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Trend and growth rate of Bajra crop in Gujarat state

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ABSTRACT

The trend of area, production and productivity for bajra important factor for successful planning and decision making for the policy makers. Forecasting also plays a crucial role in agricultural, business, industrial, government and institutional planning because many important decisions depend on the anticipated future values of certain variables. The time-series data from 1960-61 to 2012-13 on area, production and productivity of bajra crop for Gujarat were collected from Directorate of Agriculture, Gujarat state, Gandhinagar. The present study was made through fitting of different linear, non-linear and time series models viz., Linear, Quadratic, Cubic, Exponential, Gompertz and Autoregressive Integrated Moving Average (ARIMA), along with their instability index.

The results revealed that among different polynomial models for area, productivity of bajra, maximum adjusted R^2 value of 56.00 per cent and 72.61 per cent was observed in case of the exponential model and third degree polynomial model respectively, in case of ARIMA models, ARIMA (1,1,0), ARIMA (2,1,0)and ARIMA (3,1,0) as the candidate models and based on R^2 and RMSE values, ARIMA (3,1,0) is the best among ARIMA tested models in area and productivity of bajra crop. The compound growth rates for area, production and productivity were -3.62, 1.86 and 5.44 % annually in bajra crop, respectively. The instability indices area, production and productivity were observed 26.02, 27.63 and 22.34 in bajra crop, respectively. The coefficient of variation for area, production and productivity were observed 39.22, 29.35 and 39.57% in bajra crop, respectively.

Key words: ARIMA, polynomial models, compound growth rates, instability indices, trend

Bajra is the second most important millet which is used as food in drier part of the country. It is also widely used as fodder as its stalks are fed to cattle. In India, agriculture and other allied activities contribute significantly to the Gross Domestic Product (GDP). Last four decades have been an era of revolution in agriculture, especially in the field of crop production, which has brought a spectacular change in the existing cropping systems. The population of country is growing at an enormous speed and therefore, it is of paramount importance to achieve an enhanced rate of productivity of crops in order to keep pace with the population growth through better planning for optimum utilization of scare inputs such as land, capital, human mechanization and other natural resources. Since, agriculture is a vital sector of economy, even among highly industrialized countries, much care and expenditure are devoted to compilation of agricultural statistics.

In the year 2012-13, in Gujarat state production of bajra was 10.4 lakh tonnes and the productivity was 1743 kg/ha (Anon, 2012-13). Crop is severely affected with abiotic factors e.g. rainfall, humidity and other environmental factors and biotic stresses such as diseases and pest infestation which also indirectly depends upon environment. The observation on these time series variables are varying in some pattern due to the existence of artificial and natural forces. The policymakers, while formulating policies have to keep in mind the shifting pattern and stability of crops for formulating the strategic all round developmental plan for zone, state or a country. The present investigation was therefore undertaken, to study the fluctuation in area, production and productivity for bajra crop through different models viz., Linear, Quadratic, Cubic, Exponential, Gompertz and Autoregressive Integrated Moving Average (ARIMA), along with their instability index.

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MATERIALS AND METHODS

The time series data on area, production and productivity had some missing observations. Therefore, the simple moving average concept was utilized to find out missing observations. Three year simple moving averaging technique was found best for missing values during model development stage (Boken, 2000). There was a severe drought caused by the failure of south-west monsoon over major parts of India during the year 1987 (Anon., 1990). Therefore, the observations of area, production and productivity of the year 1987-88 for bajra the crop, were excluded from analysis of trends and compound growth rates. The following models were fitted for area, production and productivity of bajra crop for the purpose.

Model No.	Model	Name of the Model
I.	$Y=A+B^*X$	Linear equation
II.	$Y=A+B^*X+C^*X^2$	Second degree polynomial
III.	$Y=A+B^*X+C^*X^2+D^*X^3$	Third degree polynomial
IV.	$Y=A^*\exp(B^*X)$	Exponential model
V.	$Y=A^*\exp(-\exp(B-C^*X))$	Gompertz model

Where, Y is the area, production and productivity and X is the time points.

Among linear and non-linear models, the model having highest adjusted R^2 with significant F value, which satisfies test for goodness of fit was selected. In the case of time-series models at first the conditions of stationarity was checked and then different ARIMA models were tried. Among the ARIMA models, the model having less Akaike's Information Criterion (AIC) and Bayesian Information Criterions (BIC) as well as the significant values of estimated parameters was considered as the best fitted model. The selected model was further tested for randomness and normality of error terms. In case of more than one model having the good fit for the data, the best model was selected having lower values of Mean Absolute Error (MAE) and Root Mean Square Error (RMSE).

The compound growth rate (CGR) was calculated by fitting the exponential function given below.

