Proceedings of the 3rd International Conference on Environmental Geoscience and Earth Ecology
DOI: 10.54254/2753-8818/81/2025.21269

The Impact of Climate Change on Agriculture in the Sichuan Basin over the Past 60 Years

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Abstract: Climate change profoundly affects agriculture, particularly in locations such as the Sichuan Basin, a key grain production region in China. This study analyzes the effects of climate change on Sichuan's agriculture over the past 60 years, focusing on temperature and precipitation trends. Results show that rising temperatures and fluctuating rainfall have directly influenced crop growth cycles, yields, and susceptibility to pests and diseases. Moreover, the phenomenon of climate change has exacerbated the risks associated with extreme weather events, leading to significant ecological disruptions and increased production costs. In response to these challenges, the Sichuan government has implemented a series of adaptive strategies, which include the development of advanced irrigation infrastructure, the establishment of comprehensive agricultural insurance programs, and the promotion of the cultivation of crop varieties that are resilient to changing climatic conditions. These strategies have enhanced the resilience and sustainability of agricultural production. This research emphasizes the importance of integrating macro-level policies with farmer-level innovations to ensure stable agricultural yields and food security under changing climatic conditions.

Keywords: Climate Change, Agriculture, Sichuan Basin, Crop Growth, Adaptive Measures

1. Introduction

Climate change exerts diverse effects, with agriculture, as a fundamentally natural production endeavour, being especially vulnerable to alterations in precipitation patterns, extreme weather phenomena, natural calamities, and variations in thermal conditions. Agricultural production is integral to China’s food security. Understanding how climate change affects agriculture can enhance the sector’s adaptability to extreme weather, improve overall agricultural productivity, and stabilize national food security.

Numerous studies have explored the impact of climate change on agriculture. However, most of this research has focused on China's primary grain-producing regions, such as the middle and lower reaches of the Yangtze River and the Northeast. These studies often analyze the effects of climate change through a scientific lens on climatic variables, with limited attention to policy-driven strategies to enhance farmers' adaptability. Zhang Xinya employed a geographic centroid model to examine the effects of climatic change on crop planting structures in Anhui Province [1]. Zhang and colleagues utilised the Henceforth model to evaluate the economic impacts of many climate elements

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beyond temperature and precipitation, indicating that by the century's end, rice, wheat, and maize yields in China would decline by 36.25%, 18.26%, and 45.10%, respectively.[2].

The Sichuan Basin, located in Southwest China, is bordered by the Qinghai-Tibet Plateau and the Hengduan Mountains to the west, the Qinling Mountains and the Loess Plateau to the north, the Xiang-E Mountains to the east, and the Yunnan-Guizhou Plateau to the south. Its subtropical monsoon climate, characterized by abundant rainfall and suitable temperatures, makes it an ideal area for agricultural production. Sichuan is one of China's 13 major grain-producing areas.

The Sichuan Climate Centre has provided a comprehensive analysis indicating that between the years 1961 and 2023, there has been a significant upward trend in the annual average temperature, as well as in the annual average maximum and minimum temperatures recorded in Sichuan. Specifically, the data reveals that the annual average temperature has increased by approximately 0.19°C per decade, while the annual average maximum temperature has risen by about 0.26°C per decade, and the annual average minimum temperature has shown an increase of approximately 0.24°C per decade. These findings underscore the ongoing climatic changes in the region, highlighting the importance of continued monitoring and research in the field of climate science and its implications for environmental and societal impacts.

This paper reviews literature to explore the impact of climate change on agriculture in the Sichuan Basin over the past 60 years. It also examines how government policies and technological advancements can enhance crop adaptability to climate change, thereby ensuring stable grain production in China.

2. Overview of the Sichuan Basin

Sichuan Province lies in Southwest China and features a subtropical monsoon climate. It has mild temperatures, abundant rainfall, and diverse terrain, making it suitable for growing a variety of crops. Key agricultural products include rice, wheat, maize, rapeseed, vegetables, and fruits, with the Chengdu Plain and southern Sichuan playing particularly vital roles.

Sichuan, one of China's 13 principal grain-producing regions, encompasses an area of 485,000 km², featuring 5.23 million hectares (78.41 million mu) of arable land [3]. In 2023, the province's GDP attained 6.01 trillion yuan, while total agricultural output approached 1 trillion yuan. Sichuan's grain production reached 71.88 billion kilogrammes, reflecting a 2.4% rise over the prior year, establishing a new record and securing the ninth position nationally [4].

