Assessment of Growth and Trend Pattern of Rice Crop Production in Selected States of India

ABSTRACT
In the present paper, the time series analysis of rice production in some selected states of India has been carried out by fitting statistical models, viz. linear, exponential and cubic models. The secondary time series data on the production of rice have been utilized for the analysis. The trend values have been evaluated by fitting the concerned models, and the validity of the models has been tested by using the Chi-square test statistic. Moreover, the coefficient of determination (R^2), root mean square error (RMSE), and relative mean absolute percentage error (RMAPE) have been computed to reveal the suitability of the concerned models for exploring the trend patterns of rice production in the concerned states of India.

Keywords: *Linear model, Exponential model, Cubic model, Chi-square test, Coefficient of determination*.

1. Introduction

Rice (Oryza sativa L.) is an important and widely consumed staple food crop in the Poaceae family and its native is South India. is commonly grown in the foothills of the far Eastern Himalayas. Rice is rich in Carbohydrates, source of protein and it contains various vitamins, such as thiamin, niacin and minerals. (as per: IRRI). India is the second largest producer of rice in the world with 127.93 million tons produced in the year 2021-22. (Ministry of Agriculture and Farmers Welfare). Ready to eat products are popped and puffed rice flakes, canned rice and fermented products.

In India, the leading state in the production of rice is West Bengal (16.65 million tons), followed by Uttar Pradesh (15.66 million tons), Punjab (12.18 million tons), and other including Odisha (8.77 million tons), Andhra Pradesh (7.89 million tons). In India, the overall Production of Rice was 122.27 million tons, and the Rice yield was 2713 kg per hectare during the year 2020-21 as per: https://agriwelfare.gov.in/en/Agricultural_Statistics_at_a_Glance.

A bundle of research works have been carried out by several scientists and researchers for exploring the importance and usefulness of rice; for instance, Mishra *et al.* (2021) provided a complete review of the nutritional properties and benefits of the rice, nutritional sake of rice have been analyzed and utilized Satellite remote sensing for crop yield estimation by Biswas and Bhattacharyya (2013), utilized ARIMA time series model to forecast the area and production of rice in West Bengal. Kumari *et al.* (2014) developed an exponential smoothing models for forecasting the Productivity of rice in India. G. Ramakrishna and R. Vijaya kumari (2018), estimated the rice production in India by using ARIMA and SAS. Several academic disciplines, such as agriculture, economics, meteorology, statistics and others, depend on time series analysis. For instance, a time series analysis can be used to study the long-term trends in the area, production and productivity of several crops and to forecast the future values. For obtaining a precise predicted trend value a sufficient model should be fitted to time series data. The different models used for measuring the trend value in time series data are the linear model, exponential model, cubic model, and so on. The time series analysis of agricultural crops is almost importance for effective inventory and storage management of the crops so that they can be optimally utilized and minimized the loss.

Chicco *et al.* (2021) estimated the coefficient of determination, root mean square error and mean absolute percentage error in regression analysis evaluation. Sharma *et al.* (2013) investigated the growth and trend of pulse production in India using linear, semi-log functions. Rajarathinam *et al.* (2010) inspected the area, production and productivity trends, and growth rates of tobacco (Nicotiana tabacum) crops based on the parametric and non-parametric regression models. Tripathi *et al.* (2014) estimated the area, production and productivity of rice in Odisha state of India, by utilizing univariate ARIMA models and the models' performances were verified by comparing them with the percentage deviation from the actual values and mean absolute percent error (MAPE). Some other noteworthy contributions towards time series analysis of crops have been made by Sari *et al.* (2010), Miah M.M. (2019), Parimalarangan R. (2020), Sunandini *et al.* (2020), Joshi *et al.* (2021), Kumar and Menon (2022), Paudel *et al.* (2022), Rana and Kumar (2022), Kumar *et al.* (2024), Kumar *et al.* (2024) and Kumar *et al.* (2024)

The objective of the present study is to examine the growth and trend patterns of rice production in various states of India. For the present analysis, secondary time series data is utilized, and trend values have been obtained by fitting linear, exponential and cubic models to the concerned data. Moreover, the validity of the models has been evaluated using Chi-square (χ^2) test of "Goodness of Fit". The accuracy of the concerned models has been evaluated using coefficient of determination (R^2), root mean square error (RMSE) and relative mean absolute percentage error (RMAPE).

