Introduction to Advances in Climate Change Adaptation Research for Chinese Agriculture

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Abstract
In this paper, we firstly introduced how to calibrate the high-resolution (~50km in horizon) climate scenarios of climate model's original outputs in China with mesh climatological database generated using the interpolation method of Moving Least Squares (MLS), then introduce how to identify the priority adaptation issues based on the risk assessment with the help of the calibrated high-resolution climate scenarios. The clarified agricultural adaptation issues address how to utilize the agro-climatic resources and agricultural water resources in the high-efficiency ways, how to adjust the strategy and measures to reduce the agro-meteorological and biological disasters, and moreover how to adjust the cropping systems, grassland and livestock systems, and the agricultural ecosystem in coherence with the altered climate conditions. Nine typical adaptation examples in China were selected for case studies to summarize the incremental and transformational adaptation pathways. The perspectives on the future adaptation actions in China are proposed, especially with the emphasis on the application of System Approach methodology to unearth the theoretical mechanism of agricultural adaptation to climate change, and how to formulate the guideline for the monitoring and evaluation of implementation of adaptation actions.

Introduction

Anthropogenic climate change poses great threats to human beings, agriculture and natural ecosystems. While coping with human-induced climate change, measures should be taken not only on the level of mitigation but also on the level of adaptation. It is essential for us to understand the risks of future climate for trade-off decisions on mitigation and adaptation.

Greenhouse gases (GHGs) emission scenarios from the present to the end of the 21st century have been developed, typically as the GHGs emissions assumptions in the *Special Report on Emissions Scenarios* (SRES) [1] and *Representative Concentration Pathways* (RCPs) [2]. Then the predicted atmospheric GHGs concentrations were fed into global climate models (GCMs) to project the future trends in climate change. These generated climate scenarios were adopted as input to the impact models to assess the risk to key sectors, e.g., climate change risks to agriculture. For the assessment of agricultural impacts of climate change, the resolution of the grid in the GCM model (on the scale of approximately hundreds of kilometers in horizon) is not precise enough to meet the requirements in regional and local levels. Downscaling techniques are employed to convert the GCM coarse resolution scenarios to a higher resolution. The PRECIS (Providing Regional Climates for Impacts Studies) [3] modeling system, which is developed in the UK Hadley Climate Centre, was introduced in China for dynamic downscaling. However, how capable it is for the PRECIS modeling system, there would be a bias between the simulation and the observed climate, causing uncertainties in the future impact assessments. In the following context, we firstly demonstrate how to use the mesh climatological database[4] to calibrate the model's simulation for the baseline (1961–1990) and how to apply the calibration methodology to future climate scenarios for future risk analysis in section 1, then introduce the research advances on the critical issues regarding China's agricultural adaptation to climate change based on the risk assessments in section 2, and finally discuss the shortcomings of the present agricultural adaptation research and what are the future trends in section 3.

1 Calibration of the Baseline Climate Simulation

The simulation domain for PRECIS has been demonstrated in reference [5]. All analyses regarding the risk assessment presented in this paper is based on climate scenarios under the SRES A1B GHGs emissions assumption. The bias of the original output of model simulation minus the observed climate is shown in Figure 1a and b. The bias in temperature simulation ranges from –3 to 3℃, which could be nearly equal to the amplitude of global warming at the end of the 21st century in the RCP8.5 scenario [6]. Meanwhile, the bias of precipitation can reach –0.3 mm/day to 0.2 mm/day, which means that the bias of annual precipitation could be ~100 mm. If the original outputs of climate scenarios are applied directly to the crop model, big deviations would be caused for the agricultural impacts assessment. Calibrated climate scenarios in Figure 2a and 2b indicate that the bias is greatly reduced.

