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Variations of Rice Productivity in Different Districts of Bihar, India: A Statistical Analysis

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SUMMARY

Agriculture plays pivotal role in the economy and social well-being of people of Bihar. According to 2011 census nearly 88.70% population lives in villages where agriculture is the prime occupation. Bihar is enriched with fertile soil and plentiful water resources for favorable agriculture production. The detailed study on recent spatial and temporal trend of major crops across different districts of Bihar has not been analyzed since the formation of Jharkhand state. The current research is the first study investigating the recent trend of rice yield for 15 years data during 2004-05 to 2019-20. The temporal trend of crop production of major crop was analyzed across different agro-climatic zone over study period using. Man-Kendall ($\alpha \leq 0.05$) test and Sen.'s slope were employed for detecting trend, changes in magnitude of crop production. The result revealed that all 38 districts showed increasing productivity trend but only 7 districts showed statistically significant trend. The rice yield ranges fordifferent districts of Bihar varies from 1031 kg/ha to 3386 kg/ha.In average rice yield Rohtash shows highest productivity while Madhubani shows least rice productivity among different district of Bihar. The districts showing productivity level higher than 1400 kg/ha are mainly situated in the rich fertile plains of rivers Ganga, Kosi and Gandak.

Keywords: Crop production, Bihar, Rice, Productivity, Agriculture.

1. INTRODUCTION

With increasing human population the requirement of food-grain production in near future is likely to increase (Godfray *et al.* 2010 and Tilman *et al.* 2011). The share of agriculture in Gross Domestic Product (GDP) has shown decreasing trend from 39% in 1983 to 24% in 2000–01 and its share in total employment from 63% to 57% during the same period (Mall *et al.* 2006 and Kishore 2004). The cropping of Bihar is largely rainfed from ancient times and therefore it will be acutely affected in case of unforeseen variation in monsoon trend. The change in precipitation pattern and increase in temperature has been seen as a result of climate change. Hence, there is an inescapable requirement to improve crop production to match the increasing demand (Alexandratos 1999 and Cassman 1999). The non-improvement and stationary in crop production may have serious consequences for the crop production and subsistence for many farmers (Tilman *et al.* 2002). Bihar occupies one of the important agricultural production states in India. With around 90% of total population living in rural areas, agriculture is source of rural economy. Thus agriculture is the one of the important factor to the development of Bihar. Agriculture in Bihar is mainly dependent on monsoon. Since 57% of its gross cultivated area is irrigated, irrigation itself is largely dependent on the use of surface water. As claimed by United Nations Population Division (2015), India is anticipated to become the most populated country of the world leaving China around 2022, and its population is again predicted to grow to 1.74 billion by 2050. The increase in population size and accordingly, increase in demand of food consumption will result in increased amount of crop production and yield in India. As a result of green revolution during 1966, Bihar has witnessed continuous increase in crop production, but there is

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constant need to improve crop production to meet the food grain consumption.

With increasing population and unseen severity of the situation, researchers all over the world have come forward to undertake the crop production trend of major crops at different regional and local scale (Lin and Huybers 2012 and Ray *et al.* 2012). Above mention studies suggest that the productions of major crop arestagnating in different geographical area over the world. Brisson *et al.* (2010) reported that wheat yield is witnessing stagnant in France, while slowing growth of crop yield in Switzerland is reported by Finger (2010). Agriculture is highly exposed, as any change in climate variable impacts crop production, evaporation modeling and other management practices. Climate change impacts on agriculture are manifold average temperature, rainfall, and weather extremes.

Bihar has accomplished a remarkable increase in crop production after green revolution, but it is necessary to know the situation of present crop production trend and its spatial variation in Bihar. It is crucial to know how crop production presently changing across different districts of Bihar. Having a measurable point of view on crop production across district of Bihar will encourage local and district level authority to come out with proper package of practices and other alternative strategies for future food security. A comprehensive spatiotemporal variation of crop production trend has not been explored for major crop for districts of Bihar till now.

The present study is the first investigation that analyzes the recent crop production trend across different district of Bihar. The study undertaken set up foundation by finding out where in Bihar, rice, wheat and maize production are currently increasing and where production are presently deceasing. We analyzed the crop production trend across Bihar districts in three principal crops –rice, wheat and maize. After presenting the long-term average production district level dataset, we fitted three a linear regression model, a quadratic model. The best fit model is identified and thus crop production trend was investigated using the regression model.

In the light of above discussion, the present study is undertaken with collaborative approach, using amalgamation of statistical and GIS technique and econometric modeling, to estimate temporal trend of principal crops of Bihar, analyze spatiotemporal variation and to study the correlation between rainfall and agricultural production in different agro-climatic zone of Bihar.

