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Statistical assessment of chickpea production using nonlinear growth models for northern hills region of Chhattisgarh

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Abstract
This paper deals with a critical study of chickpea yield of Northern Hills Region of Chhattisgarh in Madhya Pradesh state with a non-linear approach. Chickpea is 3rd (FAO, 2008) among the food legumes after beans and pea. More than 50 countries are reported to grow chickpea. Major chickpea producing countries are: India (65% of annual production), Pakistan (10%), Turkey (7%), Iran (3%) and Australia (1.5%) (FAO, 2008). The secondary data of chickpea crop yield during different years is taken into consideration and different statistical models are fitted for that. The time series data on annual yield of chickpea in Northern Hills Region of Chhattisgarh from 1980-81 to 2018-19 were collected from Agricultural Statistics, published by Directorate of Agriculture, Government of Madhya Pradesh, Bhopal and the Basic Agricultural Statistics published by Commissioner, Land Record and Settlement, Gwalior, Madhya Pradesh. Growth rates are computed through non-linear models, viz. Logistic, Gompertz, Monomolecular, Richards and MMF models. The results showed that logistic model performed better followed by monomolecular and Gompertz. The models have been used to forecast yield in the subsequent three years.

Keywords: Forecasting, nonlinear growth model, chickpea production

1. Introduction

Chickpea is one of the oldest legume crops and is consumed widely across the world. Chickpea is 3rd (FAO, 2008) [4] among the food legumes after beans and pea. More than 50 countries are reported to grow chickpea. Major chickpea producing countries are: India (65% of annual production), Pakistan (10%), Turkey (7%), Iran (3%) and Australia (1.5%) (FAO, 2008) [4]. The statistical model is actually a set of equations or equation that reflects the relationship among various variables studied. The relationship among various variables must be studied for the purpose of predicting the values of one or more variables on the basis of observation on other variables. The third most important pulse crop is Chickpea, after peas and dry bean, produced in the world. In India, studies reflect chickpea accounts for around 45% of total pulses grown in the country. Chickpea, is being noticed as the major pulses consumed and cultivated in India. It is noticed as 20% of the pulses production in the whole world. Major producers of chickpea countries include India, Mexico and Pakistan.

A model which is directly proportional to the input is a linear model. In such type of model, all the parameters appear linearly. In comparison to the present, a nonlinear model at least one of the parameters appears nonlinearly. Nonlinear models also play an important role in understanding the complex inter-relationships among different variables. Nonlinear models are more difficult to specify and estimate parameter than linear models. Instead of simply listing exploratory variable, we must write the regression expression, declare parameter names, and guess initial values for them and possibly specific derivatives of the model respects to the parameters. Some models are difficult to fit and there is no guarantee that the procedure will be able to fit the model successfully.

2. Methodology

The study was confined to Agro-climatic zone viz. Northern Hills Region of Chhattisgarh of Madhya Pradesh was selected as the study area for the current work. It is the second largest state of India by area and sixth largest state by population with over 75 million inhabitants. The state is bordered on the east by Chhattisgarh, on the west by Gujarat, on the north-east by Uttar Pradesh, on the north-west by Rajasthan, and on the south by Maharashtra.

2.1 Data acquisition
The study was undertaken secondary sources and the necessary time series data were compiled for the period from 1980-81 to 2018-19. The secondary data on production ('000 Metric Tonne) of chickpea crops in Madhya Pradesh state collected from Agricultural Statistics, published by Directorate of Agriculture, Government of Madhya Pradesh, Bhopal and the Basic Agricultural Statistics published by Commissioner, Land Record and Settlement, Gwalior, Madhya Pradesh.

2.2 Statistical Analysis
Different nonlinear growth models are studied for the purpose of estimating the growth rates and fitting the best model, which help in better future prediction. A SPSS 16.0 version has been used for statistical analysis. The compound growth rates should be computed by first identifying the model that describes satisfactorily the path followed by the response variable over time.

Table 1: Nonlinear growth modes considered in this study

Models	Integral equation form	Source
Logistic Model	$Y_t = \frac{c}{(1+b\exp(-at))} + \varepsilon$	Draper & Smith (1981) [10]
Gompertz Model	$Y_t = c\exp[-b\exp(-at)] + \varepsilon$	Draper & Smith (1981) [10]
Monomolecular Model	$Y_t = c(1-b)\exp(-at) + \varepsilon$	Draper & Smith (1981) [10]
Morgan-Mercer-Flodin	$Y_t = \frac{(a*b+c*t^d)}{(b+t^d)} + \varepsilon$	Seber and Wild (1989) [9], & Morgan, Mercer and Flodin (1975) [11]
Richards Model	$Y_t = \frac{c}{[(1+b\exp(-at))^{\frac{1}{d}}]} + \varepsilon$	Ratkowskay (1983) [8]
Weibull Model	$Y_t = c - b\exp(-at^d) + \varepsilon$	Ratkowskay (1983) [8] & Seber and Wild (1989) [9]

