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RESEARCH ARTICLE

GROWTH AND TRENDS IN AREA, PRODUCTION AND PRODUCTIVITY OF SORGHUM AND BAJRA CROPS IN MIDDLE GUJARAT ZONE

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ABSTRACT

The analysis of growth is usually used in economic studies to find out the trend of a particular variable over a period of time and used for making policy decisions. The growth in the area, production and productivity of sorghum and bajra crops in middle Gujarat zone was estimated using different linear, nonlinear and time series (ARIMA) models. The compound growth rates, instability indices and shift in area during last five, five year plan periods also worked out in the study. For a period of 53 years, time-series data from 1960-61 to 2012-13 on area, production and productivity of sorghum and bajra crops for middle Gujarat zone were collected from Directorate of Agriculture, Gujarat state, Gandhinagar. In case of polynomial models, exponential and linear model was found fitted for the productivity trends of sorghum and bajra crop, respectively. In case of ARIMA models, ARIMA (0,1,1) was evolved as the best fitted trend functions for productivity trends of both the crops. None of the model was found fitted for the trends in area and production of sorghum as well as bajra crop. Productivity of sorghum was witnessed of technological and varietal improvement as it had positive and significant growth rate of 5.93% per annum with decreasing area (-7.96% per annum) and production (-3.17% per annum). The area of bajra crop also have negative growth rate of -1.83% per annum, but the production had positive growth rate of 2.80% due to improvement in productivity by 4.95% per annum.

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INTRODUCTION

Agriculture is the key sector and also forms the backbone of the Indian economy. 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 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 2012-13, in Gujarat state production of sorghum was 1.07 lakh tonnes and the production of bajra was 10.44 lakh tonnes, the productivity of sorghum during the period was 1348 kg/ha and the productivity of bajra was 1743kg/ha (Anon, 2012-13).Crops are 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 historical economics variables sequentially spaced with time are called time series variables. The observation on these time series variables are varying in some pattern due to the existence of artificial and natural forces. But it is, indeed, a hard truth that 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 or a state or a country. The appetite for getting future values of economic time series variables is suitably met by feeding them with the best models.

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The objectives of the present investigation are:

- To study fluctuation in area, production and productivity for sorghum and bajra crops through different models viz., Linear, Quadratic, Cubic, Exponential, Gompertz and Autoregressive Integrated Moving Average (ARIMA).

- To study the instability index of sorghum and bajracrops for middle Gujarat zone.

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 all five crops, were excluded from analysis of trends and compound growth rates. The time series models (ARIMA) and following polynomial models were fitted for trends in area, production and productivity of sorghum and bajra crop.

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/ productivity and X is the time points.

To fit the trends in area, production and productivity, linear (first, second and third degree), non-linear (exponential, gompertz) and time-series model were considered. Among linear and non-linear models, the model having highest adjusted R^2 with significant F value was selected, so that it satisfies test for goodness of fit. 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 rates were calculated by fitting the exponential function given below

$Y= a*bX$…………………………….. (1)

Where, Y =area/production/productivity, a=Constant,
b = Regression Co-efficient, 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 co-efficient 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:

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

Where, CV% = co-efficient of variation and R^2= co-efficient of determination from a time trend regression adjusted by the number of degrees of freedom.

RESULTS AND DISCUSSION

Trends for sorghum crop

The data presented in Table 1 for area under cultivation of sorghum crop revealed that among the five linear and non-linear models fitted, the maximum adjusted R^2 value of 69.02 per cent was observed in case of exponential model. Since all the models have significant runtest, hence none of the mode was found suitable to fit the trend in area under the sorghum crop).

