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GROWTH RATE AND TREND ANALYSIS OF WHEAT CROP IN INDIA

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Abstract: *Wheat (Triticum aestivum L.) is one of the most important cereal crops in India and a main source of vitamins and minerals such as thiamine, niacin, iron, riboflavin, vitamin D, calcium, and fiber. Since the consumption of wheat is directly proportional to the population growth. Feeding burgeoning population through the next 25 years remains an uphill task. Increasing domestic demand owing to population growth should meet the future challenges of food and nutritional security. On this prospective for the planning purposes decision to invest accordingly for the short and long-term plans , the present study has been undertaken to evaluate the growth in area, production and productivity of Wheat crop in India by using different growth models. Linear, logarithmic, Inverse, Quadratic, Cubic, Power, compound, Sigmoid, Growth, and Exponential models have been used to find out the best relationship. Adj. R^2 value has been used for selecting the best fitted model.*

Keywords: *Wheat, Growth, Trend, Linear growth rate (LGR), compound growth rate (CGR), Statistical models.*

Introduction: Wheat (*Triticum aestivum L.*) is an important cereal crop in the world under a varied range of climatic conditions. In India, Wheat is grown from 11oN to 30oN latitude and from sea level up to elevation of 3658m in the Himalayas. It is grown in a wide range of temperature and annual rainfall, from sandy loam soil to heavy black cotton clay soils [1].

Wheat is the excellent source of carbohydrates, energy and has no fat. It is wide range of agro-climatic conditions from Kashmir and other mountainous also a good source of vitamins and minerals such as thiamine, niacin, iron, riboflavin, vitamin D, calcium, and fiber. In India Wheat is cultivated under region as well as wet soils in the deltaic coastal areas to arid soils in Rajasthan. It is also grown in the coastal sandy regions in some of the hilly tracts of north. The pace of wheat production has to be maintained accordingly due to fast increasing population of the country [3]. Over 3000 varieties are under cultivation in different parts of the country and these varieties differ in their duration, grain quality and other plant characters viz., water requirement, response to fertilizers, resistance to diseases, drought, alkalinity and salinity etc. the cultivation practices adopted in different part of the country differs as per the agro climatic zones.

India occupies 2nd position in the World Wheat production. In India, Wheat was grown all over the country with an area of 30 million hectares, production of 93.2 million tones and with the productivity of 2980 kg/ha during 2010-11 [3].

Keeping in view of the above discussion, the present study has been undertaken to evaluate the growth in area, production and productivity of Wheat crop in India by using different growth models. Aimed at studying the growth rates of crops for the periods of green revolution (period I: 1960-61 to 1969-70) and post-green revolution (period II: 1970-71 to 1978-79) [4]. Studied the trend in area, production and yield of wheat at the state level in India and the factors responsible for determining yield and acreage of important food grain crops [5]. This study has been undertaken to throw light on the policy decision to invest accordingly for the short and long-term plans and also to provide a direction of research which would bring sustainable development in agriculture.

Materials and Methods

The time series secondary data of area, production and productivity of selected of wheat crop in India at in million hectare, million ton , kilogram/hectare from 1971 to 2010 are extracted from the from the publications of Centre for Monitoring Indian Economy (CMIE), Mumbai. (Fig 1,Fig 2 and Fig 3).

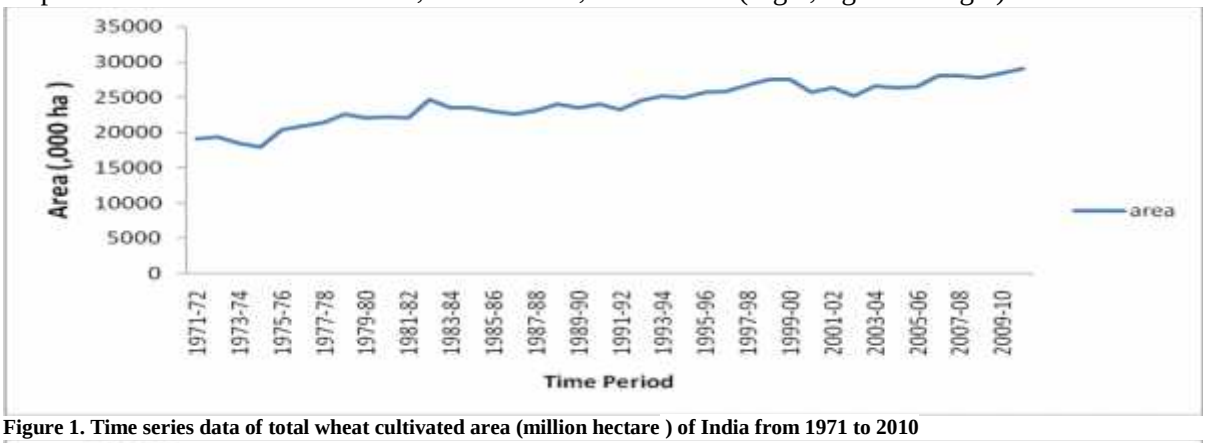

Figure 1. Time series data of total wheat cultivated area (million hectare) of India from 1971 to 2010