2. Data and Methodology

2.1 Source of Data

For the purpose of present study, we have described the importance of Rice crop, for this study we have collect secondary data according to production of rice for three states of

India *viz.*, Punjab, Andra Pradesh and Uttar Pradesh. During 2011 to 2020 as per: https://agriwelfare.gov.in/en/Agricultural_Statistics_at_a_Glance.

2.2 Terminologies and Notations

In India, the country consists of a total of 28 states, which exhibit various growth patterns of rice production, viz. (i) increasing growth pattern, (ii) decreasing growth pattern, (iii) constant growth pattern. For the present analysis, we have considered three states: Punjab (S1), Andhra Pradesh (S2) and Uttar Pradesh (S3). In these states, we observe the various above-mentioned cases of growth pattern.

2.3 Fitting of Statistical Models to the Data

In order to study the trend and growth patterns of rice production in the states S1, S2, and S3, we compute the trend values by fitting linear, exponential and cubic models to the concerned time series data on rice production as follows:

(a) Linear Model:

$$y_t = a + bt \ldots (1)$$

where y_t denotes the time series value at time t.The values of constants 'a' and 'b' are obtained on using the principle of least squares by solving the following normal equations:

$$\sum y_t = na + b\sum t \ldots (2)$$

$$\sum ty_t = a\sum t + b\sum t^2 \ldots (3)$$

where 'n' represents the number of observed values.

(b) Exponential Model:

$$y_t = ae^{bt} \ldots (4)$$

Taking natural log on both sides of above equation, we have

$$log_e\, y_t = log_e\, a + bt\, log_e\, e$$

$$\text{i.e., } Y_t = A + bt \quad \ldots (5)$$

$$\text{where } Y_t = log_e y_t\,,\ A = log_e\, a\,, \text{ and } log_e\, e = 1$$

The normal equations for estimating the values of 'A' and 'b' are as follows:

$$\sum Y_t = nA + b\sum t \ldots (6)$$

$$\sum tY_t = A\sum t + b\sum t^2 \ldots (7)$$

Finally, the value of 'a' is obtained on using

$$a = antilog\ (A)$$

(c) Cubic Model:

$$y_t = \mathrm{a} + \mathrm{bt} + \mathrm{c}t^2 + \mathrm{dt}^3 \ldots (8)$$

The values of constants 'a', 'b', 'c' and 'd' are obtained on solving the following normal equations**.**

$$\sum y_t = na + b\ \sum t + c\ \sum t^2 + \mathrm{d}\ \sum t^3 \ldots (9)$$

$$\sum ty_t = a \sum t + b \sum t^2 + c \sum t^3 + d \sum t^4 \ldots (10)$$

$$\sum t^2 y_t = a \sum t^2 + b \sum t^3 + c \sum t^4 + d \sum t^5 \ldots (11)$$

$$\sum t^3 y_t = a \sum t^3 + b \sum t^4 + c \sum t^5 + d \sum t^6 \ldots (12)$$

3. Data Analysis and Results

The secondary time series data on the rice production in the states S1, S2 and S3, is depicted in Table 1. Also, the trend values on fitting linear, exponential and cubic models to the data pertaining to states S1, S2 and S3 are computed and presented in Tables 2, 3 and 4, respectively. Moreover, the model equations for linear, exponential and cubic trends in the respective states are depicted in Table 5.

