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STATISTICAL ANALYSIS OF RICE AND WHEAT PRODUCTION GROWTH IN INDIA POST GREEN REVOLUTION

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Abstract- India is the second largest producer of rice and wheat in the world production table [1]. Before and during the struggle for independence, the agriculture sector was the driving engine of the Indian economy. In the 1960s, an immense technology transfer occurred in the Global South that resulted in increased agricultural production. India introduced High-Yielding Variety (HYV) seeds and increased the usage of fertilizers to bring the green revolution in India.

In this paper, the authors examined the shift in the production of wheat and rice in India in the decades following the green revolution, analysed the production of wheat and rice from the year 1950-51, and observed whether these two factors are still influenced by the green revolution of 1965. The paper also concentrates on the scale of the green movement in India. Time-series analysis and smoothing techniques have been applied to observe the trends and to predict the production for the year 2025. After analysing rice and wheat food grain production data (from 1950-51 to 2023-24), food grain production in India increased after 1965 (the Green Revolution was introduced in India). It has been a remarkable rise. Regression analysis has been applied to check the relation between rice production and wheat production across these years, which comes out to be a close to perfect association. At the moment of the green revolution, the technical advances introduced still impact overall output and rise over time. However, the prediction is showing that this growth may not continue, perhaps, without introducing new technologies as per current needs and taking care of climate change in the country.

Keywords: Agriculture, Green Revolution, Regression, Time-Series Analysis, Forecasting.

1. INTRODUCTION

1.1 Green Revolution in India

In the 1960s, an immense technology transfer occurred in the Global South that resulted in increased agricultural production. The switch from centuries-old cultivation methods to mechanization resulted in not only affected the horticultural productivity but also the lives of millions of people and the environment.

Before and during the struggle for independence, the agriculture sector was the driving engine of the Indian economy. Still, the situation of the agricultural sector was pitiful. From low production per acre, dearth of investment, insufficiency of technology, and more such problems afflicted the industry. Therefore, the government of India came into action to introduce farmers to HYV seeds, which led to the Green Revolution. Yadav and Anand [2] studied on the impact of green revolution on food security.

Although the third major sector contributing to the Indian economy is agriculture (and other related sectors), it accounts for only about 16 percent of GDP. This sector is showing average annual growth of 5% from the year 2017 [2]. India has distinct advantages of cultivating varied crops with the arable land area of 155.37 million hectares, due to which India is positioned at the second rank next to the USA, and varied agro-based climatic conditions. India's agricultural (primary) sector has a crucial role in politics, economics, and society. In the Global South, an enormous technology transition took place in the 1960s that succeeded in increasing agricultural production. The transition from centuries-old methods of cultivation to mechanisation has not only changed the productivity of horticulture but also the lives of millions of people and the community.

2. METHODOLOGY

2.1 Secondary Statistical Analysis

Secondary statistical analysis is a quantitative, systematic research method and an analytical tool to examine the secondary data, the already existing data that other researchers, institutions, or national governments have collected. Secondary Analysis is an empirical practice that applies similar research principles to primary data, utilizing studies. The tool provides us with a larger analytical space because we can collect, use, and apply the data for purposes other than it was originally intended. The method is cost and time-effective since we did not have to spend money or time to get access to or collect the datasets.

2.2 Regression

Linear regression is a statistical method used in various sectors like finance, investing, etc., for determining the strength of the linear relationship between one dependent variable and a series of independent variables. In simple

linear regression, one independent variable is used to predict or explain the dependent variable, and is used to find the linear approach to modelling the mathematical relationship between them. It is assumed that the variables are linearly related to each other.

The equation of the simple linear regression line can be written as:

$$h(x_i) = \beta_0 + \beta_1 x_i$$

where,

$h(x_i)$ is equal to the predicted response value (dependent variable)

b_0 indicated the y-intercept of the line

b_1 represents the slope of the regression line.

where,

$$\beta_1 = \frac{SS_{xy}}{SS_{xx}} \qquad \beta_0 = \bar{y} - \beta_1 \bar{x}$$

Where,

SS_{xy} = sum of cross-deviations of y and x: $SS_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) = \sum_{i=1}^{n} {x_i}^2 - n\bar{x}\bar{y}$

SS_{xx} = sum of squared deviations of x: $SS_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})^2 = \sum_{i=1}^{n} {x_i}^2 - n(\bar{x})^2$

The regression method has been used by Sellam and Poovammal [6] for the prediction of crop yield.

