TREND AND FORECASTING OF AREA, PRODUCTION AND PRODUCTIVITY OF MANGO CROP IN KARNATAKA, INDIA

Abstract:

Mango is one of the most important tropical and subtropical fruits of the world and is popular both in fresh and processed forms. India is the world's top producer, processor, exporter, and consumer of mangoes. The present study was carried out to analyze the trend and forecast in area, production and productivity of mango crop in Karnataka. It was obtained by using the secondary data of area, production and productivity of mango for the period of 18 years (2000-01 to 2017-18) was collected from Directorate of Economics and Statistics, Karnataka. To estimate the trend and its forecast for the next 5 years, up to 2022-23, linear, quadratic, exponential, logistic and Gompertz models were fitted and the best-fitted model was selected based on lowest MAPE. Result revealed that exponential model was best-fitted for area and production of mango, and the logistic model was found to be the best-fitted model for the mango productivity. The result also explored that the area, production and productivity of mango crop have an upward trend in Karnataka state in above study period. Based on this trend to forecast area, production and productivity of Mango crop for next five years.

Keywords: Linear and Nonlinear models, Mean Average Percentage Error (MAPE), Shapiro-Wilks test, run test, Mango, Area, Production, Productivity.

Introduction:

India is now the second largest producer of fruits and vegetables in the world and is the leader in several horticultural crops, namely mango, banana, papaya, cashew-nuts, areca nut, potato and okra (Sugam, 2018). Mango (Mangifera indica) is the leading fruit crop of India and considered to be the king of fruits. Besides delicious taste, excellent flavour and attractive fragrance, it is rich in vitamin A&C. Mango is grown in about 87 countries but it is greatly valued in India. In India, about 1500 varieties of mangos are grown, including 1000 commercial varieties. Among these, Dashehari, Langra and Chausa are the popular varieties of the northern regions of the country, while Alphanso and Pairi are popular in Deccan Plateau and Western regions. Totapuri, Neelam and Benishan are the important varieties of South India (Ravikumar *et al.* 2013). Mango was the most important crop occupying 35 per cent of the total area under the fruits crops in India and accounts around 22 per cent of the total production of fruits. The total area under cultivation of mango in India is 2258.00 thousand hectares, production is around 21822.00 thousand metric tonnes and productivity is only 9.66 metric tonnes per hectare during 2017-18. The production has registered an increase over the previous years. Consequently, mango productivity also increases from 8.81 to 9.66 tonnes per hectare during 2016-17 to 2017-18. State-wise area and production data indicated that the Uttar Pradesh continued to be the leading mango producing state in the country. It was followed by Andhra Pradesh, Bihar, Karnataka and Tamil Nadu are the other important states cultivating mango significantly and commercially (Anon, 2018).

In Karnataka, mangoes are mainly grown in the Kolar, Ramanagara, Tumkur, Dharwad, Mandya, Belagavi, Bengaluru rural and Chikkaballapur districts, which constitutes approximately 60 per cent to the total mango area. The estimated area, production and productivity for mango in the state during 2017-18 was 1.83 lakh hectare, 17.61 lakh metric tonnes and 9.61 metric tonnes per hectare respectively. Compared to previous year a decrease in area by 0.7 per cent and a rise in production and productivity by 0.8 and 3 per cent respectively was recorded (Anon, 2018).

From the above justified facts, it is evident that there is a considerable scope to study the trend and forecast in area, production and productivity of Mango crop in Karnataka, India.

Materials and Methods:

The present study is conducted with the overall objective of estimating suitable regression model that explains the trend of area, production and productivity of mango crop in Karnataka. For this study, the secondary data pertaining to area, production and productivity of mango for the period of 18 years from 2000-01 to 2017-18 was collected from Directorate of Economics and Statistics, Government of Karnataka.

Trend analysis is the changes that have occurred because of general tendency of the data to increase or decrease over a long period of time. The trend of area, production and productivity of mango crop in Karnataka was analysed using linear and Non-linear regression models.

