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Trend and Forecasting of Area, Production and Productivity of Mango Crop in Karnataka, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The current study was carried out to analyze the trend and forecast in area, production and productivity of mango crop in Karnataka. It was determined 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

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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 the period from 2018-19 to 2022-23.

Keywords: Linear and nonlinear models; Mean Average Percentage Error (MAPE); Shapiro-Wilks test; run test; mango; area; production; productivity.

1. INTRODUCTION

"India is presently the world's second-largest producer of fruits and vegetables and the world's top producer of certain horticulture crops, which is mango, banana, papaya, cashew nuts, areca nut, potato and okra" [1]. Mango (*Mangifera indica*) is one of the most significant tropical and subtropical fruit in the world and the most important fruit crop in India. Mangoes are mostly produced, processed, exported and consumed in India. Besides delicious taste, outstanding flavour and attractive fragrance, it also a great source of vitamin A&C. Although mangoes are grown in around 87 countries, but India places a high value on mango. Mangoes are grown in India in over 1500 different varieties, including 1000 commercial varieties. They include Dashehari, Langra, and Chausa, which are popular in the country's northern areas, while Alphanso and Pairi are well-liked in the Deccan Plateau and western parts. The important varieties in South India are Totapuri, Neelam, and Benishan [2]. "The mango was the most significant crop, taking up 35% of the total area used for fruit crops in India and contributing to about 22% of all fruit production. The total area under cultivation of mango in India is 2258.00 thousand ha, production is around 21822.00 thousand metric tonnes and productivity is only 9.66 metric tonnes per ha 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" [3].

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. "During the 2017–18 growing season, the state's estimated mango area, production, and productivity were 1.83 lakh hectare, 17.61 lakh metric tonnes, and 9.61 metric tonnes per hectare, respectively. Area decreased by 0.7% compared to the prior year, although production and productivity increased by 0.8% and 3%, respectively" [3].

From the above mentioned 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.

2. 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, the data regarding to area, production and productivity of mango for the 18 years was collected from Directorate of Economics and Statistics, Government of Karnataka.

"Trend analysis is the study of changes that have taken place as a result of the data's general tendency to increase or decrease over time. Using linear and non-linear regression models, the trend of the area, production, and productivity of the mango crop in Karnataka was analysed" [4].

2.1 Linear and Non-linear Regression Models

The following are some of the linear and nonlinear growth curve that are generally used to describe the growth of time-series.

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

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

Exponential $Y_t = \alpha \beta^t + \varepsilon$ (3)

Logistic $Y_t = \frac{\alpha}{1+\beta \; exp(-kt)} + \varepsilon; \; \beta = \frac{\alpha}{Y_0} - 1$ (4)

Gompertz $Y_t = \alpha\, exp(-\beta\, exp(-kt)) + \varepsilon;\ \beta = ln\left(\frac{\alpha}{Y_0}\right)$ (5)

Where,

α, β and k are parameters
Y_t: Area, production or productivity of mango crop in time period t
ε: Error term or disturbance 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 indicated different functions of the initial value Y_0 for different model" [5,6].

The LM procedure found in the PROC NLIN capability of the SAS software package was used to conduct the current statistical study. Each parameter of the models that must be estimated must have its initial estimates specified according to the LM iterative approach. Draper and Smith [7] provide more information on techniques for obtaining initial estimates of model parameters.

2.2 Assumptions of Error Term

The key assumptions of "residual independence" and "residual normality" must be checked for any violations after the parameters of the models have been estimated. This is done by analysing the diagnostic check of the residuals of the fitted models. This assumptions was supported by,

"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. *W* can have values between 0 and 1" [8]. The presented data have a distribution that is exactly normal when W=1. The assumption of normalcy is not satisfied when W is significantly less than 1.

Test statistic is provided 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 series of identical symbols followed and preceded by other symbols or by no symbols at all is the definition of a run.

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

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

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_0can be tested using test statistic:

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

A normal distribution table can be used to estimate the importance of any observed value of "Z" calculated using the equation.

