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Evaluation of non-linear growth models for wheat yield prediction under Bihar conditions

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Abstract

The present research work is carried out to study of non-linear growth models of wheat yield in different agro-climatic zones of Bihar i.e. Zone-I, Zone-II, Zone-III and also for whole Bihar. In this experiment there are various non-linear deterministic growth models can be applied such as Logistic, Gompertz, Monomolecular & compound growth models. The good suitable non-linear model is selected through different parameters i.e. R^2 , R^2_f , R^2_g , RSS, MAPE, MAE, MSE and RMSE was computed for various growth models for all three agro-climatic zones and for whole Bihar state. Among all non-linear growth models, monomolecular growth model were best fit model for predicting wheat productivity in for all three agro-climatic zones and also for complete Bihar.

Keywords: Wheat, Models, Agro-climatic zones, Forecasting

Introduction

Today's major challenge to the scientific community in the states is to increase the wheat productivity not only to provide adequate food to its ever-increasing population but also to create surplus for export to stimulate its overall growth.

Forecasting technique is an important element of research in agriculture and allied sectors. It helps the policy makers, agricultural scientists, farmers, govt. agencies to plan their operations for future. However, Reliable and timely forecasts of crop production before the harvest is a challenging problem, hence achieving greater accuracy in forecasting is a topical interest. Such forecasts are needed by the Government, agro-based industries, traders and agriculturists. The Government needs them for use as a basis for its policy decisions in regard to procurement price, distributions like DBT, buffer-stocking, import-export, price fixation, MSP and marketing of agricultural commodities while agro-based industries, traders and the agriculturists need them for properly planning their operations.

In India forecasting of crops before harvesting or by next years are being done by the Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi. Other govt. agencies like state govt. institutions, research institutions also predict the crop production. However, these forecasts are subjective in nature since these are based on eye-estimates and personal judgment of agricultural officials and the final crop production estimates through based on objective of crop -cutting experiments are limited utility as these become available quite later after the harvest.

Hence, there is a need for developing an objective methodology for pre-harvest crop forecasting. This involves a suitable forecast models using a suitable forecasting techniques which has certain merits over the traditional forecasts methods. These merits include the objectivity of forecasts and its ability to provide a maximum accurate measures of the degree of its prediction which a traditional forecast method cannot provide. Another- merit of prediction through forecasting model is their ability to reflect the impact of cultural practices. Such changes, however, despite slightly affecting the coefficients of parameters in the forecast model do not affect the models responsiveness to these changes.

Thus, the present study has its important significant impact for wheat production, planning for development and growth in future. As per above discussion it is clear that in Indian agriculture as well as in the state of Bihar also, year-to-year fluctuations in output and variations in productivity across space have remained issues of significant concern for researchers as well as policy makers.

Methodology

An attempt will be made to study the non-linear growth pattern of wheat yield in Bihar and below mentioned three agro-climatic zones. For this purpose the three agro-climatic zones comprising of the following districts have been considered.

Zone-1 (13 districts)

There are 13 districts in z-1 namely-Saran, Siwan, Gopalganj, East-Champaran, West-Champaran, Muzaffarpur, Sitamarhi, Shiwhar, Vaishali, Darbhanga, Madhubani, Samastipur and Begusarai.

Zone-2 (8 districts)

It comprises 8 districts: Saharsa, supaul, Madhepura, Purnia, Kishanganj, Araria, Katihar & Khagaria.

Zone-3 (17 districts)

Z-3 having 17 districts are Patna, Nalanda, Arwal, Bhojpur, Buxar, Bhabhua, Rohtas Gaya, Jahanabad, Nawada, Aurangabad, Munger, Sheikhpura, Lakhisarai, Jamui, Bhagalpur and Banka.

Source of data

The study was based on secondary data on productivity of wheat yield in three agro-climatic zones of Bihar and also for whole Bihar. Time series wheat data were collected from Directorate of Economics and Evaluation Department Govt. of Bihar, Patna.