Linear regression models:

In this method, trend in area, production and productivity of mango crop is measured by establishing mathematical relation between time and the response variable, which is depending on time. The mathematical expression can be represented by:

1. Linear (Straight line) $Y_t = \alpha + \beta t + \varepsilon$ … … … … … (1)

2. Quadratic (Parabolic) $Y_t = \alpha + \beta t + kt^2 + \varepsilon$ … … … … … (2)

Where, α: Intercept or Average effect

β, k: Slope or Regression Coefficients (β= linear effect parameter and k: Quadratic effect parameter)

Y_t: Area, production or productivity of mango crop in time period t

ε: Error term or disturbance term

Coefficients α, β and k are constant parameters are need to be estimated. Here, the relation is so derived that the sum of the squared deviations (errors) of the observed values from the theoretical values is least. The process of minimization of the sum of the squared errors results in some equations called normal equations. The normal equations are the equations, which are used for finding the coefficients of the relation, which is fitted by the method of least square.

Non-linear regression models:

The following are some of the important nonlinear growth curve, which are generally used to describe the growth of time-series.

1. Exponential $Y_t = \alpha\beta^t + \varepsilon$ … … … … … (3)
2. Logistic $Y_t = \frac{\alpha}{1+\beta\ exp(-kt)} + \varepsilon;\ \beta = \frac{\alpha}{Y_0} - 1$ … … … … … (4)
3. Gompertz $Y_t = \alpha\ exp(-\beta\ exp(-kt)) + \varepsilon;\ \beta = ln\left(\frac{\alpha}{Y_0}\right)$ … … … … … (5)

where, Y_t represents area, production or productivity of mango crop in time period t

α, β and k are parameters and

ε denotes the error term.

The parameter 'k' is the 'intrinsic growth rate', while the parameter 'α' represents the 'carrying capacity or yield ceiling'. For the third parameter, although the same symbol 'β' was used, yet this represented different functions of the initial value Y_0 for different models (Mohan Kumar *et al*, 2012 and Prathama, 2018).

The present statistical analysis was carried out by using the LM procedure available in PROC NLIN facility of SAS software package. The LM iterative method requires specification of the initial estimates of each parameter of the models to be estimated. Initial value specification is one of the most difficult problems encountered in estimating parameters of nonlinear models. Inappropriate initial values will result in longer iteration, greater execution time, non-convergence of the iteration and possibly convergence to unwanted local minimum sum of squares residual. To start the iterative procedure, many sets of initial values were tried to ensure global convergence. The iterative procedure was stopped when the reduction between successive residual sums of squares was found to be negligibly small. More details on methods of finding initial estimates of the parameters of models can be found in Draper and Smith (1998).

Assumptions of error term

Once the parameters of the models were estimated, diagnostic check of residuals of the fitted models has to be analyzed to check any violations in the main assumptions of 'independence of residuals' and 'normality of residuals'. This assumption was verified using,

Shapiro-Wilk's (*W*) test is the standard test for normality. The test statistic W is the ratio of the best estimator of the variance (based on the square of a linear combination of the order statistics) to the usual corrected sum of squares estimation of the variance. The values of W ranges from 0 to 1. When W=1 the given data are perfectly normal in distribution. When W is significantly smaller than 1, the assumption of normality is not met.

Test statistic is given by:

$$W = \frac{\left[\sum_{i-1}^{n} a_i x_{(i)}\right]^2}{\sum_{i-1}^{n} (x - \bar{x})^2}$$

where, $x_{(i)}$is the i^{th}order statistic, *i.e.,*, the i^{th} smallest number in the sample;

$\bar{x}$ is sample mean and the constants $a_i$is given by

$$(a_1, a_2, \cdots, a_n) = \frac{m^T V^{-1}}{\sqrt{(m^T V^{-1} V^{-1} m)}}$$

Where $m^T = (m_1, m_2, \cdots, m_n)^T$ and $m_1, m_2, \cdots, m_n$ are the expected values of the order - statistics of independent and identically distributed random variables sampled from the standard normal distribution, and V is the covariance matrix of those order statistics (Shapiro *et al*., 1968).

Run test can be used to test the randomness of residuals. A Run is defined as 'a succession of identical symbols in which are followed and preceded by different symbols or no symbols at all'. If very few runs occur, a time trend or some bunching owing to lack of independence is suggested and if many runs occur, systematic short period cyclical fluctuations seem to be influencing the scores.

Null hypothesis H_0: Sequence is random

Alternative Hypothesis H_1: Sequence is not random

Let 'n_1', be the number of elements of one kind and 'n_2' be the number of elements of the other kind in a sequence of $N = n_1 + n_2$ binary events. For small samples *i.e.*,, both n_1 and n_2 are equal to or less than 20 if the number of runs r fall between the critical values, we accept the H_0 (null hypothesis) that the sequence of binary events is random otherwise, we reject the H_0.

