

Growth and Instability Analysis of Cereal Crops in India

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ABSTRACT

The present study is an attempt to examine the growth and instability in the area, production and productivity of cereals in India. The time series data from 1951-52 to 2020-21 regarding the area, production and production of rice, wheat, maize, barley as well as total cereal and millets have been used to estimate the compound growth rate, coefficient of variation, Cuddy-Della Valle Index (CDI) and Coppock's Instability Index (CII) to obtain the objectives of the study. The period of 70 years is partitioned into seven periods. After India forcibly launched the green revolution, cereal crops helped the country transition from a food-insufficient one to a food-secure country. The study revealed that throughout the whole period, there is a positive growth rate in area, production and productivity under rice, maize, total cereal and millets except wheat has a negative growth during the fourth period in productivity. The analysis of instability in CV and CII showed that the highest and lowest variation was found under barley in area and production and almost the same instability in productivity in all the study periods except in analysis of CDI under wheat has the highest instability. To better identify which sub-period there was growth and which time there was lag, the entire study period was divided into sub-periods.

HIGHLIGHTS

- ① Cereal crops are mostly grasses cultivated for their edible seeds (actually a fruit called a caryopsis). Cereal grains like wheat, maize, and paddy are considered primary crops as they are staple foods to most of the population and provide more food energy to the human race than any other type of crop.
- ② India faced a difficult challenge in the early 1960s to feed its rapidly expanding population of 459 million people as the country was experiencing a production deficit of food grains. It is estimated that 4 million people died of hunger that year in eastern India, leaving painful memories of the Bengal famine of 1943. Therefore, India was forced to import increasing amounts of food and it was described as "Ships to Lips".
- ③ Fortunately, the Green Revolution was started in India in the 1960s employing modernised agricultural techniques such as high-yielding cultivars, enhanced agronomic techniques, plant protection techniques, pesticides, fertilisers and mechanization from the mid-1960s through the early 2000s.
- ④ These enhanced techniques also referred to as "Green Revolution technology," significantly increased agricultural output, especially for maize, rice and wheat. India's total cereal production increased from an annual average of 74 million metric tons in the 1960s, to an annual average of 100 million metric tons in the 1980s, and to an annual average of 134 million metric tons in the 1990s.
- ⑤ Post-Green Revolution, the production of wheat and rice doubled due to initiatives of the government, but the production of other food crops such as indigenous rice varieties and millets declined.
- ⑥ The country's agricultural production and associated economic gains were advanced by the Green Revolution, but this came at the expense of cultural values being lost, soil and water resources being polluted and depleted, wild and crop plant diversity declining, and general well-being and public health deteriorating.

Keywords: Cereal, growth rate, instability, green revolution

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METHODOLOGY

The study is based on the data pertaining to the area (in hectare), production (in tonnes) and productivity (in kg/ha) of cereals and millets i.e., rice, wheat, maize and barley were collected for the period of 70 years (1951-52 to 2020-21). In order to understand the decadal performance, the whole period was divided into seven decades viz. 1951-52 to 1960-61 (Period I), 1961-62 to 1970-71 (Period II), 1971-72 to 1980-81 (Period III), 1981-82 to 1990-91 (Period IV), 1991-92 to 2000-01 (Period V), 2001-02 to 2010-11 (Period VI), 2011-12 to 2020-21 (Period VII) and 1951-52 to 2020-21 (Overall Period) Data was collected from *www.indiastat.com* to obtain the trends and instability in area, production and productivity of cereal and millets in India.

Analytical framework

Trend analysis in area, production and productivity of the crops were estimated using compound annual growth rate (CAGR):

$$CAGR = [\text{antilog}(\ln B) - 1] * 1$$

The instability can be measured by different methods such as:

Coefficient of Variation has been calculated using the formula:

$$\text{Coefficient of Variation (CV\%)} =$$

$$\frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

CDI was originally developed by Cuddy and Valle (1978) for measuring the instability in area, production and productivity of the crops.