2.3 Time Series Analysis

Time series analysis is a statistical approach for analysing and finding meaningful statistical inferences from time series/dependent data. This method is being used for data-based research on agriculture quite often. Kurumatani [5] used this method to analyse the agricultural product prices. Time series data means that the data is in a series of periods or intervals. It can also be used to study and analyse how the changes are related to the chosen data point is compared to shifts in the other variables over the same period. Time series forecasting is a model that is used to predict future values based on previously observed values.

2.4 Exponential Smoothing

Exponential smoothing is a method used to predict the value of the next period based on the past and the current values [4]. It is performed by doing the averaging of data such that the non-systematic components of each observation cancel out each other. Due to the unreliability of predicted long-term forecasts using this technique, this method is better used to predict short-term forecasts.

The formula is: $\mathbf{S_t = \alpha y_{t-1} + (1-\alpha)\, S_{t-1}}$

Where,

α = the smoothing constant (0 - 1)

t = period

S_t = smoothed value of period t

3. RESULTS AND DISCUSSIONS

The wheat production was analyzed from the year 1950-51 to 2023-24 [1]. For this analysis, the year 1950-51 has been considered as year 1951, and correspondingly, all other years have been considered for calculation. The data is provided in Table 3.1.

Table-3.1 Year-wise Wheat Production in India (in million tons)

Year	Production	Year	Production	Year	Production	Year	Production	Year	Production
1951	6.46	1966	10.4	1981	36.31	1996	62.1	2011	86.87
1952	6.18	1967	11.39	1982	37.45	1997	69.35	2012	94.88
1953	7.5	1968	16.54	1983	42.79	1998	66.35	2013	93.51
1954	8.02	1969	18.65	1984	45.48	1999	71.29	2014	95.85
1955	9.04	1970	20.09	1985	44.07	2000	76.37	2015	86.53
1956	8.76	1971	23.83	1986	47.05	2001	69.68	2016	92.29
1957	9.4	1972	26.41	1987	44.32	2002	72.77	2017	98.51
1958	7.99	1973	24.74	1988	46.17	2003	65.76	2018	99.87
1959	9.96	1974	21.78	1989	54.11	2004	72.16	2019	103.6

1960	10.32	1975	24.1	1990	49.85	2005	68.64	2020	107.86
1961	11	1976	28.84	1991	55.14	2006	69.35	2021	109.59
1962	12.07	1977	29.01	1992	55.69	2007	75.81	2022	107.74
1963	10.78	1978	31.75	1993	57.21	2008	78.57	2023	110.55
1964	9.85	1979	35.51	1994	59.84	2009	80.68	2024	113.29
1965	12.26	1980	31.83	1995	65.77	2010	80.8		

This data has been analyzed, and it is clear from Figure 1 that its production is increasing with year, almost monotonically. The growth was constant till the year 1967; thereafter, growth started, which can be considered as an impact of the green revolution. Time series analysis has been applied to the data to predict the production for the year 2025, for which a 95% confidence interval has been calculated. This is shown in Figure 3.1.

