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A STATISTICAL ESTIMATION ON PRODUCTION AND PRODUCTIVITY TREND OF RICE CROP (*Oryza sativa)* IN MANIPUR STATE

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ABSTRACT

The present investigation was carried out to fit the trend in production and productivity of Rice crop data in Manipur state by using different statistical model (*e. i.* linear, nonlinear and time series model). The most suitable model was selected on the basis of adjusted R^2, significant regression coefficient, root mean square error, mean absolute error, normality (Shapiro-Wilk test) and randomness of residual's (Run test) distribution. Among the fitted models, time series *e. i.* ARIMA (2,1,1) and Gompertz models were found to be the best fitted trend equation for Rice production and productivity trend of Manipur State. The percentage growth rate during 6^{th} to 11^{th} five year plan and overall period during (1980-81 to 2013-14) show the increasing growth rate in production and productivity. Rice production and productivity has increase at the rate 2.090 per cent and 1.905 per cent per annum, respectively during the years (1980-81 to 2013-14).

KEYWORDS: Rice, Linear and Nonlinear, ARIMA, Manipur

INTRODUCTION

Rice (*Oryza sativa*) is the most important food grain crop of the world. Rice is a staple food of more than 60 per cent of Indian population. It accounts for about 43 per cent of total food grains production and 46 per cent of total cereal production in the country. In fact, rice cultivation is in crisis the world over and India is no exception, with a shrinking area (due to urbanization and severe water constraints), fluctuating annual production, stagnating yields and escalating input costs.

In literature, a large number of linear and non-linear statistical models are available *viz*., linear, polynomial, exponential, logistic, gompertz, logistic, etc. for determining the trend *i.e.* forecasting model(s). ARIMA model is an extrapolation method for forecasting and like any other such method, it requires only the historical time series data on the variables under forecasting. Among the extrapolation methods, this is one of the most sophisticated method, as it incorporates the future of all such methods, does not require the investigator to choose initial values of any variables and values of the various parameters a priori. It is robust to handle any data pattern. As one would expect this is quite a difficult model to develop and apply as it involves transformation of the variable, identification of the model, estimation through nonlinear method, verification of the model and derivation of the forecasts (Gupta, 1993).

MATERIALS AND METHODS

The time series data on production and productivity of total oilseeds grown in Manipur for the period of 2000 to 2011 is collected from the Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India (http://eands.dacnet.nic.in/). The resent study aimed at studying linear, nonlinear and time-series statistical models to fit the trend in production and productivity of rice.

Fitting of Linear Statistical Models (Rangaswamy, 2006)

Linear Regression Approach

Y = a + bt (1)

Logarithmic regression

Y= a + b ln(t) (2)

Quadratic Regression Approach

$Y=a + bt + ct^2$ (3)

Third Degree Polynomial Approach

$Y = a + bt + ct^2 + dt^3$ (4)

Exponential regression approach

Y=a*exp (b*t) (5)

Gompertz regression approach

Y=c*exp (-a*exp (-b*t)) (6)

Where Y (production) is dependent variable and t (time variable) is independent variable. The constant a, b, c and d are regression coefficient, which were estimated by using least square method**.**

Fitting of Box-Jenkins ARIMA Models (Box and Jenkins, 1976)

Appropriate ARIMA models were fitted after judging the time series data for stationary based on auto-correlation function and partial autocorrelation function. The auto correlations up to twelve leg were work out. The statistically most appropriate time-series model was selected based on various goodness of fit criteria *viz.*, Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), MAE and assumptions of residual (Sheiro-Wilks test for normality and Lijung and Box test for randomness).

Goodness of Fit of the Models (Montgomery *et al*., 2003)

The statistically most suited linear statistical models were selected on the basis of adjusted $R^{2,}$ coefficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE). They can be computed as follows:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \quad (5)$$

$$\text{Adj.}R^2 = 1 - \frac{(n-1)(1-R^2)}{(n-k)} \quad (6)$$

Where R^2 indicates the amount of variation in dependent variable accounted due to the model.

$$\text{RMSE} = \left[\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 / n \right]^{1/2} \quad (7)$$

And $$\text{MAE} = \sum_{i=1}^{n} \left| Y_i - \hat{Y}_i \right| / n \quad (8)$$

The fitted models which had lower values of these estimates were considered to be better.

