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Forecast models for area, production and productivity of paddy in Kerala

Pooja BN, Ajitha TK, Prema A, Ayyoob KC and Syama S Menon

Pooja BN
Department of Agricultural Statistics, College of Agriculture, Kerala Agricultural University, Vellanikkara, Kerala, India

Ajitha TK
Department of Agricultural Statistics, College of Agriculture, Kerala Agricultural University, Vellanikkara, Kerala, India

Prema A
Department of Agricultural Economics, College of Agriculture, Kerala Agricultural University, Vellanikkara, Kerala, India

Ayyoob KC
Department of Agricultural Statistics, College of Agriculture, Kerala Agricultural University, Vellanikkara, Kerala, India

Syama S Menon
Department of Agronomy, College of Agriculture, Kerala Agricultural University, Vellanikkara, Kerala, India

Corresponding Author:
Pooja BN
Department of Agricultural Statistics, College of Agriculture, Kerala Agricultural University, Vellanikkara, Kerala, India

Abstract
An attempt is made to construct forecast models for area, production and productivity of paddy cultivation in Kerala. ARIMA and Exponential smoothing models were fitted for different seasons. The secondary data collected from the year 1960-61 to 2019-20 on area, production and productivity for three different seasons like autumn, winter and summer on paddy in Kerala from the Official Website "Directorate of Economics and Statistics" (DES), Kerala have been made use of for the study. Time series modelling and forecasting analysis identified Browns' exponential smoothing model as the best to predict the area and production under autumn paddy with an adjusted R^2 equal to 0.99 and 0.95 respectively and also for paddy productivity in winter (adjusted R^2 = 0.87) whereas Holts' exponential smoothing model was found as the best for autumn and summer paddy productivity with adjusted R^2 equal to 0.87. Simple exponential smoothing model was the best for modelling area under summer paddy (adjusted R2 =0.93), production of winter paddy (adjusted R^2 = 0.87) and summer paddy (R^2 = 0.60) and ARIMA (0, 1, 0) was the best model for area under winter paddy with adjusted R^2 = 0.98.

Keywords: ARIMA, exponential smoothing models, time series modelling

1. Introduction

Rice cultivation in Kerala dates back to 3000 BC, It is the staple food crop of Kerala. But since 1980s its cultivation has been in steady decline from 8,500,000 ha in 1980-81 to 1,980,000 ha in 2017-18. The agricultural scenario of Kerala indicates a heavy concentration of non-food crops like rubber etc. Over 95% of the state's total food grain production is rice. To increase paddy production, the government has started several initiatives and Local governments have established special programmes in 2008-09 as well as the Kerala Paddy Wet Land Conservation Act, 2008. Time series and forecast models were used to predict area, production and productivity of paddy in three different seasons like autumn, winter and summer in Kerala.

2. Materials and Methods

2.1 ARIMA and Exponential smoothing model: To predict the area, production and productivity of paddy in Kerala, secondary data from 1960-61 to 2019-20 were collected from the official website Directorate of Economics and Statistics (DES). Forecast models were developed using ARIMA and Exponential smoothing model.

2.2 Auto regressive integrated moving average (ARIMA) models: Box and Jenkins researched ARIMA models extensively throughout 1968, and their names were also used synonymously with the ARIMA method for time series forecasting. The stochastic model for the time series data is used to forecast the future values. There is either a stationary or non-stationary stochastic process or most of the time series are non- stationary. Major steps involved in the model building are (i) Identifying the model (ii) Estimation of parameters (iii) Diagnostic check and forecasting.

ARIMA model is an extension of ARMA model which applies differencing into the model ARIMA (p, d, q), if $\nabla^d y_t = (1-B)^d \varepsilon_t$ where ε_t ~WN (0, σ^2) WN indicating White Noise. The integration parameter d is a non-negative integer. When d=0, ARIMA (p, d, q) =ARMA (p, q).

2.3 Exponential smoothing methods: It is an effective method of forecasting which can be used as a substitute to replace the most common Box-Jenkins ARIMA model. Exponential smoothing is a tool for the estimation of univariate time series data. The main concept behind this technique is that the recent values get high significance in the time series modelling.

If the values get older the significance for those values get decline exponentially.

