İSTANBUL UNIVERSITY PRESS

EKOIST Journal of Econometrics and Statistics
EKOIST 2023, 39 : 1–9
DOI: 10.26650/ekoist.2023.39.1315691

RESEARCH ARTICLE

Winter Rice Trend Analysis and Change Point Detection in Assam's North Bank Plains Zone (NBPZ): A Non-Parametric Approach

Rabijita Buragohain[1], Hemanta Saikia[2], Dhruba Das[3]

[1]Assam Agricultural University, Department of Agricultural Statistics, Jorhat, India
[2](Assist. Prof.), Assam Agricultural University, Department of Agricultural Statistics, Jorhat, India
[3](Assist. Prof.), Dibrugarh University, Department of Statistics, Dibrugarh, India

ABSTRACT

Rice from Assam is well-known for having a wide range of genetic varieties. In the past, Assam produced more rice due to its geographic location and climatic conditions. The main rice crop in Assam is winter rice, which makes up a significant amount of the state's overall rice production. The NBPZ is one of the key locations where agriculture provides many people with a means of subsistence. The goal of the study is to determine the turning point for winter rice productivity in Assam's NBPZ by analyzing trends regarding winter rice output, area, and productivity. The transition point for the productivity of winter rice was discovered by analyzing more than 30 years of NBPZ data. The study also shows the NBPZ to not just be restricted to researching winter rice's climate-resilient productivity but to also have a critical need to adopt efficient crop production and productivity measures. Thus, the study's findings are anticipated to be able to help policymakers create an effective agricultural policy that is easier for farmers to adopt.

