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Trend in Area, Production and Yield of Coffee in India

S. Aruna Prabha[1*], S. D. Sivakumar[2], D. Murugananthi[1] and A. John Joel[3]

[1]*Department of Agricultural and Rural Management, Tamil Nadu Agricultural University, Coimbatore, India.*
[2]*Directorate of Agri-Business Development, Tamil Nadu Agricultural University, Coimbatore, India.*
[3]*Department of Plant Biotechnology, Tamil Nadu Agricultural University, Coimbatore, India.*

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

Coffee, a predominant plantation crop is a highly traded commodity and mostly consumed as a hot beverage. India stands seventh among the world coffee producing countries. Consumption is higher in south India. India grows Arabica and Robusta coffee. Consumption of coffee in India increased at 2 percent per annum till 2020 and after that there was 5 per cent growth rate (ShrutiArun, 2020). The present study was proposed with the objective of studying the trend in area, production, yield of Arabica and Robusta coffee in India and Tamil Nadu and predicting the same. Compound Annual Growth Rate (CAGR) Analysis was used to find the trend in area, production and yield of coffee. Autoregressive Integrated Moving Average (ARIMA) model was used for forecasting the area and production of Arabica and Robusta in India till 2025. Area, production, yield of Arabica and Robusta coffee in India showed a positive trend. A negative trend was observed in productivity of Arabica coffee in India. Whereas in Tamil Nadu, area of Arabica and Robusta coffee showed positive trend, a negative trend was seen in production and productivity of Arabica and Robusta. ARIMA (1, 1, 1) for Arabica and ARIMA (1, 1, 0) found to provide best fit for predicting the area and production of Robusta coffee in India.

Corresponding author: E-mail: arunaprabha98@gmail.com;

Keywords: Arabica; Robusta; compound annual growth rate (CAGR); auto-regressive integrated moving average (ARIMA) model; growth rate.

1. INTRODUCTION

Coffee is a bitter bean and a modern beverage, brewed in different forms from the roasted coffee beans produced by the tropical evergreen plant of African origin. It gained popularity by an alkaloid called caffeine which has a stimulating effect and rich in antioxidants with disease fighting capacity. World coffee consumption supplier is basically of two species namely, Arabica coffee (*Coffea arabica*) and Robusta coffee (*Coffea canephora*). Arabica, grows in sub-tropical climate and distributed over a larger area than Robusta and it needs high moisture, sunshade. Robusta, cheapest and easy to produce contains double the amount of caffeine as that of Arabica. Indian coffee are diversified to a range of about 16 varieties. Coffee is produced in approximately 70 countries in the World. During 2019-2020, Global production of coffee decreased by 2.5 per cent than in previous year production due to off season and pandemic situation. India contributes 4.5 per cent of World coffee and stands seventh among the World coffee producing countries (International Coffee Organisation, 2020).

1.1 Production Status of Coffee in India

In India, traditional coffee growing States are Karnataka, Kerala and Tamil Nadu. Some of the non-traditional areas are Andhra Pradesh, Odisha and North Eastern Region including Assam, Meghalaya, Manipur, Arunachal Pradesh and Tripura. The three traditional areas together accounted for 79.7 per cent of area and 96.2 per cent of coffee production. The major coffee growing areas in India are Hassan, Chikmagalur and Coorg in Karnataka, Wayanad, Idukki and Nelliyampathy in Kerala, Shevaroys, Palani, Pulneys and Nilgiri hills in Tamil Nadu [1]. Both the varieties of coffee has been more or less equal in its area, production and productivity under traditional areas except Tamil Nadu. Tamil Nadu is the one of the State which has more production of Arabica coffee comparing with Robusta Coffee.

1.2 Production Status of Coffee in Tamil Nadu

In Tamil Nadu, Arabica coffee and Robusta Coffee are planted under 29338 and 6314 hectares which totally contributes 7.8 per cent and 5.4 per cent of production of India during the year 2019-2020. Productivity is very low compared to other major growing States (531 kg/ha), 30 per cent lower than the national average (Coffee Board, 2021). The yield levels of coffee and Arecanut continue to be well below the desired levels in comparison to the global average productivity level (Anandaraj, 2015). Arabica accounts for 82 per cent (27539 ha) of Tamil Nadu coffee area and 18 per cent area is under Robusta (6004 ha). In the production, 72.7 per cent is contributed by Arabica (13335 MT) and 27.3 per cent by Robusta (4990 MT). In Tamil Nadu 17665 holdings are there of which small holding (less than 10 ha) accounts for 98 per cent and 345 holdings (more than 10 ha) which accounts for 2 per cent. On an average, in Tamil Nadu 31260 persons are engaged in coffee plantation [1].