Fig. 1. Index map of Bihar showing different Agro-climatic zone

Source: Department of Agriculture, Government of Bihar

2. STUDY AREA

Bihar is geographically located in the north-east part of the country. It falls under the Agro climatic Zone –IV which is known as "Middle Gangetic Plain Region". The climate of Bihar varies from humid tosub humid. Bihar account for about 9,360,000 hectares area which is further bifurcated into four sub agro-climatic zones (Fig. 1, Table 1). The main soil type found in Bihar is primarily loam and sandy loam. The whole farming operations are divided into two crop seasons i.e. kharif and rabi. The mean annual rainfall of Bihar state is about 1200 mm (Chowdary et al. 2008 and Ramagundam 2009) and the average number of rainy days in a year is 52.5 days. The summers are generally quite hot and winters are fairly cool. It is located between latitude 24°-20'-10" N ~ 27°-31'-15" N and longitude 83°-19'-50" E ~ 88°-17'-40" E (GOB 2014).

3. MATERIALS AND METHODS

3.1 Yield Trend Analysis

Historical data for average production of principal food grain- rice, for all- 38 districts of Bihar during for 15 years (2004-2005 to 2019-2020) were obtained from Department of agriculture, Government of Bihar (GOB). After collection, inspection, and verification of data, the annual temporal variation for 2004-2005 to 2019-2020 in rice production and productivity for Bihar (district) is calculated. The main aim of present study is to figure out districts in Bihar where trend of rice yield are currently increasing, where yield shows neither increasing nor decreasing trend. We computed the 15 years average yield of rice over Bihar districts employing exploratory data analysis. One new district—Arwal was came into existence on August 2001, which was earlier part of Jahanabad, district Bihar. The newly formed district have agricultural data only from 2007-2008. We have computed the ratio of average yield of 2007–2008 for Jahanabad and Arwal and extrapolated this ratio for earlier year to get yield of rice for Arwal district. The yield trend of rice for different district were obtained using Mann-Kendall (MK) and its magnitude were quantified using Sen's slope technique (Sen 1986). Rice is principal crop grown in Bihar and its yield has been investigated district wise. Relationship between yield and seasonal rainfall (monsoon, Annual) were calculated using Spearman's rank correlation (Lehman 2015; Corder and Foreman 2014). The null hypothesis in this test is that as ranks of one parameter increases, the ranks of other parameter are not more likely to increase. A negative correlation value indicates that one parameter increases as the other parameter decreases, while both parameter increases that it shows positive correlation value. A correlation value of zero suggests that there is no proclivity to increase or decrease as the value of one parameter increases or decreases. When both the parameters are perfectly matched, the Spearman correlation coefficient is equal to 1.

Table 1. Description of different agro-climatic zone of Bihar

Agro-climatic zone	Plain	Initiation/ Cessation of rainfall	Type of soil
Zone I	North west alluvial	12th June/30th September to 10th October	Heavy textured sandy loam to clay, medium acidic, flood prone, PH 6.5-8.4
Zone II	North west alluvial	7th June/30th September to 10th October	Light to medium textured slightly acidic, sandy loam to clay loam with saline/alkaline patches,PH 6.5-7.8
Zone III A	South alluvial	15th June/30th September to 10th October	Old alluvium sandy loam clay, slightly alkaline patches, PH 6.8-8.0
Zone III B	South alluvial	10th June/30th September to 10th October	Old alluvium sandy loam to clay, slightly alkaline patches, PH 6.8-8.0

3.2 Mann-Kendall (MK) test

The MK test (Mann, 1945; Kendall, 1975) computes statistics as Eq. (1)

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \boldsymbol{sgn}\left(x_j - x_k\right) \tag{1}$$

where S = normal distribution with the mean, n = number of observations (≥ 10) and x_j is the jth observation and sgn () is the sign function defined as sgn (α) = 1 if α >0; sgn (α)=0; if α=0 and sgn (α)=-1 if α<0.

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18} \tag{2}$$

where n=number of tied groups having similar value for a data group and t_i = number of data in the ith tied group. The actual MK statistics is given as Eqs. (3-4)

$$Z = \frac{S+1}{\sqrt{V(S)}}, if S < 0 \quad (3)$$

$$Z = 0, if S = 0 \quad (4)$$

$$Z = \frac{S+1}{\sqrt{V(S)}}, if S < 0 \quad (5)$$

Two hypotheses are made, i.e. H_o (null hypothesis) and H_1 (alternative hypothesis). H_o indicates no statistically significant trend, while H_1 indicates a statistically significant trend.

Sen.'s slope

It is one of the most useful tests for analysingcrop production data and is a non-parametric. Computation of magnitude of change in a dataset is done by Sen.'s slope (Theil, 1950; Sen, 1968). This is a simple linear regression method, which can estimate the slope of the median of two different variables (dependent and independent). This is based on the assumptions of normality of residuals. It can be estimated using following equation:

$$d_{ijk} = \frac{X_{ij} - x_{ik}}{j-k} \quad (6)$$

where X_{ij} and x_{ik} are data value, j and k are the time series

3.3 Compound growth rate (CGR)

Compound growth rate (C.G.R.) was calculated using the regression equation in the exponential form as:

$$Y_t = ab^t \quad (7)$$

Where,

Y_t = area/ production/ yield of major crops in tth period

t = time variable (1,2,3….,n)

a = constant,

$b = (1+r)$

r = compound growth rate

After log transformation:

$$\ln Y_t = \ln a + t \ln b$$

$$r = (antilog(\ln b) - 1) \times 100$$

4. RESULTS AND DISCUSSION

4.1 Exploratory data analysis of average rice yield and production over different district

Figure 2 depicts average rice production in million tons (M.T.) of Bihar illustrating all 38 districts. Figure 3 shows the average yield (kg/ha) of rice, cross different district of Bihar based on 15 years average crop production (2004-05 to 2019-20). Rohtash district shows highest rice production while Sheohar shows least rice production across different district of Bihar (Figure 2). In average rice yield Rohtash shows highest productivity while Madhubani shows least rice productivity among different district of Bihar (Figure 3).