$Y= a^*b^X$ .... (1)

Where, Y = Area, Production and Productivity

a=Constant,

b = Regression coefficient,

X= Time variable

Thus natural log on both the sides of equation (1) was taken to convert it in to linear form.

$\text{Log } Y = \log a + X \log b$ .... (2)

CGR (%) was worked out by using following formula.

CGR (%) = (Anti log of b – 1) * 100 .... (3)

The simple coefficient of variation (CV %) often contains the trend component and thus over estimates the level of instability in time series data characterized by long-term trends. To overcome this problem, this study used the Cuddy Della Valle index which corrects the CV by:

$\text{Instability Index} = (\text{CV }\%)\sqrt{(1-R^2)}$ .... (4)

Where, CV% = Coefficient of variation

R^2 = Coefficient of determination from a time trend regression adjusted by the number of degrees of freedom.

RESULTS AND DISCUSSION

Trends in area, production and productivity of bajra crop

Different linear, non-linear and time-series models were fitted to the area, production and productivity data of bajra crop for Gujarat as a whole. The characteristics of different fitted linear, non-linear (Table 1) and time-series (Table 2) models are presented. The findings are discussed in sequence as under.

Trends in area based on linear and non-linear models

The results presented in Table 1 for area under cultivation of bajra crop revealed that among the five fitted linear and non-linear models, the exponential model have maximum adjusted R^2 value of 56.00 per cent. The Shapiro-Wilks test (test for normality) was significant for all the model indicating that the residuals were not normally distributed. The run test (test for randomness) was significant for all the models, indicating that the residuals were correlated. Hence based on R^2 value, exponential model was found suitable to fit the trends in area under the bajra crop. Gompertz non-linear model could not be fitted due to the fact that the parameters were found to be nonconvergent in area, production and productivity of bajra.

Trends in area based on time-series models

Autocorrelation up to fourteen lags were worked out for fitting the ARIMA models. Since the computed autocorrelations gk values did not tail off towards zero, the original series was found to be non-stationary. The non-stationarity was also confirmed by examining the realization visually. It was found that the mean and variance were changing over the time. However, the stationarity was achieved by differencing one time i.e., d=1. The pattern of autocorrelations k showed damped sine-wave and significant partial autocorrelations fkk at first and second lags. This suggested consideration of ARIMA (1,1,0), ARIMA (2,1,0) and ARIMA (3,1,0) as the candidate models and the results are given in Table 2. The Shapiro-Wilks test (test for normality) was significant for all the ARIMA models indicating that the residuals were not normally distributed. Therefore, based on R^2 and RMSE values, ARIMA (3,1,0) is the best among ARIMA tested models.

Trends in production based on linear and non-linear models

The data presented in Table 1 for production of the bajra crop revealed that the third degree polynomial model have showed maximum adjusted R^2 value of 19.43 per cent.

Trends in production based on time-series models

For fitting the ARIMA time-series models the autocorrelation up to fourteen lags were worked out. Since the computed autocorrelations k values did not tail off towards zero, the original series was found to be non-stationary. The non-stationarity was also confirmed by examining the realization visually. It was observed that the mean and variance were changing over the time. However, the stationarity was achieved by differencing one time i.e., d=1. The pattern of autocorrelations gk showed damped sine-wave and significant partial autocorrelations fkk at second and third lags. This suggested consideration of ARIMA (1,1,0), ARIMA (2,1,0) and ARIMA (3,1,0) as the candidate models and the results are given in Table 2. Since all the suggested ARIMA model have very low R^2 values, hence none of the ARIMA model was found suitable to fit the trends in production of bajra crop.

Trends in productivity based on linear and non-linear models

Productivity data of bajra crop presented in the Table 1 (Fig. 1) revealed that among the five fitted models, the maximum adjusted R^2 value of 72.60 per cent was observed in case of third degree polynomial model. The third degree polynomial model also showed comparatively lower values of root mean square (186.137) and mean absolute (149.934) error values in comparison to that of in other linear and non-linear models. The Shapiro-Wilks test (test for normality) was not significant for all the models indicating that the residuals were normally distributed. The run test was also not significant for third degree polynomial model indicating that the residuals were not correlated. Since all the partial regression coefficient was significant, and not significant S-W and run test, the third degree polynomial model was found suitable to fit the trends in productivity of the bajra crop.

$Y=252.741^{**}+59.915^{**}X-2.097^{*}X^2+0.028^{**}X^3$

$(R^2= 72.60^{**}\ \%)$

Vaishnav and Dixit (1998) used polynomial models to study trends of crop productivity in long term experiment.

