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Vulnerability assessment of spring wheat production to climate change in the Inner Mongolia region of China

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ABSTRACT

The main characteristics of global climate change include significant temperature increases and uneven precipitation distributions, which are both limiting factors for the sustainable development of dryland agriculture in semiarid regions. Inner Mongolia, which occupies the largest area of the semiarid region in China, is a good representation of the region's climate and dryland agricultural conditions. Spring wheat is widely grown in this region, but the negative impacts of climate change have seriously threatened spring wheat production in recent years. To adapt to these changes, it is imperative to study the influence of climate change on spring wheat production. We employed a vulnerability assessment method to quantitatively evaluate the impacts of climate change on spring wheat production in Inner Mongolia and recommended specific countermeasures based on the results. The average temperature and precipitation during the spring wheat growing season was 16.5 °C and 224 mm, respectively, from 1961 to 2012. Northeastern Inner Mongolia was characterized by lower temperature and higher precipitation; the eastern region had both higher temperature and precipitation; and the southwestern area had higher temperature and lower precipitation. The climate in this region showed a warming and drying trend from 1961 to 2012, with average temperature during the spring wheat growing season increasing with an average rate 0.3 °C/10a and average precipitation decreasing with an average rate 4.3 mm/10a. Over the study period (from 1996 to 2012), the vulnerability of spring wheat in the eastern, central, and southwestern areas of Inner Mongolia was high, whereas that in the northeast was relatively low. Assuming the adaptive capacity of spring wheat is stable, the comprehensive unit vulnerability of spring wheat production is expected to significantly increase under the investigated climate change scenarios (based on historical climate trends and RCP4.5, RCP8.5 scenarios) relative to average values over the study period. Exposure and regional vulnerability could be reduced by decreasing the proportion of spring wheat grown in vulnerable areas, such as the central and southwestern areas of Inner Mongolia.

1. Introduction

Climate change and its impacts on natural ecology, political economy, and social life have become critical global concerns. Recent studies have shown that "Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850" (IPCC, 2013). In the Northern Hemisphere, the period from 1983 to 2012 was likely the warmest 30-year period over the last 1400 years. Averaged over the Northern Hemisphere's mid-latitude land areas, precipitation has increased since 1901. In other latitudes, the area-averaged, long-term, positive or negative trends in precipitation were not significant (IPCC, 2013), but uneven distributions of precipitation at regional scales is another major characteristic of climate change.

Semiarid regions account for 13.3% of global land area and contain most of world's dryland agriculture. Agricultural production in semiarid regions contributes to the global food supply and affects social and economic development. Dryland agriculture in semiarid regions of China represents more than 60% of the nation's total arable land (Li, 2004) and is important for national food security. The Inner Mongolia region occupies the largest area of China's semiarid regions, and its climate and dryland agriculture are representative of typical semiarid regions.

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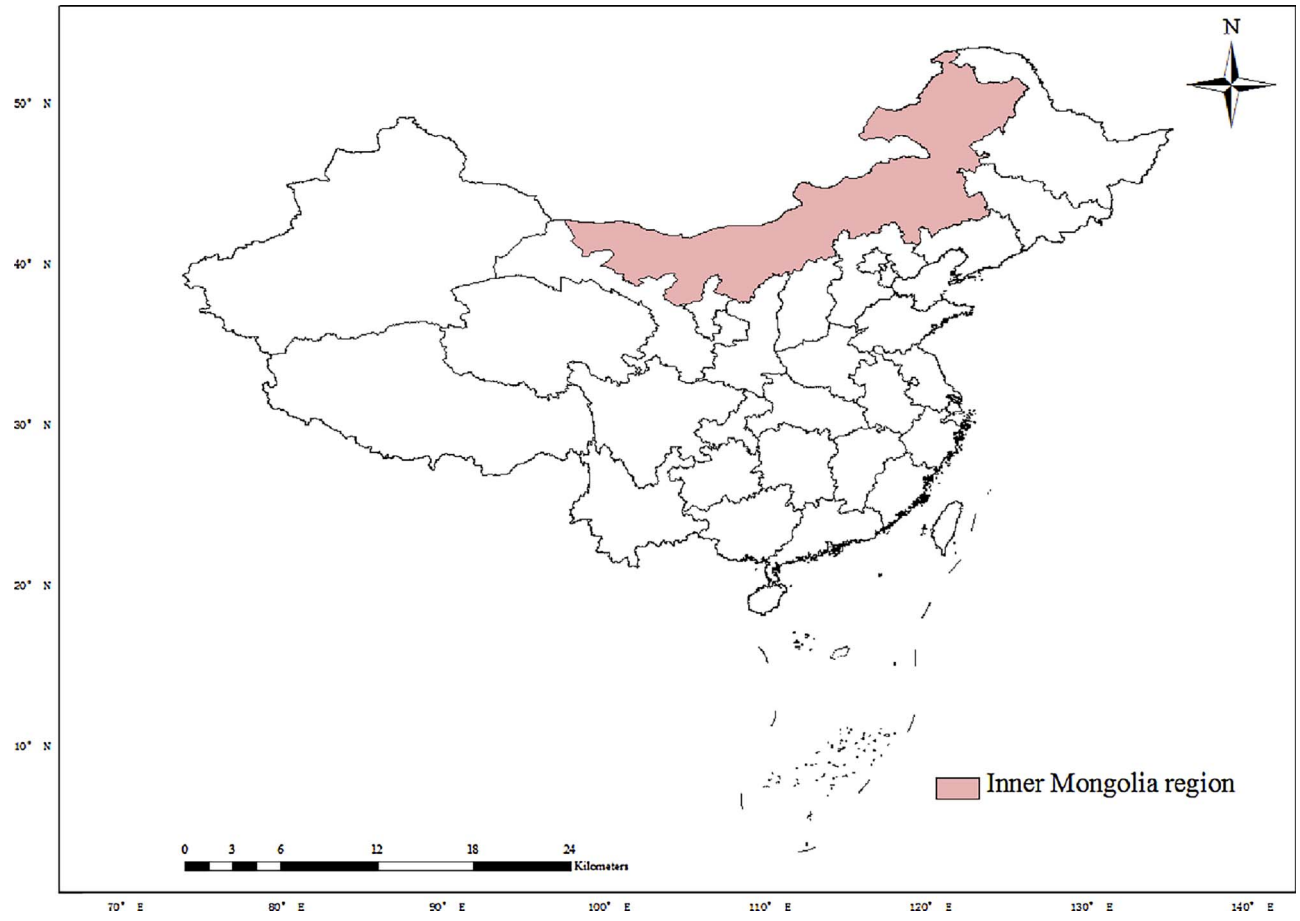

