Computational Framework for Trend Pattern Analysis of Wheat Production in Some Wheat Growing States of India

ABSTRACT

The present study deals withthe trend pattern analysis of wheat production in some wheat growingstates of India on fitting well-known statistical models. The analysis ~~is~~was carried out on utilizing secondary time series data on wheat production. The trend values ~~are~~ were obtainedon fitting the statistical models, and the goodness of fit of the models ~~is~~was tested using chi-square test.~~statistic~~. Furthermore, statistical measures, viz. coefficient of determination(R^2), root mean square error (RMSE), and relative mean absolute percentage error (RMAPE)~~are~~ were computed for revealing the model accuracy.The findings of the studyprovide some useful insights on statistical modeling techniques for forecasting the scenario of wheat production in the concerned states.

Keywords: *Time series; trend values; chi-square test; coefficient of determination; root mean square error.*

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most significant cereal crops, and the second most important staple food crop in India after rice. It belongs to the family*Gramineae* (~~or~~ *Poaceae*) ~~family~~, and is a rich source of carbohydrates, protein, multi-vitamins and other vital nutrients. Wheat is mainly consumed in processed form, for instance, bread, biscuits, cookies, noodles and etc~~e.~~, ~~porridge, pudding, pasta, vermicelli, and so on~~. In India, mostly three species of wheat are cultivated i.e., *Triticum aestivum* (common wheat or bread wheat), *Triticum durum* (~~macroni or~~durum wheat) and *Triticumdicoccum* (emmer wheat).

Formatted: Font: (Default) Times New Roman, 12 pt, Italic

Formatted: Font: (Default) Times New Roman, 12 pt, Italic

Comment [I1]: Used for pasta products

In India, the largest area under coverage of wheat species is *Triticumaestivum*(common wheat or bread wheat), followed by *Triticumdurum*(macaroni or durum wheat) and *Triticumdicoccum*(emmer wheat). The wheat species *Triticum aestivum is* commonly grown in all six agro-climatic zones of the country viz., Northern Hill Zone (NHZ), North West Plain Zone (NWPZ), North East Plain Zone (NEPZ), Central Zone (CZ), Peninsular Zone (PZ) and Southern Hill Zone (SHZ) (Joshi *et al.*[1]).

India is the second largest producer of wheat after China. In India, the leading state in the production of wheat was Uttar Pradesh (35.50 million tons) during the year 2020-21, followed by Madhya Pradesh (17.62 million tons), Punjab (17.14 million tons), Haryana (12.36 million tons), Rajasthan (11.04 million tons), and Bihar (6.34 million tons). In India, the overall production of wheat was 109.52 million tons, and the wheat yield was 3.464 tons per hectare (Source: Directorate of Economics & Statistics, DAC&FW, Govt. of India [2]).

The agriculture sector is deemed to be a significant sector as it contributes towards the economic development of a nation. In recent years, there is a significant rise in food grain production due to noteworthy developments in agriculture sector and evolution of high-yielding variety of seeds. Cheboi and Mungabe [3] conducted an experiment to determine the effect of different pre-treatments on germination of wheat seeds. Oktem and Oktem [4] conducted a field trial experiment using randomized complete block design to determine climatic effects on quality parameters of bread wheat genotypes grown under semi-arid region. Moniruzzaman*et al.* [5] carried out a field experimentation to assess the effects of organic and inorganic nitrogen fertilizers on the growth and yield of wheat. Alemu *et al.* [6] conducted an experiment to identify and promote the best adapted, high yielding, and heat tolerance bread wheat varieties for irrigated areas of different agro-ecology regions.

