Impact of Global Warming on China's Agricultural Production

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Abstract: Global warming has had an important impact on China's agricultural production, especially the intensified uneven distribution of water and heat resources and the increased frequency of extreme weather, resulting in a significant increase in the risk of agricultural production. Alleviating a series of negative effects of climate warming on agricultural production has always been the focus of governments and scholars, and it is also the basis of realizing agricultural sustainable development. This paper summarizes the impact of climate warming on China's agricultural production from five aspects: agricultural planting system and structural layout, agricultural diseases and pests, agricultural management, agricultural ecosystem and agricultural production potential. Based on the above specific impacts, the urgent problems faced by China's agricultural production are pointed out, and the countermeasures to reduce the impact of climate warming are put forward from the aspects of policy, technology, research and cooperation, in order to provide references for other governments to deal with the negative impact of global warming, and promote the sustainable development of agriculture.

Keywords: Climate change; hydrothermal resources; extreme weather;coping strategies; sustainable development.

1. Introduction

Due to the influence of human activities, the global climate is experiencing a significant change characterized by warming, which has attracted great attention of the international society and the scientific community. The average temperature is 1.2 °C higher than the pre-industrial period and may continue to rise[1]. The changes of temporal and spatial distribution of water and heat resources will have significant impact on the agricultural system with weak self-regulation ability. This impact is more manifested in negative effects, that is, crop yield reduction, which is a challenge and risk for some regions[2].

China is a sensitive region to global climate change, and the warming rate is higher than the global average level in the same period[3]. The past 20 years have been the warmest period in China since the beginning of the 20th century (Fig.1). High temperature, regional drought and extreme weather could bring a series of uncertain challenges to agricultural structure layout, planting system, diseases and pests, land use and infrastructure construction.

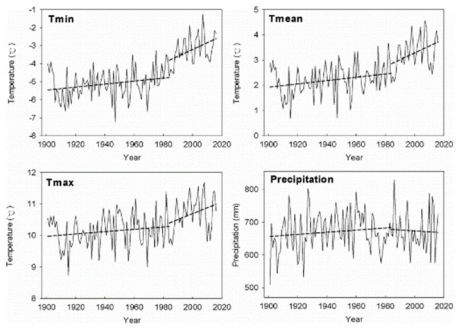

Fig. 1. Variation of annual average minimum temperature (Tmin), annual average maximum temperature (Tmax), annual average temperature (Tmean) and total precipitation from 1901 to 2016.

In recent years, lots of relevant studies[4-7] have repeatedly proposed that crop productivity and yield will change due to the global warming, and the agricultural production pattern in many areas may also change. Because of its special geographical location and topographic characteristics, China's climate change will be more complex under the background of global climate change.In addition, China has a large population, and food security is top priority. Therefore, it is of great significance to explore the extensive impact of global warming on China's agriculture. Summarizing all of the above, the main objectives of this paper were 1) to analyze the impact of climate warming on China's agriculture

production; 2) to put forward the countermeasures for alleviating the negative impacts of climate warming.

2. Impact of climate warming on agricultural production in China

2.1 Impact of climate warming on crop planting areas and cropping systems in China

In the past 60 years, the boundaries of the areas where crops mature twice or three times per year in the South have shifted on average 0.2 longitudes to the West and 0.20 latitudes to the North[8]. Moreover, the area of crops maturing three times per year has expanded, while the area where crops mature once and twice per year has shrunk.

Compared with before 1980, the boundaries of the main planting areas have changed: 1) the southern boundary of the area where crops mature twice per year in the Huang Huai Hai Plain moves northward; 2) the area of wheat and rice maturing twice per year in Jianghuai region moves northward; 3) the northern boundary of the area where crops mature twice and three times per year in Northeast Sichuan moves southward; 4) the western boundary of the area where crops mature twice per year in the Southwest Plateau moves westward; 5) the planting boundary of crops mature twice, three or more times per year in the middle and lower reaches of the Yangtze River moves northward and westward; 6) the northern boundary of crops mature three times per year in South China moved northward; 7) the northern boundary of the safe planting area of tropical crops moved northward by 0.86 latitudes[8-10].

Under the background of global warming, the boundaries of crop planting regions in China will still move northward to a certain extent in the future.

2.2 Impact of climate warming on crop diseases and pests in China

Climate warming is conducive to the safe overwintering of pests and pathogens, and its occurrence generation, wintering northern boundary and distribution range will change. This will further aggravate the instability of China's agricultural production.

Agricultural diseases and pests in Southwest China are mainly affected by sunshine hours, precipitation and minimum temperature in winter. The area affected by diseases and pests in this region is negatively correlated with the sunshine hours, which the longer the sunshine time, the more unfavorable to the outbreak of agricultural diseases and pests. The lower the minimum temperature in winter, the more unfavorable to the overwintering of pathogens and pests. The trend of climate warming in Southwest China is conducive to the occurrence and development of agricultural diseases and insect pests.

