Journal of Agrometeorology

(A publication of Association of Agrometeorologists)

ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 27 (4) : 429-434 (December - 2025)
https://doi.org/10.54386/jam.v27i4.3153
https://journal.agrimetassociation.org/index.php/jam

Research Paper

Climatic trends and its impact on rice production in different agroclimatic zones of West Bengal, India

ROHIT PRAMANICK and BISWAJIT PAL*

Department of Rural Studies, West Bengal State University, Barasat 700126, West Bengal, India
**Corresponding Author Email: biswajit.pal22@gmail.com*

ABSTRACT

Changing climate has become one of the major perils for agriculture throughout the world. Rice is one of the most important food grains in India. In this study, the effect of climatic factors on rice production of different agroclimatic zones and districts of West Bengal, India, has been assessed for the period of 1996-2019. Mann-Kendall test was used to figure out trend, Sen's slope estimator to figure out the degree of change, Pettitt's test to detect change point in the data, and finally, multiple linear regression to understand the relationship between climatic factors and rice yield. The results reveal that, in general, the rainfall is decreasing. Area is decreasing, and yield is increasing significantly in most cases. Production is increasing, but not significantly everywhere. In West Bengal and specifically in the Vindhyan Alluvial Zone, climatic factors have a significant impact on yield. Bankura is the only district in West Bengal without a significant increase in yield due to a lack of irrigation facilities and other non-environmental factors.

Key words: Agro-climatic zones, Climatic factors, Rice, Trend analysis, Change point.

In present times, climate change is considered one of the most important concerns throughout the world. Climate change can affect many natural and social phenomena. These interactions can lead to many unexpected outcomes. One of such interactions is the impact of climate change on agriculture. Impact on agriculture will directly affect food security throughout the world (Vijai *et al.,* 2023). Climate change can exert several direct and indirect impacts on agriculture. Indirect impact on agriculture includes climate change-induced extreme weather events, alteration of soil fertility and organic carbon content of soil, increasing soil salinisation, increased incidence of pests and diseases, etc. Directly, climate change can reduce the growing period of crops, increase the evapotranspiration of crops, which may lead to water scarcity. Increased temperature can cause insufficient nutrient accumulation in crops. All of this can reduce crop yield (Yuan *et al.,* 2024).

Rice is one of the most important food grains in the world. As per an impact assessment of the Ministry of Agriculture and Farmers Welfare, Govt. of India, rainfed and irrigated rice could reduce by 20% and 3.5% in 2050 (MoAFW, 2023). West Bengal is one of the largest rice-producing (rank 3 in 2023-24) states of India (GOI, 2025). From the above discussion, it is evident that the impact of climatic factors on rice production needs to be studied. This study is focused on figuring out the trend of rice production and climatic factors in different agro-climatic zones and districts of West Bengal.

MATERIALS AND METHODS

West Bengal is divided into six agro-climatic zones (Fig. 1) namely, Northern hill zone (NHZ) (Darjeeling and Kalimpong), Terai-Teesta alluvial zone (TTAZ) (Jalpaiguri, Alipurduar, Coochbehar and Uttar Dinajpur), Gangetic alluvial zone (GAZ) (Murshidabad, Nadia, North 24 Parganas, Howrah, Hooghly, East and West Burdwan), Vindhyan alluvial zone (VAZ) (Dakshin Dinajpur, Malda), Coastal saline zone (CSZ) (South 24 Parganas and East Midnapore), Undulating Red and Laterite Zone or URLZ (Purulia, Bankura, West Midnapore, Jhargram and Birbhum). But since some of these district demarcations are new, their data have been amalgamated with the existing old districts' data. Based on this procedure, data of Kalimpong district has been amalgamated into Darjeeling district's data, Alipurduar's data into Jalpaiguri, East and West Bardhaman into Bardhaman, Jhargram into West Midnapur.

