

Commentary

Food security in climatic extremes: Challenges and opportunities for ChinaFaith Ka Shun Chan,^{1,2,3,10,*} Yong-Guan Zhu,^{4,10,*} Jiayu Wang,^{4,7,*} Jiannan Chen,⁵ Matthew F. Johnson,⁶ Gang Li,⁴ Wei-Qiang Chen,⁴ Lei Wang,⁸ Pengfei Li,⁵ and Juanle Wang⁹¹School of Geographical Sciences, University of Nottingham Ningbo China, Ningbo 315100, China²Water@Leeds and School of Geography, University of Leeds, Leeds LS2 9JT, UK³Research Centre for Intelligent Management & Innovation Development/Research Base for Shenzhen Municipal Policy & Development, Southern University of Science and Technology, Shenzhen 518000, China⁴Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen 361021, China⁵College of Geomatics, Xian University of Science and Technology, Xian 710054, China⁶School of Geography, University of Nottingham, University Park, Nottingham NG7 2RD, UK⁷Nottingham Business School China, University of Nottingham Ningbo China, Ningbo 315100, China⁸British Geological Survey, Keyworth, Nottingham NG12 5GG, UK⁹State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China¹⁰These authors contributed equally*Correspondence: faith.chan@nottingham.edu.cn (F.K.S.C.), ygzhu@iue.ac.cn (Y.-G.Z.), jiayuwang@iue.ac.cn (J.W.)<https://doi.org/10.1016/j.crsus.2023.100013>

Droughts and floods in 2022 and 2023 have compounded stress on Chinese food security. China's northeast region is a major grain-producing powerhouse, but recent climatic extremes combined with El Niño effects have exposed vulnerabilities in its agricultural landscape. To address these challenges, flood relief infrastructure, protection of major croplands, and climate projection strategies must be implemented to safeguard food security.

Increasing climatic challenges

As the global climate changes, extreme climate events, such as heatwaves, droughts, and flooding, are becoming more commonplace (see <https://global.chinadaily.com.cn/a/202208/17/WS62fc2097a310fd2b29e728fb.html>; <https://www.cnbc.com/2022/08/19/china-issues-first-national-drought-emergency-scorching-temperatures-.html>; <https://public.wmo.int/en/media/news/typhoons-trigger-destruction-and-record-breaking-rainfall-china>). Like many countries, China has suffered from extreme climatic events in recent years. The summer of 2022 was one of the hottest and longest heatwaves in China's recorded history, with temperatures ranging from 35°C to 40°C along the Yangtze River Catchment (<https://global.chinadaily.com.cn/a/202208/17/WS62fc2097a310fd2b29e728fb.html>). The following year, in 2023, China suffered from severe flooding with multiple typhoons hitting the country. Typhoon Doksuri generated over 744.8 mm of precipitation between July 29 and August 2, 2023 in the North China Plain ([https://public.wmo.int/en/media/news/typhoons-trigger-destruction-and-record-breaking-rainfall-](https://public.wmo.int/en/media/news/typhoons-trigger-destruction-and-record-breaking-rainfall-china)

[china](https://public.wmo.int/en/media/news/typhoons-trigger-destruction-and-record-breaking-rainfall-china)),¹ the highest recorded since meteorological record keeping began in 1883 (Figure 1).²

The changing climate is undoubtedly causing more frequent extreme events.³ However, the impacts of increasing drought and flood severity and duration on areas of major agricultural production in China are much less appreciated. These events have the potential to affect food security with devastating impacts on crop seeding, plant growth, and harvest yields.^{4,5} The Chinese National Agricultural Authority already expects to reach at least a 20% (more than 1.05 million hectares) deficit for major crops (i.e., rice, maize, barley, soybean, and corn) due to the heatwave-enhanced severe drought in Central China along the Yangtze River catchment in 2022.⁶

Declining food security and increasing imports

China has a population of 1.4 billion, feeding approximately 20% of the global population with only 7% of the world's arable land. One immediate impact is that the country currently relies on importing major crops and food sources from

overseas. China imported 91 Mt of soybeans in 2022, which accounts for over 60% of imported grains, and imported 20.6 Mt of corn and 6.19 Mt of rice in the same year.⁷ China's diet is also changing, with increasing demand for dairy, meat, and soybean products. China imports 71% of its dairy products (i.e., milk, beef, butter, and lamb), with New Zealand as a major source.⁸ Extreme climate events are being reported globally—for example, the wildfires across North and South America, Europe, Asia, and Australia.⁹ Therefore, food security in China is partially reliant on the impacts of climatic extremes in major importing countries.