4.2 Temporal variation of average rice yield and production over different agro-climatic zone

We have also showed the time series plot of rice production and yield in Figure 4 and Figure 5 across agro-climatic zones of Bihar. For different year across different agro-climatic zone, agro-climatic zone III B showed highest average crop production yield, while agro-climatic zone III A showed least average crop production yield among different agro-climatic zone. Almost same temporal variation was found for rice yield except 2004-2005, where agro-climatic zone II showed highest yield. Ago-climatic zone I showed minimum rice yield over study period.

4.3 Percentage share of Rice production for different district of Bihar

Percentage share for rice production of different district of Bihar has been plotted in Fig. 1 can be found from the figure that Rohtash has highest percentage of share, while Sheohar has least percentage of shares among different district of Bihar. The summary statistics of average rice production across different district of Bihar is given in Table 2. The mean of average rice production 161598.21 M.T. and standard deviation 117212.33. The minimum and maximum production was found to be 28370.97 M.T. and 635278.20 M.T. respectively.

4.4 Spatial variation of annual and monsoon rainfall over study area

The spatial variation of monsoon and annual rainfall (mm) for different district of Bihar is plotted in Figure 7. We have used the rainfall information of the India Meteorological Department (IMD) report by

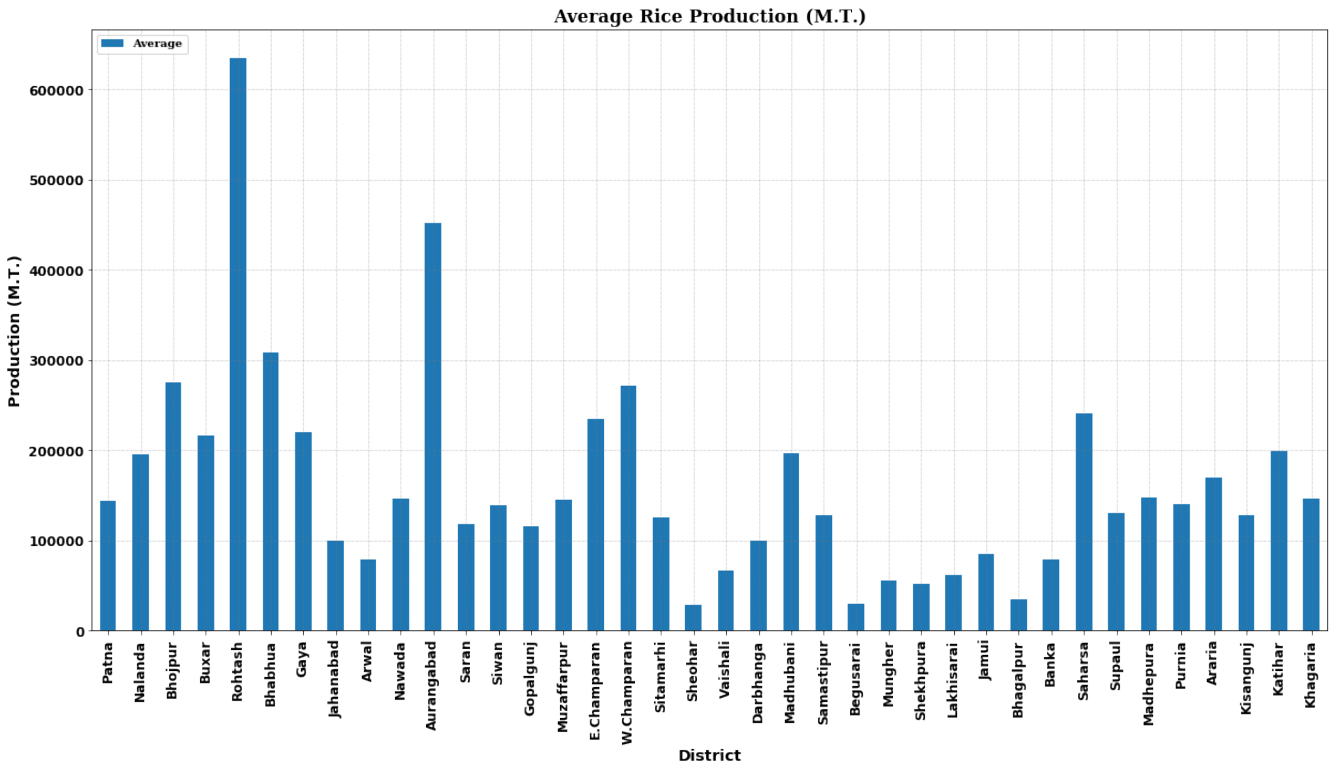

Fig. 2. Average rice production in different district of Bihar for the last 15 years

