

Climate Change and Ecologically Vulnerable Farming in Punjab: Some Highlights

Jasvir Singh* and Shivjeet Kaur

Department of Geography, Punjabi University, Patiala, Punjab, India
✉ jasvir_rs@pbi.ac.in

Received April 12, 2023; revised and accepted July 1, 2023

Abstract: The economic and technological growth in the last quarter of the 20th century and the beginning of the 21st century resulted in a drastic change in the climate (extreme weather conditions for the sustainability of human life on the earth). The updated report of CoP-25 (meeting of Parties), which was held on 3rd December 2019 in Madrid (Spain) used the term “climate emergency” instead of “climate change”. It was a warning for all the developing and developed countries, which depended heavily upon agriculture. The present study highlights some of the global climatic issues which affected the anthropological development in Punjab. This state has been regarded as the backbone of the Indian economy and is also known as the food basket of India. The cropping pattern is changing from diversification to specialisation. The farmers of the Punjab region focus only on rice-wheat cropping patterns. The major factors of resource depletion, particularly in Punjab, are land and water. The problem of food security and environmental degradation is increasing day by day.

Keywords: Agriculture; Climate change; Rainfall; Forest and temperature.

Introduction

Agriculture plays an important role in the Punjab economy and has a huge share in national income, food security, and livelihood. In India, the agricultural sector still employs about 54 percent of the country's workforce. Over the past 40 years (1969–2005), the temperature in India is increasing at a rate of 0.3°C per decade, with rising CO₂ and SO₄ (BIRTHAL et al., 2014). Asia is facing critical challenges due to climate change and variability as illustrated by various climatic models, predicting that the global mean temperature will increase by 1.5°C between 2030 and 2050 if it continues to increase at the current rate. In arid areas of the western part of China, Pakistan, and India, it is also projected that there will be a significant increase in temperature (IPCC, 2019). In the context

of climate change, many problems have been arising such as recurring droughts, floods, hurricanes, hot waves and fluctuations in temperature (GOSWAMI et al., 2006). These major events exacerbated the crisis of livelihood in the agricultural sector in the form of a significant decline in agricultural production, food security problems, and rural poverty (BHANDARI et al., 2007). The rising temperature has led to a decrease in the crop-growing period, and crop evapotranspiration, and ultimately reduced wheat yield (AZAD et al., 2018). Many scholars argued that developing countries are more likely to be affected by climate change due to insufficient use of technology, information, and resources for improvement, adaptation, and lack of infrastructure. In the recent past, an increasing number of studies have been done that deals with the effects of climate change (Sinha and Swaminathan, 1991;

*Corresponding Author

Aggarwal, 2009). This is a controlled pilot research that has been done to study the effects of climate change in which crops are exposed to fluctuations in temperature and then yields are compared between temperature levels to assess the effects of climate change. This approach is based on an understanding of agricultural science. Many agricultural scientists and agronomists (Mendelsohn et al., 1994; Kumar and Parikh, 2001; Mendelsohn and Dinar, 2009) suggested that farmers can maximise their profits by allocating land to various crops such as diversification in agriculture. On the other hand, a major criticism of this approach is that crop choices and production methods do not change over time, regardless of climate change. Based on the above discussion, this article throws light on two issues:

- (i) Changes in meteorological variables, i.e., temperature and precipitation
- (ii) Impact of climate change on the yield of important food crops.

In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) stated that “Global warming is unquestionable, as evidenced by observations of rising global warming and sea temperatures, widespread melting of snow and ice sheets, and rising sea levels globally (Solomon et al., 2007).

Vittal et al. (2016) have shown that despite the significant increase in temperature over the past century, the amount of precipitation (rainfall) has kept an unpredictable nature. As agriculture remained a climate-sensitive sector, there have been many studies over the past decade to assess the impacts of climate variability and change. Research questions related to climate change and agriculture in India include:

- (a) Is India’s agriculture likely to get affected by climate change?
- (b) How is the vulnerability of farmers to climate change characterised? Which regions are relatively vulnerable to climate change?
- (c) How will the different adapted options be effective for reducing current and future vulnerabilities?

This study provides an overview of research on the impact of climate change on Punjab agriculture, especially in terms of physical impact. Evidence suggests that the yields of important crops such as rice and wheat have significantly been reduced due to meteorological variables. However, their biophysical effects on some important crops such as sugarcane, cotton, and sunflowers are not well understood. The economic impact of climate change on agriculture is

widely studied across the world and remained a subject of debate and discussion among academic and policy-making circles.