Article info - DOI: *https://doi.org/10.54386/jam.v27i4.3153*
Received:8 August 2025; Accepted: 15 October 2025; Published online : 1 December 2025

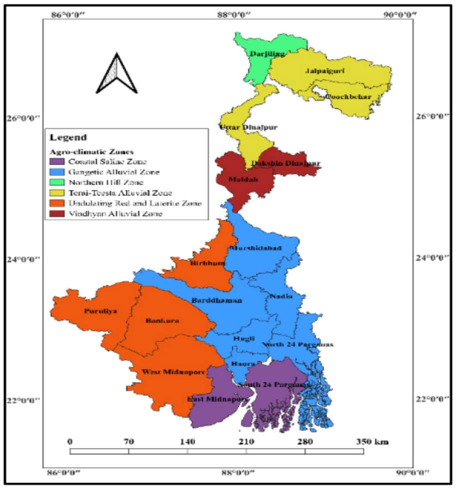

Fig. 1: Agro-climatic Zones of West Bengal

Data

The climatic data comprising of maximum temperature (°C), minimum temperature (°C), and rainfall (mm) for the period of 1996 to 2019 were collected from the gridded data archive of the India Meteorological Department (IMD). The data were collected using the IMDLIB Python library (Nandi and Patel, 2024). The data were then transformed and organised from March to the next February to depict the rice-producing season. For example, climatic data for 1996 represents values from March 1996 to February 1997. The data for rice area, production, and yield for the period from 1996 to 2019 were collected from the Evaluation Wing of the Directorate of Agriculture, Government of West Bengal. Necessary vector data related to state and district boundaries had been collected from the Survey of India online store.

Methodology

To fulfil the objectives of this study, the Mann-Kendall test and Sen's slope estimator were utilised to figure out the trend of crop and climatic variables. The Mann-Kendall test is utilised to detect a monotonic trend in time series data. The significance value is 1.97 at 95% confidence level. Values below 1.97 is considered as non-significant and above is considered as significant (Mann, 1945; Kumar *et al.,* 2013). Sen's slope estimator is used to figure out the degree of change in a time series data (Sen, 1968; Yadav *et al.,* 2014). In order to identify the change point in the time series data, Pettitt's test was utilised. This test can detect a change point in the time series without any assumption about the distribution of the data (Pettitt, 1979; Conte *et al.,* 2019; Swami, 2024). The multiple linear regression method was utilised to figure out the relationship between climatic variables and rice production (Y=aX1+bX2+cX3+C where, Y= rice yield, X1= rainfall, X2= max temp and X3= min temp and a,b and c intercepts for X1, X2 and X3 respectively). The results of the analysis were used to produce maps for a better visual presentation of the spatial dimension of trends. QGIS software has been used to make such maps. All of the statistical analyses were done in RStudio software. The 'trend' package from CRAN had been utilised (Pohlert, 2015; Aucahuasi-Almidon *et al.,* 2024).

RESULTS AND DISCUSSION

Trends in rice production

During the study period (1996-2019), the area of cultivation for rice had been decreasing significantly in West Bengal. The average rate of decrease had been 513 ha per year. A statistically significant change point had been detected in the year 2008. On the contrary, production in the state had been increasing with a statistically significant trend. Production had been increasing at the rate of 2394 thousand tonnes per year. A change point for the production had been detected in the year 2011. The yield had been increasing significantly. A change point for yield had been detected in 2008 (Table 1, Fig. 2). Except for the Undulating red laterite zone (URLZ), the rice cultivation area reduced significantly for all the agroclimatic zones. For URLZ, the area had increased significantly. Change points are different for all the ACZs. Rice production had increased significantly for all the agroclimatic zones, except the Gangetic alluvial zone (GAZ). No significant change point had been detected for the CSZ and GAZ agro-climatic zones. Yield had increased significantly for all the agroclimatic zones. The change point in yield had occurred at different times, but it is mostly around 2008, which is also the change point for the state. At the district level, the rice cultivation area is increasing significantly for West Midnapore. Both change points for increasing area and production were in 2005, and for yield, it was in 2006. A non-significant increase had been observed for Birbhum. All other districts' area of cultivation of rice is decreasing significantly, except for Murshidabad, Coochbehar, Bankura, and Purulia, where such declines are non-significant. The change points were different but mostly concentrated around 2005 and between 2008 and 2009. A significant increase in rice production is observed for all the districts, except East Midnapore, Nadia, North 24 Parganas, Howrah, Bardhaman, Uttar Dinajpur, and Bankura. Among the mentioned districts, a non-significant decrease in production is observed for Nadia, North 24 Parganas, Bardhaman, and Bankura. While a non-significant increase is observed for East Midnapore, Howrah, and Uttar Dinajpur. Except for Bankura, all other districts had a significant increase in yield (Table 1).

