

International Journal of Agriculture Extension and Social Development

Volume 8; Issue 12; December 2025; Page No. 258-262

Received: 11-10-2025
Accepted: 13-11-2025

Indexed Journal
Peer Reviewed Journal

Trend analysis and future projection of wheat crop in India

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DOI: <https://www.doi.org/10.33545/26180723.2025.v8.i12d.2766>

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Abstract

The present study focuses on the future projection of area, production and productivity of wheat crop grown in India. The future projection had been done for five years from 2022-23 to 2026-27. The time series data on area, production and productivity of wheat crop from 1980-81 to 2021-22 for trend estimation and future projection was collected. Different growth models were analysed based on Adj R square value and RMS value and the one having highest Adj R square and lowest RMS was selected. In the particular study, for trend and future prediction, exponential growth model was found best fit for area, production and productivity of wheat crop in India.

Keywords: Trend analysis, future projection, trend estimation, adjusted R square, RMS

Introduction

Wheat (*Triticum aestivum* L.) is the most widely cultivated cereal crop in the world with a total area of 217 million hectares. It is grown all over the world for its highly nutritious qualities and is among one of the top three most produced cereals, along with corn and rice. It is a world-wide staple food grain which cultivated as winter and spring crop in the different regions of the world. The global production of the crop has been reached to 778.6 million metric tons next to maize. The crop is extensively used for human consumption in different forms like chapati, dalia, halwa, upma etc. Along with this, it is consumed in processed form as breads, biscuits, cakes, pastries, noodles etc. It contributes for at least one-fifth of man's calorie intake (Ohiagu *et al.*, 1987) [5]. India is the second largest producer of wheat with a share of around 13.53% of world total production. The area, and productivity of wheat in India were 31.13 million hectare, 109.58 million tonnes and 3521 kg/ha, respectively in 2020-2021. Major portion of the wheat produced in India is used for domestic consumption. India accounts for even less than 1.00% in world wheat export. However, its share has increased from 0.14% in 2016 to 0.54% in 2020 (DGCIS 2021). This is the second most important cereal crop in India after rice. State with the highest area under wheat is Uttar Pradesh (9.85 million hectares) followed by Madhya Pradesh, Punjab and Rajasthan with area 6.08, 3.53 and 3.0 million hectares respectively. These four states constitutes around 41.00% of the country's total acreage. Production wise data reveals that Uttar Pradesh stood at first with production of 35.51 million tonnes followed by Madhya Pradesh (18.18 million tonnes), Punjab (17.17 million hectares) and Haryana (12.39 million tonnes). These states contributes around 76.00% to the

production of the country (GOI 2020-21). State with highest productivity is Punjab (4868 kg/ha). In India wheat crop is cultivated in Rabi season. It is normally sown during November and harvested between March and April. The cultivated area under wheat at national level has shown increasing trend, from 29.07 million hectares (2010-2011) to 31.13 million hectares (2020-21) with a magnitude of 2.06 million hectare (7.08%) net gain in terms of area. The rising minimum support price and government's procurement are the two key factors which led to significant increase in the area under wheat cultivation. Wheat has a significant share in consumption of food basket. It constitutes around 35% share in the total food grains produced in India. Being a major component in public distribution system. It ensures food security. The cereal is one of the cheapest sources of energy, provides a major share of protein (20.00%) and calorie intake (19.00%) from consumption ensuring nutritional security also. With increasing population there is increase in demand for food. Along with this there is growing competition for cultivable land, irrigation water and energy. This has resulted in non-judicious use of resources; reduction of natural resource base; declining total factor productivity posing serious challenges for crop production. Wheat production is facing all these challenges along with climate change also owing to its vulnerability. In this context this study measures the trend in wheat and estimate future projection of area, production and productivity of wheat.

Objectives of the study

The present study is based on the future trend estimation and prediction of area, production and productivity of wheat crop in India

Methodology

This research paper focuses on the future projection of area, production and productivity of wheat crop grown in India. The future projection had been done for five years from 2022-23 to 2026-27. The time series data on area, production and productivity of wheat crop from 1980-81 to 2021-22 for trend and future projection was collected from various published sources, government websites, FAO, etc. By using different growth models trend equations can be fit to describe the behavior of a variable overtime. Following are the different growth models:

Linear function:

In linear model, all parameters should be linear i.e. homogenous of degree one.

Mathematically expression of linear equation

$$Y_t = a + bt$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters 'a' and 'b' can be obtained

Logarithmic function

It shows very rapid growth followed by slower growth. Following are the mathematical expression of the function as follows,

$$Y_t = a + b \log(t)$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters 'a' and 'b' can be obtained

Inverse function

This function shows a decreasing growth and equation of the inverse function are as follows,

$$Y_t = a + b/t$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters 'a' and 'b' can be

Quadratic function

When there is trough or peak in the data of the past period quadratic function is very useful.

Equation of quadratic function as follows,

$$Y_t = a + bt + cT_2$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a , b and c are the parameters

By applying the ordinary least square approach parameters a , b and c can be obtained

Cubic function

When there is two peaks or two troughs in the data of the past period cubic function is useful.

