Applicability Analysis of Drought Index in Shandong Province

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Abstract. The frequent occurrence of drought disasters restricts the agricultural development of Shandong Province. To analyze the drought situation in Shandong Province reasonably, the selection of drought index is particularly important. In this paper, the standardized precipitation index SPI, precipitation Z index and precipitation anomaly Pa of each city in the dry years of Shandong Province were calculated, and the drought of Shandong Province was analyzed by ArcGIS software. The applicability of the three drought indices in Shandong Province was compared. The results show that: in November 2010, the SPI index was better reflected in the drought, the Z index did not show the mega-arid area, and the Pa index exaggerated the drought in some cities; in March 2011, the Z-index showed that most cities were Light drought, SPI index reflects better than the Pa index for drought; in August 2014, Pa index monitoring showed that more than half of the cities were light drought, Z index showed that most cities were moderately dry, and the SPI index monitoring results were similar to the actual drought conditions; In October 2015, the Z index showed that more than half of the cities had no drought. The monitoring results of the Pa index for some cities were opposite to the actual ones. The monitoring results of the SPI index were consistent with the actual drought conditions.

1. Introduction
Drought disasters are considered to be one of the most serious natural disasters due to their long duration, wide range of disasters and high frequency of 

Mckee et al [4] proposed a standardized precipitation index (SPI) in the Colorado drought study in the United States, eliminating the distribution error of drought intensity in different regions, quantifying drought conditions at multiple time scales, and having a more accurate assessment of drought intensity levels. It can effectively reflect the status of droughts and floods. Zhang CunJie et al. [5] conducted an in-depth study of the precipitation Z index to classify drought and flood levels and set new standards to improve the response of the Z index to the division of droughts and floods in the Northwest. Huang et al. [6] used the precipitation anomaly percentage Pa to analyze the spatial and temporal characteristics of seasonal drought in the southern region, and tested the rationality of the Pa index in drought monitoring and evaluation.

Previous studies have mostly applied the analysis of the applicability of drought indices in the southern, Jianghuai and Yellow River basins of China. The discussion on Shandong Province as a research area is very rare [7,8]. This paper analyzes and compares the applicability of SPI, Pa and Z indices in the drought monitoring and evaluation process in Shandong Province, and provides reference for drought monitoring, early warning and disaster prevention and mitigation work in Shandong.
2. Research area overview
Located between 34°22.9′~38°24.01′E and 114°47.5′~122°42.3′N, Shandong Province is one of the major coastal provinces and cities in China (Figure 1). The terrain of Shandong is dominated by mountainous hills, with mountainous areas in the middle, low-lying flats in the southwest and northwest, undulating hills in the east, and hilly hills in the south. It belongs to the temperate monsoon climate with an average rainfall of 676.5mm and an annual average temperature of 11°C-14°C.

3. Data sources and research methods
3.1 Data source
This paper uses the monthly average precipitation and average temperature data of 17 cities in Shandong Province, from the Shandong Statistical Yearbook [9] and the China Meteorological Science Data Sharing Service Network.

3.2 Standardized precipitation index SPI
The standardized precipitation index SPI is the standard deviation of the measured precipitation relative to the precipitation probability distribution function [10], which can better reflect the drought intensity and duration, and has the characteristics of multi-time scale application. The drought grade is divided into Table 1.

3.3 Precipitation Z index
The precipitation Z index is because the precipitation in a certain period generally does not obey the normal distribution, and the Person III type distribution fits the precipitation in a certain period of time. The drought level of each level index is shown in Table 1.

3.4 Precipitation anomaly percentage Pa
The precipitation anomaly percentage Pa index reflects the difference between the precipitation in a certain period of time and the average annual rainfall in the same period of time, which can directly reflect the drought caused by the change of precipitation [11]. The classification of drought grade is shown in Table 1.

| Drought level | Drought type | Standardized precipitation index SPI | Z index | Precipitation anomaly percentage Pa |
|---------------|--------------|--------------------------------------|---------|-------------------------------------|

Figure 1. Shandong Province Administrative Division Map
4. Results and analysis of drought conditions in Shandong Province

According to the China Meteorological Disaster Code [12], Shandong Province has a high probability of drought and a long duration, a wide range of influence, and a large drought intensity. In order to visually show the actual application of the drought index in Shandong Province, November 2010, March 2011, August 2014, and October 2015 were selected as the typical years of drought, and the actual values of the three drought indices were calculated. The actual drought situation in each city of Shandong Province was analyzed and the results were as follows.