Impacts on food production due to increasing climate extremes, also increasing reliance on external imports of food, means that China's food security is less predictable and controllable. Furthermore, long-distance food transport contributes to large carbon footprints, which works against carbon neutrality by the 2050s¹⁰ and increases food costs. China is facing a crossroads in future food security to achieve UN Sustainable Development Goal 2 (zero



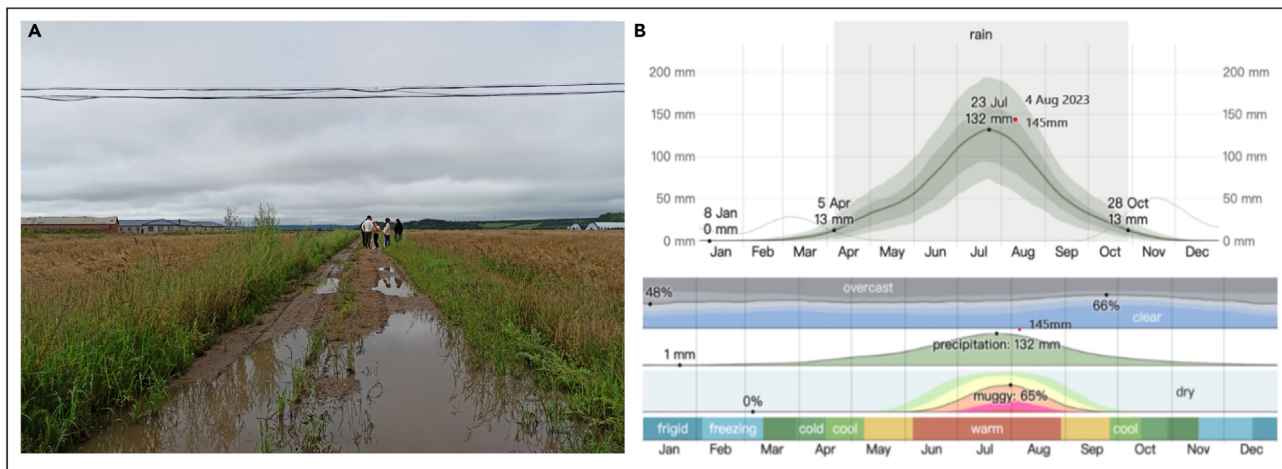


Figure 1. Severe flood in Heilongjiang Province, Northeast China during August 2023

(A) Damage to farmland in Wuchang City after heavy rainfall (photo by Yating Shao and reprinted with permission).

(B) Annual average rainfall in Wuchang City. The red dot illustrates the intensive rainstorm on August 4 to August 5, which peaked at 145 mm rainfall (24 hr), a record high in the historical record (data from China Meteorological Agency [CMA] <http://www.nmc.cn/publish/forecast/AHL/wuchang.html>).

hunger) and to keep the domestic food price at a reasonable level.

Three provinces in Chinese northeast—The “treasures”

The three Northeast Chinese provinces are some of the world’s largest areas of black (chernozemic) soils with soil organic matter content at least 1.5 to 5 times higher (with humus ranging from 4% to 16%) than other soil types at topsoil range (soil horizon at 0 cm to 10 cm).¹¹ The fertile arable black soils in the region result in high agricultural yields and contribute about 20% of the country’s grain production.¹² It is projected that the yields for a range of crops such as rice, cereal (wheat and barley), and corn will increase by up to 22% in Northeast China by the 2050s.¹³ Additionally, in this region alone, maize and soybean production accounted for 33.4% and 51.8% of the national yield.¹⁴ The Chinese National Government (CNG) realized the national importance of protecting the northeast black soils and agricultural lands from climatic extremes (i.e., drought, high temperatures), by creating a “Black Soil Protection Zone” and developing interventions to better protect the soils in this region (Figure 2).

The three Northeast Chinese provinces are typically associated with a cool to mild temperature and relatively modest precipitation from the Northwest Pacific,

creating favorable conditions for arable agriculture. But in 2023, Northeast China witnessed severe floods. The floods damaged major crop grains in China, particularly rice, maize, and soybeans (Figure 3).¹⁴ In Wuchang, Heilongjiang, a major center of rice cultivation in Northeast China, the August 2023 flood occurred when paddy rice was just advancing into flowering after seedlings were planted in the spring (April to May), leading to mass crop failure and an alarming “zero rice crop harvest” (www.chinadaily.com.cn/a/202308/07/WS64d04544a31035260b81aa16.html). The global rice market has been influenced by these events and recent rice prices have been hit at an 11-year high (<http://www.chinadaily.com.cn/a/202308/09/WS64d32b94a31035260b81b24c.html>).

