https://doi.org/10.56093/ijas.v90i4.102149

Indian Journal of Agricultural Sciences **90** (4): 681–4, April 2020/Article

Econometric modelling for harvested area, production and productivity of natural rubber (*Hevea brasiliensis*)

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Received: 15 November 2017; Accepted: 29 August 2019

ABSTRACT

The objective of present investigation was to study the trends in harvested area, production and productivity, and growth rates of natural rubber (*Hevea brasiliensis*) in Tamil Nadu from April 1991 to March 2016 by employing parametric models. The annual time-series data for the period from April 1991 to March 2016 was used for the study. The analysis was carried out during the year 2016-17. Different linear, non-linear and time-series models of parametric models were used. The statistically best fitted parametric models were chosen based on adjusted R^2, significant regression co-efficients and co-efficient of determination (R^2). After analysing the data for stationarity, the suitable time-series models were chosen based on various goodness of fit criteria, viz. Bayesian information criterion, Akaike's Information Criterion, Root Mean Square Error, Mean Absolute Error and assumptions of normality of residuals. Trends in harvested area, production and productivity were analysed based on time series models using ARIMA. Among them, the best model was extracted and tabulated. Natural rubber production increased at the rate 1.31% per annum during the period, which was a result of the combined effect of rise in harvested area and productivity at a rate of 1.09% and 0.91% per annum, respectively.

Key words: Akaike's Information Criterion, Adjusted R^2, Bayesian Information Criterion, Run test

India holds sixth position both in area and production of natural rubber (*Hevea brasiliensis*) in the global economy (The Statistics and Planning Department 2016). Natural rubber is one of the significant crops among the plantation crops in the country which makes an outstanding contribution to income and employment. In India, the livelihood of about 1.3 million growers is based on natural rubber. Natural rubber provides direct and indirect employment to a large population in the related industries. Indian rubber economy generates an income of around ₹ 6500 crore per annum. In the Indian production, Kerala contributes 77%. Tamil Nadu occupies fourth position in India's natural rubber production. About 3.7% of its total production is generated by Tamil Nadu. Total production in Tamil Nadu is around 23,785 tonnes with productivity of 1554 kg/ha (The Statistics and Planning Department 2016). In Tamil Nadu, a major share of production of natural rubber comes from Kanyakumari district.

The data on area, production and productivity of crops is vital in the decision making of states and the central government. Economic policy making, planning, statistical analysis is impossible without the statistical data. (Panse 1964). Parametric models are commonly employed to estimate the growth rates of different crops. Many research works (Rajarathinam *et al.* 2010, Sudha *et al.* 2013, Parmar *et al.* 2016, Kumar *et al.* 2017) have used parametric models to calculate growth rates. Parametric models are presently being used by the policymakers of the country. However, the statistical information may not be adapted linear or exponential models or may need fitting of higher degree polynomials or non-linear models. Further, these models fail to consider normality of residuals.

Developing a suitable econometric model to fit the trend and to estimate the growth rates in harvested area, production and productivity of natural rubber cultivated in the state of Tamil Nadu using the parametric regression model (linear, non-linear and time series) was the purpose of this study.

MATERIALS AND METHODS

Secondary data was used to analyse the trends of harvested area, production and productivity of natural rubber in Tamil Nadu. The data was collected from the publications of The Rubber Board, Ministry of Commerce and Industry, Government of India for the period from April 1991 to March 2016.

Different linear (Montgomery *et al.* 2001), non-linear (Draper and Smith 1998, Ratkowsky 1990) and Auto-Regressive Integrated Moving Average (ARIMA) time

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series models (Box *et al.* 1976) were used in parametric models. The parametric models were chosen on the basis of Mean Absolute Error (MAE), Root Mean Square Error (RMSE), adjusted R^2, significant regression co-efficients and co-efficient of determination (R^2). The linear, rational, Gompertz, quadratic and cubic models' equations are given below:

$Y = A + BX$ (Linear model) (1)

$Y = A + BX /(1 + EXP(DX^2))$ (Rational model) (2)

$Y = A + EXP\ (BX^C)$ (Gompertz model) (3)

$Y = A + BX + CX^2$ (Quadratic model) (4)

$Y = A + BX + CX^2 + DX^2$ (Cubic model) (5)

where Y, harvested area, production and productivity; X, trend; A, B, C, D are the partial regression coefficients.

