PARAMETRIC MODELLING TO ANALYSE TRENDS IN HARVESTED AREA, PRODUCTION AND PRODUCTIVITY OF NATURAL RUBBER IN KERALA

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ABSTRACT

The current study focuses on estimating trends and growth rates in harvested area, production and productivity of natural rubber (*Hevea Brasiliensis*) in Kerala from 1991-92 to 2015-16, employing parametric models. Among the parametric models, various linear, non-linear and time-series models are used for the investigation. On the basis of co-efficient of determination (R^2), adjusted R^2 and significant regression co-efficients, the statistically best-fitted parametric models are selected. After checking the data for stationarity, the best suited time-series models are selected on the basis of goodness of fit criteria, namely, Akaike's Information Criterion, Hannan-Quinn Criterion (HQC), Shapiro-Wilks Test (SW), Root Mean Square Error, Mean Absolute Error and assumptions of normality of residuals. Auto Regressive Integrated Moving Average (ARIMA) is used for time series models in order to examine trends in harvested area, production and productivity. The best models (p,d,q) are determined and tabulated on the basis of Information Criteria. On the basis of residual analysis, the randomness is tested. The natural rubber production has slightly increased at the rate of 0.73% per annum during 1992-93 to 2015-16. It is the result of a collective effect of marginal increases in harvested area and productivity at a rate of 1.47 and 0.87 % per annum, respectively.

Keywords: Akaike's Information Criterion; Hannan-Quinn Criterion; Shapiro-Wilks Test; Run Test

INTRODUCTION

India is the sixth largest producer of natural rubber (*Hevea Brasiliensis*) in the global economy (The Statistics and Planning Department, 2017). In the production of natural rubber, the state of Kerala ranks first and contributes 78% of India's total production. The state of Kerala produced 438630 tonnes during the year 2015-16, which is lower than the production of the previous year (507700 tonnes in 2014-15). Kerala is comprised of 296465 hectares of tapped area with a productivity of 1480 kg per hectare. The area also declined when compared to tapped area of the previous year 2014-15 (The Statistics and Planning Department, 2017). Price fluctuations, climatic adversity, increased wages and lack of skilled rubber tappers are some of the causes for the decline in harvested area, production and productivity of natural rubber. However, Natural rubber, one of the prominent cash crops in the state, makes a vital contribution to the Kerala economy in terms of employment, income and government revenue. In Kerala, the majority of natural rubber production is from Kottayam district (The Statistics and Planning Department, 2017).

The exact statistical information on area, production and productivity is inevitable for the efficiency of an agricultural statistical system that fosters to formulate strong governmental policies and effective planning. Trends, growth rates and their volatility can be systematically examined by utilising proper statistical tools. To analyse the growth rates of various agricultural products, parametric models are generally used by adopting linear or exponential functions. Various studies are undertaken by the researchers based on these models that are presently being applied by the policy framers of the government and its organisations too in evaluating the growth rate of agricultural commodities (Misra 2017, Parmar *et al.*, 2017).

Rajarathinam *et al.*, (2010) used parametric and nonparametric modelling to estimate area, production and productivity of tobacco in Anand region of Gujarat (1949-2008). First degree polynomial was found to be the most appropriate model to estimate and analyse the trends in Maize production in Panchamal district (1949-2009) in Gujarat (Parmar, 2010). In another study (Rajarathinam and Vinoth, 2012), the trends in area, production and productivity of wheat (1950-2010) was examined using Sinusoidal modelling. Also, Kumar *et al.* (2015) chose parametric models based on the regression co-efficient, co-efficient of determination (R^2) and adjusted R^2 to estimate the trends in area, production and productivity of cotton grown in the state of Gujarat (1985-2013). Misra (2017) employed orthogonal polynomial method in evaluating the trends in area, production and productivity of groundnut in Uttar Pradesh (1964-2014). Parmar *et al.* (2017) employed parametric and nonparametric regression models to estimate the trends of maize crop's area, production and productivity (1949-2008).

The objective of the present study is to construct an appropriate econometric model to fit the trends and to find out the growth rate of harvested area, production and productivity of natural rubber cultivated in Kerala based on parametric (Linear, non-linear and time series) regression models.

MATERIALS AND METHODS

The present study employs time-series data corresponding to the period 1991-1992 to 2015-2016 in order to meet the defined objectives. The data is extracted from the different volumes of Indian Rubber Statistics (IRS) published by The Rubber Board, Ministry of Commerce and Industry, Government of India.