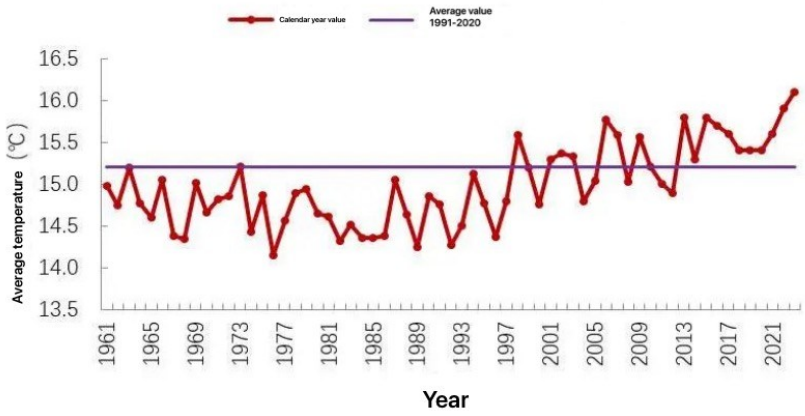

Figure 1: Average temperature from 1961-2021

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Temperature is a critical environmental factor that directly influences crop growth stages, geographical distribution, and final yields. It also indirectly affects the prevalence of crop diseases and pests, posing challenges to crop health. Meanwhile, water is essential for sustaining plant life, and its availability must remain within optimal levels. Deviations from these levels, whether excessive or insufficient, can disrupt reproduction, limit yield potential, and adversely affect crop quality. Thus, precise control of temperature and water conditions to meet crop physiological needs is essential for ensuring stable production and improving crop quality.

Between the years 1961 and 2021(Figure 1), the annual mean temperature recorded in Sichuan demonstrated a clear and significant upward trend, with a particularly pronounced intensification of warming observed since the beginning of the 21st century. In parallel, the precipitation data collected throughout this timeframe revealed substantial interannual variability. Certain years were marked by exceptionally heavy rainfall, exceeding 1,100 mm(Figure 2), whereas other years experienced markedly lower precipitation levels, dropping to as little as 700 mm. This variability highlights the inherent unpredictability associated with precipitation patterns in the region.

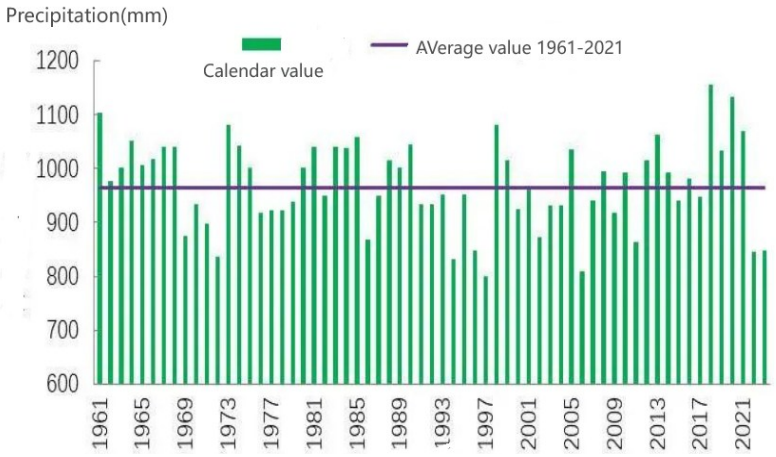

Figure 2: Precipitation from 1961-2021

3. Impacts of Climate Change on Agriculture in the Sichuan Basin

3.1. Direct Impacts

Rising temperatures are among the most direct effects of climate change on agriculture in the Sichuan Basin. Since 1961, the province's annual average temperature has increased by approximately 0.19°C per decade, with similar trends observed in maximum and minimum temperatures. Higher temperatures directly affect crop growth cycles, flowering and fruiting times, and final yields.Rice is especially susceptible to high-temperature stress during the grain-filling stage, resulting in diminished grain weight and overall quality [5].

Moreover, rising temperatures have intensified the frequency and severity of crop diseases and pest outbreaks. Warm and humid weather facilitate the spread of pests such as rice blast and aphids, which diminish crop yields and escalate farmers' pest management expenses[6].

