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Estimating Models for Area, Production and Productivity Trends of Tobacco (*Nicotiana tabacum*) Crop for Anand Region Of Gujarat State, India

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Abstract: The present investigation was carried out to study area, production and productivity trends and growth rates of tobacco (*Nicotiana tabacum*) crop grown in Anand region of Gujarat state, India for the period 1949-50 to 2007-08 based on parametric and nonparametric regression models. 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 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. None of the parametric model was found suitable to fit the trends in area, production and productivity of the tobacco crop. The Nonparametric regression was finally selected as the best fitted trend function for the area, production and productivity of tobacco crop based on lower values of root mean square and mean absolute errors. Tobacco production had increased at a rate of 1.40% which was due to combined effect of increase in area and productivity at a rate of 0.02 and 1.39% 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

India, the world's third-largest producer of leaf tobacco (*Nicotiana tabacum*) is also a very large consumer of tobacco products. Tobacco, one of the important cash crops in the country, makes a significant contribution to the Indian economy in terms of employment, income and government revenue. It generates nearly Rs. 20 billion of income per annum. There are an estimated 8,50,000 growers of tobacco in the country, characterized by small family farms, with farmers owning less than 2 ha of land forming about half of all tobacco growers. However, based on field surveys carried out by Gujarat Agricultural University, Anand, in selected tobacco growing districts of Gujarat and Karnataka states, the small-scale producers account for about a quarter of the tobacco area. In total, nearly 6 million farmers and workers depend on this sector for their livelihood and it provides direct and indirect employment to a large number of people in many related industries. In India tobacco cultivation is mainly concentrated in three states: Andhra Pradesh, Gujarat and Karnataka (Anonymous, 2003).

Among various types of tobacco grown in India, bidi tobacco ranks second, accounting for 28% of the total tobacco area under cultivation and is first in production accounting for 33% of total tobacco production. In Gujarat, tobacco is cultivated in around 65 to 85 thousand ha, the major type being bidi tobacco. The other types of tobacco grown in Gujarat are chewing (Lal and Kala chopadia), Hookah (Gadaku) and Rustica, which are grown in about 20,000 ha land. Total production in Gujarat is around 125 million kilogram (kg) with a productivity of 1800 kg ha^{-1} (Anonymous, 2002).

The statistical information on crop area, production and productivity form the backbone of agricultural statistical system. Regional data analysis is extremely vital

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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 widely employed to study the long-term trends in various agricultural crops (Panse, 1964).

The growth rates of different 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; Patel *et al.*, 1986, Kumar and Rosegrant, 1994; Kumar, 1997; Borthakur and Bhattacharya, 1998; Joshi and Saxena, 2002; Singh and Srivastava, 2003; Shah *et al.*, 2005; Sarma, 2005; Patil *et al.*, 2009) have used parametric models, to estimate growth rates, which are currently 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.

The objective of the present study is to develop a appropriate statistical model to fit the trends and to calculate growth rates in area, production and productivity of tobacco crop grown in Anand region of Gujarat state based on both parametric (linear, non-linear and time-series) and nonparametric regression models.

MATERIALS AND METHODS

To achieve the stipulated objectives, the present study had been carried out on the basis of time-series data pertaining to the period 1949-50 to 2007-08 have been collected from various publications (Margdarshika, published yearly 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 auto-correlations upto fifteen lags were worked 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), 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 time point. Residual analysis was carried out to test the randomness. Relative growth rate was calculated based on best fitted model.

RESULTS AND DISCUSSION

Different parametric (linear, non-linear and time-series) and nonparametric regression models were employed to study the trends in area, production and productivity of the tobacco crop. The findings are discussed in sequence as under.

Trends in area, production and productivity based on linear and non-linear models: Among the linear and non-linear models fitted, for the area the Rational function with the maximum adjusted R^2 of 53 %, minimum values of RMSE (100.39) and MAE (74.15) (Table 1) for the production again the Rational function with the maximum adjusted R^2 of 83%, minimum values of RMSE (163.87) and MAE (121.12) (Table 2); for productivity Logistic model with the maximum adjusted R^2 of 88%, minimum values of RMSE (159.41) and MAE (126.67) (Table 3), respectively found suitable to fit the trends. All the estimated values of the parameters in these models were found to be within the 95% confidence interval indicating that the parameters were significant at 5% level of significance.