Keywords: change point, hypothesis testing, non-parametric, trend analysis

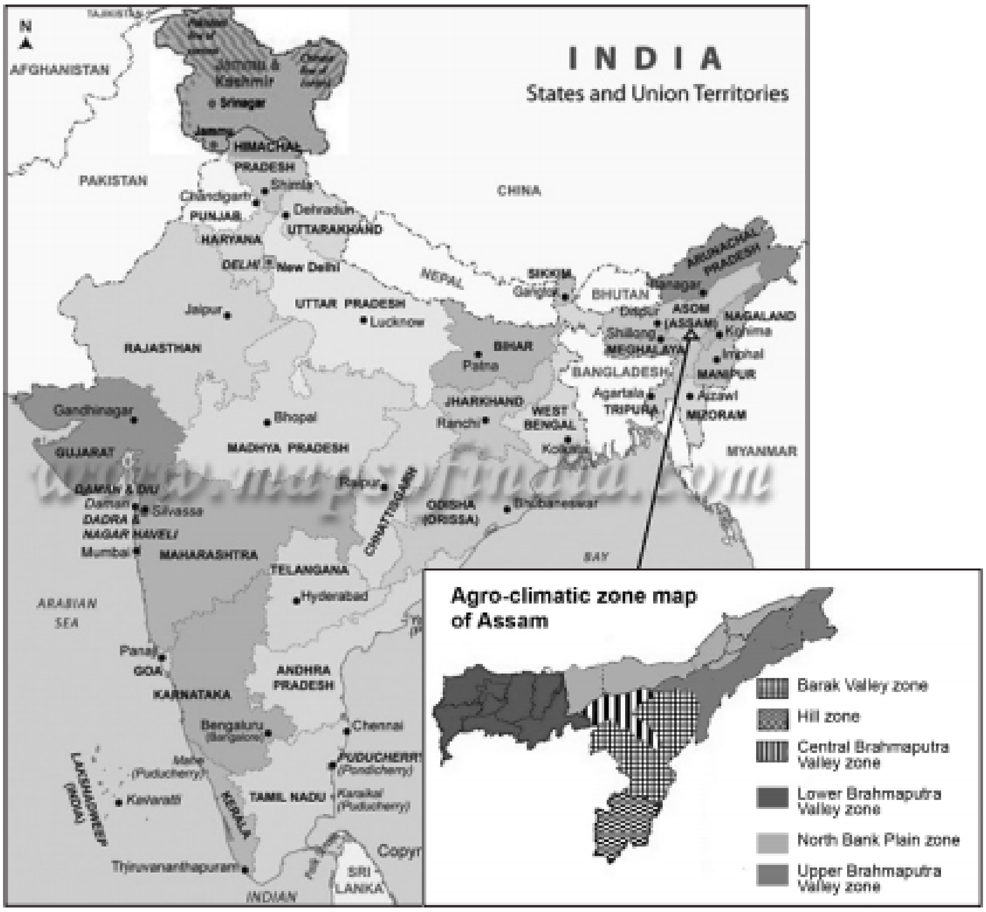
Introduction

Assam is a state in northeastern India, and 69% of its population is dependent on agriculture. Assam has six agroclimatic zones: the Upper Brahmaputra Valley Zone (UBVZ), Lower Brahmaputra Valley Zone (LBVZ), Central Brahmaputra Valley Zone (CBVZ), North Bank Plains Zone (NBPZ), Barak Valley Zone (BVZ), and Hills Zone (HZ). This study specifically focuses on the NBPZ, which is comprised of the six districts of Dhemaji, Lakhimpur, Sonitpur, Biswanath Chariali, Darrang, and Udalguri. Altogether, these districts cover 18.37% of the total area of Assam. This NBPZ area has a unique geographical location surrounded by hills, alongside which flows the mighty Brahmaputra River, which is a blessing for any crop grown in this zone. Because of its unique geographical location, the NBPZ encounters weather variability that resultantly influences the crop productivity. The NBPZ has historically produced more rice due to its physical characteristics, climatic circumstances, and geographic location. Winter rice is the main rice crop that accounts for a significant share of the nation and zone's overall rice production. Winter rice earns its name from when it is harvested. It is sown sometime between June and July and harvested between November and December.

However, the time for sowing winter rice is the same time the Brahmaputra and its tributaries deluge the NBPZ, which also causes an imbalance in agricultural crop production in this zone. Climate is a key factor for agriculture in terms of the quantity and quality of crop production. Due to the adverse heterogeneous impact of weather conditions, so many uncertainties occur that can result in failures in crop production and productivity. Therefore, assessing the past trends of the area, production, and output of winter rice is essential and can further be linked to the policymaking decisions the government of Assam makes for its stakeholders. In addition to the past trend assessment, this study also focuses on identifying the change point in the NBPZ, in particular with regard to the area, production, and productivity of winter rice.

Corresponding Author: Hemanta Saikia **E-mail:** h.saikia456@gmail.com

Submitted: 17.06.2023 • **Revision Requested:** 04.07.2023 • **Last Revision Received:** 05.10.2023 • **Accepted:** 04.10.2023



Sources: Maps of India (2014) and NESAC (n.d.)

Figure 1. Geographical location map of Assam's NBPZ.

Literature Review

The potential threats the expected fluctuations in the Earth's climate pose to crop yield have long been a source of concern, as well as the extent to which the agricultural system will be able to adapt to these changes to maintain the food supply (Wing, 2021). Usually, high temperatures result in a significant reduction in global rice production, and according to Peng et al. (2004), the yield of dry season crops in the Philippines will decrease by 15% for every 1°C increase in the growing season's average temperature. In India, the summer monsoon, often known as the southwest monsoon, dominates its climate system, albeit to a lesser extent than the northeast monsoon. As a significant source of precipitation for India and other parts of South Asia, the southwest monsoon is responsible for over 80% of all rainfall in India (Bagla et al., 2012). Rainfall is one of the most researched meteorological phenomena in India due to the monsoon's significance to the Indian economy. The distribution of rainfall over space and time, in addition to its total volume, has a significant impact on agricultural output (Goswami et al., 2006). According to studies, the Indian monsoon is swiftly and steadily degrading, with more extremes in rainfall frequency and intensity (Auffhammer et al., 2012). The number of rainy days and early and late monsoon rainfall trends in India has shown decreasing trends between 1951-2003 according to studies such as Ramesh and Goswami (2007). This has been followed by a significant increase in the overall area experiencing monsoon rainfall being one standard deviation below the mean.

