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

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Assam is well-recognized for its rich genetic diversity of rice. The climatic condition and geographical location cause better production of rice in the past of Assam. Winter rice is the leading rice crop, accounting for a major portion of the total rice production in Assam and NBPZ is one of the main regions where most of its livelihood depends on agriculture. The purpose of the study is to analyze the trend of area, production, and productivity of winter rice and identify the change point for winter rice productivity in NBPZ of Assam. Analyzing over thirty years of the data for the NBPZ led to the detection of the change point for the productivity of winter rice. The study also revealed that the NBPZ is not limited to studying climate-resilient productivity of winter rice only, but there is a great need for the implementation of effective measures on crop production and productivity. Thus, the outcome of the study has believed to reveal a better implementable plan for the farmers for designing an efficient agricultural policy by the policy makers.

keywords: Change Point, Hypothesis Testing, Non-parametric, Trend Analysis.

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1 Introduction

Assam, in the North-Eastern state of India, has sixty-nine (69) percent of the population dependent on agriculture. It has six agro-climatic zones i.e. 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 focused on NBPZ which is comprised of six districts viz. Dhemaji, Lakhimpur, Sonitpur, Biswanath Chariali, Darrang and Udalguri. Altogether these districts cover 18.37% area of the total area of Assam. This NBPZ area has a unique geographical location surrounded by hills along with the mighty Brahmaputra river flowing alongside, which is a blessing for any crop grown under this zone. Because of this unique geographical location, the NBPZ area is facing weather variability and as a result, it influences the productivity of crops. The physical features, climatic conditions, and geographical location have caused greater production of rice in the NBPZ area over the past. Winter rice is the leading rice crop accounting for a major portion of the total rice production in Assam as well as in India. Winter rice is named as per its harvesting time. The sowing time of winter rice is June-July and it is harvested from November to December. Rice requires high temperatures, high humidity levels, extended daylight hours, and a reliable water supply. An optimum growth is visible in a temperature range between 20 to 35^0C. Tillering phase demands a higher temperature than that of early growth phases. The ideal temperature range for flowering is between 26.5 to 29.5^0C. Humidity requirements also vary depending on the varieties. The average plant height for different varieties ranges from 85 to 140 cm.

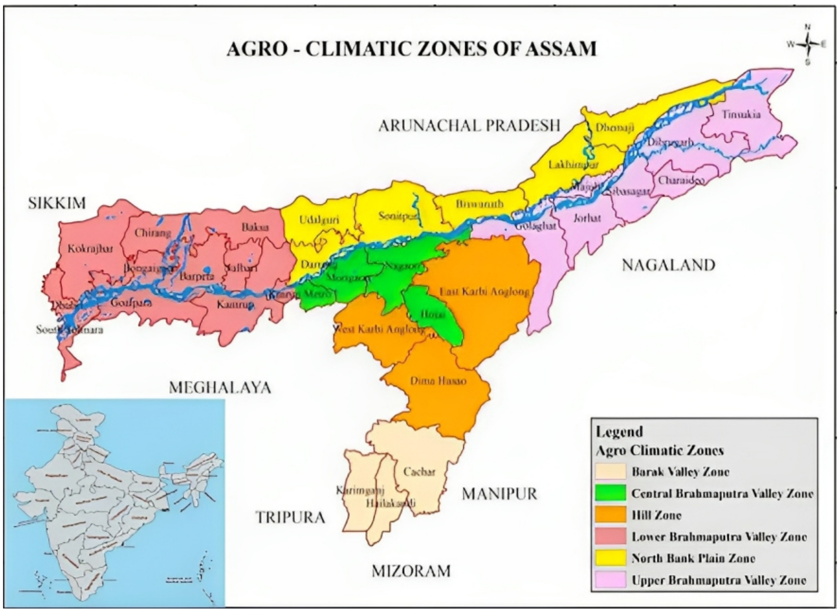

Figure 1: Geographical location MAP of NBPZ of Assam

However, during the sowing time of winter rice, the NBPZ deluges every year by the Brahmaputra and its tributaries which causes an imbalance in agricultural crop production in this zone. Climate is a key factor for agriculture in terms of quantity and quality of crop production. Due to the adverse heterogeneous impact of weather conditions, there would be so many uncertainties that make failure in crop production and productivity. Therefore, assessment of the past trend of area, production, and productivity of winter rice is essential which further could be linked to policy making decisions by the government of Assam for its' stakeholders. Besides the past trend assessment, this study also focused on identifying the change point in the NBPZ zone, especially for the area, production, and productivity of winter rice.