This article is divided into four sections including an introduction. Section two deals with the study area and methodology. The third section focusses on some highlights related to climate change and the fourth section is related to original empirical evidence regarding the forest and rainfall scenario of Punjab. The last section consists of a conclusion.

Study Area and Research Methodology

The Malwa region of Punjab is in the shape of a rough parallelogram lying between 29°-30 and 31°-10 North latitudes and 73°-50 and 76°-50’ East longitudes. This region is sandwiched between the Sutlej River to the north and west, the seasonal Ghaggar River to the south, the Shivalik Hills to the east, and Pakistan to the west. Doaba and Majha are in the north, located above the Sutlej River. Malwa region is bordered by Himachal Pradesh to the east, Haryana to the south and southeast, and Rajasthan to the southwest. The Malwa region is influenced by the Himalayas in the northeast and the Thar Desert in the south. The circulation of moist air masses to the southeast and northwest determines the presence of two wet seasons, followed by dry ones. Summers are hot and warm, and winters are cold. Physical properties such as minimal rainfall, sandy, and alkaline soils, and extreme temperature limits make the area’s vegetation suitable for growing shrubs and citrus fruit gardens. The irrigation of rice and wheat in the region is supported by canal and groundwater irrigation and is putting pressure on the already scarce natural resource of the Malwa region.

This study is based on secondary data sources. Data has been taken from the Statistical Abstract of Punjab, whereas information regarding climate change is sourced from Intergovernmental Panel on Climate Change (IPCC) reports, the Environment Directorate of Punjab, and various other documents with related studies. The calculation of data is based on a simple percentage method. The present data contains district-wise overall annual rainfall and land utilisation of the past 50 years. To look into its effects, the data were divided into six time periods, i.e., 1969, 1979, 1989, 1991, 2009, and 2019. The authors used a 3-year moving average (percentage share) method to examine the area under forest covers and rainfall scenarios across districts of the Malwa Region. The study highlights the precipitation level (rainfall) and forest cover of eight districts taken

as a sample from the Malwa region of Punjab namely Ludhiana, Firozpur, Sangrur, Bathinda, Mansa, Sri Muktsar Sahib, Faridkot and Patiala.

Some Highlights Related to Climate Change

Ecological Migration and Resettlement

The recurrence of extreme weather events such as drought, floods, desertification, and hot waves has led to mass migration due to the loss of livelihoods. The pressure on urban infrastructure due to forced migration makes it difficult to provide basic amenities and comprehensively hampers the development of industrial centers. In 2019, two different migration studies were published covering two different periods. One is related to the Iron Age migration and the other is related to the 2019 migration. Natural disasters are usually associated with temporary resettlement or displacement of people. In 1990, the Intergovernmental Panel on Climate Change (IPCC) determined that the only major impact of climate change is human migration. According to experts, by 2050, more than 200 million people will be forced to leave their homes. A term used for such group is “climate immigrants” or “climate refugees”.

Extreme Weather Conditions

Increasing temperature, retreating glaciers, rising coastal lines, and unexpected monsoon patterns will have an effect on many factors such as the health and well-being of society in the form of food production, hygiene, gender, and many more. According to the Global Climate Risks Report 2020, India had the highest number of deaths in 2018 (2,081) due to climate-related extreme weather events. As India ranked second in economic losses in 2018, the potential for more human and economic losses is clear. The report states that the Kerala disaster is “the worst in 100 years”. It should be noted that, except for some developed countries, all developing countries continue to be directly affected by climate change.

Food Security, Agriculture and Livestock

Food security is affected by food production, food availability, access to food, security of food supply, and food price volatility. Rice and wheat are the staple food for the majority of India’s population and studies have shown that climate change is causing a significant reduction in crop production. Similarly, the impact of climate change on legume production is significant. India is facing significant land constraints to compensate for increased food demand. In addition, agricultural land is subject to various types of degradation. The

intensification of agriculture, increased competition for housing, and industrialisation are leading to the depletion of resources such as land and water. The impact of climate change on food production is not limited to food crops. Livestock is another important area affected by climate change. India’s livestock economy is based on mixed farming and in parallel provides food for the livestock from its by-products and crop residues. A decrease in agricultural yield leads to decreased quantity of fodder/feed for livestock. Heat stress in animals reduces food intake. Higher temperatures and changes in precipitation (rainfall) patterns could increase the prevalence of existing vector-borne diseases, changing disease patterns, introduction/origin of new diseases, and affect reproductive behaviour in humans and animals. Therefore, it is very important to encourage the use of sustainable agricultural practices to address potential threats to food security.