The value of Cuddy Della Valle Index (CV*) was calculated by using the formula as:

$$CV^* = CV \times (1 - R^2)^{0.5}$$

CII is a close approximation of the average year to year percentage variation adjusted for trend (Kaur & Singhal 1988). Instability was also analysed using Coppock's index which is calculated as the antilog of the square root of the logarithmic variance using the following formula (Coppock 1962).

$$\text{Coppock Index} = (\text{Antilog}) \sqrt{(V \log - 1) * 100}$$

$$V \log = 1 (N - 1) \sum (\log pt + 1 - \log pt - M)^2$$

$$M = 1 (N - 1) \sum (\log pt + 1 - \log pt)$$

RESULTS AND DISCUSSION

Growth and trend in area, production and productivity of cereal crops in India

The area under rice grew from 29831 thousand hectares to 45769 thousand hectares in 1951-52 to 2020-21. The growth rate was observed 0.5 per cent. The production has widely increased from 21300 thousand tonnes to 129368 thousand tonne in 1951-52 to 2020-21. India stands the second position in production next to China; the growth rate was 2.38 per cent. Productivity also seen increased from 714 kg/ha to 2717 kg/ha during the study period. The area under wheat has increased from 9471 thousand hectares to 31125 thousand hectares and the growth rate registered 1.58 per cent. The production has vastly grown from 6183 thousand tonnes to 109586 thousand tonnes with the annual growth of 4.18 per cent and productivity also grew from 653 kg/ha to 3521 kg/ha with the annual growth of 1.86 per cent in the same study period. The sub-period in area, production and productivity under rice and wheat has shown positive growth in all the periods except negative growth was found in productivity under wheat in the fourth period. Since the focus mainly on the production of rice and wheat which involves extensive use of soil and water resources and external inputs after the green revolution period shows the decline growth trend.

The area under maize rose from 3310 thousand hectares to 9892 thousand hectares in 1951-52 to 2020-21. The growth rate was observed 1.24 per cent. Production has enormously increased from 2076 thousand tonnes to 31647 thousand tonnes and the growth rate was 3.31 per cent and productivity expanded from 627 kg/ha to 3199 kg/ha during the study period. The growth rate noticed 2.04 per cent. All the sub-period has found to be positive for all the periods. During the initiation of green revolution, a large number of indigenously developed multi-parent hybrids were released led to increase in growth rate and later declined but it reaches its peak in 2001 the major concern has been on breeding of single cross hybrids that have

the highest yield potential among various types of cultivars.

The area and production under barley has decreased from 3154 thousand hectare to 592 thousand hectare and 2367 thousand tonnes to 1656 thousand tonnes in 1951-52 to 2020-21 respectively. The growth rate has a negative 3.12 and 1.13 respectively. The study of sub-period in area shows negative growth almost in all the periods except in the sixth period wherein production except second, sixth and seventh period was found to be positive. The productivity has increased from 749 kg/ha to 2796 kg/ha in the same study period. The growth rate registered 2.06 per cent. The sub-period has shown positive growth in all the periods due to the adoption of new technology and good quality seeds during the green revolution.

The area, production and productivity under total cereal and millets has increased from 78186 thousand hectares to 101012 thousand hectares, 43576 thousand tonnes to 285279 thousand tonnes and 557 kg/ha to 282 kg/ha in study period of 1951-52 to 2020-2021. The annual growth rate was 0.16 per cent and the sub-period has shown positive growth except during fourth and seventh period it showed negative growth rate. The production and productivity of growth rate was 2.52 per cent and 2.35 per cent respectively. In terms of production and productivity during the study of sub-period has a positive growth trend in all the periods.