Trends in climatic variables

In West Bengal, the decreasing trend of rainfall is significant. The change point was detected in 2007. Both Maximum and Minimum temperatures had been increased, but the trend was not significant. Rainfall had decreased for all the agroclimatic zones. In the case of the Gangetic Alluvial Zone and Vindhyan Alluvial Zone, the decrease was significant. Both minimum and maximum temperatures had been increased for all the agroclimatic zones, but the increase was non-significant. Significantly decreasing rainfall trend has been observed in Murshidabad, Nadia, North 24 Parganas, Bardhaman, Uttar Dinajpur, Birbhum, Dakshin Dinajpur, and Malda. The maximum temperature had only increased significantly for South 24 Parganas (Table 2, Fig. 3).

Relation between climate and rice yield

From Table 3, it has been observed that no significant impact of climatic factors on state-level production. But climatic

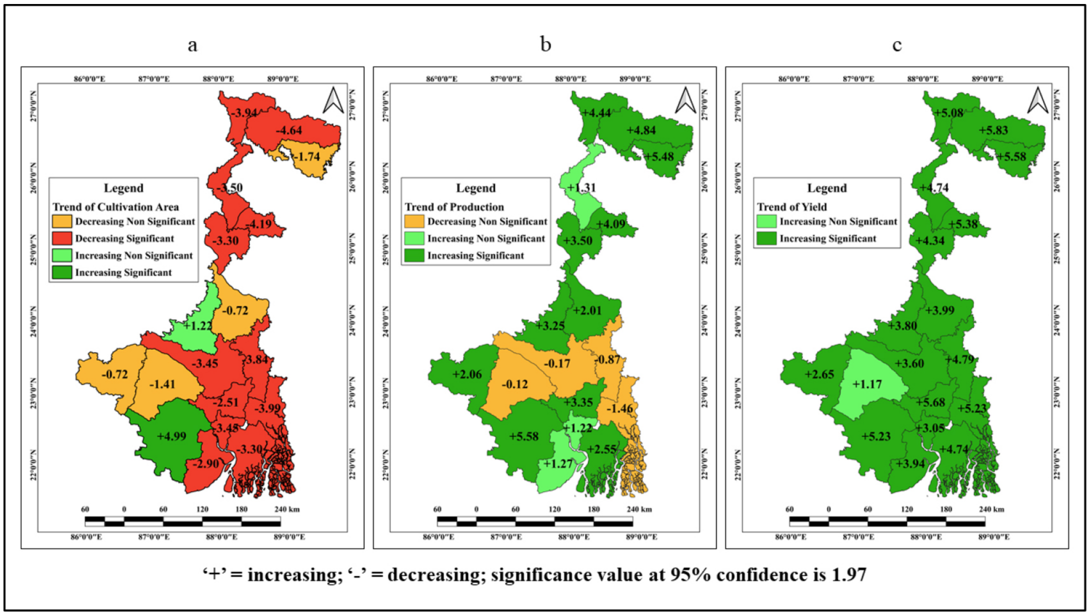

Fig. 2: Trends of (a) area, (b) production and (c) yield of rice in West Bengal

Table 1: Trend and change point of rice of different agro-climatic zones and West Bengal (1996-2019)