2.3 Model Identification

The goodness of fit of all the fitted models is determined by calculating 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 current study, linear and non-linear models were fit to the data in order to determine the model that best represented the trend in the area, production, and productivity of the mango crop". (Varalakshmi et al., 2022) Only for those models were the assumptions of "independence of residuals" and "normality of residuals" satisfied and all of the parameters are found to be significant at given level of significance were considered to be well-fit models. Based on the lowest MAPE values, the best-suited model was chosen from all the good fitted models. The area, production, and productivity of mangoes in Karnataka were forecast using this best-fit model for the five-year period from 2018–19 to 2022–23.

3. RESULTS AND DISCUSSION

"The current study was carry out 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 18-year period from 2000-01 to 2017-18 was used to build both linear models, *i.e.,* linear, quadratic form of model, and nonlinear growth models, *i.e.,* exponential, logistic, and Gompertz models. Such information has shown to be crucial and useful for policymakers as they formulate strategies" [8].

3.1 Trends in Area under Mango

The linear and nonlinear models were fitted to the area under the mango. The findings shown in Table 1 which reveals that the parameters of the exponential model were significant among the various fitted models at a 5% level of significance with a minimum MAPE value of 6.38. Further, results from Table 1 also showed that the number of runs and Shapiro-Wilk test statistic for fitted model were found to be non-significant (p-value > 0.05) at the 5% level of significance, indicating that the assumptions of "independence of residuals" and "normality of residuals" were satisfied and considered as good fitted models. The observed and expected area under mango for the study period are reported in Table 4 and the corresponding data is presented in Fig. 1 has shown an upward trend. The results indicated that the area under mango had an increased trend from 2000–2001 to 2017–18.

3.2 Trends in Mango Production

The Table 2 provides the parameter estimates of all fitted models for the production of mangoes. The exponential model was determined to be the best fit for mango production since its parameters are significant at the 5% level of significance and had the lowest MAPE value (26.33). Further, results from Table 2 also showed that for all of the fitted models above, the number of runs and Shapiro-Wilk test statistic were found to be non-significant (p-value > 0.05) at 5% level of significance, indicating that the assumptions of "independence of residuals" and "normality of residuals" were satisfied and considered as good fitted models. The observed and predicted mango production for the study period, as determined by the best fitting models, is tabulated in Table 4 and displays an upward trend when plotted on Fig. 2. The results indicated an increase in mango production from 2000–01 to 2017–18.

3.3 Trends in Mango Productivity

To evaluate the trend in mango productivity, linear and nonlinear models were fitted. According to the results shown in Table 3, the logistic model was determined to be the best fit among the several fitted models, with a minimum MAPE value of 19.23. Moreover, the parameters of this model are found to be significant at a 5% level of significance. Further, results from Table 3 also showed that the number of runs and Shapiro-Wilk test statistic were found to be non-significant (p-value > 0.05) at 5% level of significance, indicating that the assumptions of "independence of residuals" and "normality of residuals" were satisfied and considered as good fitted models. The observed and expected mango productivity for the study period is tabulated in Table 4 and displayed in Fig. 3, both of which demonstrate an upward trend. According to the results, the productivity of mangoes increased from 2000–2001 to 2017–2018.

3.4 Forecasting of Area, Production and Productivity of Mango Crops

The best-fitting model out of all the fitted linear and nonlinear models was chosen based on the minimum MAPE in order to predict the future trend of mango area, production, and productivity for the period of the next five years from 2018–19 to 2022–23.

The forecasted area, production, and productivity of mango in Karnataka are shown in Table 5. The result in Table 5 indicated an upward trend for the following five years, with the forecasted area under mango rising from 206.47 to 250.97 thousand hectares between 2018-19 and 2022-23. The production of mangoes is also expand over the five-year forecast period, from 2018-19 and 2022-23, from 2382.05 to 3897.63 thousand metric tonnes. "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" [8,9].

