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RESEARCH ARTICLE

Growth and Instability of Area, Production and Yield under Rice Cultivation in Uttar Pradesh since 1991: A Statistical Analysis

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ABSTRACT

This study aims to explore the growth and instability of area, production, and yield under rice cultivation in Uttar Pradesh since 1991. The study was based on secondary data collected from various public resources. The entire study period was divided into three subperiods, i.e., subperiod I (1990–91 to 1999–2000), subperiod II (2000–01 to 2010–11), and subperiod III (2010–11 to 2020–21). The technique was used in compound annual growth rate (CAGR) and the Cuddy della Valle instability index has been calculated for rice crops. The study reveals that there was a sharp decline in CAGR during subperiod II and Instability was high in subperiod II. The study suggested that the specific varieties to suit the soil and climatic conditions so as to derive better yields.

Key words: Canine distemper virus instability, climate condition, compound annual growth rate, rice, soil

INTRODUCTION

Steady growth is regarded as important for the growth of agriculture. From both a theoretical and an empirical point of view, there is much is written about crop yield, production growth, and instability. Apart from growth, it is important to look at how unstable crop output is in order to understand how food security and income stability work. Fluctuations in crop production not only lead to pronounced price volatility but also result in significant variations in the disposable income available to farmers. The size of the changes depends on how crops are grown, how sensitive they are to weather, the Economy, the availability of materials, and a lot of other things.[1] showed that the trend growth rate of the value of all cereals is going down all the time. In the 1980s, the growth rate of the value of India's cereal production was 2.76%. In the 1990s, it was 2.02%, and in the 2000s, it was 1.25%. In the case of rice, the value of output grew at a steady rate of 3.31% in the 1980s, 1.80% in the 1990s, and 1.13% in the 2000s. This shows that farmers' lives have been worsening in India as their crop value has decreased. It is important to keep farmers' incomes stable and to make sure there's enough food for everyone. Several studies on the growth and instability of agricultural production, in general, and food grain production. In particular, it has been found that all the states have made big gains in wheat production, area, and productivity since the end of the green revolution. Rice production, production area, and productivity went up, especially in states that grew rice after the green revolution.[2] analyzed that agri-growth was a big reason why instability was getting worse, but,[3] argument that rainfall, irrigation, and agro-physical situations were important reasons why food grain production was unstable after the green revolution. During the time after the green revolution, there were also changes in food grain production due to the use of new technology Seed-fertilizer.[4] Even though the technology is improving, input subsidies

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are increasing, and access to these services is getting better, farm prices and income vary from state to state. Changes in prices and income from year to year make it hard for farmers to decide whether or not to invest in agriculture. Even though it is clear that agricultural production needs to go up, the fact that it is becoming less stable has a number of bad effects. For example, it raises the risk of farming and makes farmers less likely to use high-paying technologies. It also affects price stability and makes low-income households more vulnerable. Food management and macroeconomic stability are also affected by how stable agriculture and food production. Several studies have tried to figure out what makes things unstable. Used data from 1996–97 to 2015–16 to figure out that under pulses is increasing poorly even after NFSM while improvements in yield are there in India. They split the 20 years into two parts: First and second decades. They saw that there was no positive link between growth and instability, and they found that the only important cause of instability was changes in the weather. Since there isn't much irrigation in India and most farming still depends on rain, changes in the weather were one of the main things that made agricultural production unstable. Even though the productivity and production of all crops went up in the areas of the green revolution, the instability of agricultural production did not go down.[1] Both production and production per hectare are affected by instability. Studies show that instability is a result of growth, which means that growth and instability are linked in a good way.

Even though instability in the agricultural sector has been studied a lot, this paper tries to answer the question of instability in UP rice production. More than 10% of the total value of India's agriculture comes from paddy rice. China makes the most rice in the world, and India comes in second. Rice is eaten by about 60% of the people in India, and farmers grow it in more than 16 states. The paper tries to figure out how the area, production, and yield of paddy change over time and how much area, production, and yield change from year to state. The paper also looks decadle compound annual growth rate (CAGR) growth rate and instability of rice in Uttar Pradesh. The study looked at the years 1990–91 to 2020–2021, which were split into three sub period. Subperiod I 1990–91 to 1999–2000, Subperiod II 2000–01 to 2009–10, and Subperiod III 2010–11 to 2020–21. The time period was chosen to determine what happened to rice production in Uttar Pradesh.