The time series analysis of agricultural crops is of utmost importance for exploring the long-term trend pattern of the crops, and policy formulation regarding inventory management, price fixation, and transportation of the crops. Considering this fact, the trend analysis of crops has been dealt by various authors. Boken [7] applied time series analysis to forecast yield of spring wheat for Saskatchewan, Canada by using well-known statistical models (viz. linear trend, quadratic trend, simple exponential smoothing, double exponential smoothing, simple moving averaging, and double moving averaging). Arunachalam and Balakrishnan [8] investigated the trends in area, production and productivity of wheat in India by utilizing non-linear as well as non-parametric regression models. Michel and Makowski [9] presented eight statistical models for analyzing wheat yield time series and predicted

Comment [U2]: Mentioned above

Comment [U3]: Also mentioned above

Formatted: Font: (Default) Times New Roman, 12 pt, Italic wheat yield at the national and regional scales, on utilizing data obtained through the Food and Agriculture Organization of the United Nations and the French Ministry of Agriculture. Dasyam*et al.* [10] modeled and forecasted the production of wheat in India by using parametric regression, exponential smoothing and Auto Regressive Integrated Moving Average (ARIMA) models. Ray *et al.* [11] proposed a hybrid model by combining Autoregressive Integrated Moving Average (ARIMA) and Wavelet Neural Network (WNN). Polisetty and Paidipati [12] examined the change point and trend analysis of wheat production in India using non-parametric methods viz. Pettitt's, standard normal homogeneity (SNH) and Buishand's range tests. Yonar*et al.* [13] 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. Rao and Naidu [14] applied various non-linear models to forecast the area, production and productivity of wheat crop in India. Madhukar *et al.* [15] analyzed the temperature and precipitation trends and their impact on wheat yield across 29 Indian states using statistical methods. Some other noteworthy contributions towards time series analysis of crops have been made by Rajarathinam*et al.* [16], Tripathi *et al.* [17], Joshi *et al.* [18], Kumar and Menon [19], Paudel *et al.* [20], and Rana and Kumar [21].

Formatted: Font: (Default) Times New Roman, 12 pt, Italic, Font color: Black

Formatted: Font: (Default) Times New Roman, 12 pt, Italic, Font color: Black

In the presentwork, an attempt ~~is~~was made to explore the trend of wheat production in some selected states of India. The analysis ~~isdone~~ was carried using well-known statistical models viz. linear, exponential and cubic models. The accuracy of the concerned models ~~has been~~was evaluated using coefficient of determination (R^2), root mean square error (RMSE) and relative mean absolute percentage error (RMAPE). Moreover, the validity of models had~~s~~ been examined through chi-square (χ^2) test of "Goodness of Fit".

2. MATERIALS AND METHODS

2.1 Source of Data

The present work dealt~~s~~ with the analysis of secondary time series data on wheat production pertaining to the period (2011-2020) in some selected states of India. The time series data ~~is~~ was obtained from the records of Directorate of Economics & Statistics, DAC&FW~~,~~Govt. of India.

2.2 Terminologies and Notations

In the present studyanalysis, three wheat growing states of India, viz. Uttar Pradesh (S1), Haryana (S2), and Bihar (S3) wereare considered. These states exhibited various trends of wheat production during the concerned period of study.

2.3 Fitting of Statistical Models to the Data

In order to analyze the growth and trend pattern of wheat production in these concerned states S1, S2 and S3, the trend values wereare computed by fitting linear, exponential and cubic models to the time series data on wheat production as follows:

(a) Linear Model:

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

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

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

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

where 'n' represents the number of observed values.

(b) Exponential Model:

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

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

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

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

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

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

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

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

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

Formatted: English (United Kingdom)

$$a = antilog\,(A)$$

(c) Cubic Model:

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

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

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

$$\sum t y_t = a \sum t + b \sum t^2 + c \sum t^3 + d \sum t^4 \ldots\ldots\ldots\ldots \text{(10)}$$

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

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

3. RESULTS AND DISCUSSION

The secondary time series data on wheat production in states S1, S2 and S3 of India is presented in Table 1. The trend values ~~are~~were obtained on fitting linear, exponential and cubic models to the data in the concerned states, and are depicted in Tables 2, 3 and 4, respectively. Moreover, the model equations for linear, exponential and cubic trends in the respective states are elaborated in Table 5.