Various linear (Montgomery *et al.*, 2003), non-linear (Draper and Smith, 1998) and Auto-Regressive Integrated Moving Average (ARIMA) time series models (Box *et al.*, 1976) are some of the parametric models applied for the research. Based on Mean Absolute Error (MAE), Root Mean Square Error (RMSE), adjusted R^2, significant regression co-efficients and co-efficient of determination (R^2), the statistically most suited parametric models are chosen.

RESULTS AND DISCUSSION

In order to study the trends in harvested area, production and productivity of natural rubber parametric and regression models are used. The results are summarized in the following discussion.

Trends in harvested area, production and productivity based on linear and non-linear models: Among the linear and non-linear models fitted, for the harvested area the Linear, Quadratic and cubic function with the adjusted R^2 of 74%, 82.7% and 81.7%, values of RMSE (18967.43, 14570.57 and 15093.36) and MAE (12476.6, 6672.103 and 7711.54) (Table 2) based on the R^2 value the best model is Quadratic model for harvested area. Production against the Cubic function with the maximum adjusted R^2 of 90%, values of RMSE (43590.3) and MAE (35921.7) (Table 3); for productivity quadratic model with the maximum adjusted R^2 of 84%, values of RMSE (91.02) and MAE (73.43) (Table 4), respectively found suitable to fit

the trends. All the calculated values of the parameters in the discussed models were seemed to be within the 95% confidence interval indicating that the parameters were significant at 5% level of significance.

Table 2: Characteristic of fitted linear and non-linear model for harvested area of natural rubber

Model	A	B	C	D	R2/ Adj R2	RMSE/ MAE	SW/ SF	Run Test
Linear	**310221.14**	**4487.4**			0.74/ 0.73	18967.43/ 12476.6	0.83/ 0.81	0.034
	(8153.33)	(548.739057)						
Quadratic	**282909.0**	**10556.8**	**-233.409**		0.827/ 0.812	14570.57/ 6672.103	0.94/ 0.91	0.032
	(106.5001)	(1916.33)	(-233.409)					
Cubic	**295881.6**	5139.536	278.37	-13.097	0.817/ 0.805	15093.36/ 7711.54	0.72/ 0.718	0.914
	(15427.3)	(5038.2)	(445.63)	(11.28)				

*Significant at 5%, ** Significant at 1% level, RMSE: Root mean squared error; values in bracket () indicates standard errors

Table 3: Characteristic of fitted linear and non-linear model for production of natural rubber

Model	A	B	C	D	R2/ Adj R2	RMSE/ MAE	SW/ SF	Run Test
Linear	**435973.9**	**12906.01**			0.434/ 0.409	10623.1/ 78341.1	0.80/ 0.79	0.001
	(45664.9)	(3071.759)						
Quadratic	**228150.9**	**59088.88**	**-1776.26**		0.774/ 0.754	67028.1/ 52413.21	0.91/ 0.87	0.022
	(46545.41)	(8249.45)	(307.99)					
Cubic	**395542.1**	-13039.09	**5029.97**	**-174.3907**	0.904/ 0.891	43590.3/ 35921.7	0.89/ 0.86	0.081
	(44553.9)	(14550.36)	(1286.93)	(32.57)				

*Significant at 5%, ** Significant at 1% level, RMSE: Root mean squared error; values in bracket () indicates standard errors

Table 4: Characteristic of fitted linear and non-linear model for productivity of natural rubber

Model	A	B	C	D	R2/ Adj R2	RMSE/ MAE	SW/ SF	Run Test
Linear	**1359.04**	**21.673**			0.46/ 0.43	168.7/ 130.9	0.71/ 0.68	0.309
	(76.5)	(4.57)						
Quadratic	**1002.33**	**100.942**	**-3.048**		0.84/ 0.825	91.02/ 73.43	0.91/ 0.86	0.0116
	(63.7)	(11.03)	(0.42)					
Cubic	**1191.4**	21.34	4.456	-0.192	0.77/ 0.75	72.32/ 61.44	0.76/ 0.71	0.0124
	(74.2)	(24.5)	(2.14)	(0.084)				

*Significant at 5%, ** Significant at 1% level, RMSE: Root mean squared error; values in bracket () indicates standard errors

