Analysis of Climate Drought Vulnerability in Qinghai-Tibet Plateau

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Abstract. Drought vulnerability assessment plays an important role in mitigation and response to drought, which can help the decision makers conduct effective management strategies associated with disaster reduction. Based on the meteorological data related to precipitation and temperature from 1980 to 2015, this paper proposes a detailed framework for drought vulnerability analysis of the Qinghai-Tibet Plateau, where the temporal and spatial distributions of meteorological drought index and drought vulnerability based on IDW interpolation method can be generated. Results indicate that the Qinghai-Tibet Plateau shows a drought trend, and a slightly dry state has happened since 2005. Additionally, a slight spatial variation in drought vulnerability across the region could be found, in which the eastern and western of this region have relatively lower vulnerabilities, while the central part shows a relatively higher vulnerability. Generally, there is a drought trend in this region but without a deterioration tendency.

1. Introduction

With the rapid development of the economy and society, the impact of human beings on climate change is also growing. The climate’s problems have emerged, and their vulnerability has become particularly acute. The vulnerability is defined as the nature of system being vulnerable to external interference, which has become a research hotspot in current years, especially research on the drought vulnerability [1]. For example, Thomas et al. used indices such as SPI to assess the vulnerability in the southern and northern regions of the Bearma basin [2]. And they found that more than 26% of the basin lied in the highly and critically vulnerable classes. Rodriguez and Santos advanced an operational approach to assess the vulnerability associated with climate variability in Tijuana, Mexico [3]. They indicated that the vulnerability could be served as a useful step to achieve sustainable development under climate change conditions. Maleki et al. assessed the drought vulnerability in Iran
and found that most areas are in medium-to-high vulnerability, in addition the water level may decrease due to different hydrological periods [4]. A majority of the previous studies have carried out many types of vulnerability research in different regions. However, most the previous studies have paid more attention on one meteorological factor, while some factors, such as precipitation and temperature, are not comprehensively taken into account, which may lead to lack of credible results and a overestimated or underestimated vulnerability. Accordingly, a comprehensive evaluation framework with both consideration of precipitation and temperature is increasingly desired for better calculating the climate drought vulnerability. In addition, the temporal and spatial distributions of meteorological drought index and drought vulnerability based on IDW interpolation method could have a powerful capacity in helping the decision makers developing the integrated management strategies. Nevertheless, such concerns have not been effectively addressed or reflected in the previous studies. Moreover, there are little research being directed at the Qinghai-Tibet Plateau. As the third pole of the earth, the Qinghai-Tibet Plateau plays a vital role in the sustainable development of mankind. What’s more, this region has its own unique climatic conditions. According to the above statements, this paper uses the vulnerability assessment method raised by Hashimoto to evaluate drought vulnerability based on the meteorological data associated with precipitation and temperature from 1980 to 2015 [5].

2. Study area and method

2.1. Study area and data

The Qinghai-Tibet Plateau is located in the southwest of China, geographically located between 78°27' and 104°43'E, 28°32'and 40°1'N (Fig. 1). The meteorological data contained precipitation and temperature in this region are from China Meteorological Science Data Sharing Service Network (http://data.cma.cn). This data contain daily precipitation and temperature data for 76 sites from 1980 to 2015. Surface distribution of climate drought index gained by using the interpolation method of IDW with the help of ArcGIS.

![Figure 1. Study area](image)

2.2. Method

In terms of the drought index, many calculation methods, such as SPI, Z index, have been widely used in the previous studies. However, most of these calculations only consider one meteorological factor, while ignoring others [6]. In response to such a defect, this paper uses precipitation temperature uniformity index which take into account of precipitation (P) and temperature (T). The calculation formula could be expressed as:
Where $G_z$ is the drought index; $P$ and $T$ are the precipitation and temperature during the time period, respectively; $\overline{P}$ and $\overline{T}$ are the annual average precipitation and temperature, respectively. $\partial P$ and $\partial T$ are the mean variance of rainfall and temperature, respectively.

This paper uses the vulnerability calculation method proposed by Hashimoto, as follow:

$$C = \sum_{i \in F} L_i \cdot e_i$$

(2)

Where $C$ is the drought vulnerability index; $F$ is the indicator state; $L_i$ is weight coefficient of vulnerability level; $e_i$ is the corresponding probability of $I$, which can be presented as follow:

$$e_i = P(D_j < i < D_{j+1})$$

(3)

Where $D_j$ ($j = 1, 2 \ldots n$) is the threshold of level $j$, and $n$ is the number of levels.

3. Results

3.1. Meteorological drought index

According to the year-by-year calculation of precipitation index of meteorological station in the Qinghai-Tibet Plateau, the trend of drought change in the Qinghai-Tibet Plateau is shown in Fig. 2. Generally, the annual variation of drought index has a downward trend with some fluctuations, which implies that the climate has a tendency to become dry during recent years in Qinghai-Tibet Plateau. Additionally, the drought rate is considered as the slope of fitting straight line (Fig. 2). That is, it changes at the rate of 0.0713 per year. According to the classification criteria of the climate drought index, the region is generally in a normal state before the year of 2005, and then generally in a dry state.

$$y = -0.0713x + 142.46$$

$$R^2 = 0.639$$

Figure 2. Annual variation of drought index

3.2. Drought vulnerability

The values of drought vulnerability index calculated by equations (2) and (3) are spatially distributed as shown in Fig. 3. Results reveal that the drought vulnerability index does not show obvious changes in the Qinghai-Tibet Plateau, but it still has some temporal and spatial differences. The drought vulnerability in the Qinghai-Tibet Plateau is between 0.17 and 0.25. The Qinghai-Tibet Plateau thus has a certain ability to resist drought. And that is why the points shows a tendency with fluctuations in Fig. 2. In terms of spatial changes, drought vulnerability has significant regionalism. The lower
Drought vulnerability index is located on the eastern and western of the region, while the higher region is located in the middle. This phenomenon shows that the middle area is more prone to drought, as a consequence, more attention should be paid in this area to protect the environment, especially when carrying out human activities in the area.

Figure 3. Spatial distribution of drought vulnerability

4. Conclusion
In this paper, drought vulnerability is calculated according the meteorological data in association with precipitation and temperature of the Qinghai-Tibet Plateau from 1980 to 2015. IDW interpolation method is applied for analyzing the temporal and spatial distributions of meteorological drought index and drought vulnerability through the software of ArcGIS. Generally, the main conclusions are summarized as follows:

1. According to meteorological drought index, the Qinghai-Tibet Plateau shows a drought trend. And since 2005, this region has exhibited a slightly dry state.

2. There is a simple spatial change in drought vulnerability across the region, where the central part presents a relatively higher vulnerability while both sides have a relatively lower vulnerability. Moreover, the overall vulnerability of the region is well. In general, there is a drought trend in this region but without a deterioration tendency.

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