ISSN 1996-3343

Asian Journal of Applied Sciences

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Asian Journal of Applied Sciences 4 (1): 42-52, 2011
ISSN 1996-3343 / DOI: 10.3923/ajaps.2011.42.52

Application of Parametric and Nonparametric Regression Models for Area, Production and Productivity Trends of Castor (*Ricinus communis* L.) Crop

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ABSTRACT

The present investigation was carried out to study area, production and productivity trends and growth rates of castor crop grown in Anand district of middle Gujarat in India for the period 1949-50 to 2007-08. In parametric models different linear, non-linear and time-series models were employed. The statistically most suited parametric models were selected on the basis of adjusted R^2, significant regression co-efficients and co-efficient of determination (R^2). Appropriate time-series models were fitted after judging the time-series data for stationarity. The statistically appropriate model was selected on the basis of various goodness of fit criteria viz., Akaike's Information Criterion, Bayesian Information Criterion, Root Mean Square Error, Mean Absolute Error, assumptions of normality and independence of residuals. In nonparametric regression optimum bandwidth was computed by cross-validation method. Epanechnikov-kernel was used as the weight function. Nonparametric estimates of underlying growth function were computed at each and every time point. Residual analysis was carried out to test the randomness. Relative growth rates of area, production and productivity were estimated based on the best fitted trend function. The nonparametric regression model emerged as the best fitted trend functions for the area, production and productivity of castor crop. The percent growth rate values obtained for the successive years during the period under study for area, production and productivity when averaged showed that the production had increased at a rate of 5.79% per annum which was due to combined effect of increase in area and productivity at a rate of 2.86 and 3.41% per annum, respectively.

Key words: Adjusted R^2, stationarity, akaike's information criterion, bayesian information criterion, lijung and box test, cross validation, band width

INTRODUCTION

Oilseed crops have contributed significantly to the agricultural economy of India since time immemorial. The major oilseeds grown in India are Groundnut, Soyabean, Rapeseed, Sesame, Linseed, Safflower, Castor, Sunflower and Nige. As on date the cultivation of these crops account for around 32 million hectares of land and a total production of 27 million tonnes per annum (Anonymous, 2007).

Castor belongs to the genus *Ricinus* of the Euphorbiaceae or spurge family. The plants range in color from bright red stems and leaves which are rich in anthocyanin to a uniform dark green. Castor is grown both as an ornamental and oilseed crop. In the tropics, castor grows between 6 to 10 m tall and has a life of 12 years. In climates with freezing temperatures, castor grows between 0.5 to 4 m tall and is an annual crop. The plant does not tolerate poorly drained soils and saline conditions and requires around 600 to 700 mm of moisture in a growing season to produce seeds (Scott, 1997).

Castor is cultivated around the world because of the commercial importance of its oil. India, the world's largest producer of castor seed produces 8.0 to 8.5 lakh tonnes of castor seed annually and accounts for more than 60% of the entire global production of seeds and oil. As per the census of 2007-08, Gujarat state in India leads in the production of castor (71%), followed by Rajasthan (16%) and Andhra Pradesh (9%). The rest of the states in India together accounts for the remaining 4% (Anonymous, 2010).

The statistical information on crop area, production and productivity form the backbone of agricultural statistical system. Regional data analysis is extremely vital since it forms the basis for economic and policy planning by the state and central governments. It is easy to formulate and initiate appropriate policy measures if the data with regard to the trend (increase or decrease) of production is obtained and analysed in advance.

Growth rate analyses are also widely employed to study the long-term trends in various agricultural crops (Panse, 1964). The growth rates of crops are estimated mostly through the parametric models by assuming the linear or exponential functional forms. A number of research workers' (Panse, 1964; Dey, 1975; Reddy, 1978; Narain *et al.*, 1982; Kumar and Rosegrant, 1994; Kumar, 1997; Joshi and Saxena, 2002; Singh and Srivastava, 2003; Shah *et al.*, 2005; Patil *et al.*, 2009) have used parametric models, to estimate growth rates, which are being used by the planners or policy makers of the country. However, the data may not be following these linear or exponential models or may require fitting of higher degree polynomials or non-linear models. Further, these models lack the econometric consideration, i.e., normality and randomness of residuals. Under these circumstances it becomes imperative to take recourse to nonparametric regression approach, which is based on fewer assumptions.