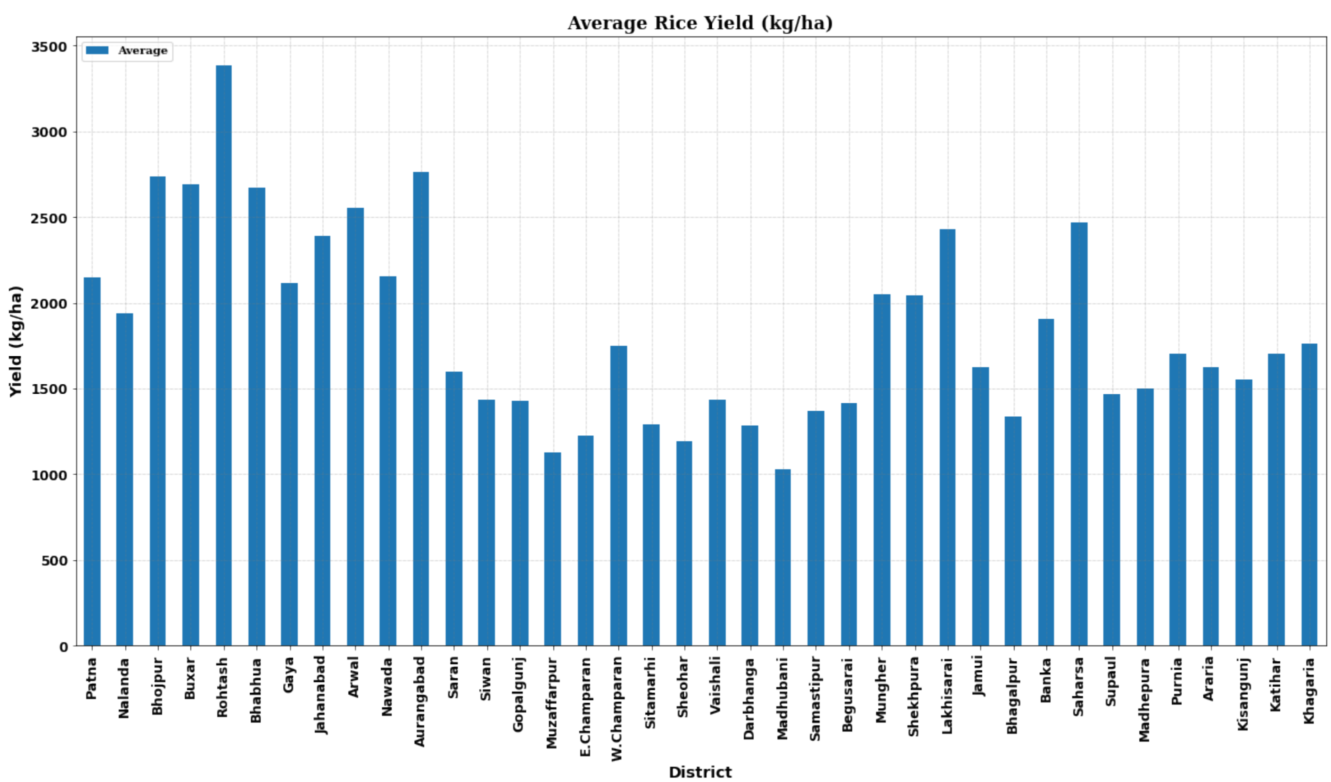

Fig. 3. Average rice yield in different district of Bihar for the last 15 years

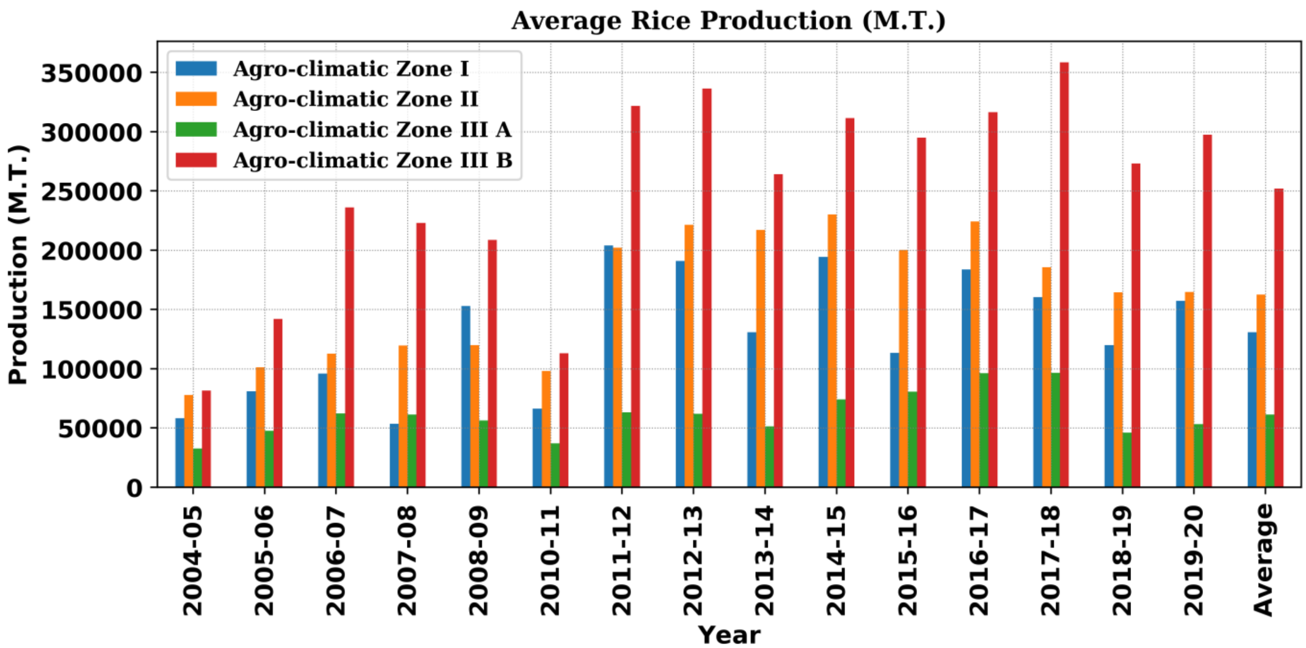

Fig. 4. Temporal variation of rice production for four agro-climatic zone of Bihar over study period

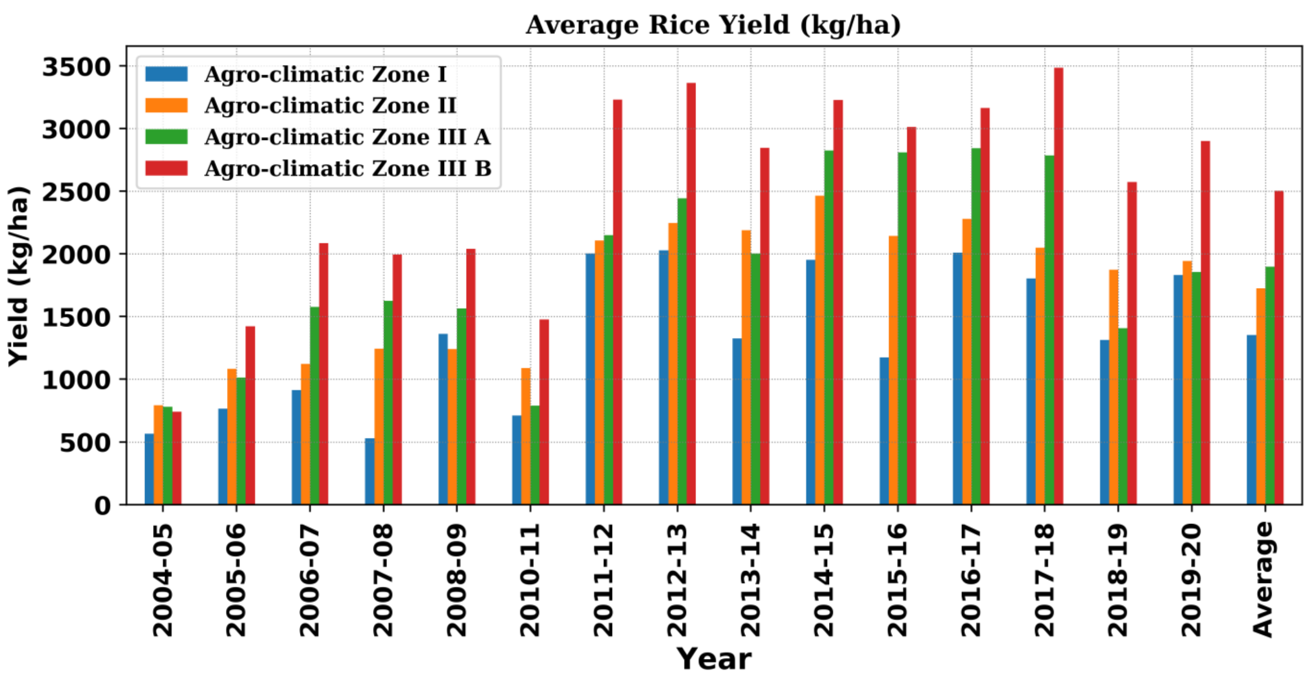

Fig. 5. Temporal variation of rice yield for four agro-climatic zone of Bihar over study period

Guhathakurta *et al.* 2020. This study utilizes 30 years rainfall data during the period 1989-2018 over different district of Bihar. It can be infer that state receives more the 85% of rainfall during monsoon. The mean and coefficient of variation (CV) annual rainfall and mean rainfall for monsoon month is given in Table 2. Temporal variation for monsoon comprises of June, July, August and September month and annual rainfall is shown in Figure 7. It has been observed that monsoon