Water Scarcity

The availability of water is the most important factor for agriculture. Excessive use of chemicals (fertilisers and pesticides) in agriculture leads to pollution of groundwater and heightens the level of depletion of nutrients. Extreme weather conditions and climatic fluctuations affect the amount and timing of rainfall. In the absence of specific mitigation policies, overfishing is also on the rise, which is a cause for concern. Oceans and other large water bodies also serve as a natural carbon sink. These sinks can partially reduce the impact of carbon dioxide emissions by absorbing carbon dioxide from the atmosphere. The gradual absorption of carbon dioxide has a reversible negative effect called ocean acidification.

Health Issues

Besides natural disasters and extreme weather conditions, human life is endangered by diseases and sudden outbreaks of epidemics. Climate change has the largest impact on vector diseases, along with food and waterborne diseases, followed by direct injuries and deaths, heat-related injuries, and mental health problems. Poor availability and poor quality of water is the main factor for common vector-borne diseases such as encephalitis, yellow fever, dengue, malaria as well as diarrhoea and malnutrition. Due to the increase in temperature and air pollution, bronchial and respiratory diseases are on the rise. Since the early 1950s, in India, despite extensive measures, these diseases have become endemic in the majority of regions.

Empirical Considerations

As we discussed, climate change as a global phenomenon has been recognised as one of the most serious threats to sustainable development, as it can have adverse effects on natural resources that in turn affect food security, human health, and economic activity. Punjab is an agricultural state that relies on limited natural resources for its livelihood and economy. However, several key sectors such as agriculture, water resources, forests, ecosystems, and biodiversity face multiple developmental and environmental constraints. Climate change has raised concerns in key sectors of the country. Observational data indicate a high degree of variability in the overall increase in temperatures during the years 1971-2000, with a decrease in the average annual rainfall. This, along with various emerging challenges, could negatively affect productivity in agriculture and related sectors.

Table 1 reveals the overall average annual rainfall, which was measured in millimeters, for some specific years in Punjab. It should be noted that 700 mm of rainfall is supposed to be normal for the harvest years in the region, which is highly fluctuating during the 21st century. In 1969, rainfall is measured at 672 mm, and the highest average rainfall in Punjab was witnessed in 1989 with 754 mm rainfall. However, in 1999, 2009

Table 1: Punjab overall average annual rainfall

<i>Years</i>	<i>Average annual rainfall (mm)</i>
1969	672
1979	739
1989	754
1999	392
2009	385
2019	427

Source: Report Government of Punjab: 1969, 1979, 1989, 1999, 2009 and 2019.

and 2019, the amount of rainfall was measured as 392 mm, 385 mm and 427 mm, respectively. The climate of Punjab is generally subtropical, with temperatures ranging from 0°C in winter to 47°C in summer, and with an average annual rainfall of 580 to 960 mm. The rainy season (June to September) receives 70-80% of the precipitation.

Table 2 reveals the decade-wise trend of land utilisation patterns in Punjab since 1969. The Application of high yield variety (HYV) seeds for agriculture during 1969-1979 was the decade of the agricultural revolution as it witnessed the highest increase in net area sown as well as in area under forest cover. After 1999, there was a gradual decline in net area sown as well as forest cover, which were 81.9 percent and 5.08 percent, respectively, in 2019. Due to the techno-commercialisation of agriculture, the share of fallow land, which was at 4.14 percent in 1969, saw a huge decline to 1.09 percent in 1979. Since then, this constituent saw a further gradual decline, down to 1.7 percent in 2019. The same trend can be seen for other uncultivated lands, which were at 2.54 percent in 1969, decreased to 1.09 percent in 1979, and further declined to 0.5 percent in 2018. Here it can be seen that both fallow land and other uncultivated land are common land resources and the main layback for the survival of the rural poor are negligibly present in Punjab. The share of land that is not available for cultivation remained approximately constant since the technological reforms were applied in Punjab. It was 12.67 percent in 1969, which declined to 9.73 percent in 1979, then again gradually increased to 10.27 percent in 2009 and stood at 10.16 percent in 2019.