4.1 Drought analysis in November 2010

The SPI index monitors the drought situation in Shandong Province in November 2010. Dezhou, Binzhou, Dongying and Yantai are light droughts, and other regions have large droughts. Weihai is a severe drought, which is in line with the actual situation; Z-index drought monitoring showed that Dezhou, Binzhou, Dongying, etc. all showed light drought, other cities showed moderate drought, no large arid area; Pa index drought monitoring showed that for most cities, such as Texas, Binzhou, etc., exaggerated the actual drought situation (Figure 2).

4.2 March 2011 drought analysis

According to the SPI index, the drought monitoring in Shandong Province in March 2011 showed that there were large droughts in Binzhou, Dongying, Yantai, etc., and Heze was a special drought. The rest of the cities were mildly dry, and no drought occurred in Jinan, Dezhou and Taian. The actual drought situation is Jining and Heze as a major drought; The drought monitoring of the Z index shows that except for Zaozhuang, which is a special drought in Shandong Province, and no drought in Liaocheng and Jinan, the rest of the cities are mildly dry, which is quite different from the actual drought situation in Shandong Province. The Z index does not reflect well in Shandong Province 2011. Drought in March; Monitoring of drought conditions by Pa index showed that moderate drought in Jinan and Jining, mild drought in Heze, Tai'an and Rizhao, and severe drought in other cities. But the actual situation showed mild drought events in Laiwu and Qingdao. Good response to this drought (Figure 3).

|   | No drought | Light drought | Medium drought | Heavy drought | Special drought |
|---|------------|---------------|----------------|---------------|-----------------|
| 1 | -0.5<SPI   | -1.0<SPI≤-0.5 | -1.5<SPI≤-1.0 | -2.0<SPI≤-1.5 | SPI≤2.0         |
| 2 | -0.52<Z    | -1.04<Z≤-0.52 | -1.65<Z≤-1.04 | -1.96<Z≤-1.65 | Z≤-1.96        |
| 3 | -40<Pa     | -60<Pa≤40     | -80<Pa≤60      | -95<Pa≤80     | Pa≤-95         |

Figure 2. Spatial distribution map of various drought indices in November 2010

Figure 3. Spatial distribution map of various drought indices in March 2011
4.3 August 2014 drought analysis
The actual drought situation in Shandong Province in August 2014 was that Qingdao was slightly dry, and there was a major drought in Zaozhuang and Zibo. The monitoring of drought conditions in Shandong Province by SPI index shows that Liaocheng, Heze and Qingdao are characterized by light drought, and other cities have different degrees of drought events; Drought monitoring of the Pa index showed that there were major droughts in Zaozhuang, Laiwu, Zibo, etc., Weizhou had a severe drought, and the rest of the cities showed mild drought; The Z-index drought monitoring showed that only four cities in Liaocheng, Heze, Zaozhuang and Qingdao were mildly dry in Shandong, and major droughts occurred in Jinan and Zibo, while other cities were moderately dry (Figure4).

4.4 October 2015 drought analysis
The actual situation in Jinan City, Shandong Province in October 2015 was mild drought in Zibo, Weifang and Linyi. The SPI index monitoring of drought conditions in Shandong Province showed that Liaocheng, Dezhou, Binzhou and other mild droughts, Dongying was moderately dry, and the rest of the region had no drought; The drought monitoring of the Z index showed that there were mild droughts in Liaocheng, Dezhou and Binzhou, and no drought in other areas. The drought monitoring of the Pa index was conducted in Dongying, Jinan and Zibo, Liaocheng, Dezhou and Binzhou. There was a mild drought and there were no drought events in other areas (Figure5).

5. Summary
Based on the monthly average precipitation and average temperature data of 17 cities in Shandong Province from 2010 to 2015, this paper analyzes the applicability of SPI, Z index and Pa index in the drought monitoring and evaluation process in Shandong Province, and draws the following conclusions:

(1) Precipitation anomaly percentage The Pa index compares the precipitation with the average annual rainfall, thus reflecting the drought. In the November 2010 drought, the vast majority of cities in Shandong Province had zero rainfall, and most of the cities were reflected in a large drought, exaggerating the degree of drought in some cities, and in March 2011.

(2) The precipitation Z index monitoring drought degree and the actual drought situation have many differences. In the drought events of November 2010 and August 2014, the precipitation Z index has not been reflected in the mega-arid city, in 2015. In October, it was not reflected in the larger dry cities.

(3) Standardized precipitation index SPI has a small error in the drought response and actual situation of individual cities. In November 2010, it was similar to the actual situation. In the March 2011 drought incident, only Jining and the facts were quite different. In the October 2015 drought incident, only the Weifang and Rizhao drought conditions were not very satisfactory. In October 2015 and the actual situation. Close to each other.
(4) Comparing the results of four drought monitoring, SPI is close to the actual drought situation for both mega- and major drought monitoring, so the SPI index is better than the other two indexes for monitoring drought conditions in Shandong Province.

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