2.4 Simple Exponential smoothing: This approach is appropriate for predicting data without any specific trend and the data which don't show any seasonal behaviour

$$Y_{T+h/T} = \propto Z_T + \propto (1-\propto) Z_{T-1} + \propto (1-\propto)^2 Z_{T-2} + \cdots$$

$\propto$ is the smoothing coefficient which ranges between 0 to 1. It determines the rate at which the weights decrease. From the above equation it is confirmed that the one-step forward forecast for the time T+1 is the weighted average of all the observations in the series $Z_1, \ldots\ldots Z_t$.

2.5 Holt's Exponential smoothing model: Holt's exponential smoothing model is an extension of simple exponential smoothing model. Holt's (1957) developed this model to forecast time series data with the trend.

Level equation $L_t = \propto\ z_t + (1-\propto)[L_{t-1} + T_{t-1}]$ …. (1)

Trend equation $T_t = \beta[L_t - L_{t-1}] + (1-\beta)T_{t-1}0$ …. (2)

Forecast equation $F_{t+1} = L_t + K\, T_t$ …. (3)

Where L_t denotes the time series' level estimate at time t, T_t signifies the time series' trend estimate at time t, and $\propto$ is the level equation's smoothing coefficient, which varies from 0 to 1. β is the trend equation's smoothing coefficient, ranging from 0 to 1.

2.6 Brown's Exponential smoothing model: The Brown's Exponential smoothing model is suitable to model the time series with trend but without seasonality. Non adaptive Brown's linear exponential smoothing is provided

For non-adaptive Brown's exponential smoothing, let S_t and T_t be the simply smoothed value and doubly smoothed value for the $(t+1)^{th}$ time period respectively. Let a_t and b_t be the intercept and the slope.

Where,

$S_t = \propto X_t + (1-\propto) S_{t-1}$ … (1)

$T_t = \propto S_t + (1-\propto) T_{t-1}$ … (2)

$a_t = 2S_t - T_t$ … (3)

$b_t = \frac{\propto}{1-\propto} \times (S_t - T_t)$ … (4)

$F_{t+1} = a_t + b_t$ … (5)

3. Results and Discussion

3.1 Forecast models for area, production and productivity of autumn, winter and summer paddy in Kerala: The actual data on area and production of paddy in autumn and winter season generally showed a declining trend whereas in summer season there was an increasing trend. In the case of productivity the trend was increasing in all the seasons. The reason behind this might be the occurrence of more number of floods in autumn season and destruction of paddy as well as straw turning the net income of farmers to a very low level and water scarcity in the drought season also was a problem to the farmers.

Time series forecasting uses information regarding historical values and associated patterns to predict future activity and the data for 60 years have been used for the analysis. Raghavender (2010) [4] forecasted paddy production in Andhra Pradesh using ARIMA model. Sivapathasundaram and Bogahawatte (2012) [5] attempted to predict paddy production in Sri Lanka using ARIMA model. Iqbal *et al*. (2005) [3] made use of ARIMA model for forecasting wheat area and production in Pakistan. Biswas and Bhattacharyya (2013) [2] employed ARIMA Modelling to forecast area and production of rice in West Bengal. A study was carried out to estimate growth pattern and also examined the best ARIMA model to efficiently forecasting Aus, Aman and Boro rice production in Bangladesh by Awal and Siddique (2011) [1].

The present study Is based on the ARIMA and Exponential smoothing model for area, production and productivity of paddy in Kerala in three different seasons like autumn, winter and summer. First the time series data from 1960-61 to 2009-10 was taken and model was built using Expert modeller in SPSS22. The model was validated using the actual data for the period from 2010-11 to 2019-20. After validation of the model forecasts were made for next five years from 2019-20 to 2023-24 using the confirmed model and potential of the model was evaluated based on maximum value of R^2 with low MAPE.

Browns' Exponential smoothing model was identified as the best model with significantly high value of $R^2 = 0.99$ for area under paddy in autumn, ARIMA (0, 1, 0) with $R^2 = 0.98$ in winter and Simple exponential smoothing model with $R^2 = 0.93$ in summer. Coming to paddy production in autumn, Brown's exponential smoothing model resulted in an $R^2 = 0.95$ and simple exponential smoothing model seemed to be the best for winter and summer season with $R^2 = 0.87$ and 0.60 respectively. Holt's Exponential smoothing model was found as the best with $R^2 = 0.87$ to predict paddy productivity in autumn and summer and Brown's exponential smoothing model with $R^2 = 0.87$ for winter paddy productivity.