Table 1. Characteristics of fitted linear and non-linear models for area, production and productivity of sorghum crop for middle Gujarat zone

Aspects	Model	Regression constant	Partial regression co-efficient			Goodness of fit				
		a	b	c	d	Adj. R^2 (%)	S-W Test	Run Test (|Z|)	RMSE	MAE
Area	Linear	2573.441**	-42.732**	-	-	65.66**	0.974	4.482**	456.887	368.874
	Quadratic	2629.197**	-48.927**	0.117	-	65.05**	0.965	4.482**	456.280	370.459
	Cubic	3057.694**	-141.562**	4.445*	-0.054*	67.89**	0.947*	5.322**	432.863	361.791
	Exponential	3134.825**	-0.036**	-	-	69.02**	0.907**	3.922**	481.069	384.952
	Gompertz	-	-	-	-	-	-	-	-	-
Production	Linear	1073.128**	-9.561*	-	-	10.07*	0.946*	4.482**	391.567	332.487
	Quadratic	993.472**	-0.710	-0.167	-	8.91*	0.962	3.361**	390.121	329.192
	Cubic	1464.569**	102.557**	4.592**	-0.60**	22.39**	0.963	4.202**	356.408	305.232
	Exponential	1024.228**	-0.014**	-	-	12.45**	0.942*	4.482*	403.629	318.215
	Gompertz	-	-	-	-	-	-	-	-	-
Productivity	Linear	254.389**	15.499**	-	-	75.65**	0.985	2.241*	130.254	102.745
	Quadratic	319.946**	8.215	0.137	-	76.27**	0.982	1.961	127.280	97.283
	Cubic	300.035***	12.519	-0.064	0.003	75.84**	0.982	1.401	127.103	97.783
	Exponential	316.331**	0.025**	-	-	74.57**	0.983	1.961	128.165	98.276
	Gompertz	-	-	-	-	-	-	-	-	-

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

Kalola *et al.* (1995), also found linear model for productivity of tobacco crop in Gujarat for the period from 1951-1952 to 1990-1991 as best fitted model. For the production of the sorghumall the models have significant S-W test, hence none of the mode was found suitable to fit the trend in production of the sorghum crop. The analysis of productivity data of sorghum crop revealed that among the five fitted models, the exponential model fulfil all the model selection criteria, so found suitable to fit the trends in productivity of the sorghum crop. Gompertz non-linear model could not be fitted due to the fact that the parameters were found to be non-convergent.

$Y=316.331^{**} \text{ X } 0.025^{**X}$ (Adj. R^2 = 74.57** %)

In ARIMA time-series methodology the auto-correlation up to fourteen lags were worked out. Since the computed auto-correlations γk 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 auto-correlations γk showed damped sine-wave and significant partial auto-correlations ϕkk at first and third lags. This suggested consideration of ARIMA (0,1,0), ARIMA (1,1,1) and ARIMA (3,1,2) as the candidate models and the results are given in Table 2. Since all the models have significant S-W test, hence none of the mode was found suitable to fit the trends in area of the sorghum crop among the ARIMA families' of time series models.

In case of production, all the models have significant S-W test, hence none of the mode was found satisfactory to fit the trends in production of the sorghum crop. ARIMA (0,1,1) model was found suitable to fit the trends in productivity of the sorghum crop among the ARIMA families' of time series models with 75.57 per centR^2value.Padhan (2012) had also reported that ARIMA (0,1,1) model as the best fitted model for productivity of cereals in India.

$$Z_t = 3.011 + 0.737^{**} a_{t-1} + \varepsilon_t \qquad (R^2 = 75.57\ \%)$$

Trends for Bajra Crop

The result of analysis of trends in area under the bajra crop (Table 3) revealed that among the five fitted linear and non-linear models, none of the model was found suitable to fit the trends due to lake of assumption of goodness of fit. For production of the bajra crop all the five fitted models have unsatisfactory R^2 values, hence found not suitable to fit the trends. Since all the partial regression co-efficient was significant, and non-significant S-W and run test, the linear model was found suitable to fit the trends in productivity of the bajra crop. Thus this result is in close agreement with Kalola *et al.* (1995), they found linear model for productivity of tobacco crop in Gujarat for the period from 1951-1952 to 1990-1991.Gompertz non-linear model could not be fitted due to the fact that the parameters were found to be non-convergent.

$Y=487.817^{**}+22.202^{**}X$ (Adj. R^2 = 73.93** %)

In case of ARIMA models (Table 4) suggested models were ARIMA (0,1,0), ARIMA (1,1,1) and ARIMA (0,1,1).

