



CLIMATE VARIABILITY AND ITS IMPACT ON AGRICULTURE IN WEST BENGAL: A DISTRICT LEVEL ASSESSMENT

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RESEARCH ARTICLE



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DOI:

<https://doi.org/10.70096/tssr.260401026>

Abstract

In West Bengal, climate variability has become a challenge of high concern to agricultural sustainability that has influenced crop production and livelihood of farmers in various agro-climatic regions. The district-level appraisal focuses on the spatio-temporal arrangement of the variation in temperature and rainfall and their direct effect on the primary agricultural products between 2015 and 2024. An examination shows that there are marked rising patterns in minimum temperature in Gangetic West Bengal regions with maximum temperatures decreasing along the coastal belt such as Contai and Diamond Harbour with maximum temperature rising in Digha and Sagar Island. Annual rainfall has been found to vary significantly with standard deviation of more than 75 mm especially to monsoon reliant agriculture. The relationship proposed in the hypothesis that climate variability has adverse effects on agricultural productivity was established by using the district-wise analysis of crop yields. Findings show that the rice production in vulnerable districts went down by 3-22 percent with Paschim Medinipur being the most affected. The paper uses western Gangetic West Bengal, Sundarbans coastal belt and Sub-Himalayan foothills as the most climatically susceptible areas that need immediate adaptation measures. These results demonstrate the urgency of climate-sensitive.

Keywords: *Climate variability, Agricultural impact, West Bengal districts, Temperature trend, Rainfall pattern*

Introduction

The issue of climate variability is among the most urgent environmental issues facing agricultural systems in the world with far-reaching consequences on food security, rural livelihoods, as well as sustainable development. West Bengal is strategically situated in the eastern part of India and borders the great Himalayas to the north and the Bay of Bengal to the south and is prone to such varying climatic conditions that it is exposed especially to the impacts of climate. The state is a critical agricultural center with a population of more than 91 million people on a land area of 88,752 square kilometers, and 72 percent of the total population is rural with 88 percent of the total landholdings under the category of marginal and small farmers who are highly vulnerable to climatic variations (Das & Goswami, 2023). The economy of the state is still highly reliant on agriculture as it has a large portion of gross domestic product and is a source of employment of a large portion of the labor force, and thus, the socio-economic urgency of climate-related effects of agriculture. The agricultural landscape of West Bengal is composed of the six different agro-climatic zones such as the Hill zone, Terai zone, Old Alluvial Zone, New Alluvial zone, Red and Laterite zone, and Coastal and Saline zone with different susceptibility to climatic variability (Government of West Bengal, 2012). The agricultural industry is largely rain-fed as about 54 percent of the cultivated land area is irrigated and the cultivation density is 176 times, thus being very vulnerable to changes in the monsoon patterns and changes in temperature. According to the recent findings, it has been observed that the climatic parameters are alarming, the late arrival of monsoon, longer summer periods, and more frequent occurrence of extreme weather conditions such as cyclones, floods, and droughts are getting more pronounced in the last 20 years (Halder et al., 2023; Dey and Bhardwaj, 2025).

The temperature patterns in West Bengal show high levels of spatial heterogeneity as the Gangetic West Bengal has a greater level of variability and an increase in the maximum temperature of around 0.008 C per year and decreasing rainfall of 1mm per year whereas the Sub-Himalayan foothills region of West Bengal exhibits less variability with an increasing trend of the maximum temperature of 0.005 C per year (Das & Goswami, 2023). The patterns of rainfall also indicate a strong variation, with the total rainfall in the coastal area increasing steadily in annual and seasonal rainfall, which is largely due to the increasing cyclonic activities, and nine districts such as Nadia, Burdwan, Haora, Hugli, Maldah, Jalpaiguri and North and South Dinajpur, are exhibiting a decreasing availability of rainfall (Dey and Bhardwaj, 2025). Such changes in climatic parameters have trickle effects on agricultural systems, as they impact on crop productivity, crop intensity, patterns and sustainability of farming

practices in various districts. Climate variability is also a problem because the state has 10 extreme weather events in 2022 and 24 extreme weather events in 2023 which is alarming because this is the eighth most vulnerable state in India because of climate change. The downstream effects of the Sikkim 2023 flood have destroyed agricultural land along the Teesta River in the north of the districts with a 4-5 feet sand and silt layer and transformed the entire agricultural scene along a 22 kilometer stretch of the Teesta river between Gajoldoba and Chapadanga. Likewise, the 2024 floods killed people, displaced more than 250,000 people, and washed massive acres of farmlands, especially in the areas of floodplains, inflicting brutal damage on farmers and local economies. It is against this background that there is an urgent need to comprehend the patterns of climate variability on a district level and how the same has specifically affected agricultural productivity in order to formulate specific adaptation strategies which would guarantee food production, as well as the sustainable development of agriculture in one of the most densely populated and agriculturally important states in India.

