www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(11): 1399-1406
© 2022 TPI
www.thepharmajournal.com
Received: 09-09-2022
Accepted: 12-10-2022

**Harish Nayak GH**
Division of Forecasting and Agricultural Systems Modeling, ICAR-Indian Agricultural Research Institute, Library Avenue, New Delhi, India

**Rajesh Reddy S**
Department of Agricultural Statistics, Applied Mathematics and Computer Science, University of Agricultural Sciences, Bengaluru, Karnataka, India

**Revappa M Rebasiddanavar**
University of Agricultural Sciences, Dharwad, Karnataka, India

**G Avinash**
Division of Forecasting and Agricultural Systems Modeling, ICAR-Indian Agricultural Research Institute, Library Avenue, New Delhi, India

**Veershetty**
Division of Sample Surveys, ICAR-Indian Agricultural Research Institute, Library Avenue, New Delhi, India

**Tamilselvi**
Division of Forecasting and Agricultural Systems Modeling, ICAR-Indian Agricultural Research Institute, Library Avenue, New Delhi, India

**Corresponding Author:**
**Rajesh Reddy S**
Department of Agricultural Statistics, Applied Mathematics and Computer Science, University of Agricultural Sciences, Bengaluru, Karnataka, India

# Forecasting area, production, and productivity of coffee in Hassan district of Karnataka

**Harish Nayak GH, Rajesh Reddy S, Revappa M Rebasiddanavar, G Avinash, Veershetty and Tamilselvi**

**Abstract**
Coffee is one of the most important commercial crops in the world. Karnataka is one of the major coffee-producing states in India, home to coffee-growing regions like Chikkamagaluru, Kodagu, and Hassan. Coffee planters confront a variety of difficulties when trying to produce and yield coffee. It prompts the researcher to investigate issues with coffee production and yield and to suggest suitable solutions. Making the right choices requires analysis of the coffee-producing region, its productivity, and its production. The research was conducted using coffee time series data obtained from the Coffee Board of India, Bengaluru, for a period of 25 years, from 1995–1996 to 2019–2020. Linear (Linear, Cubic) and nonlinear (Exponential, Logistic, and Gompertz) growth models were used to examine the data. For area under coffee in Hassan district, cubic model was found to be best fitted model. Exponential model was best-fitted for production and productivity of coffee in Hassan district. Results by the present study revealed that the area under coffee in Hassan district have an upward trend and productivity of coffee in Hassan have a downward trend over the study period. Finally, the best fitted models are used forecasting.

**Keywords:** Trend, run test, Shapiro-Wilk's test, linear and non-linear models

## Introduction
One of the most valuable commodity crops in the world is coffee. More than 50 countries' economies, primarily those of Asia, Latin America, and Africa, benefit from it. Petroleum and coffee are traded internationally. In addition to making a major contribution to foreign exchange, it significantly affects the socioeconomic position of millions of individuals in many developing countries. A total of 4,59,730 hectares in India are used for coffee farming, of which 50.7 and 49.3 percent are Arabica and Robusta, respectively.

According to botany, coffee is a member of the Rubiaceae plant family. The genus Coffea has roughly 70 commercially grown coffee species, the majority of which are native to Africa. Two of these species, *Coffea arabica*, and *Coffea canephora*, are also found in India. Another plant that is only occasionally grown is *Coffea liberica*. As a silvi-horti crop, coffee is produced in India under a tree cover for the best results. Cardamom, orange, and pepper intercrop production on coffee plantations generate additional revenue. To generate additional income during the first few years, annual crops may be planted as intercrops in the middle of young coffee plants. At early clearings, intercrop also reduces weed development, but it also challenges coffee for moisture and nutrients. Among the frequently planted intercrops are ginger and turmeric. To supplement revenue during the early non-bearing coffee time, other annual crops are also grown. These include brinjal, pineapple, chilies, cowpea, beans, horse gram, etc.

The "finest" mild shade-grown coffees in the world, according to legend, are from India. Only in India do 100% of the coffee plants grow in the shadow. Coffees that are gentle and not overly acidic typically have a rich, exotic flavor and a pleasant scent. The evergreen leguminous trees make up the two-tiered mixed shade canopy over which India's coffee is grown. The major producers of this energizing beverage crop are Karnataka, Tamil Nadu, Kerala, and Andhra Pradesh. It is also to a lesser extent planted in West Bengal, Tripura, Sikkim, Orissa, Nagaland, Mizoram, Meghalaya, Manipur, Madhya Pradesh, Assam, and Arunachal Pradesh, all of which are non-traditional agricultural regions. Coffee is also grown in predominant North-East monsoons, as in Tamil Nadu, Andhra Pradesh, and Orissa. For coffee flowering, summer showers are essential and are received in March-April.

