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*Editorial*

# Climate Change Impacts and Strategies for Mitigation and Adaptation in Agriculture

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Agriculture is highly vulnerable to climate change-induced shifts in means, variability and extremes. The climate is evolving and agriculturalists need to foresee future sensitivities and develop/promulgate adaptation strategies such as improving cultivar tolerance to high temperatures and changing crop timing. Meanwhile, the IPCC shows that agriculture and land use accounts for nearly 30% of total emissions, contributing over 50% of the global anthropogenic non-CO2 greenhouse gas (GHG) emissions [1]. Thus, in the long run, agriculture also needs to be a partner in a global mitigation effort. In planning, mitigation–adaptation synergy is also relevant. Hence, advancing the understanding of the potential impacts of climate change, as well as the implications of possible adaptation and mitigation strategies is important for science, policy and stakeholder communities.

In this Special Issue on "Climate Change Impacts and Strategies for Mitigation and Adaptation in Agriculture", six original research articles report recent findings describing: the impacts of climate change on crop yields; adaptation and mitigation strategies; and valuing the benefits of climate and weather information. The papers span a wide range of investigations. The first article focuses on Pearl River Delta, China climate change impacts on rice and optimal adaptive options under global temperatures reaching 1.5 and 2.0 °c [2]. The second and third papers consider the historical and current impacts of climate change and possible adaptation options in the Central River Gambia [3] and Jilin Province, China [4]. The fourth paper projects the effect of agricultural technological progress, bioenergy policy, and agricultural demand growth on crop, livestock, bioenergy markets, allocation of land use and GHG emissions in the United States (U.S) [5]. The last two articles value the benefit of providing public climate and weather information services for agricultural planning in the U.S. and Taiwan, respectively [6-7].

This editorial provides highlights of articles. In the first piece, Guo et al. [2] employs the Ceres-Rice Model using site-specific information of climate and soils. An interesting feature of this paper is the incorporation of CO2 fertilization and optimal adaptive rice management. The paper projects major negative impacts on rice at all study sites. They find that the flowering and maturity durations will be reduced under 2.0 °C warming as compared to 1.5 °C warming. The yields for early maturing and late maturing rice are projected to be reduced respectively by 292.5 and 151.8 kg/ha under 1.5 °C warming, while they are projected to fall by 558.9 and 380.0 kg/ha under the 2.0 °C scenario. The study finds that the positive impacts from CO2 fertilization do not compensate for the total damage from climate change. Moreover, they find adjusting the planting dates to be eight days later for early maturing and 15 days earlier for late maturing rice are optimal adaptive options. In addition, they indicate that farmers should add 240 kg/ha of fertilizer to obtain the highest rice yields in this region of China.

In the second paper, Zhao et al. [3] estimate the impact of climate change on crop yield focusing on spring maize in Jilin Province, China, which is the Chinese "golden corn belt". This study uses daily weather data from 50 meteorological stations and annual statistics on county level maize yield and planted area. The strength of this paper is the use of high-stability of meteorological yield to improve statistically significant climate indicators. Moreover, the paper divides the crop yield into two types: short-term meteorological yield fluctuation and crop longer term management-induced crop yield. They find maize is beginning to relocate with late-maturing varieties moving north and east, while the areas exhibiting higher yields have moved eastward. Such a northward shift was also observed for U.S. maize [10]. Moreover, they indicate that the eastern region has dependable sunshine in September, while the western region is strongly influenced by the number of sunshine hours. Also, they find climatic suitability is mostly affected by extremes (i.e., drought and chilling), especially in the eastern and western regions. They recommend that future research incorporate extremes in suitability assessments.