1.3 Problem Statement

Productivity of coffee declined to 531 kg/ha in 2018-19 from 596 kg in 2014-15 in India (10 per cent reduction). India stands seventh among the World coffee producing countries, consumption is higher in south India. Consumption of coffee in India increased at 2 percent per annum till 2020 and after that they observed 5 per cent growth rate (ShrutiArun, 2020). Hence the present study was proposed with the objective of studying the trend in area, production, yield of Arabica and Robusta coffee in India and Tamil Nadu and predicting the area and production of coffee in India.

1.4 Objectives of the Study

- To study the trend in area, production and yield of coffee in India and Tamil Nadu.
- To forecast the area and production of coffee in India.

2. REVIEW OF LITERATURE

Jose and Jayasekar [2] studied the trend in area, production and yield of Arecanut in India from 1971-2004. He founded that the area and production has a growth rate of 2.2 percent and 3.2 percent. Harris et al. [3] studied the Ghana annual production of coffee using ARIMA model. She interpreted that the model (0, 3, 1) was the best fit model for the study. Ashoka et al. [4] estimated the trend in area, production, productivity of Robusta coffee and Arabica coffee for the duration of 17 years from 1995-2011 by Compound Growth rate analysis. He concluded that the average productivity of Arabica and Robusta coffee grown at Non Traditional Areas are 108 kg and 109 kg/ha and for India is 592 and 968 kg/ha. Sunanda and Nagaraja [5] concluded that the production and productivity of coffee in the state of Karnataka showed an upward momentum for the stretch of 1960-2011. Darvishi and Indira (2015) studied the change in trend pattern in area, production and productivity of coffee and tea in India during pre and post liberalization period. She concluded that the area under coffee was increased by more than three times and that contributes to both increase in production and yield. Esther et al. [6] focused the forecasting of pulses production in Kenya by ARIMA model from 1960-2012. She found that the ARIMA model (1, 1, 2) was the best fit model for the prediction of pulses production in Kenya. Balakrishnan and Chandran [7] revealed the growth rate by Compound Growth Rate collected for the years (1985-2016) found a positive annual change in production and negative growth rate in productivity. Pradeepa Babu et al. [8] analysed the trend in planted area, bearing area, production and yield by Compound Growth Rate Analysis by using 18 years data. He inferred that there was a structural change in Coffee production from Arabica to Robusta. Area under coffee was at an increasing rate in Non Traditional areas but the productivity was poor. Kumareswaran et al. [9] examined that the growth rate in the area, production and yield of coffee showed that 2.4 per cent, 3 per cent, 0.6 per cent, 3.2 per cent, and 4.2 per cent for the duration of 1985 to 2015. The results of the analysis showed a stable and positive fluctuation trend. Gangadhara Rao (2019) studied the trend in growth of area, production and productivity of for states in India and select districts by using Compound Annual Growth Rate (CAGR). The results examined that the Robusta coffee growth rate was 58 percent in Karnataka but in Kerala it was declined from 47 to 38 percent during 1997-2017. Tamil Nadu showed the lower share of production (6 percent during 2012-17) with 13 percent of area [10-13].

3. DATA AND METHODOLOGY

Secondary data was used for the present study. Data on Area, Production, Productivity of Arabica and Robusta in India (1985-2020) and Tamil Nadu (2007-2020), was collected from the published sources of Coffee Board Database.

3.1 Trend Analysis - Compound Annual Growth Rate Analysis

Compound annual growth rate of coffee was worked out to examine the tendency of variable to increase, decrease or stagnant over a period of time. Compound annual growth rates of area, production and yield of coffee are estimated by using the exponential growth function of the form:

$$Y_t = a\, b^t U^t \qquad (1)$$

Where,

Y_t = Dependent variable for which growth rate of coffee was estimated
a = Intercept
b = Regression coefficient
t = Year which takes values of (1, 2, 3,…n)
U_t= Disturbance term in year 't'.

The equation (1) will be transformed in to log-linear and written as:

$$\text{Log } Y_t = \log a + t \log b + \log U_t \qquad (2)$$

Equation (2) will be estimated by using Ordinary Least Square (OLS) technique.

The compound growth rate (g) will be then estimated by the identity given in equation (3)

$$g = (b-1) \times 100 \qquad (3)$$

Where,

g = Estimated compound growth rate per annum in percentage.
b = Antilog of log b

3.2 Auto-Regressive Integrated Moving Average (ARIMA) Model

A brief description of Auto Regressive Integrated Moving Average (ARIMA) processes are given in the following sections as described by Gujarati (2003). The popularity of ARIMA model is due to its statistical properties as well as use of well-known Box-Jenkins methodology in the model building process (Jha and Sinha, 2013).

The ARIMA is an extrapolation method, which requires historical time series data of underlying variable. The methodology refers to the set of procedures for identifying, fitting, and checking ARIMA models with time series data.