3.2 Paddy area in Kerala

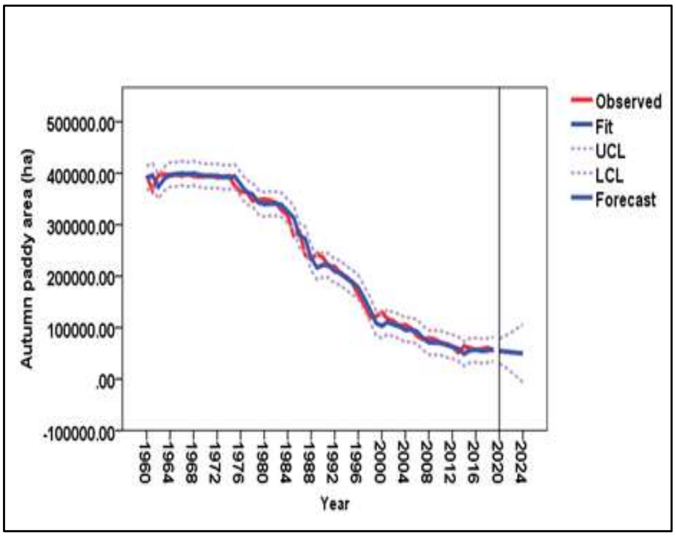

Fig 1: Area under autumn paddy in Kerala

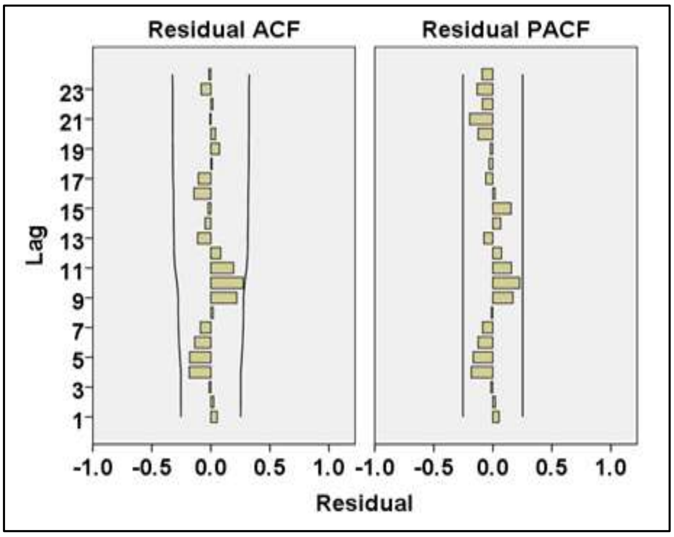

Fig 2: Residuals ACF and PACF plots area under autumn paddy

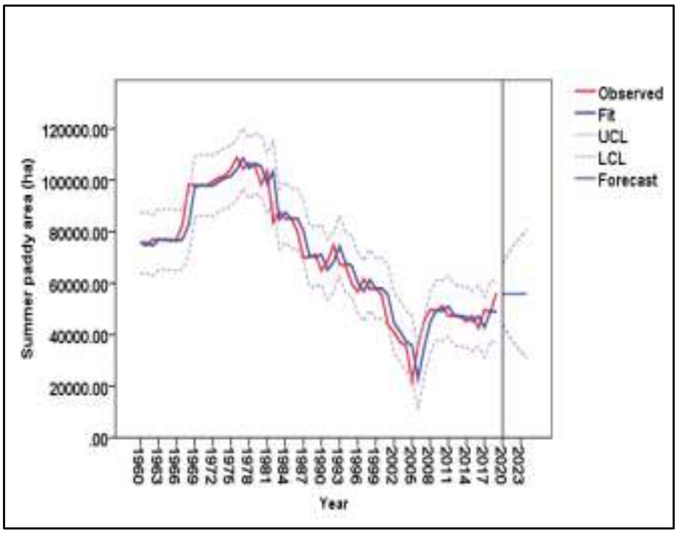

Fig 5: Area under Summer paddy in Kerala

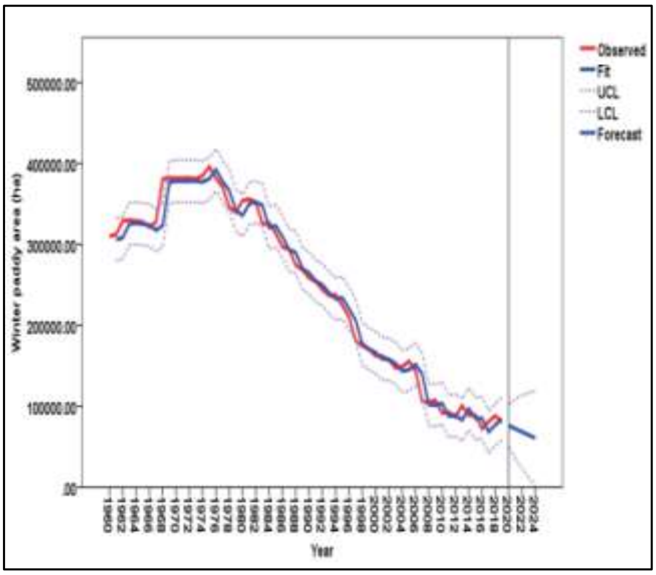

Fig 3: Area under winter paddy in Kerala

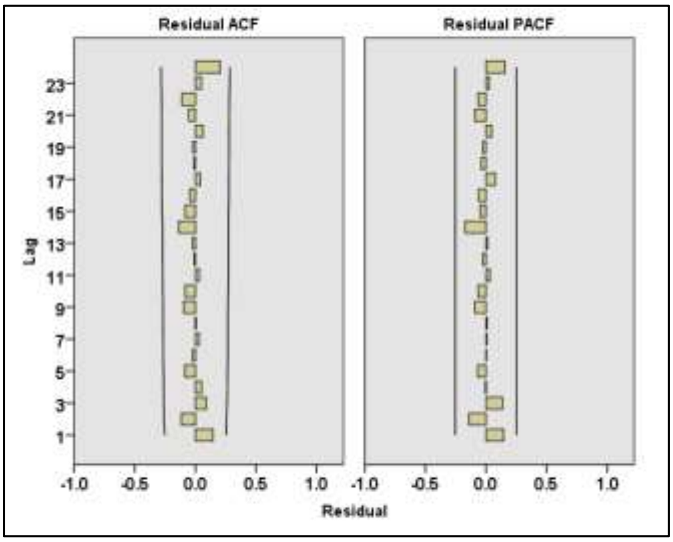

Fig 6: Residuals ACF and PACF plots area under summer paddy

3.3 Paddy production in Kerala

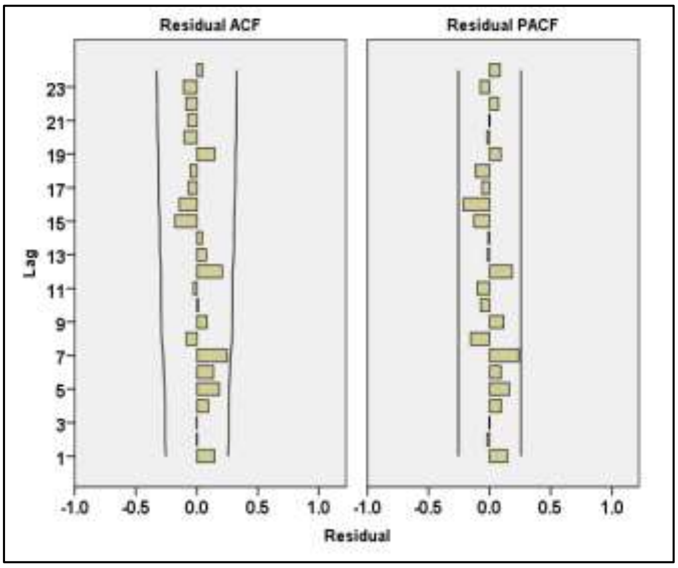

