Spatiotemporal Variation Characteristics of Drought in the Regions North and South of the Qinling Mountains Based on the SPEI Index: Postprint

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Abstract

Based on measured meteorological data from 47 weather stations in the north-south region of the Qinling Mountains from 1960 to 2016, the Standardized Precipitation Evapotranspiration Index (SPEI) was used to quantitatively analyze the spatiotemporal evolution characteristics of drought occurrence frequency and intensity at different time scales in this region, and to reveal the causes of drought occurrence. The results indicate that SPEI values can effectively reflect the drought characteristics and wet-dry evolution conditions in the north-south region of the Qinling Mountains. From a temporal perspective, the region has shown an aridification trend over the past 57 years, with the most significant trend occurring in the 1990s. The area north of the Qinling Mountains exhibited the most pronounced aridification trend; however, the region has begun to show a humidification trend in the recent 22 years. Seasonally, most areas demonstrated an aridification trend across the four seasons, with autumn showing the most significant and earliest trend, followed by spring, while the trends in winter and summer were relatively insignificant. Spatially, drought occurred at annual, seasonal, and monthly scales with extremely uneven distribution across the region. The area north of the Qinling Mountains had a higher drought occurrence frequency, while the spatial distribution patterns in other sub-regions were more complex. The intensity of drought occurrence exhibited a pattern of being strong in the central-western region and weak in the surrounding areas, with the strongest intensity in Shiquan, Shaanxi (14.7%) and the weakest in Langzhong, Sichuan (23.6%).

Full Text

Drought Characteristics in the Northern and Southern Regions of the Qinling Mountains Based on the Standardized Precipitation Evapotranspiration Index

Abstract

Drought disaster is one of the most significant natural disasters affecting the northern and southern regions of the Qinling Mountains, impacting people' s daily lives and social production to varying degrees. Based on observed meteorological data from 47 meteorological stations in the northern and southern regions of the Qinling Mountains from 1960 to 2016, and using the Standardized Precipitation Evapotranspiration Index (SPEI) at different timescales (one month, three months, and twelve months), combined with the Mann-Kendall (M-K) method and ArcGIS spatial visualization analysis, this paper analyzes the spatio-temporal evolution characteristics of drought frequency and intensity at different timescales in the Qinling Mountains and reveals the underlying causes of drought. The results demonstrate that SPEI values effectively reflect drought characteristics and the evolution of dry and wet conditions in both the northern and southern regions of the Qinling Mountains. As the timescale increases, the amplitude of SPEI decreases and drought frequency declines. Temporally, there is an obvious increasing trend in drought frequency over the past 57 years, particularly during the 1990s, with the most significant drought area being the northern Qinling Mountains. However, in the most recent 22 years, both regions have begun to show a trend toward humidification. Seasonally, most parts of the region tend toward drought in all seasons, with the most significant drought trend occurring in autumn, followed by spring, winter, and summer. Spatially, drought occurs in both the northern and southern regions with significant regional differences. The frequency of drought occurrence is high in the northern Qinling Mountains, while the spatial distribution of drought frequency in other sub-regions is more complex, mainly due to the non-uniform distribution of temperature and precipitation coupled with the influence of the Qinling Mountains themselves. The drought intensity distribution shows higher values in the midwestern region and lower values around the mountainous areas. The maximum drought intensity value of 14.7% was recorded in Shiquan, Shaanxi Province, while the minimum value of 23.6% occurred in Yanzhong, Sichuan Province. The intensity of drought in the rest of the region ranges between 17% and 22%. Changes in temperature and precipitation have a significant impact on drought in the northern and southern regions of the Qinling Mountains, the El Niño phenomenon is closely related to drought occurrence, and special geographical location also plays an important role.

Keywords: Standardized Precipitation Evapotranspiration Index; meteorological drought; drought intensity; northern and southern regions of the Qinling Mountains

1. Introduction

Drought is one of the major natural disasters affecting the northern and southern regions of the Qinling Mountains, with significant impacts on agricultural production, water resources, and ecosystems. Previous studies have used various drought indices such as PDSI, CI, Z index, and SPI to analyze drought characteristics [**?**]. In 2010, Vicente-Serrano et al. proposed the Standardized Precipitation Evapotranspiration Index (SPEI), which combines the sensitivity of PDSI to temperature with the multi-timescale characteristics of SPI [**?**]. Since then, SPEI has been widely applied in drought research across China [**?**]. Studies have shown that SPEI can effectively reflect drought trends and spatial patterns at different timescales [**?**, **?**, **?**, **?**].