Suitable ARIMA models were fitted after an evaluation of the time-series data for stationarity based on visual inspection, auto-correlation function and partial auto-correlation function. The auto-correlations up to seven lags were worked out. The most suitable time-series model was employed based on different goodness of fit criteria, viz. Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC).

RESULTS AND 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, Rational and Quadratic function with the adjusted R^2 of 97%, 98.7% and 98.1%, values of RMSE (198.43, 244.23 and 119.98) and MAE (158.34, 210.64 and 95.16) (Table 1) based on the R^2 value, the best model is Quadratic model for harvested area. Production against the quadratic function with the maximum adjusted R^2 of 92.4%, values of RMSE (955.061) and MAE (655.19) (Table 2); for productivity Logistic model with the maximum adjusted R^2 of 92.5%, values of RMSE (41.0) and MAE (33.93) (Table 3), respectively, found suitable to fit the trends. All the calculated values of the parameters in the discussed models were within the 95% confidence interval indicating that the parameters were significant at 5% level of significance.

Trends in harvested area, production and productivity based on time-series models: For the harvested area under

Table 1 Characteristic of fitted linear and non-linear model for harvested area of natural rubber

Model	A	B	C	D	R^2/ Adj R^2	RMSE/ MAE	SW/ SF	Run Test
Linear	11925.82 (85.31722)	160.3462 (5.739057)			0.971379/ 0.970135	198.43/ 158.34	0.934/ 0.929	0.002
Rational	11770.02 (85.22556)	-273.741 (89.56445)	0.037662 (0.006378)	0.000416 (3.76E-05)	0.989076/ 0.987515	244.23/ 210.64	0.928/ 0.927	0.014
Gompertz	11385.96 (285.5339)	0.038803 (0.01446)	0.663828 (0.096345)		0.975754/ 0.97355	193.8/ 185.3	0.962/ 0.965	0.168
Quadratic	11608.14 (106.5001)	230.9413 (18.87548)	-2.7152 (0.704721)		0.98291/ 0.981357	119.98/ 95.16	0.964/ 0.966	0.393
Cubic	11960.65 (114.5211)	82.59295 (37.40015)	11.27316 (3.30808)	-0.35868 (0.083739)	0.990879/ 0.98957	153.36/ 117.87	0.982/ 0.938	0.844

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

Table 2 Characteristic of fitted linear and non-linear model for production of natural rubber

Model	A	B	C	D	R^2/ Adj R^2	RMSE/ MAE	SW/SF	Run Test
Linear	15663.37** (833.4499)	424.6085** (56.06391)			0.713789/ 0.701345	1938.37/ 1489.35	0.0762/ 0.753	2.71E-05
Rational	13516.89** (618.251)	-105.895 (185.5007)	0.0535** (0.005927)	0.001325** (0.000126)	0.936221/ 0.92711	915.25/ 747.49	0.941/ 0.936	0.00051
Gompertz	0.007114 (1.618696)	14.41044 (227.4713)	0.014169 (0.217384)		0.841737/ 0.82735	741.3/ 671.61	0.924/ 0.929	2.65E-06
Quadratic	11408.52** (663.2096)	1370.13** (117.5435)	-36.3662** (4.388519)		0.930553/ 0.92424	955.061/ 635.19	0.855/ 0.836	0.0249
Cubic	12917.43** (861.9635)	735.1245 (281.499)	23.51098 (24.89886)	-1.53531 0.63028	0.945853/ 0.938118	843.32/ 685.47	0.945/ 0.933	0.0022