In recent years, the temperature in Northwest China has increased significantly, and the precipitation also has increased in some areas, which showed a warm and humid trend. Excessive rainfall and the increase of relative humidity contribute to the occurrence and development of some diseases (wheat stripe rust, wheat scab and so on), but will inhibit the expansion and spread of aphids, cotton bollworms and other pests. Climate warming will aggravate the occurrence of diseases and pests in this region.

The Yangtze River Basin is one of the main rice producing areas in China. Temperature and relative humidity are the main factors affecting the outbreak of agricultural diseases and pests in this region. The increase of temperature, especially in winter, is conducive to the safe overwintering of pathogens and larvae.

North China is one of the main grain producing areas in China. The outbreak of agricultural diseases and pests are mainly affected by precipitation, temperature and sunshine hours. Under the global warming background, the reduction of precipitation and the increase of temperature are conducive to the occurrence and development of diseases and pests in this region.

The temperature in Northeast China rises obviously, with a trend of warming and drying.Warming in winter will shorten the dormancy period of pests, increase the survival rate of pathogens and larvae, and expand the distribution area of pests, which will lead to the increase of reproduction generations of pests in a year and endanger local agricultural production.

2.3 Impact of climate warming on agricultural ecosystem in China

Climate change can also affect agricultural production by affecting agroecosystems[11,12], as shown in the following aspects: 1) affect soil nutrient reserves and their availability. The warming and drought in North China and Northeast China will accelerate the decomposition of soil organic matter and soil mineralization, cause soil nutrient loss, and directly affect the accumulation of soil organic carbon and GHG emissions; 2) affect soil carbon and nitrogen cycle and soil C/N. Climate warming could promote soil respiration, accelerates nutrient turnover in farmland, changes the ratio of C/N and soil microbial community structure. The increase of CO2 concentration leads to the enhancement of nutrient absorption by stimulating crop growth, and inhibits the potential productivity of agroecosystems and the function of soil carbon sink; 3) affect the biodiversity of agroecosystems. Climate warming will change the input mode of alien pests, pathogens and weeds, and provide new opportunities for the input of alien invasive species. This will pose new challenges to the management of diseases, pests and weeds in agroecosystems[13].

2.4 Impact of climate warming on agricultural management in China

Climate warming will also affect agricultural management and increase agricultural investment, which is reflected in the following aspects[14-18]:

1) climate warming increases the water consumption per unit area and increases the irrigation costs;

2) climate warming and drying promote weed growth and affect crop growth, increasing the weed management costs;

3) the epidemic of agricultural diseases and pests caused by climate warming will increase the use of pesticides and control costs;
4) the increasing impact of extreme climate on agricultural production has become an important factor in the substantial grain yield reductions in China, resulting in a further increase in the cost of prevention.

2.5 Impact of climate warming on agricultural production potential in China

The impact of climate change on agricultural production mainly depends on the increase of temperature, precipitation distribution pattern and the physiological response of crops to the increase of CO2 concentration. Climate warming can prolong the growth period of some crops, which is beneficial to the growth of perennial crops and crops in areas with insufficient heat. However, the increase of temperature also can accelerate the growth and development processes of some crops, resulting in poor fruit development and the decline of fruit yield and quality[19].
The rice yield in South China decreased with the increase of temperature, and the decline range of yield increased with the acceleration of temperature increase. The wheat yield will decrease by 3% ~ 10% when the temperature increases by 1°C during the growing season[9]. In the Huang Huai Hai Plain, warm winter will accelerate the growth process of wheat and increase the probability of freezing injury caused by cold weather in late spring[20]. Climate warming may prolong the growth period of crops in Northeast China and reduce the frequency of low temperature disasters and frost, which has a positive impact on agricultural production. Without considering cultivars, social economy and other factors, based on the current actual yield level of crops, the average grain yield will increase by more than 50% and 20% when crops mature once per year into twice per year and twice per year into three times per year, respectively[10] (Fig.2).

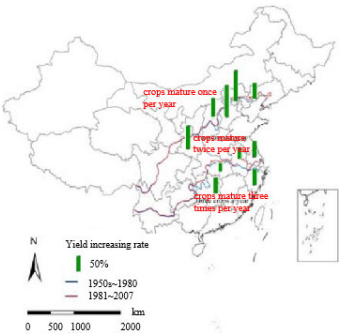

Fig. 2. The changes in planting north boundary and crops yield[10].

With the increase of atmospheric CO2 concentration, the potential production capacity of rice, rape, corn, potato and winter wheat in eastern China will be improved[21]. In the eastern part of Northwest China, precipitation decreased while evaporation increased, and large-area drought events occurred frequently, resulting in a significant decline in crop yield in some areas[22]. Overall, climate warming has a negative impact on agricultural production in North China, Southwest and Northwest China, but has no significant impact in Southeast and Central South China[23].