Table 2. Characteristics of fitted time-series models for area, production and productivity of sorghum crop for middle Gujarat zone

Aspects	ARIMA p,d,q	Constant	AR (ϕ)			MA (θ)		AIC	BIC	S-W Test	BLQ Test	RMSE	R^2 (%)
			ϕ1	**ϕ2**	**ϕ3**	**θ1**	**θ2**						
ProductArea	(0,1,0)	-25.345	-	-	-	-	-	727.379	729.311	0.892**	17.066	302.513	85.71
	(1,1,1)	-24.365	-0.839**	-	-	-0.912*	-	730.560	736.356	0.906*	17.729	306.051	85.97
	(3,1,2)	-33.843	-0.693**	-0.995**	-0.004	0.702*	-0.0975*	736.390	747.981	0.933**	17.535	315.112	86.07
	(0,1,0)	25.809	-	-	-	-	-	745.359	747.290	0.921**	15.242	360.444	29.59
	(0,1,1)	16.350	-	-	-	0.420**	-	741.625	745.488	0.919**	14.732	343.271	37.44
	(1,1,0)	23.301	-0.252	-	-	-	-	744.044	747.907	0.922**	14.262	352.018	34.21
	(0,1,0)	-0.339	-	-	-	-	-	668.057	669.989	0.967	20.645	169.101	61.57
	(0,1,1)	3.011	-	-	-	0.737**	-	648.187	652.051	0.973	10.558	136.140	75.57
	(1,1,0)	3.322	-0.537**	-	-	-	-	652.652	656.516	0.932**	10.813	143.676	72.79
Production													

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

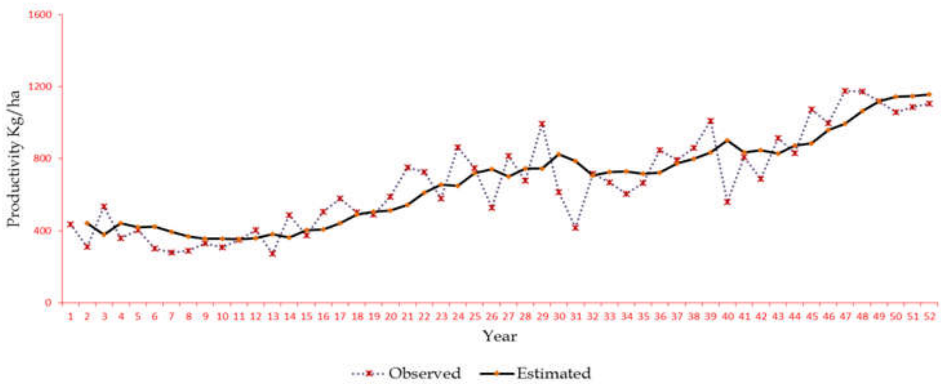

Fig. 1. Trends in productivity of sorghum crop for middle Gujarat zone based on ARIMA (0,1,1) time series model

Since the ARIMA (0,1,1) model have lower AIC (720.984) and BIC (724.847) values. The assumptions of residuals i.e. normality and independence of residuals were tested by Shapiro- Wilk test and Box-Ljung (BLQ) test indicated that all ARIMA models satisfied the assumption of normality and independence of residuals. ARIMA (0,1,1) model also have all significant parameters, hence, found suitable to fit the trends in area of the bajra crop among the ARIMA families' of time series models with 66.07 per cent R^2 value.

$$Z_t = 54.441 + 0.402^{**} a_{t-1} + \varepsilon_t \qquad (R^2 = 66.07\ \%)$$

For the production all suggested model have significant S-W test, hence were not found suitable to fit the trends in production of the bajra crop. Among the suggested ARIMA models for productivity trends the ARIMA (0,1,1) have lower AIC (688.293) and BIC (692.157) values, and satisfied all assumptions of goodness of fit, hence found fitted with R^2

Table 3. Characteristics of fitted linear and non-linear models for area, production and productivity of Bajra crop for middle Gujarat zone