The Rational function (given in 1) fitted to the area, failed to fulfill the assumption of the residuals and hence none of the linear and non-linear models were found suitable to fit the trends in area under the cultivation of tobacco crop. However, to fit the trends in production and productivity the Rational function (given in 2) and the Logistic model (given in 3), respectively were emerged as the best fitted models among the linear and non-linear models:

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

	Regression co-efficient				Goodness of fit				
Model	A	B	C	D	R^2 (%)/Adj. R^2(%)	Shapiro-Wilks test	Run test	RMSE	MAE
Linear	516.17**	3.23**	-	-	0.13**	0.699	0.000	139.34	111.22
	(37.39)	(1.08)			[0.12]				
Quadratic	320.02**	22.52**	-0.32**	-	0.44**	0.746	0.003	111.65	90.85
	(46.32)	(3.56)	(0.058)		[0.42]				
Cubic	424.46**	2.47	0.51	-0.009*	0.50**	0.200	0.003	105.80	82.51
	(60.89)	(8.72)	(0.34)	(0.004)	[0.47]				
Exponential	499.57**	0.006**	-	-	0.13**	0.625	0.000	141.97	113.21
	(33.59)	(0.002)			[0.12]				
Logistic	663.22*	1.13*	0.160*	-	0.31*	0.925	0.030	212.13	161.19
	(23.04)	(0.506)	(0.068)		[0.29]				
Monomolecular	666.51*	393.66*	0.117*	-	0.32*	0.910	0.006	123.95	99.59
	(25.26)	(98.60)	(0.0502)		[0.29]				
Gompertz relation	664.78*	-0.2083*	0.1380*	-	0.32*	0.921	0.013	123.94	99.86
	(23.94)	(0.3459)	(0.0583)		[0.30]				
Hoerl	244.60*	0.9876*	0.4082*	-	0.36*	0.761	0.001	120.64	100.04
	(54.53)	(0.0045)	(0.1061)		[0.33]				
Rational function	445.53*	-7.04*	-0.0282*	0.0002*	0.55*	0.043	0.000	100.39	74.15
	(26.27)	(0.65)	(0.0014)	(0.000031)	[0.53]				
Morgan-	343.61*	154.63*	664.29*	2.47*	0.32*	0.934	0.013	123.89	100.62
Mercer-Flodin	(96.16)	(680.21)	(30.63)	(1.87)	[0.28]				

*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 2: Characteristics of fitted linear and non-linear models for production of tobacco crop

	Regression co-efficient				Goodness of fit				
Model	A	B	C	D	R^2 (%)/Adj. R^2(%)	Shapiro-Wilks test	Run test	RMSE	MAE
Linear	352.65**	18.19**	-	-	0.57**	0.088	0.000	269.78	200.28
	(72.38)	(2.10)			[0.56]				
Quadratic	-58.77	58.65**	-0.674**	-	0.75**	0.373	0.000	205.43	174.16
	(85.23)	(6.55)	(0.106)		[0.74]				
Cubic	338.71**	-17.65	2.48**	-0.035**	0.86**	0.070	0.359	154.23	114.23
	(88.76)	(12.70)	(0.49)	(0.005)	[0.85]				
Exponential	357.92**	0.026**	-	-	0.61**	0.001	0.013	332.73	239.84
	(34.43)	(0.003)			[0.60]				
Monomolecular	1359.57	1361.57	0.0456	-	0.68*	0.513	0.001	231.83	184.03
	(276.77)	(256.99)	(0.0281)		[67]				
Hoeral Model	3.480*	0.9490*	2.163*	-	0.75*	0.467	0.695	207.37	176.00
	(3.153)	(0.010)	(0.364)		[0.74]				
Sinusoidal	830.76*	521.03*	0.085*	-3.541*	0.84*	0.477	0.049	164.32	126.52
	(34.46)	(32.18)	(0.006)	(0.222)	[0.83]				
Rational function	303.16*	-0.942*	-0.037*	0.0043*	0.84*	0.118	0.695	163.87	121.12
	(42.04)	(1.920)	(0.001)	(0.000032)	[0.83]				

