Journal of Agrometeorology

ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 27 (2) :168-172(June - 2025)
https://doi.org/10.54386/jam.v27i2.2870
https://journal.agrimetassociation.org/index.php/jam

Research Paper

Rainfall and temperature trends in northeastern states of India: Implications for agricultural productivity

JYOTSNALI CHETIA[1], and MONISHA CHETIA[2*]

[1]*Department of Economics, Sibsagar Girls' College, Sibsagar-785640, Assam, India*
[2]*Department of Physics, Nanda Nath Saikia College, Titabar, Jorhat-785630, Assam, India*
**Corresponding Author: monishachetia1@gmail.com*

ABSTRACT

We analyzed the changes in annual and seasonal rainfall and temperature across seven northeastern Indian states for the period 1970-2023. Our findings indicate significant changes in climatic conditions, including both maximum and minimum temperatures and rainfall. Specifically, there has been a significant decline in seasonal monsoon rainfall, with overall annual rainfall also decreasing, except in Mizoram. Over the past five decades, there has been a marked increase in both maximum and minimum temperatures, though the extent of this warming differs by state and period. Temperature trends show a clear rise in both maximum and minimum temperatures. Considering the agricultural dependence in these states, we also examined the impact of climatic factors on Assam's agricultural output using Autoregressive Distributed Lag (ARDL) model. Findings show that rainfall significantly affects food grain production in Assam, whereas temperature does not significantly impact food grain production.

Keywords: Northeast India, Temperature, Rainfall, Foodgrain production, Regression analysis

In agrarian nations such as India, rainfall significantly influences agriculture, water resources, and consequently the national economy. Therefore, the annual, seasonal, and monthly variations of rainfall analysis are crucial for effective regional planning and management. Over the past century, India's mean surface temperature has risen by approximately 1°C in winter, 0.3°C in the pre-monsoon period, 0.4°C during the monsoon, and 1.1°C in the post-monsoon season (Dash *et al.,* 2007). Moreover, the climatic change has led to a myriad of adverse effects including lower crop yields (Kelkar *et al.,* 2020), reduction in tropical forest coverage (Gopalakrishnan *et al.,* 2011), reduced snow-covered area, rising sea surface temperature (Dash *et al.,* 2007), more frequent summer heatwaves, heavy floods, prolonged droughts and, fluctuations in water resources (Gosain *et al.,* 2011). Many previous studies have reported that production of different crops in India is anticipated to experience a loss of agricultural productivity due to climate change (Zacharias *et al.,* 2014; Sandeep *et. al.,* 2018; Pandey, 2023; Mukherjee *et al.,* 2024). Rain-fed rice is more susceptible in the northeast region, with a range of effects dropping from -35% to +5% (Guntukula, 2020). In such a situation, improvement of agricultural productivity can be accomplished only through the adoption of seeds that are resilient to temperature fluctuations and more advanced crop management techniques (Mukherjee and Huda, 2018). As one of the most vulnerable regions to climate change, the agricultural productivity in this area is significantly impacted by these climatic factors. Therefore, it is very important to understand the effects of climate factors on food production to implement appropriate strategies and policies for the enhancement of the agricultural productivity of the region.

This study examines the trends in seasonal and annual rainfall and minimum and maximum temperatures in the northeastern states of India from 1970 to 2023. The goal is to understand the recent climatic impacts on hydrological changes. Additionally, the study seeks to evaluate how these climatic changes have affected foodgrain production in the state of Assam.

MATERIALS AND METHODS

The northeastern region of India (NER) comprises

Article info - DOI: *https://doi.org/10.54386/jam.v27i2.2870*
Received:26 December 2024; Accepted: 7 March 2025; Published online : 1 June, 2025

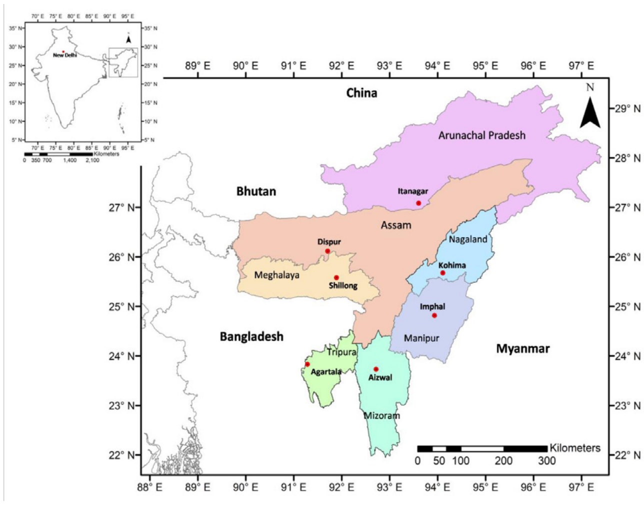

Fig. 1: Political map of the study area showing state boundary and state capitals