Keeping the above in mind the present study is aimed to develop an appropriate statistical model to fit the trends in area, production and productivity of castor crop based on both parametric (linear, non-linear and time-series) and nonparametric regression models and also to estimate growth rates based on best fitted model.

MATERIALS AND METHODS

The present investigation was carried out to study the area, production and productivity trends and growth rate of castor crop grown in Anand district of middle Gujarat in India. The time-series data on area, production and productivity for the period 1949-50 to 2007-08 have been collected from various publications (Margdarshika, published by Directorate of Agriculture) of Gujarat government.

In parametric models different linear (Montgomery *et al.*, 2003), non-linear (Ratkowsky, 1990; Bard, 1974; Draper and Smith, 1998) and Auto-Regressive Integrated Moving Average (ARIMA) time-series models (Box *et al.*, 1976) were employed. The statistically most suited parametric models were selected on the basis of adjusted R^2, significant regression co-efficients and co-efficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) values and assumptions of residuals (normalities and randomness).

Appropriate ARIMA models were fitted after judging the time-series data for stationarity based on visual inspection, auto-correlation function and partial auto-correlation function. The statistically appropriate model was selected on the basis of various goodness of fit criteria viz., Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), RMSE, MAE and assumptions of residuals (Shapiro-Wilks test for normality and Lijung and Box test for randomness).

In nonparametric regression (Hardle, 1990) the first step involved estimation of optimum bandwidth and was computed by cross-validation method. Epanechnikov-kernel was used as the weight function. Nonparametric estimates of underlying growth function were computed at each and every time point. Residual analysis was carried out to test the randomness. Relative growth rate was estimated based on best fitted model.

RESULTS AND DISCUSSION

Different parametric and nonparametric regression models were fitted to the area, production and productivity of the castor crop grown in Anand district of middle Gujarat. The findings are discussed in sequence as under.

Trends in area, based on linear and non-linear models: The result presented in Table 1 for area under cultivation of castor crop revealed that among the different linear and non-linear models fitted, the maximum adjusted R^2 of 62% was observed in case of Sinusoidal model with minimum values of RMSE (31.11) and MAE (20.49) in comparison to that of in the other models. The Shapiro-Wilks test (test for normality) and run test values (test for randomness) were found to be significant. This model failed to fulfill the model selection criteria (normality and randomness of the residuals) and hence this model was not found suitable to fit the trends in area under the castor crop cultivation.

Table 1: Characteristics of fitted linear and non-linear models for area under the caltivation of castor crop

	Regression co-efficient				Goodness of fit				
Models	A	B	C	D	R^2/Adj.R^2	Shapiro-wilks test	Run test	RMSE	MAE
Linear	13.44	2.15**	-	-	0.50**	0.000	0.000	36.79	27.29
	(9.87)	(0.286)			[0.49]				
Quadratic	28.65*	-1.98	0.069**	-	0.62**	0.000	0.003	32.14	19.06
	(13.34)	(1.03)	(0.017)		[0.60]				
Cubic	47.58**	-5.62*	0.219*	-0.0017	0.63**	0.000	0.000	31.49	20.68
	(18.12)	(2.59)	(0.099)	(0.0011)	[0.61]				
Exponential	10.35**	0.039**	-		0.59**	0.000	0.003	37.00	20.36
	(1.568)	(0.004)			[0.58]				
Monomolecular	8039.06*	8052.78*	0.000269*	-	0.50*	0.000	0.000	36.78	27.24
	(520917.94)	(520906.38)	(0.0176)		[0.48]				
Hoerl	23.84*	1.060*	-0.392*	-	0.59*	0.000	0.003	33.27	20.88
	(22.18)	(0.015)	(0.395)		[0.58]				
Sinusoidal	69.99*	63.67*	0.068*	1.962*	0.64*	0.000	0.000	31.11	20.49
	(14.96)	(12.32)	(0.015)	(0.339)	[0.62]				
Morgan-	7.838*	64780.46*	420.70*	2.52*	0.60*	0.000	0.000	32.81	22.38
Mercer-Flodin	(10.96)	(289616.83)	(1191.39)	(2.07)	[0.58]				