Various non-linear growth models

Monomolecular growth model

This model describes the progress of a growth situation in which it is believed that the rate of growth at particular time t is directly proportional to the amount of growth yet to be achieved.

It denotes the productivity of wheat yields at time t and c be the ceiling value i.e. the maximum achievable value of y in the long run (when t)

$$\frac{dy}{dt} = b(c-y)$$

Where $b(>0)$ is the rate of constant of growth pattern which in the present context depends upon a number of factors like economic condition, attitude of farmers, etc. Initial condition at $t=1$, yield the solutions of the differential equation as

$$Y_t = c - (c-a) \exp. \{-b(t-1)\} + u_t$$

Logistic Model

Logistic model is appropriate in a situation where rate of growth is proportional to the product of the present size and the further amount of growth. That is

$$\frac{dy}{dt} = by(c-y)$$

The solution of equation is

$$Y_t = c / [1 + b \exp. \{-a(t-1)\}] + u_t$$

The curve has an S-shaped between the growth value $c/(1+a)$ and c .

Gompertz Model

For Gompertz model.

$$\frac{dy}{dt} = cy \log(a/y)$$

Integration of this equation yields

$$Y_t = a \exp [-b \exp \{-c(t-1)\}]$$

However, this curve is an S-shaped one like the logistic, it is not symmetrical about its point of inflection.

Compound growth model.

If y_t denotes the observation (Wheat yield) at time t and r is the compound growth rate, model employed for estimating r is based on equation

$$y_t = y_0 (1 + r)^t$$

The usual practice is to assume a multiplicative error-term $\exp(\epsilon)$ in equation so that the model may be linearized by means of logarithmic transformation, following equation

$$\ln(y_t) = A + B_t + e$$

Criteria for selection of model

The appropriateness of the model was judged by

- (i) The value of the estimates in terms of their signs and magnitudes.
- (ii) Analysis of residuals for randomness as well as for normality assumption, and
- (iii) The value of co-efficient of determination (R^2). In addition, the following statistics were also used for model section:

a) Residual sum square (RSS)

b) Mean absolute Error (MAE) = $\sum_{i=1}^n |y_i - \hat{y}_i| / n$

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

(c) Root mean squared Error of (RMSE) RMSE is defined as

$$RMSE = \left(\sum_{i=1}^n |y_i - \hat{y}_i| / n \right)^{1/2}$$

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

Result & Discussion

The good suitable non-linear model is selected through different eight statistics i.e. R^2 , R_7^2 , R_8^2 , RSS, MAPE, MAE, MSE and RMS was computed for various growth model under the three agro-climatic zones and for whole Bihar state. The result has been shown in table 1 to 4. The model will be better if the value of R^2 , R_7^2 , R_8^2 were high and value of Residual sum of squares (RSS), Mean absolute percentage error (MAPE), Mean absolute error (MAE), Mean square error (MSE) and Root mean square error (RMSE) were low. The table from 1 to 4 supports that, after comparison from different non-linear growth model the value of R^2 , R_7^2 , R_8^2 were high other side the value of RSS, MAPE, MAE, MSE and RMSE were low, in the case of monomolecular non-linear growth model.

Table 1: Comparison of Monomolecular, Logistic, Gompertz and Compound growth models for wheat productivity under Zone-I

Parameters	Monomolecular	Logistic	Gompertz	Compound
R^2	0.658	0.648	0.652	0.627
R^2_7	0.9644	0.9633	0.9638	0.9598
R^2_8	0.9704	0.9693	0.9698	0.9462
RSS	5.930	6.112	6.031	6.686
MAPE	15.542	16.671	16.220	18.588
MAE	0.2374	0.2428	0.2409	0.2629
MSE	0.1162	0.1198	0.1182	0.1311
RMSE	0.3410	0.3461	0.3439	0.3621

Table 2: Comparison of Monomolecular, Logistic, Gompertz and Compound growth models for wheat productivity under Zone-II