Fig. 1. The study area.

Limited by precipitation and irrigation conditions, dryland agriculture is a risky industry. Natural precipitation, which mainly occurs in summer, is the major available water resource in semiarid regions (Ji et al., 2004). It is often difficult for crops to use moisture due to large soil and water losses. Seventy to eighty percent of precipitation is lost as soil runoff or invalid evaporation, causing frequent drought and decreased grain yield (Li et al., 2014). The actual yield of dryland crops is less than 50% of potential yield (Bu, 2013). Thus, increasing temperatures and uneven precipitation distributions are posing severe threats to dryland crop yield.

Spring wheat, a widely grown dryland crop, is the main food source in semiarid regions, and changes in its yield directly affect food security in these regions. Statistics have shown that the national spring wheat planting area and total yield respectively dropped from 51.9 million hectares and 8.7 million tons in 1980–15.6 million hectares and 6.0 million tons in 2008 (The Ministry of Agriculture of the People's Republic of China, 2009). The climate and daily temperature range in the Inner Mongolia region are suitable for spring wheat growth (Cao et al., 2009). Historically, spring wheat has occupied the largest planting area in this region (Liu et al., 1999), but the area has decreased in recent years (Hou et al., 2009). Decreasing soil water storage and intensifying spring droughts are seriously threatening spring wheat production, and the suitability of planting spring wheat in this region in the face of climate change remains uncertain. Thus, it is urgent for the government to make strategic decisions regarding optimal agricultural management strategies based on the impacts of climate change.

In this study, we evaluated the vulnerability of spring wheat production in Inner Mongolia to climate change. The results provide useful recommendations for countermeasures to cope with the impacts of climate change.

2. Materials and methods

2.1. The study area

The Inner Mongolia region (Fig. 1) is located in along the northern border of China and the southeastern Mongolian plateau (37°30′ to 53°20′N, 97°10′ to 126°29′E). It spans a linear distance of 2400 km from east to west and 1700 km from north to south, and most of the area is a plateau. The region has a typical temperate continental monsoon climate with four distinct seasons. Spring is characterized by rapidly increasing temperature and frequent windy weather; summer is torrid and short with concentrated precipitation. In autumn, temperature decreases rapidly, and early frost has a significant impact on agriculture. Winter is long with frequent waves of severely cold weather (Li, 2015).

2.2. Data sources

(1) Historical meteorological data

Meteorological data were acquired from China's meteorological data sharing service network (http://cdc.cma.gov.cn/home.do), the Inner Mongolia and WuChuan County meteorological bureaus, etc., and include monthly meteorological parameters from 51 observation sites (Fig. 2) during the spring wheat growing season from April to August 1961–2012 (Dong et al., 2012). Temperature (°C) and precipitation (mm) were investigated because they mostly reflect the characteristics of climate change and strongly impact agricultural production.