*Significant at 5% level; **Significant at 1% level; RMSE: Root mean square error; MAE: Mean absolute error; Values in brackets indicate standard errors; Values in square brackets indicate Adjusted R^2

$$Y = 69.99^{*} + 63.67^{*}\ COS(0.068^{*}\ X + 1.962^{*}) \qquad (R^2 = 64^{*}\ \%) \qquad (1)$$

The results obtained are in line with the findings of Bhagyashree (2009) who reported that none of the linear and non-linear models were found suitable to fit the trend in area under the castor crop in Gujarat state during the period (1949-50 to 2003-04).

Trends in area, based on time-series models: In ARIMA time-series methodology the auto-correlations upto fifteen lags were worked out. Since, the computed auto-correlations γ_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 found that the mean and variance were changing over the time. However, the stationarity was achieved by differencing two times, i.e., d = 2. The pattern of auto-correlations γ_k showed damped sine-wave and significant partial auto-correlations ϕ_{kk} at second, third and fourth lags. This suggested consideration of ARIMA (2, 2, 0), ARIMA (3, 2, 0) and ARIMA (4, 2, 0) as the candidate models (Table 4). In all these models the value of Shapiro-Wilks test values were significant indicating that all these models failed to fulfill the model selection criteria (normality of the residuals). None of the ARIMA families time-series models have been found suitable to fit the trends in area under the castor crop.

Trends in area, based on nonparametric regression model: For the area under the castor crop the optimum bandwidth was computed as 0.068 using the cross-validation method. Nonparametric estimates of underlying growth function were computed at each and every time points. Residual analysis showed that the assumptions of independence of errors were not violated at 5% level of significance. Error values of root mean square 21.21 and mean absolute 12.98 were much lower than those obtained through the parametric models, indicating thereby the superiority of this approach over the parametric approach. Hence the nonparametric regression model was selected as the best fitted trend function for the area under the castor crop. Similar trend was also observed by Bhagyashree and Rajarathinam (2009) in area under the bajra crop in Gujarat state during the period (1949-50 to 2003-04).

Trends in production, based on linear and non-linear models: The results presented in Table 2 for production of castor crop revealed that among the linear and non-linear models fitted, the adjusted R^2 (81%) was higher in the case of exponential model. The amount of variation in production explained by this model was 81%. All the partial regression co-efficients were found to be highly significant. Since, the Shapiro-Wilks and Run test values were significant, the following model failed to fulfill the model selection criteria (normality and randomness of the residuals) and hence the following model was not found suitable to fit the trends in production of castor crop.

$$Y = 2.77^{**}\ \exp(0.072^{**}X) \qquad (R^2 = 81^{**}\%) \qquad (2)$$

None of the linear and non-linear models were found suitable to fit the trends in production of castor crop. The findings obtained are similar to the results reported by Bhagyashree (2009) for the trends in production of castor crop in Gujarat state during the period (1949-50 to 2003-04).

