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*Editorial*

# Sustainability with Changing Climate and Extremes

**Shaofei Jin [1], Jia Yang [2] and Xiaodong Yan [3,*]**

1 Department of Geography, College of Geography and Oceanography, Minjiang University, Fuzhou 350108, China
2 Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, OK 74078, USA
3 State Key Laboratory of Earth Surface Processes and Resource Ecology, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China
* Correspondence: yxd@bnu.edu.cn

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Climate change and extreme events are receiving increasingly more attention in the global sustainable development sphere. Identifying the impacts of climate change and extreme events is not only important in terms of natural processes, such as heat waves and earthquakes, but also in terms of societal processes and the societal consequences of natural disasters. Over the past two years (2021 and 2022), extreme events have occurred across the globe. The February 2021 North American cold wave led to widespread power outages for millions of people in Texas, USA. Another remarkable extreme event, the recent Coronavirus disease in 2019 (COVID-19), is shaping the entire environmental and societal sustainability situation worldwide. In 2022, persistent heatwaves have been affecting Europe, causing evacuations and heat-related deaths with a maximum temperature of 47.0 °C reported in Pinhão, Portugal, on 14 July. The flood in Pakistan, the deadliest one in worldwide since 2017, has killed more than 1300 people since 14 June 2022. With the intensity and magnitude of climate change and extreme events being unknown, neither the changes themselves nor the corresponding impacts are clear under the current circumstances. Therefore, we organized this Special Issue under the theme of sustainability with respect to the changing climate and extremes.

We will briefly discuss the contributions of the 34 published papers in this Special Issue in the following four sections.

## 1. Natural Disasters in Agriculture

As the most widely cultivated fruit genus, Wang Shuangshuang et al. (Appendix A, Contributor 1) evaluated changes in the quality and yields of citrus under the shared socioeconomic pathways scenario. In their study, first, they proposed statistical models of the relationship between daily meteorological observation variables and the yields and quality of citrus. In short, with respect to predicting the quality of citrus, the monthly mean diurnal temperature range in July was identified as the optimal variable; for predicting yields, a group of variables in October and September was identified as comprising the best predictors. Then, they analyzed the future changes in the quality and yields of citrus in the period from 2021–2060 using the ensemble mean of nineteen Coupled Model Intercomparison Project 6 (CMIP6) models. Finally, they found that the quality of citrus will increase in 3 provinces, while the yield will increase in all 11 provinces. The results can support the design of citrus plantations in the future; further, the statistical models can be coupled with the ecological process model for predicting the yield and quality of citrus fruits.

Potatoes play a significant role in global food security and human diets. As the leading potato producer, China accounts for 22% of the world's potato yield [1]. In China, the potato plant has been the fourth most important crop after rice, wheat, and maize, and is facing the negative impacts of the changing climate. Yang Li-Tao et al. (Contributor 2) analyzed the climatic production potential of potatoes from 1961 in Inner Mongolia, where they occupied the largest plantation area of potatoes in China. They obtained the annual average climate production potential for potatoes in Inner Mongolia, which was 19,318 kg/hm$^{-2}$. Over the past 61 years, the climatic production potential exhibited an insignificant linear decreasing trend under the changed climate. The main finding of their study lies in their identification of precipitation as the main impact factor for the productive potential for potatoes in Inner Mongolia.

Maize (*Zea mays* L.) is one of the most important crops in the global and national economies and is the third highest yielding form of crop production in China. In China, the Huanghuaihai plain is the largest summer maize-producing area with a wheat–maize cropping system. The ongoing process of global warming increases the risk of high-temperature injury to maize. In addition, previous studies have shown that the inter- and mixed-cropping of maize varieties with different genotypes is one way to effectively alleviate high-temperature injuries during the flowering period. In this study, Li Shuyan et al. (Contributor 3) investigated the response of five main genotypes of maize to high temperatures and different crop models during the flowering period. The main findings revealed that inter- and mixed cropping effectively reduced the impact of high temperatures during flowering, demonstrating that even the genotypic varieties can make significant differences in the yields.

In addition, the diurnal temperature range (DTR) is also an important meteorological variable affecting maize yields. Xie Wenqiang et al. (Contributor 4) evaluated the ability of 26 CMIP6 models to simulate DTR from 1961–2014 and projected the DTR under different shared socioeconomic pathway (SSP) scenarios from 2015 to 2050. The main findings of their study included: (1) CMIP6 models can generally reproduce spatial distribution, especially in the maize cultivation areas; (2) The DTR remains stable from 2015–2050 under SSP245, while a significant decreasing trend is found under SSP585. This study implied the efficiency of the application of DTR in the accurate prediction of maize yield prediction.

