ABSTRACT

The study analyzed the growth, decomposition and instability of rice with regard to parameters such as area, production and yield between 1970-'71 and 2019-'20 through the utilization of time series data. The findings indicated a notable expansion in the cultivation area of rice over the decades, except during the periods of 1980-'90 and 2010-'20. There was a declining trend in the area during the 2000-'10 decade. Production displayed a substantial increase throughout all decades and the overall study period. Yield demonstrated a minimal increase in the initial decade, followed by a substantial increase in all subsequent decades. The decomposition analysis revealed that the influence of the cultivation area on rice production was more prominent compared to the impact of yield during the studied time intervals. Yield’s influence was more pronounced during the 1970-'80 and 1990-'00 decades than in all other decades, while the interaction effect was relatively less significant. The stability of rice production was found to be the most precarious factor, followed by yield, with area exhibiting the least amount of instability. Policymakers need to prioritize research to boost rice yield, ensuring sustained production growth and implementing diversified cultivation strategies and resilient practices to counteract production instability.

Key words: Decomposition, Growth, Instability, Production, Rice

INTRODUCTION

Agriculture remains the dominant driving force of the Indian economy and constitutes the fundamental pillar of the nation’s socio-economic advancement. It contributes to approximately 19% of the GDP and supports a majority of the population, encompassing about two-thirds of its inhabitants. India holds the world’s second-highest position in rice production after China (GoI, 2022). Rice serves as a staple sustenance for over 3.5 billion individuals globally, especially across Asia, Latin America, and certain parts of Africa (National Geographic Society, 2023). Encompassing an area exceeding 160 million hectares, rice cultivation thrives across diverse climatic conditions. Rice stands as a staple food for its 800 million citizens in India, contributing nearly 40% to the overall food grain yield. The country dedicates 43 million hectares to rice cultivation, resulting in the production of 112 million tons of milled rice, with an average yield of 2.6 tons per hectare (Pathak et al., 2020). Rice cultivation is distributed across nearly every state in India.

In the fiscal year 2018-19, the primary rice-producing states contributed to the nation’s...
total rice output as follows: West Bengal was the major state with 13.79%, followed by Uttar Pradesh with 13.34%, Andhra Pradesh with 12.84% and Punjab (11.01 %) (Singh et al., 2021). Rice contribution accounts for approximately 10 percent of the agricultural Gross Domestic Product (GDP), and its cultivation leads to the generation of 3.5 billion days of employment in India (Ahmad et al., 2017, Kumar et al., 2018). Over time, India has witnessed a notable rise in its rice production. Nevertheless, the nation has recently encountered notable challenges linked to environmental deterioration and shifts in climate patterns. Projections indicated a potential decline in cereal yield ranging between 10% and 40% by the year 2100. Current evidence already indicates adverse effects on wheat and paddy yields in certain Indian regions, attributable to rising temperatures, escalating water stress, and a decrease in the frequency of rainy days (Mahato, 2014). Economic instability refers to the deviation from a consistent and predictable progression over time. This concept quantifies the potential risk and uncertainty arising from fluctuations in factors such as production, trade, income, and prices. The measurement of instability, particularly concerning agricultural production is pertinent to matters related to food security and the impacts of output fluctuations on agricultural prices and producers’ returns (FAO, 1998). The study has undertaken an analysis to explore the growth, breakdown, and volatility of rice in terms of area, production, and yield across different decades.

MATERIALS AND METHODS

The research aimed to evaluate the performance of rice in India across five distinct sub-periods: Period I (1970-'71 to 1979-'80), Period II (1980-'81 to 1989-'90), Period III (1990-'91 to 1999-2000), Period IV (2000-'01 to 2009-'10), Period V (2010-'11 to 2019-'20) and the Overall Period (1970-'71 to 1999-'20). Data sourced from the Department of Economics and Statistics (DES), Government of India analysed to assess the Compound Annual Growth Rates (CAGR) and to estimate the impact of area, yield, and their interaction on total rice production. This was achieved through the utilization of log-linear growth models and a decomposition approach. Additionally, Cuddy Della Valle Index (CDVI) and the coefficient of variation (CV) were calculated to gauge the variability in area, production and yield. The collected secondary data underwent statistical analysis employing the subsequent analytical tools and techniques.