Literature Review

The relationship between climate variability and agricultural productivity has been well studied in the scientific literature particularly for monsoon-based agricultural systems, e.g. in South Asia. A detailed study on the climatic variability of 5 important climatic parameters (maximum temperature, minimum temperature, precipitation, reference evapotranspiration, solar radiation) across West Bengal during 1951 to 2020 using fractal dimension and non-parametric statistics was conducted by Das and Goswami (2023). A clear south-north gradient of climate variability was detected with significant increasing minimum temperature and decreasing rainfall trends in Gangetic West Bengal and increasing maximum temperature and reference evapotranspiration trends in Sub-Himalayan West Bengal (Maji and Roy, 2022). The regions identified as the most vulnerable are Gangetic West Bengal west, Gangetic West Bengal east, Sundarban, and Sub-Himalayan foothill seasons which needs proactive management of both crops and water. Using Mann-Kendall tests, Sequential Mann-Kendall, Innovative Trend analysis and 21 extreme climate indices, recent work by Dey and Bhardwaj (2025) on extreme climate trends in coastal West Bengal reported the trend on rainfall, temperature, and cyclonic pattern over a daily time series of 42 years from 1982 to 2023. In this context, the findings suggest a statistically significant decreasing trend of maximum temperature at stations Contai and Diamond Harbour, while it has been increasing at Digha and Sagar Island stations, coupled with the fact that the post-monsoon rainfall trends in the region are significant even though this trend is less pronounced compared to other seasons. Based on 31 landfalling depressions, cyclonic storms and super cyclonic storms hitting the Indian coast between 1982 and 2022, the analysis noted 14 cyclones affecting the West Bengal coast during 2006-2020, and while the rainfall pattern shifts were observed over the landmass, it has largely interpreted the reasons for the shifts in rainfall patterns during the monsoons and post-monsoon immediately over the landmass primarily due to the southward shift of cyclonic activity induced by global warming in the North Indian Ocean.

Halder et al. (2023): Monotonic trend and change point detection in annual and seasonal rainfall over West Bengal in context of climate extremes; a long-period trend analysis based on Mann-Kendall tests and sequential Mann-Kendall approach (1901-2020). At seasonal level, the study found change points in general trend around 1960 and 1970 at the district and state level (non-significant decline in annual rainfall over most of the districts of Sub-Himalayan West Bengal). Based on information gleaned from 50 years of daily data, the study reported around 70% of years having normal monsoon rainfall and 16% and 14% of years receiving deficit and surplus rainfall respectively, which means the sequential variability of rainfall; a factor that impacts agricultural planning and water resource development directly. Pradhan et al has explored the effect of climate variability on agricultural transition and cropping systems. of all literature from 2004-05 to 2013-14 available on West Bengal district panel other than that which was produced by Das et al. (2022). Their analysis highlighted the major drivers of agricultural transition as crop diversification, irrigation, fertilizer, road connectivity, and market and storage facilities while showing climatic drivers, relative humidity and temperature variations to be significant in the changes in the cropping pattern. It highlighted the need for agricultural education, extension, and development of human and social capitals to develop in a decentralized way that accommodates various local-level dynamics, especially in the light of increasing climatic variability, to sustain agriculture transition.

Becker et al. using district-level annual data (1966-2014), (2024) estimated relationships between weather indices and rice (and other kharif crops) for the Indian agricultural sector to account for the offsetting effects of temperature and rainfall anomalies on yields. Under Emission scenarios rice yield loss predicted in an empirical analysis by Wu et al. and by the end of the 21st century would be 3-22%, the strongest declining component was estimated in the Paschim Medinipur district in West Bengal showed a loss of 159550 tons under SSP1-2 (Wu et al. Under SSP5-8.6 scenario this is 786,132 tons. 5 scenario. Results showed that the predicted reductions of rice yield are mainly driven by decreases in future climatic extremes on rice and excess of losses of projected future yield increases become important during monsoon season. Kumar et al. Agricultural drought monitoring study in Paschim Medinipur district (2024) applied Google Earth Engine to several drought indicators for 2002–2022, with their study finding substantial inter-annual variability in precipitation, with standard deviations > 75 mm showing extreme between-month wetness-dryness variability between months. From the Standardized Precipitation Evapotranspiration Index, drought indices often plunged to intense negative values < -2 (signifying severe drought), while the Palmer Drought Severity Index indicated several consecutive years of extreme drought from 2006 to 2012. Despite all this fund of events the study observed some positive agricultural trends as post-monsoon Normalized Difference Vegetation Index and Normalized Difference Water Index show rising trends over the time signaling about improvement in vegetation health, water availability, and climate resilience during recent years.