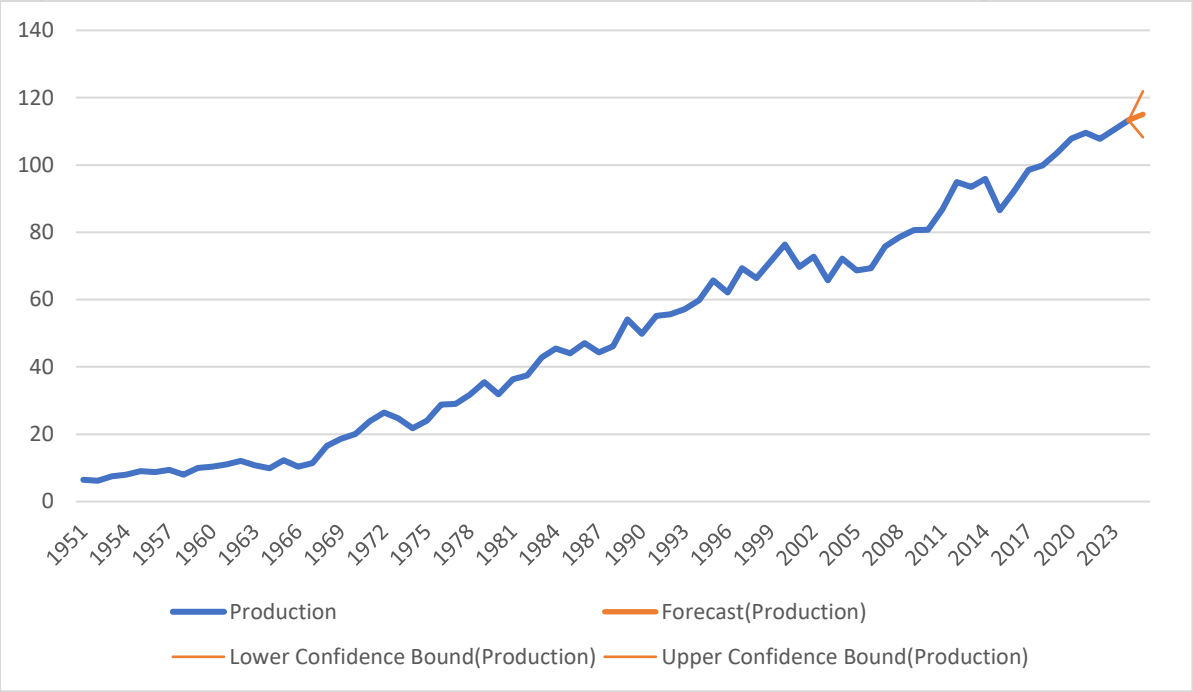

Fig. 3.1 Production of Wheat against Years (1951-2024) with a Prediction for 2025

Predicted value of wheat production in 2025:115.06 million tons. The 95% confidence interval for this forecast is (108.22, 121.90). Further, the agriculture production of rice in India was analyzed from the year 2015 to 2024 [1]. The data has been provided in Table 3.2.

Table-3.2 Year-wise Rice Production in India (in million tons)

Year	Production	Year	Production	Year	Production	Year	Production	Year	Production
1951	20.58	1966	30.59	1981	53.63	1996	76.98	2011	95.98
1952	21.3	1967	30.44	1982	53.25	1997	81.73	2012	105.3
1953	22.9	1968	37.61	1983	47.12	1998	82.54	2013	105.23
1954	28.21	1969	39.76	1984	60.1	1999	86.08	2014	106.65
1955	25.22	1970	40.43	1985	58.34	2000	89.68	2015	105.48
1956	27.56	1971	42.22	1986	63.83	2001	84.98	2016	104.41
1957	29.04	1972	43.07	1987	60.56	2002	93.34	2017	109.7

1958	25.53	1973	39.24	1988	56.86	2003	71.82	2018	112.76
1959	30.85	1974	44.05	1989	70.49	2004	88.53	2019	116.48
1960	31.68	1975	39.58	1990	73.57	2005	83.13	2020	118.87
1961	34.58	1976	48.74	1991	74.29	2006	91.79	2021	124.37
1962	35.66	1977	41.92	1992	74.68	2007	93.36	2022	129.47
1963	33.21	1978	52.67	1993	72.86	2008	96.69	2023	135.76
1964	37	1979	53.77	1994	80.3	2009	99.18	2024	137.83
1965	39.31	1980	42.33	1995	81.81	2010	89.09		

As per the analysis of the data and Figure 2, rice production has been very fluctuating, though growing with the years. An increasing trend is visible post the green revolution. Due to this fluctuating nature, the prediction for the year 2025 is showing lower than that year 2024. As per the prediction in the graph, the production in 2025 will be 137.60 million tons compared to 137.83 million tons recorded in the year 2024. A 95% confidence interval is also shown in the figure.