MATERIALS AND METHODS

This study was based on secondary data. In this time series, data pertaining to the period from 1990–91 to 2020–21 on the area, production, and productivity of rice crops have been used to study the growth trends. These time series data have been procured from the directorate of economics and statistics, Government of Uttar Pradesh. Agricultural statistics at a glance in various issues, Government of India. Handbook of statistics on Indian states, Reserve Bank of India. Indian Metrological Department. Indiastat. World Development Indicator. Ministry of Statistics and Programme Implementation, Government of India. Time series data have been classified into three sub-groups, i.e., Subperiod I (1990–91 to 1999–00), Subperiod II (2000–01 to 2009–10), and Subperiod III (2010–11 to 2020–21).

In this study, various analytical tools have been used. Data analysis has been categorized into two ways: (1) To understand the dynamics of area under cultivation, production and productivity, growth, and trends has been analyzed. Therefore, CAGR has explored, the formula given in equation 2. Further Instability in area, production, and productivity is measured for these crops. Cuddy Della Valle has been used to measure the instability. This is the robust measure to examine the instability. The formula for measuring the instability is presented in equation 3. Cuddy Della Valle has been used in the number of previous studies.[5-7]

CAGR

$$\text{CAGR} = (\text{Antilog } \beta 1^{*} - 1) \times 100$$

Cuddy Della Valle Instability Index

The coefficient of variations (CV) was calculated to provide an accurate picture of how unpredictable the Area, Yield, and production of food grains are in Uttar Pradesh.

$$I = CV\sqrt{(1 - R)^2}$$

Where,
CV is the coefficient of variation in percent,
I=Instability,
R^2 is the coefficient of determination

RESULTS AND DISCUSSION

It is reported from Figure 1 that there has been a significant growth rate of rice production and productivity, while the area was almost stable in all phases of the reform period. Although in a few years, there were fluctuations in the area under cultivation of rice, i.e., 2002–03 and 2004–05. In phase I, there has been a significant growth rate of rice production, especially during the years 1993–94 and 1999–2000, when it went up by 16.19% in 1999–2000 from 5.15% in 1993–94. While the growth rate was reported negative at −8.27, −0.02 and −6.47% in the years 1991–92, 1995–96 and 1998–99 respectively. During these years, input subsidies (on fertilizer, power, and irrigation as well as credit) provided to farmers was not sufficient as production was adversely affected.

In phase II, the higher growth of rice production was found during the years 2003-04 (35.68%) and 2008–09 (11.17 %). While the growth rate was reported negative during the years 2000–01, 2002–03, 2004–05, and 2009–10, which was −11.72, −25.36, −26.60, and −17.48%, respectively. The decline of rice production in phase II is correlated with the decrease in the amount of rainfall because the rice required more rainfall for its production.[8] reported that from 2001–02 till 2009–10, erratic rainfall distribution caused excess water stagnation or drought or both in different years except in the years 2002–03, 2004–05, and 2009–10.

In Phase III, considerable growth of the rice production was recorded in the years 2011–12 and 2018–19, which was 11.22% and 18.44%, respectively. While the growth was negative in the years 2013–14, 2014–15, and 2017–18, which was −0.52, −15.32 and −0.52%, respectively. In addition, food subsidies were not provided by the state. Here, we shall be dealing only with subsidies on fertilizer, power, and irrigation. The share of input subsidies (on fertilizers, power, and irrigation) was sharply declined from 1992–93, 1995–96, and 1998–99 at −8.27, −0.02, and −6.47%, respectively.