For large samples *i.e.*,, if either n_1 or n_2 is larger than 15, a good approximation to the sampling distribution of r (runs) is the normal distribution, with

$$\text{Mean } (\mu_r) = \frac{2n_1n_2}{n_1+n_2} + 1$$

$$\text{Variance } (\sigma_r{}^2) = \sqrt{\frac{2n_1n_2(2n_1n_2-n_1-n_2)}{(n_1n_2)^2(n_1+n_2-1)}}$$

Then H_0 can be tested using test statistic:

$$Z = \frac{r-\mu_r}{\sigma_r{}^2} \sim N(0,1)$$

The significance of any observed value of 'Z' computed using the equation may be determined from a normal distribution table.

Model adequacy checking

The goodness of fit of all the fitted models is assessed by computing Mean Absolute Percent Error (MAPE) which is given by:

Mean Average Percentage Error (MAPE):

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_t - \hat{Y}_t}{Y_t}\right| X\, 100$$

Where, Y_t= Actual values, $\hat{Y}_t$= Predicted values and *n*= number of observations

In the present study, to estimate trend area, production and productivity of mango crop, linear and non-linear models explained were fitted to find the best-fitted model. Only for those models, all the parameters are found to be significant at given level of significance, and assumptions of 'independence of residuals' and 'normality of residuals' are satisfied were considered as good fitted models. Among all the good fitted models, the best-fitted model was selected based on minimum MAPE values. This selected best-fitted model was used to forecast area, production and productivity of mango in Karnataka for the period of 5 years from 2018-19 to 2022-23

Results and Discussion

The present study was undertaken with a view to analyze the trends and forecast the future trend for the next five years in area, production and productivity of mango crop of Karnataka, the annual data pertaining to area, production and productivity of mango, for the period of 18 years from 2000-01 to 2017-18 was used to build both linear model *viz*. linear, quadratic form of model and nonlinear growth model *viz*. exponential, logistic and Gompertz models. Such type of information generated proved to be very important and helpful for the policy makers in framing the strategies.

Model based trend analysis for area under mango in Karnataka

For the area under mango, the linear and nonlinear models were fitted. The results presented in the Table 1 which reveals that, among the different fitted models, the parameters of Exponential model was found to be significant at 5 per cent level of significance with the minimum MAPE value of 6.38. Further, results from Table 1 also revealed that for the above fitted model, the number of runs and Shapiro-Wilk test statistic was found to be non-significant (*p*-value > 0.05) at 5 per cent level of significance indicating that assumptions of 'independence of residuals' and 'normality of residuals' were satisfied and considered as good fitted models. The observed and predicted area of mango by best fitted model for the study period is tabulated in Table 4 and the same is plotted in Fig. 1. The findings shown that the mango area has upward trend over the study period from 2000-01 to 2017-18.

Table 1: Parameter estimates and goodness of fit criteria by different models for area under mango (in thousand hectare) for the period of 2000-01 to 2017-18

Parameter	Models				
	Linear	**Quadratic**	**Exponential**	**Logistic**	**Gompertz**
α	-13080.00^{NS}	80.92*	81.71*	452.30*	-817.10*
β	6.57*	3.93^{NS}	1.05*	4.79*	0.10^{NS}
k	-	0.14^{NS}	-	0.07*	-0.05*
Test for randomness, normality of residuals and goodness of fit criteria					
Runs test (Z): (p –value)	1.94^{NS} [0.05]	1.70^{NS} [0.09]	1.70^{NS} [0.09]	1.70^{NS} [0.09]	1.70^{NS} [0.09]
Shapiro-Wilk (W): (p –value)	0.97^{NS} [0.79]	0.95^{NS} [0.40]	0.95^{NS} [0.42]	0.96^{NS} [0.65]	0.95^{NS} [0.42]
MAPE	7.13	6.44	**6.38**	6.52	6.38

* Significant at 5% level of significance, NS: Not Significant; Values in (.) indicate standard error; Values in [.] indicate Probability values