**Compound Annual Growth Rates (CAGR) analysis**

In order to obtain an estimate of the compound annual growth rate (CAGR), the exponential time trend equation, which takes the following form was utilized:

\[ Y = a b^t \]  

When expressed in logarithmic form, the equation becomes linear.

\[ \ln (Y) = \ln a + t \ln (b) \]  

\[ Y: \text{The variable whose rate of increase was being calculated} \]
\[ t: \text{Chronological time (1, 2...n)} \]
\[ a \text{ and } b \text{ were estimated using regression.} \]

This formulation presupposed a sustained, unchanging growth rate as time progressed. When ‘b’ was a negative value, it implied a continuous deceleration. If ‘b’ equaled zero, it signified the absence of any discernible trend, whereas, a positive ‘b’ value suggested a persistent acceleration in growth. In the context of estimating the Compound Annual Growth Rate (CAGR) using the
exponential time trend equation, Dandekar (1980) pointed out that employing the parameter 'B' which was equivalent to the natural logarithm of 'B' as the annual growth rate was an incorrect approach. Instead, the formula for finding growth rate \( (e^B - 1) \) was derived using the compounding formula. Thus, the CAGR (percent) was given by \( (e^B - 1) \times 100 \), using the compounding formula.

\[
Y_t = Y_0 (1+r)^t
\]

or
\[
\ln (Y_t) = \ln (Y_0) + t \ln (1+r)
\]

or
\[
\ln (Y_t) = A + tb
\]

where
\[
A = \ln (Y_0) \quad \text{and} \quad B = \ln (1+r)
\]

This equation is the log linear form of the exponential function and gives CAGR when differentiated with respect to t as follows:

\[
\frac{1}{Y_t} \frac{dY_t}{dt} = \ln(1+r)
\]

\[
e^B = 1 + r
\]

\[
r = e^B - 1
\]

Thus, the CAGR (percent) was given by \( (e^B - 1) \times 100 \). Y represents the area or production or yield of the crop.

**Decomposition analysis**

The initial structured method of breaking down the growth trend was introduced by Minhas and Vaidyanathan (1965). Several scholars (Rehman and Salam, 2011; Sharma et al., 2017; Devegowda et al., 2019) have adapted and modified this model, presenting it in the following format:

\[
P_0 = A_0 \times Y_0
\]

\[
P_n = Y_0 \times Y_n
\]

\[
P = P_n - P_0 \quad \text{(Production change)}
\]

\[
A_n = \text{Area (Current year)}
\]

\[
Y_o = \text{Yield (Base year)}
\]

\[
Y_n = \text{Yield (Current year)}
\]

"A"=Change in Area \( (A_n-A_o) \)

"Y"=Change in Yield \( (Y_n-Y_o) \)

Finally,

\[
P = P_n-P_0 = A_0 \times \Delta Y + Y_0 \times \Delta A + \Delta A \times \Delta Y
\]

When a more significant alteration in production primarily results from the yield effect, it indicates that technological advancements, particularly in yield, have played a crucial role in driving the changes in production. This research assessed the impacts of cultivation area, yield and their combined interaction on the variations in crop production over five distinct time periods. To minimize or remove potential biases by employing triennium averages of area, production and yield for both the reference and current years of the respective crops. We subjected the data related to production aspects of the chosen crops to statistical analysis using the following analytical tools and methods.