Table 1: Compound growth rate and trend of area, production and productivity of cereal crops, 1951-52 to 2020-21

| CAGR | | | |
|---------------------------------------|---------|------------|--------------|
| Crop | Area | Production | Productivity |
| Period I (1951-52 to 1960-61) | | | |
| Rice | 1.54*** | 4.44*** | 2.86*** |
| Wheat | 3.71*** | 5.10*** | 1.35* |
| Maize | 2.85*** | 5.94*** | 3.01*** |
| Barley | -0.12 | -0.11 | 0.01 |
| Total cereal and millets | 1.46*** | 3.90** | 2.40*** |
| Period II (1961-62 to 1970-71) | | | |
| Rice | 0.76*** | 1.91* | 1.14 |
| Wheat | 3.24*** | 9.29*** | 5.86*** |
| Maize | 3.52*** | 5.25*** | 1.67* |
| Barley | -1.34 | 0.94 | 2.30* |

| | | | |
|--|----------|----------|---------|
| Total cereal and millets | 1.12*** | 3.47** | 2.33** |
| Period III (1971-72 to 1980-81) | | | |
| Rice | 0.91*** | 2.58* | 1.65* |
| Wheat | 2.34 | 4.91 | 2.51* |
| Maize | 0.04 | 1.40 | 1.36* |
| Barley | -4.85*** | -3.25* | 1.68* |
| Total cereal and millets | 0.53** | 3.06*** | 2.52*** |
| Period IV (1981-82 to 1990-91) | | | |
| Rice | 0.64* | 4.54*** | 3.88*** |
| Wheat | 0.43 | 3.96* | -0.74* |
| Maize | 0.06 | 2.57* | 2.50* |
| Barley | -5.71*** | -2.28** | 3.65*** |
| Total cereal and millets | -0.27 | 3.09 | 3.37*** |
| Period V (1991-92 to 2000-01) | | | |
| Rice | 0.78*** | 1.87*** | 1.07** |
| Wheat | 1.40*** | 3.11*** | 0.28 |
| Maize | 1.17*** | 3.74*** | 2.55*** |
| Barley | -2.37*** | -0.72 | 1.70** |
| Total cereal and millets | 0.13 | 2.11*** | 1.93*** |
| Period VI (2001-02 to 2010-11) | | | |
| Rice | 0.11 | 1.71* | 1.60** |
| Wheat | 1.34*** | 2.55*** | 1.20** |
| Maize | 2.91*** | 6.00*** | 3.00** |
| Barley | 0.05 | 1.53 | 1.47* |
| Total cereal and millets | 0.27 | 2.25** | 1.98*** |
| Period VII (2011-12 to 2020-21) | | | |
| Rice | 0.30* | 1.86*** | 1.56*** |
| Wheat | 0.20 | 1.95*** | 1.75** |
| Maize | 1.15*** | 4.01*** | 2.83*** |
| Barley | -1.67** | 0.001 | 1.70** |
| Total cereal and millets | -0.07 | 1.93*** | 2.01*** |
| Overall Period (1951-52 to 2020-21) | | | |
| Rice | 0.52*** | 2.38*** | 1.86*** |
| Wheat | 1.58*** | 4.18*** | 2.46*** |
| Maize | 1.24*** | 3.31*** | 2.04*** |
| Barley | -3.12*** | -1.13*** | 2.06*** |
| Total cereal and millets | 0.16*** | 2.52*** | 2.35*** |

Note: ***, ** and * significant at 1, 5 and 10 per cent level of significance.

Instability in area, production and productivity of cereal crops

Analysis on Coefficient of Variation

Table 2 reveals that in case of total cereal and millets in India 5.89 per cent variation was observed in area, 46.73 per cent in production and 45.62 per cent in productivity during the study period. The highest variation was seen in area under barley as well as lowest in terms of production as compared to the other but productivity under all the crops was almost the same trend during the study period.