Trends in harvested area, production and productivity based on time-series models: For the harvested area under natural rubber, the stationarity was attained by differencing one time i.e., d=1. The pattern of auto-correlations γ_k and partial auto-correlations ϕ_{kk} showed damped sine-wave. This suggested consideration of ARIMA (2, 1, 3) as the model. The AIC, HQC, RMSE and MAE values were 21.64, 22.63, 63.99 and 38.75 respectively. The stationarity of production data of natural rubber was achieved by differencing one times i.e., d=1. The pattern of auto-correlations γ_k showed damped sine wave and significant partial auto-correlations ϕ_{kk} at first two lags. This suggested consideration of ARIMA (2, 1, 0) as the model. The AIC, HQC, RMSE and MAE values of this model were 16.01, 15.25, 97.26 and 55.221 respectively. In case of productivity of natural rubber, the stationarity was achieved by differencing first times, i.e., d=1. The pattern

of auto-correlations γ_k showed damped sign-wave and significant partial auto-correlations ϕ_{kk} at first lags. This suggested consideration of ARIMA (1, 1, 0) and as the model. The ARIMA (1, 1, 0) model AIC, HQC, RMSE and MAE values are 11.34, 11.858, 51.4 and 31.72 respectively (Table.5).

Table 5: Characteristic of fitted time Series model for harvested area, production and productivity of natural rubber

Aspects	ARIMA (p,d,q)	Constant	Φ_1	Φ_2	θ_1	θ_2	θ_3	θ_4	AIC	HQC	RMSE	MAE	Shapiro Wilks
AREA	(2,1,3)	4953.4	-0.230	-0.668	0.889	-0.884	-0.89	-0.94	21.64	22.63	63.99	38.75	0.72
PRODUCTION	(2,1,0)	540885.2	**1.5561****	**-0.648****					16.01	15.25	97.26	55.221	0.69
PRODUCTIVITY	(1,1,0)	15.247	**-0.39****						11.34	11.858	51.416	31.72	0.89

RMSE: Root Mean Squared Error, MAE: Mean Absolute Error, **The estimated t-values are greater than or equal to 2

Growth rates in area, production and productivity of natural rubber

Statistical data from 1992-93 to 2015-16 with three-year intervals is analyzed and depicted here in Table.7.

Table 7: Relative growth rates of harvested area, production and productivity of natural rubber

Period	Harvested Area (%)	Production (%)	Productivity (%)
1992-95	1.33	6.30	4.91
1995-98	1.36	4.53	3.13
1998-01	0.95	1.22	0.27
2001-04	1.99	4.12	2.09
2004-07	0.70	4.28	3.55
2007-10	0.11	-0.34	-0.45
2010-13	1.15	1.26	0.12
2013-16	0.80	-12.21	-4.42
Whole period (1992-2016)	1.47	0.73	0.87

Source: Authors computed and data on natural rubber is taken from IRS

From 1992 to 1995, the annualised growth rate of natural rubber production was 6.30% per annum. This could be attributed to the rise in productivity which was 4.91% per annum during the same period, which is the highest growth rate of production and productivity during the entire period considered in the study. During the next three-year period (1995-1998), the growth in productivity decreased to 4.53% per annum. This could be due to the corresponding fall in the growth of productivity which was at 3.13% per annum. During the sixth time period, production shrank to -0.34% per annum. This could be due to the negative growth rate in productivity (at -0.45% per annum). In the recent three-year period 2013-16, production was severely affected and the growth rate was at -12.21% per annum in spite of the growth in rubber harvested area. This was entirely due to the negative growth rate of productivity (-4.42% per annum).

The growth rate analysed from the data for the successive periods during 1992 to 2016 for the harvested area, production and productivity shows that the production increased slightly at a rate of 0.73% per annum which is a result of cumulative effect of a slight increase in harvested area and productivity at a rate of 1.47 and 0.87 % per annum, respectively. Table 6 depicts an overview of the figures for each interval.

CONCLUSION

The quadratic model was seemed to be most suited in the trends in harvested area under the cultivation of natural rubber. On the other hand, for the production, cubic model was the most appropriate model and for productivity, only the quadratic function was found fitted for trend models. Among the ARIMA families of time-series models, the model ARIMA (2,1,3), ARIMA (2,1,0) and ARIMA (1,1,0) were seemed to be suited for the trends in area, production and productivity, respectively.Natural rubber production had accelerated at a rate of 0.73% per annum which was perhaps a result of joined outcome of marginal increase in harvested area and productivity at a rate of 1.47 % and 0.87% per annum, respectively.

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