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Assessing vegetation response to multi-time-scale drought across inner Mongolia plateau

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ABSTRACT

This study assessed the impacts of climate change in IMP by investigating vegetation responses drought in multiple timescales. Methods used included the Normalized Difference Vegetation Index (NDVI) and Standardized Precipitation Evapotranspiration Index (SPEI), by annual maximum Pearson correlation (Rmax) and the corresponding month (Rmonth) of drought. Results showed that: (1) It is necessary to zone IMP when analyzing the vegetation responses to drought. (2) Rmax is significantly positive correlation in IMP, indicating that vegetation was largely influenced by drought; the most seriously affected areas are in the north-eastern part of typical steppe, south-western parts of steppe desert and southern part of desert steppe, while light seriously are distributed in the south-eastern of typical steppe and forest steppe. (3) Vegetation in typical steppe, steppe desert and desert steppe are sensitive to shorter time-scales of droughts, while in the forest, forest steppe and sand desert, vegetation shows a close relationship with the longer drought time-scales. (4) The effects of drought related climate extremes can also contribute to Rmax and Rmonth between SPEI and NDVI. Vegetation in forest and sand desert areas, have lower sensitivity to drought under the effect of climate extremes. Adaptation measures, such as building drought resilience vegetation types, applying biochar and monitoring and forecasting drought, must be timely and effectively initiated, especially, in the typical steppe, steppe desert and desert steppe in IMP since vegetation in these four areas is affected seriously, once drought occur. The results from this study may provide useful information about appropriate adaptation and mitigation strategies against the inverse effects of drought on vegetation, and even alleviate the losses caused by drought.

1. Introduction

Climate change is known to impact on society and ecosystems in a variety of ways (Leal Filho, 2015). One of the obvious ways is drought, which is period of below-average precipitation in a given region, resulting in prolonged shortages in the water supply, such as continuous no rain days or the anomaly of the precipitation (Zhang and Li, 2007). In such circumstances, supply cannot satisfy the existing demand (Vicente-Serrano et al., 2013). According to statistics from Emergency Events Database (www.em-dat.net), throughout the world, droughts account for 5% of the natural disasters, but losses from droughts have caused up to 30% of losses from all disasters, ranking droughts the first among all the natural hazards. With global warming, it is now generally agreed that the global hydrological cycle would intensify and that the extremes of drought would become more common and become even more

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serious, especially since the late 1990s (Yu et al., 2014). Drought has the characteristics of high frequency, long duration and wide influence, and has far-reaching impact on agricultural production, ecological environment and social and economic development, especially in agricultural production on (Donald, 1994). Compared with other land use types, grassland is most sensitive to drought (Zhang et al., 2017). Drought with increasing frequency has extremely important effects on animal husbandry and pasturing (Natsgadorj, 2003) and can result in huge losses. According to Xinhua news (http://news.xinhuanet.com/english/2017-07/14/c_136444349.htm), in July 2017, only in Inner Mongolia Autonomous Region of People's Republic of China, there are 2.7 million hectares of crops and 34.3 million hectares of grassland being severely affected by drought, resulting in the direct economic loss was up to 5 billion CNY. It is of great practical significance to explore the effect of drought on vegetation growth and to drought impact assessment and agricultural production. Analysis how grassland vegetation responds to drought is the key point to alleviate the losses caused by drought. Thus, grassland vegetation response to drought is a crucial scientific issue in the domain of climate research.

Inner Mongolia Plateau (IMP) is the largest cross-long distance between the provinces in People's Republic of China with a span of 2400 km, and its climate differences from south to north are obvious, which results in its vegetation differences. Vegetation have different demands on water in different growing periods; therefore, the drought has different effects on grassland vegetation (Liu et al., 2012). That indicates different vegetation has different stability and resilience to drought resistance (Zhang et al., 2017), thus, different grassland types have different responses to the drought during the growing periods. Additionally, the spatial variability was covered by using the limitation mean of overall vegetation response to drought in IMP. To reduce influences of these biases, zoning of vegetation needs to be done when analysis its response to drought. What's more, drought in multi-time-scale needed to be taken into consideration (McKee et al., 1993). Hence, when analysis vegetation response to drought, different vegetation types need to be studied separately and their responses to drought in different time-scale also require consideration. The effects of drought are complex and difficult to grasp and predict, and it is necessary to use several well-established drought indices to qualitatively and quantitatively measure the drought. After analysis, Standardized Precipitation Evapotranspiration Index (SPEI) is a widely used method to evaluate drought index, which is a site-specific drought indicator quantifying deviations from the average water balance (precipitation minus potential evapotranspiration) and has various time-scales (Vicente-Serrano et al., 2010). And we used Normalized Difference Vegetation Index (NDVI) to calculate vegetation coverage, which a good indicator of vegetation activity and has been widely used to estimate dynamic of vegetation (Guo et al., 2014). Vicente-Serrano et al. (2013) have investigated vegetation response to drought by analysis the relationship between SPEI and NDVI.