Fig 4: Residuals ACF and PACF plots area under winter paddy

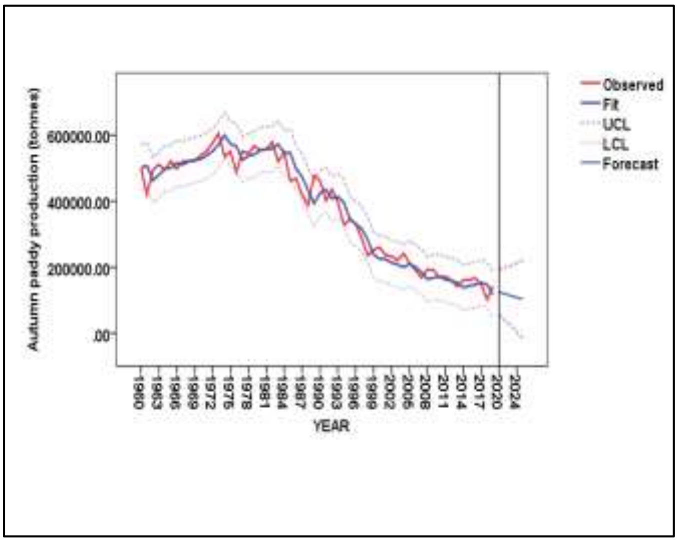

Fig 7: Autumn paddy production in Kerala

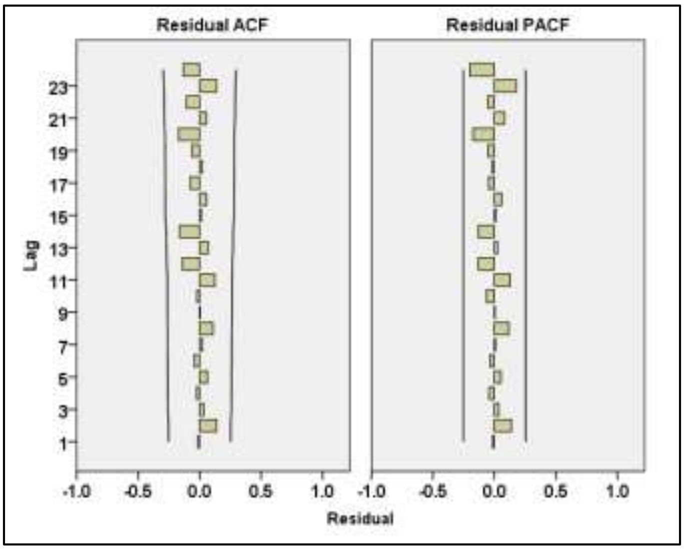

Fig 8: Residuals ACF and PACF plots autumn production

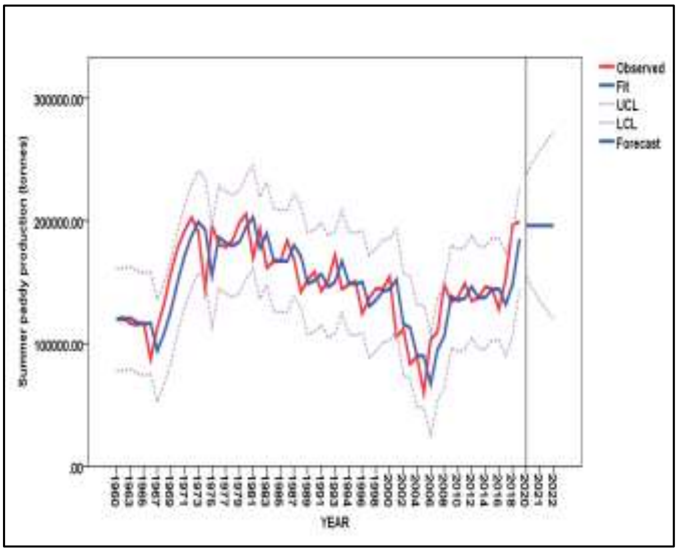

Fig 11: Summer paddy production in Kerala

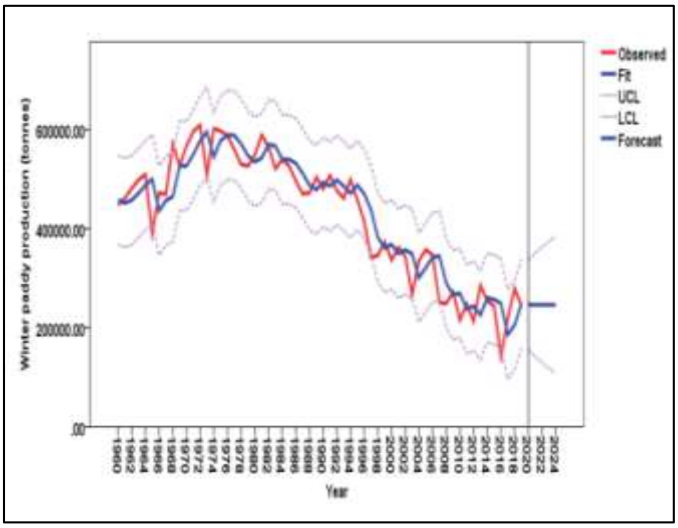

Fig 9: Winter paddy production in Kerala

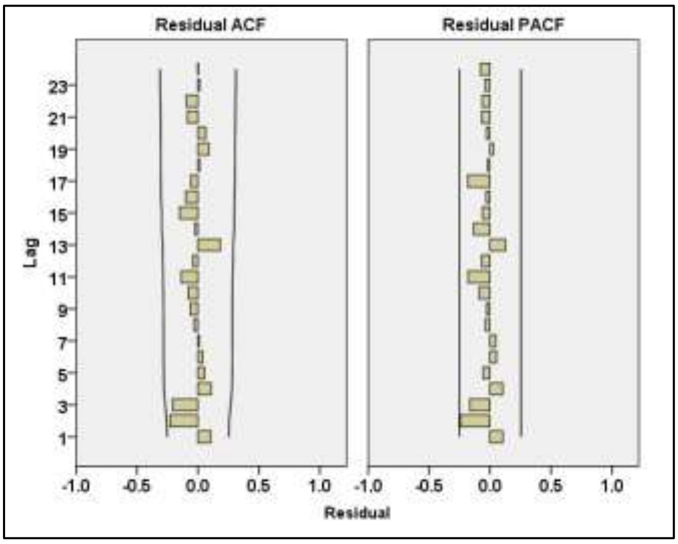

Fig 12: Residuals ACF and PACF plots Autumn production

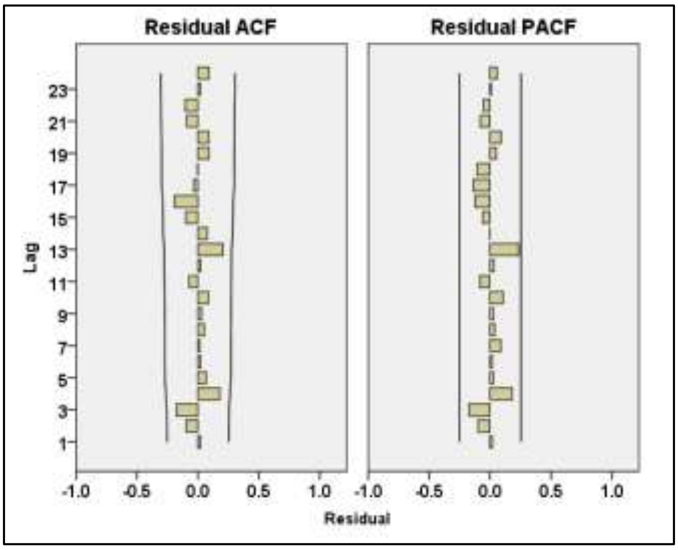

Fig 10: Residuals ACF and PACF plots Autumn production