2 Review of Literature

There has long been a source of concern about the potential threats to crop yield posed by expected fluctuations in the Earth's climate, as well as the extent to which the agricultural system will be able to adopt these changes to maintain food supply (Wing et al., 2021). Usually, high temperatures resulted in a significant reduction in global rice production and it is reported by Peng et al. (2004) that for every 1^0C increase in the growing season average temperature would reduce the yield of dry season crops by 15% in the Philippines. In India, the summer monsoon, often known as the south-west monsoon, dominates its climate system (lesser extent than the north-east monsoon). Rainfall from the south-west monsoon is a key source of precipitation for India and areas of South Asia (Ramanathan et al., 2005), accounting for approximately 80% of India's total rainfall (Bagla, 2012). Because of the monsoon's importance to the Indian economy, rainfall is one of the most studied weather phenomena. Agricultural productivity is highly dependent not only on the amount of rainfall but greatly on its distribution over space and time (Goswami et al., 2006). According to studies, the Indian monsoon is deteriorating gradually and rapidly, with increased frequency and intensity of rainfall extremes (Auffhammer et al., 2012). From 1951 to 2003, studies indicated decreasing trends in early and late monsoon rainfall as well as the number of rainy days in India, followed by a considerable increase in total area with monsoon rainfall one standard deviation below the mean (Ramesh and Goswami, 2007). For the rice crop, the appropriate combination of rainfall and temperature is required throughout its all growing stages. It was found that in the seedling growth of rice, more defense mechanisms are activated as the temperature rises (Han et al., 2009). Since temperature near the apical meristem controls leaf appearance (Ritchie, 1993), floodwater temperature in fields is also important. Although higher temperatures increase tiller numbers (Yoshida, 1973) and the plant height gets steeper at high temperatures than at ambient temperatures (Oh-e et al., 2007). In general, the ripening temperature of rice is thought to be 24^0C at which the highest grain weight is seen (Kobata et al., 2004). However, depending on the cultivar and growth stage, temperatures above 35°C produces several types of heat harm to rice crop (Yoshida et al., 1981). Therefore, the negative impact of weather parameters in any stage of crop growth ultimately results in low productivity. An index-based approach was utilized by Ravindranath et al. (2011) where key sectors of vulnerability for North-East India at the district level due to climate change were selected by principal component analysis. The study found that most districts in North East India were at that time and in near future vulnerable to climate change and accordingly ranked the districts based on the vulnerability index. Similar consequences of climate change were studied by Das et al. (2009) due to its Geo-ecological fragility, strategic location, the eastern Himalayan landscape with international borders, and its trans-boundary river basins. Though the NBPZ is in a high-rainfall region with a subtropical climate merely even high rainfall areas are experiencing drought-like conditions in recent years because of global climate change. Droughts and floods are both severe climatic conditions caused by a lack of or excess rainfall. Drought is more significant in rainfed areas, such as North-East India. Unprecedented drought-like conditions have harmed the entire NER in recent years. Attention should be paid to the years 2005, 2006 and 2009. Conservation agriculture, afforestation, rainwater harvesting, efficient input use, and proper agro-techniques for drought are some of the management options that need to be immediately popularized among farming communities to mitigate the impact of climate change in the absence of scientific data about the region's vulnerability to climate change. The impact of climate change on tea-growing areas of North-East India was studied by Dutta (2014) to provide predictions for future climatic conditions and their impact on tea production by 2050. The study showed that there was a possibility of an increase in average temperature by 2^0C in 2050, while no variation was observed in the rainfall pattern in North-Eastern region of India.

3 Objective of the Study

The prime objective of the study is to analyze the trend of area, production, and productivity and to detect the change point for winter rice in NBPZ of Assam.

4 Data and Methodology

4.1 Study Area and Data Collection

The districts covered under NBPZ in this study were Dhemaji, Lakhimpur, Sonitpur, Biswanath Chariali, Udalguri, and Darrang. The area, production, and productivity data of winter rice were collected from the Directorate of Economics & Statistics, Assam (Government of Assam, 2014 [1]), for the period from 1988 to 2018 for the above-mentioned districts of NBPZ of Assam. The analytical work has been performed with the help of statistical software viz. Microsoft Excel and XL-STAT.

