index for drought monitoring and relying on results of this index in forecasting drought is highly uncertain and will be unreliable.

5. References