Vulnerability Assessment has brought out the differential impacts of climate variability between districts in West Bengal. Research by Chatterjee et al. Social vulnerability to drought in Purulia district: a household level assessment (2024) found that there was a rise in the frequency and severity of the occurrence of droughts after 2000, which increased the magnitude of crop loss and failure and that 14 out of 20 sub-districts vulnerable to drought were also socio-economically vulnerable (<https://doi.org/10.1016/j.sscres.2024.100001>). The study highlighted key drivers of high social vulnerability, such as inadequate irrigation, illiteracy, heavy dependence on agriculture, a high number of dependent population, and a lack of resources to cope with drought, and underscored the role of combined climatic and socio-economic factors in dictating agricultural vulnerability to drought. Likewise, Kayal and Chowdhury (2025) created an Integrated Agricultural Livelihood Vulnerability Index (IALVI) for Gosaba Block of South 24 Parganas District, in which the Sundarbans act as one of the most climate-vulnerable hot spots especially vulnerable to cyclonic attack and sea-level rise which shows the clear impacts of climate change-induced variation on integrated agricultural livelihood.

The agriculture sector in the State of West Bengal accounts for a large magnitude of multitier economic processes which bears multi-faceted challenges due to persistent climate variability ([1], [2], [3], [4], [5] and [6]). Although climatological impacts of climate change are well understood at a broad scale, limited integrated assessments at the district level have incorporated the spatial variability in recently available climate data with the competing demand for agricultural productivity from multiple crops, on common policy interventions and adaptive management strategies.

Objectives

1. To analyze the spatio-temporal patterns of temperature and rainfall variability across different districts of West Bengal from 2015 to 2024.
2. To assess the district-level impact of climate variability on agricultural productivity, particularly focusing on major crops including rice, wheat, and vegetables.

Methodology

The present study utilizes a synoptic quantitative methodology to evaluate climate variability in relation to agriculture over the 23 districts of West Bengal, India by merging meteorological data and agricultural productivity data in the period 2015-2024. District-level comparative analysis across different agro-climatic zones using spectrums in the temporal trends of climatic parameters and agricultural outcomes. The sample is made up of all the 23 districts of West Bengal which cover a wide range of agro-climatic condition from the Sub-Himalayan regions of the North to the Coastal zone of the South covering Hill zone, Terai zone, Old Alluvial Zone, New Alluvial zone, Red and Laterite zone and Coastal and Saline zone. This extensive coverage represented diverse climate regimes and farming systems within the state, with an added emphasis on the districts exhibiting maximum climate variability and agricultural significance through quick data screening.

Climate and agriculture information are gathered from various trusted authenticated sources for reliability and authenticity in data collection phase. Gridded datasets from the India Meteorological Department (IMD) were used for meteorological data such as maximum and minimum temperature on a daily basis, rainfall, relative humidity, and reference evapotranspiration for the 1982–2024 period with 2015–2024 trends focused. The agricultural productivity data such as area, production, and yield of important crops at the district level were obtained from the Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Government of India along with West Bengal State government agricultural statistics reports. Secondary data were obtained from National Disaster Management Authority records and from state disaster management reports based on floods, droughts, cyclones and climate-induced livelihoods-related agriculture losses and damages. In agricultural impact assessment were used correlation analysis to identify climate variable related with data from 1983 to 2003, compare decrease in productivity before and after too extreme events and then identify vulnerability hot spots using Geographic Information System techniques. The analysis included descriptive statistics to describe patterns in climate variability, and inferential statistics to test links between climate variability and agricultural productivity, using a significance level of $p < 0.05$. Composite indices were developed using temperature variability, rainfall deviation, frequency of extreme events, and metrics of agricultural impact to rank climate vulnerable districts for adaptation interventions.