Table 1 and Figure 2 present the CAGR of the area dedicated to rice cultivation. The data demonstrates a significant decline, with the rate decreasing from 0.94% in subperiod I to −0.44% in subperiod II and again declining to −0.20% in subperiod III. This reduction in rice cultivation area was due to various factors, including urbanization, changes in land use, and shifting preferences toward other crops. Several studies support this finding, including those by Jing *et al.*, Asai *et al.*, Qaswar *et al.* Zhang *et al.*[9-12]

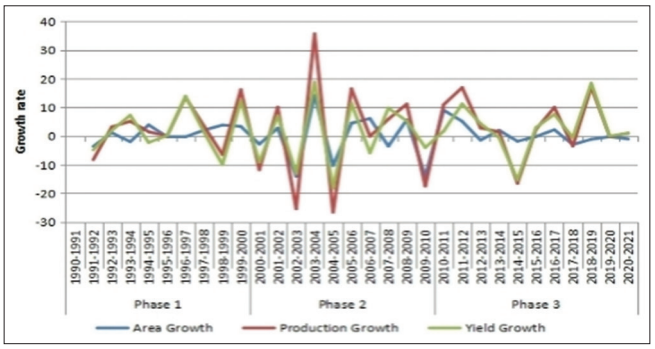

Figure 1: Phase wise growth of area, yield and production under rice cultivation
Sources: Author's calculation.

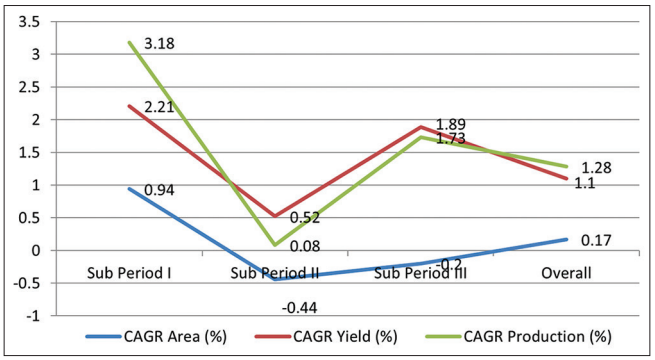

Figure 2: Decadal compound annual growth rate of area, yield, and production under rice cultivation
Area, Production, and Yield, in CAGR in percentage
Source: Author's calculation.

Table 1: Decadal CAGR of area, yield, and production under rice cultivation

Periods	CAGR area (%)	CAGR yield (%)	CAGR production (%)
Sub Period I	0.94	2.21	3.18
Sub Period II	−0.44	0.52	0.08
Sub Period III	−0.20	1.89	1.73
Overall	0.17	1.10	1.28

Area, Yield and production in percent
Source: Author's calculation
CAGR: Compound annual growth rate

In terms of rice productivity, the CAGR was estimated at 2.21% in the first subperiod. However, it decreased to 0.52% during the second sub-period and then increased again in the third sub-period, with a CAGR of 1.89% for rice yield. The decline in rice productivity during the second subperiod can be attributed to factors such as poor farming practices, and attacks by unfavorable weather conditions.[13] Pests and diseases by Bouman *et al.*[14], and environmental challenges as.[15] On the other hand, in the third subperiod, the CAGR of rice productivity increased because farmers adopted improved agricultural practices. This encompasses the adoption of high-yield cultivars, proficient irrigation systems, and successful strategies for pest and disease management. Studies by Koirala *et al.*, Ram *et al.*, Chandio *et al.*[16-18] highlight the positive impact of these practices on crop performance and the overall increase in rice productivity.

In the first subperiod, the CAGR of rice production was 3.18%. However, it sharply declined in the second sub-period, to 0.08%. This decline in sub-period II was attributed to both a decrease in cultivation area and productivity. Several studies, such as those by Bouman *et al.*, and Swain[13,19] have highlighted the factors leading to a reduction in rice production. Climate change is another significant factor posing risks to rice production. Altered temperature and rainfall patterns associated with climate change can result in reduced yields in certain regions. Studies by Peng *et al.*, Lobell *et al.*[20,21] have emphasized the impact of climate change on rice production. However, a notable increase in CAGR was observed during the third sub-period, reaching 1.73%. This increase in CAGR of rice production during sub-period III was driven basically by the increased in yield. Research conducted by Yu *et al.*, Cheng *et al.*,[22,23] has demonstrated that improved agricultural practices, including the adoption of high-yielding varieties, efficient irrigation systems, and better pest and disease management, contribute to an increase in rice productivity and thereby production. Figure 3a illustrates the rice yield during the same period. It shows a consistent increase in rice productivity, albeit with some fluctuations throughout the period. The decline in productivity from 2000–2001 to 2009–2010 was due to unfavorable weather conditions or other factors that negatively affected rice cultivation during that