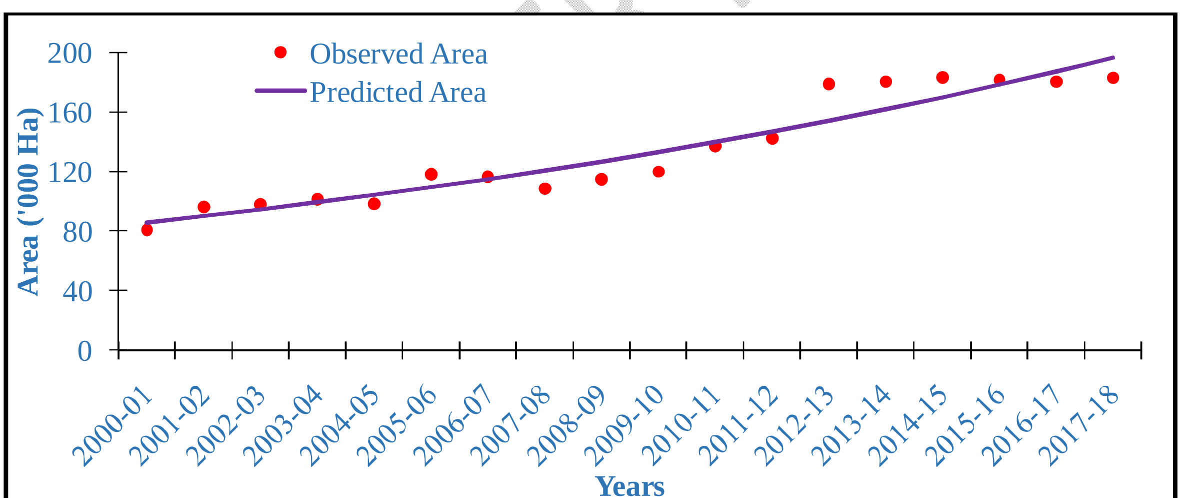

Fig.1: Observed and predicted values of area under mango by exponential model for the period of 2000-01 to 2017-18

Model based trend analysis for production of mango in Karnataka

The parameter estimates of the all fitted models for mango production are presented in Table 2 Exponential model was found to be the best fit for production of mango as the parameters of this model is found to be significant at 5 per cent level of significance with the minimum value of MAPE (26.33). Further, results from Table 2 also revealed that for all the above fitted models, the number of runs and Shapiro-Wilk test statistic was found to be non-significant (p-value > 0.05) at 5 per cent level of significance indicating that assumptions of 'independence of residuals' and 'normality of residuals' were satisfied and considered as good fitted models. The observed and predicted production of mango by best fitted models for the study period is tabulated in Table 4 and the same is plotted in Fig. 2. The findings shown that the mango production has upward trend over the study period from 2000-01 to 2017-18.

Table 2: Parameter estimates and goodness of fit criteria by different models for mango production (in thousand metric tonnes) for the period of 2000-01 to 2017-18

Parameter	Models				
	Linear	**Quadratic**	**Exponential**	**Logistic**	**Gompertz**
α	-124.32^{NS}	273.26^{NS}	229.70*	2395.10 *	-2.92 ^{NS}
β	106.63*	-12.64^{NS}	1.13*	28.38*	1.00^{NS}
k	-	6.28*	-	0.27*	32.10^{NS}
Test for randomness, normality of residuals and goodness of fit criteria					
Runs test (Z): (p –value)	2.65* [0.01]	0.68^{NS} [0.49]	0.54^{NS} [0.59]	2.65* [0.01]	4.13* [0.0001]
Shapiro-Wilk (W): (p –value)	0.95^{NS} [0.35]	0.92^{NS} [0.12]	0.97^{NS} [0.05]	0.95^{NS} [0.74]	0.80* [0.002]
MAPE	39.48	23.39	**26.33**	31.37	94.45

* Significant at 5% level of significance, NS: Not Significant; Values in (.) indicate standard error; Values in [.] indicate Probability values