In an Auto-Regressive Integrated Moving Average (ARIMA) model, time series variable is assumed to be a linear function of the previous actual values and random shocks. In general, an ARIMA model is characterized by the notation ARIMA (p, d, q), where p, d and q denote orders of Auto-Regression (AR), Integration (differencing) and Moving Average (MA), respectively.

A pth –Order Auto-Regressive model: AR (p), which has the general form

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} ..... + \alpha_p y_{t-p} + \varepsilon_t \quad \text{--1}$$

y_t = Coffee Production, Area at time t

$y_{t-1}, y_{t-2}, y_{t-3}$ ---- y_{t-p} = Coffee production, Area at time lags t-1, t-2,……, t-p, respectively

α_0 , α_1 , α_2 ,....., α_p = coefficients to be estimated,

ε_t= Error term at time t

A qth-order Moving Average model: MA (q), which has the general form:

$$y_t = \mu + \varepsilon_t - \phi_1 \varepsilon_{t-1} - \phi_2 \varepsilon_{t-2} - ..... - \phi_q \varepsilon_{t-q} \quad \text{-2}$$

y_t = Coffee Production, Area at time t

μ = constant mean

$\phi_1, \phi_2, ...\phi_q$ = Coefficients to be estimated

ε_t = Error term at time t

$\varepsilon_{t-1}, \varepsilon_{t-2}, ...\varepsilon_{t-q}$ = Errors in previous time periods that are incorporated in Y_t

Auto Regressive Moving Average Model: ARMA (p, q), which has general form:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} ..... + \alpha_p y_{t-p} + \varepsilon - \phi_1 \varepsilon_{t-1} - \phi_2 \varepsilon_{t-2} - ..... - \phi_q \varepsilon_{t-q} \quad \text{---3}$$

y_t = Coffee Production, Area

α_0 , α_1 , α_2 ,….., α_p , ϕ_1 , ϕ_2 ,…. ϕ_q = Coefficients to be estimated
ε t= Error term at time t

$\varepsilon_{t-1}, \varepsilon_{t-2}, ...\varepsilon_{t-q}$ = Errors in previous time periods that are incorporated in Y_t

The first step in the process of ARIMA modelling is to identify the model using Auto Correlation Functions (ACFs) and Partial Auto Correlation Functions (PACFs) to achieve stationary and tentatively identify patterns and model components. A series is regarded stationary if its statistical characteristics such as the mean and the autocorrelation structures are constant over time. Determine whether the series is stationary or not by considering the graph of ACF. If a graph of ACF of the time series values either cuts off fairly quickly or dies down fairly quickly, then the time series values should be considered stationary. If the original series is stationary, d = 0 and the ARIMA models reduce to the ARMA models. However, many economic time series are non-stationary, that is, they are integrated. If a time series is integrated with an order of 1, it implies that the first difference of the price is effective and it is denoted as I (0). This implies that mean and covariance have attained stationarity. In general, if a time series integrated as I (d), after differencing it d times we obtain a stationary I (0) series. If a price series is non-stationary it is differentiated'd' times to make it stationary using ARIMA (p, d, q) model. The stochastic trend of the series is removed by differencing, multiple ARMA models are chosen on the basis of Auto-Correlation Function (ACF) and Partial Auto- Correlation Function (PACF) that closely fit the data.

The second step involves determining the coefficients and estimation is through maximum likelihood approach such that the overall measure of errors is minimized or the likelihood function is maximized. The third step involves diagnostics checking using ACFs and PACFs of residuals to verify whether the model is valid. In this step, model must be checked for adequacy by considering the properties of the residuals whether the residuals from an ARIMA model must has the normal distribution and should be random. Otherwise repeat the steps of identification, estimation and diagnostics. The most suitable ARIMA model is selected using the smallest Akaike Information Criterion (AIC) or Schwarz-Bayesian Criterion (SBC) value and root mean square error and lowest Mean Absolute Percentage Error (MAPE) criterion. The MAPE calculates the forecast error as a percentage of actual value. MAPE is used as relative measure to compare forecasts for the same series across different models.

The MAPE is calculated using the following formula

$$\text{MAPE} = \frac{\sum_{t=1}^{n} \left| \frac{y_t - \hat{y}_t}{y_t} \right|}{n} * 100$$

y_t = Actual value at time t

$\hat{y}_t$ = Predicted value at time t

n = Number of observations

The procedure for these tests is drawn from Makridokis and Wheelright (1978). The final step is forecasting simple statistics and confidence intervals to determine the validity of the forecast and track model performance to detect out of control situation. In this study, all estimations and forecasting of ARIMA model have been done using SPSS 26.

4. RESULTS AND DISCUSSION

4.1 Trend in Area, Production and Productivity of Coffee in India

The trend in area, production, yield of Arabica and Robusta coffee in India were computed from 1985 to 2020. The compound annual growth rates and their significance were estimated for area, production and yield by employing the exponential growth model for the given period (1985-2020). The results of estimated growth rates are presented in Table 1.