Karnataka, Tamil Nadu, and Kerala are the three Indian states where coffee is largely farmed. Karnataka takes pride in its output of coffee, which makes up 71.03 percent of all Indian production. 20.46, 6.68, and 1.83 percent of the nation's total production are produced in Kerala, Tamil Nadu, and non-traditional regions, respectively. Chikkamagaluru, Kodagu, and Hassan are the only three districts in Karnataka where coffee is still produced. These districts produce 33.71, 52.68, and 13.60 percent of the state's coffee, respectively, and account for 38.54, 44.96, and 16.49 percent of the region. In 2019–20, the state's coffee plantations employed 5,16,776 people on average, with the Kodagu district accounting for 51.11 percent (264427 people/day), Chikkamagaluru for 28.55 percent (147542 people/day), and Hassan for 20.28 percent (104808 people/day).

The geographic area of the district of Hassan is 6845 square kilometers. The population is 15.67 lakhs and the average rainfall is about 1031 mms annually. Coffee, Black Pepper, Potato, Paddy and Sugarcane are the major agricultural crops. Coffee planters confront a variety of difficulties when trying to produce and yield coffee. It prompts the researcher to investigate issues with coffee production and yield and to suggest suitable solutions (Panchali and Prabakaran, 2017; Parmar *et al.*, 2018; Parmar *et al.*, 2016) [12, 13, 14]. Given the significance of coffee to the state's economy, this study will detail the expansion and trends in the area, output, and productivity of coffee in a few Karnataka districts.

## Material and Methods

The present study is based on the secondary data relating to area, production and productivity of coffee in Chikkamagaluru district. The time series data on coffee was collected for the period of 25 years *i.e.*, from 1995- 96 to 2019-20 from Coffee Board of India, Bengaluru.

### Analytical tools and techniques applied

The changes that have happened as a result of the data's long-term tendency to increase or decrease are what the rate of growth analysis measures. Without taking into account interstitial short-term variations, it evaluates long-term trends in a time series (Yasmeena *et al.*, 2019) [18]. The least squares estimation approach has typically been used to estimate the long-term trend of acreage, production, and productivity of the coffee crop. This method involved developing a mathematical relationship between the response variable, which depends on time, and the trend in the area, production, and productivity of coffee (Ajay and Sisodia, 2018; Arun and Gupta, 2020; Dhekale *et al.*, 2014; Dinesh *et al.*, 2018; Gomathi *et al.*, 2019; Ishfaq, 2019) [1, 2, 3, 4, 5, 6]. The following can be used to represent the mathematical expression:

**1. Linear (Straight line) model**

$$Y_t = \alpha + \beta t + \varepsilon \qquad [1]$$

**2. Cubic model**

$$Y_t = \alpha + \beta t + \gamma t^2 + kt^3 + \varepsilon \qquad [2]$$

where, $\alpha$: Intercept or Average effect, $\beta, \gamma$ *and* $k$: Slope or Regression Coefficients $Y_t$: Area, production or productivity of coffee in time period $t$ and $\varepsilon$: Error term

Coefficients $\alpha$, $\beta$, $\gamma$ and $k$ are parameters which are to be estimated. The relationship between the response variable and the time period is thought to be linear or curved in the models mentioned above. However, the actual data seen in nature may not conform to the assumptions of linearity, curvilinearity, or exponential functional shape (Mohankumar, 2012a, 2012b, 2012c) [10, 11]. In order to describe the long-term trend in variables over time in different agricultural crops, growth rate analysis is also frequently used. Most growth models are "mechanistic," and the parameters have biologically relevant interpretations (Prajneshu and Das, 2000) [15].

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

**3. Exponential model**

$$Y_t = \alpha\beta^t + \varepsilon \qquad [3]$$

**4. Logistic model**

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

**5. Gompertz model**

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

where, $Y_t$ represents area, production or productivity of Coffee in time period *t*. $\alpha$, $\beta$ and $k$ are parameters and $\varepsilon$ denotes the error term.The parameter '$k$' is the 'intrinsic growth rate', while the parameter '$\alpha$' 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 (Khan *et al.*, 2013; Mehazabeen and Srinivasan, 2019; Selvi *et al.*, 2015) [7, 8, 16].

Following the estimation of the model's parameters, a diagnostic analysis of the residuals from the fitted models is required to look for any violations of the fundamental assumptions of "residual independence" and "residual normality". The Run-test and Shapiro-Wilk tests, respectively, were used to evaluate the central hypotheses of "independence of residuals" and "normality of residuals" (Prajneshu and Das, 2000) [15].