Table 2: Classification of crops based on CV of area, production and productivity, 1951-51 to 2020-21

| Coefficient of variation | | | |
|--|-------|------------|--------------|
| Crop | Area | Production | Productivity |
| Period I (1951-52 to 1960-61) | | | |
| Rice | 4.71 | 14.74 | 10.53 |
| Wheat | 12.20 | 16.34 | 8.21 |
| Maize | 9.10 | 19.55 | 11.49 |
| Barley | 4.61 | 8.65 | 6.24 |
| Total cereal and millets | 4.77 | 12.91 | 8.53 |
| Period II (1961-61 to 1970-71) | | | |
| Rice | 2.75 | 11.19 | 9.14 |
| Wheat | 12.81 | 33.32 | 20.13 |
| Maize | 11.08 | 18.68 | 9.65 |
| Barley | 9.67 | 16.31 | 11.85 |
| Total cereal and millets | 3.93 | 14.18 | 10.42 |
| Period III (1971-72 to 1980-81) | | | |
| Rice | 3.24 | 12.57 | 9.72 |
| Wheat | 8.03 | 16.73 | 9.51 |
| Maize | 2.49 | 10.71 | 9.18 |
| Barley | 18.42 | 18.74 | 11.10 |
| Total cereal and millets | 2.28 | 11.59 | 9.58 |
| Period IV (1981-82 to 1990-91) | | | |
| Rice | 3.59 | 15.08 | 12.27 |
| Wheat | 3.67 | 15.57 | 34.41 |
| Maize | 2.09 | 16.09 | 14.84 |
| Barley | 18.73 | 10.08 | 11.92 |
| Total cereal and millets | 2.57 | 11.19 | 10.95 |
| Period V (1991-92 to 2000-01) | | | |
| Rice | 2.59 | 6.40 | 4.19 |
| Wheat | 5.13 | 10.11 | 31.66 |
| Maize | 3.80 | 12.11 | 9.05 |

| | | | |
|--------------------------|------|------|------|
| Barley | 9.19 | 8.67 | 6.72 |
| Total cereal and millets | 1.01 | 6.91 | 6.16 |

| Period VI (2001-02 to 2010-11) | | | |
|--------------------------------|------|-------|-------|
| Rice | 3.21 | 8.815 | 6.71 |
| Wheat | 4.41 | 8.92 | 4.87 |
| Maize | 8.77 | 20.18 | 12.79 |
| Barley | 5.83 | 12.73 | 7.89 |
| Total cereal and millets | 2.34 | 8.95 | 7.21 |

| Period VII (2011-12 to 2020-21) | | | |
|---------------------------------|------|-------|------|
| Rice | 1.71 | 6.25 | 5.26 |
| Wheat | 2.42 | 7.31 | 7.53 |
| Maize | 4.41 | 12.91 | 9.35 |
| Barley | 7.56 | 6.71 | 7.48 |
| Total cereal and millets | 1.71 | 6.79 | 6.96 |

| Overall Period (1951-52 to 2020-21) | | | |
|-------------------------------------|-------|-------|-------|
| Rice | 10.87 | 44.91 | 36.87 |
| Wheat | 29.45 | 65.28 | 49.59 |
| Maize | 26.42 | 71.44 | 44.46 |
| Barley | 62.87 | 29.23 | 41.94 |
| Total cereal and millets | 5.89 | 46.73 | 45.62 |

Analysis on Cuddy-Della Valle Index

As depicted in Table 3, computed CDI was 5 per cent variation under area, 7.89 per cent in production and 5.83 per cent in productivity in terms of total cereal and millets. It was seen that the instability values were lower as compared to CV because the CV is the simplest measure of instability and it overestimates the level of instability in time series data which are characterized by long-term trends, but the CDI method de-trends the value and provides reliable results. Among the crops the lower instability in the area was found under rice, wheat and maize whereas under production only rice has the lowest variation due to improvement emphasized selection in traditional varieties to develop new, locally adapted cultivars and wheat has the highest instability in terms of productivity due to launch of Green Revolution program in 1965-66, which brought changes in the cropping pattern. The instability was higher in the starting sub periods in both production and yield, it may be due to launch of various development schemes in that decade by the government to improve Indian agriculture