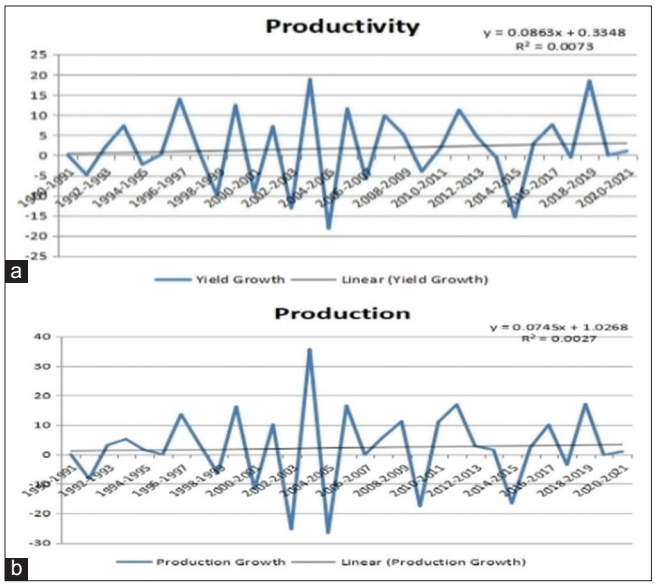

Figure 3: (a and b) Trends analysis of rice in productivity and production

period. Figure 3b presents the trend in rice production from 1990–1991 to 2020–2021. It demonstrates an overall upward trend in rice production despite continuous fluctuations along the way. Notable fluctuations occurred in the years 2002–2003, 2004–2005, 2009–2010, and 2014–2015.

Based on the data presented in Table 2 and Figure 4, the CDV (Cuddy Della Valley) Instability Index for the area under rice cultivation exhibited significant variations across different sub-periods. During subperiod I, the index was 2.65%, which sharply increased to 6.19% in subperiod II. However, the index decreased significantly to 1.96% in sub-period III. These findings indicate fluctuations in the stability of rice cultivation in the region during the study period. The increase in the rice cultivation area during subperiod II can be attributed to the uneven spread of the monsoon, leading to deficient rainfall in the main rice-growing region. Such irregular rainfall patterns can impact rice productivity and contribute to increased instability in production. In addition, changes in land use patterns, such as the shifting of rice cultivation to new areas or converting rice fields to other crops, can also influence rice production and contribute to instability. These factors have been highlighted in previous studies conducted by Pathak and Ladha, Priya *et al.*[24,25]

Regarding rice productivity, the CDV Instability Index was initially estimated at 4.99% during sub-period I but showed a significant increase to 7.08% in sub-period II, and further rose to 8.39% in

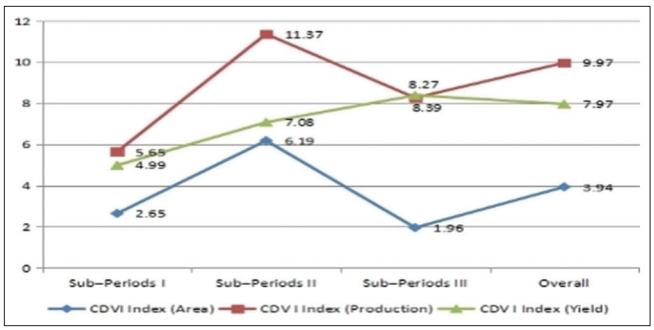

Figure 4: Cuddy della valle index of area, yield, and production under rice cultivation
Area, yield, and production in percentage
Source: Author's calculation

Table 2: CDVI index of area, yield, and production under rice cultivation

Periods	CDV I index (area)	CDV I index (yield)	CDV I index (production)
Sub-period I	2.65	4.99	5.65
Sub-period II	6.19	7.08	11.37
Sub-period III	1.96	8.39	8.27
Overall	3.94	7.97	9.97