IMP is a typical agriculture-gazing transitional zone with 8.7 million hectares of grassland in the Inner Mongolia Plateau, accounting for 76.5% of the total area, and ranking this area as the first of five major grasslands in People's Republic of China. Agriculture and animal husbandry is the main economic basis of Inner Mongolia Plateau, which contribute about 26% of region's gross domestic product, while 80% of the output value of agriculture and comes from animal husbandry. While animal husbandry in Inner Mongolia is affected by the drought (Li et al., 2007) and large agricultural and economic losses were caused by drought, which further harmed social life (Yuan et al., 2013). Investigation of vegetation response to different time-scales droughts across IMP will give us insight into the impacts of droughts on grasslands and help to make plans and management to reduce agricultural and economic loss. Many investigations (e.g. Wang et al., 2017a,b) have been focused on vegetation responses on climate change or the occurrence and intensity of drought. In addition, most research is focused on local elements, ignoring the spatial heterogeneity (Wang et al., 2017a,b). Nevertheless, the response mechanism of different grassland vegetation to drought is still far from complete.

Based on the points above, responses of different steppe vegetation to drought in different time-scales in IMP need to be the subject of considerable attention. The objectives of this study were: (1) to investigate relations and sensitivities of vegetation in different grasslands responses to drought in different time-scales in IMP; (2) to understand impacts of drought-related climate extremes on vegetation responses to droughts. The following section is an introduction of the study area in IMP; Section 3 gives an overview of data and methods applied in this study; Section 4 and Section 5 present the results and discussions, respectively; The conclusions and some suggestions for further researches are given in Section 6.

2. Study area

Inner Mongolia Plateau (IMP) is selected as study area in this paper, which extends over more than 6° of latitude (between 37°24′ N and 53°23′ N) and 19° on longitude (between 97°12′ E and 126°04′ E) (Fig. 1), with a total area of about 1.18 million km^2. Due to its elongated shape elevations ranging from 82 m to 3430 m (above sea level). Greater Hinggan Mountains are located on the northeast and Ho-lan Mountains is on the west. Yin Mountains run across the central portion of this province. There are a wide variety of regional climates in IMP and most parts of them are arid, semi-arid or semi-humid from west to east, except for the relatively humid Greater Hinggan Mountains region (Liu et al., 2016). Meanwhile, precipitation gradually decreases from east to west with the annul change between 50 and 450 mm. The average annual temperature is approximately −1 to 10 °C, because of this complex topography and distance from the oceans, vast grasslands are distributed in the east of the region and deserts are mainly widespread in the west. IMP is one of the most important bases for agriculture and livestock

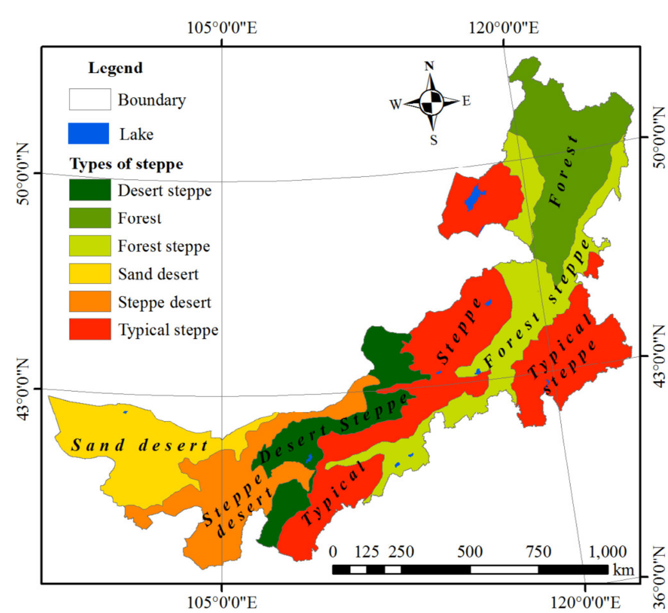

Fig. 1. Location of different steppes in IMP.