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A Statistical Approach for Assessment of Growth Rate and Instability of Wheat in Selected States of India

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Abstract: In the present paper, the analysis of growth and instability in production, area and yield of wheat for some wheat growing states of India is carried out by computing compound growth rate (CGR) and Cuddy-Della Valle (CDV) instability index on utilizing secondary time series data of wheat pertaining to the period 2011–2020 in the concerned states. The percentage change in production, area and yield of wheat is examined by considering the base year as 2011. Moreover, the percentage share of production, area and yield of wheat are demonstrated graphically for the year 2020.

Keywords: percentage change; percentage share; coefficient of variation; coefficient of determination; instability index; compound growth rate

1. Introduction

Wheat (*Triticumaestivum* L.) is a significant staple food crop, which holds second position after rice in India. It belongs to Poaceae family, and mainly consumed in raw as well as processed form, such as porridge, wheat flour, semolina, vermicelli and much more. It is a highly nutritious cereal comprising of carbohydrate, protein, fiber and other vital nutrients. In India, it is mainly grown in rabi season.

India holds second position in production of wheat after China. During the year 2020–2021, the largest producer of wheat in India was Uttar Pradesh (i.e., 35.50 million tons), followed by Madhya Pradesh (17.62 million tons), Punjab (17.14 million tons), Haryana (12.36 million tons), and Bihar (6.34 million tons). Moreover, the overall production of wheat in India was 109.52 million tons during the concerned year [1].

Among the global staple cereals, wheat is considered as a major component of the human diet. It holds a significant role for ensuring global food demand and food security [2]. Several researchers and scientists have carried out time series analysis and forecasting of wheat crop for various geographical regions across the globe [3]. utilized Multiple Linear Regression (MLR) Technique and discriminant function analysis for estimating the wheat productivity in Varanasi district of eastern Uttar Pradesh [4]. developed regression models for forecasting spot blotch severity in susceptible and resistant genotypes of wheat crop under Irrigated timely sown condition (ITS), Irrigated late sown condition (ILS), and Rainfed timely sown condition (RFTS). CRI, tillering, jointing, flowering, milking and dough stages of wheat were considered for studying the effect of weather parameters on yearly spot blotch severity. The correlation coefficients between the yearly spot blotch severity and weekly weather parameters (Maximum temperature, maximum relative humidity and their joint effects) were computed for measuring the quantitative relationship between these variables [5]. developed a simple linear regression model with ARIMA errors to yearly production of wheat in India during the period of 1960–2016.The fitted model was observed to be more accurate than ARIMA model [6]. utilized linear, quadratic, exponential, s-curve, double exponential smoothing, single exponential smoothing, moving average and ARIMA models for forecastingof wheat production in Pakistan [7]. utilized ARIMA, Artificial neural network (ANN) and hybrid time series models for forecasting of wheat production in Haryana. Moreover, compound annual growth rate (CAGR) was also



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evaluated in the study [8]. modeled and forecasted the production of wheat in South Asian region countries, viz. Afghanistan, Bangladesh, Bhutan, China, India, Nepal, and Pakistan, on utilizing ARIMA and Holt's linear trend models [9]. forecasted wheat production in Iran using univariate time series models and the Artificial Neural Network (ANN) model. The comparison between ANN and ARIMA (1,1,1) models were made in the study. Some other noteworthy contributions towards time series analysis of crops have been made by [10–17].

In recent years, the time series analysis of agricultural crops has become indispensable for exploring the long-term trend pattern of the crop, and policy formulation regarding bulk storage, price fixation, transportation, crop insurance and food security. Considering the given fact, an attempt has been made in the present paper to analyze the growth and instability in production, area and yield of wheat for some wheat growing states of India.

2. Data and Methodology

2.1. Source of Data

In the present study, the secondary time series data pertaining to the period 2011 to 2020, on production, area and yield of wheat in selected states of India is considered. The concerned time series data is obtained from Directorate of Economics & Statistics, DAC&FW, Govt. of India [1].