For rice crops, the appropriate combination of rainfall and temperature is required throughout all of its growing stages. More defense mechanisms are found to be activated in the seedling growth of rice as temperatures rise (Han et al., 2009). Because the temperature around the apical meristem controls leaf appearance (Ritchie, 1993), floodwater temperatures in fields are also important. Although higher temperatures increase the cultivation numbers (Yoshida, 1973) and plant height (Oh-e et al., 2007), the ripening temperature of rice is generally thought to be 24°C, which is when the highest grain weight is seen (Kobata et al., 2004). However, depending on the cultivar and growth stage, temperatures above 35°C produce several types of heat that are harmful to rice crops (Yoshida et al., 1981). Therefore, the negative impact of weather parameters during any stage of crop growth ultimately results in lower productivity. Ravindranath et al. (2011) utilized an index-based approach by using principal component analysis to select the key sectors of vulnerability for Northeast India at the district level as a result of climate change. The study concluded the majority of districts in Northeast India to currently and in the near future be vulnerable to climate change and ranked the districts in accordance with the vulnerability index. Das et al. (2009) researched similar effects of climate change in the eastern Himalayan terrain with international boundaries, and its trans-boundary river basins due to its geographical and ecological fragility and strategic location.

Despite the NBPZ's subtropical climate and substantial rainfall, it has recently faced drought-like conditions as a result of global climate change. Both severe climatic conditions, as well as droughts and floods have been brought on by insufficient or excessive rainfall. In locations with a rainy climate such as Northeast India, drought has been more severe. In recent years, the entire northeastern region of India has suffered from unprecedented drought-like circumstances, with 2005, 2006, and 2009 requiring special consideration. In the absence of scientific evidence about the region's susceptibility to climate change, farming communities need to be immediately encouraged to adopt management practices such as conservation agriculture, afforestation, rainwater harvesting, efficient input use, and appropriate agricultural techniques for drought. Dutta (2014) researched the effects of climate change on the tea-growing regions of Northeast India to make projections for future climatic conditions and their impact on tea output by 2050. According to the study, the average temperature in Northeastern India might rise 2°C by 2050, yet no change is expected to occur in the region's rainfall patterns.

Data and Methodology

Study Area and Data Collection

This study covers the NBPZ districts of Dhemaji, Lakhimpur, Sonitpur, Biswanath Chariali, Udalguri, and Darrang and gathered data on winter rice production, area, and productivity from Assam's Directorate of Economics and Statistics for these NBPZ districts from 1988-2018. The analytical studies have been performed with the help of the statistical software programs Microsoft Excel and XL-STAT.

Trends in Winter Rice Area, Production, and Productivity Analysis

The Mann-Kendall test is a type of non-parametric distribution-free test that can be used to determine whether the relevant variable of interest has a monotonic upward or downward trend over time. A monotonic upward or downward trend may or may not be linear and denotes a consistent growth or reduction in the variable over time. This test can also be used in place of a parametric linear regression analysis to determine whether or not the estimated linear regression line's slope deviates from zero. The Mann-Kendall test statistic is defined as:

$$S = \Sigma_{k=1}^{n-1} \Sigma_{j=k+1}^{n} sgn(X_j - X_k) \tag{1}$$

where

$$sgn(x) = \left\{ \begin{array}{lll} 1\ if & x > & 0 \\ 0\ if & x = & 0 \\ \text{-1}\ if & x < & 0 \end{array} \right\}$$

The mean of S is Σ[S] = 0, and the variance σ^2 is defined as:

$$\sigma^2 = \{n(n-1)(2n+5) - \Sigma_{j=1}^{p} t_j(t_j - 1)(2t_j + 5)\}/18 \tag{2}$$

where p is the number of tied groups in the data set and t_j is the number of data points in the jth tied group. The S statistic is normally distributed as an approximation, provided that the following Z-transformation is employed:

$$\left\{ \begin{array}{lll} \frac{s-1}{\sigma}\ if & S & > 0 \\ 0\ if & S & = 0 \\ \frac{s+1}{\sigma}\ if & S & > 0 \end{array} \right\} \tag{3}$$

The S statistic is closely related to Kendall's τ, which is given by:

$$\tau = \frac{S}{D} \tag{4}$$

$$whereD = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\Sigma_{j=1}^{p} t_j(t_j - 1)\right]^{\frac{1}{2}} \left[\frac{1}{2}n(n-1)\right]^{\frac{1}{2}}$$