Table 1: Time series data on rice production in selected states of India

Year	***Production (in million tons) for the states**		
	S1	**S2**	**S3**
2011	10.54	12.9	14.02
2012	11.37	11.51	14.42
2013	11.27	12.72	14.64
2014	11.11	7.23	12.17
2015	11.82	7.49	12.5
2016	11.59	7.45	13.75
2017	13.28	8.17	13.27
2018	12.82	8.23	15.55
2019	11.78	8.66	15.52
2020	12.18	7.89	15.66

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

Table 2: Trend values for linear, exponential and cubic models in state S1

Year (t)	**Production (y_t)**	**Trend Values**		
		Linear Model (L_t)	**Exponential Model (E_t)**	**Cubic model (C_t)**
2011	10.54	10.91	10.52	10.80
2012	11.37	11.10	10.69	10.88
2013	11.27	11.29	10.87	11.13
2014	11.11	11.48	11.05	11.47
2015	11.82	11.68	11.23	11.85
2016	11.59	11.87	11.42	12.20
2017	13.28	12.06	11.61	12.45

2018	12.82	12.25	11.80	12.54
2019	11.78	12.44	11.99	12.41
2020	12.18	12.63	12.19	11.99

Table 3: Trend values for linear, exponential and cubic models in state S2

Year (t)	Production (y_t)	Trend Values		
		Linear Model (L_t)	Exponential Model (E_t)	Cubic Model (C_t)
2011	12.9	11.53	8.58	13.47
2012	11.51	11.02	8.16	11.53
2013	12.72	10.50	7.76	10.04
2014	7.23	9.99	7.38	8.97
2015	7.49	9.48	7.02	8.26
2016	7.45	8.96	6.68	7.87
2017	8.17	8.45	6.36	7.73
2018	8.23	7.94	6.04	7.82
2019	8.66	7.42	5.75	8.07
2020	7.89	6.91	5.47	8.44

Table 4: Trend values for linear, exponential and cubic models in state S3

Year (t)	Production (y_t)	Trend Values		
		Linear Model (L_t)	Exponential Model (E_t)	Cubic Model (C_t)
2011	14.02	13.28	13.80	14.62
2012	14.42	13.48	13.98	13.83
2013	14.64	13.67	14.17	13.35
2014	12.17	13.86	14.35	13.16
2015	12.5	14.05	14.54	13.21
2016	13.75	14.24	14.74	13.48
2017	13.27	14.43	14.93	13.93
2018	15.55	14.62	15.13	14.54
2019	15.52	14.81	15.33	15.26
2020	15.66	15.01	15.53	16.08

Table 5: Model equations for linear, exponential and cubic trends in selected states of India

States	Linear Model	Exponential Model	Cubic Model
S1	$y_t = 11.87 + 0.19t$	$y_t = 5\text{E} - 14e^{0.016t}$	$y_t = 12.2 + 0.31t - 0.05t^2 - 0.01t^3$
S2	$y_t = 8.96 - 0.51t$	$y_t = 4\text{E} + 44e^{-0.05t}$	$y_t = 7.87 + 0.25t + 0.13t^2 - 0.008t^3$
S3	$y_t = 14.24 + 0.19t$	$y_t = 5\text{E} - 11e^{0.013t}$	$y_t = 13.48 + 0.36t + 0.09t^2 - 0.005t^3$

In Tables 2, 3 and 4, the term 'y_t' denotes the observed value of rice production (in million tonnes) at time t ($t = 2011,\ 2012, \ldots, 2020$), '$L_t$'denotes the linear trend value of rice production at time t, 'E_t'denotes the exponential trend value of rice production at time t, 'C_t'denotes the cubic trend value of rice production at time t.

In order to illustrate the relative influence of linear, exponential and cubic trend values on the observed values of rice production for the states S1, S2, and S3, the graphical plots are obtained and demonstrated in figures 1 to.9.