### Test for independence (randomness) of residuals by Run Test

Non-parametric Run test is used to test the randomness of residuals. A Run is defined as a succession of identical symbols 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 of residuals is random

Alternative Hypothesis ($H_1$): Sequence of residuals 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 $H_0$ 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.

**Test for normality of residuals by Shapiro-Wilk's (W) test**

This 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 usually corrected sum of squares estimation of the variance. $W$ may be thought of as the correlation between given data and their corresponding normal scores. The values of $W$ range 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. A significant $W$ statistic causes us to reject the assumption that the distribution is normal. Shapiro-Wilk's $W$ is more appropriate for small samples up to n=50

Null hypothesis $(H_0)$: Samples are from a normally distributed population.

Alternative Hypothesis $(H_1)$: Samples $x_1, \ldots, x_n$ are not from a normally distributed population.

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) [17]. Reject the null hypothesis if $W$ is too small (near to zero).

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

**Mean Absolute 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

**To fit the forecasting models for the area, production and productivity of Coffee**

By using historical data, forecasting is the practice of estimating a future event. The estimate of the future value is created by methodically combining the historical facts in a predetermined way. A good prognosis can be quite useful and would be very helpful. In the current study, linear and non-linear models were fitted to obtain the best fit in order to assess the trend in coffee production, area, and productivity. By assessing the student t-test and estimating the 95 percent asymptotic confidence intervals of the estimated parameters for the remaining models, it was possible to determine the statistical significance of the parameters of the linear and quadratic models. Diagnostic check for residuals of the fitted models were checked to know if there were any violations in the main assumptions of 'independence of residuals' and 'normality of residuals' using the 'Run-test' and 'Shapiro-Wilk test' respectively. Only for those models, where all the parameters are found to be significant at given level of significance, and the 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 Coffee crop.

## Results and Discussion

To estimate the trend in area, production and productivity of Coffee crop in Karnataka, the annual data pertaining to area, production and productivity of Coffee for the period of 25 years from 1995-96 to 2019-20 were used to build both linear model (*viz*. linear, cubic form of model) and nonlinear growth models (*viz.* exponential, logistic and Gompertz models). The results obtained are presented under the following headings.

**Area under coffee**

The parameter estimates of the all fitted models and their standard errors (given in parenthesis) for area under Coffee are presented in Table 1. The main assumptions of 'independence' and 'normality' of error terms of each model were examined by using respectively the 'Run-test' and 'Shapiro-Wilk test', and test statistic along with probability values are presented in Table 1. The result revealed that parameters of linear, cubic and exponential models were found to be significant at 5 per cent level of significance, and some of parameters of other models *viz.*, logistic and Gompertz models were found to be non-significant. Further, results from Table 1 also revealed that for all the models, the number of runs and the Shapiro-Wilk test statistic were found to be non-significant at 5 per cent level significance indicating that assumptions of randomness and normal distribution of residual were satisfied. Only those models, whose parameters were found to be significant at 5 per cent level of significance, and assumptions of 'independence of residuals' and 'normality of residuals' are satisfied were considered as best fitted models. Therefore, linear, cubic and exponential models were best fitted to the data on area under coffee during the study period.

**Table 1:** Parameter estimates and goodness of fit criteria by different models for Area ('000 ha) under Coffee in Hassan district for the period from 1995-96 to 2019-20

| Parameter | Models | | | | |
|---|---|---|---|---|---|
| | **Linear** | **Cubic** | **Exponential** | **Logistic** | **Gompertz** |
| $\alpha$ | 28.98* (0.32) | 27.76* (0.44) | 29.30* (0.30) | 64.87* (29.55) | 75.49$^{NS}$ (51.39) |
| $\beta$ | 0.47* (0.02) | 1.12* (0.16) | 0.01* (0.0006) | 7.22$^{NS}$ (30.85) | 0.95$^{NS}$ (0.66) |
| $\gamma$ | - | -0.06* (0.01) | - | 33.63$^{NS}$ (17.93) | 0.98* (0.01) |
| $k$ | - | 0.001* (0.0004) | - | - | - |
| **Test for randomness, normality of residuals and goodness of fit criteria** | | | | | |
| Runs test ($Z$) ($p$ –value) | -2.92$^{NS}$ [0.06] | -0.41$^{NS}$ [0.67] | -2.50$^{NS}$ [0.12] | -2.92$^{NS}$ [0.06] | -2.92$^{NS}$ [0.06] |
| Shapiro-Wilk ($W$) ($p$ –value) | 0.97$^{NS}$ [0.86] | 0.94$^{NS}$ [0.17] | 0.97$^{NS}$ [0.81] | 0.97$^{NS}$ [0.88] | 0.98$^{NS}$ [0.89] |
| MAPE | 1.89 | 1.34 | 1.92 | 1.91 | 1.90 |