Criteria for Selection of Model

The model was selected on the basis of following condition.

- The model should possess significant F value for Coefficient of Determination.
- The regression coefficient in the model should be significant.
- The residuals should be normally and independently distributed.

Relative growth rate was calculated base in the best fitted model.

RESULTS AND DISCUSSIONS

Trend in Production Based Linear and Nonlinear Statistical Models

The results of fitted linear and non linear statistical models for the production of Rice are given in Table 1. Among the fitted models, maximum adjusted R^2 value of 0.517 was observed in Gomertz model. Gompertz model also showed comparatively lower RMSE (69.264) and MAE (48.99) values as compared to other linear and nonlinear model. All the partial regression coefficient values for quadratic and cubic model were found to be non significant. The values of Run test were non-significant in all model and Sapiro-Wilk test was significant in all the model except logarithmic model indicating all the residual were fulfil the assumption of randomness and non of the residual fulfil the assumption of normality except Logarithmic model. Hence Logarithmic model is the best fitted model among the linear and non linear model. Logistic model could not be fitted due to non-convergent.

Trend in Area Based on Time-Series Models

As the series was found non-stationary, the new variable X_t was constructed by taking differences of one (*i.e.* d=1) to make the series stationary.

The ACF (Υ_k) and the PACF (φ_{kk}) values suggested that algebraic family of ARIMA models on p=0, 1, 2 and q=0, 1, 3 could be fitted to these data. Different possible models were fitted and from these models some models were selected on the basis of lower value of AIC, SBC, RMSE and principle of parsimonious, and results are given in Table 2. From the fitted models, ARIMA (1,1,0), ARIMA(2,1,0) and ARIMA (2,1,1) model had significant AR (φ) and MA (θ) coefficient term. Among these three models, ARIMA (2,1,1) model is found to be higher R^2 value (0.663) and lower RMSE value (60.572). The assumptions of residual *i.e.* normality and independence of residuals were tested by Shapiro-Wilk test and Box-Ljung (Q) test indicated that all the ARIMA models except ARIMA(1,1,0) and ARIMA (1,1,2) were satisfied the assumption normality and the independent residuals. The ARIMA (2, 1, 1) also higher R^2 value than the

Logarithmic model (*e.i.* best fitted model of linear and non linear models), hence ARIMA (2, 1,1) is the best fitted model for the production of Rice in Manipur. The graph of the trend of production of rice crop using ARIMA (2, 1,1) model is depicted at figure 1.

Trend in Productivity Based on Linear and Nonlinear Statistical Models

The results of fitted linear and non linear statistical models for the productivity of Rice are given in Table 3. Among the fitted models, maximum adjusted R^2 value of 0.658 was observed in Gomertz model. Gompertz model also showed comparatively lower RMSE (69.264) and MAE (48.99) values as compared to other linear and nonlinear model. All the partial regression coefficient values for quadratic and cubic model were found to be non significant. The assumptions of residual *i.e.* normality and independence of residuals were tested by Shapiro- Wilk test and Run (Z) test indicated that all the models were satisfied the assumption normality and the independent residuals. Hence Gompertz model is the best fitted model among the linear and non linear model with R^2 value 0.658.

Trend in Productivity Based on Time-Series Models

As series was found non stationary, the new variable X_t was constructed by taking differences of one (*i.e.* d=1) to make the series stationary.