Opportunities to safeguard food security in China

Based on the risks to food security described above, we offer three key actions as opportunities to ensure future food security in China.

Urgent call for improving climate mitigation and resilience

The CNG should adopt climate projection practices that incorporate more resilient hydrological practices in agricultural and farming systems in Northeast China. In particular, the CNG and the northeast provincial governments should use the

lessons from the 2023 flood to review current infrastructure and determine their capacity to withstand projected future events, taking into account increasing intensities of rainstorms and interactions with El Niño effects (http://bgimg.ce.cn/cysc/sp/info/202308/14/t20230814_38670957.shtml).^{11,12} The northeast region was less affected by severe floods in the past and, as a consequence, was underprepared for flooding. This flood event is, therefore, a reality check—raising important questions about flood resilience and response and the capacity of riverine flood protection schemes. As this region is critical to the food security of the nation (http://bgimg.ce.cn/cysc/sp/info/202308/14/t20230814_38670957.shtml), there are urgent calls to better assess the climatic and hydrological resilience of dams, river system capacities, and protection standards under future projected hydrological conditions (i.e., peak discharge, river bank protection standard, flood storage, agricultural drainage protection standard, etc.) until the 2050s and beyond. This commentary serves as a foundation for legislation and amendments enacted by the CNG, provincial governments, and relevant authorities to better prepare for future climate uncertainties,¹⁵ including the provision of nature-based solutions that can create resilience within hydrological catchments to climate extremes.