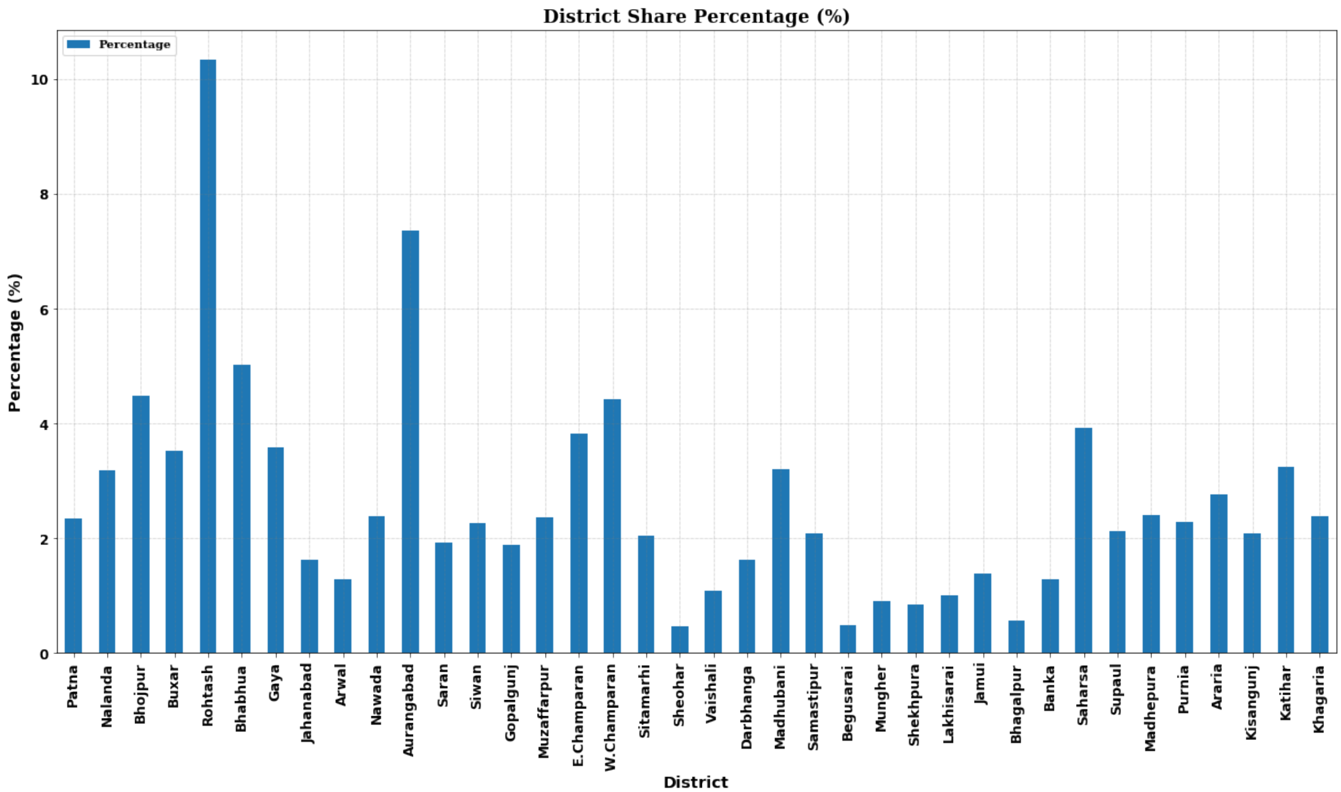

Fig. 6. Percentage share of rice production across different district of Bihar over the study area

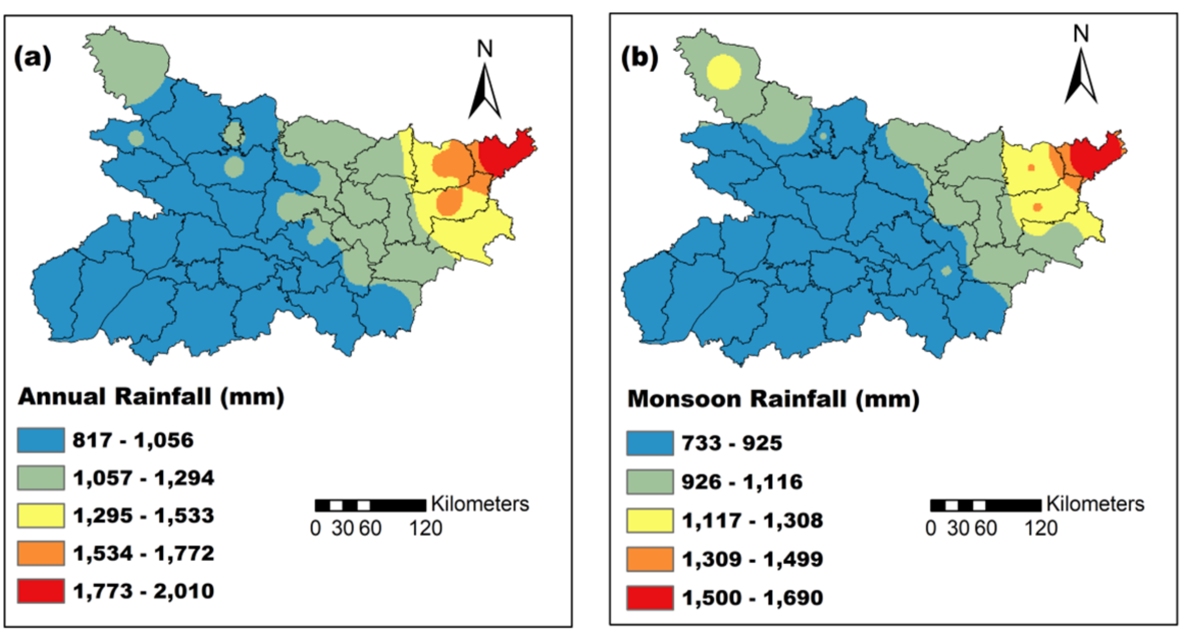

Fig. 7. Spatial variation of rainfall (a) Annual (b) during the period 1989-2018 over study area

shows significant decreasing trend while annual rainfall shows non-significant decreasing trend.