2.2. Terminologies and Notations

Three wheat growing states of India, namely, Uttar Pradesh (S1), Haryana (S2), and Bihar (S3) are considered for the present analysis. In these states, significant variations are observed in production, area and yield of wheat during the concerned period of study. In order to examine these variations, we have computed the Cuddy-Della Valle (CDV) instability index, compound growth rate, and other statistical coefficients and measures which are elaborated in the subsequent sections.

2.3. Statistical Measures and Coefficients

(a) Percentage change in area, production and yield of wheat

$$\%\ change\ in\ X = \frac{Value\ of\ X\ in\ the\ current\ year - Value\ of\ X\ in\ the\ base\ year}{Value\ of\ X\ in\ the\ base\ year} \times 100$$

where X = Area, Production, or Yield (as the case may be). The year 2011 is selected as the base year for the present study.

(b) Percentage share of area, production and yield of wheat in India:

$$\%\ share\ of\ X\ in\ state\ S_i = \frac{Value\ of\ X\ in\ state\ S_i}{Overall\ Value\ of\ X\ in\ India} \times 100;\ (i = 1,2,3)$$

where X = Area, Production, or Yield (as the case may be) for the given year.

(c) Coefficient of Variation (CV)

The coefficient of variation (CV) is expressed as:

$$CV(X) = \frac{SD(X)}{\bar{X}} \times 100,$$

where $SD(X)$ denotes the standard deviation of the variable X (which may be either of area, production or yield, as the case may be). Also, $\bar{X}$ denotes the mean of the variable X.

(d) Instability Index

In order to measure the level of instability in production, area and yield of wheat for the selected states S1, S2, and S3 of India, the Cuddy-DellaValle (CDV) instability index is used. The instability index is given by the formula:

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

where R^2 represents the coefficient of determination, which is obtained on fitting linear model to the concerned time series data on production, area and yield of wheat for the respective states. Also, CV represents the coefficient of variation.

(e) Compound Growth Rate (CGR)

The compound growth rate (CGR) in production, area and yield of wheat is obtained on using the following function:

$$y_t = a(1+r)^t \tag{1}$$

where y_t is the observed value of production, area or yield (as the case may be) of wheat at time *t.* Also, '*a'* is a statistical constant, and *'r'* denotes the compound growth rate.

From (1), we have

$$logy_t = loga + t\{log(1+r)\}$$

$$i.e., Y_t = A + Rt \tag{2}$$

where $Y_t = logy_t$, $A = loga$, and $R = log\,(1 + r)$.

The normal equations for estimating 'A' and 'R' are given below:

$$\sum Y_t = nA + R\sum t \tag{3}$$

$$\sum tY_t = A\sum t + R\sum t^2 \tag{4}$$

Finally, on solving (3) and (4), the estimated values of '*a'* and '*r'* are obtained as follows:

$$\hat{a} = antilog(A)$$

$$\hat{r} = antilog(R) - 1$$

Here, $\hat{r}$ denotes the compound growth rate (CGR), and is generally expressed in terms of percentage as follows:

$$\hat{r} = [antilog(R) - 1] \times 100$$

3. Data Analysis and Results

The secondary time series data on production, area and yield of wheat in the states S1, S2, and S3 of India are elaborated in Tables 1–3 respectively. Moreover, the percentage change in production, area and yield of wheat for the selected states of India are depicted in Tables 4–6 respectively.

Table 1. Time series data on production of wheat in selected states of India.

Year	* Production (in Million Tons) for the States		
	S1	S2	S3
2011	30.29	12.68	4.79
2012	30.30	11.12	5.36
2013	30.25	11.80	5.08
2014	22.42	10.35	3.99
2015	25.43	11.35	4.74
2016	30.06	11.55	5.11
2017	31.88	11.16	5.74
2018	32.74	12.57	6.47
2019	33.82	11.88	5.58
2020	35.50	12.36	6.34

(*** Source:** Directorate of Economics & Statistics, DAC&FW, Govt. of India [1].).

Table 2. Time series data on area under wheat cultivation in selected states of India.

Year	* Area under Cultivation (in '000 Hectares) of the States		
	S1	S2	S3
2011	9.73	2.52	2.17
2012	9.73	2.50	2.21
2013	9.96	2.50	2.26
2014	9.85	2.60	2.15
2015	9.65	2.58	2.11
2016	9.66	2.56	2.11
2017	9.75	2.53	2.04
2018	9.54	2.55	2.16
2019	9.85	2.53	2.15
2020	9.85	2.56	2.22

(*** Source:** Directorate of Economics & Statistics, DAC&FW, Govt. of India [1].).