Table 1. Time series data on wheat production 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)

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	30.29	27.08	29.91	31.80
2012	30.30	27.79	30.61	28.49
2013	30.25	28.50	31.32	26.84
2014	22.42	29.21	32.05	26.54
2015	25.43	29.91	32.80	27.27
2016	30.06	30.62	33.57	28.72
2017	31.88	31.33	34.35	30.59
2018	32.74	32.04	35.16	32.56
2019	33.82	32.75	35.98	34.32
2020	35.50	33.46	36.82	35.56

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	12.68	11.44	10.90	12.54
2012	11.12	11.49	10.95	11.60
2013	11.80	11.55	11.00	11.11
2014	10.35	11.60	11.05	10.96
2015	11.35	11.66	11.11	11.07
2016	11.55	11.71	11.16	11.34

2017	11.16	11.76	11.21	11.69
2018	12.57	11.82	11.27	12.02
2019	11.88	11.87	11.32	12.23
2020	12.36	11.93	11.38	12.25

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	4.79	4.55	5.31	5.16
2012	5.36	4.72	5.47	4.78
2013	5.08	4.89	5.65	4.65
2014	3.99	5.06	5.83	4.71
2015	4.74	5.24	6.02	4.91
2016	5.11	5.41	6.21	5.21
2017	5.74	5.58	6.41	5.55
2018	6.47	5.75	6.61	5.87
2019	5.58	5.92	6.82	6.12
2020	6.34	6.09	7.04	6.25

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

State	Linear Model	Exponential Model	Cubic Model
S1	$y_t = 29.914 + 0.709\,t$	$y_t = 2\text{E} - 19e^{0.0231\,t}$	$y_t = 27.265 + 1.144\,\text{t} + 0.362\,t^2 - 0.052\,t^3$
S2	$y_t = 11.655 + 0.054\,t$	$y_t = 7\text{E} - 4e^{0.0048\,t}$	$y_t = 11.068 + 0.207\,\text{t} + 0.083\,t^2 - 0.015\,t^3$
S3	$y_t = 5.235 + 0.170\,t$	$y_t = 2\text{E} - 27e^{0.0314\,t}$	$y_t = 4.913 + 0.260\,\text{t} + 0.046\,t^2 - 0.009\,t^3$

In Tables 2, 3 and 4, the term ‘y_t’ denotes the observed value of wheat production (in million **tons**) for the year ‘t’ ($t = 2011,\ 2012,\ \ldots\ ,2020$). Moreover, ‘$L_t$’ denotes the linear trend value of wheat production for the year ‘t’. In a similar manner, ‘E_t’ denotes the exponential trend value of wheat production, and ‘C_t’ denotes the cubic trend value of wheat production.