Magnitude of Trend

Sen (1968) created Sen's slope, which has been extensively used to determine the size of trends in long-term temporal data (Tabari et al., 2011). Because Sen's slope, symbolized by Q, is unaffected by data outliers, it is thought to be a stronger indicator of a linear relationship. The temporal data shows a positive trend when Qi values are positive and a negative trend when Qi values are negative. The annual magnitude of slope is the unit of measurement of Sen's slope Qi. According to Sen's technique, this test determines the slope (i.e., linear rate of change) and the intercepts. The following formula is initially used to calculate a set of linear slopes:

$$d_k = \frac{X_j - X_i}{j - i} \tag{5}$$

for (1 ≤ i < j ≤ n), where d is the slope, x denotes the variable, n is the number of observations, and i and j are indices. Sen's slope is then calculated as the median from all slopes, where b = the median (d_k), after which the intercepts are computed for each time step t as given by:

$$a_t = X_t - (b \times t) \tag{6}$$

The median of all intercepts is also the corresponding intercept. The upper and lower confidence bounds of Sen's slope can also be calculated using this technique.

Homogeneity Test and Change Point Detection

The homogeneity test is carried out to determine whether the series may be regarded as homogeneous over time or if a point occurs where a change happens (Jaiswal et al., 2015). Numerous tests are available for verifying the homogeneity of a series. Finding the change points in a time series is crucial for determining where the substantial changes have occurred. In order to examine the homogeneity of series and identify any change points, this study takes into account two homogeneity tests, namely the Pettitt and Buishand tests.

Pettitt's Test

A significant change point may be found using Pettitt's test, which can detect a large shift in the average of a time series of data even when the precise timing of the change is unknown. The statistic used for Pettitt's test is defined as U_k, and has been indicated by Kang and Yusof (2012), Dhorde and Zarenistanak (2013), and many others as:

$$U_k = 2\Sigma_{i=0}^{n} m_i - k(n+1) \tag{7}$$

where m_i is the rank of the ith observation of k whose values are 1, 2, . . . , n; the series values $x_1, x_2, \ldots, x_n$ are also sorted in ascending order. As the next step, the statistical change point test is defined as follows:

$$K = max|U_k|, \qquad 1 \le k \le n \tag{8}$$

A change point occurs in the series when U¬k reaches the highest value of k. The crucial value is obtained as follows:

$$U_k = [-ln \propto (n^3 + n^2)/6]^{\frac{1}{2}} \tag{9}$$

where the critical value α is determined by the threshold of significance, and n is the number of observations.

Buishand's Test

Buishand's (1982) test is a non-parametric test. The following model with a single shift (change point) is calculated as follows, with X standing for a normal random variate:

$$\begin{aligned} X_i &= \mu + \Delta + \epsilon_i \qquad i = 1, \ldots, m \\ &\mu + \Delta + \epsilon_i \qquad i = m+1, \ldots, n\epsilon_i \approx N(0, \sigma). \end{aligned} \tag{10}$$

The null hypothesis $\Delta = 0$ is tested against the alternative $\Delta \neq 0$. The rescaled adjusted partial sums are calculated as $S_K = \Sigma_{i=1}^{k}(X_i - \hat{X})$. Thus, Buishand's U test is calculated as:

$$U = [n(n+1)]^{-1}\Sigma_{k=1}^{n-1}\left(\frac{S_K}{D_X}\right)^2 \tag{11}$$

where $D_X = \sqrt{n^{-1}\Sigma_{i=1}^{n}(X_i - \bar{X})}$and a Monte Carlo simulation with m repetitions is used to evaluate the p value (Pohlert, 2016).

Results and Discussions

Based on the trend analysis results from the Mann-Kendall Test and Sen's slope, the NBPZ is observed to have shown a significantly decreasing trend (see Figure 2 in the Appendix), with a magnitude of - 419.5 ha/year in terms of area (see Table 1). The Government of Assam's Directorate of Economics and Statistics has also cited the cultivable land in Assam to have decreased considerably over the last five years as per the report from the Land Utilization Statistic (Provisional) for 2019-2020. Many studies have established several reasons behind the disappearance of cultivable land, such as increased populations, urbanization, and floods. Another huge concern is river erosion. River erosion has wreaked havoc in the NBPZ, as each year this region must face a huge loss of area due to flood and river erosion. When the Brahmaputra and its tributaries rise in the NBPZ, thousands of cultivable lands immediately get submerged by the river. Reports have shown the Brahmaputra River to throw up new islands every 10 to 15 years, which are called the *char-chapori* (riverine) area.

