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Cropping system innovation for coping with climatic warming in China

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ABSTRACT

China is becoming the largest grain producing and carbon-emitting country in the world, with a steady increase in population and economic development. A review of Chinese experiences in ensuring food self-sufficiency and reducing carbon emission in the agricultural sector can provide a valuable reference for similar countries and regions. According to a comprehensive review of previous publications and recent field observations, China has experienced on average a larger and faster climatic warming trend than the global trend, and there are large uncertainties in precipitation change, which shows a non-significantly increasing trend. Existing evidence shows that the effects of climatic warming on major staple crop production in China could be markedly negative or positive, depending on the specific cropping region, season, and crop. However, historical data analysis and field warming experiments have shown that moderate warming, of less than 2.0 °C, could benefit crop production in China overall. During the most recent warming decades, China has made successful adaptations in cropping systems, such as new cultivar breeding, cropping region adjustment, and cropping practice optimization, to exploit the positive rather than to avoid the negative effects of climatic warming on crop growth. All of these successful adaptations have greatly increased crop yield, leading to higher resource use efficiency as well as greatly increased soil organic carbon content with reduced greenhouse gas emissions. Under the warming climate, China has not only achieved great successes in crop production but also realized a large advance in greenhouse gas emission mitigation. Chinese experiences in cropping system innovation for coping with climatic warming demonstrate that food security and climatic warming mitigation can be synergized through policy, knowledge, and technological innovation. With the increasingly critical status of food security and climatic warming, further efforts should be invested in new agricultural policy, knowledge and technology creation, and popularization of

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climate-smart agriculture, and more financial investments should be made in field infrastructure development to increase cropping system resilience in China.

1. Introduction

There is evidence of genuine world climatic warming [1]. The global annual average surface temperature in 2015 is set to reach 1 °C above the pre-industrial average and is predicted to increase by 1.3–1.7 °C by 2050 [2]. Even if the world can reduce global carbon emissions by 2020 to a lower level than that of 1990, the temperature will still increase by 2.0 °C by 2100. Simultaneously, there is another critical issue, food security, associated with global population increase and economic development. For ensuring global food security, world grain production will need to increase by more than 60% from its 2005–2007 levels by 2050 [3]. However, global total crop production increased by only 28% between 1985 and 2005 [4].

Great efforts have been made in the assessment of climatic warming impacts on global crop production. For example, one study showed that even a 1 °C increase in daily minimum temperature would reduce rice yield by 10% [5]. However, other studies show that the effects of climatic warming on crop production will differ by cropping region and crop [6–8]. Global maize and wheat production may decline by 3.8% and 5.5%, respectively, while soybean and rice may remain unchanged owing to a global balance between winners and losers [3]. In some regions at high latitude, climatic warming may benefit crop production [9]. To our knowledge, there are still large uncertainties in the assessment of climatic warming effects on global grain production. Reducing the uncertainty will greatly benefit the development of strategy for innovation in crop production technology and policy for coping with climatic warming. Further efforts still need to be made in the evaluation of climatic warming effects on crop production in specific areas.

China is the largest food-producing and -consuming country, owing to having the highest rates of population increase and economic development. Total grain (rice, wheat, and corn) production in China was 557.2 Mt in 2014, accounting for 19.7% of global grain production. However, total grain and soybean imports were 19.5 and 71.4 Mt, respectively, in the same year [10]. China is becoming the largest grain-importing country in the world. Obviously, a reduction in Chinese grain production will affect food security not only in the country but also in the world. However, a large proportion of farmland in China is highly vulnerable to climate change, owing to limited arable land area and available fresh water, so that even moderate warming may exert a severe effect on crop production [11]. During the past decades, increases in air temperature warming and extreme weather occurrence frequency in China have exceeded the average levels in the world [12]. Thanks to improvement in crop cultivars and innovations in agronomic practices, China has achieved great successes in grain production with a sustained increase rate during the latest, warmest years. For developing strategies for crop production aimed at ensuring food security, it is very helpful to study historical experiences in coping with climatic warming [11]. We have accordingly conducted a comprehensive review based on previous publications and our own investigations of changes in cropping systems in China in recent decades. Our objectives were to summarize climatic warming trends, effects of warming on major staple food crop production, and adaptations of cropping systems in the country, with the aim of providing references for other regions and countries faced with maintaining food security under climatic warming.

2. Evidences and trends of climatic warming in China

2.1. Changes in air temperature

Increasing evidence indicates that climate change in China shows considerable similarity to global change, though there are still some marked differences between the two [12,13]. The country-averaged annual mean surface air temperature has markedly increased over the past 100 years and the change ranged between 0.5 and 0.8 °C [14], slightly higher than the global temperature increase during the same periods. Showing a trend similar to the global warming trend, northern China in the winter season has experienced the greatest increases in surface air temperature.

Based on records of the Chinese Meteorological Administration [15], the annual mean surface air temperature has increased by 1.2 °C over the past 55 years (Fig. 1-a), a greater increase than that of a previous assessment [16]. Especially during the past 20 years over 1994–2014, the mean air temperature increased rapidly, with values of 0.65 °C. Spatial interpolation of mean air temperature trends also shows that northern and northwestern China, high-latitude regions, experienced the greatest—of more than 0.5 °C—increases in surface air temperature over 1960–2014 (Fig. 2-a). However, no clear trend was found in southwestern China, and there was only a slight increase in other parts of southern China. Although there are great differences in warming rates among different cropping regions in China during the past decades, most previous studies and present records show that China has experienced pronounced warming, especially in the last 20 years [12]. Changes in air temperatures may have strongly influenced and will continue to affect cropping systems via effects on crop growth period and the formation of grain yield and quality.

2.2. Changes in annual precipitation

There are large spatial differences in water resource and precipitation availability in China [12]. Southern China receives abundant precipitation and has experienced a moderate increase in air temperature, whereas northern China has a severe lack of effective precipitation and has experienced a strong warming trend. Given that temperature is the key driving force of the atmospheric hydrologic cycle, climatic warming