It could be concluded from the table that the area under Arabica coffee increased by 2.14 per cent per annum. The production of Arabica coffee in India increased slowly at 0.57 per cent per annum while the productivity of coffee recorded a negative trend at the rate of -1.53 per cent per annum. Growth in area, production of coffee were statistically significant. Pradeepa babu have also found that the productivity of Arabica coffee in India was declined due to climatic change like erratic rainfall, very high temperature in the recent years.

The results could be examined from the table that the area under Robusta coffee increased to 2.47 per cent per annum. The production of Robusta coffee in India were increased to 3.50 per cent per annum while the productivity of coffee recorded a positive and significant growth rate of 1.06 per cent per annum. Trend in area, production and productivity of Robusta coffee were statistically significant. In total coffee area, production and productivity of Robusta coffee noticed a positive trend during the study period.

4.2 Trend in Area, Production and Productivity of Coffee in Tamil Nadu

The trend in area, production, yield of Arabica and Robusta coffee in Tamil Nadu were computed from 2007 to 2020. The compound growth rates and their significance were estimated for area, production and yield by employing the exponential growth model for the given period (2007-2020). The results of estimated growth rates are presented in Table 2.

Table 1. Compound annual growth rate (CAGR) in area, production and productivity of Arabica and Robusta Coffee in India (1985-2020)

S.No	Variable	Growth rate(Percentage)	
		Arabica	**Robusta**
1	Area	2.14***	2.41***
2	Production	0.57***	3.50***
3	Productivity	-1.53***	1.06***

*(*** 5% level of significance)*

Table 2. Compound annual growth rate (CAGR) in area, production and productivity of arabica & robusta coffee in Tamil Nadu (2007-2020)

S.No	Variable	Growth rate(Percentage)	
		Arabica	**Robusta**
1	Area	1.45***	0.64***
2	Production	-0.99***	-0.42***
3	Productivity	-2.32***	-1.50***

*(*** 5% level of significance)*

From the Table 2, it could be determined that the area under Arabica coffee in Tamil Nadu showed a positive growth rate of 1.45 per cent per annum. But the production of productivity of Arabica coffee in Tamil Nadu noticed a high negative and non-significant growth during the study period.Pradeepa babu had found that the production and yield of Arabica coffee exhibited a negative trend due to susceptibility of pests mainly white stem borer which results in very low output of Arabica coffee.

The results of the trend in area of Robusta coffee in Tamil Nadu depicted a positive and significant growth. But a negative and non-significant growth were observed in the production and productivity of Robusta coffee at -0.42 and -1.50 per cent annum. Gokavi and Kishore found that it was due to extreme weather conditions prevailing in most of the coffee growing regions in Tamil Nadu. It could be inferred that the production and yield was low even if the area under Robusta coffee was high.

4.3 ARIMA Model Outcomes

The first step in building ARIMA model is the identification stage. This identification is done through plotting the autocorrelation values. Autocorrelations are numerical values that indicate how a data series is related to itself over time. These measures are most often evaluated through graphical plots called "correlograms". A correlogram plots the auto- correlation values for a given series at different lags. This is referred to as the "autocorrelation function" and is very important in the ARIMA method. The results were depicted in the Figs.1 and 2.

If a graph of ACF of the time series values either cuts off fairly quickly or dies down fairly quickly, then the time series values should be considered stationary. In our graph since the values are not dies down quickly it could be considered for non-stationarity of the series. Hence differencing could be done to make the series stationary. The model will be ARIMA.

In order to arrive the best fit model, different ARIMA models (p, d, q) were compared. The best fit model from the table was examined as (1, 1, 1) for Area and Production of Arabica coffee and for Robusta coffee was (1, 1, 0) with lowest MAPE values. The MAPE values of the former were 1.637 and 8.253 and for the latter were 1.600 and 11.338.

The Residual ACF and PACF of the selected ARIMA (1, 1, 1) model is presented below in the Fig. 3 for Arabica Coffee.