Parameters	Monomolecular	Logistic	Gompertz	Compound
R^2	0.5104	0.5011	0.5046	0.4681
R^2_7	0.9425	0.09414	0.9419	0.9394
R^2_8	0.9510	0.9499	0.9503	0.9000
RSS	6.7804	6.9086	6.8596	7.1522
MAPE	24.5342	26.3653	25.5066	26.8797
MAE	0.2746	0.2825	0.2785	0.3013
MSE	0.1329	0.1354	0.1345	0.1402
RMSE	0.3646	0.3680	0.3667	0.3744

Table 3: Comparison of Monomolecular, Logistic, Gompertz and Compound growth models for wheat productivity under Zone-III

Parameters	Monomolecular	Logistic	Gompertz	Compound
R^2	0.7800	0.7547	0.7643	0.5351
R^2_7	0.9754	0.9729	0.9740	0.9547
R^2_8	0.9818	0.9793	0.9804	0.9976
RSS	3.8438	4.2348	4.0716	7.1010
MAPE	21.8380	26.8847	25.0039	31.7738
MAE	0.1937	0.2028	0.1992	0.2843
MSE	0.0753	0.0830	0.0798	0.1392
RMSE	0.2745	0.2881	0.2825	0.3731

Table 4: Comparison of Monomolecular, Logistic, Gompertz and Compound growth models for wheat productivity of Bihar

Parameters	Monomolecular	Logistic	Gompertz	Compound
R^2	0.75	0.74	0.74	0.67
R^2_7	0.9749	0.9736	0.9742	0.9667
R^2_8	0.9812	0.9799	0.9805	0.9739
RSS	3.9615	4.1742	4.0786	5.2667
MAPE	12.9654	14.2330	13.6916	18.0290
MAE	0.1892	0.1955	0.1927	0.2400
MSE	0.0776	0.0818	0.0799	0.1032
RMSE	0.2787	0.2860	0.2827	0.3213

Fitting of Monomolecular model for agro climatic zones and for whole Bihar

Zone I

After comparing with different growth models in zone I. monomolecular model were found to be best fitted with comparison to logistic, Gompertz & compound growth. As its low% FE. Estimated yield for subsequent year were fitted by below mention model

$$\hat{Y} = 3.3719 - (3.3719 - 0.7139) \exp. \{-0.67102 (t-1)\}$$

Zone II

Under this zone also monomolecular model has been found suitable in comparison with other models (Table 2). The run test doesn't support the basic assumption of the model where asshapira-wilk support the basic assumption of model. Estimated yield for subsequent year were fitted by below mention model.

$$\hat{Y} = 3.17098 - (3.17098 - 0.01447) \exp. \{-0.4335 (t-1)\}$$

Zone III

The compound growth model very high% FE while the RSS and RMSE, for the monomolecular model lower than other non-liner growth models. Estimated yield for subsequent year were fitted by below mention model

$$\hat{Y} = 2.6626 - (2.6626 - 0.01262) \exp. \{-0.4335 (t-1)\}$$

Bihar

For complete Bihar the monomolecular model fits well for data value (Table 4). The run test support the randomness. Estimated yield for subsequent year were fitted by below mention model

$$\hat{Y} = 2.90546 - (2.90546 - 0.02684) \exp. \{-0.5862 (t-1)\}$$

Conclusion

The present study is based on non-linear growth model such as Monomolecular, Logistic, Gompertz and compound Growth model. The utility of these models is that they provide insight into the underlying mechanism.

In the present study four non-linear models namely Monomolecular, Logistic, Gompertz and Compound for the wheat productivity under various climatic zones I, II, III and complete Bihar has been developed and the result obtained through statistical software. The value has been obtained using the data collected and the method described Draper and Smith (1981) [15]. The four models have been compared considering R^2 , R^2_7 , R^2_8 , RSS, MAPE, MAE, MSE, RMSE. On the basis of these statistics, monomolecular model has been found to be most appropriate suitable for describing the

wheat productivity data after comparison among all the models and their fulfillment of assumption has been studied.

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