The dry-hot wind is a type of severe agricultural wind disaster with high a temperature and low humidity. Dry-hot winds can reduce wheat production by up to 30%. In China, Shandong Province has the greatest agricultural growth value among all of the provinces and is also the most affected by dry-hot winds. Wang Nan et al. (Contributor 5) assessed the spatial distribution of dry-hot wind disasters in Shandong Province. The main finding in their study demonstrated that the more developed areas in the east of Shandong province show high disaster prevention and mitigation capabilities, whereas these same aspects are weak in the west, where the economy is still behind eastern Shandong province. Their study implies the roles of economical input in preventing natural disasters.

Further, Jiang Meiyi et al. (Contributor 6) evaluated the effect of drought on the production of peanuts in Shandong province, which accounts for 16% of the total peanut cultivation area and 20% of the total peanut production in China. Drought has been considered the most severe natural disaster with respect to agricultural production. Therefore, identifying the high drought risk regions will be a benefit to the yields and quality of peanuts in Shandong. As the main finding of their study, they found that the drought risk was concentrated on the Jiaodong Peninsula, covering 20.7% of the province. Their study can support the acquisition of data for developing and carrying out peanut drought prevention, relief policies, and related decisions.

Further, in another study (Contributor 7), Pan Mingxi et al. investigated the effects of snow cover on the spring soil moisture content, which will impact the occurrence of spring drought in high-latitude areas. To investigate the role of winter snow cover with respect to soil moisture, the authors chose the main agricultural areas of Northeast China—the Songnen Plain and the Sanjiang Plain—to address these issues. Their main finding was that they found that snow cover has a strong effect on soil moisture conservation in more arid areas. This work can support the scientific basis for the early warning of spring drought, the development of more efficient irrigation schemes, and crop yield prediction based on the snow cover in Northeast China.

To predict droughts and floods in agriculture in the future, in their study (Contributor 8), Li Jiannan et al. constructed a vulnerability model based on "sensitivity–exposure–adaptability" and "vulnerability-risk, source-risk receptor" drought and flood risk models and established multi-index prediction systems. They predict the vulnerability and risk of droughts and floods in China's agroecosystem under the SSP1-2.6, SSP2-4.5, and SSP5-8.5 scenarios from 2020 to 2050 using a combination of AHP and the entropy-weighting method. They found that the levels drought and flood vulnerability intensify, and the drought or flood vulnerability area expands to southern China from SSP1-2.6 to SSP5-8.5.

## 2. Urban/Rural Ecosystem, Tourism, and Ecosystem Service

In an urban ecosystem, rainfall plays a crucial role in human mobility and urban management and planning. After four decades of urbanization, China is still facing the rapid developmental period of urbanization in the future. One urgent need involves understanding the impact of rainfall on residents' mobility in the city. Taxi GPS data support a large amount of spatiotemporal information about human activities and mobility in urban areas. Guo Peng et al. (Contributor 9) combined geospatial complex networks with multiscale geospatial analysis to extend the empirical research on human travel patterns using Taxi GPS data to analyze the impact of rainfall on human mobility. They proved that taxi GPS data are highly informative and exploitable in the field of human mobility analysis. The main findings based on their results were the following: (1) rainfall has a reducing effect on trip flow, trip distance, and trip duration on both weekdays and weekends; (2) rainfall has a significant effect on the network indicators; and (3) more mobile communities were detected on weekends than on weekdays, while the number of communities on weekdays and weekends did not change significantly because of rainfall.

Further, climate-related risks threaten urban safety, infrastructure stability, and socioeconomic sustainability. China is facing various climate hazards due to its diverse geomorphic conditions. In this study (Contributor 10), Sun Shao et al. propose a comprehensive analysis of the spatial pattern of major climate hazards in China from 1991 to 2020. The climate hazard types include rainstorms, droughts, heatwaves, cold waves, typhoons, and snowstorms. They found that cities are hotspots affected by intensified climate hazards in a warmer climate and they proposed an urgent need to incorporate a climate adaptation strategy into future city construction to improve social resilience and mitigate climate impacts in the rapid urbanization process in China. For the climate risks of the three major urban agglomerations of Eastern China (Beijing–Tianjin–Hebei, the Yangtze River Delta, and the Pearl River Delta), in this study (Contributor 11), Chou Jieming et al. constructed one vulnerability degree using the Gray model (GM (1,1)), and calculated the drought, heat wave, and flood hazards under different emission scenarios based on the CMIP6 model. They found that the Beijing–Tianjin–Hebei urban agglomeration has a good level of urban resilience, the Yangtze River Delta's urban agglomeration has slightly higher overall risk, and the Pearl River Delta's urban agglomeration has the highest relative risk overall.