The autocorrelation (ACF) and (PACF) coefficients of various orders of X_t were computed to identify the values of p and q. The ACF (Υ_k) of transformed variables was damping towards zero with cut-off initial and fifth spikes and the PACF (φ_{kk}) also cut-off at first and second lags. The different models among different values of p and q were fitted. Among the models, those model having lower value AIC and SBC are given in Table 4. From the fitted models only ARIMA (1,1,0) models have significant MA (θ) coefficient term with R^2 value of 0.416. The assumption of residuals *i.e.* normality and independence of residuals were tested by Shapiro- Wilk test and Box-Ljung (Q) test indicated that all the fitted ARIMA models were satisfied the assumption normality and independence of residuals, so ARIMA (1,1,0) is the best fitted model among the time series model. But R^2 value of Gompertz model is higher than ARIMA (1,1,0). So Gompertz model is the best fitted model among the linear, nonlinear and time series statistical model for the productivity trend of Rice in Manipur. The graph of the trend of productivity of rice crop using Gompertz model is depicted at figure 2. And also the trend equation of rice productivity is given by

$$Y= 2451.1*\exp(-0.579*\exp(-0.084*time))$$

Growth Rate in Production and Productivity of Rice Crop

Relative growth rate of production and productivity of rice were calculated from the year 1980-81 to 2014-15 base on the best fitted model (*e.i* ARIMA (2,1,1) and Gompertz for production and productivity, respectively). The values for each year for production and productivity were also computed year wise for every fifth year period and the average of five year period of each plan had been computed from sixth five years plan to eleventh five years plan commencing from (1980-81 to 2013-14) and presented in the table 5 and depicted in the figure 3.

During the 10^{th} five years plan, the average rate of production was increase at 6.217 % per annum. The main reason behind the increase in production is due to the increase in productivity and cultivated areas of rice crop. For productivity of rice average growth rate was maximum at 6^{th} five year plan at the rate of 3.283% per annum and minimum at 11th five year plant at the rate of 0.317 % per annum. The percentage growth rate values for the successive years during (1980-81 to 2013-14) were also increase at the rate 2.090 and 1.905% per annum for production and productivity, respectively. This was because of increasing the application of new technology in agricultural activities and introduction of new improved varieties as well as hybrid seed for rice crop in Manipur.

TABLES AND FIGURES

Table 1: Characteristics of Fitted Linear and Non Linear Model for Production of Rice Crop in Manipur

Model	Regression constant	Regression coefficients			Adj. R^2	RMSE	MAE	S-W Test	Run test (|Z|)
	a	b	c	d					
Linear	237.726	7.297**	-	-	0.501**	67.60	46.223	0.900**	0.174
Logarithmic	167.282	76.050**	-	-	0.401**	73.815	55.616	0.971	0.174
Quadratic	236.486	7.503	-0.006	-	0.485**	67.358	46.265	0.902**	0.174
Cubic	261.776	-0.587	0.567	-0.011	0.475****	66.907	46.459	0.906**	0.174
Exponential	252.152	0.019**	-		0.486**	68.101	47.460	0.900**	0.522
Gompertz	1.304	0.023	872.6	-	0.517**	69.264	48.998	0.903**	0.147

* Significant at 5% level

Table 2: Characteristics of Fitted ARIMA Models for Production of Rice in Manipur

ARIMA	AIC	SBC	AR(ϕ)	MA(θ)	CONS	R^2	RMSE	SW-TEST	BLQ-TEST
(1,1,0)	398.128	399.625	-0.610**	-	5.588	0.063	101.347	0.918**	34.330**
(1,1,1)	386.019	389.012	-0.389	0.998	8.006	0.559**	70.740	0.959	21.214
(1,1,3)	376.829	382.815	-0.481	0.722,0.728,-0.991	8.764	0.658**	64.527	0.973	10.085
(2,1,0)	372.451	375.44	-0.902**,-0.914**	-	6.746	0.663**	61.842	0.939	13.092
(2,1,1)	374.134	378.623	-0.759**,-0.767**	0.540**	8.291	0.688**	60.572	0.980	9.226
(2,1,2)	373.747	379.733	-1.050**,-0.759**	0.017, 0.974	8.244	0.752**	54.955	0.973	6.191

* Significant at 5% level

Table 3: Characteristics of Fitted Linear and Non Linear Model for Productivity of Rice Crop in Manipur