Auto Correlation plot of Bearing area and Production of Arabica coffee

Partial Auto Correlation plot of Bearing area and Production Arabica coffee

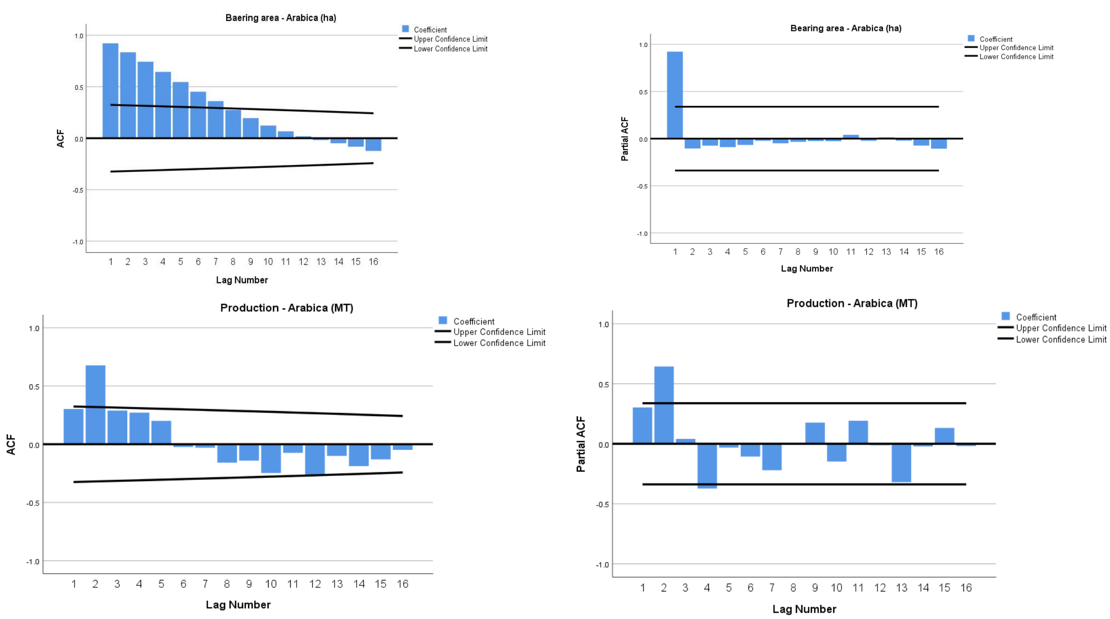


Fig. 1. Auto correlation and partial auto correlation of arabica coffee

Auto Correlation plot of Bearing area and Production of Robusta coffee

Partial Auto Correlation plot of Bearing area and Production of Robusta coffee

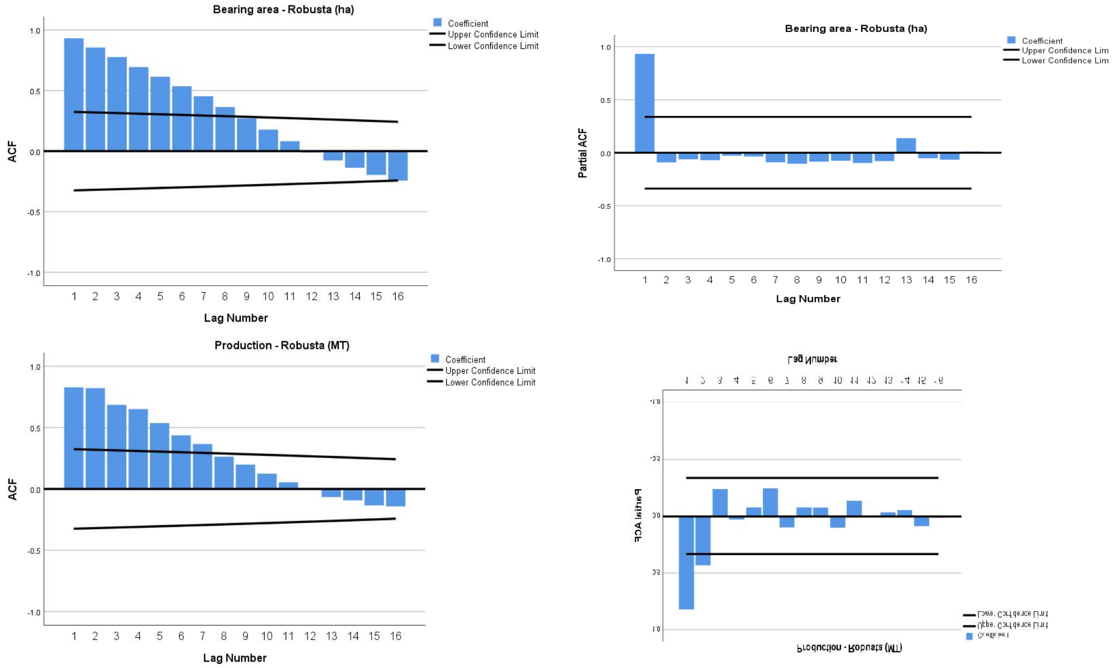
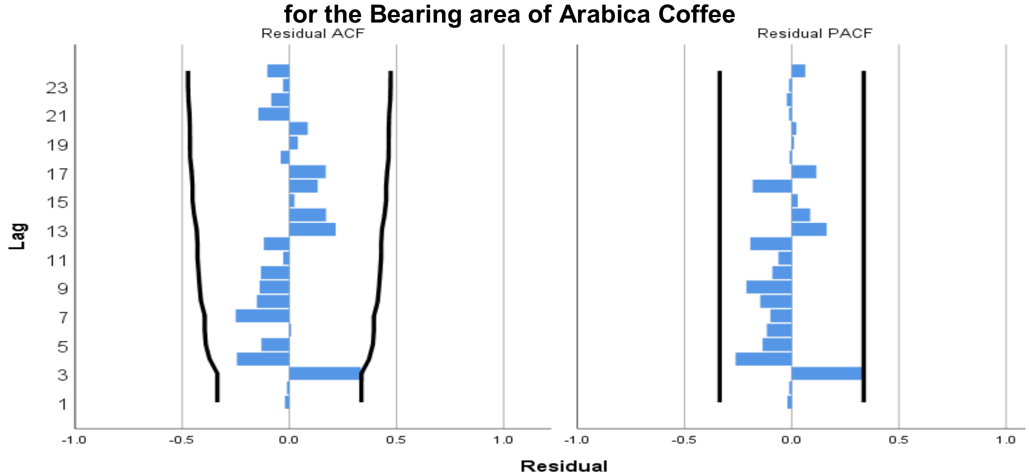