Table 2: Characteristics of fitted linear and non-linear models for production of castor crop

Models	Regression co-efficient				Goodness of fit				
	A	B	C	D	R^2/Adj.R^2	Shapiro-wilks test	Run test	RMSE	MAE
Linear	41.71**	3.340	-	-	0.50**	0.000	0.000	56.46	38.04
	(15.15)	(0.439)			[0.50]				
Quadratic	14.41	-2.18	0.092	-	0.59**	0.000	0.000	51.17	28.12
	(21.23)	(1.63)	(0.026)		[0.58]				
Cubic	21.77	-3.59	0.150	-0.00065	0.59	0.000	0.000	51.11	29.05
	(29.42)	(4.21)	(0.162)	(0.0018)	[0.57]				
Exponential	2.77**	0.072**	-	-	0.81**	0.000	0.000	54.66	24.73
	(0.436)	(0.0046)			[0.81]				
Logistic	165.16*	168844.59*	0.299*	-	0.61*	0.000	0.049	50.17	28.75
	(19.03)	(882081.55)	(0.134)		[0.60]				
Gompertz relation	184.37*	5.29*	0.138*	-	0.60*	0.000	0.013	50.57	29.03
	(38.86)	(2.63)	(0.073)		[0.59]				
Sinusoidal	163.78*	164.92*	0.039*	2.60*	0.59*	0.000	0.000	51.06	29.14
	(221.23)	(215.92)	(0.035)	(0.617)	[0.57]				
Morgan-Mercer-Flodin	-6.014*	91639.23*	795.06*	2.528*	0.59*	0.000	0.000	51.59	30.78
	(17.13)	(316850.30)	(4185.17)	(2.184)	[0.57]				

*Significant at 5% level; **Significant at 1% level; RMSE: Root mean square error; MAE: Mean absolute error; Values in brackets indicate standard errors; Values in square brackets indicate Adjusted R^2

Trends in production, based on time-series models: In ARIMA time-series methodology the auto-correlation upto fifteen lags were worked out. Since the computed auto-correlations γ_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 found that the mean and variance were changing over the time. However, the stationarity was achieved by differencing two times i.e., d = 2. The pattern of auto-correlations γ_k showed damped sine-wave and significant partial auto-correlations ϕ_{kk} were found at second, third and fourth lags. This suggested consideration of ARIMA (2, 2, 0), ARIMA (3, 2, 0) and ARIMA (4, 2, 0) as the candidate models (Table 4). Since the Shapiro-Wilks test (test for normality) values were found to be significant in all these models, these models have failed to fulfill the model selection criteria (normality of the residuals). None of the ARIMA families of time-series models have been found suitable to fit the trends in production of castor crop.

The above results are in agreement with Shukla (2007) who reported that none of the polynomial as well as ARIMA model was found satisfactory to explain the trends in production of groundnut crop grown in Jamnagar district of Gujarat state.

Trends in production, based on nonparametric regression model: Nonparametric regression model was fitted to the production data of castor crop. The optimum bandwidth was computed as 0.10 using the cross-validation method. Nonparametric estimates of underlying growth function were computed at each and every time points. Residual analysis showed that the assumptions of independence of errors were not violated at 5% level of significance. The root mean square and mean absolute errors were 42.06 and 21.96, respectively. These values were found to be minimum in comparison to that of the parametric models, indicating thereby the superiority of this approach over the parametric approach. Hence the nonparametric regression model was selected as the best fitted trend function for the production data of the castor crop. Similar trend was noted by Bhagyashree (2009) in castor production of Gujarat state during the period (1949-50 to 2003-04).

Trends in productivity, based on linear and non-linear models: For productivity of castor crop revealed that among the linear and non-linear models fitted, the adjusted R^2 was higher in the case of exponential (68%) model (Table 3). The amount of variation in production explained by this model was 69%. All the partial regression co-efficients were found to be highly significant. Since, the Shapiro-Wilks and run test values were significant, the following model failed to fulfill the model selection criteria (normality and randomness of the residuals) and hence this model was not found suitable to fit the trends in productivity of castor crop.

$$Y = 270.26^{**} \exp(0.0325^{**}X) \qquad (R^2 = 69^{**}\ \%) \tag{3}$$

The results of the present study are in agreement with those observed by Shukla (2007) that none of the polynomial models were found suitable to fit the trends in groundnut productivity in Amreli district of Gujarat state.