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

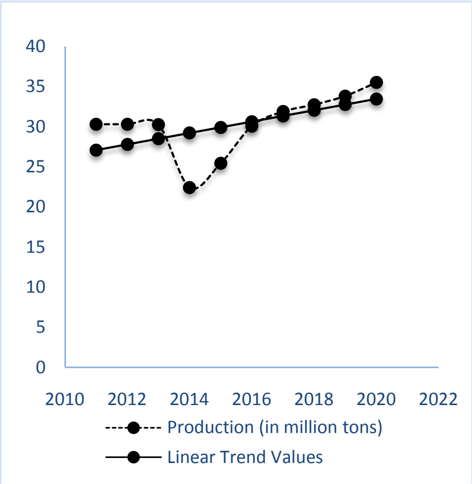

Fig. 1. Trend values for linear model in state S1

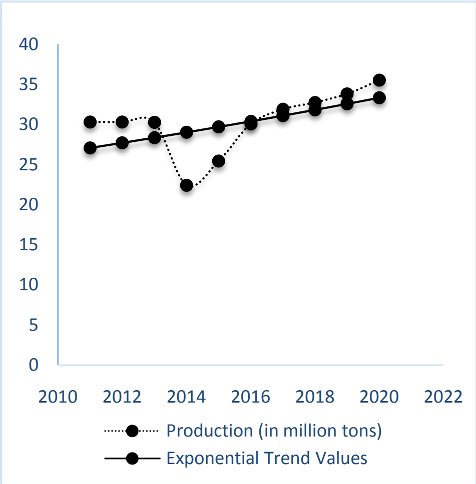

Fig. 2. Trend values for exponential model in state S1

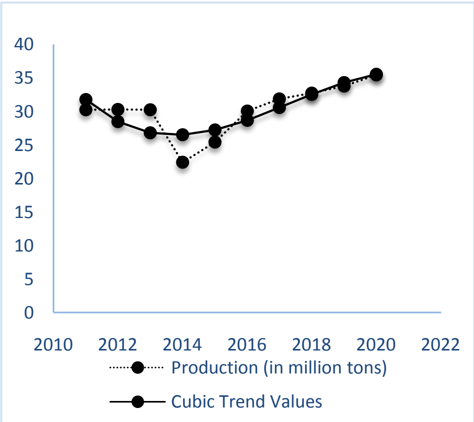

Fig. 3. Trend values for cubic model in state S1

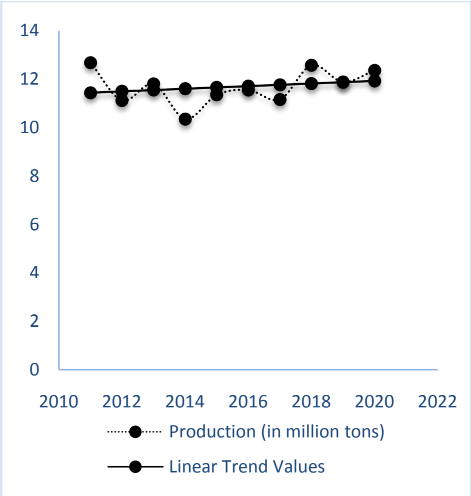

Fig. 4. Trend values for linear model in state S2

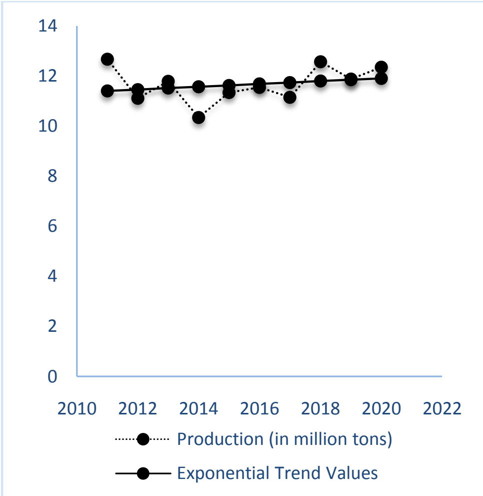

Fig. 5. Trend values for exponential model in state S2

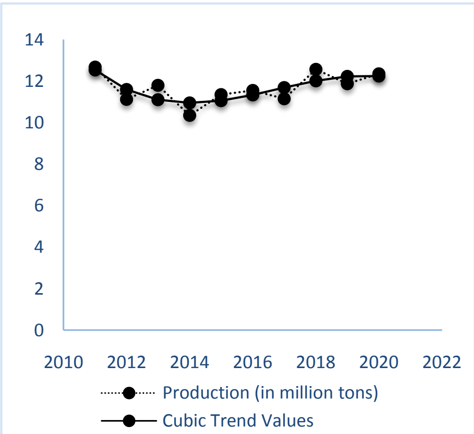

Fig. 6. Trend values for cubic model in state S2

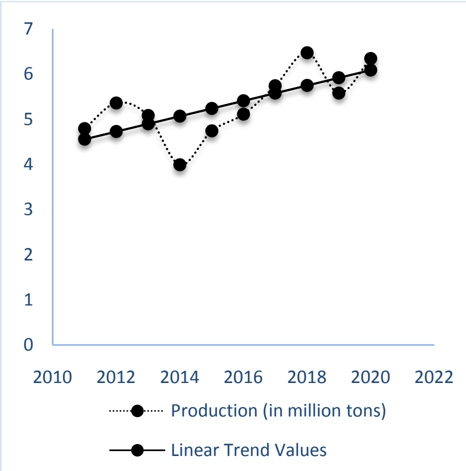

Fig. 7. Trend values for linear model in state S3

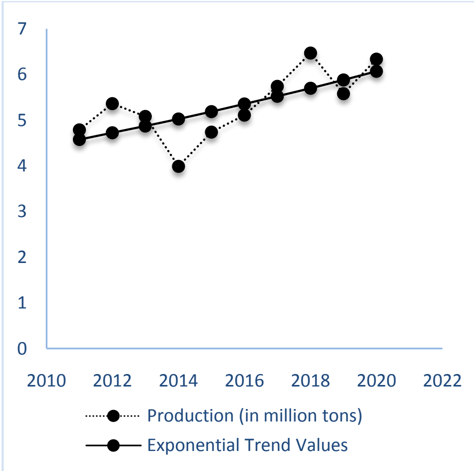

Fig.8: Trend values for exponential model in state S3

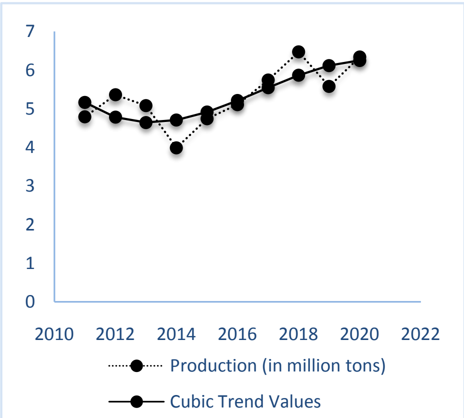

Fig. 9. Trend values for cubic model in state S3

In order to test the suitability of various fitted models, the statistical measures, viz. coefficient of determination (R^2), root mean square error (RMSE) and relative mean absolute percentage error (RMAPE) were~~are~~ computed for the selected states on 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 wheat 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 model, or exponential model, or cubic model, as the case may be) to the variable Y.

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

Table 6. Model evaluation for wheat production in selected states of India

State	Model	R^2	RMSE	RMAPE
S1	Linear	0.31	3.04	8.72
	Exponential	0.33	3.00	8.79
	Cubic	0.69	2.03	5.85
S2	Linear	0.05	0.67	4.64
	Exponential	0.05	0.67	4.62
	Cubic	0.59	0.44	3.45
S3	Linear	0.47	0.52	8.77
	Exponential	0.49	0.51	8.60
	Cubic	0.62	0.44	7.46

~~From~~ Table 6~~,~~ shows the following results ~~are obtained~~:

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

(ii) In each of the three states S1, S2 and S3, ~~we~~it was observed that $R^2 > 0.5$ for the cubic model, whereas $R^2 < 0.5$ for the linear and exponential models. Hence, among all the three models, cubic model ~~is~~was the best fitted model.

(iii) In each state, the values of RMSE ~~are~~were least for cubic model as compared to the linear and exponential models. Furthermore, the values of RMSEwere~~are~~ nearly the same for both the linear and exponential models.

(iv) In each state, the values of RMAPE ~~are~~were least for cubic model as compared to the linear and exponential models. Also, the values of RMAPEwere~~are~~ found approximately the same for both the linear and exponential models.