Agro-climatic Zones	MK test (Z)			Sen's Slope (Q)			Change from 1996 to 2019			Change Point (Pettitt's test)		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Coastal saline zone (CSZ)	-3.89**	2.16*	4.39**	-6.00	11.87	32.16	-138.12	273.02	739.79	2003	NA	2009
Gangetic alluvial zone (GAZ)	-3.65**	0.00	5.38**	-19.99	0.29	30.84	-459.71	6.58	709.43	2009	NA	2009
Northern hill zone (NHZ)	-3.94**	4.44**	5.08**	-0.23	1.45	55.15	-5.26	33.4	1268.45	2005	2007	2007
Terai-Teesta alluvial zone (TTAZ)	-4.49**	5.38**	5.88**	-5.50	32.87	58.32	-126.56	756.11	1341.47	2008	2009	2008
Undulating red laterite zone (URLZ)	3.20**	4.34**	4.09**	7.69	67.74	27.00	176.84	1557.92	620.99	2011	2005	2005
Vindhyan alluvial zone (VAZ)	-3.75**	4.09**	5.13**	-2.86	13.63	50.84	-65.82	313.38	1169.22	2005	2009	2009
West Bengal	-3.45**	4.59**	6.33**	-22.31	143.24	41.94	-513.19	3294.47	964.71	2008	2011	2008

A = Area in '000 hectare; P = Production in '000 tonnes; Y = Yield in kg ha^{-1}; '*' =p<0.05; '**' = p<0.01

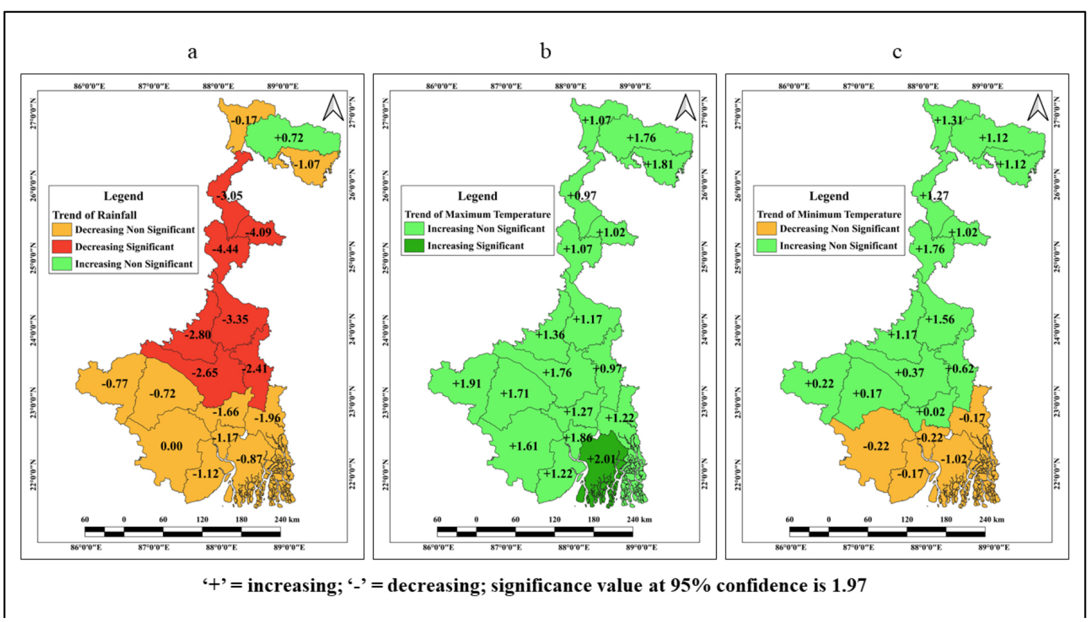

Fig. 3: Trends of (a) rainfall, (b) maximum temperature and (c) minimum temperature in West Bengal