3. Countermeasures of China's agricultural production for climate warming

In order to cope with the damage caused by climate warming to agriculture, engineering technology, management technology, cultivation technology and breeding technology have been developed (Table 1).

Table 1 Agricultural measures for coping with climate warming

Affected areas	Technologies	Measures
arid and water-deficient areas	1)dry farming technology 2)agricultural water saving technology	1)breeding of drought resistant varieties; 2)water-saving irrigation technology
flood-prone areas	irrigation and drainage engineering technology	1)water storage technology 2)levee or spillway systems
pest infested areas	pest control technology	1)ecological control technology 2)chemical pesticide control techniques
areas with increased heat	1)planting structure adjustment 2)variety improvement technology	1)northward movement of planting boundary 2)hybrid breeding
Areas with frequent extreme weather	1)extreme-weather forecasting technology 2)agricultural management measures	1)extreme-weather forecasting system 2)mulching measures

3.1 Adjusted the agricultural planting system and structure layout

Under the influence of climate warming, heat resources in some areas become more abundant. Different patterns of crop intercropping, rotation and multiple cropping can be used to make full use of water and heat resources[24]. In arid or semi-arid areas where water resources are scarce, the local water resource utilization efficiency can be improved by reducing the planting area of high water consuming crops and increasing the planting area of

drought resistant crops. The agricultural planting structure can also be adjusted according to the sensitivity and vulnerability of different regions to climate warming. For example, as the planting area boundary of overwintering crops and thermophilic crops moves northward and expands, the planting proportion and area of crops can be adjusted appropriately to improve the land use efficiency.

3.2 Created new cultivars

As one of the applied strategies, crop cultivars breeding can effectively reduce the adverse impact of climate warming on agricultural production[25]. New cultivars can be created from the perspective of climate warming, including middle and late maturing cultivars, drought tolerant cultivars, early maturing cultivars after disaster, disease and insect resistant cultivars, etc. Under the condition of abundant heat resources, some early maturing cultivars and some cultivars with weak cold resistance can be replaced by middle and late maturing cultivars and cultivars with strong cold resistance, so as to increase the yield potential. In arid or semi-arid areas, it is necessary to replace high water consumption cultivars with drought tolerant cultivars. In areas with frequent weather disasters or outbreaks of diseases and pests, high yield-quality cultivars with strong stress resistance, high light efficiency and strong disease and pests resistance can be cultivated and developed.

3.3 Improved the agricultural infrastructure construction

1) Irrigation and water conservancy infrastructure needs to be built and consolidated.

In view of the uneven distribution of water resources in different regions, the construction of water conservancy projects should be carried out according to local conditions[26]. The summer precipitation in Eastern China is relatively concentrated, so reservoirs could be built in mountainous and hilly areas to store precipitation in preparation for drought. The drought in mountainous and hilly areas of South China is relatively serious, the construction of water conservancy projects such as small reservoirs, pools and water cellars should be strengthen. The water resources in Northwest China are scarce, so more water conservancy projects for rainwater collection and irrigation should be built.

2) Strengthen the construction of Agrometeorological infrastructure.

Through the establishment of agrometeorological disaster monitoring and early warning system, the prevention ability to deal with short-term, long-term and sudden disasters can be improved. The government can formulate emergency plans before some disasters, and timely guide farmers and relevant departments to respond correctly. Farmers can also adjust the planting plan or harvest in time according to the government's forecast to reduce the loss of agricultural production.

3.4 Strengthen scientific research on agricultural response to climate warming

The research on agricultural response to climate warming needs to focus on global climate change, fully learn from the research results of different regions and countries, and establish a scientific and systematic basic research system to strengthen the ability to deal with the impact of climate warming on agriculture[27,28].

1) Strengthen the research on agricultural regional planning and planting system, as well as excellent cultivars and tillage technique to adapt to climate warming. Strengthen research on water-saving agriculture, rainwater harvesting agriculture, dryland agriculture and integrated pest control technology.

2) Strengthen the research on coping with extreme weather disasters, establish and improve the monitoring and early warning capacity of agricultural climate disasters, so as to improve the ability of agriculture to cope with climate warming and reduce the losses caused by climate disasters.

3) Strengthening the research on carbon sequestration and emission reduction technologies of agroecosystem. The enhancement of carbon sequestration capacity of cultivated soil is helpful to alleviate the greenhouse effect.

4. Summary

Improving the adaptability of agricultural production to climate warming is of great significance to ensure national food security and realize comprehensive rural revitalization. By combing the problems faced by China's agricultural production under climate warming, we recognize its vulnerability. We need to make efforts to increase agricultural capital investment, innovate practical technologies, continue to carry out relevant research and strengthen international cooperation, and formulate more reasonable agricultural management measures on this basis, so as to effectively alleviate the impact of climate change on agricultural production and realize the sustainable development of agriculture.

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