Since the cubic model attains the least values of RMSE and RMAPE in each state, hence the cubic model is more precise, as compared to the linear and exponential models, for exploring the trends of wheat production in the concerned states.

3.1 Formulation of Hypotheses

~~Wetestt~~The following null hypotheses tested;~~:~~

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

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

H_{0C}: Cubic model fits the data on wheat production.

against the following respective alternative hypotheses;~~:~~

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

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

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

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

3.2 Hypotheses Testing and Validation

The chi-square values had~~ve~~ been computed for the linear, exponential and cubic models (i.e., χ_L^2 , χ_E^2 and χ_C^2,respectively) in the concerned states of India, and the findings are depicted in

Table 7. The chi-square values, on fitting the concerned models, hadve 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 values of the terms 'y_t', 'L_t', 'E_t' and 'C_t' are obtained from Tables 2, 3 and 4, for the concerned states S1, S2 and S3 of India.

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

State	Chi-square values		
	Linear Model (χ_L^2)	Exponential Model (χ_E^2)	Cubic Model (χ_C^2)
S1	3.1593	3.1048	1.5069
S2	0.3921	0.3925	0.1704
S3	0.5216	0.5087	0.3733

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

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

From Table 7, the following results are obtained:

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

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

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

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, it waswe concluded that the linear, exponential and cubic models fit the time series data on wheat production in the concerned states S1, S2 and S3 of India.

Comment [I4]: Add this to the conclusion

4. CONCLUSION

The present study deals with time series analysis of wheat production in some selected states of India, viz. S1 (Uttar Pradesh), S2 (Haryana), and S3 (Bihar). The secondary time series data on wheat production pertaining to the period (2011-2020) have been utilized for the analysis. The growth and trend pattern of wheat production have been examined by fitting some well-known statistical models, viz. linear model, exponential model and cubic model to the time series data in the concerned states. The statesUttar Pradesh(S1) and Bihar(S3) exhibit slight increase in growth pattern of wheat production, whereas the state Haryana(S2) reveals a constant growth pattern of wheat production. Moreover, the production of wheat in the state S1 remains the highest, as compared to the states S2 and S3, during the concerned period.

Comment [I5]: To These are not conclusion

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 time series data on wheat production in the respective states during the concerned period. Hence, the above mentioned models could be effectively utilized for forecasting of future trend of wheat production in the concerned states. Moreover, it has been observed from the results of Table 6 that the cubic model is slightly more appropriate, as compared to the linear and exponential models, for exploring the trends of wheat production in the concerned states.

Comment [I6]: Not conclusion to be delete

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

REFERENCES

1. Joshi, A., Kumar, A. and Kashyap, S. (2020). Genetic analysis of yield and yield contributing traits in bread wheat. *International Journal of Agriculture, Environment and Biotechnology*, 13(2): 119-128.

2. Anonymous (2020). Agricultural Statistics at a Glance. *Directorate of Economics & Statistics, DAC&FW, Government of India.*

3. Cheboi, J.J. and Mungabe, G. (2019). Effects of different pretreatment methods on germination of wheat (*Triticumaestivum*, *Poaceae*). *Asian Journal of Research in Crop Science*, 3(4): 1-5.

4. Oktem, A.G. andOktem, A. (2019). Climatic effects on quality parameters and their relationships of bread wheat genotypes (*Triticum aestivum* L.) grown under semi-arid region. *Asian Journal of Research in Crop Science*, 3(1): 1-11.

5. Moniruzzaman, M., Rabbi, R.H.M., Paul, N.C., Imran, S., Mahamud, M.A., Islam, M.S., Uddin, M.R. and Sarker, U.K. (2022). Influence of organic and inorganic nitrogen on the growth and yield of wheat. *Asian Journal of Research in Crop Science*, 7(4): 103-114.