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

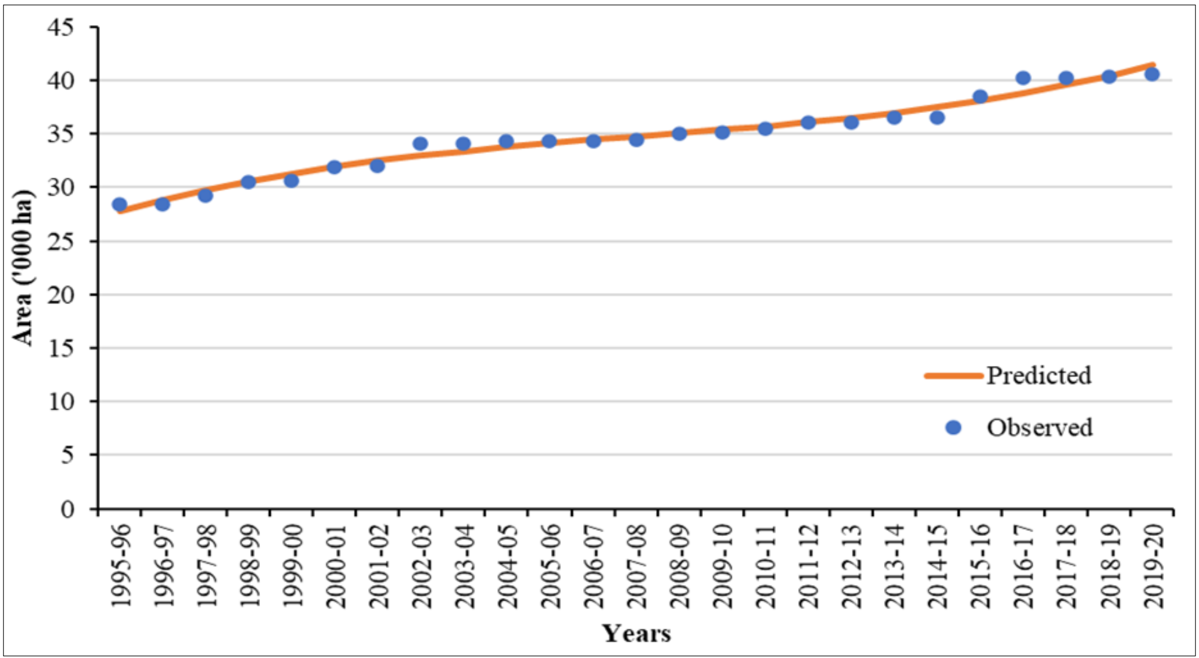


**Fig 1:** Observed and predicted values of Area under Coffee in Hassan district by Cubic model for the period from 1995-96 to 2019-20.

**Coffee production**

The parameter estimates of the all fitted models and their standard errors (given in parenthesis) for Coffee production are presented in Table 2. The results reveal that parameters of linear and exponential models were found to be significant at 5 per cent level of significance, and some of parameters of other models *viz.*, cubic, logistic and Gompertz models were found to be non-significant. Further, results from Table 2 also revealed that for all the models, the number of runs and the Shapiro-Wilk test statistic was found to be non-significant ($p$-value > 0.05) at 5 per cent level significance indicating that the assumptions of randomness and normal distribution of residual were satisfied. Only for those models, whose parameters are found to be significant at 5 per cent level of significance, and assumptions of 'independence of residuals' and 'normality of residuals' are satisfied were considered as best fitted models. Thus, linear and exponential models were best fitted to the data on production of Coffee during the study period.

**Table 2:** Parameter estimates and goodness of fit criteria by different models for Production ('000 MT) of Coffee in Hassan district for the period from 1995-96 to 2019-20

| Parameter | Models | | | | |
|---|---|---|---|---|---|
| | **Linear** | **Cubic** | **Exponential** | **Logistic** | **Gompertz** |
| $\alpha$ | 22.29* (1.09) | 23.80* (1.99) | 22.52* (1.00) | 39.85$^{NS}$ (2.41) | 45.49$^{NS}$ (5.13) |
| $\beta$ | 0.37* (0.07) | -0.35$^{NS}$ (0.73) | 0.01* (0.002) | -1.86$^{NS}$ (0.50) | 0.95$^{NS}$ (0.66) |
| $\gamma$ | - | 0.07$^{NS}$ (0.07) | - | 6.62$^{NS}$ (1.26) | 0.98* (0.01) |
| $k$ | - | -0.001$^{NS}$ (0.001) | - | - | - |
| **Test for randomness, normality of residuals and goodness of fit criteria** | | | | | |
| Runs test ($Z$) ($p$ –value) | -2.08$^{NS}$ [0.36] | -1.66$^{NS}$ [0.94] | -2.08$^{NS}$ [0.36] | -2.08$^{NS}$ [0.36] | -2.92$^{NS}$ [0.34] |
| Shapiro-Wilk ($W$) ($p$ –value) | 0.94$^{NS}$ [0.16] | 0.95$^{NS}$ [0.29] | 0.94$^{NS}$ [0.21] | 0.94$^{NS}$ [0.21] | 0.98$^{NS}$ [0.89] |
| MAPE | 7.58 | 7.28 | **7.57** | 7.57 | 8.92 |

