I J C R M

International Journal of Contemporary Research In Multidisciplinary

Research Article

Climate Change and Its Impact on Major Crops in Malwa Region, Punjab

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DOI: https://doi.org/10.5281/zenodo.15289003

Abstract

Climate change seriously impacts the availability of various resources on the Earth, especially water, which sustains life on this planet. Environmental changes, biodiversity, and natural resources significantly affect human health and quality of life. Throughout the 21st century, India is anticipated to experience warming above the global level. India will also begin to suffer more seasonal variation in temperature, with higher warming in the winters than summers. Longevity of heat waves across India has extended in recent years with warmer night temperatures and hotter days, and this trend is expected to continue. The average temperature change is anticipated to be 2.33°C-4.78°C with a doubling in CO_2 concentrations. These heat waves would lead to increased variability in summer monsoon precipitation, which would result in dramatic consequences on the agriculture sector in India. Global temperatures and carbon dioxide (CO_2) concentrations are expected to gradually increase, according to climate models. However, these models are not very good at forecasting how local weather conditions will evolve in the future. When combined with locally adapted plant varieties, cropping systems, and soil conditions, local weather conditions like rain, temperature, sunshine, and wind can optimize food production as long as plant diseases can be controlled. Assessing the sustainability of food systems requires accurate estimates of how climate change will affect crop production. For almost 40 years, global, regional, and site-specific crop simulation studies have been carried out, providing valuable information for assessments of the effects of climate change. Nevertheless, the abundance of data generated by these studies has not been made publicly available. In this work, we create a global dataset by combining data from a new literature search covering recent crop simulations with previously published meta-analyses, building on 8703 simulations from 202 studies published between 1984 and 2024. Along with geographic coordinates, current temperature and precipitation levels, and anticipated temperature and precipitation changes, it includes projected yields of the four major crops (wheat, soybean, rice, and maize) in 91 countries under major emission scenarios for the twenty-first century, both with and without adaptation measures. This dataset will support the quickly evolving data-driven machine learning applications and offers a strong foundation for a quantitative evaluation of the effects of climate change on crop production.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 12-03-2025
- **Accepted:** 31-03-2025
- **Published:** 26-04-2025
- **IJCRM:**4(2); 2025: 330-335

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Saluja R, Juneja A, Singh M. Climate Change and Its Impact on Major Crops in Malwa Region, Punjab. Int J Contemp Res Multidiscip. 2025;4(2):330-335.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Behavioural Economics, Public Policy, Nudge Theory, Policy Design, Behavioral Interventions, Public Health Policies, Economic Behavior

INTRODUCTION

The climate of Punjab State has been changing and it hurts the agricultural yields. The consequences of climate change on food Crops are not the only source of output. Through its direct or indirect effects on other elements of the agricultural production systems, it will have an impact on food production and food security. It is expected that climate change will persist for a long time and significantly impact farmers' livelihoods and the sector's overall economy. Global surface temperatures are expected to rise by 1.0 to 1.8 degrees Celsius under the very low GHG emissions scenario (SSP1-1.9), by 2.1 to 3.5 degrees Celsius under the intermediate GHG emissions scenario, and by 3.3 to 5.7 degrees Celsius under the very high GHG emissions scenario, according to the sixth assessment report recently released by the Intergovernmental Panel on Climate Change. The yield of all major crops is expected to reduce by 1 to 10% by 2035, 3 to 18% by 2065, and 4 to 26% by 2100 due to anticipated changes in rainfall and temperature. A quantitative evaluation of the climate of Punjab's many crops is crucial in light of the forecasts of a major shift in the future climate. To do this, we use panel data of crop yields and key climatic variables, like temperature and rainfall, from various districts in Punjab. We then apply a fixed-effect panel model technique to this dataset to produce estimates of how temperature and rainfall affect the yield of Punjab's main rabi and kharif crops. This study adds significantly to the body of knowledge regarding the detrimental effects of climate change on Punjab's key crops. Although rice and wheat have been the focus of traditional measures, we have taken into account cotton, maize, and potato crops in this study, which contributed 6.02 percent, 2.80 percent, and 2.57%, respectively. This analysis helps direct agricultural policy in the prioritization of climate risks, and the results provide a solid foundation for enhancing community resilience, sustainability, and productivity.