Table 1. The parametric values of fitted linear and non-linear models for area under mango

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):	1.94^{NS}	1.70^{NS}	1.70^{NS}	1.70^{NS}	1.70^{NS}
(p –value)	[0.05]	[0.09]	[0.09]	[0.09]	[0.09]
Shapiro-Wilk (W):	0.97^{NS}	0.95^{NS}	0.95^{NS}	0.96^{NS}	0.95^{NS}
(p –value)	[0.79]	[0.40]	[0.42]	[0.65]	[0.42]
MAPE	7.13	6.44	6.38	6.52	6.38

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

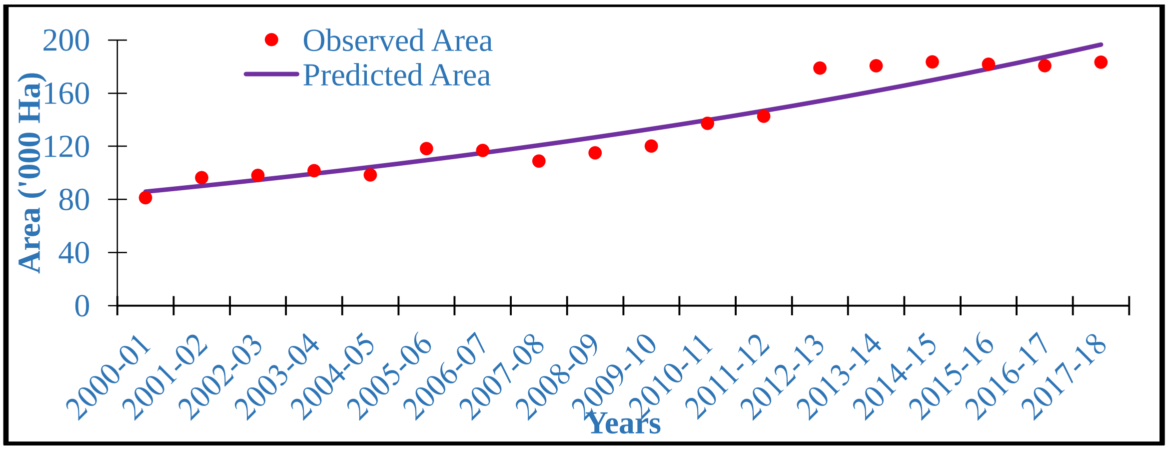

Fig. 1. Illustration of the observed area and the predicted area by exponential model

Table 2. The parametric values of fitted linear and non-linear models for mango production

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):	2.65*	0.68^{NS}	0.54^{NS}	2.65*	4.13*
(p –value)	[0.01]	[0.49]	[0.59]	[0.01]	[0.0001]
Shapiro-Wilk (W):	0.95^{NS}	0.92^{NS}	0.97^{NS}	0.95^{NS}	0.80*
(p –value)	[0.35]	[0.12]	[0.05]	[0.74]	[0.002]
MAPE	39.48	23.39	26.33	31.37	94.45