Fig. 2. Auto correlation and partial auto correlation of robusta coffee

Table 3. Accuracy performance measures of forecast

Model	MAPE values of Arabica		Model	MAPE values of Robusta	
	Area	Production		Area	Production
110	1.738	8.259	**110**	**1.600**	**11.338**
011	1.806	9.832	011	1.602	12.199
100	3.187	10.305	100	3.453	21.046
101	2.919	9.507	101	3.299	18.322
111	**1.637**	**8.253**	111	1.608	11.379

The ACF and PACF of the selected ARIMA (1,1,1) model is presented for the Bearing area of Arabica Coffee



The ACF and PACF of the selected ARIMA (1,1,1) model is presented for the Production of Arabica Coffee

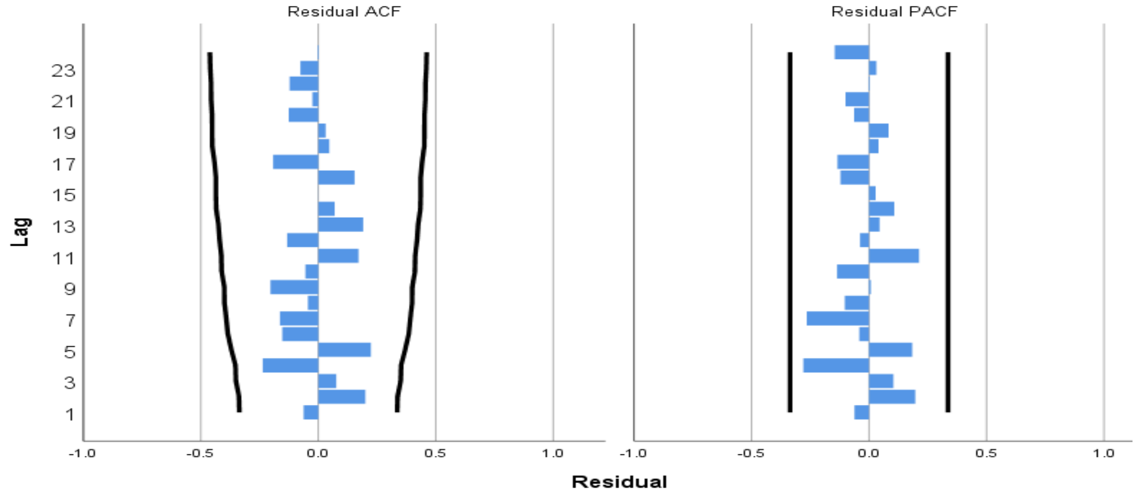


Fig. 3. Auto correlation and partial auto correlation plot of residuals of selected ARIMA (1, 1, 1) model of Arabica coffee

From the above Fig. 3, it could be inferred that the residuals are white noise and the fitted modelARIMA (111) was valid, therefore one of the values are used for forecasting.