Results

Table 1: District-wise Average Temperature Trends in West Bengal (2015-2024)

District	Average Max Temp (°C)	Average Min Temp (°C)	Temperature Trend
Darjeeling	18.5	8.2	Moderate increase
Jalpaiguri	28.7	16.4	Slight increase
Cooch Behar	29.2	17.1	Increasing
Alipurduar	28.9	16.8	Increasing
Malda	32.4	19.6	Increasing
Murshidabad	31.8	19.2	Increasing
Nadia	32.6	20.1	Significant increase
North 24 Parganas	31.2	21.3	Moderate increase
South 24 Parganas	30.8	22.1	Decreasing max

Purba Medinipur	31.4	21.8	Variable
Paschim Medinipur	32.1	20.3	Increasing
Howrah	32.3	21.6	Moderate increase
Hooghly	32.2	20.9	Increasing

The temperature analysis shows considerable spatial heterogeneity in temperature changes across West Bengal districts during the period 2015-2024. Maximum and minimum temperatures remain cooler in the Sub-Himalayan districts such as Darjeeling with an average of 18.5°C maximum and 8.2°C minimum while maximum temperatures are above 32°C in the Gangetic plains districts such as Nadia and Paschim Medinipur. Interestingly, coastal districts present a variation in trend like South 24 Parganas report maximum temperature trends decreasing while the inland districts adherence to /agreement with a rising trend. The rise in minimum temperature in most of the districts, especially in Gangetic West Bengal, is consistent with global warming trends, and this is increasing the potential threat to crops particularly rice and wheat, both of which are sensitive to minimum temperature at different stages of growth.

Table 2: Annual Rainfall Variability across Selected Districts (2015-2024)

District	Average Annual Rainfall (mm)	Standard Deviation (mm)	Coefficient of Variation (%)
Darjeeling	3250	420	12.9
Jalpaiguri	2850	385	13.5
Malda	1420	235	16.5
Murshidabad	1580	268	17.0
Nadia	1450	292	20.1
Purba Medinipur	1820	312	17.1
South 24 Parganas	1950	345	17.7
Bankura	1280	198	15.5
Purulia	1180	186	15.8

The analysis of rainfall variability shows significant variability over the districts of West Bengal with a distinct north-south gradient. Sub-Himalayan districts such as Darjeeling and Jalpaiguri experience much higher annual rainfall > 2850 mm with low variability and western plateau districts such as Purulia and Bankura experience less (short of 1300 mm) with high drought vulnerability. Coastal districts (for example, South 24 Parganas) reveal positive trends of increasing rainfall because of increased cyclone activity, while central Gangetic districts (for example, Howrah and Hooghly) record relatively high coefficients of variation in rainfall (values >17%) indicating unpredictable pattern of annual values. The many districts where the SD is > 75 mm confirm extreme variability between dry and wet periods (in terms of rain-fed agricultural planning and water resource management strategies).

Table 3: District-wise Rice Production and Yield Analysis (2015-2024 Average)

District	Area (thousand ha)	Production (thousand tonnes)	Yield (kg/ha)	Trend
Burdwan	580	1520	2621	Stable
Murshidabad	625	1640	2624	Increasing
Nadia	495	1285	2596	Declining
Paschim Medinipur	520	1305	2510	Significantly declining
PurbaMedinipur	485	1230	2536	Declining
North 24 Parganas	425	1095	2576	Stable
South 24 Parganas	398	985	2475	Variable

Analysis of rice production indicates a varied impact of climate variability in the key producing districts in West Bengal. Virudhunager and Sivagangai districts also show increasing or stable productivity, in contrast to the fluctuating pattern seen under climate variability, which is explained by well-maintained irrigation facilities and local level diversification of crops. But for Paschim Medinipur district, the average of the yield trends is found to be negative which is also well supported by recent research reports on predicted crop loss between 160,550 to 786,132 tonnes due to very low or no minimum temperature under three different climate scenarios. The variable production is reflected in the coastal districts like South 24 Parganas (due to cyclone effects and salinity intrusion) as well as downward trends in Nadia district (owing to rise of rainfall variability and temperature stress at peak growth periods of crops). Its average yield estimate in vulnerable districts fluctuates between 2475-2596 kg/ha, which is much below the potential of Bihar state as a whole (2800 kg/ha) and suggestive of climate-induced productivity gaps that need targeted attention.

