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Original Articles

An assessment of the impacts of climate extremes on the vegetation in Mongolian Plateau: Using a scenarios-based analysis to support regional adaptation and mitigation options

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ABSTRACT

Climate change is known to have an impact on the vegetation and on the well-being of ecosystems. Whereas there is a limited number of studies which have assessed historical vegetation changes in the Mongolian Plateau (MP), there are even fewer considering future changes. This paper therefore fills a gap in the literature, by investigating such changes in temporal and spatial scales, and by assessing their effects (1982–2100). The methods used in the study mainly included Pearson correlation and Mann-Kendall test. Results showed that climate extremes in MP, significantly influence vegetation growth. In addition, vegetation trends in MP, vary according to different scenarios. Potentially vulnerable areas of grassland and forest in the future are pointed out. Among the adaptation options available, better management of farmland and water resources should be pursued, and planting of vegetation types should be considered separately. Improvement of the barren area in MP requires international cooperation between Mongolia and China and it is necessary to integrate adaptation options into relevant policies. For mitigation, the projection indicates the emission under Scenario A1B is better for grass growth in MP and great attention should be paid to the greenhouse gas (GHG) emissions from grassland systems in detail, apart from the high quality and low GHG emission animal species, the types of intake grass also need to be seriously considered. In addition, management of sheepfolds in MP is also an important way to reduce GHG emissions. The results from this study will provide useful information about appropriate adaptation and mitigation strategies which may influence vegetation growth in MP.

1. Introduction

A climate extreme (extreme weather or climate event) means the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of a given variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as climate extremes (Field et al., 2012). However, the description of climate extreme is still complex, even if in a statistical sense, there is no extreme, it can still lead to extreme conditions or impacts (Nicholls et al., 2012). An Expert Team on Climate Change Detection and Indices (ETCCDI) of the World Meteorological Organization Working Group has attempted to facilitate the analysis of such climate extremes by defining a set of extreme climate indices that provide a comprehensive overview of

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temperature and precipitation statistics focusing particularly on extreme aspects (Sillmann et al., 2013a). Until now, these sets of extreme climate indices have been widely used by many scholars. For instance, the indices are well used not only in global studies (Sillmann et al., 2013a,b), but also in regional studies (Xu et al., 2015; Wu et al., 2017; Arefi et al., 2017).

Some changes in climate extremes observed in the late 20th century are projected to continue (Kharin et al., 2013) in particular:

a) temperature extremes keeping substantial warming (Seneviratne et al., 2012),
b) precipitation with high frequency and proportion increasing by the end of the 21st century over many areas of the globe (Nicholls et al., 2012).

In addition, extreme events are expected to increase not only in their frequency but also in their magnitude (Ferńandez-Giḿenez et al., 2012). The effects of climate extremes are widely spread in semiarid biomes, which cover 40–50% of the terrestrial surface and where 40% of the world population lives (Reynolds et al., 2007). To date, only a few studies have been focused on the impacts of extreme winters unique to the Mongolian Plateau (Hoover et al., 2016), where one of the largest remaining grassland ecosystem is located (Angerer et al., 2008). While compared with other land use types, grassland is most sensitive to climate extremes (Zhang et al., 2017).

The grassland ecosystems in Mongolian Plateau (MP), mainly including Mongolia (M) and Inner Mongolia (M) of China, are very special. It not only provides abundant natural resources for the regional economic development but also safeguards the environment of Asia as it acts as an ecological protective screen (Dan et al., 2013). However, grassland degradation has become one of the most serious environmental problems and is posing a threat to sustainable development of this area (Miao et al., 2015). This is because the livelihoods in MP are primarily based on livestock and grassland resources (Miao et al., 2015). Researchers have found rangelands in IM have been steadily deteriorating at a rate of approximately 2% of the land area annually (Angerer et al., 2008), and account for 59% of the total grassland area in IM compared with its value in the 1950s (He et al., 2015). While in M, 70–80% of pastures suffered from degradation of varying intensity (Tian et al., 2014), and rangeland degradation near settlements, roads, and water points have also been observed (Angerer et al., 2008). For grassland changes, effects contributed by climate extremes are also huge and cannot be ignored (Mu et al., 2013). Thus, detecting and understanding how future climate extremes potentially affect vegetation change in MP and mitigation and adaptation of these climate extremes, are urgent and this knowledge may guide measures which also bring benefit for indigenous pastoralists, who rely on stock farming.