[1] Directorate of Economics and Statistics, Government of Assam (2014). Area, Average Yield and Production of Nine Principal Crops in Assam, Report Under 13^{th} Finance Commission Grant, November 4, 2014, Assam.

4.2 Analysis of Trends in Area, Production, and Productivity of Winter Rice

Mann-Kendall Test is a type of distribution-free non-parametric test. It can be used to assess if there is a monotonic upward or downward trend of the concerned variable of interest over time. A monotonic upward (downward) trend means that the variable consistently increases (decreases)through time, but the trend may or may not be linear. This test can also be used in place of parametric linear regression analysis to test whether the slope of the estimated linear regression line is different from zero or not. The Mann-Kendall test statistic is defined as

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

with

$$sgn(x) = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases}$$

The mean of S is $E[S] = 0$ and the variance σ^2 is

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

where p is the number of tied groups in the data set and t_j is the number of data points in the j^{th} tied group. The statistics S is approximately normal distributed provided that the following Z transformation is employed.

$$Z = \begin{cases} \frac{s-1}{\sigma} & \text{if } s > 0 \\ 0 & \text{if } s = 0 \\ \frac{s+1}{\sigma} & \text{if } s < 0 \end{cases} \tag{2}$$

The statistics S is closely related to Kendall's τ and it is given by

$$\tau = \frac{S}{D} \tag{3}$$

where

$$D = [\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=1}^{p} t_j(t_j-1)]^{\frac{1}{2}}[\frac{1}{2}n(n-1)]^{\frac{1}{2}}$$

4.3 Magnitude of Trend

Sen's slope is developed by Sen (1968) and it has been widely used to calculate the magnitude of trends in long-term temporal data (Tabari and Marofi, 2011). Sen's slope is considered better to detect the linear relationship as it is not affected by outliers in the data. It is denoted by Q. The positive Q_i values indicate an increasing trend, while the negative values tell that there is a negative trend in the temporal data. The unit of the Sen's slope Q_i is the slope magnitude per year. This test computes both the slope (i.e. the linear rate of change) and intercepts according to Sen's method. At first, a set of linear slopes is calculated as follows.

$$d_k = \frac{X_j - X_i}{j - i} \tag{4}$$

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

$$a_t = X_t - (b \times t) \tag{5}$$

and the corresponding intercept is as well the median of all intercepts. This function could also compute the upper and lower confidence limits for Sen's slope.

4.4 Homogeneity Test and Change Point Detection

A homogeneity test is performed to identify whether the series may be considered homogeneous over time, or if there is a time at which change occurs (Jaiswal et al., 2015). There are various tests to check the homogeneity of a series. The change point detection is an important aspect to assess the period from where significant change has occurred in a time series. This study considered two homogeneity tests, i.e., Pettitt's test and Buishand's test for checking the homogeneity of series and to detect the change point if it exists.

4.4.1 Pettitt's Test

Pettitt's test could identify the most significant change point. It can detect a significant change in the average of a time series data when the exact time of the change is unknown. The statistic used for Pettitt's test has been explained by Kang and Yusof (2012); Dhorde and Zarenistanak (2013) and many others and it is denoted by U_k and defined as

$$U_k = 2\sum_{i=0}^{n} m_i - k(n+1) \tag{6}$$

where, m_i is the rank of the i^{th} observation when the values $x_1, x_2, ...x_n$ in the series are arranged in ascending order and k takes values from $1, 2, ..., n$. The next step is to define the statistical change point test as

$$K = max|U_k|, \quad 1 \leq k \leq n \tag{7}$$

when U_k attains maximum value of k in a series, then a change point will occur in the series. The critical value is obtained by

$$U_k = [-ln \propto (n^3 + n^2)/6]^{\frac{1}{2}} \tag{8}$$

where n is the number of observations and $\propto$ is the level of significance that determines the critical value.

4.4.2 Buishand's Test

It is a non-parametric test developed by Buishand (1982). Let X denotes a normal random variate, then the following model with a single shift (change-point) can be proposed as

$$X_i = \begin{cases} \mu + \epsilon_i, & i = 1, ..., m \\ \mu + \Delta + \epsilon_i, & i = m + 1, ..., n \end{cases} \tag{9}$$

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

$$U = [n(n+1)]^{-1} \sum_{K=1}^{n-1} (\frac{S_K}{D_X})^2 \tag{10}$$

where, $D_X = \sqrt{n^{-1} \sum_{i=1}^{n}(X_i - \bar{X})}$ and the p-value is estimated with a Monte Carlo simulation using m replicates (Pohlert, 2016).