2. Data and Methods

2.1 Data Sources and SPEI Calculation The study utilized monthly meteorological data from 47 stations in the northern and southern regions of the Qinling Mountains from 1960 to 2016. The SPEI was calculated at three timescales: 1-month (SPEI-1), 3-month (SPEI-3), and 12-month (SPEI-12) to capture drought characteristics at different temporal scales. The calculation followed the method described by Vicente-Serrano et al. [**?**], using the log-logistic distribution to fit the difference between precipitation and potential evapotranspiration.

The Mann-Kendall trend test was applied to detect significant trends in SPEI values at the 0.05 and 0.01 significance levels. Spatial analysis was conducted using ArcGIS to visualize the distribution patterns of drought frequency and intensity.

2.2 Temporal Evolution Characteristics The temporal evolution of SPEI values shows distinct patterns at different timescales [Figure 2: see original paper]. At the 12-month scale, SPEI values exhibit clear interannual variability with a decreasing trend (drying) from the 1960s to the 1990s, followed by a slight increasing trend (wetting) in recent years. The trend is particularly pronounced in the northern region, where the drying rate reached -0.19℃·(10a) ^{1} in autumn .

The frequency of drought occurrence at different levels shows significant temporal variation [Figure 4: see original paper]. During the period 1960–2016, the northern region experienced drought in approximately 33-35% of the time, with severe drought events concentrated in the 1990s. The southern region showed a slightly lower drought frequency of 27-31%, with more spatial variability.

2.3 Spatial Distribution Patterns The spatial distribution of drought frequency reveals clear regional differences [Figure 5: see original paper]. The northern Qinling region consistently shows higher drought frequencies across all timescales, with 31-35% of months experiencing drought conditions (SPEI -0.5).

The southern region exhibits more complex patterns, with drought frequency varying from 24% in the southeast to 39% in the northwest.

Drought intensity distribution [Figure 6: see original paper] shows the highest values concentrated in the mid-western part of the study area, particularly in Shaanxi Province. The maximum intensity of 14.7% occurs in Shiquan, while the minimum intensity of 23.6% is found in Yanzhong, Sichuan. Most other areas experience drought intensities between 17% and 22%.

2.4 Causes of Drought The primary causes of drought in the Qinling region include:

1. **Climate change:** Temperature has increased significantly at a rate of $0.23℃ \cdot (10a)^{1}$ from 1951–2016 [**?**], while precipitation shows high spatial heterogeneity between the northern and southern slopes of the mountains [**?**, **?**].
2. **El Niño-Southern Oscillation (ENSO):** The El Niño phenomenon is closely related to drought occurrence in the region, with severe drought events often coinciding with El Niño years [**?**, **?**].
3. **Geographical factors:** The Qinling Mountains act as a significant climatic boundary, creating distinct differences in temperature and precipitation patterns between the northern and southern regions [**?**, **?**]. This topographical effect contributes to the complex spatial distribution of drought.

3. Conclusions

The SPEI index effectively characterizes drought conditions in the northern and southern regions of the Qinling Mountains. Key findings include:

1. Drought frequency has increased significantly over the past 57 years, particularly in the 1990s, with the northern region being most severely affected. However, both regions have shown a humidification trend in the last 22 years.
2. Seasonally, autumn shows the strongest drying trend, followed by spring, winter, and summer. All seasons exhibit a tendency toward drought conditions across most of the region.
3. Spatially, drought frequency is higher in the northern Qinling Mountains, while the southern region shows more complex patterns due to topographical influences.
4. Drought intensity is highest in the mid-western region and lowest around the mountainous periphery, with values ranging from 14.7% to 23.6% across the study area.
5. The primary drivers of drought are non-uniform changes in temperature and precipitation, coupled with ENSO events and the special geographical

location of the Qinling Mountains.

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