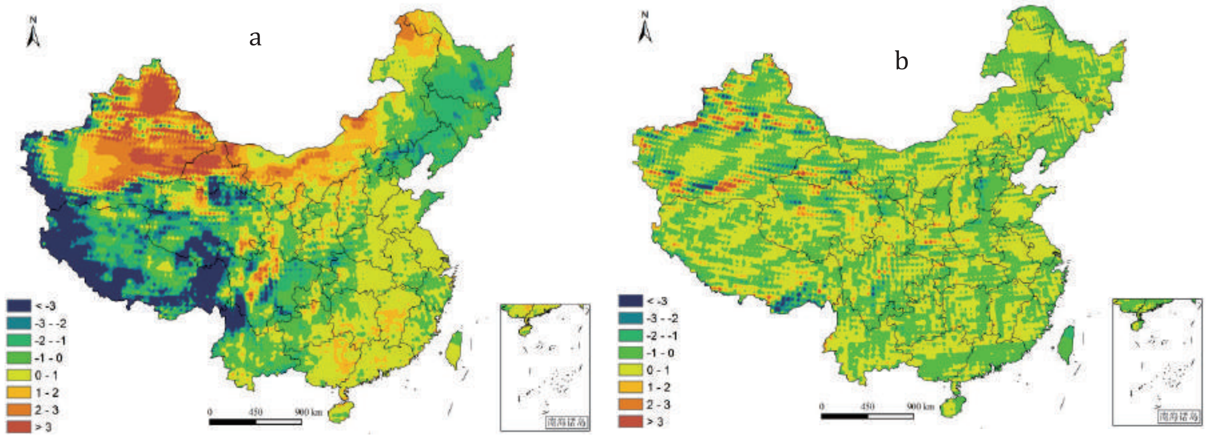

Figure 1 Comparison of the model's original outputs and the calibrated results for temperature (a) the bias of original model's outputs of temperature minus the observed values in baseline period (1961-1990); (b) calibrated model's outputs of temperature with MLS-generated mesh climatological datasets minus the observed values in baseline (Unit: ℃)

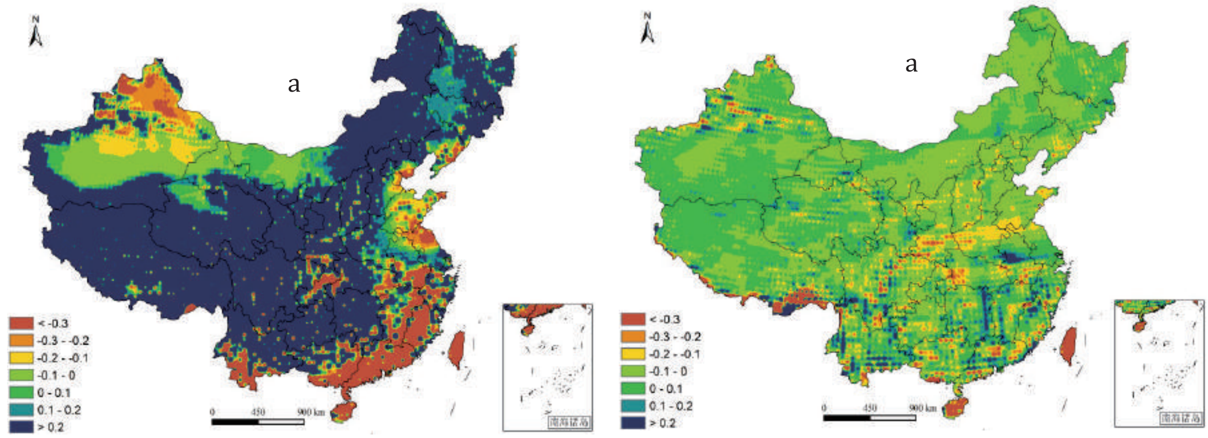

Figure 2 Comparison of the model's original outputs and the calibrated results for precipitation (a) the bias of original model's outputs of precipitation minus the observed values in baseline period of 1961-1990; (b) calibrated model's outputs of precipitation with MLS-generated mesh climatological datasets minus the observed values in baseline (Unit: mm/day)

2 Priority Adaptation Issues in Agriculture

The calibrated climate scenarios were adopted for agricultural risk assessment of future climate change. Adaptation issues were clarified based on the risk mapping. Systematic analyses had been done in China to identify the priority adaptation issues in agriculture. This section summarizes the advances in the layers of background, utilization of agro-climatic resources and agricultural water resources, reduction of agro-meteorological disasters and biological disasters, adjustments of cropping systems and grassland & livestock as well as agricultural ecosystem, and the case studies and perspectives on future work [7].

Background

Changes in the average trend and extreme climate events were initially analyzed based on the recorded climate in the past decades and projections of future climate until the end of the 21st century under GHGs emission scenarios, then the impacts of climate change on Chinese agriculture is estimated for the bio-physical component. Subsequently, the present vulnerability and future risks of Chinese agriculture to climate change considering the socio-economic factors were assessed, and the effects of the adopted adaptation measures for reducing the vulnerability and risks were evaluated. Moreover, future challenges and potential opportunities for Chinese agriculture to adapt to climate change were envisaged.

Utilization of Agro-climatic Resources

First, the features of China’s agro-climatic resources under climate change were summarized, including heat, radiation, and water resources. Changes in the productive potential of main crops under climate change in different areas were assessed, especially focusing on changes in the multi-cropping index, suitable planting boundaries of winter wheat, double and triple rice, summer maize, and tropical crops.