*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 3: Characteristics of fitted linear and non-linear models for productivity of tobacco crop

	Regression co-efficient				Goodness of fit				
Model	A	B	C	D	R^2 (%)/Adj. R^2(%)	Shapiro-Wilks test	Run test	RMSE	MAE
Linear	680.19**	24.64**	-	-	0.81**	0.759	0.006	205.26	155.43
	(55.07)	(1.60)			[0.80]				
Quadratic	408.38**	51.37**	-0.446**	-	0.87**	0.877	0.894	169.67	132.29
	(70.39)	(5.41)	(0.087)		[0.86]				
Cubic	602.33**	14.14	1.09*	-0.017**	0.89**	0.490	0.695	156.21	123.07
	(89.91)	(12.87)	(0.50)	(0.005)	[0.88]				
Exponential	716.44**	0.020**	-	-	0.72**	0.748	0.000	262.36	199.20
	(41.41)	(0.002)			[0.72]				
Monomolecular	2330.77*	1909.04*	0.028*	-	0.86*	0.668	0.088	177.44	139.12
	(241.85)	(198.55)	(0.00779)		[0.85]				
Logistic Model	1944.11*	3.19*	0.086*	-	0.88*	0.919	0.089	159.41	126.67
	(62.009)	(0.420)	(0.010)		[0.88]				
Sinusoidal	1252.58*	645.20*	0.062*	-2.913*	0.89*	0.579	0.149	153.09	120.68
	(71.01)	(60.39)	(0.0077)	(0.302)	[0.88]				

* 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

$$Y = (445.53^{*}-7.04^{*} X)/(1-0.0282^{*} X+0.0002^{*} X^2) \quad (R^2 = 55^{*}\%) \quad (1)$$

$$Y = (303.16^{*}-0.942^{*} X)/(1+0.037^{*} X+0.0043^{*} X^2) \quad (R^2 = 84^{*}\%) \quad (2)$$

$$Y = 1944.11^{*}/(1+3.19^{*}EXP(-0.086^{*} X)) \quad (R^2 = 88^{*}\%) \quad (3)$$

(*Significant at 5% level)

Trends in area, production and productivity based on time-series models: For the area under the cultivation of tobacco crop, 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 and third lags. This suggested consideration of ARIMA (2,2,0) and ARIMA (3,2,0) as the candidate models. The ARIMA (3,2,0) model had comparatively lower AIC and BIC values with significant auto-regressive co-efficients. The RMSE and MAE values were 126.84 and 94.38, respectively. The stationarity of production data of tobacco crop 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. The ARIMA (4,2,0) had comparatively lower AIC and BIC values with significant auto-regressive co-efficients. The RMSE and MAE values of this model were 189.02 and 139.14, respectively. In case of productivity of tobacco crop the stationarity was achieved by 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 and third lags. This suggested consideration of ARIMA (2,1,0) and ARIMA (3,1,0) as the candidate models. The ARIMA (2,1,0) model had comparatively lower AIC, BIC, RMSE and MAE values with significant auto-regressive co-efficients. The root mean square and mean absolute error values of this model were 155.71 and 117.27, respectively (Table 4).

Among the ARIMA families of time-series models, the models ARIMA (3,2,0), ARIMA (4,2,0) and ARIMA (2,1,0), respectively were found suitable to fit the trends in area, production and productivity of the tobacco crop. In all these models the residuals were independently and normally distributed (Table 4).

Trends in area, production and productivity based on nonparametric regression model: Using the cross-validation method, for the area, production and productivity of the tobacco crop, the optimum bandwidth was computed as 0.085, 0.086 and 0.102, respectively. Nonparametric estimates of underlying growth function were computed at each and every time point. Residual analysis showed that the assumptions of independence of errors were not violated at 5% level of significance. The RMSE, MAE values were for area 72.85 and 54.97; for production 116.68 and 90.99; productivity 119.80 and 91.20, respectively. These values were much lower than those obtained through the parametric models, indicating thereby the superiority of this approach over the parametric approach. The nonparametric regression model was selected as the best fitted trend function for the area. The decling trend was observed in area (Fig. 1) as well as in production (Fig. 2). However the productivity trend was increasing (Fig. 3) which might be due to technological innovation.