**Cuddy Della Valle Index**

Extent and type of instability within the area, production, and yield of the rice crop across India, was calculated using coefficient of variation (CV). However, the basic CV does not adequately capture the underlying trend present within the time series data. To address this issue, a measure of instability was determined using the Cuddy Della Valle Index (CDVI) was originally developed by Cuddy and Valle (1978), which rectifies the shortcomings of the coefficient of variation. This index is represented by the following equation:
Coefficient of Variation (CV) = SD / Mean *100

where, SD = Standard deviation of area/ production/ yield

CDVI = CV* “1 - \( \hat{R}^2 \)

where,

\( \hat{R}^2 \) is the adjusted \( R^2 \) from a time trend regression.

RESULTS AND DISCUSSION

Compound annual growth rate (CAGR) in the area, production and yield in rice

During period I, the yield exhibited a positive yet non-significant growth rate, whereas both area and production experienced positive and significant growth rates at the one percent and 10 percent levels, as shown in Table 1. The growth rate of the area was positive but non-significant in periods II and V. During period IV, it was negative and statistically non-significant but, in the period III, and the entire observation period, the growth rates of area, production and yield were positive and statistically significant at the one percent level. However, during periods II, IV and V, the growth rates of production and yield were positive and statistically significant at the one percent and 10 percent levels.

The growth rate of the cultivated area was at its lowest during period IV (-0.02 percent). Conversely, period I recorded the highest growth rate in area (0.89 percent), outperforming period III (0.68 percent), period II (0.41 percent), the entire time span (0.32 percent).

Table 1. Compound annual growth rates in the area, production and yield of rice in India

<table>
<thead>
<tr>
<th>S.No</th>
<th>Time Period</th>
<th>Area (%)</th>
<th>Production (%)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Period I (1970 - '80)</td>
<td>0.89 ***</td>
<td>1.90 *</td>
<td>1.00 NS</td>
</tr>
<tr>
<td>2</td>
<td>Period II (1980 - '90)</td>
<td>0.41 NS</td>
<td>3.62 ***</td>
<td>3.20 ***</td>
</tr>
<tr>
<td>3</td>
<td>Period III (1990 - '00)</td>
<td>0.68 ***</td>
<td>2.00 ***</td>
<td>1.32 ***</td>
</tr>
<tr>
<td>4</td>
<td>Period IV (2000 - '10)</td>
<td>-0.02 NS</td>
<td>1.59 *</td>
<td>1.61 ***</td>
</tr>
<tr>
<td>5</td>
<td>Period V (2010 - '20)</td>
<td>0.17 NS</td>
<td>1.87 ***</td>
<td>1.69 ***</td>
</tr>
<tr>
<td>6</td>
<td>Overall Period (1970 - '20)</td>
<td>0.32 ***</td>
<td>2.20 ***</td>
<td>1.88 ***</td>
</tr>
</tbody>
</table>

*** Statistically significant at 1% percent level; ** Statistically significant at 5% level
* Statistically significant at 10% level; NS - Statistically non-significant

Table 2. Average in the area, production and yield of rice in India

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Time Period</th>
<th>Average Area (Lakh ha)</th>
<th>Average Production (Lakh tonnes)</th>
<th>Average Yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Period I (1970 - '80)</td>
<td>386.48</td>
<td>447.60</td>
<td>1158.15</td>
</tr>
<tr>
<td>2</td>
<td>Period II (1980 - '90)</td>
<td>406.58</td>
<td>597.73</td>
<td>1470.16</td>
</tr>
<tr>
<td>3</td>
<td>Period III (1990 - '00)</td>
<td>432.15</td>
<td>799.96</td>
<td>1851.15</td>
</tr>
<tr>
<td>4</td>
<td>Period IV (2000 - '10)</td>
<td>434.13</td>
<td>891.91</td>
<td>2054.46</td>
</tr>
<tr>
<td>5</td>
<td>Period V (2010 - '20)</td>
<td>436.95</td>
<td>1080.86</td>
<td>2473.63</td>
</tr>
<tr>
<td>6</td>
<td>Overall Period (1970 - '20)</td>
<td>419.26</td>
<td>763.61</td>
<td>1821.35</td>
</tr>
</tbody>
</table>
percent) and period V (0.17 percent). As for the production growth rate, period II exhibited the highest increase (3.62 percent), followed by the overall period (2.20 percent), period III (2.00 percent), period I (1.90 percent), period V (1.87 percent) and period IV (1.59 percent) respectively.