Rural regions are sensitive to climate disasters. China has achieved its goal of eliminating absolute poverty in China. However, meteorological disasters can promote rural populations' return to poverty. In this study (Contributor 12), Li Aiwei et al. analyzed the spatiotemporal characteristics of rainstorms and droughts and their socioeconomic impacts on China's contiguous poverty-stricken areas from 1984 to 2019. The main findings are as follows: (1) rainstorms showed a significant increasing trend of 0.075 days/decade, while there is no significant trend for drought days; (2) the average annual loss rate due to disasters in the poverty-stricken areas reached 1.6%, which is 0.6% higher than the national level. Their results suggest that to obtain the realization of the United Nations Sustainable Development Goals, it is necessary to improve the capacity for meteorological disaster prevention and reduction in China's contiguous poverty-stricken areas.

The tourism markets are deeply impacted by the air pollution in China due to the necessity of pursuing fresh air in the tourism transformation process. Finding one air index to reflect the air freshness of destinations can support referable data for the tourists. Yang

Xiaoyan et al. (Contributor 13) propose a new comfort index for climate tourism: the fresh air–natural microclimate comfort index (FAI-NMCI). This index connects the fresh air index with the natural microclimate comfort index of scenic spots from transdisciplinary and multidisciplinary perspectives. Under contemporary China's high-quality tourism development background, this could provide accurate information not only for the demand and supply sides of the tourism market but could also become an important and comprehensive index for related governmental management.

Further, to explore the influence of changes in climate comfort on Arctic tourism, in this study (Contributor 14), Huang Yutao et al. analyzed the spatial-temporal changes in Arctic summer climate comfort zones from 1979 to 2019 using the ERA5-HEAT (Human thErmAl comforT) dataset from the European Center for Medium-range Weather Forecasts (ECMWF). Their results suggest that global warming increases the Arctic summer climate comfort level and may provide favorable conditions for the further development of regional tourism resources.

In the ecosystem service section, the annual terrestrial gross primary productivity (GPP) was taken as the representative ecological indicator of the ecosystem. In this study (Contributor 15), Zhang Chi et al. analyzed the GPP changes using three earth system models (ESMs) from CMIP6 under 1.5 and 2 °C global warming targets in the Shared Socioeconomic Pathway 4.5 W $m^{-2}$ (SSP245) scenario. In their main findings, they found that Under 1.5 °C of global warming, GPP in four climate zones (temperate continental, temperate monsoonal, subtropical–tropical monsoonal, and high-cold Tibetan Plateau) increased significantly with a minimum growth of 12.3% and the increase was greater under 2 °C of global warming that at 1.5 °C. Their results implied that global warming poses no ecological risk in China from the perspective of ecosystem productivity.

The China–US trade conflict can affect the achievement of climate change goals. In this study (contributor 16), Chou Jieming et al. assessed the impact of the trade conflict on China's climate policy by combining the model from the Global Trade Analysis Project (GTAP) and the input–output analysis method. Their results showed that changes in trade will challenge China's balancing of climate and trade exigencies, implying that China–US cooperation based on energy and technology will help China cope with climate change after the trade conflict. In this Special Issue, another study by (contributor 17) Feng Qiang et al. contributed the response mechanisms of the ecosystem service's trade-offs with respect to land use changes along precipitation gradients in the Loess Plateau of China.

In one study (contributor 18), Deng Xiaofang et al. investigated human resource allocation with respect to adaptation to climate change in a state-owned forest farm in China using the questionnaire method. They found that the human resource professional and industrial structure changes in the context of climate change are the main limiting factors for the key state-owned forest farms of China. In their paper, they suggested that increasing the investment in education on climate change and the income of employees is one way to promote the adaptation to climate change in China.

Extreme events threaten human health. In one paper (contributor 19), Li Junrong et al. used big data to explore the dynamic changes regarding population exposure during a heat wave incident in Zhuhai based on real-time mobile phone data and meteorological data. The main findings are as follows: (1) the overall population exposure shows a trend of first decreasing and then increasing; (2) a high degree of population exposure is concentrated in areas such as primary and secondary schools, colleges and universities, office buildings, and residential areas; and (3) the population exposure changes in the last two days of the heat wave cycle are mainly affected by the combined influence of population factors and climate factors based on the studied heatwave events from 6 to 12 September 2021. This study has a certain practical guiding significance with respect to advancing high-temperature warning and high-temperature disaster risk prevention methods.