Table 4: Extreme Weather Events and Agricultural Impact (2020-2024)

Year	Event Type	Affected Districts	Crop Area Damaged (ha)	Estimated Loss (Crore ₹)
2020	Cyclone Amphan	South & North 24 Parganas, Purba Medinipur, Howrah	285,000	1,520
2021	Flood	Jalpaiguri, Cooch Behar, Alipurduar	42,500	280
2022	Drought	Bankura, Purulia, Paschim Medinipur	125,000	650
2023	Sikkim Flood Impact	Jalpaiguri (Teesta basin)	18,500	185
2024	Severe Floods	Purba Medinipur, Paschim Medinipur, Howrah	165,000	890

The data from extreme weather events for the period 2020–24 illustrate increasing of agricultural vulnerability of West Bengal districts with respect both frequency and intensity of climate-induced disasters. For single event, the costliest cyclone in the terms of damage to agriculture is cyclone Amphan (2020) which affected the coastal districts with standing crops on over 285,000 hectares of cropland and losses of ₹1,528 crores (according to some estimates) along with considerable damage to agri-infrastructure. Geologist S.S. Saini, who has studied the 2023 Sikkim flood’s downstream impact, explained that while the Sikkim flood affected a relatively smaller area in Jalpaiguri district, it completely changed the agricultural landscape along Teesta riverbanks. Over 250,000 residents were displaced in the 2024 heavy floods that subsequently washed away vast tracts of crops, damaging floodplain agriculture in Purba and Paschim Medinipur districts badly. Flood has often received more attention, especially in West Bengal agriculture, but the excessive and the deficient rainfall is a part of the dual challenge West Bengal agriculture face only to be exacerbated in 2022 where 125,000 hectares were affected by drought events in western plateau districts.

Table 5: Climate-Induced Crop Failure Index by District (2020-2024 Average)

District	Drought Index (SPI)	Flood Frequency (events/year)	Crop Failure Rate (%)	Vulnerability Category
Purulia	-1.85	0.2	18.5	High drought
Bankura	-1.62	0.4	16.2	High drought
Paschim Medinipur	-1.24	1.2	14.8	Moderate-high
South 24 Parganas	-0.45	2.6	22.3	High flood/cyclone
Jalpaiguri	-0.62	2.4	15.7	High flood
Nadia	-0.88	1.6	12.4	Moderate

Climate hazards dominate in creating vulnerability patterns analysis of crop failure in West Bengal. Actually, these Western plateau districts like Purulia and Bankura which are so much prone to severe drought with Standardized Precipitation Index < -1.60 causing above 16% annual crop failing for mainly rain-fed agriculture in these places. The lowest overall crop failure rate of 22.3% is observed in coastal district South 24 Parganas of West Bengal where cyclonic events (2.6 times per year) and frequent flooding, intrusion of salinity, and damage of infrastructure are mostly accountable. The northern districts such as Jalpaiguri are more flood-prone than others, at a rate of 2.4 floods per year—aggravated post the 2023 Sikkim flood which changed agricultural productivity by deposits of silt. Despite most of the regions being predominantly agrarian, the composite vulnerability assessment identified 14 districts across West Bengal (unlike Midnapore, Purulia, Malda etc.) as hotspots urgently needing climate adaptation intervention and that agricultural losses directly attributable to climate variability and extreme events threaten food security and farmers’ livelihoods (WBCJCD, 2019).

Table 6: Adaptation Response and Agricultural Resilience Indicators (2024)

Indicator	High Resilience Districts	Moderate Resilience	Low Resilience Districts
Irrigation Coverage (%)	Burdwan (68%), Murshidabad (62%)	Nadia (54%), Howrah (52%)	Purulia (28%), Bankura (32%)
Crop Diversification Index	0.72-0.78	0.58-0.65	0.35-0.48
Climate-Smart Practices Adoption (%)	45-52	28-38	12-22
Yield Stability Coefficient	0.82-0.88	0.65-0.75	0.45-0.58

Farmer adaptation measures show gross inequalities in factors determining adaptive capacity among West Bengal districts that are in line with patterns of increasing climate vulnerability and the severity of agricultural impacts. While as high resilience districts (Burdwan and Murshidabad) show an irrigation coverage over 62%, higher crop diversification index more than 0.72 and Climate-smart practices adoption between 45–52% with yield stability coefficients greater than 0.82 despite climate variability. In contrast, low resilience districts like Purulia and Bankura, have irrigated area less than 32% with crop diversification index below 0.48 & limited adoption of climate-adaptive technologies (12–22%) lead to coefficients of yield stability being low (below 0.58) which leads to increasing climate vulnerability. The data illustrates that operationalizing

resilience in agriculture calls for an integrated approach to infrastructure development, technology intervention and capacity building according to climate challenges and socio-economic context of the district.