Trends in productivity based on time-series models

In ARIMA time-series methodology the autocorrelation up to fourteen lags were worked out. Since the computed autocorrelations gk values did not tail off towards zero, the original series was found to be non-stationary. The non-stationarity was also confirmed by examining the realization visually. It was found that the mean and variance were changing over the time. However, the stationarity was achieved by differencing one time i.e., d=1. The pattern of autocorrelations gk showed damped sine-wave and significant partial autocorrelations fkk at second and third lags. This suggested consideration of ARIMA (1,1,0), ARIMA (2,1,0) and ARIMA (3,1,0) as the candidate models and the results are given in Table 2. Since the AIC (704.082) and BIC (711.809) in ARIMA (3,1,0) were found smaller than that of in other two ARIMA models. The assumptions of residuals i.e. normality and independence of residuals were tested by Shapiro-Wilks test and Box-Ljung (BLQ) test indicated that ARIMA (3,1,0) model satisfied the assumption of normality and independence of residuals. Thus, the ARIMA (3,1,0) model was found suitable to fit the trends in productivity of the bajra crop for Gujarat as a whole with 62.92 per cent R^2 value. Sridhar *et al.* (1994) developed ARIMA model using 35 years district wise yield data of wheat for seven districts in Madhya Pradesh. They observed that forecasts were 15.8, 10.0 and 6.0% lower than post-harvest estimates of

Table 1: Characteristics of fitted linear and non-linear models for area, production and productivity of bajra crop in Gujarat

Aspects	Model	Regression constant	Partial regression coefficient			Goodness of fit				
		a	b	c	d	Adj. R^2 (%)	S-W Test	Run Test (|Z|)	RMSE	MAE
Area	Linear	18290.403**	-193.062**	-	-	30.70**	0.468**	3.361**	4218.073	1880.864
	Quadratic	15838.723**	79.347	-5.140	-	33.54**	0.487**	4.762**	4089.137	2012.654
	Cubic	14092.120**	456.940	-22.782	0.222	33.56**	0.488**	2.521*	4046.617	1836.143
	Exponential	18987.937**	-0.016**	-	-	56.00**	0.492**	3.361**	4326.101	1885.647
	Gompertz	-	-	-	-	-	-	-	-	-
Production	Linear	9253.414**	66.783*	-	-	7.97*	0.948*	1.120	3043.756	2628.080
	Quadratic	7232.986**	291.275*	-4.236*	-	13.47**	0.966	0.840	2921.819	2447.792
	Cubic	4661.136*	847.276**	-30.214*	0.327*	19.43**	0.972	1.120	2790.513	2371.142
	Exponential	8610.451*	0.008**	-	-	11.41**	0.948*	1.120	3097.410	2606.423
	Gompertz	-	-	-	-	-	-	-	-	-
Productivity	Linear	397.242**	20.308**	-	-	68.51**	0.987	0.840	203.651	164.196
	Quadratic	476.875**	11.460	0.167	-	68.75**	0.984	0.280	200.857	166.362
	Cubic	252.741*	59.915**	-2.097*	0.028**	72.60**	0.977	1.120	186.137	149.934
	Exponential	465.609**	0.023**	-	-	68.14**	0.982	0.280	200.775	168.970
	Gompertz	-	-	-	-	-	-	-	-	-

* Significant at 5% level, ** Significant at 1% level

Table 2: Characteristics of fitted time-series models for area, production and productivity of bajra crop in Gujarat