However, the trend for the production and productivity of winter rice in the NBPZ is found to have been significantly increasing, with a magnitude of 1,733 kg/ha for production and 29.90 kg/ha for productivity (see Table 1) Overall, despite the decrease in area, evidence (see Figures 3 & 4 in the Appendix) shows the production and productivity of winter rice to have increased over the last 30 years. All the improvements made over the past years in the agricultural sector, such as improved crop patterns, the use of hybrid crops (HYVs), the expansion of high yield variety areas, the status of irrigation infrastructure, and the ease with which farmers' packaging and practices can be assessed have caused an upward trend in production.

Table 1. Mann-Kendall Test of Trend and Sen's Slop Estimation for the NBPZ

Variables	Mann-Kendall test		Sen's slope	Trend
	p	Change Year		
Area	0.032*	2004	-419.5	decreasing
Production	0.007*	2008	1,733	increasing
Productivity	0.001*	2009	29.90	increasing

* Significance determined at a level of $\alpha = 0.05$

In addition to identifying the homogeneity of the series and detecting the change points using the two non-parametric tests (i.e., the Pettitt and Buishand tests), the change point has also been detected by examining the high and low values in the data set. The results from these change point tests could reveal the exact year in which a break or change occurs. This change point leads to a trend line that may either increase or decrease the trend. Moreover, for winter rice production, the two tests identified different years for the change points.

A slight deviation occurred when identifying the change points using Pettitt's test and Buishand's test, and this deviation was also observed by Pal (2018). In such a case, fitting a trend line confirmed the usefulness of the correct test. If the presence of a trend is shown, then one can consider that the data to be non-homogeneous. Namely, a change point has occurred in the series, and no change point is present when no trends occur. For example, in terms of the NBPZ, the Pettitt test resulted in a change point in 2003, whereas Buishand's test resulted in the same change point occurring in 2004. Moreover, Pettitt's test revealed the data to be homogeneous, whereas Buishand's test revealed the data to be non-homogeneous. Therefore, computing the Mann-Kendall trend test has confirmed a significant trend to be present in the series, thus accepting Buishand's test results and the change year for the NBPZ accordingly being 2004 (see Table 1). Regarding production and productivity, both the tests imilarly revealed the data to no longer be homogeneous and provided results showing the changes to have happened in 2008 and 2009, respectively.

Conclusion and Future Scope of the Study

As an outcome, the study indicates that, winter rice production and productivity in the NBPZ have increased over the past 30 years despite the area having decreased. Winter rice production and productivity trends are greatly influenced by climatic and non-climatic elements that also mark a change point in the trend. In addition, the atmosphere of this region is mostly humid due to the NBPZ's geographical and topological conditions. Therefore, the crop needs an optimum temperature to complete its life cycle, from panicle initiation to maturation. Therefore, to increase the winter rice output, thorough research on the cultivation of cold-tolerant types of the variety is highly required to enhance productivity alongside its best indigenous features, because the indigenous or local varieties have been least affected by the changes in weather conditions. Recently, most farmers who are officially listed as beneficiaries of the government agricultural sector were observed to have switched over to cultivating improved or high-yield varieties (HYV) in place of indigenous winter rice varieties. Although the Assam Government provides the HYVs, focus should be placed on high-yielding, cold-tolerant, nutrient-rich varieties in addition to water- and stress-resistant varieties, because the area is mostly humid and more susceptible to flooding.

Due to the NBPZ being geographically suitable for agriculture, the need exists for regular monitoring of weather impacts on agriculture. Additionally, monitoring all the socio-economic factors related to agriculture must be studied simultaneously so that government schemes can be gainfully implemented to enhance winter rice production and productivity. Such schemes and policies can bring proper approximation of inputs, such as a minimum support price index, suitable credit disbursement, or different kinds of crop insurance schemes. The implementation of such real-valued schemes and policies can undoubtedly provide a ray of hope for a better future for the agrarian society. Similarly, the responsible body should take appropriate action to counteract climate change impacts on agriculture in this region in order to achieve sustainable agricultural development and provide food security for the constantly growing population. To highlight regional distinctions and direct intense measures regarding the viewpoint on climate change, more of this type of region-specific study should be performed. Researchers can also use stepwise regression analyses by considering weather parameters such as rainfall, humidity, and maximum and minimum temperatures to identify the factors responsible for increasing the trends in production and productivity.

Peer Review: Externally peer-reviewed.

Conflict of Interest: The author has no conflict of interest to declare.

Grant Support: The author declared that this study has received no financial support.