Equation of cubic function as follows,

$$Y_t = a + bt + cT_2 + dT_3$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a , b , c and d are the parameters

By applying the ordinary least square approach parameters can be calculated.

Compound function

When it is known that there is increasing growth or decreasing growth in the past period this function is useful.

Equation of compound function as follows,

$$Y_t = ab^t$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters can be calculated

Power function

Equation of power function as follows,

$$Y_t = at^b$$

$$\text{Or } \ln Y_t = \ln a + b \ln(t)$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters can be calculated

It is similar to exponential fit but produces a forecast curve that increases or decrease at different rates

S-curve

Equation of S – curve as follows,

$$Y_t = \text{Exp}(a + b/t)$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters can be calculated

Growth function

Equation of growth function as follows,

$$Y_t = \text{Exp}(a + bt)$$

$$\text{or } \ln Y_t = a + bt$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters can be calculated Power function:

Exponential fit

If value of 't' arranged in an arithmetic series the corresponding values of Y form a geometric series which is an exponential type of relation.

Equation of exponential fit as follows,

$$Y_t = a \text{Exp}(bt)$$

$$\text{or } \ln Y = \ln a + (bt)$$

Where,

Y_t = trend value (area/production/productivity)

t = time period in years (1, 2, ...n)

a and b are the parameters

By applying the ordinary least square approach parameters can be calculated

Methodology for future projection

Future projection of area, production and productivity of wheat in India up to 2026-2027 AD, estimated by the best fitted growth model used for fitting the trend equation.

Best fitted model

The trend equation used by many researchers is R^2 or adjusted R^2 ($\bar{R}^2$) as the criterion for the model selection;

$$R^2 = \frac{\text{Explained variation}}{\text{Total variation}}$$

$$R^2 = 1 - \frac{\sum_{i=1}^n (Y - \hat{Y})^2}{\sum_{i=1}^n (Y - \bar{Y})^2}$$

$$\text{Adj } R^2 (\bar{R}^2) = R^2 - \frac{K-1}{N-K} (1 - R^2)$$

Where,

K = constant

N = number of observations

To examine the goodness of fit of a model R^2 is not enough in 1978 it was observed by the Reddy, in addition to $\text{Adj } R^2$, the residual mean square which will also measures the accuracy for the forecasting is the best criterion to select a model amongst the alternative available.

The model with least residual mean square (RMS) and significant $\text{Adj } R^2$ will considered to be best suited model in the current analysis.

Results

In the current analysis, ten growth models viz., linear, logarithmic, inverse, quadratic, cubic, compound, power, s-curve, growth and exponential were fitted in the data of area, production and productivity of the wheat crop in Indi. Below, the results are given:

Fitting of different growth models for India

The wheat area in India showed an increasing growth pattern in study period from 1980-81 to 2021-22. The findings achieved are given in table 1 by fitting all the ten growth models. For all models the $\text{Adj } R^2$ was found between -0.017 to 0.272 in case of S function and linear function, respectively. All growth models have significant $\text{Adj } R^2$ with significant level.

Table 1: Growth models for wheat area in India

Models	Adj R^2	RMS
Linear	0.272**	3.619
Logarithmic	0.165**	4.158
Inverse	0.022	4.86
Quadratic	0.268**	3.69
Cubic	0.267*	3.64
Compound	0.091**	0.377
Power	0.039**	0.399
S curve	-0.017	0.422
Growth	0.091**	0.377
Exponential	0.091**	0.377

**significant at 1% level

*significant at 5% level

Out of all growth models shown in table. 1, Linear has the maximum $\text{Adj } R$ square of 0.277 per cent with RMS of (3.619) which is not least residual mean square. So, we reject the linear model for prediction purpose. Now we will further proceed for the prediction and select the best fitted model. Quadratic showed the second highest $\text{Adj } R$ square of 0.268, but again it will be rejected as it is not having the minimum RMS value. By further observation, we found that Compound, growth and exponential function is having the least RMS of value 0.377. Therefore, these three were considered as the best fitted model and we can take any of these as these are having same $\text{Adj } R$ square value also equal to 0.091. Exponential function was taken in the present study.

Table 2: Growth models for wheat production in India

Models	Adj R^2	RMS
Linear	0.0961**	1.74
Logarithmic	0.780**	9.78
Inverse	0.325**	3.00
Quadratic	0.964**	1.61
Cubic	0.970**	1.34
Compound	0.956**	0.004
Power	0.946**	0.011
S curve	0.434**	0.054
Growth	0.956**	0.004
Exponential	0.956**	0.004

**significant at 1% level

For the future projection of wheat in India, the various growth models were used that are shown in table 2. The table depicts that though Cubic function is having highest

Adj R square among all the growth models equal to 0.970 but it was rejected because of not having lowest RMS value. Therefore, we shifted towards exponential function again which is having lowest RMS equal to 0.004. Although same value of Adj R square and RMS is shown by growth and compound model but exponential was taken in the study by choice.

