

Forecasting of Potato Area, Production and Productivity Trends Through Linear and Non Linear Regression Models in India

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Abstract Attempts have been made to identify the best Linear and Non-Linear Regression models to predict the future projections up to 2020 A.D in area, production and productivity of Potato crop in India by utilising the data of 40 years of study period i.e., from 1973-74 to 2012-13. The best fitted model was chosen based on model selection criteria like highest coefficient of determination (R^2), Adjusted R^2 and with least RMS values for the purpose of future predictions up to 2020 A.D. Besides, the important assumption

of randomness of residuals was tested using one sample run test. Compound function was found to be best fitted model for area whereas cubic function for production and productivity of potato crop in India. Growth per annum during study period was studied by compound growth rate. The production of Potato had increased at a rate of 4.7% which was due to combined effect of increase in area and productivity at a rate of 3% and 1.6% per annum, respectively.

Keywords Adjusted R^2 , Future projections, Potato, Trend.

Introduction

Potato popularly known as ‘The king of vegetables’, has emerged as fourth most important food crop in India after rice, wheat and maize. India is the second largest producer of potato after China. India produced 45.34 million tonnes from 1.99 million ha with an average yield of 22.76 tonnes/ha of Potato during 2012-13 [1]. In India the major potato producing state are Uttar Pradesh, West Bengal, Bihar, Madhya Pradesh, Gujarat, and Punjab. Potato is consumed by more than one billion people in the world. It is a high quality vegetable cum food crop. There is a huge potential for processed potato products such as potato flakes, potato powder, frozen potatoes, frozen French fries, potato chips/wafers. It is so far the largest product category within snacks, with 85% of the total market share. India is one of the largest snack markets in the Asia-Pacific region contributing 3% to the total Asia-

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Table 1. Mathematical equations for ten growth models. Where, Y_t is the dependent variable i.e., area, production and productivity, t is the independent variable, time in years, a , b , c and d are the constants.

Sl No.	Growth models	Mathematical equation
1	Linear function	$Y_t = a + bt$
2	Logarithmic function	$Y_t = a + b \ln(t)$
3	Inverse function	$Y_t = a + b/t$
4	Quadratic function	$Y_t = a + bt + ct^2$
5	Cubic function	$Y_t = a+bt+ct^2+dt^3$
6	Compound function	$Y_t = ab^t$ or $\ln Y_t = \ln a + t \ln b$
7	S-curve	$Y_t = \text{Exp}(a+bt)$ or $\ln Y_t = a+bt$
8	Growth function	$Y_t = \text{Exp}(a+bt)$ or $\ln Y_t = a+bt$
9	Power function	$Y_t = at^b$ or $\ln Y_t = \ln a + b \ln(t)$
10	Exponential	$Y_t = a \text{Exp}(bt)$ or $\ln Y_t = \ln a + (bt)$

Pacific snack market share. This huge demand shows the significance of potato in India.

The study aimed to make a long-term forecast analysis on crop production and thus provide the public, researchers, and decision-makers with basal data on crop and to understand possible changes in crop production, make decisions for agricultural management and food commerce.

The objective of the present investigation is to find out the growth rate, to measure the trend and to estimate the future projections by 2019-20 AD in area, production and productivity of Potato crop in India based on ten growth models.

Materials and Methods

The present study was based on secondary data for the period of 40 years from 1973-74 to 2012-13 which were collected from the publications of Directorate of Economics and Statistics (DES) [1], Ministry of Agriculture. The study examines growth rates of area, production and yield of Potato in India by employing Compound Growth Rate (CGR). The compound growth rate (CGR) is estimated by fitting an exponential function $Y = ab^t$, where, Y defines the time series data of area, production and yield of Potato, ' t ' is the trend term, ' a ' is the constant coefficient and ' b ' is the slope coefficient. We can calculate the compound growth rate using the equation: $\text{CGR} (\%) = (b-1) \times$

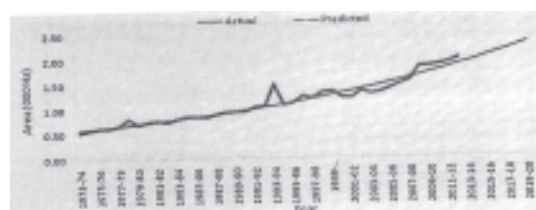


Fig. 1. Trends of potato area in India and projections by 2019-20 AD.