Fluctuations in precipitation have also directly affected agricultural production in Sichuan. Excessive rainfall has caused flooding in some years, while reduced precipitation has led to droughts in others. For instance, severe flooding in 2020 submerged large areas of farmland, causing significant crop damage. Conversely, drought conditions during hot summers have exacerbated water shortages for crops like rice and maize, limiting their growth and reducing yields.

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3.2. Indirect Impacts

Beyond direct effects, climate change has indirectly impacted agriculture by increasing the frequency of extreme weather events such as heatwaves, droughts, and floods. These events have heightened production uncertainty and posed greater risks for farmers.

For example, extreme heat events in recent years have disrupted labor schedules and extended production cycles, increasing the physical and financial burden on farmers. Additionally, frequent natural disasters have forced farmers to invest more in irrigation, fertilization, and pest control.

Climate change has impacted the ecological ecosystem of the Sichuan Basin. Alterations in the region's ecosystems, including wetlands and woodlands, have jeopardised soil quality, water conservation, and biodiversity. These ecological changes have intensified soil erosion and increased the susceptibility of agricultural environments.

4. Government Policies and Their Benefits

Under the context of climate change, the Sichuan provincial government has implemented a series of measures to enhance the adaptability and resilience of agricultural production. First, in terms of irrigation expansion and water infrastructure construction, Sichuan introduced the “Agricultural Water Resource Efficiency Action Plan” in 2016, which promoted the widespread application of efficient water-saving irrigation technologies, such as sprinkler irrigation, drip irrigation, and micro-irrigation. These technologies are particularly suitable for mountainous regions and water-scarce areas in Sichuan, significantly improving water resource utilization. For example, Luzhou City implemented drip irrigation systems, greatly enhancing irrigation efficiency and ensuring a stable water supply for farmland. At the same time, Sichuan strengthened water diversion projects, such as the Dadu River Water Source Project, which has provided additional water resources for the Sichuan Basin and improved the stability of agricultural production under extreme climatic conditions.

In addition, Sichuan introduced an agricultural meteorological disaster insurance system to help farmers mitigate risks associated with climate change. Since 2018, the province has implemented agricultural insurance policies covering natural disasters such as droughts, hailstorms, and floods, allowing farmers to insure their crops and receive compensation in the event of such disasters. In 2019, during the significant flooding in Sichuan, the agricultural meteorological insurance policy significantly mitigated farmers' economic losses and facilitated a swift recovery of production capacity.[7].

In the realm of technological innovation, the province of Sichuan has actively fostered the development of advanced agricultural research institutions aimed at creating and implementing technologies that significantly bolster farmers' capacity to adapt to the challenges posed by climate change. Notably, the Sichuan Academy of Agricultural Sciences has successfully engineered crop varieties that exhibit resilience to critical environmental stressors, including drought, elevated temperatures, and excessive flooding. The strategic promotion of these innovative crop varieties has led to remarkable advancements in Sichuan's agricultural production, facilitating a robust adaptation to the adverse effects of climate change. For instance, the introduction of drought-resistant and pest-resistant rice varieties has not only resulted in enhanced crop yields but has also contributed to the improvement of overall crop quality. These forward-thinking policies, coupled with groundbreaking technological innovations, have played a pivotal role in advancing the sustainable development of agriculture within Sichuan. This, in turn, has ensured a stable grain production system while simultaneously fortifying the resilience of the agricultural sector against the uncertainties of climate variability.

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5. Conclusion

Over the past sixty years, the Sichuan Basin has undergone considerable climatic transformations, characterized by a notable increase in average temperatures and unpredictable precipitation patterns. These climatic shifts have introduced significant challenges to agricultural productivity, manifesting in altered phenological growth cycles of crops, heightened incidences of pest infestations, and an increased susceptibility to extreme weather phenomena. While these adversities pose a serious threat to food security within the region, the Sichuan government has implemented a series of proactive measures aimed at alleviating their detrimental effects. These measures encompass the formulation of targeted agricultural policies, the promotion of technological innovations, and the enhancement of critical infrastructure, all designed to bolster resilience in the face of these climatic challenges. Measures like efficient irrigation systems, crop insurance, and climate-resilient crop development have proven effective in maintaining agricultural stability. It is essential to enhance the integration of scientific research, policy frameworks, and agricultural education to develop a more climate-resilient agricultural system in the Sichuan Basin. These efforts will not only safeguard regional food production but also serve as a model for other areas facing similar climate challenges.

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