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Editorial

Modeling the Adaptation of Agricultural Production to Climate Change

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Climate change and its impacts on agricultural production and food security are a significant source of public concern around the world. In order to reduce the negative impacts of climate change on agriculture, maintain crop production levels, and even discover opportunities in agricultural intensification, researchers have made great efforts to assess changes in agricultural climate resources and develop adaptation measures in different growing areas of the world experiencing climate change. Modeling is a key tool for exploring the impacts of climate change on agriculture and proposing adaptation strategies. Currently, the two main fields where further progress is required include a more mechanistic understanding of climate impacts and management options for adaptation and mitigation, and a focus on cropping systems and integrative multiscale assessments instead of single season and crops. Therefore, establishing closer links between experiments and statistical and/or eco-physiological crop models may not only facilitate the necessary methodological advances but also achieve the above goals.

With these goals in mind, we have organized this Special Issue "Modeling the Adaptation of Agricultural Production to Climate Change (MAAPCC)". The Special Issue of MAAPCC has a total of 21 papers [1–21], and papers were submitted from five countries: China, Japan, Thailand, Iran, and South Africa. Moreover, the Special Issue covers a wide range of plants, including not only grain crops such as maize [15], rice [6,10], wheat [2,4,16], and soybean [14], and cash crops such as cotton [7] and sugarcane [3], but also the apple tree [1] and traditional Chinese medicinal plants such as Rheum nanum (*R. nanum*) [17]. In terms of the research time scale, the Special Issue not only focused on climate change and its impact in the historical period, but also analyzed the impacts of different climate scenarios on plant distribution, crop production, and climatic resources in the future in 10 papers [1,6,8,12,14–17,19,20], and some of the papers adopted the latest climate scenario data, namely Shared Socioeconomic Pathways (SSPs) from the Coupled Model Comparison Program (CMIP6). As for the research methods, these papers not only use the traditional statistical analysis methods, but also involve the widely used crop mechanism models, including the Agricultural Production Systems Simulator (APSIM) [2], the Crop Environment Resource Synthesis (CERES)-Wheat [4], CERES-Rice [6], the denitrification-decomposition (DNDC) [12], the integrated climate–hydrological–economic model [13], CROPWAT [14], and Environmental Policy Integrated Climate (EPIC) [15]. In addition, part of the papers also used the current, more popular, machine learning method for analysis and prediction [2,18]. Overall, the papers in the Special Issue of MAAPCC were grouped into three categories: assessment of climate resources in the context of climate change [5,7,8,14,19,20], assessment of the impact of climate change on crop production [1,3,10,13,15–17], and some methodological studies related to climate change [2,4,6,9,11,12,18,21].

The first category has six papers under the following sub-heading: assessment of climate resources in the context of climate change.

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Generally, evaluating the response of evapotranspiration to climatic change can provide theoretical support on the optimal allocation of regional water resources and agricultural water management under climate change. In the two papers in this section, the trends and climatic causes of potential evapotranspiration (ET_0) in Heilongjia Province from 1960 to 2019 [5] and in the Xinjiang Autonomous Region of China from 1957 to 2017 [7] have been quantitatively assessed, and the results suggested that historical climate change has had significant impacts on regional ET_0 and will further affect crop water demand and consumption. Moreover, the paper by Li et al. [14] investigated the spatial and temporal distribution of ET_0, crop water requirement (ET_C), irrigation water requirement (I_r), effective precipitation (P_e), and the coupling degree of ET_C and P_e for soybean during the growth period for the future period from 2021 to 2080 in Heilongjiang Province, China.

Assessing the climatic suitability of crops is critical for mitigating and adapting to the negative impacts of climate change on crop production. The paper by Zhao et al. [20] developed a climate suitability model of maize and investigated the climate suitability of summer maize during the past and future periods in the North China Plain. The paper by Nooni et al. [19] investigated the future changes in drought events for four SSPs in the African continent. The projected wetter trends in humid areas may benefit agricultural production and ecological conservation, and the drier trends in non-humid areas may require appropriate drought adaptation strategies and development plans to minimize impacts [19]. The last paper in this section was from Shi et al. [8], which proposed a land use/land cover (LULC) simulation framework from 2000 to 2030 for four different development scenarios in the Xinjiang region. This study stated that both the supply and demand of carbon stock in Xinjiang would increase in 2025 and 2030, with the demand exceeding the supply [8].

The second category is the assessment of the impacts of climate change on crop production.