METHODOLOGY

The data for the present study will consist of secondary data. The secondary data will be collected from the Directorate of Economics and Statistics, Punjab, Krishi Bhawan, Regional Meteorological Center, Official Press, Journalist Statistical Handbook of Punjab, Government Diary of Punjab Government, and the economic survey of Punjab.

Climate of Punjab

The location of Punjab from both geographical and latitudinal points is such that the state experiences a big alteration in temperature almost every month. The temperatures generally reach their maximum in the period from mid-May to June. The state experiences the minimum temperature in the period from December to February. Punjab mainly goes through three major seasons. Summer from mid-April to June end, Monsoon from early July to September end, and Winter from early December to February end. Punjab also observes transitional seasons apart from the main seasons. These seasons are the pre-summer season from March to mid-April and the post-monsoon season from September to November. The pre-summer season is the transition phase between winter and summer. The post-monsoon season is the transition between monsoon and summer. The highest recorded temperature in Punjab is 46.1 degrees Celsius and 0.2 degrees Celsius in Ludhiana and Amritsar, respectively. The state received maximum monsoon by the state and a little winter rain.

Climate change in Punjab

The climate of Punjab is changing unusually. Severe impacts of climate change on the temperature, groundwater discharge, precipitation, agriculture, and evapotranspiration. Urgent and effective steps must be taken to minimize such changes in the climate of Punjab and its effects. Punjab, well-known for its immense growth in the agriculture domain, is going through the need for intense water extraction, negligible forest cover, and excessive use of fossil fuels, making the state more affected by climate change. In the last five decades, the wrong cropping patterns and urbanization without proper planning have naturally led to the relentless use of resources. Due to this, large changes have occurred in the climate of Punjab. Abnormal rain patterns have affected crop yield and farmers' income at an extreme level. The frequent floods and droughts were not something the state used to experience a few decades ago. For instance, Punjab sometimes witnesses heavy rainfall in August, which is uncommon and a great concern for the state and the country. A clear strategy to maintain the climate of Punjab and avoid uncommon climate changes in the state is needed.

Changes in Rainfall and Temperature

Number of Rainy Days

The number of rainy days in Punjab shows a decreasing trend over the past, except during 1990-99 when it increased to 430 days.

Changing pattern of several rainy days in Punjab

Period	Central Region			Western Plain Region	Western Region		Average
	Amritsar	Ludhiana	Patiala	Faridkot	Abohar	Bathinda	
1970-1979	387	361	361	-	-	-	370
1980-1989	399	389	377	-	-	269	359
1990-1999	452	428	413	-	-	302	430
2000-2009	357	376	328	254	-	245	339
2010-2019	367	410	453	268	183	310	353
Average	392	393	386	261	183	282	370

Note: Rainfall ≥ 2.5 mm is counted as one rainy day.

Incidence of Extreme Weather Events in Punjab

The study of the occurrence of extreme weather events is very important as these events have a direct and immediate effect on crops, livestock, and humans. The rainfall events in which the total amount of rainfall was greater than 100 mm were considered as extreme rainfall events, and the data revealed that:

Extreme Rainfall Events

The incidence of extreme rainfall events increased in the state up to 1990-99 and then decreased. The incidence of rainfall events > 100mm was maximum during 1980-89, when floods occurred during 1984 and 1988 in the whole of the Punjab. Again, 1990-99 had a high incidence of rainfall events >100mm and resulted in the occurrence of floods during 1995.

Incidence of rainfall event >100 mm (No. of days) in Punjab

Period	Central Region			Western Plain Region	Western Region		Average
	Amritsar	Ludhiana	Patiala	Faridkot	Abohar	Bathinda	
1970-1979	3	2	3	-	-	-	2.7
1980-1989	6	7	15	-	-	5	8.3
1990-1999	7	8	7	-	-	5	8.0
2000-2009	6	5	5	1	-	1	3.8
2010-2019	5	7	5	1	3	2	4.3
Average	5.4	5.8	7.0	1.0	3.0	3.3	5.4

Temperature

High Temperature

On average, the number of days with temperatures higher than 40°C has increased in Punjab. During the past maximum number of days with temperatures higher than 40°C was observed at Bathinda, followed by Amritsar and Patiala. Among all the locations highest number of days with temperature higher than 40 °C was observed at Bathinda during 1980-89, followed by 2010-19.