Author Contributions: Conception/Design of study: H.S., R.B.; Data Acquisition: R.B.; Data Analysis/Interpretation: R.B., H.S.; Drafting Manuscript: R.B., H.S., D.D.; Critical Revision of Manuscript: H.D., D.D.; Final Approval and Accountability: R.B., H.S., D.D.

ORCID:

Rabijita Buragohain 0009-0008-8747-3631
Hemanta Saikia 0000-0002-6367-485X
Dhruba Das 0000-0001-8546-0193

REFERENCES

Auffhammer, Maximilian, V., Ramanathan and Vincent, J.R. (2012): Climate change, the monsoon, and rice yields in India. *Climatic Change*, **111**: 411-424.

Bagla, P. (2012): Drawing a bead on India's enigmatic monsoon. *Science*, **335**(6071): 910.

Buishand, T.A. (1982): Some methods for testing the homogeneity of rainfall records. *J. Hydrol*. **58**(1-2): 11-27.

Chaliha, S., Sengupta, A., Sharma, N. and Ravindranath, N. H. (2012): Climate variability and farmer's vulnerability in a flood-prone district of Assam. *International Journal of Climate Change Strategies and Management.*

Das, A., Ghosh, P. K., Choudhury, B. U., Patel, D. P., Munda, G. C., Ngachan, S. V. and Chowdhury, P. (2009): Climate change in North East India: Recent facts and events worry for agricultural management. In: *Proceedings of the workshop on impact of climate change on agriculture*, (pp. 32-37).

Dhorde, A. G. and Zarenistanak, M. (2013): Three-way approach to test data homogeneity: an analysis of temperature and precipitation series over southwestern Islamic Republic of Iran. *J. Ind. Geophys.Union.***17**(3):233-242.

Dutta, R. (2014): Climate change and its impact on tea in Northeast India. *Journal of Water and Climate Change,* **5**(4): 625-632.

Goswami, B.N. (2006): Increasing trend of extreme rain events over India in a warming environment. *Science*, **314**: 1442-1445.

Han, F., Chen, H., Li, X. J., Yang, M. F., Liu, G. S. and Shen, S. H. (2009): A comparative proteomic analysis of rice seedlings under various high-temperature stresses. *Biochim. Biophys. Acta.*, **1794**: 1625-1634.

Jaiswal, R. K., Lohani, A. K. and Tiwari, H. L. (2015): Statistical analysis for change detection and trend assessment in climatological parameters. *Environmental Processes,* **2**(4): 729-749.

Kang, H. M. and Yusof, F. (2012): Homogeneity tests on daily rainfall series. *Int. J. Contemp. Math. Sciences*, **7**(1): 9-22.

Kobata, T., Uemuki, N., Inamura, T. and Kagata, H. (2004): Shortage of assimilate supply to grain increases the proportion of milky white rice kernels under high temperatures. *Jpn. J. Crop Sci*., **73**: 315–322.

Oh-e, I., Saitoh, K. and Kuroda, T. (2007): Effects of high temperature on growth, yield and dry-matter production of rice grown in the paddy field. *Plant Prod. Sci*., **10**: 412–422.

Pal, K. (2018). Analysis of Rainfall Trend over long period in Uper betwa Basin, Madhya Pradesh. Ph.D Thesis, Banasar Hindu University, Varanasi-221005.

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C., Visperas, R. M., Zhong, X., Centeno, G. S., Khush, G.S. and Cassman, K. G. (2004): Rice yield decline with higher night temperature from global warming. P*roceedings of the National Academy of Sciences,* **101**(27): 9971-9975.

Pohlert, T. (2016). Non-parametric trend tests and change-point detection. *CC BY-ND*, 4.

Ramanathan *et al*. (2005): Atmospheric brown clouds: Impacts on South Asian climate and hydrological cycle. *Proceedings of the National Academy of Sciences*, **102**(15): 5326-5333. 53.

Ramesh, K.V. and Goswami, P. (2007): Reduction in temporal and spatial extent of the Indian summer monsoon. *Geophysical Research Letters,* **34**: 1-6.

Ravindranath, N. H., Rao, S., Sharma, N., Nair, M., Gopalakrishnan, R., Rao, A. S. and Bala, G. (2011): Climate change vulnerability profiles for North East India. *Current Science,* 384-394.