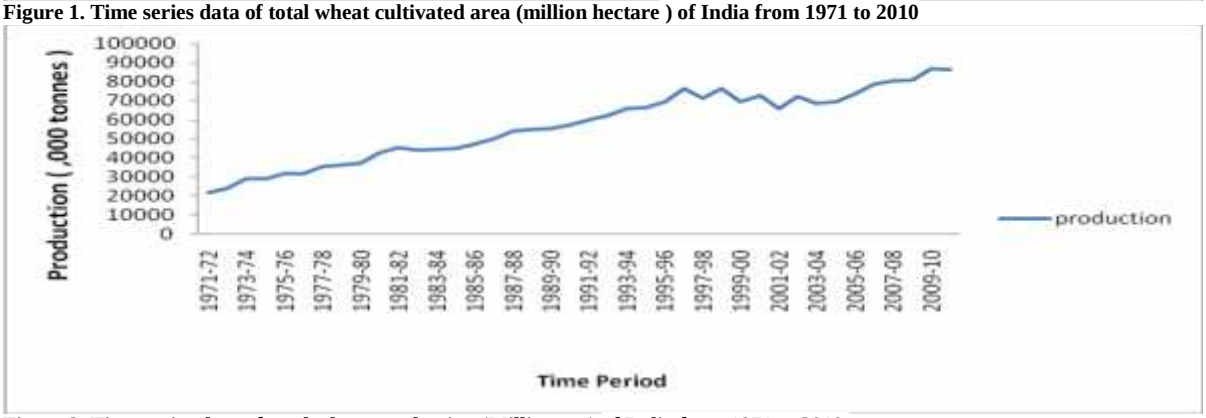

Figure 2. Time series data of total wheat production (Million ton) of India from 1971 to 2010.

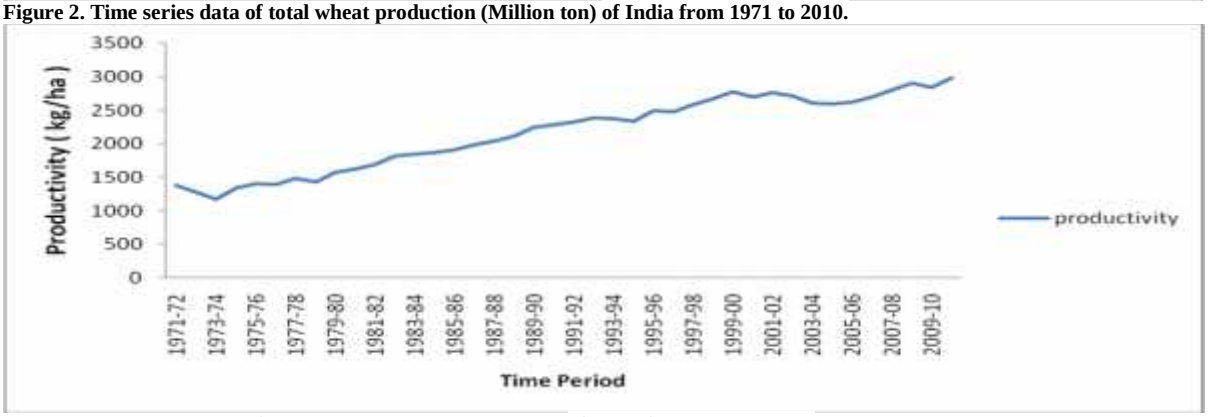

Figure 3. Time series data of total wheat productivity (Kg/ha) of India from 1971 to 2010.

Estimation of Growth Rate: Linear growth rate (LGR) and compound growth rate (CGR) were used for the estimation of growth rates in crop characteristics i.e., area, production and productivity of Wheat crop in India.