Table 3. Time series data on yield of wheat in selected states of India.

Year	* Yield (in Quintal/Hectare) for the States		
	S1	S2	S3
2011	31.13	50.30	22.06
2012	31.13	44.52	24.27
2013	30.38	47.22	22.51
2014	22.77	39.81	18.51
2015	26.36	44.07	22.44
2016	31.13	45.14	24.27
2017	32.69	44.12	28.16
2018	34.32	49.25	29.98
2019	34.32	46.87	25.95
2020	31.13	50.30	22.06

(*** Source:** Directorate of Economics & Statistics, DAC&FW, Govt. of India [1].).

Table 4. Percentage change in wheat production for selected states of India.

Year	Percentage Change (%) in Production for the States		
	S1	S2	S3
2011	---	---	---
2012	0.03	−12.3	11.9
2013	−0.13	−6.94	6.05
2014	−25.98	−18.38	−16.7
2015	−16.04	−10.49	−1.04
2016	−0.76	−8.91	6.68
2017	5.25	−11.99	19.83
2018	8.09	−0.87	35.07
2019	11.65	−6.31	16.49
2020	17.20	−2.52	32.36

Table 5. Percentage change in area under wheat cultivation for selected states of India.

Year	Percentage Change (%) in Area for the States		
	S1	S2	S3
2011	---	---	---
2012	0	−0.79	1.84
2013	2.36	−0.79	4.15
2014	1.23	3.17	−0.92
2015	−0.82	2.38	−2.76
2016	−0.72	1.59	−2.76
2017	0.21	0.40	−5.99
2018	−1.95	1.19	−0.46
2019	1.23	0.40	−0.92
2020	1.23	1.59	2.30

Table 6. Percentage change in wheat yield for selected states of India.

Year	Percentage Change (%) in Yield for the States		
	S1	S2	S3
2011	---	---	---
2012	0	−11.49	10.02
2013	−2.41	−6.12	2.04
2014	−26.86	−20.85	−16.09
2015	−15.32	−12.39	1.72
2016	0	−10.26	10.02
2017	5.01	−12.29	27.65
2018	10.25	−2.09	35.90
2019	10.25	−6.82	17.63
2020	15.77	−3.86	29.42

From Tables 4–6, it is revealed that for the year 2020, the percentage change in production of wheat is positively high for the state S3 (i.e., 32.36%) as compared to the state S1 (i.e., 17.20%), whereas a negative

percentage change is observed in production for the state S2 (i.e., −2.52%). Moreover, the percentage change in area under wheat cultivation is positively high for the state S3 (i.e., 2.30%), followed by the states S2 (i.e., 1.59%) and S1 (i.e., 1.23%). Furthermore, the percentage change in yield of wheat is positively high for the state S3 (i.e., 29.42%) as compared to the state S1 (i.e., 15.77%), whereas a negative percentage change is observed in the yield for the state S2 (i.e., −3.86%).

The percentage share of production, area and yield of wheat for the year 2020 in various wheat growing states of India are depicted graphically in Figures 1–3 respectively.

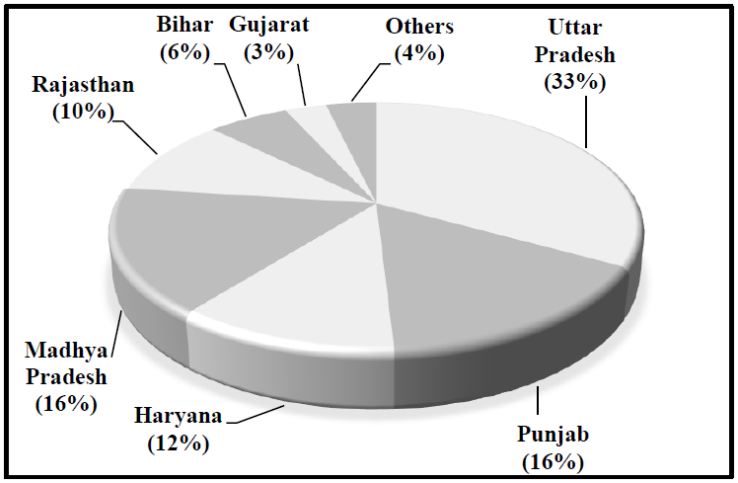


Figure 1. Percentage share of wheat production in the year 2020.