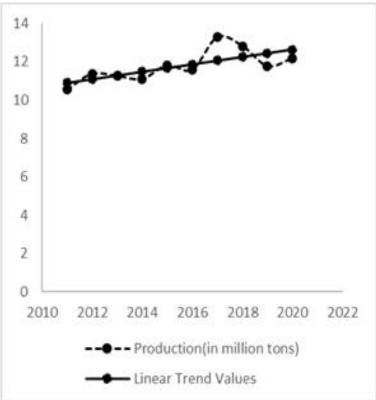	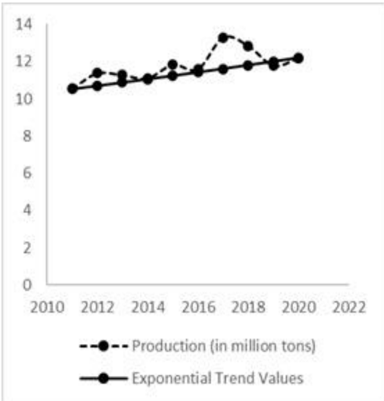	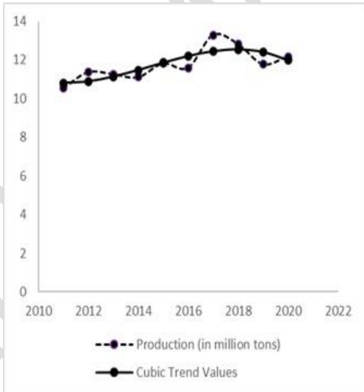
Fig. 1: Trend values for Linear Model in state S1	**Fig. 2:** Trend values for Exponential Model in state S1	**Fig. 3:** Trend values for Cubic Model in state S1

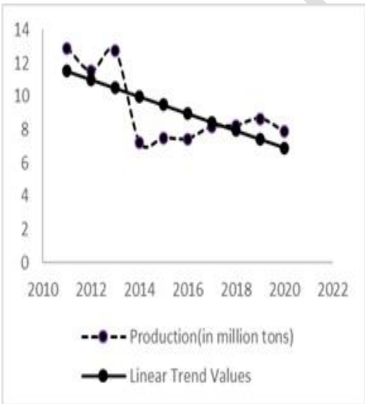	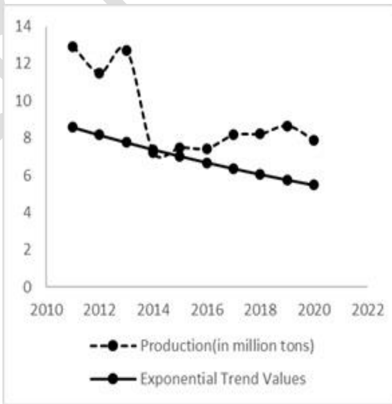	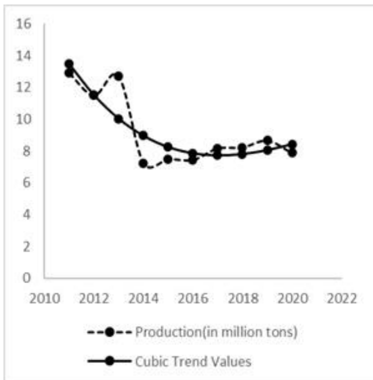
Fig. 4: Trend values for Linear Model in state S2	**Fig. 5:** Trend values for Exponential Model in state S2	**Fig. 6:** Trend values for Cubic Model in state S2