Table 3: Growth models for wheat productivity in India

Models	Adj R ²	RMS
Linear	0.910**	24863.79
Logarithmic	0.824*	48377.00
Inverse	0.387	169001.84
Quadratic	0.912**	24228.83
Cubic	0.932**	18773.11
Compound	0.872**	0.006
Power	0.862*	0.006
S curve	0.447	0.026
Growth	0.872**	0.006
Exponential	0.872**	0.006

**significant at 1% level

*significant at 5% level

In case of future projection of productivity of wheat in India, Cubic model showed highest Adj R square value of 0.932 but it was further rejected for not having the lowest RMS value. The models like linear, quadratic, logarithmic

was having the highest Adj R square values but were failed to give lowest RMS values and hence, they were not selected as the best fit model. Further in this study, compound, growth and exponential function showed the same values in Adj R square and RMS, therefore, by choice, exponential was selected as best fit model.

Future projection of area, production and productivity of wheat crop in India

The predicted values of area, production and productivity of the wheat crop was estimated and is shown in fig. 4.

Year	Area ('000 ha)	Production ('000 tonnes)	Productivity (kg./ha)
2022-23	33924.74	116177.40	3674.44
2023-24	34565.10	119070.90	3737.06
2024-25	35217.55	122036.60	3800.76
2025-26	35882.32	125075.60	3865.54
2026-27	36559.63	128190.70	3931.42

Area under wheat crop, production and productivity in India was projected using exponential function which was found to be best fit. The trend equation was found out using this best fit function and then variables were put in the trend equation shown in graph fig 1,2 and 3, respectively, and then projection was done for the aforementioned years

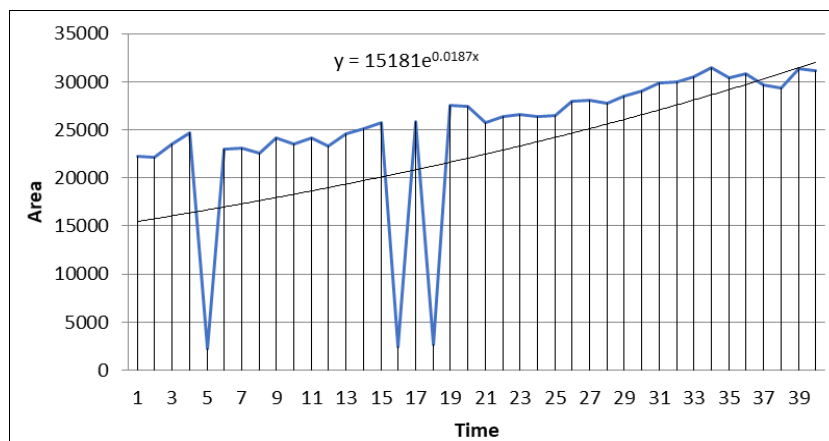


Fig 1: Trend of wheat area in India

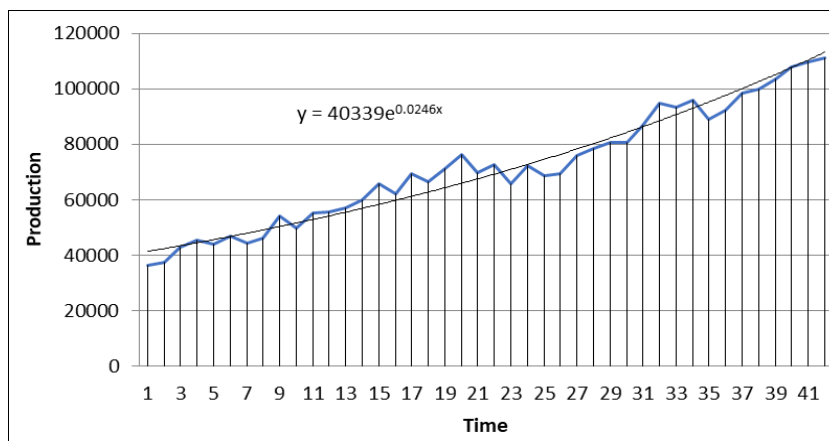


Fig 2: Trend of wheat production in India

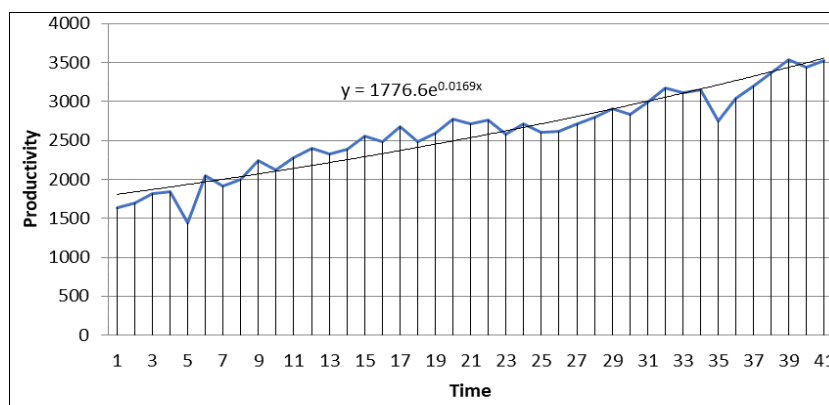


Fig 3: Trend of wheat productivity in India

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