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

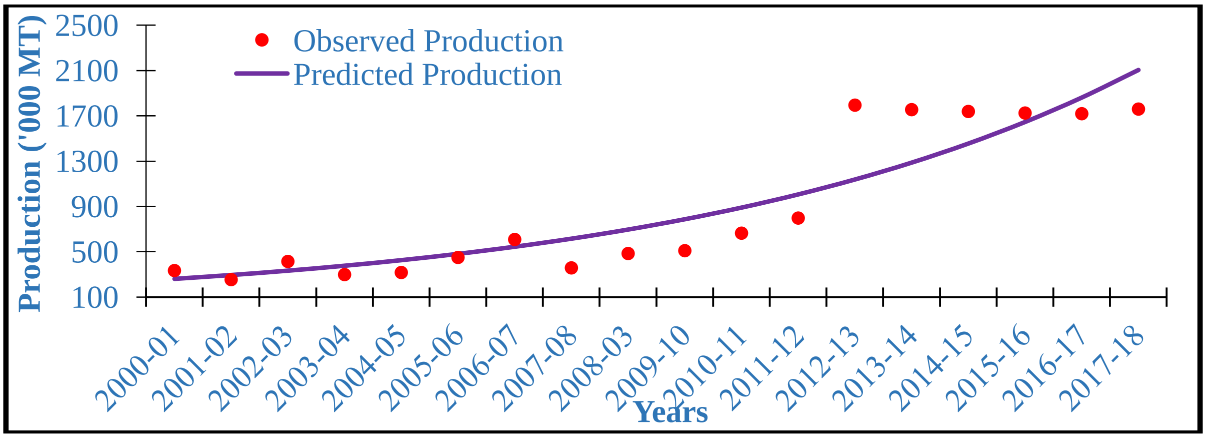

Fig. 2. Illustration of the observed production and the predicted production by exponential model

Table 3. The parametric values of fitted linear and non-linear models for mango productivity

	Models				
Parameter	**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

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

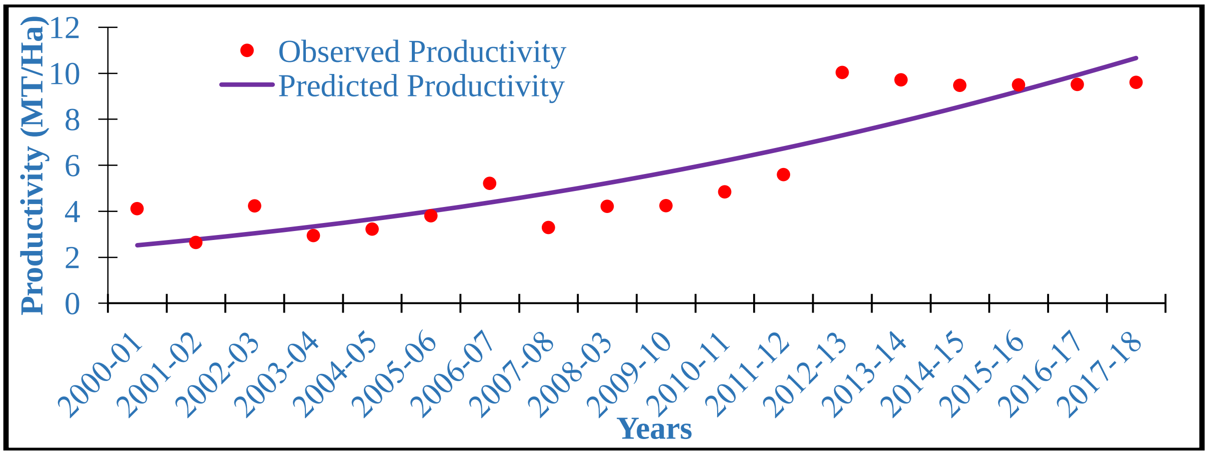

Fig. 3. Illustration of the observed productivity and the predicted productivity by logistic model

The best-fitting model for the area and production of mango was determined to be an exponential model with minimal MAPE values of 6.38 and 26.33, respectively. While the logistic model, which had the lowest MAPE value, was found to be the best-fit model for mango productivity (19.23). Every parameter in the models that were chosen was significant and met the residuals' assumptions. The study period, from 2000-01 to 2017-18, showed an upward trend in mango area, production, and productivity.

Table 4. Actual and predicted values of area, production and productivity of mango

Years	By Exponential model		By exponential model		By logistic model	
	Actual area values	Predicted area values	Actual production values	Predicted production values	Actual productivity values	Predicted productivity 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

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

The area and production of mangoes forecasted by the exponential model for the years 2022–23 would be 250.97 thousand ha and 3897.63 thousand metric tonnes, respectively, showing an upward tendency. The logistic model was determined to be the best-fitted model for forecasts into the future, and it was predicted that mango productivity will rise to 14.79 metric tonnes per hectare by 2022–2023.

4. CONCLUSION

Two linear and three non-linear models were fitted to analyse the trend in the area, production, and productivity of the mango crop in Karnataka. Results by the current 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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