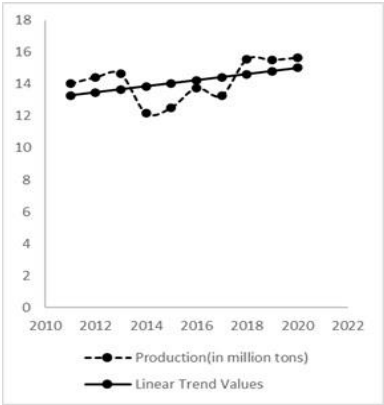	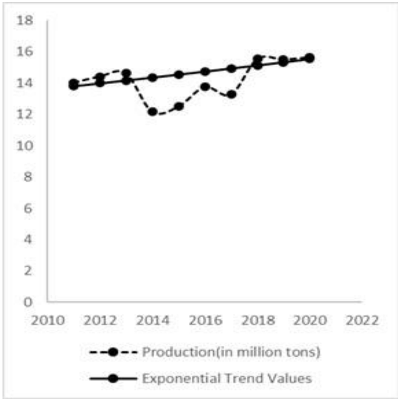	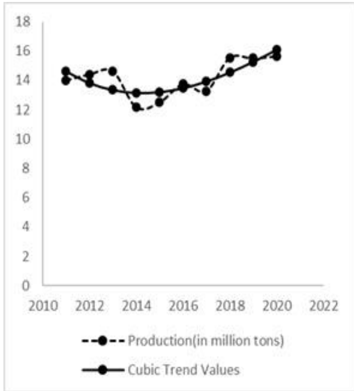
Fig. 7: Trend values for Linear Model in state S3	**Fig. 8:** Trend values for Exponential Model in state S3	**Fig. 9:** Trend values for Cubic Model in state S3

In order to test the suitability of various fitted models, we have computed the coefficient of determination (R^2), Root Mean Square Error (RMSE) and Relative Mean Absolute Percentage Error (RMAPE) for the selected states, by using the following formulae:

$$R^2 = 1 - \frac{\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}{\sum_{t=1}^{n}(y_t - \bar{y})^2}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}$$

and

$$RMAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100$$

where y_t denotes the observed value of rice production (Y), and $\bar{y}$ is the mean value of the variable Y. Also, $\hat{y}_t$ is the trend value of the variable Y, which is obtained on fitting the respective statistical model (such as linear or exponential or cubic model, as the case may be) to the variable Y.

The values of R^2, RMSE and RMAPE for the concerned states are obtained on fitting linear, exponential and cubic models and presented in Table 6.

Table 6: Model evaluation for rice production in selected states of India

States	Models	R^2	RMSE	RMAPE
S1	Linear	0.51	0.54	3.61
	Exponential	0.50	0.70	3.89
	Cubic	0.66	0.45	3.21
S2	Linear	0.48	1.53	15.19

	Exponential	0.52	2.78	23.28
	Cubic	0.73	1.11	8.98
S3	Linear	0.22	1.05	7.17
	Exponential	0.22	1.16	6.66
	Cubic	0.60	0.75	4.88

From Table 6, the following results are obtained:

i) In each of the three states S1, S2 and S3, the values of R^2 are more for the cubic model as compared to the linear and exponential models. Moreover, the values of R^2 are nearly the same for the both linear and exponential models in each state.

ii) In all the three states S1, S2 and S3, the values of RMSE are least for cubic model as compared to the linear and exponential models. Furthermore, the values of RMSE are nearly the same for the both linear and exponential models in state S1 and S3.

iii) In the states S1, S2 and S3, the values of MAPE are least for cubic model as compared to the linear and exponential models. Furthermore, the values of MAPE are nearly the same for the both linear and exponential models in state S1 and S3.

iv) On the basis of values of R^2, RMSE and MAPE, we conclude that the cubic model is the best fitted model, as compared to the linear and exponential models, for analyzing the growth and trend pattern of rice production in concerned states of India.

3.1 Formulation of Hypotheses

We test the following null hypotheses:

H_{0L}: Linear model fits the given data on the rice production.

H_{0E}: Exponential model fits the given data on the rice production.

H_{0C}: Cubic Polynomial model fits the given data on the rice production.

against the following respective alternative hypotheses:

H_{1L}: Linear model does not fit the given data on the rice production.

H_{1E}: Exponential model does not fit the given data on the rice production.

H_{1C}: Cubic Polynomial model does not fit the given data on the rice production.

The above-mentioned hypotheses for model fitting on rice production are tested using chi-square test statistic, in the concerned states S1, S2 and S3 of India.