Table 2: Trend and change point of climatic factors of different agro-climatic zones and West Bengal (1996-2019)

Agro-climatic Zones	MK test (Z)			Sen's Slope (Q)			Change from 1996 to 2019			Change Point (Pettitt's test)		
	Rain	Tmax	Tmin	Rain	Tmax	Tmin	Rain	Tmax	Tmin	Rain	Tmax	Tmin
Coastal saline zone (CSZ)	-1.22	1.86	-0.47	-21.45	0.02	0.00	-493.25	0.46	-0.11	NA	NA	NA
Gangetic alluvial zone (GAZ)	-2.46**	1.41	0.27	-110.21	0.02	0.00	-2534.74	0.44	0.06	NA	NA	NA
Northern hill zone (NHZ)	-0.17	1.07	1.31	-2.06	0.01	0.02	-47.40	0.29	0.37	NA	NA	NA
Terai-Teesta alluvial zone (TTAZ)	-0.92	1.31	1.31	-24.42	0.02	0.01	-561.72	0.38	0.27	NA	NA	NA
Undulating red laterite zone (URLZ)	-1.36	1.17	0.27	-38.67	0.01	0.00	-889.45	0.19	0.08	NA	NA	NA
Vindhyan alluvial zone (VAZ)	-4.39**	0.92	1.27	-87.90	0.01	0.02	-2021.78	0.31	0.35	2009	NA	NA
West Bengal	-2.75**	1.56	0.97	-269.34	0.02	0.01	-6194.91	0.40	0.24	2007	NA	NA

Rain = Total Rainfall in mm; Tmax = Maximum Temperature in °C; Tmin = Minimum Temperature in °C; '*' = p<0.05; '**' = p<0.01

Table 3: Regression between climatic factors and rice yield of different districts and West Bengal (1996-2019)

Districts	Equation	R^2
East Midnapore	Y = 9042.37 - 0.47*X1 + 181.82X2 - 508.98X3	0.28*
South 24 Pgs	Y = 1342.43 - 0.13X1 + 196.65X2 - 222X3	0.00
Murshidabad	Y = -6636.20 - 0.34X1 + 169.32X2 + 217.79X3	0.16
Nadia	Y = 1412.95 - 0.21X1 - 26.38X2 + 119.27X3	-0.07
North 24 Pgs	Y = -388.05 - 0.18X1 + 165.18X2 - 206.12X3	0.04
Howrah	Y = 4687 + 0.09X1 + 286.35X2 - 530.43X3	0.01
Hooghly	Y = -5602.25 - 0.16X1 + 197.93X2 + 112.18X3	0.08
Bardhaman	Y = 2936.14 - 0.29X1 - 22.97X2 + 59.25X3	0.04
Darjeeling	Y = -10754.91 - 0.58*X1 + 71.38X2 + 748.84*X3	0.20
Uttar Dinajpur	Y = -4943.74 - 0.44**X1 + 28.51X2 + 373.76*X3	0.32**
Jalpaiguri	Y = -11620.12 - 0.15X1 + 333.45X2 + 291.39X3	-0.01
Coochbehar	Y = -11242.82 - 0.34X1 + 354.22X2 + 283.86X3	0.06
Bankura	Y = 2861.67 + 0.26X1 + 12.31X2 - 44.68X3	0.01
Birbhum	Y = -4060.70 - 0.31X1 - 92.65X2 + 509.32*X3	0.18
Puruliya	Y = 2097.11 + 0.73X1 + 158.79X2 - 292.46X3	0.10
West Midnapore	Y = -6215.87 + 0.11X1 + 389.09X2 - 166.62X3	0.05
Dakshin Dinajpur	Y = -3770.59 - 0.55**X1 + 139.26X2 + 142X3	0.56**
Maldah	Y = -3535.68 - 0.77**X1 + 136.6X2 + 163.59X3	0.64**
West Bengal	Y = -3253.68 - 0.05**X1 - 21.35X2 + 400.22X3	0.42**