In table Y_t represents the dependent variable (area, production and productivity) at time t; a, b, c, d are parameters and ε denotes the error term. The parameter 'a' is the 'intrinsic growth rates', while the parameter 'c' represents the 'carrying capacity'. For the third parameter, although the same symbol 'b' was used, yet this represented different functions of the 'initial value' Y(0) for different models and 'd' is the added parameter (Prajneshu and Das, 2000) [12]

2.3 Goodness of Fit
The use of Coefficient of Determination (R^2), Mean Square Error (MSE), MAE, Correlation coefficient and Root Mean Square Error (RMSE) statistics as a measure of goodness of fit and, therefore, as a criterion for choosing the best model

2.4 Examination of data
The main assumption of 'independence' and 'normality' of error term were examined by using respectively the 'Run test' and 'Shapiro-Wilk test'. It may be mentioned that none of these assumption was violated for any data set and model combination considered in this study

Prior to applying any modelling or predictive techniques, the analyst is to examine the data using a variety of techniques amongst which is visual inspection of various plots which can be obtained prior to processing. Two important assumptions made in the model are

a) Errors are randomly distributed (Run test for randomness) and
b) Errors are normally distributed (Shapiro-Wilk Test)

3. Results and Discussion
3.1 Nonlinear statistical models for chickpea production in Northern Hills Region of Chhattisgarh
The non-linear models, viz Logistic, Gompertz, monomolecular, Richards, MMF and Weibull models were applied for chickpea production in Norther Hills region of Chhattisgarh. Based on performance of these fits, best non-linear models were chosen for the selected series. In the first instance, attempts were made to identify the model that best described this crop yield data set. Parameters employed examination of residuals and goodness of fit statistics for all models have been shown in Table 2. Study revealed that the series had upward trends with fluctuation in quantity produced in Northern Hills Region of Chhattisgarh. It is evident, from the analysis, production of chickpea is fluctuating and all six models are not suitable to fit. The initialization of parameters done using Ratkowsky method and the results are compared using statistics such as R^2, RMSE, MSE, MAE and correlation coefficient r (Y, $\hat{Y}$). The Logistic, Gompertz and monomolecular models have almost same R^2 value (Table 2), i.e. all the goodness of fit statistics almost same.

Statistical Package for Social Science (SPSS 16.0) software package was employed for data analysis. The annual growth rates for all the models were computed and has been given in the Table 2. Evaluation of residuals using run test and Shapiro- Wilk test shows that residuals are chosen at random and the normality assumptions are not violated in any of the models. However, on the basis of various goodness of fit criteria, we are able to restrict our search for the best model in a particular situation to one or two models. So in comparison of existing model, monomolecular or Logistic or Gompertz model may be considered for explanation of the chickpea production of Northern Hills Region of Chhattisgarh. Residual plots of all the fitted models are presented in Fig. 1. Weibull model was least performed than other models.

3.2 Estimation of forecast for chickpea production
Based on the performance of model fit and goodness of fit criteria, one best nonlinear model was chosen for future projection of chickpea production in Northern Hills Region of Chhattisgarh. As depicted in Table 2, monomolecular model fitted very well to chickpea production data in view of the low goodness of criteria values and highest R^2. Thus, monomolecular model may be selected as the best model for describing the chickpea production trends. The identified monomolecular model was utilized for forecasting the chickpea production from 2020-21 to 2022-23, and forecasted values are exhibited in Table 3. Forecasting of chickpea

production in Northern Hills Region of Chhattisgarh on the basis of monomolecular model was found to be 45.38 ('000 MT) and 46.10 ('000 MT) in 2020-21 and 2022-23 respectively. Figure 1 shows the plotted residual of fitted nonlinear models. If the error plot showed that the errors have a homogenous variance then the models are adequate to model the data. The plot showed that the residual are distributed along the zero line and we can conclude that the residual from the fitted models are normally distributed. The scattered plot of the errors is important in deciding whether the residual values are uniformly distributed, there is no systematic trend of the residual values or the variance is consistent or not.