100. The t - test was applied to test the significance of ' b '.

Trend was examined by fitting ten Regression models. Mathematical equations of ten Regression models are shown in Table 1. The constants ' a ', ' b ', ' c ' and ' d ' (Table 1) of mathematical equations are estimated by applying the Ordinary Least Square approach.

The model which showed relatively high significant Adj R^2 with least residual mean square (RMS) was chosen to fit a trend equation. In best fitted model the disturbance term should satisfy the conditions of randomness. The assumption of randomness of residuals is verified by Run test.

The future projections of area, production and productivity of Potato crop in India up to 2020 AD was estimated upon the best fitted growth model which were used for fitting the trend equations.

The growth rates of different crops were studied mostly through Compound growth rate by assuming the exponential functional forms [2, 3]. Some of research workers have used linear and non-linear regression models for measuring trends, which are currently being used by the planners or the policy makers of the country [4]. Test for randomness of the residuals and the estimation of future projections by best fitted model was also used earlier [5, 6].

Results and Discussion

In India during the study period (1973-74 to 2012-13)

Table 2. Growth models for the area of potato in India. **Significant at 1% level, *Significant at 5% level.

Models	a	b	c	d	AdjR ²	RMS	Runs
Linear	0.45	0.03			0.907**	0.02	11
Logarithmic	0.07	0.38			0.682**	0.05	9
Inverse	1.25	-1.23			0.261**	0.12	7
Quadratic	0.59	0.01	0.001		0.929**	0.16	5
Cubic	0.48	0.04	-0.001	3.204E-05	0.937**	0.13	6
Compound	0.57	1.03			0.941**	0.01	14
Power	0.37	0.37			0.816**	0.11	5
S	0.19	-1.3			0.377**	0.01	16
Growth	-0.58	0.03			0.940**	0.04	13
Exponential	0.57	0.03			0.940**	0.01	16

the average area, production and productivity under potato were 1.12 million hectares, 18.8 million tonnes and 15.98 tonnes/ha respectively.

Growth rates in area, production and productivity of potato crop in india

Growth rate analyses are widely employed to study the long-term trends in various agricultural crops. Relative growth rate of area, production and productivity of Potato crop were calculated for years 1973-74 to 2012-13 based on the exponential function. Compound growth rate of Potato during study period for area, production and productivity were recorded as 3%, 4.7% and 1.6% per annum respectively. Those were found to be positive and significant at 1% level of significance. There was a substantial growth in area, production and productivity of potato during the study period.

Fitting of regression models for area, production and productivity of potato in India.

Different linear and non-linear regression models were employed to study the trends in the area, production and productivity data of the potato crop. The findings are discussed in sequence, as follows.

Trends in area

The data presented in Table 2 for the area under the potato crop revealed that among the ten models fitted the maximum adjusted R² of 94.1%, was observed in case of compound function with comparatively lower values of RMS (0.01) in comparison to that of other models. However the run test (test for randomness) value was non-significant indicating that the residuals were independently distributed. All the estimated parameters values were in the 99% confidence

Table 3. Growth models for the production of potato in India. **Significant at 1% level, *Significant at 5% level.