the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. Stretching from 88ºE to 96ºE longitude and 22ºN to 29ºN latitude, the northeastern region shares borders with five neighboring countries. The NER is characterized by a humid subtropical climate influenced by various geographical features such as the Himalayas, the Meghalaya plateau and the Naga-Patkai hills (Fig. 1). The state-wise monthly rainfall data for the period of 1970 to 2023 have been collected from India's Water Resources and Information System (https://indiawris.gov.in) and temperature datasets were downloaded from the official website of IMD, Pune (https://www.imdpune.gov.in/cmpg/Griddata/Max_1_Bin.html). To evaluate the effect of climatic change on agricultural output in the region, data on foodgrain production from 1980 to 2023 has been gathered for the state of Assam from Handbook of Statistics on the Indian Economy, published the Reserve Bank of India (https://www.rbi.org.in/scripts/annualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy). The reason behind selecting Assam is that in the entire northeastern region of India Assam is endowed with the highest plain area.

The rainfall and temperature datasets were analysed seasonally and annually. For seasonal analysis each year was divided into four seasons based on the climatic features of the months given by the Indian Meteorological Department; Winter season (January and February), Pre-monsoon season (March, April, and May), Monsoon (June, July, August and September) and Post monsoon (October, November and December) (Subash and Sikka, 2014). The Mann-Kendall test and Sen's slope estimator have been employed for analyzing trends and determining the slope of changes in rainfall and temperature. Previous studies have employed similar methodologies for assessing the climate change (Swami, 2024; Sunny and Sidana, 2017).

Rainfall and temperature were considered as sole explanatory variables to see their impact on foodgrain production. Autoregressive Distributed Lag Model (ARDL) approach has been used to examine the impact of explanatory variables on the dependent variable. The following econometric model (Dell *et al.,* 2014) has been used for assessing the impact of climatic factors on foodgrain production in Assam:

$$Food\_Prod_t = \beta_0 + \beta_1 food\_prod_{t-1} + \ldots. + \beta_p food\_prod_{t-p} + \sigma_1 rainfall_{t-1} + \sigma_2 rainfall_{t-2} + \ldots. + \sigma_q rainfall_{t-q} + \gamma_1 temp_{t-1} + \gamma_2 temp_{t-2} + \ldots. + \gamma_p temp_{t-p} + \acute{\varepsilon}_t$$

where, food_prod= food production, temp = temperature, t indicates time unit (t= 1, 2, 3 ……). β_s, σ_s, and γ_s are coefficients of parameters and $\acute{\varepsilon}$ is the error term.

RESULTS AND DISCUSSION

Trends of rainfall and temperatures

Table 1 presents the average seasonal rainfall trends. The overall trend across the states indicates a decline in seasonal rainfall, especially in winter and monsoon periods. This research reveals an upward trend in temperatures in general (Table 1). Both maximum and minimum temperatures have risen significantly across all states, with the most pronounced increases in Nagaland, Manipur, and Tripura, especially in maximum temperatures during the post-monsoon season. The annual rainfall trend was decreased in the states except in Mizoram (Table 1). Significant declines were observed in Arunachal Pradesh, Assam, Manipur, and Tripura, with Arunachal Pradesh experiencing the largest significant decrease at -18.024 mm year^{-1}. The annual maximum temperature trends showed significant increases across all seven northeastern states (Table 1). Manipur and Nagaland saw the highest rise in annual mean maximum temperatures, followed by Meghalaya, Arunachal Pradesh, Assam, and Tripura. Annual minimum temperatures also significantly increased in all the states. Tripura had the highest rise in annual mean minimum temperature, followed by Assam, Mizoram, and both Manipur and Meghalaya (Table 1).