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

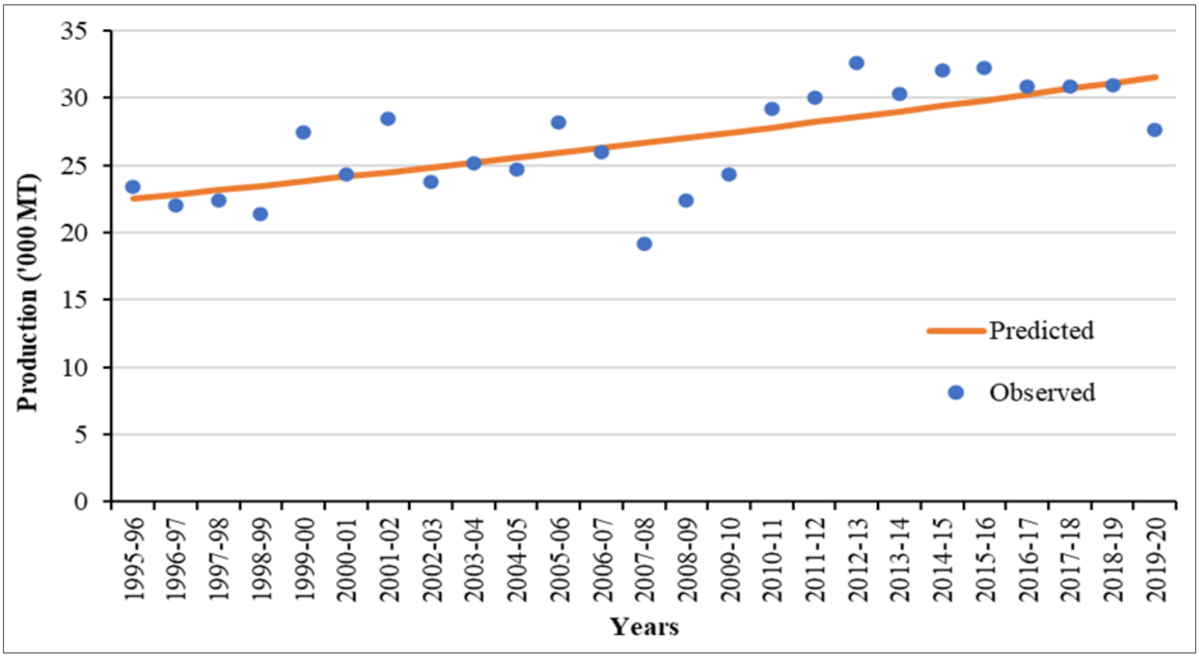


**Fig 2:** Observed and predicted values of Production of Coffee in Hassan district by exponential model for the period from 1995-96 to 2019-20.

### Coffee productivity

The parameter estimates of the all fitted models and their standard errors (given in parenthesis) for coffee productivity are presented in Table 3. The results revealed that only exponential model parameters were found to be significant at 5 per cent level of significance, and some parameters of other models were found to be non-significant, *viz.*, linear, cubic, logistic and Gompertz models. Further, results from Table 3 also shows that for all the models, the number of runs and Shapiro-Wilk test statistic were found to be non-significant at 5 per cent level significance indicating that assumptions of randomness and normal distribution of residuals were satisfied. Only for those models, whose parameters were found to be significant at 5 per cent level of significance and assumptions of 'independence of residuals. and normality of residuals 'are satisfied were considered as best fitted models. Thus, exponential model was found to be the best fitted model to the data on productivity of coffee during the study period.