Linear Function

Linear function is given by the equation: $Y = a + bt$

Where,

t is the time in years, independent variable
Y is the trend value of the dependent variable
a and b are constants

The above equation is fitted by using the least squares method of estimation.
The linear growth rate is calculated by the formula:

Linear growth rate (LGR %) = $\frac{b}{y}$ x 100

Compound Function

Compound function is given by the equation: $Y = a\ b^t$

or Log y = log a + t log b

Where,

t is the time in years, independent variable

y is the characteristic (area, production or productivity of dependent variable)

a and b are parameters

The 'a' and 'b' are calculated by applying the method of Least Squares .

The compound growth rate : CGR (%) = (b-1) x 100

Fitting the Trend Equations: The trend equations were fitted by using different growth models. Growth models are nothing but the models that describe the behavior of a variable overtime. Linear, logarithmic, Inverse, Quadratic, Cubic, Power, Sigmoid, Growth, and Exponential models have been used in the present study.

Table1. Expressions of Model

Sl.No	Model	Expression
1	Linear	$y = b_0 + b_1 x$
2	Logarithmic	$y = b_0 + b_1 \ln(x)$
3	Inverse	$y = b_0 + \frac{b_1}{x}$
4	Quadratic	$y = b_0 + b_1 x + b_2 x^2$
5	Cubic	$y = b_0 + b_1 x + b_2 x^3 + b_3 x^4$
6	Compound	$y = b_0 b_1^x$
7	Power	$y = b_0 x^{b_1}$
8	Sigmoid (S)	$y = exp^{b_0 + \frac{b_1}{x}}$
9	Growth	$y = exp^{b_0 + b_1 x}$
10	Exponential	$y = b_0 exp^{b_1 x}$

Results and Discussion

The linear growth rates and compound growth rates for the study period of 1971 to 2010 were estimated by fitting the linear function and compound function to the area, production and productivity of Wheat crop, respectively. The models fitted to the time series data of area, production and productivity were linear, logarithmic, inverse, quadratic, cubic, compound, S-curve, growth, power and exponential.

Growth Rates in Area, Production and Productivity of Wheat Crop in India

Growth Rates in Area: It was found that, in India average area under Wheat during the study period (1971 - 2010) was 24.22 million hectares. The coefficient of variation recorded for the study period was 11.71 percent and the linear and compound growth rates recorded during study period were 0.948 and 0.97 percent per annum respectively (Table 2). The area of wheat in India exhibited a positive trend and it was found significant at 1% level of significance.

Table 2. LGR and CGR of India in respect to Area (m ha), Production (m t) and Productivity (kg/ha)

Growth Rate (%)	India		
	Area(m ha)	**Production(m t)**	**Productivity(kg/ha)**
LGR (%)	0.94**	2.92**	2.11**
CGR (%)	0.97**	3.28**	2.28**
CV (%)	11.71	34.28	27.99

Growth Rates in Production: In India the average production during the study period (1971-2010) was 54.02 thousand tonnes with coefficient of variation 34.82. Linear and compound growth rates were 3.92 and 3.28 per cent per annum respectively. The production of wheat in India exhibited a positive trend and it was significant at 1% level of significance (Table 2).

Growth Rates in Productivity: Regarding the productivity of wheat in India during the study period (1971-2010) was 2159.67 kg/hectare. Productivity of India showed a coefficient of variation 27.99 per cent. Linear and Compound growth rate observed were 2.11 and 2.28 per cent respectively. The productivity growth rates of wheat in India exhibit positive trend and it was also significant at 1 % level of significance (Table 2). As a whole, the growth rates of

production were higher than area and productivity.

Fitting of Different Growth Models to Area, Production and Productivity Wheat of Crop in India

Fitting of Different Growth Models to Area: Area of Wheat in India showed a constant growth pattern in the study period of 1971 to 2010. The results obtained by fitting all the ten growth models were presented in Table 3.Adj R^2 values for all the models were 0.895 for linear function, 0.893 for logarithmic function, 0.405 for inverse function, 0.902 for quadratic function, 0.911 for cubic function, 0.875 for compound function, 0.858 for power function, 0.438 for S-curve, 0.873 for growth function, and 0.873 for exponential function, respectively. All the models Adj R^2 values were significant at 1% level of significance. Cubic model was found to be the best for estimation of area of wheat in India with higher AdjR^2 value 0.911.