The growth rate of yield was found to be highest in period II (3.20 percent), followed by overall period (1.88 percent), period V (1.69 percent), period IV (1.61 percent), period - III (1.32 percent) and period I (1.00 percent). The decline in area in period - IV, could be attributed to drought, dry spells, unremunerative prices, low farm level technical efficiency, lower profitability. Results obtained are in conformity with the findings of Kumar (2019) and Pathak et al. (2020).

Table 2 showed gradual increase in average area, production and yield of rice over the decades. Overall period noticed average increase in 419.26 lakh ha, with the average production 763.61 lakh tonnes and average yield 1821.35 kg ha\(^{-1}\) indicated in Figure 1. The highest average area (436.95 lakh ha), production (1080.86 lakh tonnes) and yield (2473.63 kg ha\(^{-1}\)) was recorded in Period V compared to other periods.

**Decomposition annual of area, production and yield of rice in India**

Table 3 indicated the instability in area, production and yield of rice in India. Production change of 80.78% was noticed for the Period I subsequently 156.43% for Period II, 121.56% for Period III, 116% for Period IV and 138.61% for Period V, respectively. Whereas, for the overall period it was 745.22%. Area effect of 57.87% for Period I that was least among all, Period II noticed 87.62%, 66.55% for Period III, 96.40% for Period IV, 87.47% for Period V, whereas, for the overall period 76.86%. Yield effect was highest for Period I (37.86%), 9.77 % for Period II, second highest of 30.15% found in Period III, Period IV found
Table 4. Instability in area, production and yield of rice in India

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>Area (Lakh ha)</th>
<th>Production (Lakh tonnes)</th>
<th>Yield (kg ha⁻¹)</th>
<th>Area (Lakh ha)</th>
<th>Production (Lakh tonnes)</th>
<th>Yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean</td>
<td>386.48</td>
<td>447.60</td>
<td>1155.86</td>
<td>434.13</td>
<td>891.91</td>
<td>2052.41</td>
</tr>
<tr>
<td>2</td>
<td>SD</td>
<td>12.51</td>
<td>51.71</td>
<td>100.45</td>
<td>14.56</td>
<td>78.47</td>
<td>139.93</td>
</tr>
<tr>
<td>3</td>
<td>CV</td>
<td>3.24</td>
<td>11.55</td>
<td>8.69</td>
<td>3.35</td>
<td>8.80</td>
<td>6.82</td>
</tr>
<tr>
<td>4</td>
<td>CDVI</td>
<td>1.92</td>
<td>10.49</td>
<td>8.55</td>
<td>3.56</td>
<td>7.93</td>
<td>5.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Period II (1980 - '90)</td>
<td></td>
<td></td>
<td>Period V (2010 - '20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Mean</td>
<td>406.58</td>
<td>597.73</td>
<td>1466.98</td>
<td>436.95</td>
<td>1080.86</td>
<td>2473.13</td>
</tr>
<tr>
<td>2</td>
<td>SD</td>
<td>12.44</td>
<td>79.82</td>
<td>161.43</td>
<td>5.15</td>
<td>66.33</td>
<td>140.16</td>
</tr>
<tr>
<td>3</td>
<td>CV</td>
<td>3.06</td>
<td>13.35</td>
<td>11.00</td>
<td>1.18</td>
<td>6.14</td>
<td>5.67</td>
</tr>
<tr>
<td>4</td>
<td>CDVI</td>
<td>2.97</td>
<td>8.15</td>
<td>5.64</td>
<td>1.12</td>
<td>2.66</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Period III (1990 - '00)</td>
<td></td>
<td></td>
<td>Overall Period (1970 - '20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Mean</td>
<td>432.15</td>
<td>799.96</td>
<td>1849.69</td>
<td>419.26</td>
<td>763.61</td>
<td>1799.62</td>
</tr>
<tr>
<td>2</td>
<td>SD</td>
<td>10.46</td>
<td>53.96</td>
<td>86.29</td>
<td>22.72</td>
<td>233.02</td>
<td>478.01</td>
</tr>
<tr>
<td>3</td>
<td>CV</td>
<td>2.42</td>
<td>6.74</td>
<td>4.67</td>
<td>5.42</td>
<td>30.52</td>
<td>26.56</td>
</tr>
<tr>
<td>4</td>
<td>CDVI</td>
<td>1.35</td>
<td>3.19</td>
<td>2.64</td>
<td>3.00</td>
<td>6.53</td>
<td>5.21</td>
</tr>
</tbody>
</table>
The decomposition analysis revealed that change in production was more influenced by area effect in period I, while in period II, period III, period IV, period V and overall period respectively. Similar results were reported by Kumar (2019) and Pathak et al. (2020) in the crop.