Table 3: Classification of crops based on Cuddy-Della Valle Index of area, production and productivity, 1951-51 to 2020-21

| Cuddy -Della Valle Index | | | |
|--|-------------|-------------------|---------------------|
| Crop | Area | Production | Productivity |
| Period I (1951-52 to 1960-61) | | | |
| Rice | 0.99 | 7.42 | 6.74 |
| Wheat | 6.25 | 8.17 | 7.58 |
| Maize | 3.57 | 10.16 | 7.84 |
| Barley | 4.88 | 9.17 | 6.62 |
| Total cereal and millets | 2.23 | 6.90 | 5.05 |
| Period II (1961-61 to 1970-71) | | | |
| Rice | 1.60 | 10.29 | 9.04 |
| Wheat | 8.42 | 18.17 | 10.55 |
| Maize | 3.51 | 8.98 | 8.49 |
| Barley | 9.23 | 17.02 | 10.29 |
| Total cereal and millets | 2.07 | 10.11 | 8.19 |
| Period III (1971-72 to 1980-81) | | | |
| Rice | 1.86 | 10.43 | 9.61 |
| Wheat | 4.30 | 9.11 | 6.29 |
| Maize | 2.64 | 10.44 | 8.71 |
| Barley | 11.55 | 16.92 | 10.51 |
| Total cereal and millets | 1.73 | 7.49 | 6.19 |
| Period IV (1981-82 to 1990-91) | | | |
| Rice | 3.24 | 7.33 | 4.52 |
| Wheat | 3.64 | 11.57 | 36.48 |
| Maize | 2.21 | 15.09 | 13.62 |
| Barley | 4.87 | 7.69 | 4.96 |
| Total cereal and millets | 2.58 | 6.58 | 4.36 |
| Period V (1991-92 to 2000-01) | | | |
| Rice | 1.10 | 3.36 | 2.88 |
| Wheat | 3.16 | 4.42 | 33.58 |
| Maize | 1.50 | 5.77 | 5.62 |
| Barley | 5.88 | 8.91 | 4.80 |
| Total cereal and millets | 0.99 | 3.09 | 2.40 |
| Period VI (2001-02 to 2010-11) | | | |
| Rice | 3.38 | 7.82 | 5.24 |
| Wheat | 1.96 | 4.84 | 3.44 |
| Maize | 2.38 | 10.23 | 9.52 |
| Barley | 6.18 | 12.52 | 6.85 |
| Total cereal and millets | 2.33 | 6.52 | 4.47 |
| Period VII (2011-12 to 2020-21) | | | |
| Rice | 1.54 | 2.75 | 2.46 |

| | | | |
|--------------------------|------|------|------|
| Wheat | 2.48 | 3.20 | 5.84 |
| Maize | 2.88 | 4.91 | 4.06 |
| Barley | 5.94 | 7.12 | 1.59 |
| Total cereal and millets | 1.80 | 3.58 | 3.62 |

| Overall Period (1951-52 to 2020-21) | | | |
|--|-------------|-------------------|---------------------|
| Crop | Area | Production | Productivity |
| Rice | 4.35 | 8.59 | 6.75 |
| Wheat | 9.54 | 16.12 | 30.44 |
| Maize | 8.41 | 15.75 | 11.24 |
| Barley | 16.12 | 17.27 | 8.93 |
| Total cereal and millets | 5.00 | 7.89 | 5.83 |

Analysis on Coppocks Instability Index

The computed CII is shown in Table 4. In case of total cereal and millets the estimated variation was 39.10 per cent under area, 61.24 per cent in production and 59.06 per cent in productivity. Among the crops the instability area under barley was found to be highest instability whereas in production and productivity under wheat has the highest instability due to Hailstorms, unseasonal rainfall and high-speed winds during February–March caused lodging and damaged the crop in about 6 m ha area in major wheat-growing states, namely Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh and Maharashtra.