Aspects	Model	Regression constant	Partial regression co-efficient			Goodness of fit				
		a	b	c	d	Adj. R2 (%)	S-W Test	Run Test (|Z|)	RMSE	MAE
Area	Linear	2894.769**	-18.365**	-	-	34.37**	0.979	4.482**	565.702	367.090
	Quadratic	2479.711**	27.753*	-0.870**	-	48.03**	0.948*	2.521*	525.612	298.750
	Cubic	1779.939**	179.034**	-7.939**	0.089**	74.65**	0.947*	0.840	225.415	163.664
	Exponential	2907.652**	-0.008**	-	-	35.52**	0.975	4.482*	378.655	303.750
	Gompertz	-	-	-	-	-	-	-	-	-
Production	Linear	1945.251**	28.612**	-	-	24.89**	0.954*	3.641**	717.662	591.627
	Quadratic	1648.903**	61.540*	-0.621	-	25.68**	0.951*	3.081**	706.675	557.536
	Cubic	728.503	260.518**	-9.918**	0.117**	38.73**	0.986	2.521*	635.079	497.503
	Exponential	1856.975**	0.012**	-	-	29.18**	0.959	3.641**	731.912	598.923
	Gompertz	3008.960	0.094	0.153	-	32.8	0.954*	2.521*	685.830	507.432
Productivity	Linear	487.817**	22.202**	-	-	73.93**	0.982	1.961	195.211	163.153
	Quadratic	628.269**	6.596	0.294*	-	75.85**	0.961	1.961	185.989	156.654
	Cubic	475.839**	39.555**	-1.245	0.019	77.23**	0.952*	1.961	178.766	154.634
	Exponential	537.833**	0.021**	-	-	73.72**	0.967	1.961	185.952	159.409
	Gompertz	-	-	-	-	-	-	-	-	-

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

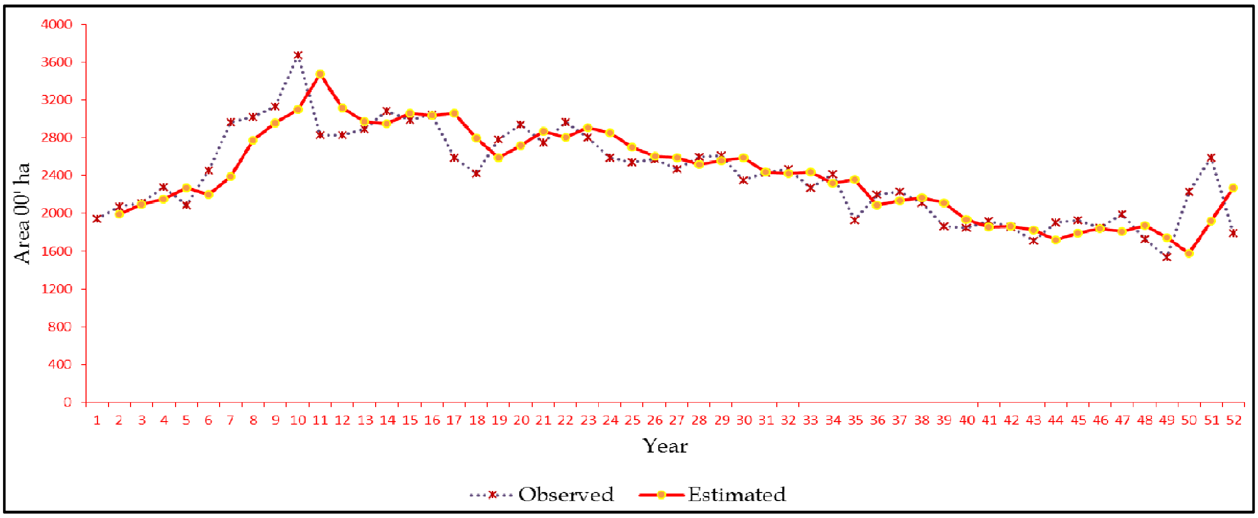

Fig. 2 Trends in area of bajra crop for middle Gujarat zone based on ARIMA (0,1,1) time series model

Table 4. Characteristics of fitted time-series models for area, production and productivity of bajra crop for middle Gujarat zone