3.2 Hypotheses Testing and Validation

The chi-square values have been computed for the linear, exponential and cubic models (i.e., χ_L^2 , χ_E^2 and χ_C^2) in the concerned states of India, and the findings are depicted in Table 7. The chi-square values, on fitting the concerned models, have been obtained using the following formulae:

$$\chi_L^2 = \sum_{t=1}^{n} \frac{(y_t - L_t)^2}{L_t} = \sum_{t=1}^{10} \frac{(y_t - L_t)^2}{L_t},$$
$$\chi_E^2 = \sum_{t=1}^{n} \frac{(y_t - E_t)^2}{E_t} = \sum_{t=1}^{10} \frac{(y_t - E_t)^2}{E_t},$$
$$\chi_C^2 = \sum_{t=1}^{n} \frac{(y_t - C_t)^2}{C_t} = \sum_{t=1}^{10} \frac{(y_t - C_t)^2}{C_t},$$

where the terms 'y_t', 'L_t', 'E_t' and 'C_t' have been utilized from the Tables 2, 3 and 4, for the concerned states S1, S2 and S3 of India.

Table 7: Values of chi-square statistic on fitting linear, exponential and cubic models

States	Chi-square values		
	Linear Model (χ_L^2)	**Exponential Model (χ_E^2)**	**Cubic Model (χ_C^2)**
S1	0.24	0.42	0.16
S2	2.45	10.64	1.29
S3	0.78	0.92	0.40

The tabulated values of chi-square (χ^2) at 1% and 5% levels of significance with 9 degrees of freedom are given, respectively, by

$$\chi^2_{0.01,9} = 21.67 \text{ and } \chi^2_{0.05,9} = 16.92$$

From Table 7, the following results are obtained:

(i) $\chi^2_{L(S_i)} < \chi^2_{0.01,9}$ and $\chi^2_{L(S_i)} < \chi^2_{0.05,9}$ $(i = 1,2,3)$

(ii) $\chi^2_{E(S_i)} < \chi^2_{0.01,9}$ and $\chi^2_{E(S_i)} < \chi^2_{0.05,9}$ $(i = 1,2,3)$

(iii) $\chi^2_{C(S_i)} < \chi^2_{0.01,9}$ and $\chi^2_{C(S_i)} < \chi^2_{0.05,9}$ $(i = 1,2,3)$

Hence, on the basis of above results, the null hypotheses H_{0L}, H_{0E} and H_{0C} are accepted at 1% and 5% levels of significance. So, we conclude that the linear, exponential and cubic models fit the given time series data on rice production for the concerned states S1, S2 and S3 of India.

4. Discussion and Conclusion

The present paper deals with time series analysis of rice production in some selected states of India. The secondary time series data on rice production pertaining to the period (2011-2020) have been utilized for the analysis. The growth and trend patterns of rice production have been examined by fitting well-known statistical models, viz. linear model, exponential model and cubic model to the concerned time series data for selected states of India.

It has been observed from the empirical results of section 3 that the cubic model is more precise and suitable, as compared to the linear and exponential models, for exploring the trends of rice production in the concerned states S1 (Punjab), S2 (Andhra Pradesh) and S3 (Uttar Pradesh) of India. The growth patterns of rice production in the states S1 (Punjab) and S2 (Andhra Pradesh) is slightly increasing. Moreover, in the state S3 (Uttar Pradesh), we observe a constant growth pattern of rice production.

In order to test the "Goodness of Fit" of the linear, exponential and cubic models for the states S1, S2 and S3, the chi-square test statistic values (i.e., χ_L^2, χ_E^2 and χ_C^2) have been computed for the respective states. These values are then compared with the tabulated values of chi-square at 1% and 5% levels of significance. It has been observed that all the considered models fit the given time series data on rice production for the concerned states.

The present study could be enhanced further by considering the scenario of rice production in the other states of India. Moreover, on considering the benefits and usefulness of rice, the potential farmers could be encouraged for its cultivation.

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