Table 4: Classification of crops based on Coppocks Index of area, production and productivity, 1951-52 to 2020-21

| Coppock's Instability Index | | | |
|--|-------------|-------------------|---------------------|
| Crop | Area | Production | Productivity |
| Period I (1951-52 to 1960-61) | | | |
| Rice | 38.47 | 42.39 | 40.72 |
| Wheat | 41.45 | 43.26 | 39.78 |
| Maize | 40.13 | 44.49 | 41.12 |
| Barley | 38.44 | 40.09 | 39.05 |
| Total cereal and millets | 38.53 | 41.77 | 39.94 |
| Period II (1961-61 to 1970-71) | | | |
| Rice | 37.76 | 41.03 | 40.25 |
| Wheat | 41.34 | 49.54 | 44.41 |
| Maize | 40.83 | 43.38 | 40.05 |
| Barley | 40.20 | 42.68 | 41.23 |
| Total cereal and millets | 38.17 | 41.99 | 40.59 |
| Period III (1971-72 to 1980-81) | | | |
| Rice | 37.94 | 41.38 | 40.30 |
| Wheat | 39.73 | 43.19 | 40.30 |

| | | | |
|--|-------|-------|-------|
| Maize | 37.67 | 40.70 | 40.13 |
| Barley | 43.92 | 44.09 | 40.91 |
| Total cereal and millets | 37.60 | 41.04 | 40.25 |
| Period IV (1981-82 to 1990-91) | | | |
| Rice | 38.08 | 42.46 | 41.33 |
| Wheat | 38.09 | 43.01 | 73.48 |
| Maize | 37.54 | 42.99 | 42.38 |
| Barley | 43.79 | 40.46 | 41.14 |
| Total cereal and millets | 37.71 | 40.87 | 40.77 |
| Period V (1991-92 to 2000-01) | | | |
| Rice | 37.70 | 39.11 | 38.30 |
| Wheat | 38.63 | 40.52 | 72.28 |
| Maize | 38.13 | 41.40 | 40.21 |
| Barley | 40.11 | 39.94 | 39.28 |
| Total cereal and millets | 37.14 | 39.31 | 39.03 |
| Period VI (2001-02 to 2010-11) | | | |
| Rice | 37.92 | 40.21 | 39.35 |
| Wheat | 38.36 | 40.02 | 38.52 |
| Maize | 40.06 | 44.52 | 41.45 |
| Barley | 38.87 | 41.33 | 39.57 |
| Total cereal and millets | 37.63 | 40.17 | 39.42 |
| Period VII (2011-12 to 2020-21) | | | |
| Rice | 37.39 | 38.99 | 38.65 |
| Wheat | 37.64 | 39.43 | 39.57 |
| Maize | 38.35 | 41.52 | 40.16 |
| Barley | 39.53 | 39.28 | 39.54 |
| Total cereal and millets | 37.39 | 39.19 | 39.28 |
| Overall Period (1951-52 to 2020-21) | | | |
| Rice | 41.20 | 59.71 | 53.67 |
| Wheat | 51.35 | 86.30 | 68.36 |
| Maize | 47.87 | 72.17 | 56.06 |
| Barley | 71.28 | 48.79 | 56.02 |
| Total cereal and millets | 39.10 | 61.24 | 59.06 |

CONCLUSION

From the analysis of growth in rice, wheat, maize it was found that area, production and productivity show a positive growth trend in all the study

period except in productivity under wheat during fourth period was found to be negative. Instability analysis showed that in all the crops area instability has lower variation as compared to production and productivity. It also observed that in terms of productivity the instability has almost same except in the CDI analysis wheat has a peak instability than the others due to witnessed development of dwarf wheat cultivars in order to increase production and improve Indian agriculture. In India, the wheat-growing regions of Punjab, Haryana, and Western U.P. have seen the most impact from the Green Revolution. In South India, the effects of the Green Revolution have been concentrated in the States of Andhra, Tamil Nadu, and Kerala.

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