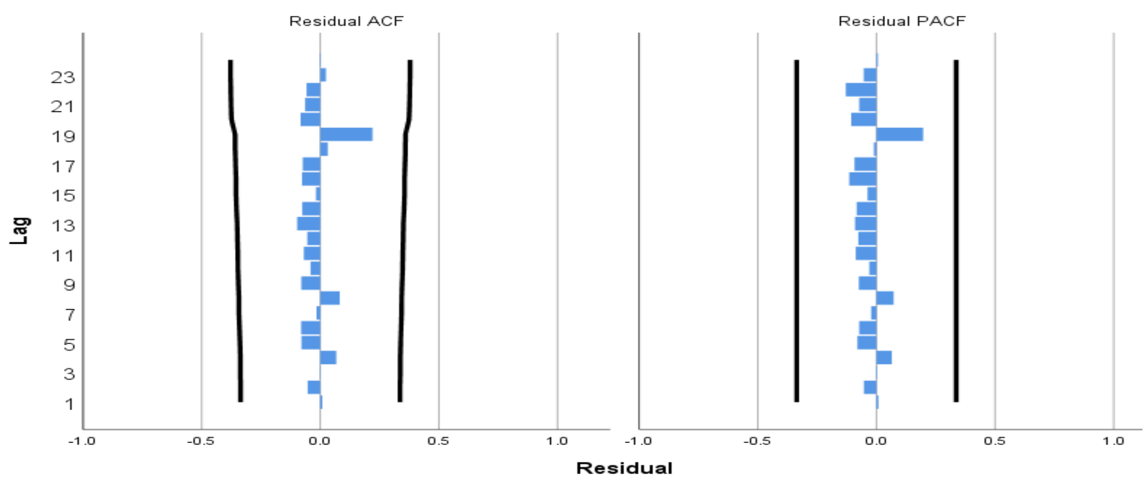
The residual ACF and PACF of the selected ARIMA (1, 1, 0) model is presented below in the Fig. 4 for Robusta coffee.

From the shows Fig. 4, it could be inferred that the residuals are white noise and the fitted model ARIMA (1, 1, 0) was valid, therefore the values are used for forecasting.

4.4 Forecasted Area and Production by Using Different ARIMA Models

Based on MAPE value and residual ACF and PACF ARIMA (111) model was the best fit model for predicting area and production of Coffee in India. The results of forecasts of various ARIMA models are presented in the Table 4.

The residual ACF and PACF of the selected ARIMA (1,1,0) model for Bearing area of Robusta coffee



The ACF and PACF of the selected ARIMA (1,1,0) model is presented for the Production of Robusta coffee

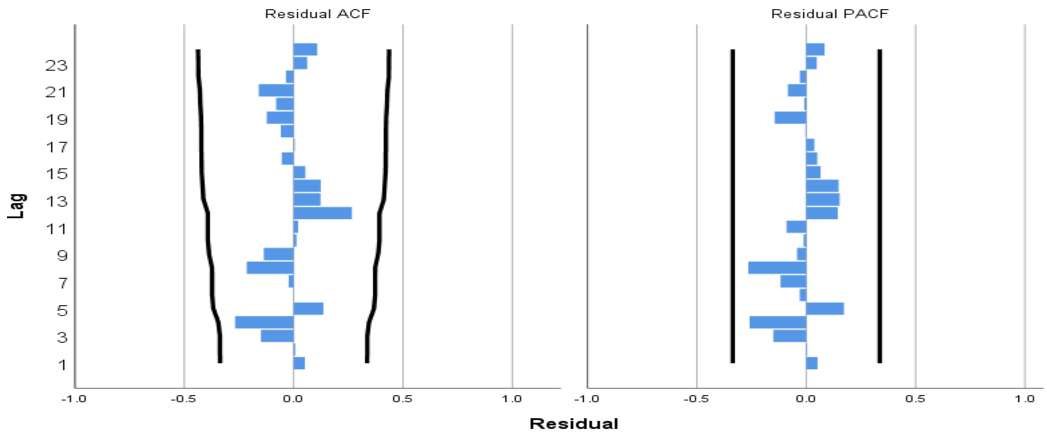


Fig. 4. Auto correlation and partial auto correlation plot of residuals of selected ARIMA (1, 1, 0) model of Robusta coffee

Table 4. Forecasted area and production for arabica coffee from 2021-2025

	Bearing area of Arabica Coffee (ha)					Production of Arabica Coffee (MT)				
Model	**2021**	**2022**	**2023**	**2024**	**2025**	**2021**	**2022**	**2023**	**2024**	**2025**
100	203093	202869	202645	202422	202200	92496	92928	93068	93112	93127
110	208355	211029	213741	216466	219196	89094	93353	90622	93333	91808
111	**208416**	**210970**	**213567**	**216192**	**218834**	**89608**	**93823**	**91342**	**93780**	**92605**
101	203091	202686	202285	201887	201493	91828	91750	91682	91622	91569
011	208509	211268	214027	216786	219545	94968	95469	95970	96471	96972

Table 5. Forecasted area and production for robusta coffee from 2021-2025

	Bearing area of Robusta Coffee (ha)					Production of Robusta Coffee (MT)				
Model	**2021**	**2022**	**2023**	**2024**	**2025**	**2021**	**2022**	**2023**	**2024**	**2025**
100	213920	213574	213229	212887	212547	201575	197407	193563	190019	186752
110	**220596**	**223767**	**226943**	**230118**	**233294**	**223481**	**233926**	**234035**	**241364**	**243649**
111	220731	223900	227084	230265	233446	222737	233577	233096	241007	242697
101	213578	213030	212487	211950	211418	212557	211271	210008	208768	207551
011	220641	223818	226996	230173	233351	236819	241522	246224	250926	255629