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

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

Model	A	B	C	D	R^2 / Adj R^2	RMSE/MAE	SW/SF	Run Test
Linear	1299.06** 44.93743	16.34308** 3.022819			0.559648/ 0.540503	104.53/ 85.233	0.882/ 0.889	2.2E-05
Rational	1030.272** 47.83201	80.76871 43.06391	0.003354 0.024086	0.001421** 0.000181	0.934092/ 0.924676	81.415/ 61.55	0.838/ 0.837	0.000288
Gompertz	6.44E-33 4.86E-29	80.76885 7535.434	0.003354 0.310721		0.349078/ 0.336654	152.53/ 126.09	0.756/ 0.765	2.72E-05
Quadratic	1056.612 28.49802	70.22037 5.050827	-2.0722 0.188574		0.932137/ 0.925967	41.038/ 33.93	0.9740/ 0.9743	0.0022
Cubic	1030.218 41.17324	81.32804 13.44631	-3.11959 1.189339	0.026856 0.030106	0.934614/ 0.925274	40.282/ 31.598	0.9626/ 0.9600	0.00239

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

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. No significant spikes are visible in the correlogram. This suggested consideration of ARIMA (0, 1, 0) as the model. The AIC, BIC, RMSE and MAE values were 13.12, 13.169, 163.9409 and 130.375, 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 lags. This suggested consideration of ARIMA (1, 0, 0) as the model. The AIC, BIC, RMSE and MAE values of this model were 16.706, 16.8533, 897.22 and 553.227, respectively. In case of productivity of natural rubber the stationarity was achieved by differencing two times, i.e. d=2. 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, 2, 0) and as the model. The ARIMA (1, 2, 0) model AIC, BIC, RMSE and MAE values were 11.069, 11.218, 54.818 and 24.278, respectively.

Discussion in area, production and productivity trends: Patel *et al.* (1986) examined the trends in area, production and productivity of tobacco in India (1960-84), based on parametric models. Bhagyashree and Rajarathinam (2009) studied the trends in area under cultivation of bajra crop in Gujarat (1949-2004) by fitting nonparametric regression as the best model. Parmar (2010) employed first degree polynomial as the best model for the analysis of the trends in area under Maize crop in Panchamal district (1949-2009) in Gujarat. Sudha *et al.* (2013) studied trends in area, production and productivity of maize crop of Guntur district in Andhra Pradesh (1970-2008) by employing growth models. Parmar *et al.* (2016) used parametric and non parametric methods for evaluating trends in area, production and productivity of cotton in Gujarat state (1949-2008). Kumar *et al.* (2017) examined the goodness of fit based on linear, exponential and alogarithmic model for analysing trends in area, production and productivity of major crops in Meghalaya (2013-2017).

Growth rates in harvested area, production and productivity of natural rubber: An average of the values for every three years is calculated starting from 1992-93 to 2015-16 to get equal time intervals (Fig 1).

During the first period, from 1992 to 1995, the average rate of increase in the production was 1.87% per annum. This could be a result of the increase in the harvested area which was at the rate of 1.2% per annum. In the second period, 1995-1998, the production increased at an average rate of 3.42% per annum due to expansion in harvested

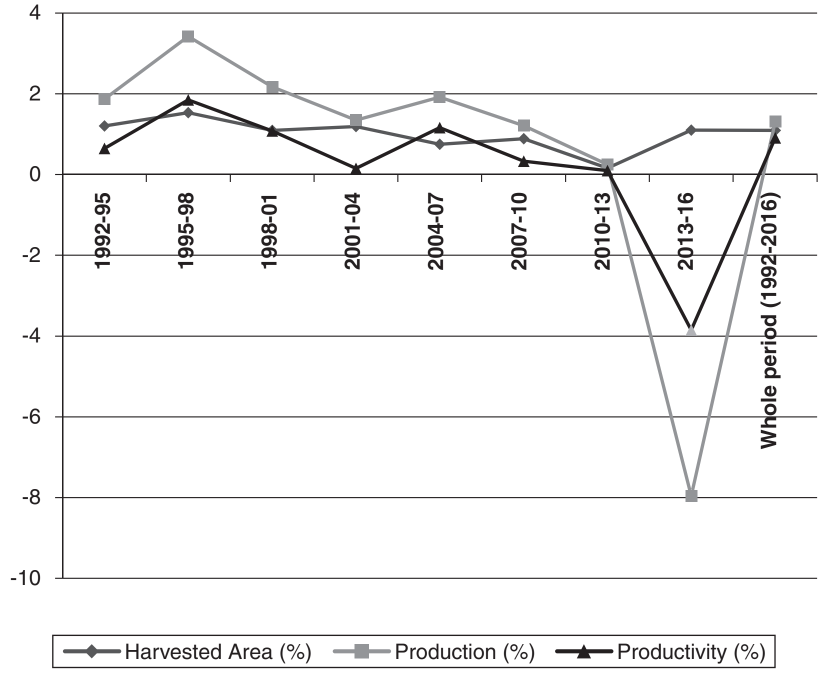

Fig 1 Relative growth rates of harvested area, production and productivity of natural rubber.

