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Research paper

Evaluation of agricultural water demand under future climate change scenarios in the Loess Plateau of Northern Shaanxi, China

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ABSTRACT

Climate change will affect the future availability of water resources for agriculture. An understanding of the impact of future climate change on regional agricultural water use can provide a basis for regional agricultural production and water management. This paper evaluated the agricultural water demand under three future climate change scenarios in the Loess Plateau of northern Shaanxi (LPNS), China. The results showed that in the scenarios RCP2.6, RCP4.5, and RCP8.5, the temperature, effective precipitation, and relative humidity were on the rise, the wind speed decreased slightly, and the trend of sunshine duration was unclear. The irrigation water requirements of the main crops exhibited a downward trend under future climate change scenarios. The decreasing trend of the irrigation water requirement was highest in the RCP8.5 (−0.90%) scenario, followed by the RCP4.5 (−0.77%/year) and the RCP2.6 (−0.30%/year) scenarios. Based on the impact of the changes in the evapotranspiration of future crops and the effective precipitation in the RCP2.6 scenario, the irrigation water requirements of the agricultural industry showed a downward trend and decreased from 1.84×10^9 m^3/year (2010–2014 average) to 1.29×10^9 m^3/year (2040–2049 average); the irrigation water requirements of the agricultural industry showed a significant downward trend ($P < 0.05$) in the RCP4.5 and RCP8.5 scenarios, decreasing from 1.84×10^9 m^3/year (2010–2014 average) to 1.20×10^9 m^3/year (2040–2049 average) and 1.15×10^9 m^3/year (2040–2049 average), respectively. Future research should be aimed at improving the regional climate downscaling and developing a better understanding of the responses of agriculture to regional climate change.

1. Introduction

Global warming has become an accepted fact in recent years and climate change is one of the pressing issues. Due to the increase in global temperatures, the water holding capacity and the water vapor transport of the atmosphere have increased (Menzel and Bürger, 2002; Sun et al., 2013). The imbalance between water availability and water demand causes water scarcity, which has become one of the most pressing issues in the world (Sun et al., 2016a). In many parts of the world, the hydrologic cycle has accelerated due to changes in soil moisture, runoff, and precipitation over the past century (Groisman et al., 1999; Ziegler et al., 2003; Huntington, 2006; Gao et al., 2006; Zhang et al., 2009). The Intergovernmental Panel on Climate Change (IPCC) and the Food and Agriculture Organization (FAO) of the United Nations has listed agriculture as one of the most vulnerable industries affected by climate change, particularly in developing countries. Currently, irrigation remains an important means of ensuring sufficient food production. In developing countries, the crop yields in irrigated farmland account for 60% of the total crop production (Fischer et al., 2007). Increasing competition for water between agricultural and other sectors, as well as challenges brought by climate change, future available water resources for agriculture production will continue to decline (Sun et al., 2016b).

To date, the prediction of future climate change has been mainly based on General Circulation Models (GCMs). Scientists around the world have established a series of GCMs over the past 20 years. GCMs can simulate large-scale average features well. Although the models cannot predict the future climate, they can describe the possible

