



Wheat production modelling in Madhya Pradesh using nonlinear statistical growth models

*D.P. Singh, *S. S. Gautam and **R. R. Saxena

*MGCGV, Chitrakoot, Satna (M.P.) India

**Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) India

Abstract: To develop appropriate nonlinear statistical models with a view to provide analytical approach to describe the wheat production trend in Madhya Pradesh. For time series data pertaining to production of wheat for the period of 36 years (i.e. 1980-81 to 2015-16) collected from various secondary sources. Specific objectives of the study are; to find out suitable nonlinear statistical model(s) for production of wheat crop for Madhya Pradesh State. Some important non linear models viz. Logistic Gompertz, Monomolecular and Richard model have been employed for analysis and selected best model for Madhya Pradesh state based on various goodness of fit criteria viz. Coefficient of determination (R^2), Mean absolute error (MAE), and Root mean square Error (RMSE).

Key words: Non linear growth model, goodness of fit, wheat production

I. Introduction

Growth model methodology has been widely used in the modelling of crop growth. Since growth of living things are normally nonlinear in nature [1], it is reasonable to explore the use of nonlinear growth model to wheat yield. The problem in modelling wheat yield growth is that it does not follow a linear model. It is normally follows the nonlinear growth curve. With the increase in the number of independent variables, modelling a nonlinear curve becomes more complex. This causes the model to be more inaccurate. Agriculture in India is a way of life, a tradition which for countries has shared the thought, the outlook, the cultural and the economic life of the people of India. Agriculture, therefore, is and will continue to be central to all strategies for planned socio-economic development of the country. Rapid growth of agriculture is essential not only to achieve self reliance at national level but also for household for security.

The usual parametric approach for growth rate analysis is to assume multiplicative error in the underlying nonlinear geometric model and then fit the linearized model by 'method of least squares'. The available data of wheat during different years is taken into consideration and different statistical models are fitted for that. The nonlinear models, viz. Logistic, Gompertz, Monomolecular and Richard's models are applied for wheat of Madhya Pradesh, a comparative study, growth rate, forecasting was conducted for these models.

II. Materials and Method

We studied the some important nonlinear statistical growth models, examination of residuals and goodness of fit criterion. The growth models viz; Monomolecular, Logistic Gompertz and Richards's model considered for study the trends of wheat production ('000 MT) in Madhya Pradesh state which would be able to describe the path of production of crop and also to forecast future production. The secondary data collected from various secondary sources i.e. Department of Agriculture and Commissioner Land Record and Settlement, Government of Madhya Pradesh for the period of 1980-81 to 2015-16.

Table 1: Nonlinear models considered in this study

Model	Integral equation Form	Source
Logistic	$Y_t = \frac{c}{(1 + b \exp(-at))} + e$	[2]
Gompertz	$Y_t = c \exp(-b \exp(-at)) + e$	[2]
Monomolecular	$Y_t = c(1 - b \exp(-at)) + e$	[2]
Richard's	$Y_t = \frac{c}{[1 + b (\exp(-at))^{1/d}] + e}$	[3]

Examination of Residuals: The next important step is to see whether the assumptions made regarding the error term are valid or not. This is being done by examining residuals. Residuals are the differences between what is actually observed, and what is predicted by the fitted model i.e. the amount which is unexplained by the model. Two important assumptions made in the model are:

1. Errors are randomly distributed and (run test)
2. Errors are normally distributed. (Shapiro-Wilk Test)

Goodness of Fit: An important question that arises when a modeler wants to develop model is that of how a specified model fits the given data set [4]. There is a need for statistics which will help us to test the goodness of fit comparison among different competing models.

1. **Root Mean Square Error (RMSE):**

$$RMSE = \sqrt{\frac{\sum (Y_i - \hat{Y})^2}{n}}$$

2. **Mean Absolute Error (MAE):**

$$MAE = \frac{\sum |Y_i - \hat{Y}|}{n}$$

The smaller the value of errors, the better is the model.

III. Results and Discussion

Four model viz., Monomolecular, Logistic, Gompertz and Richard's model are considered for studying wheat production in Madhya Pradesh state and also for developing an appropriate nonlinear statistical growth model which would be able to describe the path of wheat production and also forecast future production. Initial parameters values are required for fitting of these models. Initial estimates of the parameter are obtained by different methods. Goodness of fit statistics viz., RMSE, MAE is computed using MS-Excel. The result of fitting various model are presented in Table 2.