Ritchie, J. T. (1993): Genetic specific data for crop modelling. In: Systems Approaches for Agricultural Development. Eds. *Kluwer Academic Publishers, Dordrech*., pp. 77–93.

Tabari, H. and Marofi, S. (2011): Changes of pan evaporation in the west of Iran. *Water Resour. Manag.*, **25**: 97-111.

Wing, I. S., De Cian, E. and Mistry, M. N. (2021): Global vulnerability of crop yields to climate change. *Journal of Environmental Economics and Management*, 102462.

Yoshida, S. (1973): Effects of temperature on growth of rice plant *(Oryza sativa L.)* in a controlled environment. *Soil Science Plant Nutriton*, **19**: 299-310.

Yoshida, S., Satake, T. and Mackill, D. J. (1981): High-temperature stress in rice (Review).*IRRI Res. Paper Series*, **67**: 5

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. *Journal of the American statistical association* 63, 324: 1379-1389.

How cite this article

Buragohain, R., Saikia, H., & Das, D. (2023). Winter rice trend analysis and change point detection in Assam's North Bank Plains Zone (NBPZ): A non-parametric approach. *EKOIST Journal of Econometrics and Statistics,* 39, 1-9. https://doi.org/10.26650/ekoist.2023.39.1315691

Appendix

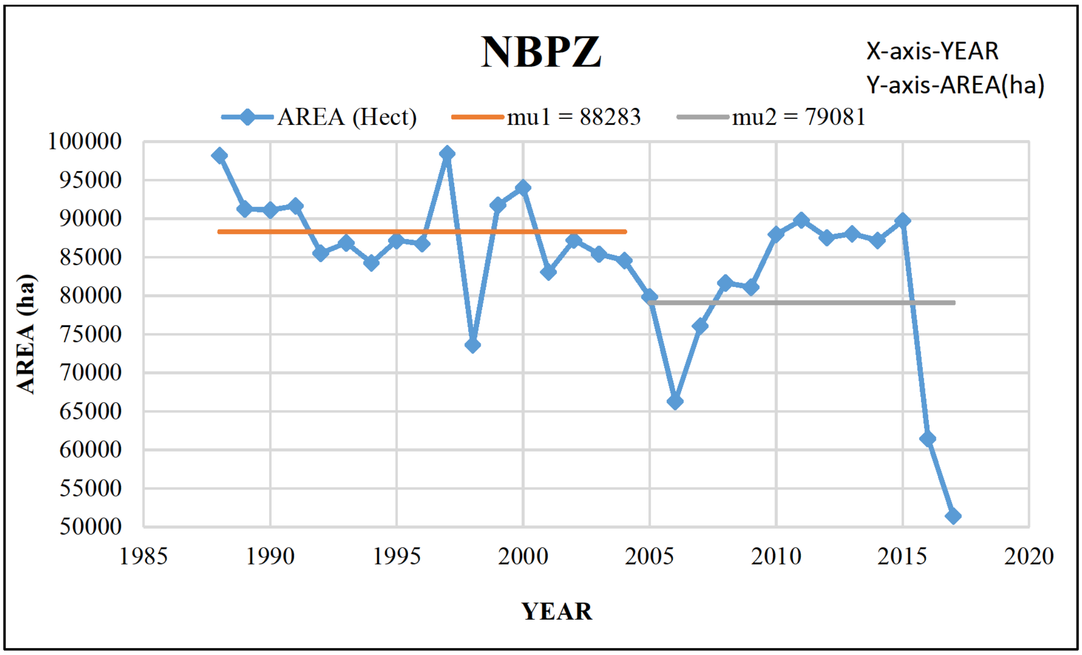


Figure 2. Trend and change point identification for area of winter rice in the NBPZ.