Model	Regression constant	Regression coefficients			Adj. R^2	RMSE	MAE	S-W Test	Run test (|Z|)
	a	b	c	d					
Linear	1589.228	26.924**	-	-	0.600**	204.171	173.917	0.951	1.219
Logarithmic	1231.872	318.016*	-	-	0.627**	197.2046	156.448	0.979	1.567
Quadratic	1425.123	54.275**	-0.781	-	0.630**	193.449	155.510	0.972	1.219
Cubic	1291.725	98.950**	-3.786	0.057	0.365**	189.041	149.57	0.973	0.871
Exponential	1594.958	0.014**	-	-	0.593**	210.4113	187.291	0.963	1.219
Gompertz	0.579	0.084	2451.1		0.658**	197.254	159.337	0.971	1.219

* Significant at 5% level

Table 4: Characteristics of Fitted ARIMA Models for Productivity of Rice in Manipur

ARIMA	AIC	SBC	AR(ϕ)	MA(θ)	CONS	R	RMSE	SW-TEST	BLQ-TEST
(1,1,0)	461.101	462.598	-0.458**	-	48.479	0.416**	260.365	0.976	18.854
(1,1,1)	459.099	462.092	0.077	0.99	51.416	0.575**	225.977	0.976	11.548
(1,1,3)	461.933	467.920	-1.000**	-0.17, 0.99,0.17	57.481	0.593**	229.189	0.983	11.732
(2,1,0)	457.747	460.470	-0.625, -0.478	-	53.253	0.537**	236.051	0.956	12.258
(2,1,3)	457.198	458.694	-0.062,-0.974**	1.00, -1.00, 0.99	56.998	0.600**	231.645	0.970	14.209
(0,1,1)	458.924	461.917	-	0.996	54.968	0.576**	222.059	0.975	13.150

* Significant at 5% level

Table 5: Plan Period-Wise Relative Growth Rates of Production and Productivity of Rice Crop in Manipur

Period	Production (%)	Productivity (%)
6th five year Plan (1980-81 to 1984-85)	0.538	3.283
7th five year Plan (1985-86 to 1989-90)	4.679	2.100
8th five year Plan (1992-93 to 1996-97)	2.894	1.141
9th five year Plan (1997-98 to 2001-02)	0.128	0.742
10th five year Plan (2002-03 to 2006-07)	6.217	0.485
11th five year Plan (2007-08 to 2011-12)	2.791	0.317
Whole period (1980-81 to 2013-14)	2.090	1.905