Nonlinear statistical models for Wheat Production

The models were diagnosed using error analysis. The error analysis is performed to analyze the difference between the error value and the estimated value of observation [5]. 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. The error plot showed that the errors have a homogenous variance then the models are adequate to model the data.

All the four models are fitted well to the wheat production data. The least square estimates of the parameters of the nonlinear models for wheat production and time relationship are given in Table 2. Examination of residuals using run test and Shapiro-Wilk test shows that residuals are random and the normality assumptions are not violated in all the models [6].

As not much variation is observed among the models in respect to R^2 , RMSE and MAE are presented in Table 2. R^2 value of Logistic and Gompertz model is high (0.699) as compared to rest of the model. As not much variation is observed among the models in respect to RMSE, and MAE are concerned (Table 2). Hence, Gompertz and Logistic model may be considered for explain the wheat production of Madhya Pradesh state. The actual and fitted value of wheat production data presented in Fig. 1.

Table 2 Fitting of various model to wheat production data for M.P.

Parameter	Monomolecular	Logistic	Gompertz	Richard's
a	0.00013	0.00031	131.12	-0.0052
b	1.470	1.114	9746.5	-0.311
c	2796.42	2967.32	372	3230.31
d	-	-	-	7.060
Examination of Residual				
No. of Run	17	17	15	13
Sapiro-Wilk test	-1.89	-1.89	-1.82	-2.51
Goodness of Fit Statistics				
R²	0.650	0.699	0.699	0.551
RMSE	912.54	780.83	867.07	1021.83
MAE	687.33	667.45	651.57	796.24

Figure 1: Actual and fitted value for wheat production ('000 MT) of M.P.