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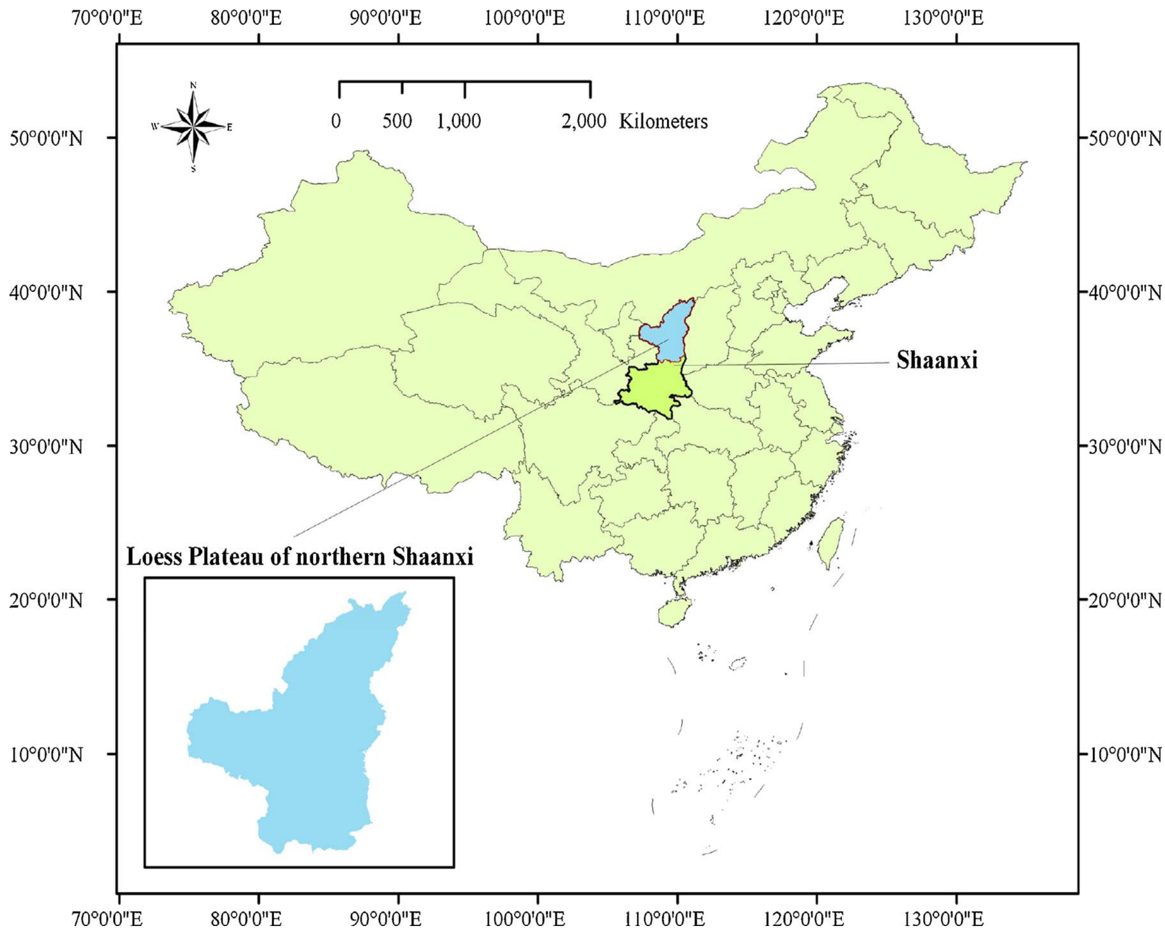

Fig. 1. The geographical location of the LPNS.

changes in the future climate. GCMs can reflect future climate change coupled with crop models that reflect crop growth changes (i.e., model simulations); this approach has been used to research the impact of climate change on irrigation water requirements, which recently has received increasing attention. Tao et al. (2003) obtained the temporal and spatial variations of reference crop evapotranspiration (ET_0), the evapotranspiration (ET_c), the soil water deficit, and the irrigation water requirements based on the Hadley Centre Coupled Model (HadCM2)-driven crop-soil-water simulation model. Silva et al. (2007) used the HadCM3 A2 and B2 scenarios combined with the crop model CROPWAT to predict the effects of climate change on rice irrigation water requirements in Sri Lanka. Tao et al. (2008) coupled the GCMs and the CERES-Rice crop models to study the relationship between global warming, rice production, and irrigation water requirements in China, and presented a probabilistic assessment of the changes in future rice production and irrigation water requirements. Moriondo and Bindi (2006) evaluated the performance of a general circulation model, a regional circulation model, and an artificial neural network for a cropping systems simulation for the present climate. Toews and Allen (2009) predicted the sensitivity of recharge to different climate models in an irrigated agricultural region by using climate change scenarios from three global climate models. Based on the Conformal Cubic Atmospheric Model driven by four GCMs, the effects of increased temperature on the initiation and the duration of key crop phenophases and on the occurrence of heat stress and cold shocks during the growing season were evaluated (Luo et al., 2014). The future distributions of *Gossypium* (cotton) and *Triticum aestivum* L. (wheat) were modeled using the CLIMEX software with the A2 emission scenario generated by the CSIRO-Mk3·0 and the MIROC-H global climate models (Shabani and Kotey, 2016). The effect of sampling weather data was evaluated for simulating the yields of winter wheat in a region in Germany over a 30-year period (1982–2011) using 12 process-based crop models (Bussel et al., 2016). Many of the previous studies have directly calculated the irrigation water requirements while ignoring the changes in rainfall patterns. Changes in irrigation water requirements are a common result of changes in crop water demand and rainfall and changes in crop water demand alone are not enough to provide a basis for the development of irrigation strategies to address climate change. Ecological fragility and a shortage of water resources are pressing issues in the Loess Plateau of northern Shaanxi (LPNS). An analysis of the supply and demand of agricultural water resources in the future and a clarification of the impact of future climate change on regional agricultural water use can provide policy support for the maintenance of regional water resources and for sustainable agricultural development.

This study aimed to explore the changes in agricultural water demand in the future by using a statistical downscaling method. First, the major climatic factors were simulated using a back propagation artificial neural network. Second, the changes in the evapotranspiration of major crops as a result of future climate change were analyzed. Finally, the characteristics of agricultural water demand were assessed by analyzing the crop evapotranspiration and effective precipitation under future climate change scenarios. The results of this study will provide a basis for understanding the potential impacts of climate change on the regional agricultural water demand and its characteristics.

2. Material and methods

2.1. Study area

The LPNS is located in the central part of the Loess Plateau in China,

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