Table 4: Characteristics of fitted time-series models for area, production and productivity of tobacco 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)	-1.851	-0.812**	-0.547**	-	-	722.16/728.29	0.711	22.03	138.50/102.61
		(7.504)	(0.115)	(0.111)					[21.02]	
	(3,2,0)	-1.518	-1.063**	-0.904**	-0.484**	-	710.59/718.76	0.578	11.81	126.84/94.38
		(4.605)	(0.118)	(0.138)	(0.117)				[19.67]	
Production	(2,2,0)	-1.906	-0.933**	-0.549**	-	-	775.405/781.534	0.108	37.47	212.41/156.23
		(11.367)	(0.112)	(0.111)					[21.02]	
	(3,2,0)	-2.015	-1.149**	-0.909**	-0.379**	-	768.29/776.46	0.560	24.10	197.88/147.76
		(7.664)	(0.125)	(0.156)	(0.125)				[19.67]	
	(4,2,0)	-1.626	-1.283**	-1.213**	-0.756**	-0.321*	764.07/774.28	0.198	12.83	189.02/139.14
		(5.525)	(0.129)	(0.192)	(0.193)	(0.131)			[18.30]	
Productivity	(2,1,0)	18.677	-0.764**	-0.427**	-	-	753.82/760.00	0.815	9.76	155.71/117.27
		(9.449)	(0.121)	(0.122)					[21.02]	
	(3,1,0)	18.665	-0.752**	-0.407**	0.026	-	755.83/764.07	0.827	6.71	157.10/117.13
		(9.785)	(0.136)	(0.162)	(0.137)				[16.91]	

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

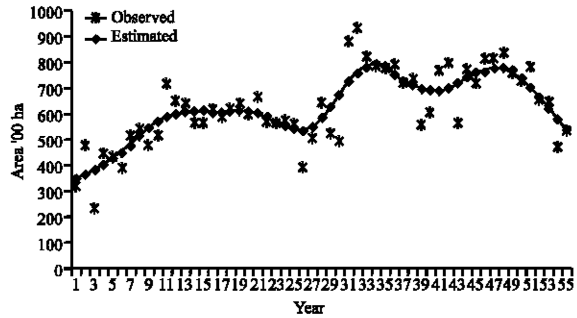

Fig. 1: Trends in area based on nonparametric regression

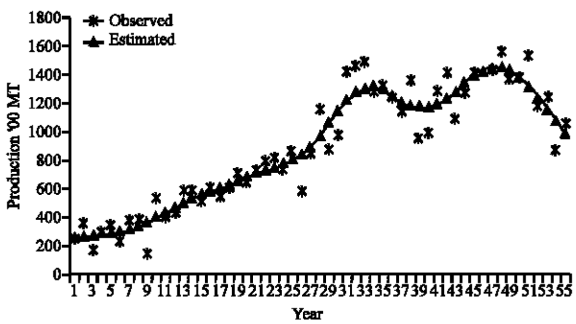

Fig. 2: Trends in production based on nonparametric regression

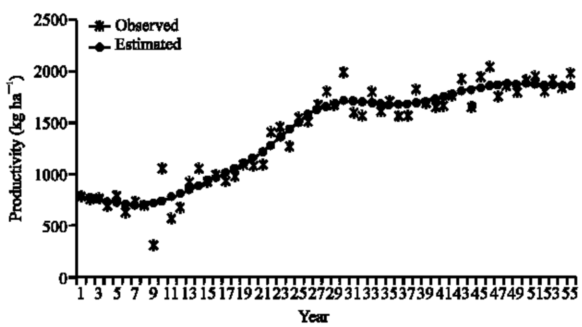

Fig. 3: Trends in productivity based on nonparametric regression

Discussion in area, production and productivity of tobacco crop: Patel *et al.* (1986) studied the trends in area, production and productivity of tobacco crop grown in all over India for the periods (1960-61 to 1983-84) based on parametric models. Kalola *et al.* (1995) reported that for area the second degree (Quadratic) polynomial model; for production and productivity the first degree polynomial models were found suitable to fit the trend of tobacco crop grown in Gujarat state for the period 1951-52 to 1990-91. Sarma (2005) used the first degree polynomial model of the form Log Y = a+b*t to study the trend in area, production and productivity of tobacco crop grown in Assam state for the period 1972-73 to 1999-2000. In all these studies the test for normality and randomness 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). In the present study the test for normality and randomness of the residuals were carried and it was found that the residuals due to first and second degree polynomial models were not independently distributed.

