

## Drought Characteristics of Grasslands in the Tianshan Mountains, Xinjiang Based on the SPEI Index over the Past 55 Years (Postprint)

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**Date:** 2019-09-10T00:00:00+00:00

### Abstract

The Standardized Precipitation Evapotranspiration Index (SPEI) characterizes the degree of deviation of a region's dry-wet conditions from the normal state by standardizing the difference between potential evapotranspiration and precipitation, serving as a new ideal indicator for analyzing drought evolution trends that has currently been widely applied in drought assessment, water resource management, and other fields. Using SPEI and monthly precipitation and monthly mean temperature data from 8 representative stations in the Tianshan mountainous area of Xinjiang from 1961 to 2015, this study analyzed the variation characteristics of temperature and precipitation, drought characteristics at different time scales, and drought characteristics and trends during the grassland growing season in the Tianshan mountainous area over the past 55 years. The results indicate that: over the past 55 years, temperature in the Tianshan mountainous area has shown a significant upward trend; precipitation has exhibited a slightly upward trend overall, but with large interannual variations and an insignificant trend; the numbers of drought events at monthly, seasonal, semi-annual, and annual scales in the Tianshan mountainous area were 42, 25, 16, and 7, respectively; the frequencies of mild, moderate, and severe drought during the grassland growing season in the Tianshan mountainous area were 37.5%, 7.1%, and 1.8%, respectively; over the past 55 years, precipitation during the grassland growing season in the Tianshan mountainous area has increased, but due to enhanced evapotranspiration caused by rising temperatures, the climate still shows a drying trend. Over the past 55 years, the climate during the grassland growing season in the Tianshan mountainous area has exhibited a drying tendency, with dramatic interannual variations in drought severity, which exerts a substantial influence on interannual differences in grassland growth conditions.

## Full Text

# Drought Trend over the Grasslands in the Tianshan Mountains, Xinjiang in Recent 55 Years Based on SPEI

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**Abstract:** The Standardized Precipitation Evapotranspiration Index (SPEI) is calculated by standardizing the difference between potential evapotranspiration and precipitation, showing the deviation of drought degree from normal conditions. As an ideal indicator for analyzing drought evolution trends, SPEI is widely used in drought assessment, water resources management, and other fields. Using monthly mean air temperature and precipitation data from 8 meteorological stations across the Tianshan Mountains in Xinjiang from 1961 to 2015, this study analyzes the characteristics of temperature, precipitation, and the temporal distribution and variation of slight, moderate, and severe drought frequencies during the grassland growing season. Results show that the annual temperature in the study area exhibited a significant increasing trend over the past 55 years. Precipitation showed a slight increasing trend with large inter-annual variability, but the change trend was not significant. The numbers of drought events at monthly, seasonal, semi-annual, and annual scales in the Tianshan Mountains were 42, 25, 16, and 7, respectively. The frequencies of slight, moderate, and severe drought in the grassland growing season were 37.5%, 7.1%, and 1.8%, respectively. Over the recent 55 years, the climate over the grasslands in the Tianshan Mountains during the growing season became drier, and the annual degree of drought changed dramatically, which significantly affected grassland growth.

**Keywords:** drought; SPEI; grasslands growing season; climate change; Tianshan Mountains; Xinjiang

## 1 Introduction

Drought is one of the most damaging natural disasters, significantly impacting agricultural production, water resources, and ecological environments. With global climate change, the frequency and intensity of drought events have shown increasing trends in many regions, drawing widespread attention from researchers. The Standardized Precipitation Evapotranspiration Index (SPEI), developed based on the Standardized Precipitation Index (SPI), incorporates

both precipitation and potential evapotranspiration, making it suitable for analyzing drought evolution under climate change scenarios.

The Tianshan Mountains region, characterized by its unique topography and climate, represents an important ecological barrier and pastoral area in Xinjiang. Grassland ecosystems here are particularly sensitive to climate fluctuations. Understanding drought characteristics during the grassland growing season is crucial for regional ecological security and sustainable development. Previous studies have examined drought patterns in Xinjiang and surrounding areas, but systematic analysis of drought trends specifically for grassland growing seasons in the Tianshan Mountains remains limited. This study employs SPEI to analyze spatiotemporal drought characteristics from 1961-2015, providing scientific support for drought mitigation and grassland management.