Agricultural Water Resources

Impacts of climate change on China’s agricultural water resources can be sorted into direct and indirect impacts. Direct impact occurs due to changes in climatic factors, while the indirect impact is quite complex, involving the freshwater ecosystem, management, technology, and the regionalized distribution as well as the interaction with the crop layouts. All these factors were put together to clarify the priority adaptation issues for agricultural water resources.

Agro-meteorological Disasters

The frequency, intensity, and damage extent of agro-meteorological disasters were presented with new features due to the enhanced occurrence of extreme climate events and unreasonable human actions along with the development of social economy. The principle for clarifying the priority adaptation issues is combining the factors of crop, climate and human activities together, and always adjusting the disaster reduction countermeasures according to the new features of agro-meteorological disasters.

Agricultural Diseases, Pests and Weeds

Many new features in crop disease, pests and weeds arise from climate change. These include the following: advances in initial and outbreak periods of disease and pest, increased number, generations and extended range of pests, prolonged damage periods and increased damage areas, aggravated harm degrees due to the outbreak of the former less important diseases, pests, and weeds, etc. Besides the use of pesticides, monitoring, planning, and controlling the biological invasion, and other biological measures should be considered in the comprehensive adaptation actions.

Adjustment of Cropping System Structure

According to the definition in the IPCC (Intergovernmental Panel on Climate Change) report, adaptation is a process of adjustment to actual or expected climate and its effects [8]. Adjustment of the cropping system structure is an essential component for Chinese agriculture to adapt to the climate change, but it is also a quite complex issue. We simplified our summary of the issues to include the following: increase in cropping index, changes in intercropping and proportions for cropping patterns, northward expansion and transformation of layout for crop planting, and adoption of late-matured, stress-resistant (drought, chill, heat waves, etc.) crop varieties for the crop variety layout.

Grassland and Livestock

The adaptation should address the following factors: changes in the phenophase of grassland, reduction of biomass, loss of grassland biodiversity, direct impacts of climatic variables on livestock, desertification of grassland, snow disasters and chilling damage, drought, cold rains in spring, grassland fires, pests, rodents, and harmful weeds, etc. Specific adaptive features in China were highlighted for off-site fattening of livestock, and combination of farming and animal husbandry in the agriculture-pasture eco-tone.

Agro-ecosystem

The challenges facing adaptation of the agricultural ecosystem include the following: alteration of nutrients of cereal food due to the elevated CO_2 concentration, impacts on food production and quality due to soil and water deterioration, changes in the temporal and spatial distribution and structure of the agricultural ecosystem, enhanced soil erosion, desertification, agricultural pollution, and loss of agricultural biodiversity.

Case Studies

Typical examples of autonomous adaptation actions already accomplished in China were selected for case studies. These include frost prevention for winter wheat and water-preservation in North China Plain, adjustment of the crop varieties layout in Northeast China, rain harvesting for drought-resistant crop planting in the Loess Plateau, shift of cotton production from North China Plain to Xinjiang, selenium sand melon planting in Ningxia in Northwest China, adjustment of planting structures in the hilly region of Sichuan Province in Southwest China, agricultural development in Tibet River Valley, and northward expansion of tropical crops. Based on these case studies, the features and criteria for incremental and transformational adaptation actions were summarized.

Perspectives on Agricultural Adaptation

Summarizing the abovementioned analyses, a list of priority adaptation issues of Chinese agriculture was formulated, and the putative bottleneck is proposed to be the theoretical mechanism for undertaking of the effective adaptation actions. Therefore, a systematic adaptation methodology should proceed to lead theoretical innovation, and then provide guidelines for the monitoring and evaluation of adaptation actions. Methods for strengthening the decision-making for adaptation and enhancing the risk management for agricultural adaptation are also proposed.

3 Discussion and Looking Forward

In the present paper, advances in agricultural adaptation research are introduced. An initial step for the work is risk assessment, which is based on the simulated high-resolution climate scenarios with calibration using the mesh climatological database generated with the MLS method. Our work mainly focuses on cereal crops, grassland and livestock, and agro-ecosystems. We propose for the priority adaptation issues mainly to address the following aspects: utilization of agro-climatic resources and agricultural water resources, reduction of agro-meteorological and biological disasters, adjustments of cropping systems, grassland and livestock, agricultural ecosystem. The work still lacks in terms of analysis of cash crop, horticulture, aquaculture, agricultural eco-services such as eco-tour, and the tertiary industry for market, insurance, food processing, storage, transportation, and consumption. The research is also needed to strengthen on the evaluation of the cost-effectiveness of adaptation measures, and subsequently to promote wider and more effective adaptation actions for Chinese agriculture.

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