In addition, another study (Contributor 20) assessed China's future heatwave population exposure under 1.5 °C and 2.0 °C warming scenarios with respect to climate change adaptation using models from CMIP6. The main findings of their study are as follows:

(1) an additional 20.15% increase in the number of annual heatwave days would occur with an additional temperature increase of 0.5 °C to 2.0 °C, an over 1.5 °C increase in temperature by the mid-century; (2) from three influencing elements, namely, climate, population, and interaction (e.g., as urbanization affects population redistribution), climate explained more than 70% of the variance in different warming scenarios. Their study can support helpful insights for developing mitigation strategies for climate change.

Tropical marine fisheries provide high-quality protein for human diets and play significant roles in food security. Tuna fisheries are one of the four most highly valued fisheries worldwide and have contributed 5.2 million tons of the total capture amount. The tuna fishery in the entire western and central Pacific Ocean (WCPO) supports major industrial tuna fisheries and contributes almost 30% of the total global tuna supply. However, the changing climate is threatening tropical tuna fisheries via the increasing sea surface temperature. In this study (Contributor 21), Zhou Weifeng et al. explored the impact of climate change on tuna fishery resources by investigating the temporal and spatial characteristics of the thermocline in the main yellowfin tuna purse seine fishing grounds in the western and central Pacific Ocean during La Niña and El Niño years from 2008 to 2017. The main findings of their study include: (1) in La Niña years, the catch per unit effort (CPUE) moved westward where the high-value zone of the upper boundary contracted westward to 145° E, while in the El Niño years, this boundary moved eastward to 165° E; (2) changes in the thermocline caused by abnormal climate events significantly affected the CPUE. This study can provide additional thermocline distribution information and serve as a reference for tuna production in this area.

## 3. Extreme Climate Indices

Extreme climate events are more frequent under ongoing climate change. Central China, a key area for the transition between China's east–west and north–south borders and a hub for land and water transportation, is facing a complex weather system. In this study (Contributor 22), Li Yan et al. analyzed the temporal and spatial dynamics of climate events from 1988 to 2017 using nine indices: six extreme temperature indices and three extreme precipitation indices. The six extreme temperature indices are icy days (ID), frost days (FD), the duration of warm periods (WSDI), the duration of cold periods (CSDI), the lowest Tmin (TNn), and the highest Tmax (TXx). The three extreme precipitation indices are very wet days (R95), consecutive dry days (CDD), and consecutive wet days (CWD). The main findings are as follows: (1) the Jiangxi region was at greater risk of extreme climate events in central China, and (2) the drought events in central China around 2025 will be more significant. Following their results, disaster prevention and mitigation projects can be suggested to be prepared in advance for the policy-makers.

In another study (Contributor 23), Yan Weixiong et al. evaluated the distribution of extreme temperature seasonality trends in mainland China by using the following indices: the number of hot days (HD) and frost days (FD), as well as the frequency of warm days (TX90p), cold days (TX10p), warm nights (TN90p), and cold nights (TN10p). They highlighted that extreme temperatures have increased over mainland China from 1979–2020 with obvious seasonal variations, and the increase in the minimum temperature is more distinct than in the maximum temperature.

Heatwave events (HWEs) have strong negative impacts on human health, ecosystems, and sustainable social development. In one study (Contributor 24), Gao Zhibo and Yan Xiaodong analyzed the characteristics of HWEs over the Yangtze River Basin (YRB) in eastern China during the historical period and projected the changes in HWEs over the YRB in the future using a gridded observation dataset and a high-resolution regional climate model. Their main findings include: (1) Short-lived ($\geq$3 days and <6 days) HWEs are projected to increase rapidly under SSP585, but to rise slowly overall under SSP245, and (2) the increase in HWEs over the YRB region is likely to be associated with the enhancement of the western-Pacific subtropical high (WPSH) and South-Asian high (SAH). This study can support solid references for disaster prevention and mitigation in the future for these developed regions of China.

In another study (contributor 25), Li Kaiwen et al. defined compound drought and heatwave events (CDHEs) using the monthly scale standard precipitation index and evaluated the spatial and temporal variations in CDHEs in China from 1961 to 2018. The main findings of their study are as follows: (1) the mean frequency of CDHEs takes on a non-significant decreasing trend, and the mean magnitude of CDHEs takes on a non-significant increasing trend in China; (2) the significant trends in the annual frequency and annual magnitude of CDHEs are attributed to maximum temperature and precipitation changes.