Area, yield, and production in percentage.
Source: Author's calculation.
CDVI: Cuddy della valle index

subperiod III. These figures suggest a moderate level of instability in rice productivity during the study period. Erratic rainfall patterns leading to excessive water stagnation and drought in different years may be responsible for this instability, as mentioned in studies by Dwivedi, Jain, Kumar and Singh.[8,26-28] Furthermore, the CDV Instability Index for rice production demonstrated a notable increase from 5.65% in subperiod I to 11.37% in sub-period II, with a slight decrease in sub-period III to 8.27%. This indicates moderate instability in rice production in the region. The increase in the CDVI index during subperiod II may be attributed to both the expansion of the cultivation area and the increase in yield. Conversely, the decrease in sub-period III could be due to changes in cultivation practices, weather conditions, or other factors affecting rice production.

CONCLUSION

The study was based on secondary data collected from various public resources, i.e.[29,30] This study incorporates the conclusion of the entire work, providing an assessment of the findings and outcomes of research conducted on the growth and instability in agricultural production in Uttar Pradesh during the post-reform periods. It presents the results and outcomes of the study, and has been divided into two sections. The first section focuses on the growth performances in terms of area productivity and production, and examines examining how these factors have evolved over time. The second section delves into the instability experienced in terms of area productivity and production, exploring the fluctuations and variations observed.

Growth Performance in Rice

- The area dedicated to rice cultivation was analyzed across different periods. Overall, there was a CAGR of 0.17%. In sub-period I, the CAGR reached its highest point at 0.94%, but it decreased to −0.44% in sub-period II. However, in sub-period III, the CAGR increased again to 0.30%.
- During the post-reform period, the productivity of rice exhibited an overall positive CAGR of 2.21%. The maximum CAGR was observed in subperiod I, reaching 2.21%, but it declined to 0.52% in sub-period II. However, it reached 1.89% in sub-period III.
- The analysis of rice production during the post-reform period clearly indicates that sub-period II had the lowest CAGR. This decline in CAGR can be attributed to both the decrease in cultivated area and productivity during that particular sub-period.

Instability in Rice Cultivation

- The instability index of rice cultivation exhibited significant changes across different sub-periods. In subperiod I, the instability index stood at 2.65%. However, there was a sharp decrease in subperiod III, when it dropped to 1.96%. This indicates that the area under rice cultivation remained relatively stable during that time. On the other hand, there was a notable increase in instability, with the index reaching 6.19% in subperiod II.
- The instability index of rice productivity underwent noteworthy changes across different subperiods. During subperiod I, the instability index was

estimated at 4.99%, which then significantly increased to 7.08% in subperiod II. Furthermore, the instability index of rice yield further rose to 8.39% in subperiod III. These observations suggest that rice productivity in the region exhibits a moderate level of instability over time.

- The CDV Instability Index of Rice production experienced significant fluctuations across different subperiods. In sub-period I, the instability index was recorded at 5.65%; however, it sharply increased to 11.37% in sub-period II. However, there was a slight decrease in sub-period III, where the index was observed at 8.27%. Despite these variations, the overall pattern suggests that rice production remained moderately unstable during this period.

Policy Implications

Based on the above findings, the following suggestions are recommended for formulating suitable policies:

- Encouraging diversification means countering the shrinking areas of certain crops. Policies should promote diversification by encouraging farmers to cultivate a variety of crops. This can help to reduce over-reliance on specific crops and enhance overall agricultural resilience.
- Implementing price stabilization mechanisms entails introducing measures to shield farmers from sudden price fluctuations and provide them with a more stable income.
- Focusing on sustainable agriculture involves encouraging practices such as organic farming and water conservation, which contribute to long-term environmental and economic stability. Capacity building and training are essential in providing farmers with training and capacity-building programs on modern farming techniques, empowering them to adopt best practices and enhance productivity.

These recommendations aim to address the challenges highlighted in the study and foster a more stable and sustainable agricultural sector in Uttar Pradesh. Proper policy formulations based on these suggestions can contribute to the overall growth and development of the agriculture sector in the region.

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