Models	a	b	c	d	AdjR ²	RMS	Runs
Linear	2.13	0.82			0.866**	14.09	9
Logarithmic	-6.83	9.32			0.622**	39.67	9
Inverse	22.04	-29.55			0.228**	80.93	5
Quadratic	7.69	0.02	0.02		0.917**	8.72	12
Cubic	2.66	1.41	-0.06	0.001	0.943**	6.01	7
Compound	6.38	1.04			0.949**	7.39	16
Power	3.24	0.58			0.864**	76.28	5
S	3.03	-2.16			0.447**	7.39	16
Growth	1.85	0.045			0.949**	26.42	11
Exponential	6.38	0.045			0.949**	7.39	16

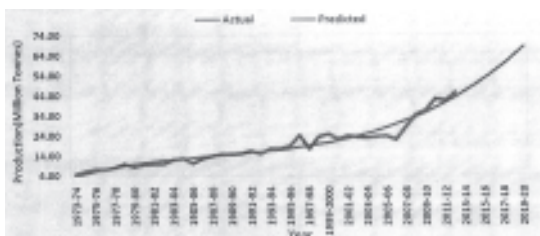


Fig. 2. Trends of potato production in India and projections by 2019-20 AD.

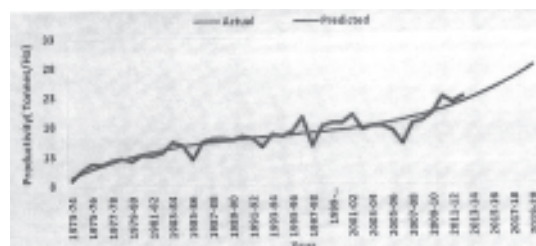


Fig. 3. Trends of potato productivity in India and projections by 2019-20 AD.

interval indicating that the parameter values were significant (Table 2).

$$Y_t = 0.57 * 1.03^t$$

(Adj R² = 94.1%)

The graph of the fitted trend for the area of potato crop using the Compound Model is shown in the Figure 1.

Trends in production

In case of the production of potato crop, the model that had significant adjusted R² of 94.3% with the comparatively lower values of RMS (6.01) among the regression models fitted and with the assumption of randomness of residuals satisfied is cubic model. The run tests test values for cubic model were found non-significant indicating that the residuals due to this model were independently distributed. All the estimated parameter values were in the 99% confidence

interval indicating that the parameter values were significant (Table 3).

$$V_t = 2.66 + 1.41 * t - 0.06 * t^2 + 0.001 * t^3$$

(Adj R² = 94.3%)

The graph of the fitted trend for the production of potato crop using the cubic Model is depicted in the Figure 2.

Trends in productivity

The data presented in Table 4 for productivity of potato crop revealed that among the linear and nonlinear models fitted, the maximum adjusted R² of 83.8% was observed in the case of cubic model with the comparatively lower values of RMS (1.69). All the estimated values of the parameters in the model were found to be within the 99% confidence interval indicating that the parameters were significant at 1% level of significance. The run test (test for randomness)

Table 4. Growth models for the productivity of potato in India. **Significant at 1% level, *Significant at 5% level.

Models	a	b	c	d	AdjR ²	RMS	Runs
Linear	10.87	0.24			0.808**	2.01	18
Logarithmic	7.08	3.22			0.754**	2.56	11
Inverse	17.28	-12.15			0.407**	6.18	7
Quadratic	10.48	0.31	-0.001		0.805**	2.03	18
Cubic	8.64	0.81	-0.032	0.001	0.838**	1.68	14
Compound	11.25	1.02			0.801**	2.14	12
Power	8.54	0.21			0.833**	5.60	9
S	2.84	-0.88			0.524**	2.14	12
Growth	2.42	0.016			0.801**	2.20	15
Exponential	11.25	0.016			0.801**	2.14	14

Table 5. Productions of area, production and productivity of potato in India.