Knowledge regarding vegetation responses in MP to external impacts is at present still incomplete, especially those influenced by climate extremes. Hitherto, there is a paucity of studies considering the combination of the climate extremes depending on the amount and quality of relevant observational data. Based on this, the specific questions tackled by this paper are: (1) how has vegetation responded to climate extremes in the past, especially throughout the last decades (1982–2014), across MP? and (2) were there any significant differences in the vegetation responses between the two political units, IM and M? (3) The answers to these questions may assist efforts towards adaptation and mitigation to climate extremes.

2. Study area

The investigated site consisted of parts of Mongolia (M) in the northwest and Inner Mongolia, China (IM) in the southeast. The Mongolian Plateau (MP) lies in between latitudes 37°22′ N ~ 53°23′ N and longitudes 87°43′ E ~ 126°04′ E (Fig. 1). It covers a total area of 2.75 billion km^2, with an average elevation of 1600 m above sea level.

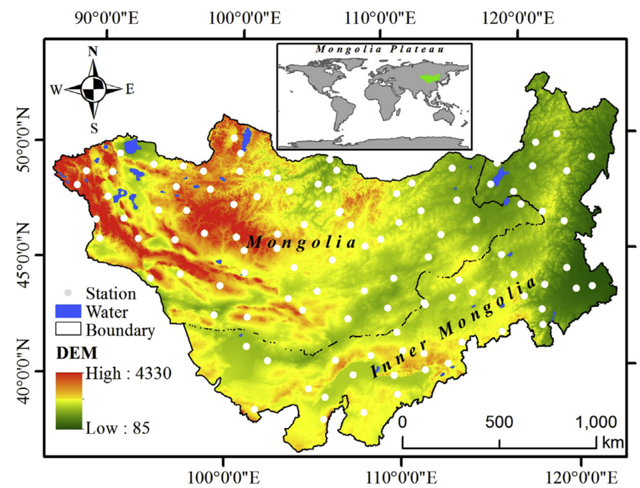

Fig. 1. Location of Mongolian Plateau (MP).

In this area, low mountains are located in the east while high mountains are distributed in the west, and the Yinshan mountain ranges to the south, with the Sayan and Hentiy mountain range to the north. The average annual temperature varies approximately −26 to 17 °C while the annual average precipitation in most regions is < 200 mm, although it may reach 400 mm or higher in the eastern, northeastern, or northern mountainous areas (Zhang et al., 2009). The unique location determines its special distribution of vegetation. There are three biomes in MP, including forest (northern and eastern parts), grassland (middle) and Gobi Desert (west). Most of the regions are covered by desert, vegetation and sparse grasslands. Livestock and grassland resources are the primary livelihoods (Miao et al., 2015), MP experiences a typical continental climate with extreme cold in the winter and heat in the summer (Zhang et al., 2009) and has suffered some extreme events, such as frequent drought and heavy snowfall (Rao et al., 2015).

3. Data and methods

3.1. Data

3.1.1. Observation data

The recorded daily maximum and minimum temperature, and precipitation data for the forty-three and sixty-eight meteorological monitoring stations in IM and M, respectively during 1982–2014, were used in this study. The data in IM were obtained from the Climate Data Center (CDC) of the National Meteorological Center of the China Meteorological Administration (CMA), while the data in M were obtained from the Information and Research Institute of Meteorology, Hydrology and Environment, in Mongolia. Before obtaining the station-based extreme climate indices, daily data, quality control and homogeneity assessment in the 111 meteorological stations were processed by RClimDex Software Version 1.1 (available from http://etccdi.pacificclimate.org/authenticated_downloads/RClimDex/rclimdex1.1_131115.r) and RHtest V4 software (Available online at http://etccdi.pacificclimate.org/software.shtml), respectively (Li et al., 2018a).

Taking daily maximum and minimum temperatures, and precipitation as inputs, through the RClimDex 1.1, twenty-six core station-based observations of extreme climate indices (16-temperature based and 10-precipitation based) were calculated (as the output data), and their details can be seen in Table 1.

3.1.2. Model data

Land-use and land-cover change data at a 1 km resolution for 2010 to 2100 based on Human-Environment interactions (Li et al., 2017), was used in this study to represent the simulation of vegetation change. This data was simulated by a new model proposed by Liu et al. (2017),