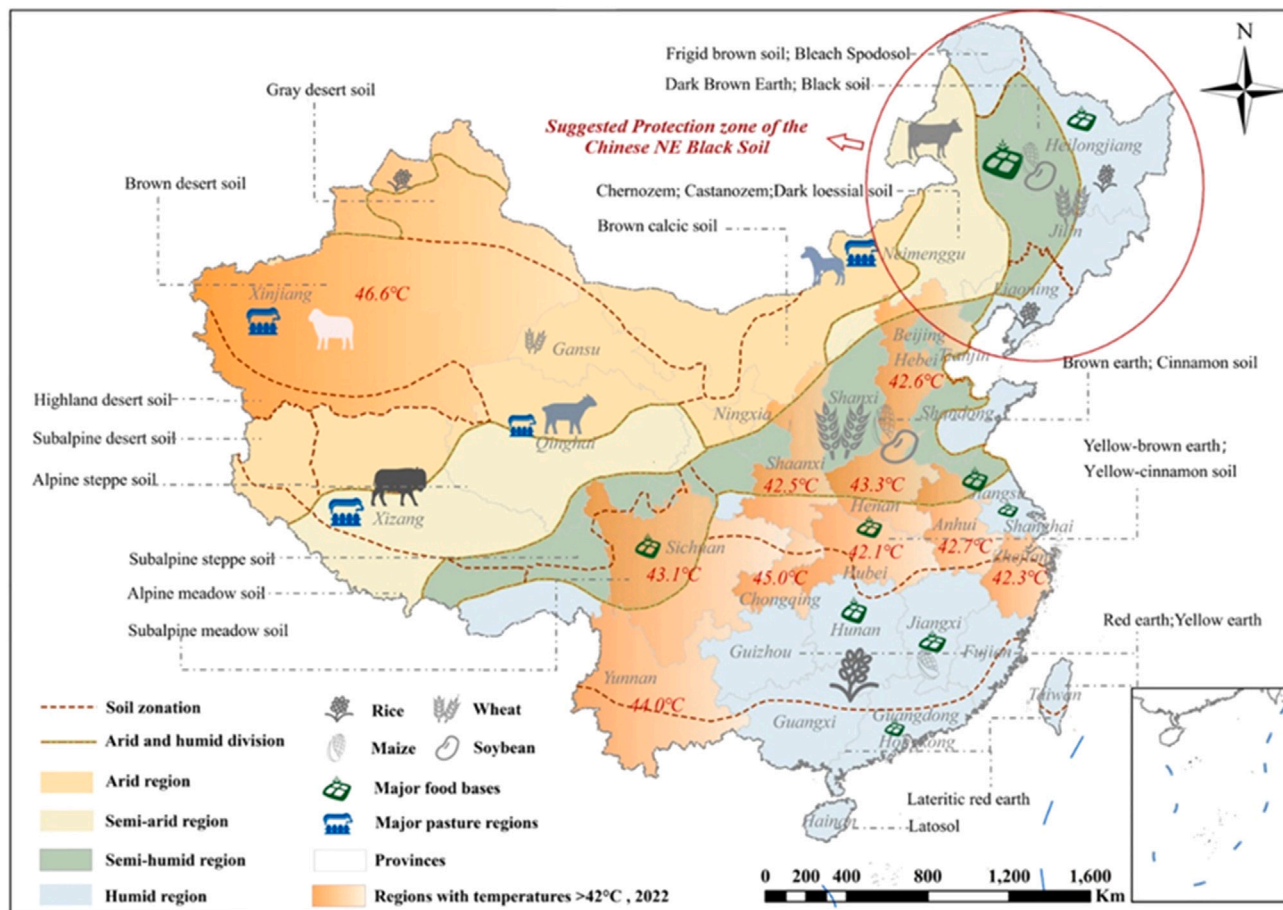


Figure 2. The heatwave in Central China and the agricultural production in the 2022 summer

The heatwave in Central China and the agricultural production in the 2022 summer and the potential development of the “northeast black soil protection zone”, circled with a red boundary.

**Improve climate adaptations—
Deliver short and long-term
practice**

We suggest that the CNG and provincial governments deliver both short- and long-term climate adaptation practices. The 2022 heatwave and 2023 flooding are unlikely to be isolated events, and interventions to minimize future impacts of climate extremes are needed.

Short-term practices should include improvements to agricultural field drainage systems to better convey sudden peak discharges and ensure that drainage channels are well-drained without any blockages. Additionally, the relevant authorities should allocate resources for the deployment of temporary resilient-engineering solutions. These may include the implementation of emergency infrastructures such as emergency rubber floodgates,

the provision of sufficient sandbags, the deployment of facilities for water pumps in agricultural fields, spillway facilities, and the improvement of proper flood warning signals and systems. These practices are vitally important to reduce risks and protect communities, agricultural fields, and their properties. Where possible, creating areas for flood water storage, which can be more slowly released downstream (both offline and in line with the main channel), would alleviate pressure on the channelized network, creating an integrated catchment risk minimization plan—utilizing both engineered and nature-based solutions^{16,17}

Long-term practices should be based on the development of a “long-term climate action and adaptation plan” integrated with the Northeast China Future Development Plan and the National

Agricultural Development Plan.¹⁸ These long-term initiatives would only ensure more resilient agricultural services (e.g., with better drainage engineering support, seedling, plantations, and harvest technical support), but they would also adopt more advanced agricultural climate communication systems that can provide climate information (i.e., rainfall, humidity, and soil hydrological information) to local farmers. The authorities should also educate local farmers on climatic risks and resilient approaches, equipping them with the knowledge needed to effectively interpret and apply climate information. In the longer term, land-use planning authorities should institute a climate risk zoning system, incorporating nature-based solutions at the catchment scale (e.g., natural flood management strategies) and aiming to integrate smaller,