5 Results and Discussions

Based on the trend analysis result of the Mann-Kendall Test and Sen's Slope, it has been observed that NBPZ showed a significantly decreasing trend (*cf.* Figure 2, see Appendix) with a magnitude of -419.5 ha/year in terms of area (*cf.* Table 1). The Directorate of Economics and Statistics, Government of Assam also cited that cultivable land in Assam has considerably decreased in the last five years as per the report of Land Utilization Statistic (Provisional) during 2019-20. Many studies established several reasons that made the disappearance of cultivable land such as increasing population, urbanization, flood, etc. Another huge concern is river erosion. River erosion is havoc for the NBPZ, as every year this region must face a huge loss of area due to flood and river erosion. In NBPZ, the Brahmaputra and its tributaries rise and immediately thousands of cultivable lands get submerged in the river. Reports had shown that the Brahmaputra River throws up new islands every 10 to 15 years, those called the "charchapori"(riverine) area. However, for the production and productivity of winter rice in NBPZ, the trend is found to be significantly increasing with a magnitude of 1733 kg/ha and 29.90 kg/ha respectively (*cf.* Table 1) Overall, although the area is decreasing, we have seen pieces of evidence that the production and productivity (*cf.* Figure 3 & Figure 4, see Appendix) of winter rice have been increasing over the last thirty years. We can consider all the improvements over the past years in the agricultural sector viz. improved cropping pattern, use of Hybrid (HYV), expansion of high yielding variety area, the status of irrigation infrastructure, easy assessment of package and practices by farmers to make the production in an upward direction. Apart from that two non-parametric tests viz. Pettitt's test and Buishand's test have been performed to identify the homogeneity of the

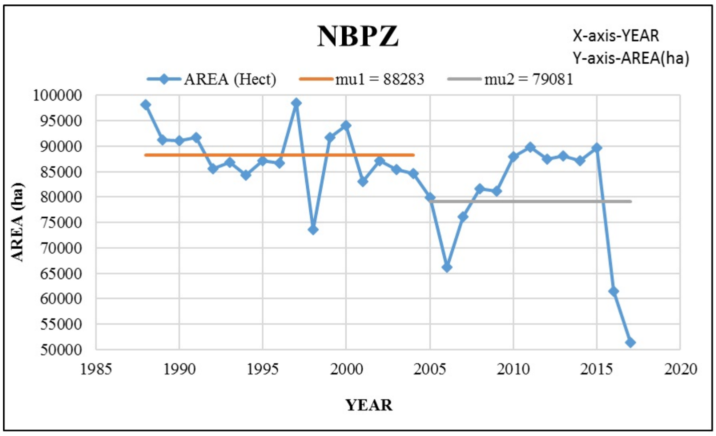

Figure 2: Trend and Change Point Identification for Area of Winter Rice in NBPZ

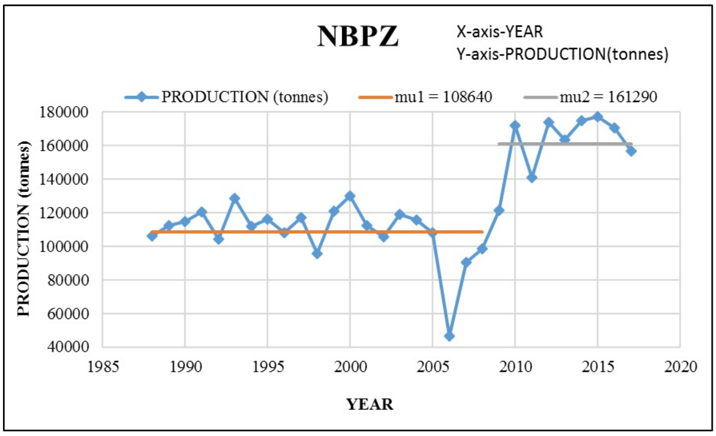

Figure 3: Trend and Change Point Identification for Production of Winter Rice in NBPZ

series and to detect the change point. The change point has been detected by examining the high and low values in the data set. The results of these change point tests could reveal the exact year in which a break or change occurs. This change point led to a trend line whether it may increase or decrease the trend. Moreover, for winter rice production, the years of change point identified by the two tests were not identical. There is a slight deviation in identifying change points by Pettitt's test and Buishand's test, which was also observed by Pal (2018). In such a case, fitting a trend line confirmed the usefulness of the correct test. If it shows the existence of a trend, then one can consider that the data are not homogeneous. So, there is a change point in the series or vice-versa. For example, in terms NBPZ area, Pettitt's test resulted in a change point in the year 2003 whereas Buishand's test resulted from the same in 2004. Moreover, Pettitt's test revealed that data are homogeneous, but Buishand test revealed that data are not homogeneous. So,