Table 2. Variation of Mean rainfall (mm) and coefficient of variation (CV) for Bihar

	June	July	August	September	JJAS	Annual
Mean	160.2	313.9	264.5	200.1	938.7	1098.9
CV	40.3	33.4	26.6	40.5	19.3	18.2

4.5 Rice yield trend over study area

The findings of Mann-Kendall statistics (Z) and Sen's slope for temporal variation of rice productivity is plotted spatially in Figure 8. It can be seen from Figure 8 (a) that all districts shows increasing trend, as depicted by the positive Z values. Sen's slope values as shown in Figure 8 (b) indicate the increase in rice yield (kg/Ha) per year for different district of Bihar. Its magnitude varies from 39.69 to 149.88 kg/Ha per year over the study area. However, all the districts do not exhibit statistically significant trend at 95% confidence interval, as shown by the p value greater than equal to 0.05 in Fig. 9.

4.6 Calculation of compound growth rate and instability

The compound growth rate (CGR) for rice yield is plotted in Figure 10. Samastipur showed highest growth rate followed by Nalanda among different district of Bihar. Banka showed least rice yield compound growth rate. Similar pattern was found in the coefficient of variation pattern of rice yield across different district of Bihar. The rice yield of Rohtash district was found to be more consistent as compared to different district of Bihar, while Samastipur showed more variability in rice yield.