area and progress in productivity at an average rate of 1.53 and 1.85% per annum, respectively. This was the highest production rate among all the periods. In the seventh period, 2010-13, the production declined to 0.25% per annum, as a result of all in the rate of increase in harvested area (0.16% per annum) as well as productivity (0.10% per annum). During 2013-16, the production became negative (-7.96 per annum), not as a result of changes in harvested area (1.10% per annum) but due to the decline in productivity (-3.85% per annum).

The growth rates in percentage calculated for the successive three-year periods from the financial year 1992-93 to 2015-16 for the harvested area, production and productivity of natural rubber showed an average annual increase in rubber production at 1.31% per annum. This growth was possibly achieved due to modest increase in harvest area (at 1.09% per annum) and productivity (at 0.91% per annum). Fig 1 provides an overview of the figures for each time period.

The linear and non-linear models were found to be best fitted in the trends in harvested area under the cultivation of natural rubber. However, for the production and productivity only the quadratic function was found suitable for trend models. Among the ARIMA families of time-series models, the model ARIMA (0,1,0), ARIMA (1,1,0) and ARIMA (1,2,0) were found suitable to fit the trends in area, production and productivity, respectively. Natural rubber production had increased at a rate of 1.31% per annum which was perhaps a result of combined effect of marginal increase in harvested area and productivity at a rate of 1.09 and 0.91% per annum, respectively.

REFERENCES

Bhagyashree S D and Rajarathinam A. 2009. Statistical Modeling on area, production and productivity trends crop grown in Gujarat state. *International Journal of Agricultural and Statistical Sciences* **27**(1–2): 291–6.

Box G E P, Jenkins G M and Reinsel G C. 1976. *Time Series Analysis: Forecasting and Control*, Holden Day, California.

Draper N R and Smith H. 1998. *Applied Regression Analysis*, John Wiley and Sons, New York, USA.

Kumar V, Shylla M D and Chand R. 2017. Comparative study of eleven districts of Meghalaya, India for trend analysis of area, production and productivity. *International Journal of Engineering Technology, Science and Research* **4**(9): 1450–57.

Montgomery D C, Peck E A and Vining G G. 2001. *Introduction to Linear Regression Analysis.* John Wiley and Sons, New York.

Panse V G. 1964.Yield trends of rice and wheat in first two five-year plans in India. *Journal of the Indian Society of Agricultural Statistics* **16**: 1–50.

Parmar R S. 2010. 'Statistical modeling on area, production and productivity of major crops of Middle Gujarat: A case study'. Ph D Thesis, Anand Agricultural University, Anand, Gujarat.

Parmar R S, Rajarathinam A, Patel H K and Patel K V. 2016. Statistical modeling on area, production and productivity of cotton (*Gossypium* spp.) crop for Ahmedabad region of Gujarat state. *Journal of Pure and Applied Microbiology* **10**(1): 751–59.

Patel R H, Patel G N and Patel J B.1986. Trends and variability in area, production and productivity of Tobacco in India. *Indian Tobacco Journal* **18**: 3–5.

Rajarathinam A, Parmar R S and Vaishnav P R. 2010. Estimating models for area, production and productivity trends of tobacco (*Nicotiana tabacum*) crop for Anand region of Gujarat state, India. *Journal of Applied Sciences* **10**(20): 2419–25.

Ratkowsky D A. 1990. *Handbook of Non–linear Regression Models*. Marcel Dekker, New York.

Sudha C K, Srinivasa R V and Suresh C. 2013. Growth trends of maize crop in Guntur district of Andhra Pradesh. *International Journal of Agricultural and Statistical Sciences* **9**(1): 215–20.

The Statistics and Planning Department. 2016. *Indian Rubber Statistics 2016*. Vol. 37, The Rubber Board, Kottayam, India.