**Instability of area, production and yield in rice in India**

Table 4 presents variations in stability across different factors, specifically area, production and yield. In the initial period (I), the highest level of variability was identified in production, accounting for 11.55%, followed by yield with 8.69% and then area with 3.24%. Notably, a consistent pattern was observed when examining the Cuddy Della Valle Index (CDVI), with production at 10.49, yield at 8.55 and area at 1.92. During the subsequent period (II), a similar pattern persisted, with production displaying the greatest instability at 13.35%, followed by yield at 11% and area at 3.06%. CDVI values for this period stood at 8.15 for production, 5.64 for yield and 2.97 for area. Period III exhibited the highest instability in production, standing at 6.74%, while yield showed a variation of 4.67%, and area exhibited the lowest instability with a coefficient of variation (CV) of 2.43%. CDVI values for this period were 3.19 for production, 2.64 for yield and 1.35 for area. Transitioning to the fourth period (IV), instability percentages were 8.80% for production, 6.82% for yield and 3.56% for area. Correspondingly, CDVI values were highest for production at 7.93, followed by yield at 5.21 and area at 3.56. In the most recent decade, period V, the trend remained consistent with the previous periods, showing instability percentages of 6.14% for production, 5.67% for yield and 1.18% for area. In general instability found more in production followed by yield but less instability found in area. Instability was highest in the Period II among all. Overall period also noticed instability highest for production subsequently by yield and area. CDVI also followed same pattern for all it was highest for area followed by yield and production. Results were confirmatory with Kumar (2019) and Pathak et al. (2020).

**CONCLUSIONS**

Rice crop was noticed with significant increase growth in the area over the period, non-significant increase for the period 1980-'90 and 2010-'20 but negative trend in area production.
was observed for rice area in the 2000-'10 decade attributed to drought, dry spells, unremunerative prices, low farm level technical efficiency, lower profitability. Production observed significant growth for all the three decades and overall period. Yield found to be non-significant increase in the first decade and significant in all other periods. Decomposition analysis confirmed area effect more in the rice for the periods compared to yield effect 1970-'80 decade and 1990-'00 decade sowed more of yield effect compared to other decades but interaction effect was less for rice. Production has the most instable, followed by yield, but area has the least. 1980-'90 decade had the most instable over all the periods. Increase in area affected the production positively. There is a need for policy emphasis on bolstering rice yield through focused research, enabling consistent production growth. Also, to address fluctuations in cultivation area and production instability, adopting diversified cultivation strategies, resilient practices, and efficient early warning systems becomes imperative for sustainable rice sector management.

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