3.4 Paddy productivity in Kerala

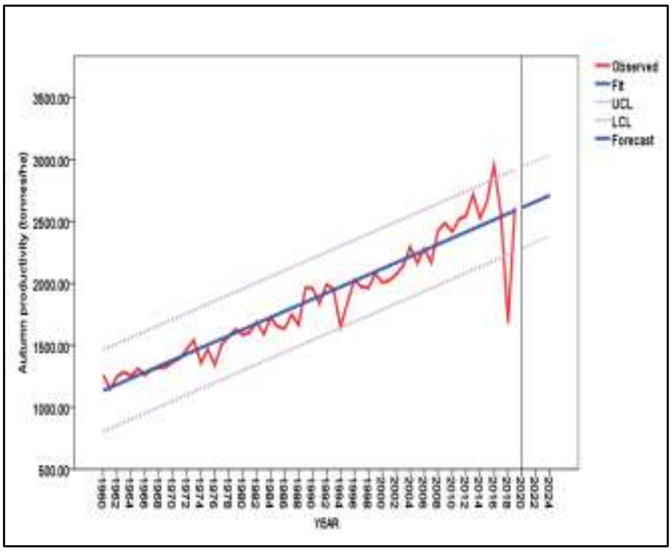

Fig 13: Autumn paddy productivity in Kerala

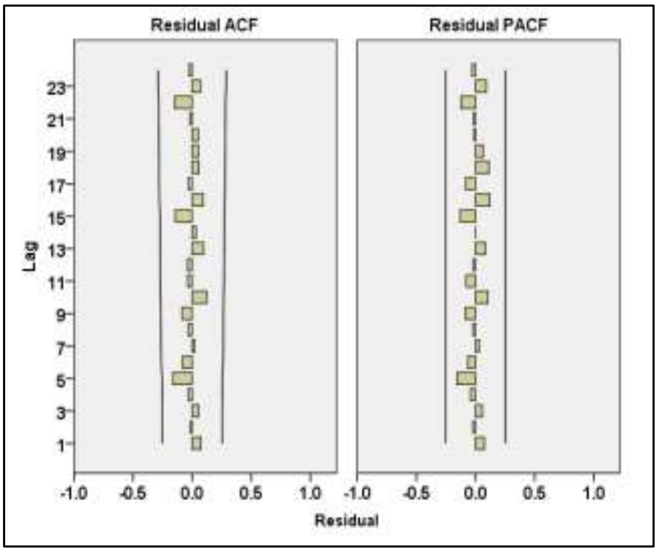

Fig 14: Residuals ACF and PACF plots Autumn productivity

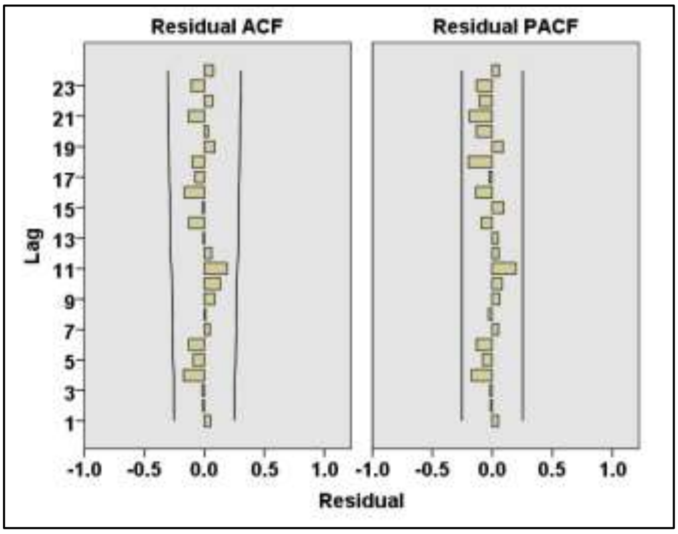

Fig 16: Residuals ACF and PACF plots Autumn productivity

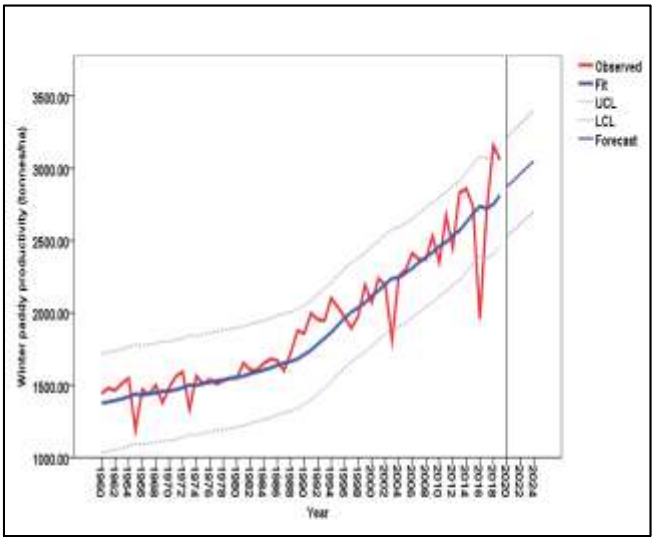

Fig 15: Winter paddy productivity in Kerala

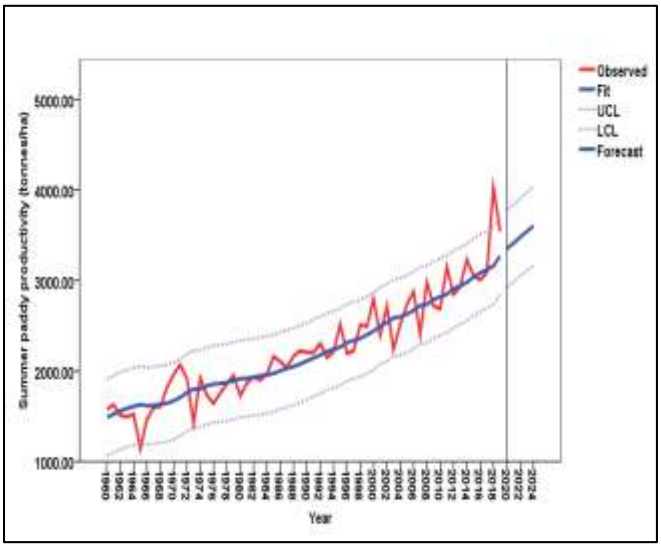

Fig 17: Summer paddy productivity in Kerala

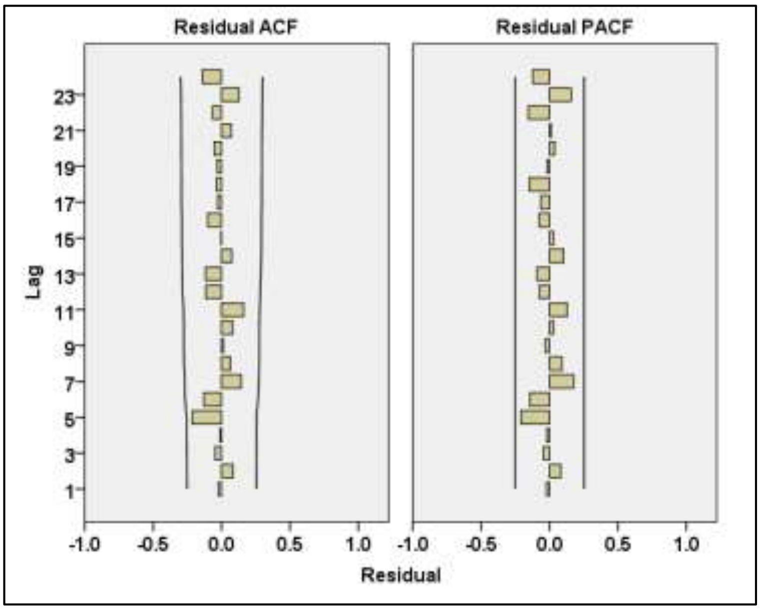

Fig 18: Residuals ACF and PACF plots Autumn productivity