Incidence of temperature >40 °C (No. of days) in Punjab

Period	Central Region			Western Region	Average
	Amritsar	Ludhiana	Patiala	Bathinda	
1970-1979	334	278	256	-	289
1980-1989	319	279	93	646	336
1990-1999	226	208	260	429	265
2000-2009	311	230	244	407	283
2010-2019	339	279	326	442	322
Average	306	255	276	481	303

Low Temperature

On average, the number of days with temperatures below 2°C has decreased in Punjab. During the past highest number of days with temperature below 2°C was observed at Amritsar, followed by Bathinda.

Among all the locations highest number of days with temperature below 2°C was observed at Amritsar during 1980-89, followed by 2000-2009.

Incidence of temperature < 2 °C (No. of days) in Punjab

Period	Central Region			Average	
	Amritsar	Ludhiana	Patiala	Bathinda	
1970-1979	153	91	6	-	83
1980-1989	173	28	1	140	70
1990-1999	141	12	5	68	57
2000-2009	169	31	2.2	69	74
2010-2019	99	9	2	44	36
Average	147	34	7	80	62

The major 4 crops And Time in Punjab are: In Punjab, the two main cropping seasons are Rabi and Kharif.
Rabi crops are grown during the winter season, from October to March. The main Rabi crops in Punjab are:
Kharif crops are grown during the summer season, from April to September. The main Kharif crops in Punjab are**:**

1. **Wheat**: One of the biggest producers of wheat in India, wheat is Punjab's principal crop. Approximately 20% of the nation's total wheat production, or more than 15 million tonnes, are produced annually in Punjab.
2. **Rice:** Rice is the second most significant crop in Punjab, and the state is a major producer of basmati rice. Approximately 15% of the nation's total rice production, or more than 10 million tonnes, are produced annually in Punjab.
3. **Cotton:** One of Punjab's main cash crops, the state ranks among India's top producers of the commodity. Over 2 million tonnes of cotton are produced annually in Punjab, accounting for around 10% of the nation's total cotton production.
4. **Maize:** Punjab produces more than 1 million tonnes of maize annually, making it another significant crop in the state. In addition to being consumed by humans, maize is fed to livestock and fowl.
   The state's economy is largely reliant on these four crops, which form the foundation of Punjabi agriculture. The following seasons are used to grow the crops:
   Wheat: October to April
   Rice: June to October
   Cotton: April to October
   Maize: June to October

The following areas of Punjab are used to grow the crops:
Wheat: Punjab's central and western regions
Rice: Punjab's eastern and southern regions
Cotton: Punjab's southern and western regions
Maize: Punjab's central and southern regions

In order to encourage the growth of these crops, the Punjab government offers farmers a number of incentives and assistance programs, like as crop insurance, fertilizer, seed, and irrigation subsidies.

The impact of climate change on the 4 major crops in the Malwa region of Punjab
The Malwa region of Punjab is a major agricultural hub, with wheat, rice, cotton, and maize being the four major crops grown in the region. However, climate change is having a significant impact on the productivity and sustainability of these crops.

Wheat
1. Temperature increase: Rising temperatures are expected to reduce wheat yields by 2-3% for every 1°C increase in temperature.
2. Changing precipitation patterns: Erratic rainfall patterns, including droughts and floods, can damage wheat crops and reduce yields.
3. Shift in growing season: Warmer temperatures are causing the growing season to shift, which can lead to reduced yields and lower quality wheat.
4. Increased pest and disease pressure: Climate change is altering the distribution and prevalence of pests and diseases that affect wheat, such as aphids and powdery mildew.
5. Impact on yield: Wheat yields in the Malwa region are expected to decline by 10-15% by 2030 due to climate change.

Rice
1. Temperature increase: Rising temperatures are expected to reduce rice yields by 1-2% for every 1°C increase in temperature.
2. Changing precipitation patterns: Erratic rainfall patterns, including droughts and floods, can damage rice crops and reduce yields.
3. Increased flooding: Sea-level rise and more frequent extreme weather events are increasing the risk of flooding, which can damage rice crops and reduce yields.
4. Shift in growing season: Warmer temperatures are causing the growing season to shift, which can lead to reduced yields and lower quality rice.
5. Impact on yield: Rice yields in the Malwa region are expected to decline by 5-10% by 2030 due to climate change.