The trend of rising temperatures is significant across all the states. By the end of the twenty-first century, in North East India, the maximum and minimum temperatures are expected to increase by 4ºC and 5.5ºC respectively (Paul and Maity, 2023). Annually, rainfall is declining while temperatures are increasing. Also, future projected seasonal rainfall during 2011-2060 is expected to decrease while the temperature is expected to increase (Soraisam *et al.,* 2018). Significant decline in monsoonal rainfall in the Ganges and Brahmaputra watersheds was reported (Roxy *et al.,* 2015) due to increased Indian Ocean warming, which has reduced the land-ocean thermal gradient. During the last century, the sea surface temperatures (SST) of the Arabian Sea and the Bay of Bengal have been increased by almost 1ºC (Dash *et al.,* 2007) decreasing the frequency of depressions, and thereby weakening the summer monsoon circulation.

Impact of rainfall and temperature on foodgrain production

The Augmented Dickey-Fuller (ADF) test for stationarity (Table 2) showed that rainfall is stationary at levels, while food production and temperature are stationary at first differences, indicating the presence of a mixed order of integration. Given this, the Autoregressive Distributed Lag (ARDL) model was chosen for analysis.

Table 1: Sen's slope for seasonal and annual rainfall and temperatures for northeastern states of India

Seasons	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Tripura
				Rainfall (mm year^{-1})			
Winter	-1.790*	-0.558*	-0.590*	-0.234	-0.437*	-0.357	-0.437*
Summer	-4.045*	-0.048	0.887	0.378	-0.903	0.718	-4.548
Monsoon	-7.716*	-4.357*	-5.164*	-6.60	2.037	-1.432	-4.439*
Post monsoon	-2.134*	-1.093	-0.990	-1.583	0.725	0.152	-0.047
Annual	-18.024*	-6.09*	-7.541*	-7.712	0.987	-1.692	-10.698*
				Maximum temperature (°C year^{-1})			
Winter	0.031*	0.021*	0.032*	0.023*	0.014	0.035*	0.011
Summer	0.016	0.011	0.017*	0.012	0.010	0.020*	0.009
Monsoon	0.026*	0.026*	0.032*	0.031*	0.028*	0.029*	0.026*
Post monsoon	0.037*	0.028*	0.038*	0.033*	0.024*	0.038*	0.019*
Annual	0.025*	0.021*	0.029*	0.026*	0.021*	0.029*	0.018*
				Minimum temperature (°C year^{-1})			
Winter	0.017*	0.018*	0.018*	0.015*	0.016*	0.018*	0.019*
Summer	0.009*	0.015*	0.010*	0.011*	0.015*	0.010*	0.019*
Monsoon	0.014*	0.021*	0.014*	0.018*	0.021*	0.012*	0.025*
Post monsoon	0.018*	0.017*	0.018*	0.015*	0.016*	0.018*	0.020*
Annual	0.013*	0.018*	0.015*	0.015*	0.017*	0.014*	0.022*

Note: * indicates statistical significance at 5% as per the Mann-Kendall test (+ve for increasing and –ve for decreasing)

Table 2: Results of ADF test

Variables	At Level		At first difference		Decision
	C	C & T	C	C & T	
	t-stat	t-stat	t-stat	t-stat	
Rainfall	-60254**	-7.323**			I (0)
Temp	-2.894	-5.114*	-7.706**	-7.597**	I (I)
Food_Prod	-1.344	-7.991	-2.996**	-7.865**	I (I)

Note: * & ** indicates significant at 5% and 1% respectively

Table 3: Results of Bound test

Model	F-Statistic	Critical values	I (0)	I (I)
FoodProd| Rainfall| Temp	3.014**	10%	2.63	3.35
		5%	3.10	3.87
		1%	4.13	5

** indicates <5% level

To examine the long-run relationship among the variables the ARDL bound test was used. Results (Table 3) portrayed no significant relationship long run relationship, as the F-statistic (3.014) is below the upper bound I(I) at the 5% significance level. Diagnostic tests confirm no issues with autocorrelation, heteroscedasticity, or normality of errors. The Ramsey RESET test indicates good model fit (p = 0.995), while the Breusch-Pagan-Godfrey test (p = 0.209 and Breusch-Godfrey serial correlation LM test (p = 0.819) show no heteroscedasticity or serial correlation. The Jarque-Bera test confirms normal distribution (p = 0.286). The CUSUM test indicates parameter stability at 5% significance level shown in Fig. 2, confirming that the model is stable and the results are valid.