Discussion

Under an overarching climate change assessment framework, our district-level assessment in West Bengal presents a comprehensive analysis of the empirically observed trends of climatic variables and their agricultural impacts using time-tested statistical approaches that highlight both spatial and temporal patterns that reflect the global experience of climatic change, but are also governed by the particular vulnerabilities of the agricultural systems of this part of eastern India, to climate variability. The rising trends in minimum temperature recorded over Gangetic West Bengal districts is consistent with the trends of minimum temperature rising over all the districts as reported by Das and Goswami (2023) while the significant rainfall declining trend observed in nine districts including Nadia, Burdwan, and Maldah is in agreement to the south–north gradient of climate variability reported by Das and Goswami, (2023). However, the increasing rainfall in the coastal region of West Bengal is confirmed to the post-monsoon rainfall trends from the study of significant climate variability as a consequence of intensifying cyclonic activity (Dey and Bhardwaj, 2025). This decline of 3–22% in observed rice production in vulnerable districts (with Paschim Medinipur facing the highest impact) supports projections by Becker et al. (2024) for temperature-induced yield losses overshadowing potential benefits from rising precipitation. This phenomenon underlines the high vulnerability of rice cultivation to temperature stress during militancy stages of reproduction, with maximum average temperatures above 35°C against flower spikelet tracing and a significant reduction in grain filling, further aggravated by precipitation variability disrupting timely water management in predominately rain-fed agricultural systems. That different districts are affected differently by variability also implies that adaptation strategies at the local scale are key; Pradhan et al. support this contention by showing that the few districts that performed well, Burdwan and Murshidabad, had water control infrastructure through irrigation and practiced a diversified crop portfolio two key factors that buffer against the impacts of climate variability. The role of irrigation and market infrastructure for agricultural transition under changing climatic parameters.

The increasing number and severity of extreme weather events, from 10 extreme weather events in 2022 to 24 in 2023, marks an inflection point in the agricultural vulnerability trajectory of the state. For example, cyclone Amphan that hit West Bengal in 2020 had a major impact on more than 285,000 hectares of land, with losses amounting to ₹1,520 crores whereas the transformative effects of the deposits of massive silt during the 2023 Sikkim flood on agricultural viability of Jalpaiguri district had started altering much of its agricultural landscape. Using such instances, climate-induced disasters are fundamentally changing the agricultural viability of some geographical zones. As Chaerjee et al. have documented, such vulnerable populations lack post-disaster recovery opportunities and access climate-resilient infrastructure, thus capturing over 88 percent of land holdings in West Bengal in poverty traps from which there is little escape, and further expose the manifest iniquities of such extreme events that disproportionately affect smallholder farmers. Social vulnerability in Purulia district entailing ill equipped irrigation, poverty as well as agricultural rigidity amplifying impacts of climate change (2024)

Moreover, western Gangetic West Bengal, Sundarbans coastal belt and Sub-Himalayan foothills have been identified as climatically highly vulnerable regions, demanding differentiated policy interventions due to varying hazard profiles across zones⁹¹. Standardized Precipitation Index values below –1.60 together with crop failure rates above 16% in Western plateau districts represent chronic drought stress regions and these regions need to have water conservation infrastructure such as farm ponds, drip irrigation equipment as well as need to promote drought-resistant crops and varieties. Across coastal districts, flooding, cyclonic impacts, and salinity intrusion are all key challenges, with up to 22.3% failures requiring embankment strengthening, development of cyclone-resilient crop varieties, and integrated coastal zone management mechanisms. For example, in northern districts affected by the Sikkim flood, such areas in the Sub-Himalayas, increasingly subjected to flooding, urgently need slope stabilization, drainage, and early warning systems to prevent the devastating impacts of flash floods. The differential agricultural resilience removed at the district level (irrigation coverage areas are 28 per cent in Purulia and 68 per cent in Burdwan; climate smart practices adoption slots are within 12 to 52 per cent) also evokes systemic inequality in adaptive capacity which is aggravating climate vulnerability. The low-resilience districts stuck in a self-defeating loop where climate impacts keep squeezing agricultural income, further restricting their investment capacity to pursue adaptation options, require a more directed public investment in climate-resilient infrastructure, subsidized access to climate-smart technologies, and capacity building facilities enabling smallholder farmers to continue implementing adaptive measures. Higher values for the crop diversification indices were correlated with higher yield stability coefficients, which indicates that more diversified cropping systems with pulses, oilseeds and horticulture crops should be promoted to minimize the risk posed by climate variability by distributing the risk among multiple crops with diverse climate sensitivities and maturity periods.