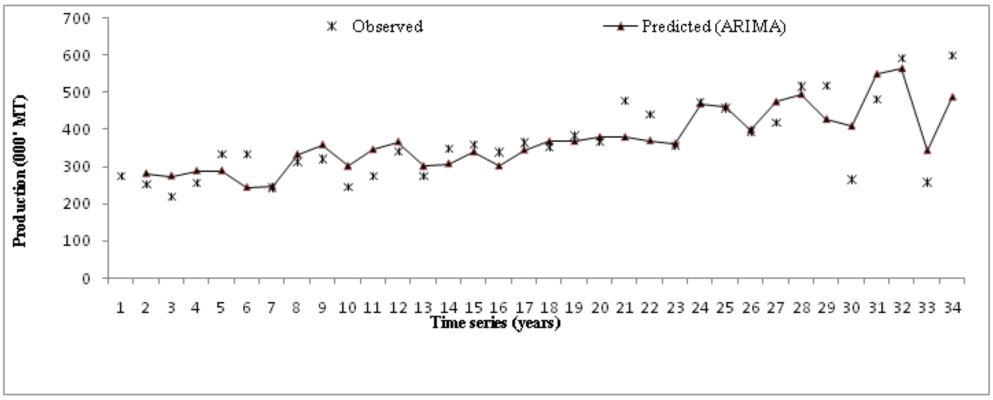

Figure 1: Trend in Rice Production Based On ARIMA (2, 1, 1) Model in Manipur

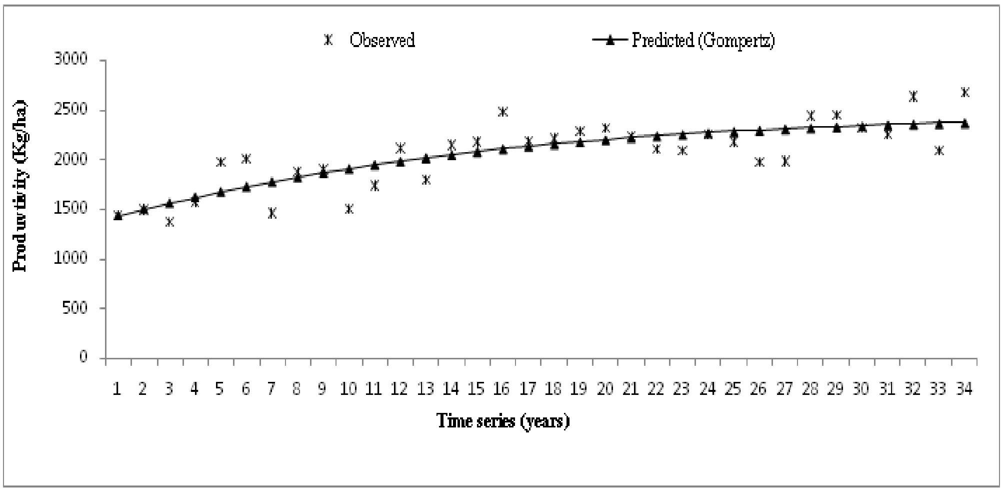

Figure 2: Trend in Rice Productivity Based On Gomprtz Model in Manipur

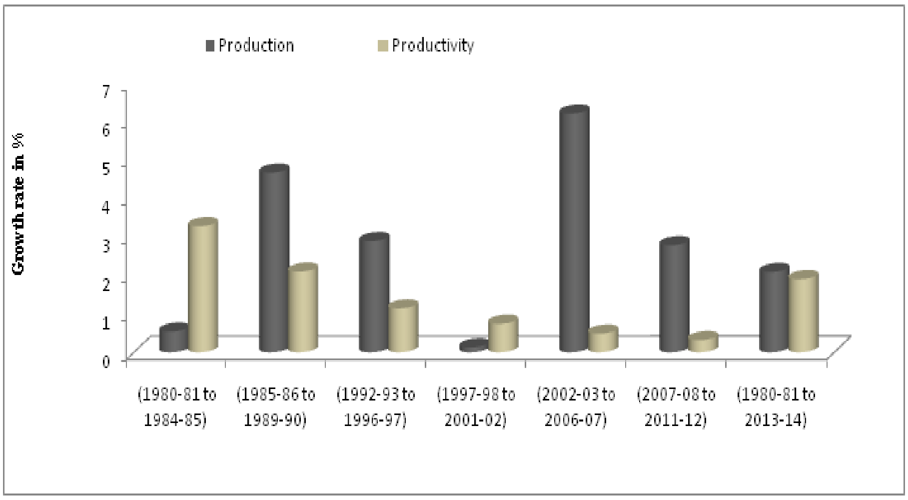

Figure 3: Plan Period-Wise Relative Growth Rates of Production and Productivity of Rice Crop in Manipur

CONCLUSSIONS

The Gompertz and Time series (ARIMA) model analysis indicated that production and productivity of rice crop increase significantly through the year Plan 1980-81 to 1913-14 in Manipur State. This might attributed to the availability of good quality seed of high yielding variety, expansion of irrigation facility and increase the profitability of the crop.

It is also suggested that the linear and nonlinear model based on original data with reasonably good R^2 can be used for future prediction while model based on moving averages can be used to predict average trend value. The future prediction by using ARIMA model is not valid for long period of time, it can be used only upto next two to three years, because time series (ARIMA) model is fitted after converting non stationary data to stationary data. Hence it is required to update time series model for every two to three year for getting good forecasting values.

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