Trends in productivity, based on time-series models: In ARIMA time-series methodology the auto-correlation upto fifteen lags were worked out. Since, the computed auto-correlations γ_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 found that the mean and variance were changing over the time. However, the stationarity was achieved by

Table 3: Characteristics of fitted linear and non-linear models for productivity of castor crop

	Regression co-efficient				Goodness of fit				
Models	A	B	C	D	R^2/Adj.R^2	Shapiro-wilks test	Run test	RMSE	MAE
Linear	181.83*	23.01**	-	-	0.64**	0.016	0.000	291.82	208.75
	(78.29)	(2.27)			[0.64]				
Quadratic	70.08	34.00**	-0.183	-	0.65**	0.022	0.003	287.93	213.77
	(119.45)	(9.18)	(0.148)		[0.64]				
Cubic	149.31	18.80	0.445	-0.0070	0.66**	0.008	0.049	286.65	210.66
	(164.98)	(23.61)	(0.910)	(0.0099)	[0.64]				
Exponential	270.26**	0.0325**	-	-	0.69**	0.012	0.000	332.46	231.66
	(27.06)	(0.0029)			[0.68]				
Monomolecular	2511.84*	2439.05*	0.0142*	-	0.65*	0.023	0.003	288.33	213.40
	(1497.01)	(1408.82)	(0.0130)		[0.64]				
Hoerl	31.49*	0.989*	1.100*	-	0.65*	0.026	0.013	288.89	216.84
	(32.54)	(0.013)	(0.418)		[0.64]				
Logistic	1377.62*	8.50*	0.100*	-	0.67*	0.008	0.049	282.69	207.34
	(113.83)	(3.66)	(0.025)		[0.66]				
Gompertz	1532.44*	0.954*	0.056*	-	0.66*	0.011	0.049	284.36	210.06
relation	(215.67)	(0.218)	(0.018)		[0.65]				
Morgan-	279.85*	919879.38*	1324.02*	4.31*	0.68*	0.010	0.049	278.44	198.12
Mercer-Flodin	(89.86)	(5314323.99)		(111.80)	(1.83)	[0.66]			

*Significant at 5% level; **Significant at 1% level; RMSE: Root mean square error; MAE: Mean absolute error; Values in brackets indicate standard errors; Values in square brackets indicate Adjusted R^2

Table 4: Characteristics of fitted time-series models for area, production and productivity of castor crop

Aspects	ARIMA (p,d,q)	Constant	Auto-regressive co-efficient ϕ_1	ϕ_2	ϕ_3	ϕ_4	Goodness of fit AIC/BIC	Shapiro-wilks test	Box-Ljung	RMSE/MAE
Area	(2,2,0)	0.755	-0.713**	-0.429**	-	-	580.92/587.05	0.000	34.47	38.28/22.73
		(2.397)	(0.129)	(0.134)					[21.02]	
	(3,2,0)	0.729	-0.738**	-0.467**	-0.058	-	582.80/590.97	0.000	33.48	38.58/22.64
		(2.289)	(0.144)	(0.164)	(0.149)				[19.67]	
	(4,2,0)	0.520	-0.778**	-0.734**	-0.451**	-0.573**	564.06/574.27	0.000	17.04	32.00/18.77
		(1.234)	(0.118)	(0.145)	(0.146)	(0.122)			[18.30]	
Production	(2,2,0)	0.989	-0.984**	-0.476**	-	-	651.29/657.422	0.000	18.067	70.71/33.35
		(3.860)	(0.122)	(0.124)					[21.02]	
	(3,2,0)	0.871	-1.112**	-0.734**	-0.268	-	649.25/657.43	0.000	14.28	68.74/35.11
		(2.981)	(0.134)	(0.177)	0.137				[19.67]	
	(4,2,0)	0.776	-1.198**	-0.967**	-0.609**	-0.313*	645.54/655.75	0.000	6.17	65.74/34.96
		(2.189)	(0.133)	(0.195)	(0.196)	(0.136)			[18.30]	
Productivity	(2,1,0)	22.971	-0.370**	-0.277*	-	-	843.25/849.43	0.000	26.59	337.93/220.39
		(27.189)	(0.129)	(0.129)					[12.02]	
	(3,1,0)	23.797	-0.465**	-0.400**	-0.319*	-	838.78/847.03	0.002	12.92	321.70/212.31
		(19.669)	(0.129)	(0.132)	(0.128)				[19.67]	
	(4,1,0)	24.261	-0.577**	-0.538**	-0.474**	-0.323**	834.04/844.35	0.014	6.76	305.30/203.13
		(14.113)	(0.128)	(0.135)	(0.135)	(0.128)			[18.30]	