Table 3 explains the decade-wise average annual rainfall in sampled districts of the Malwa region. The data in the table reveals that range of average annual rainfall in sampled districts has increased sharply. Except for Ludhiana and Patiala, (with less range in average annual rainfall than normal 700 mm); Bathinda and Sangrur districts witnessed a high range, i.e., maximum

Table 2: Decade-wise pattern of land utilisation in Punjab

<i>Land utilisation classification</i>	<i>Years</i>					
	<i>1969</i>	<i>1979</i>	<i>1989</i>	<i>1999</i>	<i>2009</i>	<i>2019</i>
Net Area Sown	78.38	83.79	83.55	84.14	82.87	81.9
Forest Area	2.27	4.32	4.41	5.58	5.88	5.08
Land not Available for Cultivation	12.67	9.73	10.09	8.98	10.27	10.16
Fallow Land	4.14	1.09	1.01	0.64	0.78	1.7
Other Uncultivated	2.54	1.09	0.94	0.62	0.20	0.5

Source: Statistical Abstract of Punjab: 1969, 1979, 1989, 1999, 2009 and 2019.

differences in normal average rainfall and actual average rainfall. Notwithstanding much difference, since 1969, these two districts witnessed 388.9 mm and 526.4 mm average annual rainfall, respectively, 356.8 mm and 300.6 mm in 2019. Extreme variability can be seen in the case of Firozpur and Sangrur, where mere 95.6 mm average annual rainfall occurred in the year 1999 in Firozpur and 1979 in Sangrur where only 85.3 mm average annual rainfall occurred. The Mansa district has seen very low rainfall from 2009 to 2019 in comparison to 1999. Overall, the Malwa region is the dry region of Punjab with the least average annual rainfall.

Table 4 shows the trends in the percentage of the area under forest cover in a sampled area of the Malwa region. Keeping structural and inherent aspects constant, absolute forestation is a key measure to combat climate change in public policy. In sampled districts of the

Malwa region, the trend of forest cover shows much insight as Patiala district has the highest area under forest cover in 1969 with 30.51 percent to 26.70 percent in 2019. Ludhiana district has 11.89 percent forest cover in 1969 and 23.65 percent in 2019. This increase in forest cover in the Ludhiana district is attributed to the CSR (corporate social responsibility) content of industrial units of the area. Firozpur district saw a homogenous trend with low differences; it has 22.32 percent forest cover in 1969 and 22.01 percent forest cover in 2019. Bathinda saw an enormous decline in area under forest cover as it was 23.16 percent in 1969; it came down to 15.46 percent in 2019. Sangrur has the least percentage with respect to area under forest cover in sampled Malwa region at 12.15 percent in 1969 and 2.18 percent in 2019. An increase in temperature and CO₂ fertilisation has increased insect pest infestation

Table 3: Decade-wise average annual rainfall (mm) in sample districts of Malwa region

<i>District</i>	<i>Year</i>					
	<i>1969</i>	<i>1979</i>	<i>1989</i>	<i>1999</i>	<i>2009</i>	<i>2019</i>
Ludhiana	487.8	651.9	664.8	504.4	775.9	575.2
Firozpur	283.6	359.8	439.7	95.6	224.1	93.2
Bathinda	388.9	210.3	330.0	42.5	336.7	356.8
Sangrur	526.4	85.3	574.7	228.8	355.5	300.6
Mansa	N.A.	N.A.	N.A.	208.3	139.3	159.5
Faridkot	N.A.	N.A.	N.A.	732.7	520.6	411.8
Shri Muktsar Sahib	N.A.	N.A.	N.A.	N.A.	379.6	287.1
Patiala	430.1	649.7	749.9	471.6	950.9	542.2

N.A.: Data not available

Source: Statistical Abstract of Punjab: 1969, 1979, 1989, 1999, 2009 and 2019

Table 4: Percentage share of area under forest cover in Malwa region

<i>District name</i>	<i>Years</i>					
	<i>1969</i>	<i>1979</i>	<i>1989</i>	<i>1999</i>	<i>2009</i>	<i>2019</i>
Ludhiana	11.86	21.2	19.35	17.86	18.87	22.22
Firozpur	22.32	16.39	20.25	21.43	22.64	22.22
Bathinda	23.16	24.82	18.26	12.50	11.32	13.33
Sangrur	12.15	10.12	12.66	12.50	9.43	2.22
Mansa	N.A.	N.A.	N.A.	5.36	5.66	4.44
Faridkot	N.A.	N.A.	N.A.	3.57	3.77	4.44
Shri Muktsar Sahib	N.A.	N.A.	N.A.	0.00	3.77	4.44
Patiala	30.51	27.47	29.48	26.79	24.53	26.67
Total	100	100	100	100	100	100

N.A.: Data not available

Source: Statistical Abstract of Punjab: 1969, 1979, 1989, 1999, 2009 and 2019.

for forest trees in South-west Punjab (Bao et al., 2019). Rising temperatures, elevated carbon dioxide (CO₂), and fluctuating precipitating patterns lead to the rapid development of insect pests and ultimately more progeny will attack forest trees in Punjab (Raza et al., 2015). Ergo, forest cover is reducing in south-west Punjab at an alarming rate.