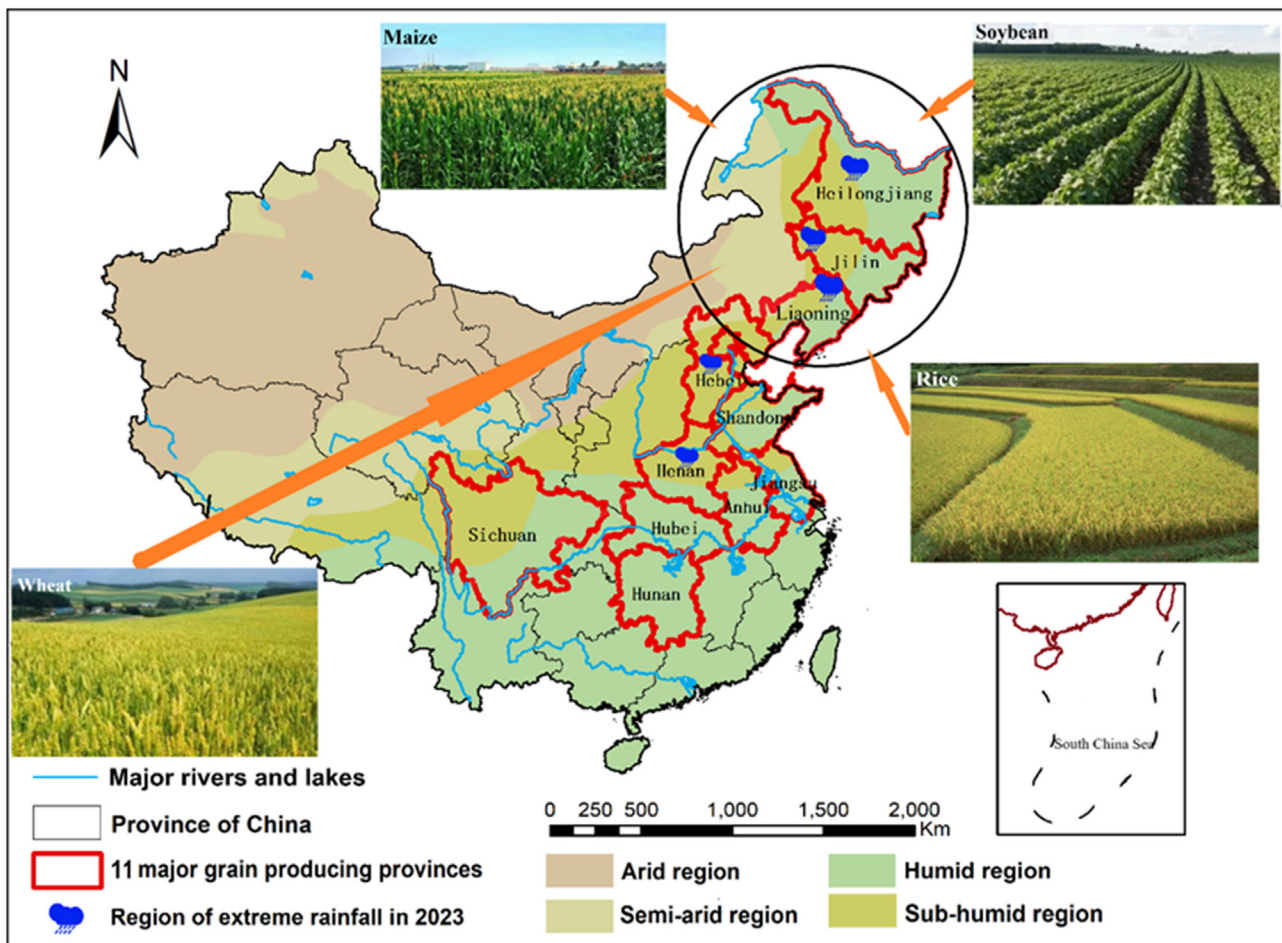


Figure 3. Major crop yields and production areas in China that were affected by the floods in July to August of 2023

Major crop yields and production areas in China that were affected by the floods in July to August of 2023 from typhoon-enhanced intensive rainstorms in North and Northeast China (circled on the figure are the northeast three provinces that provided the major crop yields of wheat, rice, maize, and soybean).

short-term interventions into a holistic, risk mitigation plan to optimize future activities. This should also include a well-protected climatic emergency financial aid package and an adequate agricultural insurance system to protect the local farmers from the financial implications of climate-related challenges.

Designate the “Sustainable Agricultural Development Plans” to protect the fertile black soil

Lastly, we recommend that relevant authorities protect their treasured fertile, black soil. The CNG should integrate the northeast black soil protection scheme with a sustainable agricultural development plan (i.e., promoting no-tillage, organic, green, and precision farming systems via novel technologies), which is fully enacted within the legislation. Furthermore, the CNG should encourage

and closely collaborate with the northeast provincial governments, including Heilongjiang, Jilin, Liaoning, and the Inner Mongolia Autonomous Region in the northeast. These regions are not only the cradle of black soil but essential contributors to China’s long-term food security. We suggest that these local governments enhance their soil production schemes and undertake best-fit practices to safeguard their black soil. An important part of these schemes will be the need for extensive education campaigns targeting farmers and stakeholders. These programs should aim to improve awareness and sensitivity to climatic changes and soil conditions; by fostering a deeper understanding of the environment, we can encourage responsible land stewardship. Land stewardship practices that have been used in the past may not be practical

in future climatic conditions, and in some cases, poor land stewardship contributes to the detrimental impacts of climatic hazards by increasing risks of soil and crop loss.^{19,20}

Conclusion

The northeast region of China is critical to food security and food prices but is under threat from frequent and intense climatic extremes, including both droughts and floods, compounded by factors including unsustainable agricultural practices. With growing pressure on urban populations and food demands, and climatic extremes also affecting key international food trading partners, the CNG should promote sustainable agricultural development plans (i.e., promoting no-tillage, organic, green, and precision farming systems) that are fully enacted

within binding legislation and learn lessons from nature-based solutions and holistic catchment management approaches. This would lead to a more sustainable, climate resilient, and healthy (i.e., reduced pesticide and chemical use) environment and agricultural infrastructure, working toward addressing future, uncertain climatic and non-climatic risks to the food security of the Chinese population of 1.4 billion.

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AUTHOR CONTRIBUTIONS

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DECLARATION OF INTERESTS

The authors declare no competing interests.

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