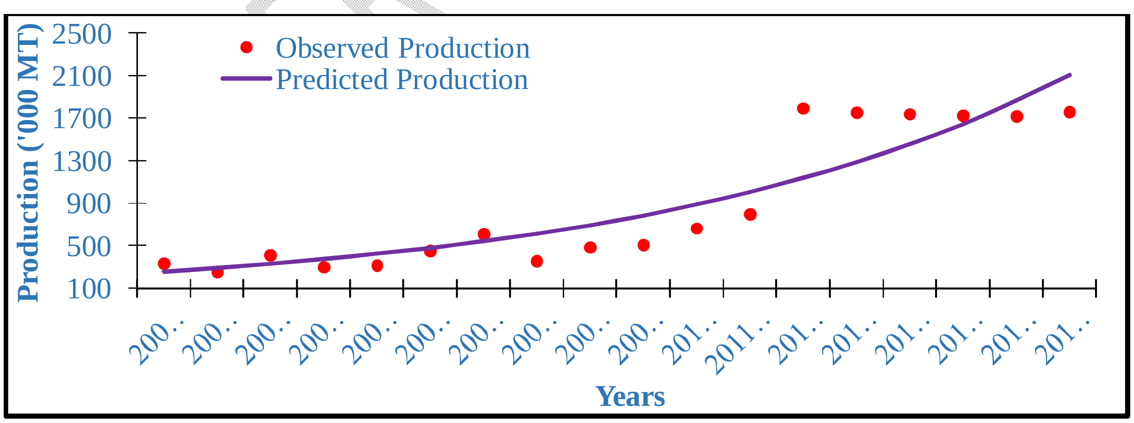

Fig.2: Observed and predicted values of mango production by exponential model for the period of 2000-01 to 2017-18

Model based trend analysis for productivity of mango in Karnataka

Linear and nonlinear models were fitted to estimate the trend in productivity of mango. The results presented in the Table 3 which reveals that, among the different fitted models, logistic model was found to be the best fit with the minimum MAPE value of 19.23 and also the parameters of this model is found to be significant at 5 per cent level of significance. Further, results from Table 3 also revealed that for all the above fitted models, the number of runs and Shapiro-Wilk test statistic was found to be non-significant (p-value > 0.05) at 5 per cent level of significance indicating that assumptions of 'independence of residuals' and 'normality of residuals' were satisfied and considered as good fitted models. The observed and predicted productivity of mango by best fitted models for the study period is tabulated in Table 4 and the same is plotted in Fig. 3. The findings shown that the mango productivity has upward trend over the study period from 2000-01 to 2017-18.

Table 3: Parameter estimates and goodness of fit criteria by different models for mango productivity (in metric tonnes per hectare) for the period of 2000-01 to 2017-2018

Parameter	**Models**				
	Linear	**Quadratic**	**Exponential**	**Logistic**	**Gompertz**
α	1.54*	3.33*	2.48 *	34.66*	-4.39^{NS}
β	0.46*	-0.08^{NS}	1.09*	14.10*	1.00^{NS}
k	-	0.03*	-	0.10*	32.30^{NS}
Test for randomness, normality of residuals and goodness of fit criteria					
Runs test (Z):	1.70^{NS}	0.54^{NS}	0.54^{NS}	0.54^{NS}	4.13*
(p –value)	[0.09]	[0.59]	[0.59]	[0.59]	[0.0001]
Shapiro-Wilk(W):	0.95^{NS}	0.94^{NS}	0.98^{NS}	0.93^{NS}	0.87*
(p –value)	[0.47]	[0.07]	[0.12]	[0.19]	[0.02]
MAPE	22.68	17.73	19.34	**19.23**	94.44

* Significant at 5% level of significance, NS: Not Significant; Values in (.) indicate standard error; Values in [.] indicate Probability values