Table 3. Growth Models for the Area of Wheat in India

Model	b_0	b_1	b_2	b_3	AdjR^2	RMSE
Linear	19510.88	229.74			0.895**	864.33
Logarithmic	16007.83	2977.75			0.893**	1325.52
Inverse	25360.34	-10656.13			0.405**	4793.29
Quadratic	18775.49	334.79	-2.56		0.902**	787.06
Cubic	17892.16	578.42	-17.24	0.24	0.911**	717.20
Compound	19709.30	1.01			0.875**	971.46
Power	16855.32	0.13			0.858**	1089.09
S- curve	10.14	-0.47			0.438**	4435.12
Growth	9.89	0.01			0.873**	971.46
Exponential	19709.30	0.01			0.873**	971.46

Fitting of Different Growth Models to Production: The Production of Wheat in India showed a systematic growth pattern during the study period of 1971 to 2010. The results obtained by fitting all the ten growth models were presented in Table 4. Adj R^2 values among all the models were 0.962 for linear function, 0.819 for logarithmic function, 0.332 for inverse function, 0.966 for quadratic function, 0.966 for cubic function, 0.925 for compound function, 0.888 for power function, 0.411 for S- curve, 0.925 for growth function, and 0.925 for exponential function, respectively. In all the models, Adj R^2 values were significant at 1% level of significance. Cubic model was found to be the best for estimation of area of wheat in India with higher AdjR^2 value 0.966.

Table 4. Growth models for production of Wheat in India

Model	b_0	b_1	b_2	b_3	AdjR^2	RMSE
Linear	21639.123	1579.416			0.962**	1335.44
Logarithmic	95.795	19550.778			0.819**	6400.30
Inverse	60903.874	-64383.802			0.332**	23642.55
Quadratic	18611.058	2011.997	-10.551		0.966**	1200.92
Cubic	20408.445	1516.275	19.306	-0.485	0.966**	1196.30
Compound	25981.997	1.033			0.925**	35.40
Power	15634.555	0.425			0.888**	28.68
S- curve	10.987	-1.485			0.411**	208.04
Growth	10.165	0.032			0.925**	35.40
Exponential	25981.997	0.032			0.925**	35.40

Fitting of Different Growth Models to Productivity: The Productivity of Wheat in India showed an increasing trend during the study period of 1971 to 2010. The results obtained by fitting all the ten growth models were presented in Table 5. Adj R^2 values for all the models were 0.944 for linear function, 0.834 for logarithmic function, 0.342 for inverse function, 0.964 for quadratic function, 0.969 for cubic function, 0.914 for compound function, 0.869 for power function, 0.384 for S- curve, 0.914 for growth function, and 0.914 for exponential function, respectively. In all the models, Adj R^2 values were significant at 1% level of significance. Cubic model was found to be the best for estimation of area of wheat in India with higher AdjR^2 value 0.969.

Table 5. Growth models for productivity of Wheat in India

Model	b_0	b_1	b_2	b_3	AdjR^2	RMSE
Linear	1232.803	45.766			0.944**	169.90
Logarithmic	579.670	576.983			0.834**	501.40
Inverse	2375.091	-1908.041			0.342**	1993.88
Quadratic	1044.012	72.736	-0.658		0.964**	108.17
Cubic	1165.890	39.122	1.367	-3.292E-02	0.969**	93.71
Compound	1318.261	1.023			0.914**	334.82
Power	927.574	.296			0.869**	276.48

S- curve	7.756	-1.012		0.384**	1777.59
Growth	7.184	.023		0.914**	334.82
Exponential	1318.261	.023		0.914**	334.82

Conclusion: The present investigation has been undertaken to evaluate the growth in area, production and productivity of Wheat crop in India. The linear growth rates and compound growth rates for the study period of 1971 to 2010 were estimated by fitting the linear function and compound function to the area, production and productivity of Wheat crop, respectively.

The average area, production and productivity under Wheat in India during the study period were 24.22 million hectares, 54.01 million tonnes and 2171.00 kg/ha respectively and exhibited significantly increasing trend with the linear and compound growth rates of 0.94 and 0.97 per cent, respectively for area and for the production it was 2.92 and 3.28 per cent, respectively. However, the productivity of Wheat exhibited a positive trend with the linear and compound growth rates of 2.11 and 2.28 per cent, respectively.

Among the area, production and productivity in India, the production exhibited higher growth rates with an increasing trend due to increased trend in growth rates of area and productivity. Among the area, production and productivity, the productivity exhibited higher growth rates with an increasing trend due to increased trend in growth rates of area and productivity. On the basis of the AdjR^2 values, cubic model was found to be the best for estimation of area, production and productivity of wheat in India.

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