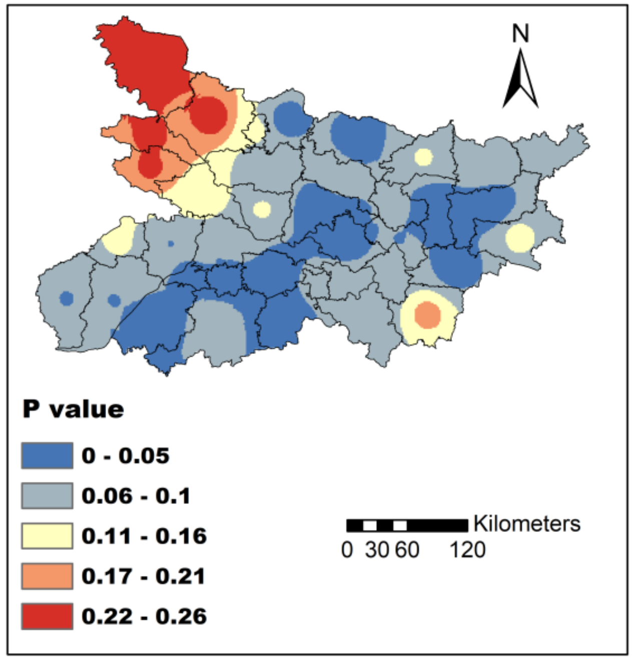

Fig. 9. Spatial variation of p value for Mann-Kendall test during study period

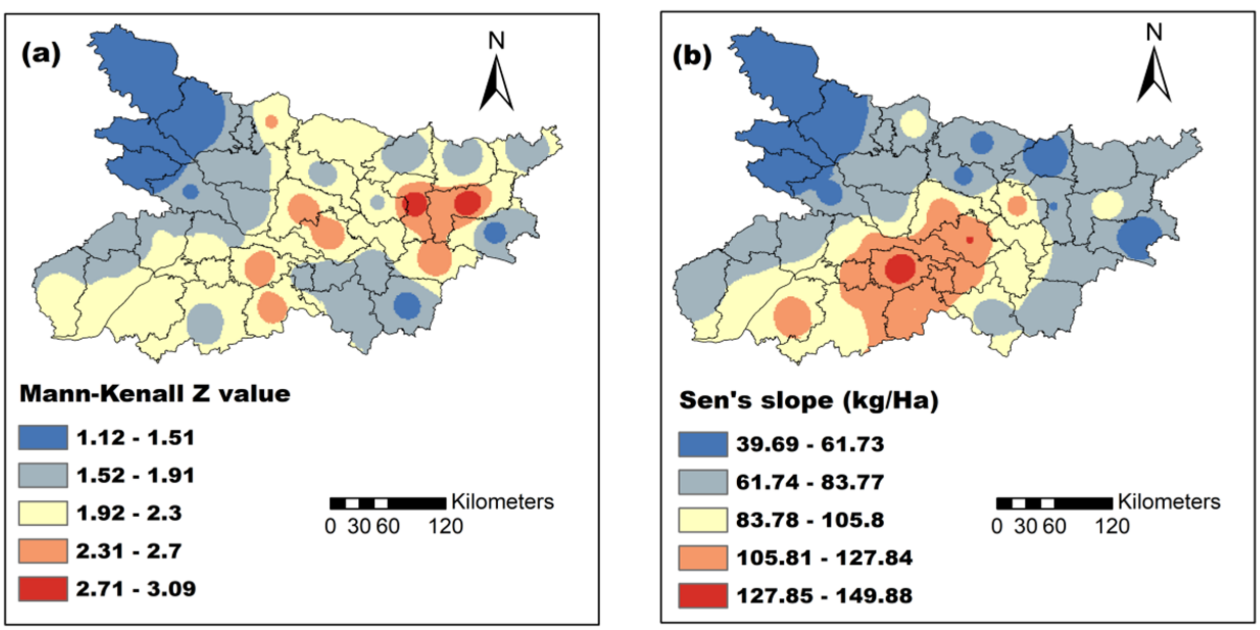

Fig. 8. Spatial variation of (a) Mann–Kendall Z value and (b) Sen's slope results for rice productivity during study period

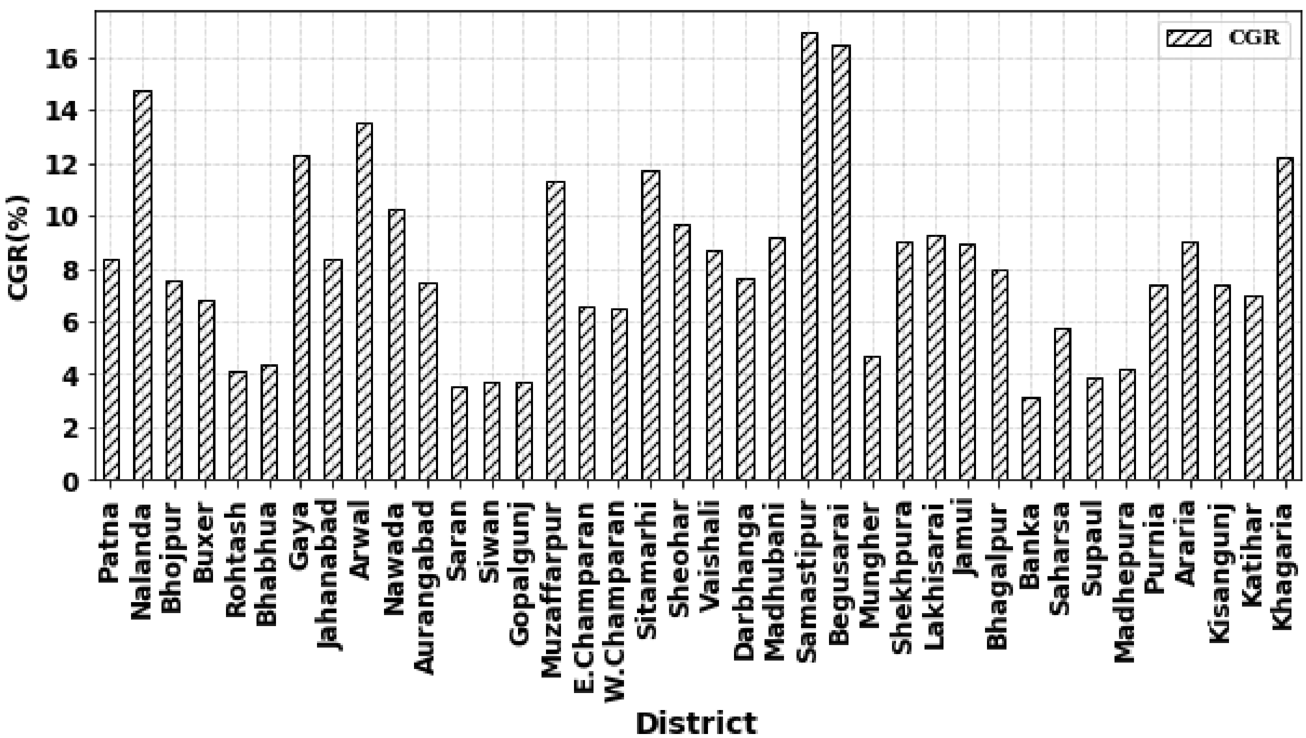

Fig. 10. Compound growth rate (CGR) variation of different districts of Bihar over study period

5. CONCLUSION

The study undertaken was first of its kind to explore temporal as well as spatial trend for different districts of Bihar since its reorganization for rice crop. This work found the crop yield trend of rice by analyzing 15 years crop production data emphasizing the districts where the crop yield is currently increasing or not. The result showed that there is improving trend for rice crop in all districts of Bihar. For different year across different agro-climatic zone, agro-climatic zone III B showed highest average crop production yield, while agro-climatic zone III A showed least average crop production yield among different agro-climatic zone. The result highlights a bigger argument regarding steady crop production of rice in majority of districts. It needs further interrogation comprehension of different parameters affecting crop production. Marking and noting the particular factors to particular district will encourage the best adoption strategies to meet future demand.

Conflicts of Interest: The authors declare no conflicts of interest.

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