Table 4 shows the results of short run relationship that shows that the previous rainfall lag (1), lag (2), and lag (3) significantly affect foodgrain production in Assam. However, the temperature does not show any significant impact on foodgrain yields in the state. This result is supported by previous research (Guntukula, 2020, Babu and Uma, 2023), which show that rainfall directly influences agricultural production in India. Guntukula (2020) found that rainfall, along with maximum and minimum temperatures, significantly impacts major crop yields, though the extent of this impact varies among different crops. Further, to evaluate whether the inclusion of lagged values of rainfall significantly improves the prediction of food production Granger Causality test was applied. The results displayed that past values

Table 4: Ordinary least square (OLS) estimation by ARDL regression on food production

Variables	Coefficients	Standard error	P-values
FD (-1)	-0.200973	0.075207	0.0121*
Rainfall	0.372077	1.715466	0.0959
Rainfall (-1)	1.426654	0.470655	0.0047*
Rainfall (-2)	0.872459	0.353463	0.0195*
Rainfall (-3)	0.644970	0.238972	0.0113*
Temperature	-141.0277	4559.570	0.3978
C	7964.267	164.3962	0.0909

*Significant at 0.05 level of significance

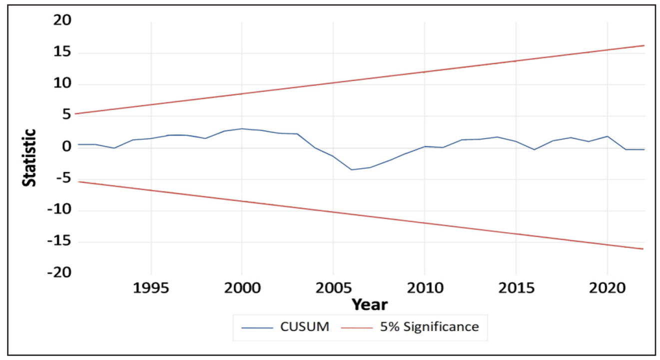

Fig. 2: Cumulative sum (CUSUM) test for stability

of rainfall do not provide statistically significant information to improve the prediction of food production (F-stat= 1.65; p>0.05) in the short run within the current dataset.

CONCLUSION

The findings show significant warming in both maximum and minimum temperatures across seven states over the past 50 years, with a notable decline in rainfall, particularly during the monsoon season. While rainfall decline is not statistically significant in many states, it remains concerning. Findings also indicate that rainfall significantly affects foodgrain production in the short run, while temperature has no significant impact. The ARDL finding suggests that variations in climatic factors directly and temporarily affect foodgrain production over the time period under study. The predictive causality shows that past values of rainfall does not significantly improve the prediction of food production. Non-climatic factors such as agricultural inputs, market conditions etc. might have more significant influence on food production of the state. The study's insights are crucial for developing region-specific policies to enhance agricultural productivity.

ACKNOWLEDGEMENT

We sincerely appreciate the esteemed anonymous reviewer for the insightful comments and thorough review, which have greatly contributed to the substantial improvement of the manuscript. We extend our gratitude to various web sources for providing free access to essential data.

***Conflict of Interest*:** The authors declare that there is no conflict of interest related to this article.

Funding: The research did not receive any financial support.

***Data availability*:** Rainfall data is accessible on Water Resources and Information System (https://indiawris.gov.in) and temperature datasets are available at the website of IMD, Pune (https://www.imdpune.gov.in/cmpg/Griddata/Max_1_Bin.html). Data on food production is available at Handbook of Statistics on the Indian Economy, published the Reserve Bank of India (https://www.rbi.org.in/scripts/annualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy).

Authors contribution: **J. Chetia**: Methodology, Visualization, Data Curation, Investigation, Writing-Original Draft, Writing-Review and Editing; **M. Chetia**: Conceptualization, Methodology, Formal analysis, Writing-Original Draft, Writing-Review and Editing

Authors' certificate: We confirm that this manuscript is original and has not been published elsewhere and is not under consideration for publication by any other journal.