Year	Area (Mha)	Production (Mt)	Productivity (tonnes/ha)
2015-16	2.04	52.62	24.05
2016-17	2.10	56.16	24.91
2017-18	2.17	59.92	25.83
2018-19	2.23	63.93	26.82
2019-20	2.30	68.18	27.89

values were found to be non-significant indicating that the residuals fulfilled model selection criteria. Among the ten growth models, the Cubic model was found suitable to fit the trends in productivity of potato crop.

$$Y_t = 8.64 + 0.81 * t - 0.03 t^2 + 0.001 * t^3$$

(Adj R² = 83.8%)

The graph of the fitted trend for the productivity of potato crop using the cubic Model is depicted in the Figure 3.

Future projections of area, production and productivity of potato crop in India up to 2019-20 AD

The future projections of area, production and productivity of potato crop in India by 2019-20 AD were calculated based upto the best fitted model and the results were presented in the Table 5.

Area under potato in India was projected by using compound function which was found to be best for this purpose as it has high significant Adj R² with least residual mean square and also fulfilled the assumption of randomness of residuals. The area under potato projected by compound function by 2019-20 AD would be 2.30 Million ha which is in increasing trend depicted in Figure 1.

Regarding the production of potato, cubic function was found to be the best model for future projections by 2019-20 AD as it has the high significant Adj R² with least residual mean square, and also satisfied the assumption of randomness of residuals. The projected production would be increasing to 68.18 Mt by

2019-20 AD shown in Figure 2.

Regarding the productivity of potato, cubic function was found to be the best model for future projections by 2019-20 AD as it has the high significant Adj R² with least residual mean square and also satisfied the assumption of randomness of residuals. The projected productivity would be increasing to 27.89 tonnes/ha by 2019-20 AD shown in Figure 3.

Similar studies made by Ramakrishna [5] revealed that the trends in area, production and productivity of rice crop for 40 years (1969–2009) in Andhra Pradesh and found logarithmic model in area and linear model in production and productivity were best fitted models. Those best fitted models were used for future projections by 2014 AD. Rajendra [6] analysed the trends of area, production and productivity of Maize in Telangana for 40 years (1969–2009) and best fitted were compound model in area and production and S-curve in productivity were used for future projections by 2014 AD.

Conclusion

The trend and growth rate of potato area, production and productivity for the period 1973-74 to 2012-13 were analysed and forecasted to the year 2019-20 in India. In India during the study period the average production of potato was 18.8 Million Tonnes from the average area of 1.12 Million Hectares with average productivity 15.9 Tonnes/Ha. Potato production had increased at a rate of 4.7% which was due to combined effect of increase in area and productivity at a rate of 3 and 1.6% per annum respectively. Forecasting in case of area by compound function indicated increasing trend, in case of production and productivity by cubic function also indicated increasing trend. The future projection by 2019-20 AD for area, production and productivity of potato would be 2.3 Mha, 68.18 Mt and 27.89 tonnes/ha respectively.

References

1. Directorate of economics and statistics (DES) (2014) Dep of Agric and Co-operation, Ministry of Agric.
2. Saleem A, Nisar AS, Abdul H, Arshad F, Masood Asif (2014) Growth and trend in area, production and yield

- of major crops of khyber pakhtunkhwa, Pakistan, Asian J Agric and Rural Develop 4 : 149—155.
3. Isah MA, Samuel E, Makama SA, Kiresur VR (2015) Trend of area, production and productivity of major cereals: India and nigeria scenario. Res J Agric and For Sci 3 : 10—15.
 4. Rajarathinam, Vinoth B (2012) Statistical modeling for wheat (*Triticum aestivum*) crop production. Int J Stat and Appl 2 : 40—46.
 5. Ramakrishna G (2013) Temporal variations in area, production and productivity of rice crop in three region of Andhra Pradesh. MSc (Ag) thesis. Acharya N. G. Ranga Agric Univ, Hyderabad, Andhra Pradesh.
 6. Rajendra, Supriya P, Bhave MHV (2012) Growth trends of maize crop in Telangana region of Andhra Pradesh. J Res ANGRAU 40 : 104—107.