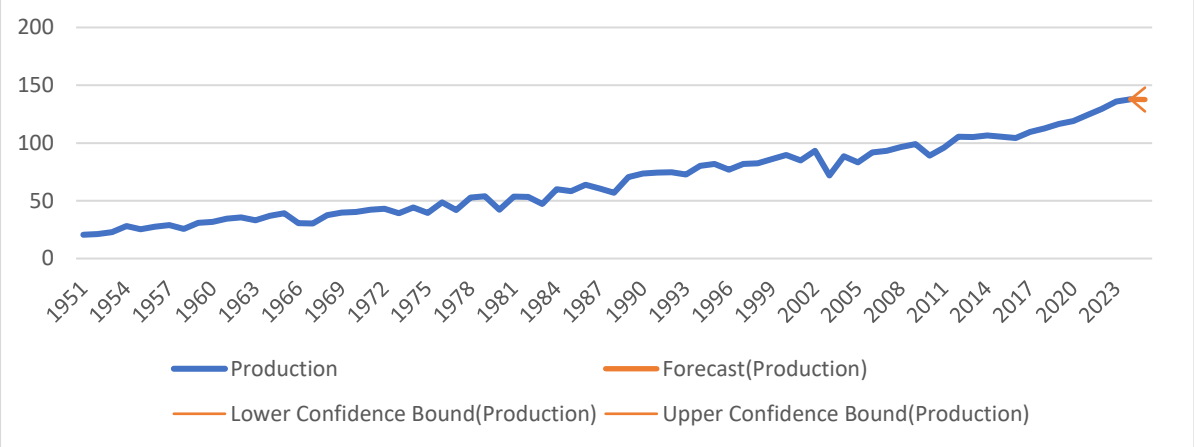

Fig. 3.2 Production of Rice against Years (1951-2024) with a Prediction for 2025

Predicted value of wheat production in 2025:137.60 million tons. The 95% confidence interval for this forecast is (127.34, 147.87). Regression analysis to study the association of the production of rice and wheat provided the line of regression as follows:

$$Wheat\ Production = 1.03 * Rice\ Production - 19.05$$

This is strongly fitted to a line, which is evident from the regression plot provided in Figure 3.3.

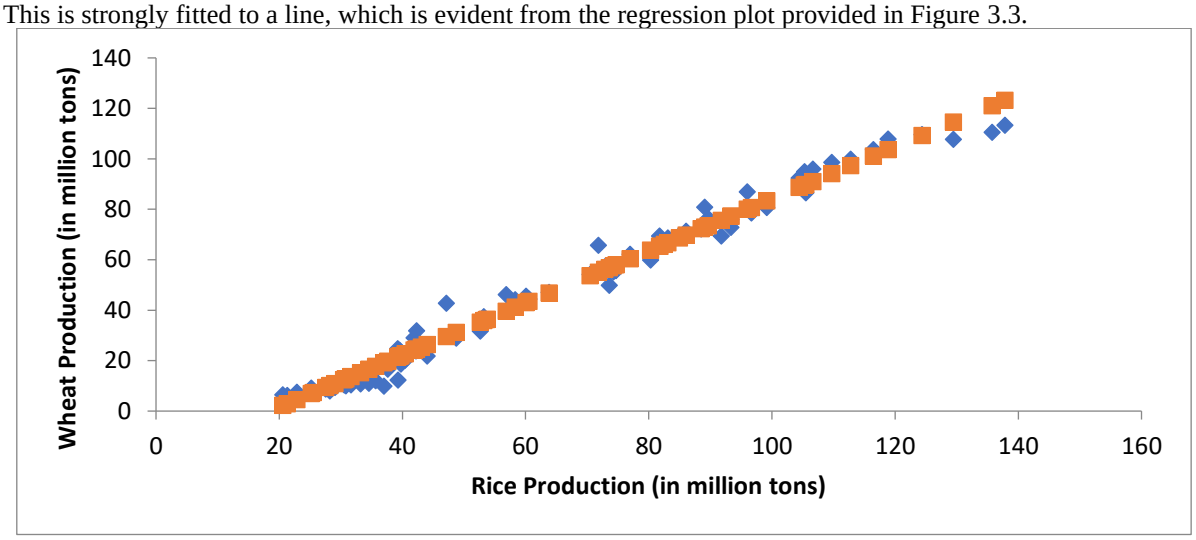

Fig. 3.3 The Production of Wheat and Rice

CONCLUSION

In India, the Green Revolution has helped in achieving self-sufficiency in food production. There is a significant growth in the wheat production as well as the production of rice. However, variation in rice production across the years is an area of concern. A study is needed to look into the factors for this behaviour of the data. This is also concluded that the growth seems to be saturated now, and technological interventions are needed to maintain this growth to cater to the needs of the increasing population.

A strong association between the production of rice and wheat is reasonable, though data indicates that if we can control the fluctuating behaviour of rice production, the wheat production will certainly grow similarly. This way, a focus on increasing rice production consistently is recommended from this study.

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