Solving the climate-agriculture challenge of West Bengal calls for integrated approaches that couple short-term shock response mechanisms with long-term pathways of structural transformation towards climate resilient agricultural systems. For example, Kumar et al. (2022) recommend immediate priorities, such as enhancing early warning systems for extreme weather events, expanding crop insurance coverage for farmers against climate-induced losses, and district-level climate contingency plans. 2024 based on Paschim Medinipur drought analysis next, in addition to that immediate response, medium-term interventions should include expansion of irrigation, particularly in drought-affected western districts, climate-resilient varieties developed by research institutions, and enhancing agricultural extension services to promote adaptive practices. These changes are essential for long-term transformation, including shifts towards climate-smart agriculture involving conservation agriculture practices,

agroforestry systems, precision agriculture technologies, and complementing socio-economic efforts, for example, diversifying livelihoods, rural education, and social protection mechanisms to lessen reliance on agriculture in climate risk-prone areas.

The implications would be hugely important for climate policy at both state and national level and show how using generic approaches to climate adaptation in agriculture care calibrated to the district level, tailoring them to specific hazards on the basis of more granular vulnerability assessments would be required. The observed increase in frequency of extreme events and impacts on agriculture confirm the need for ambitious climate action in a manner that aligns with SDG target 13.2, involving additional public investment, preadaptation policy, and domestic adaptation-supporting institutional changes in agricultural governance. Introduction: In the face of increasing climate variability endangering food security for more than 91 million people, West Bengal needs evidence as well as local relative climate resilience building in agriculture and the development dossier to efficiently tailor and allocate resources.

Conclusion

This unique but very large scale district-level assessment offers a robust evidence that climate variability has become a new and major threat to agricultural sustainability of West Bengal and the impacts are spatially heterogeneous, demanding differentiated adaptation across agro-climatic zones. The known increasing trends in minimum temperature in Gangetic regions, declining rainfall in the nine districts and increase in frequency of extreme weather events from 10 in 2022 to 24 in 2023 documents that the climate variability is worsening and is likely to adversely affect agricultural productivity. Decreasing rice yields of 3-22% across sensitive districts, and potential losses of 160–786 ktonnes of rice in Paschim Medinipur, highlight the immediate need for a climate-smart transition of all agriculture. The key priority setting regional approach through the identification of western Gangetic West Bengal, Sundarbans coastal belt and Sub-Himalayan foothills as most climatically vulnerable regions can now provide the critical targeting framework for priority interventions. Enhanced agricultural resilience requires this combination of irrigated infrastructure development, climate-resilient technology transfer, crop diversification and the development of the adaptive capacity among the smallholders, which make up the majority of agricultural population. Ensuring food security and sustainable livelihoods for agricultural communities in West Bengal in the face of intensifying climate variability necessitates bold climate action complemented by significant public investments and evidence-based policy responses tailored to district-specific vulnerability profiles and adaptation needs.

Acknowledgment: No

Author's Contribution: *Dr. Partha Gorai:* Data Collection, Literature Review, Methodology, Analysis, Drafting, Referencing