RMSE: Root mean square error; MAE: Mean absolute error; **The estimated t-values are greater than or equal to 2; Values in the brackets are corresponding standard errors; Values in the square brackets indicate critical values for Chi-square statistic at 5% level of significance

differencing one time, i.e., d = 1. The pattern of auto-correlations γ_k showed damped sine-wave and significant partial auto-correlations ϕ_{kk} at second, third and fourth lags. This suggested consideration of ARIMA (2, 1, 0), ARIMA (3, 1, 0) and ARIMA (4, 1, 0) as the candidate models (Table 4). But since the Shapiro-Wilks statistic (test for normality) values were found to be significant in all these models, these models have failed to fulfill the model selection criteria (normality of the residuals). None of the ARIMA families of time-series models have been found suitable to fit the trends in productivity of the castor crop.

Rajarathinam and Dixit (2007) reported that the ARIMA time-series models were found suitable to fit the trends in groundnut yield in long-term fertilizer experiment conducted at Junagadh, Gujarat state. Balanagammal *et al.* (2000) also employed the ARIMA (1, 1, 0) model to fit the trends in groundnut productivity of Tamil Nadu state. These results are not in agreement with the present study indicating that appropriateness of the models are influenced by the crop as well as the location.

Trends in productivity based on nonparametric regression model: Nonparametric regression model was fitted to the productivity data of castor crop. The optimum bandwidth was computed as 0.12 using the cross-validation method. Nonparametric estimates of underlying growth function were computed at each and every time points. Residual analysis showed that the assumptions of independence of errors were not violated at 5% level of significance. The root mean square (258.02) and mean absolute (180.93) error values were found to be lower than those in other linear and non-linear models, indicating thereby the superiority of this approach over the parametric approach. Hence the nonparametric regression model was selected as the best fitted trend function for the productivity of the castor crop. Bhagyashree (2009) reported similar trend in productivity of castor crop in Gujarat state during the period (1949-50 to 2003-04). Prajneshu and Chandran (2005) used nonparametric regression with jump-point to describe the trends in country's oilseed yield, however in the present study nonparametric regression without jump-point was evolved as the best fitted trend function. Further no significant jump-point was observed in castor productivity in the present study.

Discussion regarding area, production and productivity of oilseed crops: Patel and Agrawal (1994) studied the growth and instability of groundnut in Saurashtra region of Gujarat state by using linear and exponential models. Vaishnav and Dixit (1998) used polynomial models to study the trends in productivity of groundnut crop of Gujarat state. Singh (2002) by using linear and exponential model studied major oilseeds production in Gujarat state. In all the above mentioned studies test for randomness and normalities of the residuals were not reported. However, it is essential to test the randomness as well as normalities of the residuals for the best fitted trend models (Sananse and Maidapwad, 2009). The test for normality and randomness were carried out in the present study and it revealed that none of the polynomial, non-linear and time-series models were found suitable to fit the trends in area, production and productivity of castor crop since the residuals failed to fulfil the assumptions of normalities and independence.