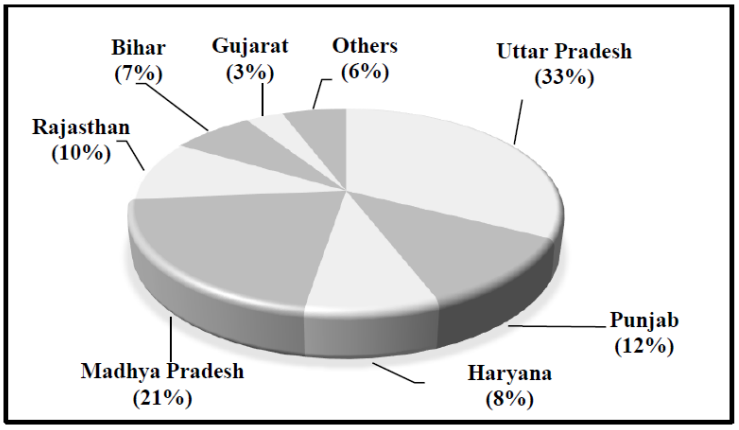


Figure 2. Percentage share of area under wheat cultivation in the year 2020.

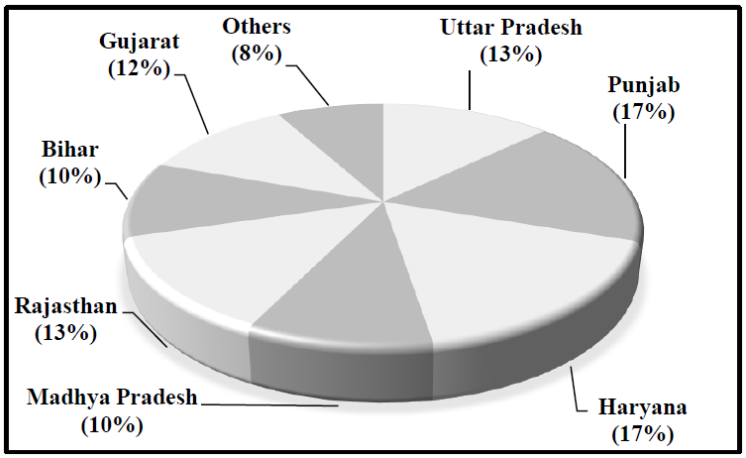


Figure 3. Percentage share of wheat yield in the year 2020.

It is observed from Figure 1 that the state Uttar Pradesh (S1) exhibits highest percentage share for wheat production in the year 2020 (i.e., 33%), followed by Madhya Pradesh and Punjab (i.e., 16%), Haryana (S2) (i.e., 12%), Rajasthan (i.e., 10%) and Bihar (S3) (i.e., 6%). The state Gujarat exhibits the least percentage share for wheat production in the year 2020 (i.e., 3%). Moreover, from Figure 2, it is observed that the state Uttar Pradesh (S1) exhibits highest percentage share for area under wheat cultivation in the year 2020 (i.e., 33%), whereas the least percentage share for area under wheat cultivation is observed in the state Gujarat (i.e., 3%). Furthermore, from Figure 3, it is revealed that the states Haryana (S2) and Punjab exhibit highest percentage share for wheat yield (i.e., 17%) as compared to the other states, whereas the least percentage share for wheat yield is observed in the states Bihar (S3) and Madhya Pradesh (i.e., 10%).

The values of various statistical coefficients, i.e., coefficient of variation (CV), coefficient of determination (R^2), and Cuddy-Della Valle instability index (I) for production, area and yield of wheat in the states S1, S2, and S3 of India are summarized in Table 7. In order to compute the values of R^2 for production, area and yield of wheat in the concerned states, a linear model is fitted to the time series data on wheat. Moreover, the compound growth rates (CGRs) for production, area and yield of wheat in the concerned states are computed and the findings are presented in Table 8.