### 1.1 Data Sources and Study Area

The study utilizes monthly temperature and precipitation data from 8 meteorological stations in the Tianshan Mountains region spanning 1961-2015. Data quality control and homogeneity testing were performed to ensure reliability. The grassland growing season is defined as April-September, covering the primary vegetation growth period.

### 1.2 Methods

**1.2.1 SPEI Calculation** The SPEI calculation involves several steps: First, potential evapotranspiration (PET) is calculated using the Thornthwaite method based on monthly mean temperature. The monthly water balance  $D$  is then obtained as the difference between precipitation and PET. A three-parameter log-logistic probability distribution is fitted to the  $D$  series at different time scales (1, 3, 6, and 12 months). Finally, the cumulative probability is transformed to a standard normal distribution to obtain the SPEI values. The log-logistic distribution function is given by:

$$F(x) = \frac{1}{1 + \left(\frac{x}{\alpha}\right)^\beta}$$

where  $\alpha$ ,  $\beta$ , and  $\gamma$  are scale, shape, and origin parameters, respectively.

Drought classification based on SPEI values follows the standard categories: slight drought (-1.0 to -1.49), moderate drought (-1.5 to -1.99), and severe drought (-2.0).

**1.2.3 Trend Analysis** The Mann-Kendall (M-K) non-parametric test is employed to detect trends in temperature, precipitation, and SPEI series. This method is widely used in hydro-meteorological trend analysis due to its robustness against non-normal distributions and missing values. The significance level

is set at  $\alpha = 0.05$ . All calculations were performed using Matlab 2010 and ArcGIS 10.1 for spatial analysis.

## 2 Results and Analysis

### 2.1 Temperature and Precipitation Changes

During 1961-2015, the annual mean temperature in the Tianshan Mountains showed a significant increasing trend at a rate of  $0.30^{\circ}\text{C}$  per decade ( $p < 0.01$ ). The M-K test detected an abrupt change around 1989, with a significant warming trend thereafter. Annual precipitation exhibited a slight increasing trend of  $13.5$  mm per decade, though the trend was not statistically significant. Inter-annual variability was substantial, with precipitation fluctuations showing an increasing pattern particularly after 1990.

[Figure 1: see original paper]

**Figure 1.** Change trend of temperature and precipitation in the Tianshan Mountains during 1961-2015

The spatial distribution reveals that temperature increases were more pronounced in the central and eastern Tianshan regions, while precipitation changes showed greater heterogeneity, with some stations recording decreases despite the overall slight upward trend.

### 2.2 Drought Characteristics Analysis

SPEI values were calculated at multiple time scales (1, 3, 6, and 12 months) to capture different drought types. Analysis of the 1961-2015 period shows:

At the monthly scale, 42 drought events were identified, with seasonal, semi-annual, and annual scales showing 25, 16, and 7 events respectively. During the grassland growing season (April-September), the frequencies were: - Slight drought: 37.5% - Moderate drought: 7.1% - Severe drought: 1.8%

[Figure 2: see original paper]

**Figure 2.** Mann-Kendall test of temperature and precipitation in the Tianshan Mountains during 1961-2015

The M-K trend test applied to SPEI series indicates a significant drying trend during the growing season ( $p < 0.05$ ), particularly pronounced since the late 1980s. Spatial analysis shows that 42.9% to 51.8% of the region experienced increasing drought frequency, with the most severe trends in the southern and western slopes. The proportion of areas showing significant drying trends reached 30.4% to 44.6% at the 6-month scale.

The decadal analysis reveals that the 2000s experienced the most severe drought conditions, with SPEI values consistently below  $-1.0$  during several growing seasons. This drying trend aligns with the observed temperature increase and

precipitation instability, suggesting that enhanced evapotranspiration under warming conditions has exacerbated drought stress despite slight precipitation increases.

[Figure 3: see original paper]

**Figure 3.** Temporal variation of SPEI at different time scales in the Tianshan Mountains during 1961-2015

The results demonstrate that climate change has significantly altered the drought regime in the Tianshan Mountains grassland region, with implications for ecosystem productivity and livestock carrying capacity. The increasing frequency and intensity of drought events during the critical growing season pose substantial challenges for sustainable grassland management and regional pastoral economies.

*Note: Figure translations are in progress. See original paper for figures.*

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