Table 2: Fitting of various models to Chickpea production data for Northern Hills Region of Chhattisgarh

Parameter	Logistic	Gompertz	Monomolecular	MMF	Richards
a	0.01	0.00	2.39	21.38	0.05
b	9.946	8.78	0.91	0.50	5.149
c	2.997	1.967	38.00	38.10	1.707
d	-	-	-	-	-
Examination of residuals					
Run Test	3.21	3.21	3.21	1.86	1.86
Shapiro-wilk test	0.80	0.79	0.77	0.66	0.70
Goodness of Fit Statistics					
R^2	0.32	0.33	0.44	0.21	0.14
RMSE	29.88	25.47	24.03	25.08	29.81
MSE	225.57	307.78	161.94	292.28	123.79
MAE	32.00	29.09	25.01	37.00	33.00
$r(Y, \hat{Y})$	0.28	0.23	0.48	0.32	0.21

Table 3: Computation of future forecast for Chhattisgarh Plains

Year	Production ('000 MT)		
	Monomolecular forecast	Confidence Interval (95%)	
		Lower	Upper
2020-21	45.38	29.38	61.38
2021-22	45.74	29.14	62.34
2022-23	46.1	28.9	63.3

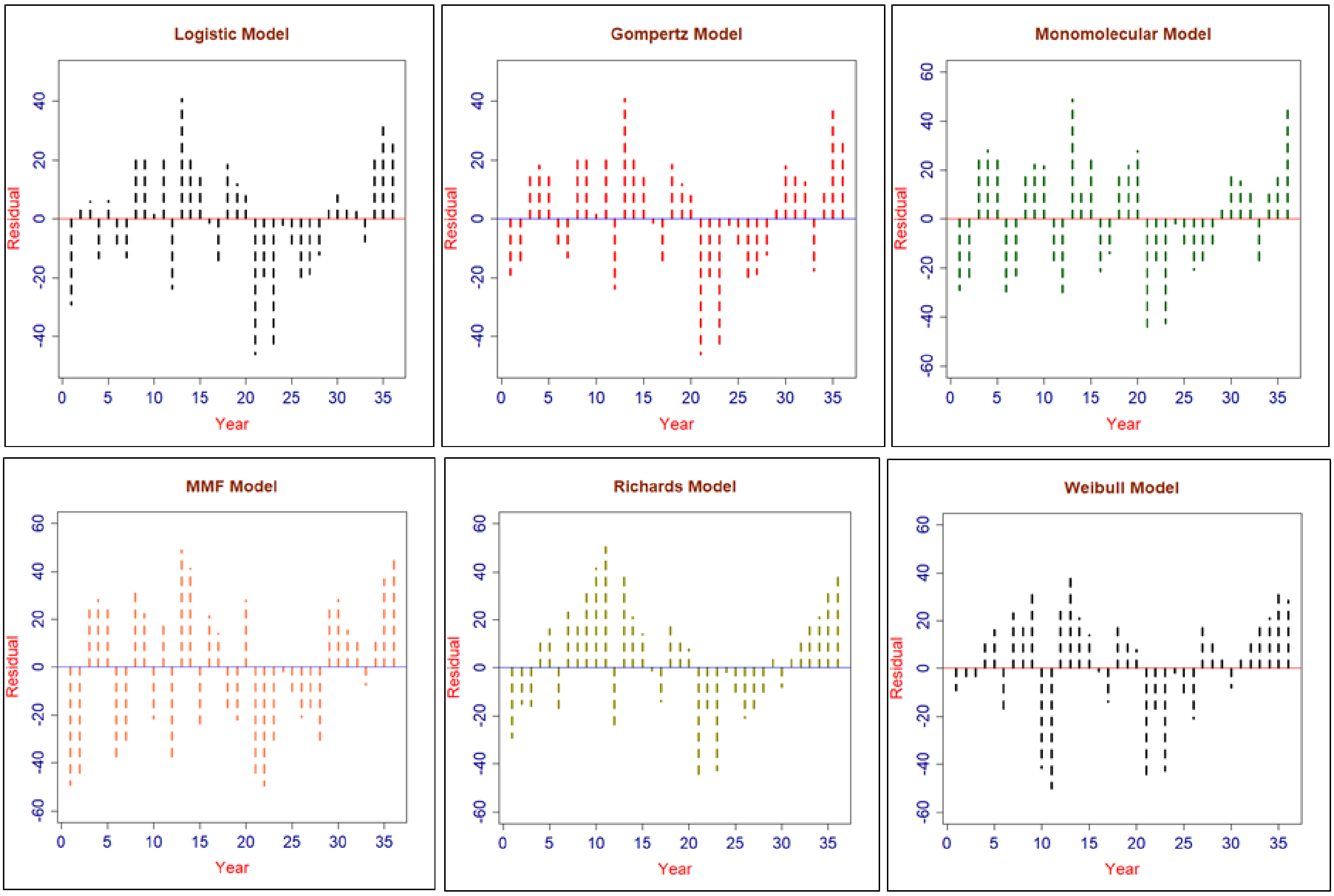

Fig 1: Residual plot of the fitted models to chickpea production of Northern Hills Region of Chhattisgarh

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