'Y'= yield; 'X1' = rainfall; 'X2' = maximum temperature; 'X3' = minimum temperature; '*' = p<0.05; '**' =p <0.01

factors (rainfall, maximum temperature, minimum temperature) had a significant impact on the yield of rice for West Bengal. Climatic factors can explain 42% of the variation in the yield. The beta values reveal that rain had a negative impact on rice yield. Only a significant relation is found for VAZ. Climatic variables can explain 42% and 69% of the variation for production and yield. The beta value of rainfall is significant in both cases. At the district level, climatic variables can explain significant variation in production for North 24 Parganas (27%), Bankura (33%), Purulia (29%), Dakshin Dinajpur (41%), and Malda (33%). A significant relation between climatic variables and yield is found only for East Midnapore, where climatic variables can explain 28% of the variation in yield. In the case of Uttar Dinajpur, Dakshin Dinajpur, and Maldah, both production and yield are significantly affected by climatic variables. For Uttar Dinajpur, climatic variables can explain 27% of the variation in production and 32% variation in yield. In Dakshin Dinajpur 41% for production and 56% for yield. In Maldah district, it is 33% for production and 64% for yield.

Increase in production, despite decrease in area, could be due to use of better cultivars and shifting to improved cultivars from time to time (Ladha *et al.,* 2003). Studies had pointed out that main reason behind difference of district wise production was availability of irrigation. Bankura is the only district where non-significant increase in yield was observed, mainly due to lack of irrigation facilities (De,1999). The trend of climate observed for South 24 parganas is in accordance with other studies (Mandal *et al.,* 2013).

CONCLUSION

Study revealed that the area of rice cultivation decreased in all the agroclimatic zones of West Bengal, except in Undulating red laterite zone. However, rice production and yield have increased in all the zones under study. These changes have different change points. In every agro-climatic zone rainfall has decreased, but it was significant for Gangetic alluvial zone and Vindhyan alluvial zone. Maximum temperature has increased in all the zones. Minimum temperature has also increased in all the zones, except Coastal saline zone but it was not significant in the southern and coastal districts of West Bengal. The regression results suggest that rainfall had a negative effect on the states level rice yield. Rainfall also had negative impact on production and yield in Vindhyan alluvial zone. In zones where direct impact of climatic factors is not observed, it may be due to influence of other non-environmental factors role. Since, in this study, individual trend and change point of each variable related to rice and climate had been reported, the change points could give more insights to preciously connect both environmental (e.g., major disasters) or non-environmental factors (e.g., economic policies, market dynamics, political factors,) to economic factors like production and yield of rice.

ACKNOWLEDGEMENT

Authors are grateful to Directorate of Agriculture, Govt. West Bengal and India Meteorological Department for providing the necessary secondary data.

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

***Funding*:** University Grants Commission (JRF in Humanities and Social Sciences).

***Data Availability*:** District level rice data is available at Evaluation wing of Directorate of Agriculture, Govt. West Bengal. The climate data is available at https://imdpune.gov.in/lrfindex.php. However, for this study the climate data was accessed through IMDLIB python library (https://imdlib.readthedocs.io/en/latest/). Districts boundaries as vectors are available at https://onlinemaps.surveyofindia.gov.in/.

Authors contribution: **R. Pramanick**: Conceptualization, data collection, data analysis, visualization, manuscript drafting; **B. Pal**: Conceptualization, manuscript finalization, supervision.