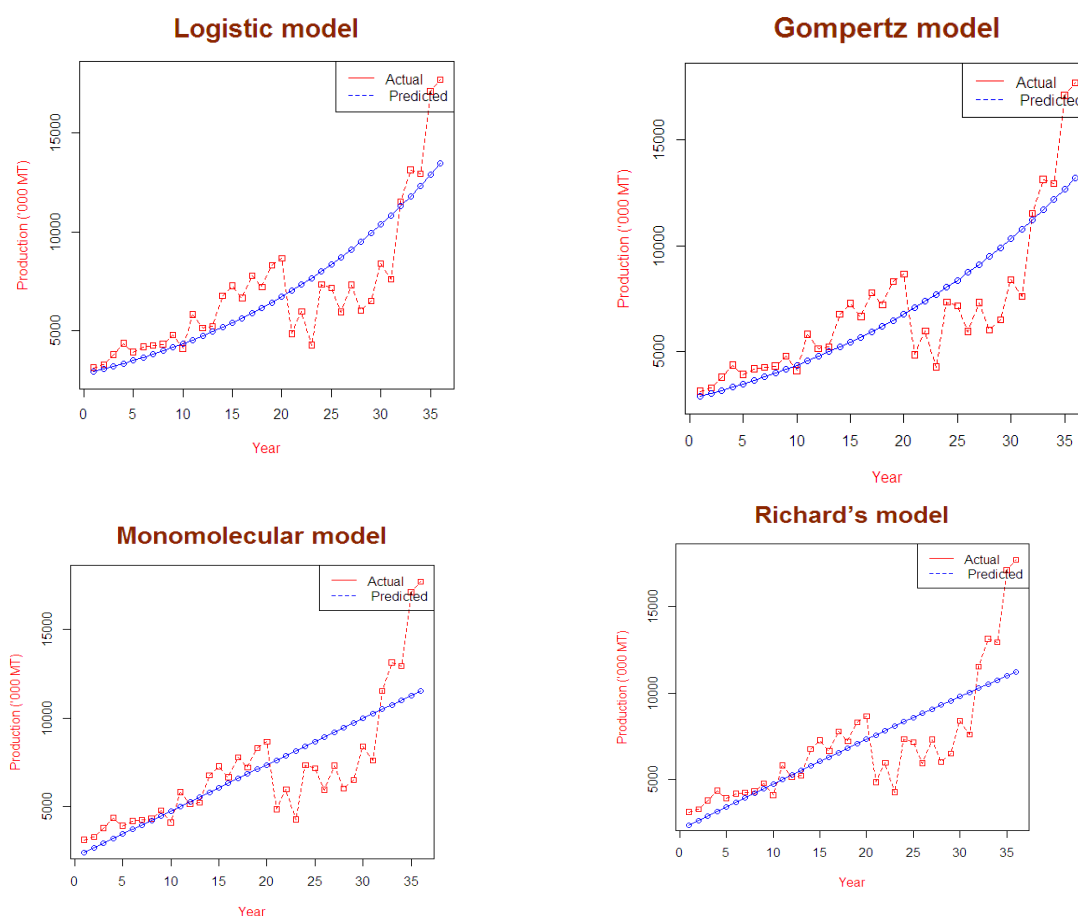
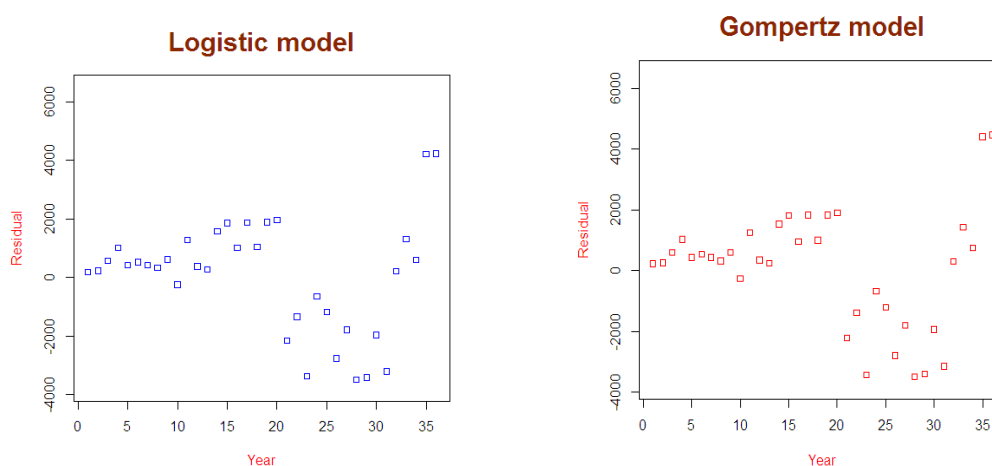
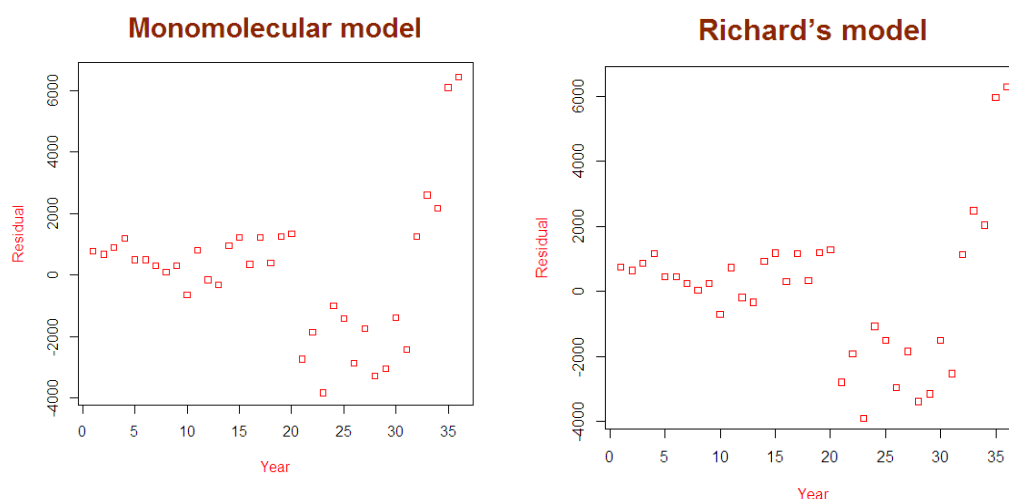


Figure 2 shows the plotted residuals of fitted nonlinear models. The plot showed that the residual are distributed along the zero line and we can conclude that the residual from the fitted models are normally distributed. Next, the models were diagnosed using error analysis. The error analysis is performed to analyze the difference between the error values and the estimated values of observation. This analysis is able to investigate the goodness of fit of nonlinear models graphically and all the plots are illustrated in Figure 2. 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 [1]. It is proved that the nonlinear growth models used in this study has the ability concerning the behaviours of the wheat production data.

Figure 2: Residual plot for Logistic, Gompertz, Monomolecular and Richard's Models





IV. References

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