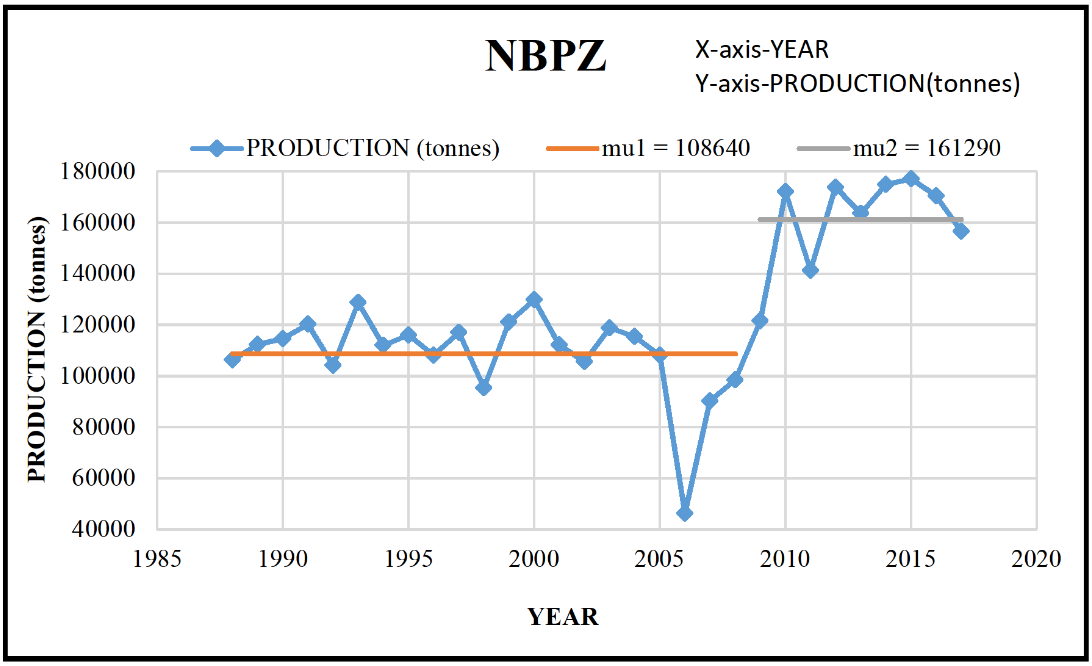


Figure 3. Trend and change point identification for production of winter rice in the NBPZ.

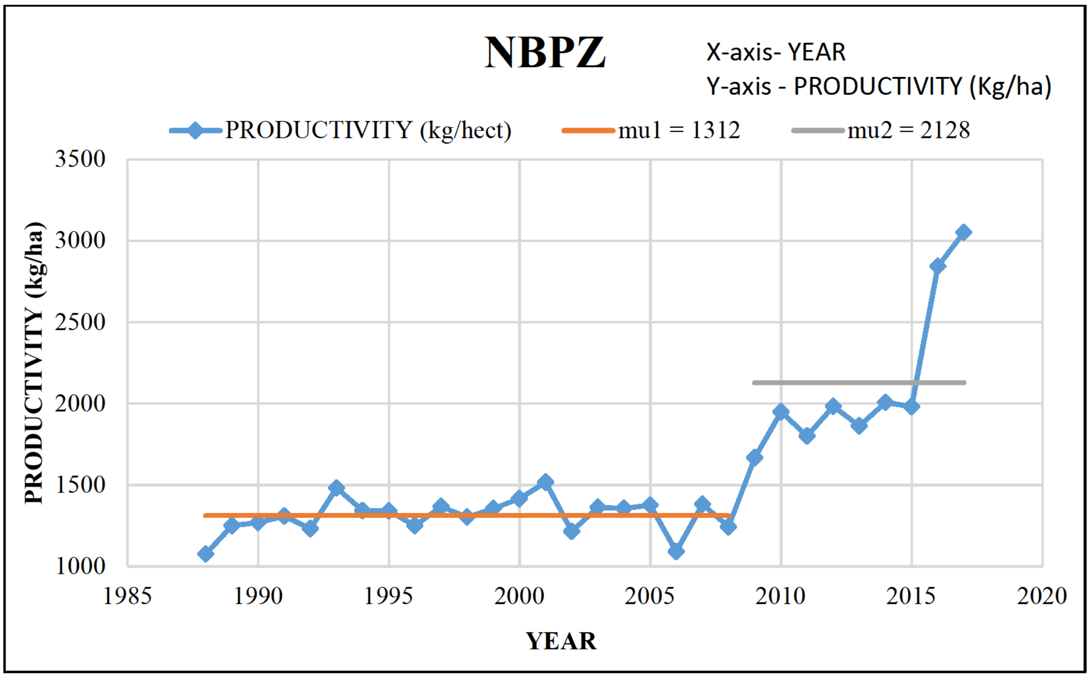


Figure 4. Trend and change point identification for productivity of winter rice in the NBPZ.