**Table 3:** Parameter estimates and goodness of fit criteria by different models for Productivity (Kg/ha) of Coffee in Hassan district for the period from 1995-96 to 2019-20

| Parameter | Models | | | | |
|---|---|---|---|---|---|
| | **Linear** | **Cubic** | **Exponential** | **Logistic** | **Gompertz** |
| $\alpha$ | 771.25* (33.34) | 841.62* (58.85) | 771.20* (33.31) | 398.57$^{NS}$ (24.12) | 218.95$^{NS}$ (50.36) |
| $\beta$ | 0.12$^{NS}$ (2.38) | -34.10$^{NS}$ (21.68) | 0.001* (0.003) | 18.66$^{NS}$ (50.68) | 9.52$^{NS}$ (6.63) |
| $\gamma$ | - | 3.35$^{NS}$ (2.12) | - | 6.62$^{NS}$ (2.91) | 0.98* (0.01) |
| $k$ | - | -0.08$^{NS}$ | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| | | (0.05) | | | |
| **Test for randomness, normality of residuals and goodness of fit criteria** | | | | | |
| Runs test (*Z*) (*p* –value) | $-1.25^{NS}$ [0.21] | $-1.16^{NS}$ [0.09] | $-1.25^{NS}$ [0.21] | $-2.08^{NS}$ [0.36] | $-2.92^{NS}$ [0.34] |
| Shapiro-Wilk (*W*) (*p* –value) | $0.96^{NS}$ [0.43] | $0.96^{NS}$ [0.56] | $0.96^{NS}$ [0.43] | $0.94^{NS}$ [0.21] | $0.98^{NS}$ [0.89] |
| MAPE | 8.34 | 7.49 | 8.34 | 9.70 | 9.77 |

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

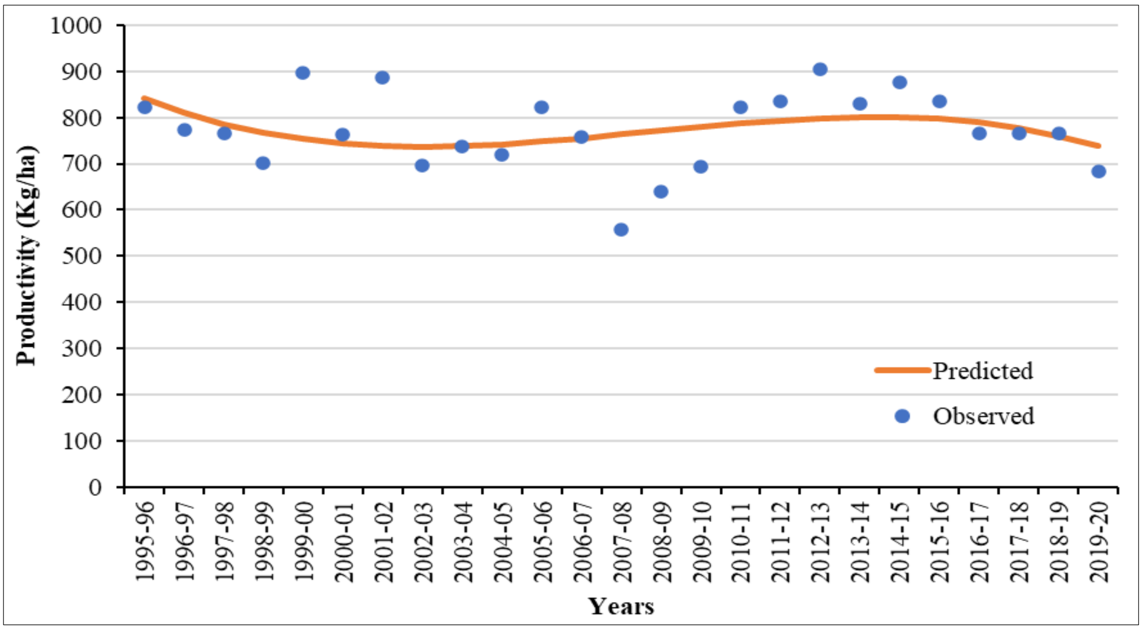


**Fig 3:** Observed and predicted values of Productivity of Coffee in Hassan district by exponential model for the period from 1995-96 to 2019-20.

### Forecasting the Area, Production and Productivity of coffee

Finally, the best fitted models with the lowest MAPE values were chosen from the aforementioned fitted models, and they were then utilised to forecast the area, production, and productivity of coffee. The best fitted model for forecasting area was Cubic model, for production it was linear model and Gompertz model for forecasting productivity of coffee were the best fitted models. The results are presented in Table 4.