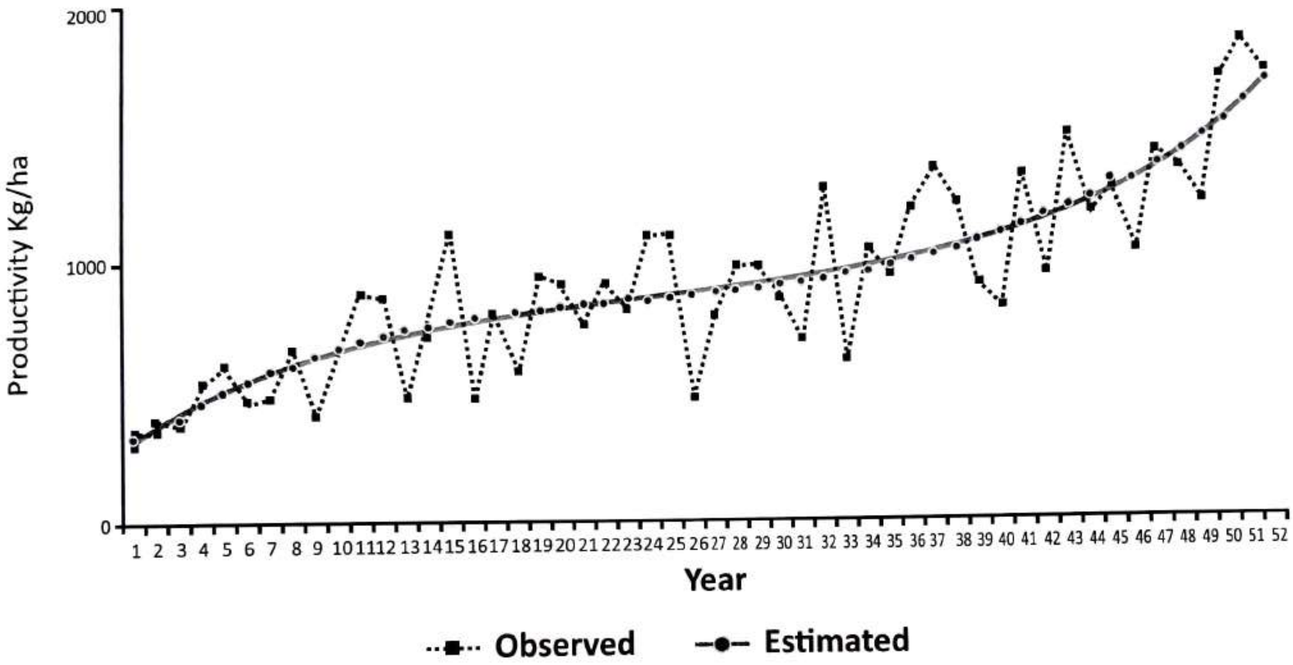
Aspects	ARIMA p,d,q	Constant	AR (ϕ) ϕ_1	ϕ_2	ϕ_3	ϕ_4/ ϕ_5	MA ( ) θ_1	AIC Test	BIC Test	S-W	BLQ	RMSE	R^2(%)
Area	(1,1,0)	191.263	-0.449**	-	-	-	-	1017.32	1021.18	0.526**	8.558	5125.48	7.30
	(2,1,0)	188.153	-0.576**	-0.272	-	-	-	1015.38	1021.17	0.544**	6.762	4969.73	14.66
	(3,1,0)	196.384	-0.642**	-0.40*	-0.228	-	-	1014.72	1022.44	0.525**	5.177	4876.50	19.58
Production	(1,1,0)	462.294	-0.469**	-	-	-	-	986.498	990.362	0.981	38.014**	3784.46	0.00
	(2,1,0)	428.351	-0.650**	-0.375**	-	-	-	980.911	986.707	0.980	32.313**	3534.66	0.00
	(3,1,0)	425.967	-0.780**	-0.617**	-0.373*	-	-	975.996	983.723	0.980	16.586	3310.77	0.00
Productivity	(1,1,0)	11.251	-0.533**	-	-	-	-	711.314	715.177	0.987	30.711*	254.849	52.89
	(2,1,0)	10.352	-0.713**	-0.326*	-	-	-	707.612	713.407	0.971	25.364	242.467	58.25
	(3,1,0)	10.961	-0.823**	-0.570**	-0.332*	-	-	704.082	711.809	0.972	19.727	230.961	62.92

* Significant at 5% level, ** Significant at 1% level

Table 3 Compound growth rates and instability indices of area, production and productivity of bajra in Gujarat state

Characters	CGR (% p.a.)	Instability Index	CV%	R^2
Area	-3.62*	26.02	39.22	0.5600
Production	1.86*	27.63	29.35	0.1141
Productivity	5.44*	22.34	39.57	0.6814

Fig.1 Trends in productivity of bajra crop for Gujarat based on cubic regression model



production, acreage and yield, respectively. Rajarathinam and Dixit (2007) used time-series model to study the trend in groundnut yield in long-term fertilizer experiment. Among the families' of ARIMA models, ARIMA (1,1,0) model was found to be best fitted trend equation. Padhan (2012) fitted ARIMA models for productivity of different crops in India for the data from 1950 to 2010. He fitted ARIMA (1,1,0) with Adjusted R^2 0.16 for wheat crop.

Compound growth rates and Instability indices

The compound growth rates and instability indices were calculated and are given in Table 3.The results revealed that the area of bajra crop decreased with as an annual rate of -3.62% per annum with medium instability index. During the study period the rate of increase in production was 1.86% per annum as a result of improvement in bajra productivity at an average rate of 5.44% per annum with in the category of positive and significant growth rates with medium instability index. The instability indices area, production and productivity were observed 26.02, 27.63 and 22.34 in bajra crop, respectively. The coefficient of variation for area, production and productivity were observed 39.22, 29.35 and 39.57% in bajra crop, respectively.

Kalola *et al.* (1995) studied trends and variability in area, production and productivity of tobacco in Gujarat. Hasija *et al.* (2004) analysed trends in area, production and productivity of wheat in Haryana. The results showed that in eastern zone, the area increased at an average annual growth rate of 6.23, 2.42 and 0.28 per cent, under period I, II and III, respectively, while in western zone, the area had increased with an annual growth rate of 5.94, 3.22 and 2.21 per cent respectively under the three periods. The highest increase in production growth was under period I in eastern zone (10.04%) followed by period I in western zone (8.00%).

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