6. Alemu, Y.A., Liyew, S.Y. andWassie, T.K. (2023). Adaptation and promotion of improved beard wheat (*Triticum aestivum* L.) varieties under irrigation condition in north west Amhara, Ethiopia. *Asian Journal of Research in Crop Science*, 8(4): 361-374.

7. Boken, V.K. (2000). Forecasting spring wheat yield using time series analysis: A case study for the Canadian Prairies. *Agronomy Journal*, 92(6): 1047-1053.

8. Arunachalam, R. and Balakrishnan, V. (2012). Statistical modeling for wheat (*Triticum aestivum*) crop production. *International journal of statistics and applications*,2(4): 40-46.

9. Michel, L. and Makowski, D. (2013). Comparison of statistical models for analyzing wheat yield time series. *PLoS One*, 8(10): 1-11.

10. Dasyam, R., Pal, S., Rao, V.S. and Bhattacharyya, B. (2015). Time series modeling for trend analysis and forecasting wheat production of India. International Journal of Agriculture, Environment and Biotechnology, 8(2): 303-308.

Formatted: Font: (Default) Times New Roman, 12 pt, Italic

Formatted: Font: (Default) Times New Roman, 12 pt, Italic

Formatted: Font: Italic

Formatted: Font: (Default) Times New Roman, 12 pt, Italic

11. Ray, M., Rai, A., Ramasubramanian, V. and Singh, K.N. (2016). ARIMA-WNN hybrid model for forecasting wheat yield time-series data. *Journal of the Indian Society of Agricultural Statistics*, 70(1):63-70.

12. Polisetty, K. and Paidipati, K.K. (2020). Statistical assessment of trend analysis on production of wheat crop over India. *Sarhad Journal of Agriculture*, 36(1): 178-184.

13. Yonar, A., Yonar, H., Mishra, P., Kumari, B., Abotaleb, M. and Badr, A. (2021). Modeling and forecasting of wheat of South Asian region countries and role in food security. *Advances in Computational Intelligence*, 1: 1-8.

14. Rao, S.G. and Naidu, G.M. (2021). Statistical modeling on area, production and productivity of wheat in India. *International Journal of Agricultural & Statistical Sciences*, 17(2): 539-543.

15. Madhukar, A., Kumar, V. and Dashora, K. (2022). Temperature and precipitation are adversely affecting wheat yield in India. *Journal of Water and Climate Change*, 13(4): 1631-1656.

16. Rajarathinam, A., Parmar, R.S. and Vaishnav, P.R. (2010). Estimating models for area, production and productivity trends of Tobacco (*Nicotiana tabacum*) crop for Anand region of Gujarat state, India. *Journal of Applied Sciences*, 10(20): 2419-2425.

17. Tripathi, R., Nayak, A.K., Raja, R., Shahid, M., Kumar, A., Mohanty, S., Panda, B.B., Lal, B. and Gautam, P. (2014). Forecasting rice productivity and production of Odisha, India, using autoregressive integrated moving average models. *Advances in Agriculture*, 2014: 1-9.

18. Joshi, P., Gautam, P. and Wagle, P. (2021). Growth and instability analysis of major crops in Nepal. *Journal of Agriculture and Food Research*, 6: 1-6.

19. Kumar, M. and Menon, S.V. (2022). Statistical modeling and trend analysis of jackfruit production in the districts of Kerala in India. *International Journal of Agriculture, Environment and Biotechnology*, 15(03): 745-752.

20. Paudel, A., Basnet, K.B., Paudel, A., Gurung, B. and Poudel, U., (2022). Trend analysis of area, production, productivity, and supply of potato in Sindhuli district and Nepal: A comparative study. *Malaysian Journal of Sustainable Agriculture,* 6(1): 29-37.

21. Rana, S.K. and Kumar, M. (2022). Growth rate and instability analysis of sugarcane in selected states of India. *International Journal of Agriculture, Environment and Biotechnology*, 15(04): 837-843.