Cotton

1. Temperature increase: Rising temperatures are expected to reduce cotton yields by 3-4% for every 1°C increase in temperature.

2. Changing precipitation patterns: Erratic rainfall patterns, including droughts and floods, can damage cotton crops and reduce yields.

3. Increased pest and disease pressure: Climate change is altering the distribution and prevalence of pests and diseases that affect cotton, such as aphids and bollworms.

4. Shift in growing season: Warmer temperatures are causing the growing season to shift, which can lead to reduced yields and lower quality cotton.

5. Impact on yield: Cotton yields in the Malwa region are expected to decline by 15-20% by 2030 due to climate change.

Maize

1. Temperature increase: Rising temperatures are expected to reduce maize yields by 2-3% for every 1°C increase in temperature.

2. Changing precipitation patterns: Erratic rainfall patterns, including droughts and floods, can damage maize crops and reduce yields.

3. Increased pest and disease pressure: Climate change is altering the distribution and prevalence of pests and diseases that affect maize, such as corn borers and rootworms.

4. Shift in growing season: Warmer temperatures are causing the growing season to shift, which can lead to reduced yields and lower quality maize.

5. Impact on yield: Maize yields in the Malwa region are expected to decline by 10-15% by 2030 due to climate change.

Overall, climate change is having a significant impact on the 4 major crops in the Malwa region of Punjab, with wheat, rice, cotton, and maize yields all expected to decline by 2030. These impacts will have significant consequences for food security, livelihoods, and the economy in the region.

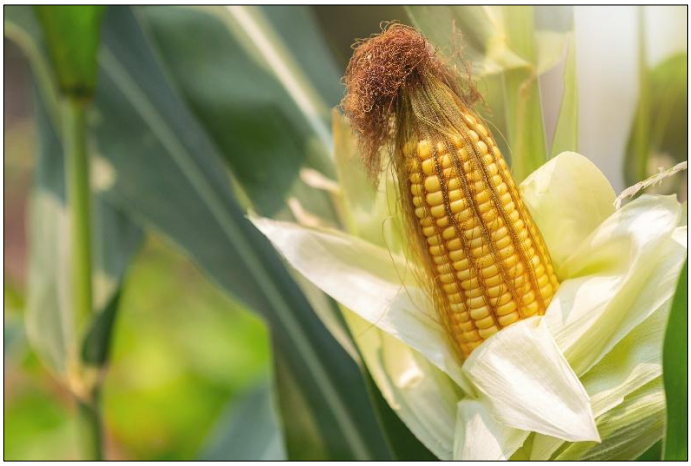
Regional Impacts

1. Bathinda district: The Bathinda district is expected to experience a decline in wheat yields of 12-15% by 2030 due to climate change.

2. Mansa district: The Mansa district is expected to experience a decline in cotton yields of 18-20% by 2030 due to climate change.

3. Sangrur district: The Sangrur district is expected to experience a decline in rice yields of 8-10% by 2030 due to climate change.

4. Patiala district: The Patiala district is expected to experience a decline in maize yields of 12-15% by 2030 due to climate change.



Projected yield loss: According to reports from The Times of India, climate change is expected to significantly impact major crops in Punjab, with studies predicting a decline in yields of maize (up to 13%), cotton (around 11%), and to a lesser extent, rice (around 1%) by 2050, primarily due to rising temperatures and altered rainfall patterns; this could lead to a significant decrease in agricultural productivity in the state.

Most affected crops: Maize is projected to experience the most substantial yield reduction, followed by cotton, while the impact on rice is relatively smaller.

Impact on yield: Studies indicate a potential decrease in crop yields ranging from 11-13% for maize and cotton, and around 1% for rice by 2050.

Accumulating impact: The negative effects of climate change are expected to worsen over time, with further yield losses anticipated in the coming decades. Due to the effects of climate change, Punjab, which produces 10% of the country's food grains, may witness a decline in the yield of between 13% and 1% in its major Kharif and Rabi crops by 2050. This has been pointed out in the synthesis report of the Intergovernmental Panel on Climate Change (IPCC). Assessing the current state of scientific knowledge related to climate change, the report brought together the findings from various scientific studies to provide a clear picture of the risks and impacts of climate change,

as well as the options for mitigating and adapting to those risks. (Times of India, 7 Jan 2023).

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