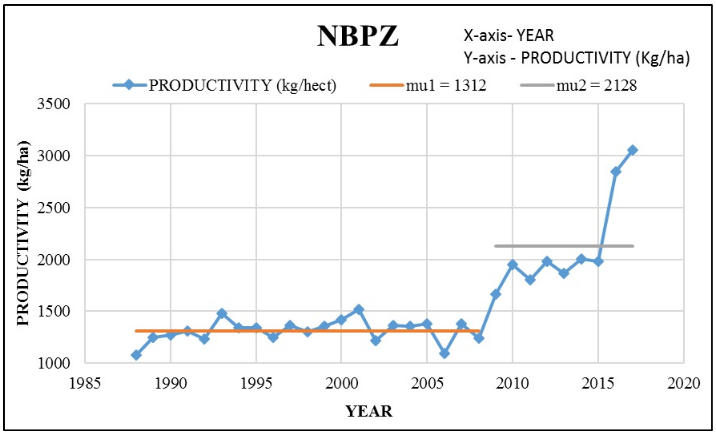

Figure 4: Trend and Change Point Identification for Productivity of Winter Rice in NBPZ

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

Variables	Mann-Kendall test		Sen's slop	Trend
	p-value	Change Year		
Area	0.032*	2004	-419.5	decreasing
Production	0.007*	2008	1733	increasing
Productivity	0.001*	2009	29.90	increasing

*significance level at $\alpha = 0.05$

computing the Mann-Kendall trend test confirmed that a significant trend was present in the series. Thus, Buishand's test result was accepted, and accordingly the change year for the NBPZ area is 2004 (cf. Table 1). Similarly, in the case of production and productivity, both the test revealed that data are no longer homogeneous and provided the changes that happened in the years 2008 and 2009 respectively.

6 Conclusion and Future Scope of the Study

As an outcome of the study, even though the area is decreasing, the study indicated that over the past thirty years in the NBPZ, winter rice production and productivity have increased. Winter rice production and productivity trends are greatly influenced by climatic and non-climatic elements, which also mark a change point in the trend. In addition, the atmosphere of this region is mostly humid due to the geographical and topological conditions of NBPZ. So, the crop needs an optimum temperature to complete its life cycle from panicle initiation to maturation. Therefore, to increase winter rice output, thorough research on the cultivation of cold-tolerant types of variety is highly required to enhance its productivity along with its best indigenous features. Because the indigenous or local varieties are least affected by changes in weather conditions. Recently, it has been observed that most farmers who are officially listed as beneficiaries of the government agricultural sector have switched over to cultivating improved or High-Yield Varieties (HYV) instead of indigenous winter rice varieties. Although the Government is providing HYV, focus should be placed on high-yielding viz. Ranjit and Bahadur, cold-tolerant viz. Joymoti and Kanaklata, nutrient-rich, glutinous varieties viz. Rangalee, Bhogalee and Bahadur in addition to water-stress-resistant varieties or late Sali viz. Monohar Sali, Solpona, Prasad bhog etc because the area is mostly humid and more susceptible to flooding.

Since the NBPZ is geographically suitable for agriculture, there is a need 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 viz. minimum support price index, suitable credit disbursement, different kinds of Bema Yojana, etc. The implementation of such real-valued schemes and policies can undoubtedly provide a ray of hope for a better future for the Agrarian society. In a similar manner, the responsible body should take appropriate action to counteract climate change impacts on agriculture in this region to achieve sustainable agricultural development and provide food security for the constantly growing population. To highlight regional distinctions and direct intense measures on the viewpoint of climate change, more of this type of region-specific study should be performed. One can use stepwise regression analysis by considering weather parameters like rainfall, humidity, maximum and minimum temperature, etc. to identify the factors responsible for increasing the trend of production and productivity.

Conflict of Interest

The authors declare that they have no conflict of interest.

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