In the third piece, Bagagnan et al. [4] uses farm-level data in the Central River Region of the Gambia to examine farmer perceptions of climate variability and use of adaptation measures. They indicate that the region rainfall is irregular and unpredictable. This paper contains several interesting aspects. The first aspect is the study location which is considered as the "food basket" of the Gambia. The second is the focus on how farmers perceive their exposure to climatic change and possible losses. The third aspect is the investigation of farmers' preferences regarding the cost and effectiveness of adaptation measures. Lastly, the study combines data collected from farm households through transect walks and focus group discussions. Several important findings arise, for example, a majority of their sampled farmers perceive an increase in heat and extremes and that they are vulnerable to drought as also found in India, Burkina Faso, and Myanmar [11-13]. Next, while the use of chemical fertilizers is the most expensive adaptative measure, a majority of the sampled farmers believe that it is the most effective measure. They also find smallholder farmers are more likely to apply chemical fertilizers than are large-scale ones. Finally, they find that farmers only apply chemical fertilizers when they expect favorable weather conditions and that crop rotation is the most implemented adaptation measure.

In the fourth paper, Kapilakanchana and McCarl [5] consider the role of agricultural technological progress and the use of bioenergy as a mitigation option in the US. The paper examines scenarios that simultaneously vary agricultural technological progress, the US renewable fuel standard (RFS), and agricultural demand growth as they influence crop, livestock and bioenergy markets; land use allocation; and greenhouse gas (GHG) emissions. They employ econometric models with several functional forms to investigate the role of technological progress on the major crop yields. Then, nine main scenarios are simulated using a dynamic simulation model. Several interesting findings arise. For example, the article reveals that technological progress negatively influences land use for biofuel and pasture, while it positively affects land use for crop production. Also, they find the prices of most crops will increase over time (except for soybean), whereas the broiler price is projected to increases after 2020. Moreover, technological progress of main field crops does not statistically determine their prices. In addition, increasing technological progress tends to reduce overall GHG emissions. This finding is supported by Khanna et al. [14] who found that the bioenergy from corn has a lower carbon intensity than gasoline and technological improvements have made bioenergy from corn increasingly competitive. Finally, they indicate that technological improvement is a key factor in meeting growing global demand for food and energy and reducing emissions. Their study provides a key takeaway to policy makers that technological improvement is a greenhouse gas mitigation approach.

The last two articles estimate the benefit of publicly provided climate and weather information. Specifically, Rhodes and McCarl [6] estimate the value of ocean-related decadal climate variability (ODCV) information in the U.S. going beyond previous studies that mostly evaluated the value of forecasts for El Niño Southern Oscillation (ENSO). An interesting feature of this paper is combination of the econometric panel data yield models with s stochastic agricultural sector nonlinear optimization model. The paper firstly econometrically estimates crop yield impacts and, in turn, the value of releasing ODCV information on crop yields with eight joint ODCV phase combinations. Then, the authors plugged in the changes in crop yields into a US wide agricultural sector model. The methods used in this study can easily be adjusted to handle different indices and extended to evaluate the economic benefits of other systematic weather influencing phenomena. The study $86 million annual gains when using conditional forecasts and welfare gains of $1.1 billion annually under perfect forecasts. Therefore, they indicate that public spending on ODCV information is likely merited.

Lastly, Lin et al. [7] estimate the economic value of meteorological information services for Taiwanese farmers from a study over 400 registered farmers in 20 municipalities. They use a contingent valuation method. Their study provides new contributions to the literature in using nonmarket valuation mechanisms to elicit information on economic value of the Taiwanese meteorological information service. This article also shows how to construct a calibration model that reduces starting point bias for censored data. The study reveals that agricultural producers' willingness to pay (WTP) is determined by weather forecast accuracy, farm size, and first bid price. Moreover, they find that annual WTP ranges from 56.06 US dollars to 90.92 US dollars and in turn that the annual economic value of meteorological information services for agricultural producers in Taiwan is between 28.06 and 45.51 million US dollars.

Collectively, this group of articles updates the reader on the impacts of climate change on crop yields, possible mitigation and adaptation options for several regions, use of modern techniques, models and unique data. We thank the authors for their excellent contributions and hope that this special issue stimulates ideas, collaboration, and a means to move us forward toward a more resilient agriculture that can better cope with a changing climate.

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