Nonparametric regression model was selected as the best fitted trend function for the area, production and productivity of castor crop and the same is depicted in Fig. 1-3, respectively.

Growth rates in area, production and productivity of castor crop: The results presented in Table 5 shows relative growth rates of area, production and productivity of castor crop under

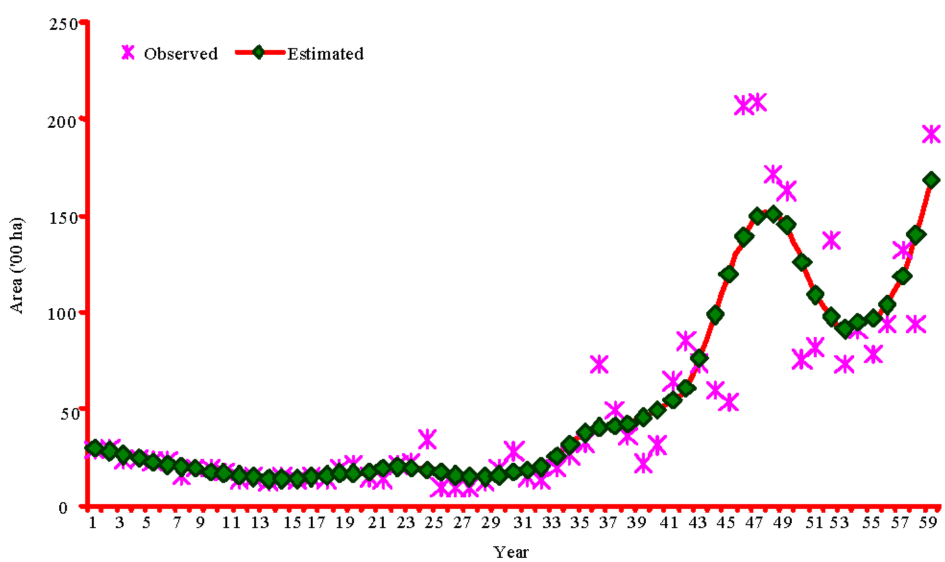

Fig. 1: Trends in area based on nonparametric regression

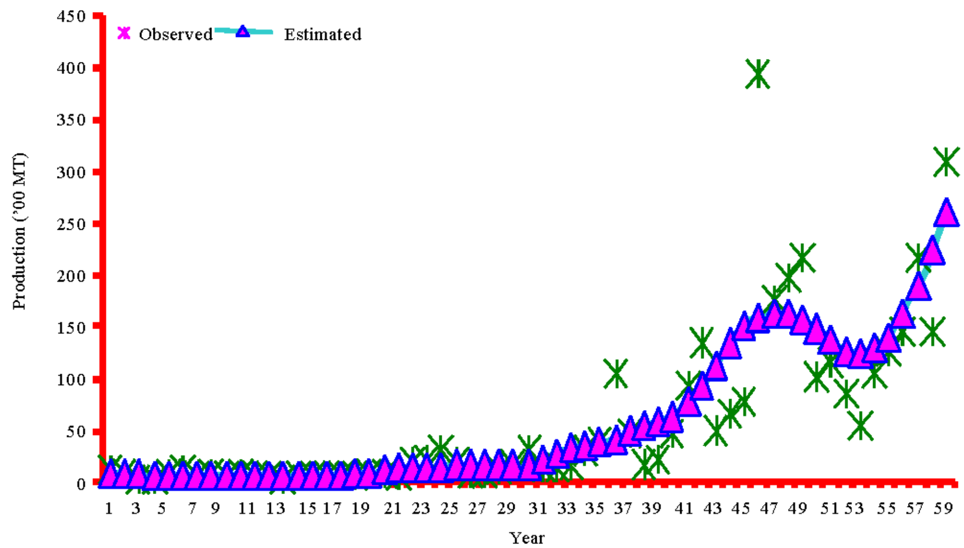

Fig. 2: Trends in production based on nonparametric regression

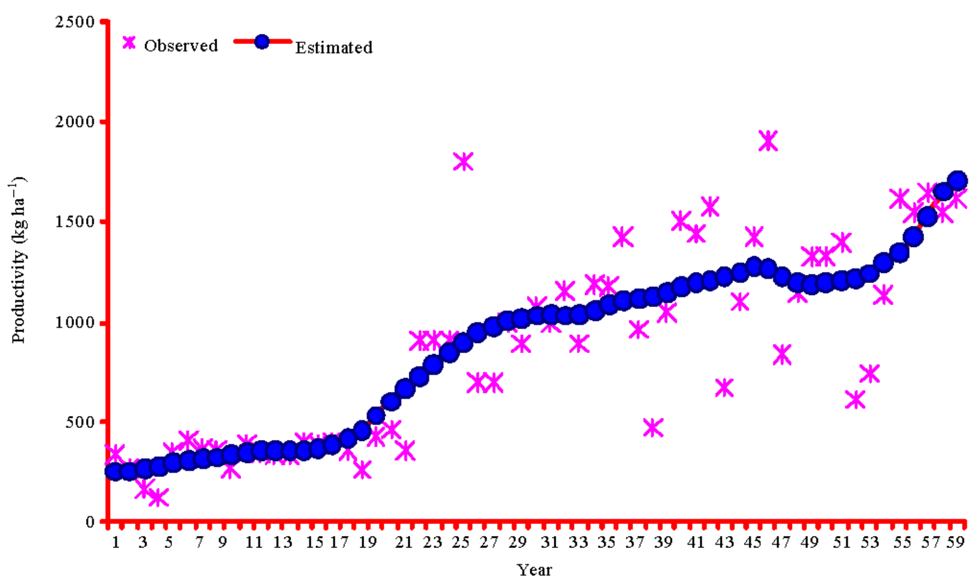

Fig. 3: Trends in productivity based on nonparametric regression

successive plans-period wise, starting from 1951-52 to 2006-07 based on the best fitted growth function, the nonparametric regression model.

The average percent growth rate values obtained for the successive years during (1949-50 to 2007-08) for the area, production and productivity led to the conclusion that the production had increased at a rate of 5.79%, which might be due to the combined effect of increase in area and productivity at a rate of 2.86 and 3.41% per annum, respectively.

Table 5: Plan period-wise relative growth rates of area, production and productivity of castor crop