Bhagyashree and Rajarathinam (2009) reported that nonparametric regression model was found suitable to fit the trends in area under the *bajra* crop in Gujarat state during the period (1949-50 to 2003-04). Bhagyashree (2009) employed nonparametric regression model to study the trends in area, production and productivity of tobacco crop grown in Gujarat state during the period (1949-50 to 2003-04). The results of the present study are in agreement with these researchers.

Parmar (2010) used first degree polynomial model to study the trends in area under cultivation of Maize crop grown in Panchmahal district for the period 1949-50 to 2008-09. This result is not in agreement with the present study indicating that appropriateness of the models are influenced by the crop as well as the location.

Growth rates in area, production and productivity of tobacco crop: Relative growth rate of area, production and productivity of tobacco crop were calculated for the successive years starting from 1949-50 to 2007-08 based on the best fitted growth function, the nonparametric regression. Also, the values for each year for area, production and productivity were computed year wise for every fifth plan periods commencing from 1951-52 to 1955-56 and the average of five years period of each plan had been computed and presented in Table 5.

During the first five year plan the average rate of increase in production was 3.76% per annum. This was because the area under the crop increased at an average rate of 5.88% per annum. In the second plan period the production increased at an average rate of 8.10% per annum as a result of both expansion in area and improvement in yield at an average rate of 4.36 and 3.78% per annum, respectively. Even though the area under the crop declined during third and fourth plan periods declined in the state, the production showed positive growth rate due to increase in productivity. Highest production (7.76% per annum) was observed in the fifth plan period due to increase in area (5.68% per annum) and productivity (2.24% per annum). In ninth plan as well as in the 10th plan periods production declined due to the decline in area as well productivity (Table 5).

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

Period	Area (%)	Prod^{un} (%)	Prod^{ty} (%)
1st five year plan (1951-52 to 1955-56)	5.88	3.76	-2.15
2nd five year plan (1956-57 to 1960-61)	4.36	8.10	3.78
3rd five year plan (1961-62 to 1965-66)	-0.14	3.92	4.18
4th five year plan (1969-70 to 1973-74)	-2.85	2.73	5.39
5th five year plan (1974-75 to 1978-79)	5.68	7.76	2.24
6th five year plan (1980-81 to 1984-85)	-0.55	-0.85	-0.51
7th five year plan (1985-86 to 1989-90)	-1.28	-0.36	1.04
8th five year plan (1992-93 to 1996-97)	1.43	2.04	0.63
9th five year plan (1997-98 to 2001-2002)	-5.43	-5.39	-0.08
10th five year plan (2002-03 to 2006-2007)	-7.97	-8.81	-0.56
Whole period (1949-50 to 2007-08)	0.02	1.40	1.39

The percent growth rate values obtained for the successive years during 1949-50 to 2007-08 for the area, production and productivity when averaged showed that the production had increased at a rate of 1.40% which was due to combined effect of marginal increase in area and productivity at a rate of 0.02 and 1.39% per annum, respectively (Table 5).

CONCLUSION

None of the linear and non-linear models were found suitable to fit the trends in area under the cultivation of tobacco crop. However, for the production and productivity the Rational function and logistic models, respectively were emerged as the best fitted trend models. Among the ARIMA families of time-series models, the models ARIMA (3,2,0), ARIMA (4,2,0) and ARIMA (2,1,0) were found suitable to fit the trends in area, production and productivity, respectively. The nonparametric regression was finally selected as the best fitted trend function for the area, production and productivity of tobacco crop based on lower values of root mean square and mean absolute error. Tobacco production had increased at a rate of 1.40% which was due to combined effect of increase in area and productivity at a rate of 0.02 and 1.39% per annum, respectively.

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