**Table 4:** Actual and Predicted values of the best fitted models for Area ('000 ha), Production ('000 MT) and Productivity (Kg/ha) of Coffee in Hassan District.

| Years | By Cubic model | | By Exponential model | | By Exponential model | |
|---|---|---|---|---|---|---|
| | Actual area | Predicted value | Actual production | Predicted value | Actual productivity | Predicted value |
| 1995-96 | 28.483 | 27.762 | 23.400 | 22.523 | 821.543 | 841.627 |
| 1996-97 | 28.483 | 28.825 | 22.000 | 22.842 | 772.396 | 810.785 |
| 1997-98 | 29.245 | 29.764 | 22.400 | 23.165 | 765.943 | 786.123 |
| 1998-99 | 30.490 | 30.590 | 21.400 | 23.494 | 701.869 | 767.113 |
| 1999-00 | 30.645 | 31.314 | 27.500 | 23.826 | 897.373 | 753.227 |
| 2000-01 | 31.935 | 31.947 | 24.350 | 24.164 | 762.486 | 743.935 |
| 2001-02 | 32.070 | 32.500 | 28.450 | 24.506 | 887.122 | 738.710 |
| 2002-03 | 34.090 | 32.985 | 23.750 | 24.853 | 696.685 | 737.023 |
| 2003-04 | 34.090 | 33.412 | 25.150 | 25.205 | 737.753 | 738.345 |
| 2004-05 | 34.290 | 33.793 | 24.700 | 25.562 | 720.327 | 742.148 |
| 2005-06 | 34.290 | 34.138 | 28.225 | 25.924 | 823.126 | 747.904 |
| 2006-07 | 34.290 | 34.459 | 25.975 | 26.292 | 757.509 | 755.084 |
| 2007-08 | 34.465 | 34.767 | 19.175 | 26.664 | 556.362 | 763.159 |
| 2008-09 | 35.015 | 35.073 | 22.375 | 27.042 | 639.012 | 771.602 |
| 2009-10 | 35.115 | 35.387 | 24.350 | 27.425 | 693.436 | 779.884 |
| 2010-11 | 35.525 | 35.721 | 29.245 | 27.813 | 823.223 | 787.475 |
| 2011-12 | 36.025 | 36.087 | 30.050 | 28.207 | 834.143 | 793.848 |
| 2012-13 | 36.025 | 36.495 | 32.600 | 28.607 | 904.927 | 798.475 |
| 2013-14 | 36.575 | 36.955 | 30.350 | 29.012 | 829.802 | 800.826 |
| 2014-15 | 36.575 | 37.481 | 32.030 | 29.423 | 875.735 | 800.374 |
| 2015-16 | 38.540 | 38.081 | 32.220 | 29.839 | 836.014 | 796.590 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2016-17 | 40.279 | 38.768 | 30.875 | 30.262 | 766.528 | 788.944 |
| 2017-18 | 40.279 | 39.553 | 30.875 | 30.691 | 766.528 | 776.910 |
| 2018-19 | 40.410 | 40.446 | 30.920 | 31.125 | 765.157 | 759.959 |
| 2019-20 | 40.534 | 41.459 | 27.670 | 31.566 | 682.637 | 737.561 |

The predicted values obtained from the best fitted models were found to be very close to the actual or observed values for area, production and productivity.

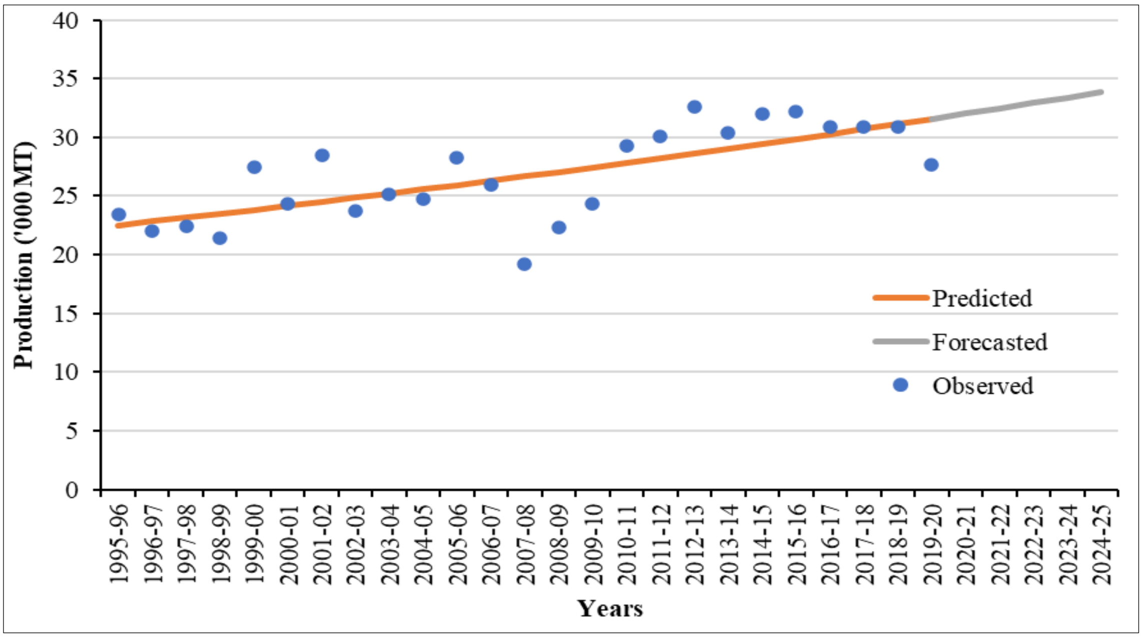


**Fig 4:** Forecasted production ('000 MT) of Coffee in Hassan district by exponential model for the period of 2020-21 to 2024-25.