Period	Area (%)	$Prod^{un}$ (%)	$Prod^{ty}$ (%)
Ist Five Year Plan (1951-52 to 1955-56)	-6.54	-1.03	4.92
IInd Five Year Plan (1956-57 to 1960-61)	-6.26	-4.12	1.74
IIIrd Five Year Plan (1961-62 to 1965-66)	3.13	3.40	2.63
IVth Five Year Plan (1969-70 to 1973-74)	-3.05	6.78	9.19
Vth Five Year Plan (1974-75 to 1978-79)	3.83	2.62	1.09
VIth Five Year Plan (1980-81 to 1984-85)	16.96	13.15	1.16
VIIth Five Year Plan (1985-86 to 1989-90)	5.73	10.38	1.88
VIIIth Five year Plan (1992-93 to 1996-97)	12.88	7.16	-0.84
IXth Five Year Plan (1997-98 to 2001-2002)	-10.10	-8.19	0.34
Xth Five Year Plan (2002-03 to 2006-2007)	9.42	14.01	6.27
Whole Period (1949-50 to 2007-08)	2.86	5.79	3.41

CONCLUSION

None of the parametric models have been found suitable to fit the trends in area, production and productivity data of castor crop due to lack of assumption of residuals. Nonparametric regression was selected as the best fitted trend function for the area, production and productivity of castor crop. Castor production had increased at a rate of 5.79% which was due to combined effect of increase in area and productivity at a rate of 2.86 and 3.41% per annum, respectively. Increase in area, production and productivity of castor crop has been observed in the present study.

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