Table 7. Values of various statistical coefficients for production, area and yield of wheat in the selected states of India.

States	Production			Area			Yield		
	CV	R^2	I	CV	R^2	I	CV	R^2	I
S1	12.74	0.69	7.07	1.26	0.45	0.94	12.71	0.70	6.96
S2	15.02	0.06	14.59	1.30	0.67	0.75	6.70	0.60	4.24
S3	14.14	0.62	8.69	2.92	0.67	1.68	14.28	0.68	8.13

Table 8. CGR (in percentage) for production, area and yield of wheat in selected states of India.

States	Production	Area	Yield
S1	2.34	−0.03	2.37
S2	0.48	0.14	0.33
S3	3.19	−0.22	3.43

It is observed from Table 7 that the Cuddy-Della Valle instability index (I) in production of wheat is highest for the state S2 (i.e., 14.59%), followed by the states S3 (i.e., 8.69%), and S1 (i.e., 7.07%). Hence, production of wheat in the state S2 is comparatively more instable as compared to the states S1 and S3. Moreover, the pattern of instability in area and yield of wheat are observed to be the same, i.e., highest instability is observed for area and yield in the state S3, followed by the states S1 and S2.

The Table 8 reveals that, for state S1, the compound growth rates (CGRs) for production and yield of wheat are positive, whereas there is a negative growth rate in area under wheat cultivation. A similar pattern of growth rates for production, area, and yield of wheat are observed in the state S3. Moreover, the state S2 exhibits positive and steady growth rates in production, area, and yield of wheat.

4. Conclusions

In the present paper, the assessment of growth rate and instability in production, area, and yield of wheat is carried out for some wheat growing states of India, viz. S1 (Uttar Pradesh), S2 (Haryana), and S3 (Bihar). The secondary time series data pertaining to the period 2011–2020 is considered for the investigation.

The percentage change in production, area and yield of wheat has been evaluated, by considering the base year as 2011. It is revealed from Section 3 that among all the three states, the percentage change in production, area, and yield of wheat is positively high for the state Bihar in the year 2020.

The percentage share of production, area and yield of wheat for the year 2020 in various wheat growing states of India are elaborated in Section 3. It is revealed that among all the three considered states, the percentage share of production and area of wheat is highest in the state Uttar Pradesh, followed by the states Haryana and Bihar. Moreover, the percentage share of yield of wheat is highest in the state Haryana, followed by the states Uttar Pradesh and Bihar.

The level of instability in production, area and yield of wheat is measured for the concerned states by using Cuddy-Della Valle (CDV) instability index. It is observed from the results of Section 3 that the production of wheat in the state Haryana is comparatively more instable as compared to the states Uttar Pradesh and Bihar.

Moreover, the pattern of instability in area and yield of wheat are observed to be the same, i.e., highest instability is observed for area and yield in the state Bihar, followed by the states Uttar Pradesh and Haryana.

In Section 3, the compound growth rates (CGRs) in production, area and yield of wheat are examined for the states considered under study. It is revealed that for state Uttar Pradesh, the compound growth rates (CGRs) for production and yield of wheat are positive, whereas there is a negative growth rate in area under wheat cultivation. A similar pattern of growth rates for production, area, and yield of wheat are observed in the state Bihar. Moreover, the state Haryana exhibits positive and steady growth rates in production, area, and yield of wheat.

The findings of the study provide significant insights on the growth rate scenario of wheat in Uttar Pradesh, Haryana, and Bihar. The study could be enhanced further for some other states of India as well. Since wheat holds a prominent position in human diet and has nutritional benefits as well, hence the potential farmers can optimize their income through wheat cultivation, along with integrated farming practices.

Author Contributions

G.P.: data analysis, writing—original draft preparation; M.K.: conceptualization, methodology, supervision, writing—reviewing and editing; S.K.R.: data tabulation, visualization; S.G.K.: statistical analysis. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

All relevant data are available within the article, and publicly on the official websites of Directorate of Economics & Statistics, DAC&FW, Govt. of India.

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Conflicts of Interest

The authors declare no conflict of interest.

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