## Conclusion

To analyse the growth and trend in area, production and productivity of Coffee crop in Karnataka, two linear and three non-linear models were fitted. For area under coffee in Hassan district, cubic model was found to be best fitted model. Exponential model was best-fitted for production and productivity of coffee in Hassan district. Results by the present study revealed that the area under coffee in Hassan district have an upward trend and productivity of coffee in Hassan have a downward trend over the study period.

## References


1. Ajay KG, Sisodia BV. Analysis of trend and growth rate of wheat crop and forecast of its production in Uttar Pradesh. J. Pharmacogn. Phytochemical. 2018;7(5):3306-3310.
2. Arun K, Gupta RK. Forecasting the production and area of mango in Himachal Pradesh by using different statistical models. International Journal of Bio-resource and Stress Management. 2020;11(1):14-19.
3. Dhekale BS, Mahdi SS, Garde YA, Sahu PK. Parametric and nonparametric regression models for area, production and productivity trends of rice (*Oryza sativa*) crop. Int. J. Agric. Stat. 2014;10(1):211-216.
4. Dinesh KP, Bishvajit B, Manjunath V. Nonlinear modeling of area and production of sugarcane in Tamil Nadu. Int. J Curr. Microbiol. App. Sci. 2018;7(10):3136-3146.
5. Gomathi T, Vasanthi R, Padmarani S, Patil SG, Kalpana M. Statistical analysis of area and production of banana in Trichy district. Int. J Chem. Stud. 2019;7(3):2544-2547.
6. Ishfaq AS. Trend analysis of area, production and productivity of apple fruit in Jammu and Kashmir. J. Gujarat Res. Society. 2019;15(21):601-611.
7. Khan Shaista, Bhardwaj RK, Sexena RR, Bhagat RK, Jatav GK. Non-linear statistical modeling for area, production and productivity of rice crop in Chhattisgarh. Asian J Soil Sci. 2013;8(1):98-102.
8. Mehazabeen A, Srinivasan G. A study on area, production and productivity of banana in Y.S.R. district of Andhra Pradesh. Int. J Res. Anal. Rev. 2019;6(2):1-6.
9. Mohan Kumar TL, Sathishgowda CS, Darshan MB, Andsheelarani S. Coffee production modelling in India using nonlinear statistical growth models. Agric. Update. 2012b;7(1&2):63-67.
10. Mohankumar TL, Darshan MB, Sathishgowda CS, Sheelarani S. Comparison of nonlinear statistical growth models for describing coffee export trend in India, Asian J. Hort. 2012a;7(1):31-35.
11. Mohankumar TL, Sathishgowda CS, Munirajappa R, Surendra HS. Nonlinear statistical growth models for describing trends in area under coffee production in India. Mysore J Agric. Sci. 2012c;46(4):745-750.
12. Panchali MS, Prabakaran. Linear and non-linear models on paddy crop in different agro climatic zones of Tamil Nadu. Int. J. Stat. Appl. Math. 2017;2(6):277-281.
13. Parmar RS, Bhojani SH, Chaudhari GB. Application of regression models for area, production and productivity trend of maize crop for Panchmahal region of Gujarat state. Int. J Trend in Sci. Res. Dev. 2018;4(1):1-5.
14. Parmar RS, Rajarathinam A, Patel HK, Patel KV. Statistical modeling on area, production and productivity of cotton crop for Ahmedabad region of Gujarat state. J Pure. Appl. Microbiol. 2016;10(1):751-759.
15. Prajneshu, Das PK. Growth models for describing state-wise wheat productivity. Indian J Agric. Res. 2000;34(3):179-181.

16. Selvi RP, Muraligopal S, Vasanthi R, Swaminathan B. Statistical analysis of trend in the maize area, production and productivity in India. Ann. Plant and Soil Res. 2015;17:233-237.
17. Shapiro SS, Wilk MB, Chen HJ. A comparative study of various tests for normality. J Amer. Stat. Assoc. 1968;63(324):1343-1372.
18. Yasmeena I, Mir SA, Nageena N, Wani MH, Pukhta MS. Trend analysis of area, production and productivity of cherry in Jammu and Kashmir. Int. J Curr. Microbiol. App. Sci. 2019;8(2):2135-2144.