Table 1. Forecasted area under paddy in Kerala in different seasons for the period 2019-20 to 2023-24

Year	2019-20	2020-21	2021-22	2022-23	2023-24
Autumn area (ha)	54724.89	53507.39	52289.89	51072.39	49854.89
Winter area (ha)	76150.77	72252.81	68354.86	64456.90	60558.95
Summer area (ha)	55833.46	55833.46	55833.46	55833.46	55833.46

Table 2. Forecasted paddy production (tonnes) in Kerala in different seasons for the period 2019-20 to 2023 -24

Year	2019-20	2020-21	2021-22	2022-23	2023-24
Autumn production	124579.03	119134.05	113689.08	108244	102799.13
Winter production	246371.68	246371.68	246371.68	246371.68	246371.68
Summer production	196123.78	196123.78	196123.78	196123.78	196123.78

Table 3. Forecasted paddy productivity (kg/ha) in Kerala in different seasons for the period 2019-20 to 2023 -24

Year	2019-20	2020-21	2021-22	2022-23	2023-24
Autumn productivity	2611.69	2636.33	2660.97	2685.61	2710.25
Summer productivity	2873.85	2918.16	2962.47	3006.79	3051.10
Winter productivity	3351.74	3414.90	3478.07	3541.24	3604.41

4. Conclusion

It has been observed that in Kerala, area and production of paddy showed a decreasing trend in autumn and winter whereas an increasing trend in summer season. The increasing trend in summer might be because of the water logging, flood or drought in other seasons, the farmers were ready to use leased lands and cultivate paddy in summer season. Time series model building have resulted in models like Simple exponential, Brown's exponential and Holt's exponential model with high predictability combined with low MAPE to forecast the area, production and productivity of paddy in Kerala for autumn, winter and summer season.

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