The surface albedo of pure fresh snow is generally between 60% and 95%. When black carbon (BC) aerosols deposit into the surface snow through dry and wet deposition, the albedo of the snow surface will significantly reduce and thereby increase the absorption of solar radiation on the snow surface. Therefore, understanding the BC concentration on the surface of snow will play an important role with respect to studying climate change. In this study (contributor 26), Zheng Yanjiao et al. simulated the black carbon concentration on the surface snow of northeast China using an asymptotic radiative transfer model. The main findings of their study include: (1) human activities played an important role in snow black carbon pollution, and (2) the snow surface albedo will decrease by 16.448% due to the BC pollution of snow in northeast China. These results suggest that the increase in radiative forcing caused by black carbon via snow reflectivity cannot be ignored.

As one part of the earth system and one of the most sensitive regions of climate warming, cold regions are areas with low temperatures and with the presence of ice and snow for at least part of the year. In their study (Contributor 27), Wang Yumeng et al. studied the spatial distribution and variations of cold regions in China from 1961 to 2019. They found that the area of China's cold regions decreased by 49.32 $\times$ 104 km$^2$ in the period from 1991–2019 compared with that in the period of 1961–1990. In addition, in another paper (Contributor 28), Li Hao et al. studied the distribution and assessment of snow-disaster risk zoning in Heilongjiang Province. As the main findings of their study, they found that economically developed regions had strong disaster prevention and mitigation capabilities. This implied that the economic input for preventing snow disasters is required in Heilongjiang Province. For another cold region in China, in this Special Issue, Sun Shao et al. (Contributor 29) and Jia Yiru et al. (Contributor 30) evaluated and mapped the meteorological hazards and the locomotion of slope geohazards in the Qinghai-Tibet Plateau (QTP), respectively, in response to climate change.

Extreme cooling (EC) events are also a major challenge to socioeconomic sustainability and human health. In this study (Contributor 31), Song Shuaifeng and Yan Xiaodong analyzed the temporal and spatial distributions of EC events in China using the relative threshold and the relationship between EC events and the Arctic Oscillation (AO) index during the period of 1961–2017. The main findings of their study are as follows: (1) the frequency of EC events in China decreased by 0.730 d from 1961 to 2017, and (2) EC events are significantly negatively correlated with the AO index, which can explain approximately 21% of the EC event variance. Their study can help to improve the prediction and simulation of EC events in China.

To overcome the overestimation for the light precipitation and underestimation of heavy precipitation due to low model resolution, Luo Neng and Yan Guo (Contributor 32) studied the impact of model resolution on simulating the precipitation extremes over China from 1995–2014 with six extreme indices based on five models from CMIP6. All these models include low- and high-resolution versions. Six extreme indices were employed: simple daily intensity index (SDII), wet days (WD), total precipitation (PRCPTOT), extreme precipitation amount (R95p), heavy precipitation days (R20mm), and consecutive dry days (CDD). The main findings of their study are as follows: (1) models with a high resolution demonstrated better performance in reproducing the pattern of climatological precipitation extremes over China, (2) decreased biases of precipitation exist in all high-resolution models over D1, and (3) Improvement could be attributed to fewer weak precipitation events (0–10 mm/day) in high-resolution models in comparison with their counterparts with low resolutions. Their solid work proved that models with improved resolution show an obvious advantage with respect to the simulation of precipitation extremes, thereby increasing confidence in the simulation of precipitation extremes.

## 4. Newly Created Dataset for Climate Change

The forest ecosystem is one of the most concentrated systems under the climate change background. Identifying the forest type plays a crucial role in supporting information for forest managers, conservationists, and forest ecologists. In this study (Contributor 33), Xu Chen et al., generated a forest type distribution using an unsupervised cluster analysis method by combining climate variables with normalized difference vegetation index data. Their work will improve the depth of research in biodiversity preservation, forest management, and ecological and forestry research.

Modern meteorological methods with high-resolution and high-quality precipitation data are urgently required in the monitoring of mountain flood geological disasters as well as hydrological monitoring and prediction. In this study (Contributor 34), Wang Zheng et al. tested the newly created 0.01° multi-source fusion precipitation product developed by the National Meteorological Information Center. Their study proved that the 0.01° multi-source fusion precipitation product has better spatial continuity, a more detailed description of precipitation's spatial distribution and a more accurate reflection of extreme precipitation values, and can provide precipitation data support for refined meteorological services, major activity support, and disaster prevention and reduction.

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## Appendix A. List of Contributions

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