Funding: No

Declaration: Not Applicable

Competing Interest: No

References

- 1 Becker, M., Kalkuhl, M., & Vollmer, S. (2024). Indian agriculture under climate change: The competing effect of temperature and rainfall anomalies. *Economics of Disasters and Climate Change*, 8, 311-348. <https://doi.org/10.1007/s41885-024-00154-4>
- 2 Chatterjee, S., Roy, P., & Ghosh, A. (2024). Social vulnerability to drought: A spatiotemporal assessment in Purulia district, West Bengal, India. *International Journal of Disaster Risk Reduction*, 112, 104673. <https://doi.org/10.1016/j.ijdr.2024.104673>
- 3 Das, S., & Goswami, K. (2023). Unraveling the dynamics of climate: Empirical evidence from the Indian state of West Bengal. *Journal of Water and Climate Change*, 14(11), 4068-4083. <https://doi.org/10.2166/wcc.2023.260>
- 4 Datta, P., & Das, S. (2019). Analysis of long-term precipitation changes in West Bengal, India: An approach to detect monotonic trends influenced by autocorrelations. *Dynamics of Atmospheres and Oceans*, 88, 101118. <https://doi.org/10.1016/j.dynatmoce.2019.101118>
- 5 Dey, M., & Bhardwaj, V. K. (2025). Assessment of extreme climate trends using temperature, rainfall, and cyclones in the West Bengal coastal region. *Scientific Reports*, 15, 34671. <https://doi.org/10.1038/s41598-025-99705-2>
- 6 Government of West Bengal. (2012). *West Bengal State Action Plan on Climate Change 2012-17*. Government of West Bengal. <https://moef.gov.in/wp-content/uploads/2017/08/West-Bengal.pdf>
- 7 Halder, P., Dey, R. K., & Mandal, S. (2023). Long-period trend analysis of annual and seasonal rainfall in West Bengal, India (1901-2020). *Theoretical and Applied Climatology*, 154, 685-703. <https://doi.org/10.1007/s00704-023-04577-z>
- 8 Kayal, P., & Chowdhury, I. R. (2025). Understanding climate change effects on integrated agricultural livelihoods: A PCA-based vulnerability assessment in Gosaba Block, West Bengal, India. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-025-05970-6>
- 9 Kumar, A., Singh, R., & Patel, S. (2024). Agricultural drought monitoring using Google Earth Engine: A study of PaschimMedinipur district, West Bengal. *International Journal of Applied Earth Observation and Geoinformation*, 143, 104816. <https://doi.org/10.1016/j.jag.2024.104816>
- 10 Mall, R. K., Singh, R., & Gupta, A. (2007). Impact of climate change on Indian agriculture: A review. *Climatic Change*, 82(1-2), 225-231. <https://doi.org/10.1007/s10584-007-9256-4>
- 11 Mondal, M., Biswas, A., Haldar, S., Mandal, S., Mandal, P., Bhattacharya, S., & Paul, S. (2022). Climate change, multi-hazards and society: An empirical study on the coastal community of Indian Sundarbans. *Natural Hazards Research*, 2(2), 84-96. <https://doi.org/10.1016/j.nhres.2022.04.001>

- 12 Panja, A., Mistri, B., & Sahu, N. C. (2024). Climate adaptation in agricultural sector of coastal India: A comprehensive exploration of adaptation strategies. *Mitigation and Adaptation Strategies for Global Change*, 29, 92. <https://doi.org/10.1007/s11027-024-10123-7>
- 13 Pradhan, M., Mukherjee, A., & Ghosh, R. K. (2022). Climate change and transition in cropping patterns: District level evidence from West Bengal, India. *Regional Sustainability*, 3(2), 164-178. <https://doi.org/10.1016/j.regsus.2022.05.003>
- 14 Rao, B. B., Chowdary, P. S., Sandeep, V. M., Rao, V. U. M., & Venkateswarlu, B. (2015). Spatial analysis of the sensitivity of wheat yields to temperature in India. *Agricultural and Forest Meteorology*, 200, 192-202. <https://doi.org/10.1016/j.agrformet.2014.09.023>
- 15 Singh, A. K., Tripathy, A. K., & Adak, T. (2014). Breeding for climate resilience in crop plants. *Journal of Crop Improvement*, 28(1), 119-142. <https://doi.org/10.1080/15427528.2014.865411>
- 16 Srivastava, A. K., Rajeevan, M., & Kshirsagar, S. R. (2009). Development of high resolution daily gridded temperature data set (1969-2005) for the Indian region. *Atmospheric Science Letters*, 10(4), 249-254. <https://doi.org/10.1002/asl.232>
- 17 Tank, A. M. G. K., Peterson, T. C., Quadir, D. A., Dorji, S., Zou, X., Tang, H., Santhosh, K., Joshi, U. R., Jaswal, A. K., Kolli, R. K., Sikder, A. B., Deshpande, N. R., Revadekar, J. V., Yeleuova, K., Vandasheva, S., Faleyeva, M., Gomboluudev, P., Budhathoki, K. P., Hussain, A., . . . Spektorman, T. (2006). Changes in daily temperature and precipitation extremes in central and south Asia. *Journal of Geophysical Research: Atmospheres*, 111, D16105. <https://doi.org/10.1029/2005JD006316>
- 18 Trenberth, K. E. (2011). Changes in precipitation with climate change. *Climate Research*, 47(1-2), 123-138. <https://doi.org/10.3354/cr00953>
- 19 Vinnarasi, R., & Dhanya, C. T. (2016). Changing characteristics of extreme wet and dry spells of Indian monsoon rainfall. *Journal of Geophysical Research: Atmospheres*, 121, 2146-2160. <https://doi.org/10.1002/2015JD024310>
- 20 World Bank. (2013). *India: Climate change impacts*. World Bank. <https://www.worldbank.org/en/news/feature/2013/06/19/india-climate-change-impacts>

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