There were seven papers exploring the effects of climate change on crop (or plant) distribution and production. In general, climate change plays an important role in the distribution of suitable zones of plant cultivation. In the two papers in this section, the potential distribution of suitable habitats and range shifts of apple trees in the near present and near future (i.e., the 2030s and the 2050s) under two climate scenarios (i.e., SSP126 and SSP585) was simulated based on three pieces of software (the maximum entropy model, IDRISI, and ArcGIS) [1], and the potential distribution of *Rheum nanum* (*R. nanum*), a famous traditional Chinese medicinal plant, was developed for three periods (current, 2050s: 2041–2060, and 2070s: 2061–2080) using MaxEnt and ArcGIS [17]. These two studies may improve our understanding of the effects of climate warming on plant distribution and could be useful for relevant agricultural decision-making. In addition, the paper by Wu et al. [16] determined the planting boundary of winter wheat in north China for the future period based on four critical parameters of percentages of extreme minimum temperature years (POEMTYs), first day of the overwintering period (FD), sowing date (SD), and precipitation before winter (PBW).

Currently, a large number of studies focus on the effects of climate change on crop yields and/or production. The paper by Choruma et al. [15] assessed the effects of future climate change on maize yield in the Eastern Cape Province of South Africa, and indicated a decrease in maize production for two future periods (mid-century (2040–2069) and late century (2070–2099)). The paper by Shayanmehr et al. [13] constructed a new integrated climate–hydrological–economic model to assess the impact of future climate change on water resources and crop production. The findings noted that in the majority of cases, crop production will reduce in response to climate scenarios so that rainfed wheat will experience the greatest decline (approximately 59.95%) [13]. Zhang [10] analyzed the spatiotemporal change in heat stress and its impacts on rice growth in the middle and lower reaches of the Yangtze River, China, and indicated that the change in heat stress is attributed to climate changes and extreme meteorological events. The last paper in this section was from Yao et al. [3], which comprehensively assessed multiple sugarcane agrometeorological disasters with regard to sugarcane yield in Southern China. The results suggested that the yield-reducing effect of sugarcane flood was more obvious than that of drought [3].

The last category is some methodological studies related to climate change.

To meet the challenges of climate change and the increasing food demand, an accurate, timely, and dynamic yield estimation of regional or global crop yield is critical to food trade and policy-making. In the two papers in this section, the winter wheat yield in the North China Plain [2] and in China [18] was accuracy predicted by coupling the crop model with machine learning algorithms based on multi-source data. These findings indicated that the prediction model can be used to develop adaptation strategies to mitigate the negative effects of climate change on crop productivity and provide the data support for food security. Moreover, the paper by Zheng et al. [6] used a process-based crop model (CERES-Rice) which was calibrated and validated based on experimental data from the Songnen Plain of China, and driven by multiple global climate models (GCMs) from the CMIP6 to predict rice growth period, yield, and light and heat resource utilization efficiency under future climate change conditions. The results showed that optimizing the sowing date could make full use of climate resources to improve rice yield and light and heat resource utilization indexes under future climate conditions [6]. In addition, the CERES-Wheat model was applied to investigate the optimal irrigation amount for high yield, water saving, and the trade-off between high yield and water saving of winter wheat in the North China Plain [4]. Therefore, crop mechanism models play an important role in assessing the effects of climate change on crop production and proposing effective coping strategies. In the future, we need to continuously develop crop models to improve the effectiveness and versatility of their simulation.

In this section, three papers developed models or devices to simulate or observe greenhouse gas emissions from agricultural processes, which have made a significant contribution to climate warming [9,11,12]. In the paper by Salehi et al. [11], two types of data-driven models were proposed to predict biogas production from the anaerobic digestion of spent mushroom compost supplement with wheat straw used as a nutrient source. The paper by Yi et al. [12] evaluated crop yields, nitrous oxide (N_2O) emission, and soil organic carbon (SOC) in a typical wheat–corn rotation system field on the North China Plain on a 50-year scale using the denitrification-decomposition (DNDC) model, and proposed adaptive strategies for each climate scenario. Moreover, a gas diffusion analysis method for simulating N_2O surface flux from soil gas measured in a soil-interred silicone diffusion cell using a low-cost device was developed by Bandara et al. [9]. The last paper in this section was from Huang et al. [21], which evaluated the accuracy of three reanalysis temperature data systems (e.g., the China Meteorological Administration Land Data Assimilation System (CLDAS), the U.S. Global Land Data Assimilation System (GLDAS), and the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis Version 5 (ERA5)-Land) across China. The results indicated that the CLDAS product demonstrated a relatively high reliability, which was of great significance for the study of climate change and forcing crop models [21].

In summary, this Special Issue focuses on the quantitative assessment of the impact of climate change on agricultural production based on multi-source model simulation and reveals the role and mechanism of improved management measures in adapting to climate change. It is expected that insights derived from this Special Issue will be helpful for relevant decision-makers in the areas of agricultural adaptation and food security.

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