Conclusion

Achieving the goals of global climate commitment will require significant changes in the form of positive research and development, environment-friendly agricultural practices, planning of natural resources, etc. A majority of agricultural practices start from the local level, these implementations must be supplemented by updated information, technology, and knowledge at the local level. Adaptation assessment requires the exploration of new tools and approaches. Agent-based modelling for the analysis of social interactions of agents is one of the new tools in this context. Historical anthropogenic disturbances have put great pressure on land and water resources, further creating unsustainable and vulnerable conditions for future generations. All these problems can only be solved with planned sustainable development and logical use of present natural resources.

References

- Aggarwal, P.K., 2009. Vulnerability of Indian agriculture to climate change: Current state of knowledge. *In*: National Workshop–Review of Implementation of Work Program towards Indian Network of Climate Change Assessment (Vol. 14). Indian Rice Research Institute, New Delhi.
- Azad, N., Behmanesh, J., Rezaverdinejad, V. and Tayfeh, R.H., 2018. Climate change impacts modeling on winter wheat yield under full and deficit irrigation in Myandoab-Iran. *Arch. Agron. Soil Sci.*, **64**: 731-746.
- Bao, Y., Wang, F., Tong, S., Na, L., Han, A., Zhang, J., et al., 2019. Effect of drought on outbreaks of major forest pests, pine caterpillars (*Dendrolimus* spp.), in Shandong Province, China. *Forests*, **10**: 264-272.
- Bhandari, H., Pandey, S., Sharan, R., Naik, D., Hirway, I., Taunk, S.K. and Sastri, A.S.R.A.S., 2007. Economic costs of drought and rice farmers' drought-coping mechanisms in eastern India. pp. 43-112.
- Birthal, P.S., Khan, T., Negi, D.S. and Agarwal, S., 2014. Impact of climate change on yields of major food crops in India: Implications for food security. *Agricultural Economics Research Review*, **27(2)**: 145-155.
- Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodanan, M.S., Xavier, P.K., 2006. Increasing trend of extreme rain events over India in a warming environment. *Science*, **314(5804)**: 1442-1445.
- Central Ground Water Board, 2022. Ground Water Resources of Punjab State. Retrieved from Ground Water Management Circle, Water Resources Department, Punjab. <http://cgwb.gov.in/>.
- IPCC, 2019. Global warming of 1.5°C. Summary for Policy Makers. Switzerland: World Meteorological Organization, United Nations Environment Program, and Intergovernmental Panel on Climate Change. Bern, Switzerland.
- Kumar, K.K. and Parikh, J., 2001. Indian agriculture and climate sensitivity. *Global Environmental Change*, **11(2)**: 147-154.
- Mendelsohn, R., Dinar, A. and Williams, L., 2006. The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, **11(2)**: 159-178.
- Mendelsohn, R., Nordhaus, W.D. and Shaw, D., 1994. The impact of global warming on agriculture: A Ricardian analysis. *The American Economic Review*, **84(4)**: 753-771.
- Raza, M.M., Khan, M.A., Arshad, M., Sagheer, M., Sattar, Z., Shafi, J., et al., 2015. Impact of global warming on insects. *Arch. Phytopathol. Plant Protection*, **48**: 84-94.
- Sinha, S.K. and Swaminathan, M.S., 1991. Deforestation, climate change and sustainable nutrition security: A case study of India. *Climatic Change*, **19(1-2)**: 201-209.
- Solomon, S., Qin, D., Manning, M., Averyt, K. and Marquis, M. (Eds.), 2007. Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC (Vol. 4). Cambridge University Press.
- Statistical Abstract of Punjab: 1969, 1979, 1989, 1999, 2009 and 2019. Retrieved from Government of Punjab. <https://punjab.gov.in/>
- Vittal, H., Ghosh, S., Karmakar, S., Pathak, A. and Murtugudde, R., 2016. Lack of dependence of Indian summer monsoon rainfall extremes on temperature: An observational evidence. *Scientific Reports*, **6(1)**: 1-12.