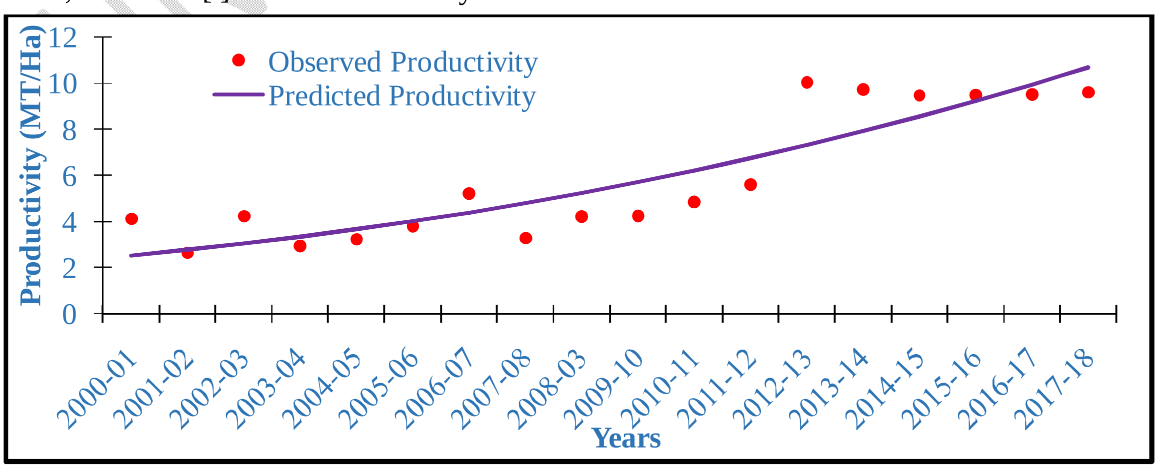

Fig.3: Observed and predicted values of mango productivity by logistic model for the period of 2000-01 to 2017-18

Table 4: Trend values of area (in thousand hectare), production (in thousand metric tonnes) and productivity (in metric tonnes per hectare) of mango by best fitted models

Years	By Exponential model		By Exponential model		By Logistic model	
	Actual Area	Area Trend values	Actual Production	Production Trend values	Actual Productivity	Productivity Trend values
2000-01	81.20	85.80	334.76	259.79	4.12	2.52
2001-02	96.30	90.09	255.03	293.82	2.65	2.77
2002-03	97.99	94.59	415.25	332.31	4.24	3.04
2003-04	101.53	99.32	299.49	375.85	2.95	3.34
2004-05	98.35	104.28	317.83	425.08	3.23	3.66
2005-06	118.16	109.50	450.69	480.77	3.81	4.01
2006-07	116.78	114.97	609.38	543.75	5.22	4.38
2007-08	108.77	120.72	358.56	614.98	3.30	4.79
2008-09	114.97	126.76	485.38	695.54	4.22	5.23
2009-10	120.08	133.10	510.41	786.66	4.25	5.70
2010-11	137.20	139.75	665.01	889.71	4.85	6.20
2011-12	142.55	146.74	798.29	1006.26	5.60	6.73
2012-13	178.80	154.08	1795.10	1138.09	10.04	7.31
2013-14	180.53	161.78	1755.56	1287.17	9.72	7.91
2014-15	183.46	169.87	1739.64	1455.79	9.48	8.55
2015-16	181.70	178.36	1725.67	1646.50	9.50	9.22
2016-17	180.60	187.28	1719.73	1862.20	9.52	9.93
2017-18	183.23	196.64	1760.60	2106.14	9.61	10.67

Forecasting of area, production and productivity of mango crops

Based on minimum MAPE, the best-fitted model was selected from among all the fitted Linear and nonlinear models to forecast future trend of mango area, production and productivity for the period of next 5 years from 2018-19 to 2022-23.

The forecasted area, production and productivity of mango in Karnataka are presented in the Table 5. The result in Table 5 shown that, the forecasted area under mango will be increased from 206.47 to 250.97 thousand hectares during the period from 2018-19 to 2022-23 by indicating an upward trend for the next five years. Forecasted mango production will also have increased trend from 2382.05 to 3897.63 thousand metric tonnes during the period from 2018-19 to 2022-23 by indicating an upward trend for the next five years. Further, an increasing trend can also be observed in productivity of mango from 11.44 to 14.79 metric tonne per hectare for the period from 2018-19 to 2022-23.

Table 5: Forecasted area, production and productivity of mango in Karnataka

Year	Area ('000 Ha)	Production('000 MT)	Productivity (MT/Ha)
2018-19	206.47	2382.05	11.44
2019-20	216.71	2694.20	12.23
2020-21	227.64	3047.02	13.05
2021-22	239.02	3446.18	13.89
2022-23	250.97	3897.63	14.79

CONCLUSION

To analyse the trend in area, production and productivity of mango crop in Karnataka, two linear and three non-linear models were fitted. Results by the present study revealed that exponential model was found to be the best-fitted model for area and production of mango, and logistic model was best fitted for productivity of mango. It was observed that the area, production and productivity of mango have an upward trend over the study period.

The forecasted area, production and productivity of the mango crop for the period from 2017-18 to 2022-23 revealed that an increasing trend in area, production and productivity of mango.

Further, it can be concluded from the study that the area, production and productivity of mango crop has been increased since 2000 by replacing other horticulture and cereal crops area and their production in Karnataka over the study period.

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