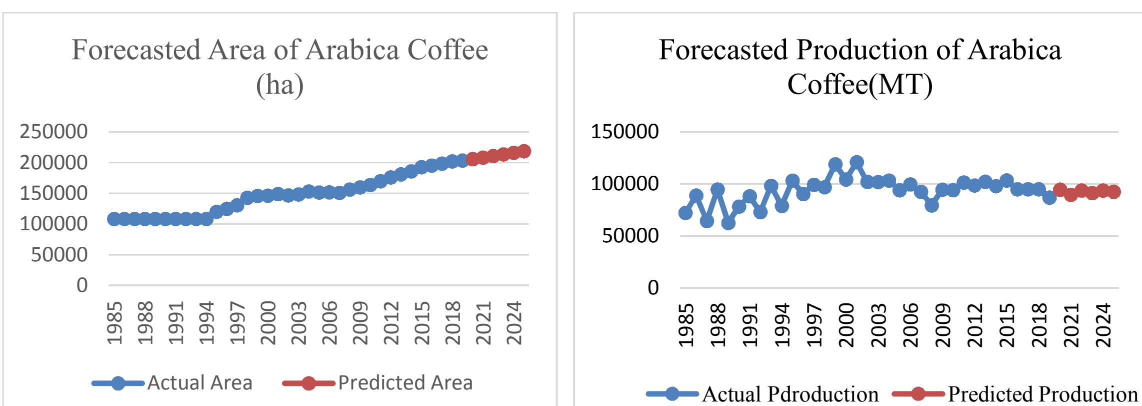


Fig. 5. Forecasted graphical representation of arabica coffee in India

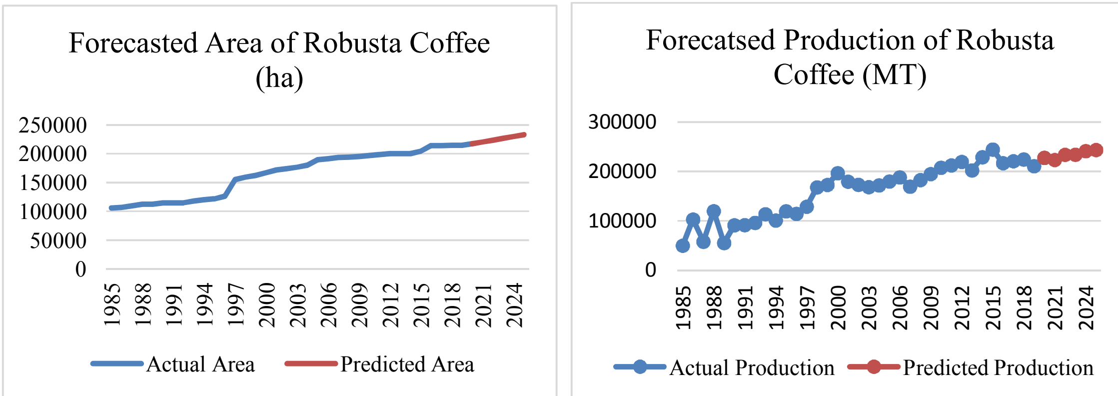


Fig. 6. Forecasted graphical representation of robusta coffee in India

Based on the results it could be inferred that there observed marginal increase in area and mixed trend in production. In 2022 increase in production was observed whereas in 2023 decline in production was seen again increase in production was seen in 2024 and decline in 2025.

Based on the results it could be inferred that there observed marginal increase in area and production of Robusta coffee in India.

4.5 Graphical Representation of Forecasted Area and Production

From the above figure 5 and 6, actual value and predicted value of Arabica and Robusta coffee was forecasted in India using ARIMA Model (1, 1, 1) and (1, 1, 0).

5. SUMMARY AND CONCLUSION

Area, production, yield of Arabica and Robusta coffee in India showed a positive trend. A negative trend was observed in productivity of Arabica coffee in India. Whereas in Tamil Nadu, area of Arabica and Robusta coffee showed positive trend, a negative trend was seen in production and productivity of Arabica and Robusta due to extreme weather conditions like erratic rainfall, high temperature and pest incidence prevailing in the major growing regions of Tamil Nadu. ARIMA (1, 1, 1) for Arabica and ARIMA (1, 1, 0) found to provide best fit for predicting the area and production of Robusta coffee in India. Increase in labour and input cost increased the cost of production of coffee. This indicated that the status of mechanisation has to be encouraged as the share of labour costs gets reduced which results in enhancing the living standard of people. To increase the productivity of coffee, the farmers have to be trained with adoption of Good Agricultural Practices (GAP) and Good Management Practices for improving the yield of the planation. Moreover, the plantations have to be maintained properly and the planters may be incentivised for compensating the higher labour and input cost.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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