***Disclaimer*:** The contents, opinions, and views expressed in the research article published in the Journal of Agrometeorology are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

***Publisher's Note*:** The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

Aucahuasi-Almidon, A., Cabrera-Carranza, C., andGarate-Quispe, J. (2024). Trend analysis and change-point detection of temperature and rainfall in southern Peruvian Amazonand its relation to deforestation. *J. Agrometeorol.,* 26(4): 425-430. https://doi.org/10.54386/jam.v26i4.2687

Conte, L. C., Bayer, D. M., and Bayer, F. M. (2019). Bootstrap Pettitt test for detecting change points in hydroclimatological data: Case study of Itaipu Hydroelectric Plant, Brazil. *Hydrol. Sci. J.,* 64(11): 1312-1326. https://doi.org/10.1080/02626667.2019.1632461

De, U. (1999). Nature and Causes of Inter-District Variations in Yield of Rice in West Bengal, 1970-71 to 1994-95. *Indian J. Agric. Econ.,* 54(4): 554-565.

Kumar, J. A., M. Muralidhar, M. Jayanthi, and M. Kumaran. (2013). Trend analysis of weather data in shrimp farming areas of Nagapattinam district of Tamil Nadu. *J. Agrometeorol.,* 15(2): 129-134. https://doi.org/10.54386/jam.v15i2.1459

Ladha, J. K., Dawe, D., Pathak, H., Padre, A. T., Yadav, R. L., Singh, B., Singh, Y., Singh, Y., Singh, P., Kundu, A. L., Sakal, R., Ram, N., Regmi, A. P., Gami, S. K., Bhandari, A. L., Amin, R., Yadav, C. R., Bhattarai, E. M., Das, S., … Hobbs, P. R. (2003). How extensive are yield declines in long-term rice–wheat experiments in Asia? *Field Crops Res.,* 81(2-3): 159-180. https://doi.org/10.1016/S0378-4290(02)00219-8

Mandal, S., Choudhury, B. U., Mondal, M., and Bej, S. (2013). Trend analysis of weather variables in Sagar Island, West Bengal, India: A long-term perspective (1982-2010). *Curr. Sci.,* 105(7): 947-953.

Mann, H. B. (1945). Nonparametric Tests Against Trend. *Econometrica*, 13(3): 245. https://doi.org/10.2307/1907187

GOI. (2025). Ministry of Finance, Economic Survey 2024-25.

MoAFW. (2023, March 21). Impact of Climate Change on Agriculture. https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1909206

Nandi, S., and Patel, P. (2024). iamsaswata/imdlib: Version: 0.1.20 (Version 0.1.20) [Computer software]. Zenodo. https://doi.org/10.5281/ZENODO.4405232

Pettitt, A. N. (1979). A Non-Parametric Approach to the Change-Point Problem. *Appl. Stat.,* 28(2): 126. https://doi.org/10.2307/2346729

Pohlert, T. (2015). trend: Non-Parametric Trend Tests and Change-Point Detection (p. 1.1.6) [Dataset]. https://doi.org/10.32614/CRAN.package.trend

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. *J. Am. Stat. Assoc.*, 63(324): 1379–1389. https://doi.org/10.1080/01621459.1968.10480934

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

Vijai, C., Wisetsri, W., andElayaraja, M. (2023). Climate change and its impact on agriculture. *Int. J. Agric. Sci. Vet. Med.,* 11(4): 1-8. https://doi.org/10.25303/1104ijasvm0108

Yadav, R., S. K. Tripathi, G. Pranuthi, and S. K. Dubey. (2014). Trend analysis by Mann-Kendall test for precipitation and temperature for thirteen districts of Uttarakhand. *J. Agrometeorol.,* 16(2): 164-171. https://doi.org/10.54386/jam.v16i2.1507

Yuan, X., Li, S., Chen, J., Yu, H., Yang, T., Wang, C., Huang, S., Chen, H., andAo, X. (2024). Impacts of Global Climate Change on Agricultural Production: A Comprehensive Review. *Agron.,* 14(7): 1360. https://doi.org/10.3390/agronomy14071360