REFERENCES

Babu, S.R. and Uma, G. (2023). Analyzing the impact of rainfall patterns on agriculture, economy and tourism in India: a statistical approach. *Int. J. Env. Clim. Change,* 13(11): 4626-4637. https://doi.org/https://doi.org/10.9734/ijecc/2023/v13i113642

Dash, S.K., Jenamani, R.K., Kalsi, S.R. and Panda, S.K. (2007). Some evidence of climate change in twentieth-century India. *Climate Change*, 85:299-321. https://doi.org/http://dx.doi.org/10.1007/s10584-007-9305-9

Dell, M., Jones, B. F. and Olken, B. A. (2014). What do we learn from the weather? The new climate-economy literature. *J. Econ. Lit.*, 52(3): 740-798. http://dx. doi.org/10.1257/jel.52.3.740

Gopalakrishnan, R., Jayaraman, M., Bala, G. and Ravindranath, N.H. (2011). Climate change and Indian forests. *Curr. Sci.,* 101(3):348-355.

Gosain, A. K., Rao, S. and Arora, A. (2011). Climate change impact assessment of water resources of India. *Curr. Sci.,* 101(3): 356-371.

Guntukula, R. (2020). Assessing the impact of climate change on Indian agriculture: Evidence from major crop yields. *J. Public Aff.,* 20(1):1-7. https://doi.org/10.1002/pa.2040

Kelkar, S.M., Kulkarni, A. and Rao, K.K. (2020). Impact of climate variability and change on crop production in

Maharashtra, India. *Curr. Sci.,* 118(8): 1235-1245.https://doi.org/10.18520/cs%2Fv118%2Fi8%2F1235-1245

Mukherjee, A. and Huda, A.K. (2018). Assessment of climate variability and trend on wheat productivity in West Bengal, India: Crop growth simulation approach. *Climate Change,* 147(1-2): 235-252. DOI: 10.1007/s10584-017-2113-y

Mukherjee, A., Banerjee, S., Saha, S., Nath, R., Naskar, M. and Mukherjee, A. (2024). Developing weather-based biomass prediction equation to assess the field pea yield under future climatic scenario. *J. Agrometeorol.,* 26(1): 45-50. https://doi.org/10.54386/jam.v26i1.2461

Paul, A.R. and Maity, R. (2023). Future projection of climate extremes across contiguous northeast India and Bangladesh. *Sci. Rep.,* 13: 15616. https://doi.org/10.1038/s41598-023-42360-2

Roxy, M.K., Ritika, K., Terray, P., Murtugudde, R., Ashok, K. and Goswami, B.N. (2015). Drying of Indian subcontinent by rapid Indian Ocean warming and a weakening land-sea thermal gradient. *Nat. Comm.,* 6(1): 7423. http://dx.doi.org/10.1038/ncomms8423

Soraisam, B., Karumuri, A. and Pai, D. S. (2018). Uncertainties in observations and climate projections for the North East India. *Global Planet. Change,* 160: 96-108.https://doi.org/10.1016/j.gloplacha.2017.11.010

Subash, N. and Sikka, A.K. (2014). Trend analysis of rainfall and temperature and its relationship over India. *Theor. Appl. Climatol.,* 117: 449-462. http://dx.doi.org/10.1007/s00704-013-1015-9

Pandey, V. (2023). Climate variability, trends, projections and their impact on different crops: A case study of Gujarat, India. *J. Agrometeorol.,* 25(2): 224-238. https://doi.org/10.54386/jam.v25i2.2151

Sandeep, V. M., Rao, V. U. M., Rao, B., Pramod, V. P., Chowdary, P. S., Kumar, P. B., Bharathi, G., Patel, N. R. and Mukesh, P. (2018). Impact of climate change on sorghum productivity in India and its adaptation strategies. *J. Agrometeorol.,* 20(2): 89-96. https://doi.org/10.54386/jam.v20i2.517

Sunny, K. and Sidana, B.K. (2017). Climatic variability and its impact on rice and wheat productivity in Punjab. *J. Agrometeorol.,* 19(4): 359-362. https://doi.org/10.54386/jam.v19i4.607

Swami, P. (2024). Trend analysis and change-point detection of monsoon rainfall in Uttarakhand and its impact on vegetation productivity. *J. Agrometeorol.,* 26(1):103-108. https://doi.org/10.54386/jam.v26i1.2214

Zacharias, M., Naresh Kumar, S., Singh, S. D., Swaroopa Rani, D. N. and Aggarwal, P. K. (2014). Assessment of impacts of climate change on rice and wheat in the Indo-Gangetic plains. *J. Agrometeorol.,* 16(1): 9-17. https://doi.org/10.54386/jam.v16i1.1480