Aspects	ARIMA p,d,q	Constant	AR (ϕ)				MA (θ)	AIC	BIC	S-W Test	BLQ Test	RMSE	R^2 (%)
			ϕ1	ϕ2	ϕ3	ϕ4	θ1						
Area	(0,1,0)	66.108	-	-	-	-	-	722.876	724.808	0.955	20.245	287.005	62.81
	(1,1,1)	48.962	0.693**	-	-	-	0.998	723.300	729.05	0.960	13.775	275.078	67.23
	(0,1,1)	54.441	-	-	-	-	0.402**	720.984	724.847	0.962	13.819	276.960	66.07
Pro	(1,0,0)	1883.989**	0.422**	-	-	-	-	837.929	841.832	0.938**	8.983	673.029	38.97
	(0,0,1)	1923.521**	-	-	-	-	-0.423**	859.359	863.261	0.947*	8.365	675.767	38.47
Productivi	(0,1,0)	100.79	-	-	-	-	-	699.253	701.185	0.983	23.151	229.409	64.95
	(0,1,1)	0.975	-	-	-	-	0.640**	688.293	692.157	0.965	14.714	201.121	73.61
	(1,1,0)	4.241	-0.391**	-	-	-	-	693.141	697.005	0.987	24.369	213.345	70.30
	(2,1,0)	0.405	-0.529**	0.341*	-	-	-	689.394	695.189	0.984	11.175	202.328	73.85

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

Table 5. Compound growth rates and instability indices of area, production and productivity of sorghum and bajra crops for middle Gujarat zone

Crop	CGR (% p.a.)			Instability Index		
	Area	Prod.	Yield	Area	Prod.	Yield
Sorghum	-7.96*	-3.17*	5.93*	30.71	48.06	20.31
Bajra	-1.83*	2.80*	4.95*	15.54	26.29	18.58
Crop	CV%			R^2		
	Area	Prod.	Yield	Area	Prod.	Yield
Sorghum	55.18	51.37	40.47	0.6902	0.1245	0.7457
Bajra	19.35	31.24	36.24	0.3552	0.2918	0.7372

* Significant at 5% level

Table 6. Classification of different categories of compound growth rates along with their respective categories of instability indices of area, production and productivity of major cereal crops for middle Gujarat zone

CGR (% p.a.)	Instability Indices								
	Area			Production			Productivity		
	Low (<12.40)	Medium (12.40-33.85)	High (>33.85)	Low (<21.78)	Medium (21.78-52.57)	High (>52.57)	Low (<18.22)	Medium (18.22-20.67)	High (>20.67)
(+) significant	-	-	-	-	Bajra	-	-	Sorghum Bajra	-
(-) significant	-	Sorghum Bajra	-	-	Sorghum	-	-	-	-
Non-significant	-	-	-	-	-	-	-	-	-
Mean of instability indices		23.13			37.18			19.45	
SD of instability indices		10.73			15.39			1.22	

Low = Less than (Mean - SD), Medium = Between (Mean ± SD), High = Greater than (Mean + SD)

value of 73.61 percent. The same model was also found suitable to fit the productivity trends of cereals in India, (Padhan, 2012).

$$Z_t = 0.975 + 0.640^{**} a_{t-1} + \varepsilon_t \qquad (R^2 = 73.61\ \%)$$

Compound growth rates and instability indices

The results (Table 5 and Table 6) revealed that the area of sorghum crop decreased with an average rate of -7.96% per annum with medium instability index. The production of sorghum crop also decreased with an average rate of -3.17% per annum due to reduction in area. The productivity of sorghum crop was increased at an average rate of 5.93% per annum with medium instability index. The possible reasons behind the increasing growth rate in productivity with decreasing rates in area and production are technological and varietal improvement in sorghum crop. It is cleared in analysis that the area of bajra crop decreased as an annual rate of -1.83% per annum with medium instability index. Production increased at an average rate of 2.80% per annum as a result of improvement in productivity of bajra at as an average rate of 4.95% per annum. Production and productivity of bajra crop was found in the category of positive and significant growth rates with medium instability indices.

Conclusion

In case of polynomial models, exponential and linear model was found fitted for the productivity trends of sorghum and bajra crop, respectively.

In case of ARIMA models, ARIMA (0,1,1) was evolved as the best fitted trend functions for productivity trends of both the crops. None of the model was found fitted for the trends in area and production of sorghum as well as bajra crop. Increase in government funding to agriculture, selection of high yielding varieties, increase agricultural linkage between farmers and research institutes are important reasons behind the positive and significant compound rates in productivity and production of both the crops.

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