Int.J.Curr.Microbiol.App.Sci (2019) *8*(11): 1710-1719

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 11 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.811.199

Forecasting of Coconut Production in India: An approach with ARIMA, ARIMAx and Combined Forecast Techniques

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Keywords

Coconut, Modeling, Forecasting, ARIMA, ARIMAx, Combined forecast

Article Info

Accepted:
12 October 2019
Available Online:
10 November 2019

A B S T R A C T

Coconut is an important plantation crop which India holds third position in production. Coconut has the never ending list of uses also is facing numerous hurdles adding pressure to the mere survival of the sector. With increasing human population forecasting methods can help estimate many such future aspects. ARIMA, ARIMAx and Combined forecast techniques used to model and forecast the production of coconut until 2020 using time series data for a period of 1949 to 2015. For India as a whole the best fitted models ARIMA (1,1,2), ARIMAx (1,1,0) and the Combined forecast techniques projected coconut production to be 23396.122, 33013.792, 28204.957 Million nuts respectively. It is found that combined forecasting performed better compared with ARIMA and ARIMAx in all most all cases considering the criteria of R2, RMSE, MAE and MAPE. Among the three methods of modeling and forecasting ARIMAx models outperform ARIMA models and combined forecasting method yields better modeling and forecasting accuracy.

Introduction

India is the third largest producer of coconut. Kerala, Tamil Nadu, Karnataka, Andhra Pradesh and West Bengal are the major states which are producing (More than 92% together) coconuts in India. Coconut sector is facing numerous hurdles like vagaries of weather coupled with climatic change, lack of investment, quality cultivars, mostly confined to small holdings, decrease in planting areas due to various reasons like rapid urbanization, labour migration, increased wages, non-availability of quality inputs, risks confronted at the marketing sector like stiff competition from global players, trade agreements, tariff structure, government intervention, price transmission from the global markets, fluctuating currency, etc. add pressure to the mere survival of this sector not only in domestic sector but also in international sector. World population particularly the population of developing world is increasing at an alarming rate. To feed these ever increasing human populations remains a challenging task to the planners.

Planning for the future is a critical aspect of managing. The planners should have idea about the likely production scenario of the concerned crops. Forecasting methods can help estimate many such future aspects of any business operation and so also in agriculture. With advancement in science various statistical techniques has been evolved for future predictions of crop production. But sometimes it may not be feasible to develop a single model based on different types of data. In such a situation separate models based on different group of variables may be developed and forecasts obtained from these models may be combined to get a composite forecast and same is attempted here in the present study of area, production and productivity which in turn have a motto to foresee what could be the future behavior of coconut in India.

Materials and Methods

Depending upon the production performance of the major growing states for coconut and scrutinizing the data for each state, it was noticed that continuous and quality data were available for Kerala, Tamil Nadu, Karnataka, Andhra Pradesh and West Bengal (produces more than 92% together) of total Indian coconut production respective. State wise time series data on area, production and productivity of coconut and also state-wise NPK fertilizer consumption data for the period of 1949-2015 was collected from www.Indiastat.com and various issues of fertilizer statistics respectively. First data is scrutinized for the presence of any outliers using Grubbs' test. On rejection of outlier or replacement of extreme values if any by median, the data are subjected to test of randomness using turning point test. The most widely used descriptive measure of central tendency and dispersion like minimum, maximum, arithmetic mean, standard deviation, skewness, kurtosis along with simple and compound growth rates are used to explain each series.

Each time series is later subjected by two important stationarity test-ADF (Augmented Dickey Fuller) and KPSS (Kwiatkowski–Phillips–Schmidt–Shin) test. When the data are non-stationary, to be brought into stationary by the methods like differencing.

Box-Jenkins [Auto Regressive Integrated Moving Average (ARIMA)] model

Box-Jenkins time series models written as ARIMA (p, d, q) was first popularized by Box, G.E.P and Jenkins, G.M (1976). This model take care of three types of processes, viz., auto regressive of order p; differencing to make a series stationary of degree d and moving average of order q as this method applies only to a stationary time series data.

Autoregressive model

The notation AR (*p*) refers to the autoregressive model of order *p*. The AR(*p*) model is written

$$X_t = c + \sum_{i=1}^{P} \rho_i X_t + \varepsilon_t$$

Where $\rho_1, \rho_2 .....\rho_p$ are the parameters of the model, c is a constant and ε_t is white noise. Sometimes the constant term is avoided.

Moving average model

The notation MA (*q*) refers to the moving average series of order *q*:

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}$$

Where the $\theta_1,\ldots,\theta_q$ are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0), and the $\varepsilon_t, \varepsilon_{t-1}$ are error term.

ARIMAx technique for forecasting of coconut production and yield

As present performance in production of any crop not only depends on its past performances but also on other supporting input factors, these were also included in the model; as such ARIMAx models were also conceived. ARIMAx model is a generalization of ARIMA model and is capable of incorporating external input variable(s) (X's). ARIMAx is carried for the production and productivity data of the crops considered. Here in the current study annual total nitrogen, total phosphorus and total potassium consumption by states and India as a whole was considered as the external input. Initially, considered input variable(s) (X's) are modeled individually to get the estimated values for the observed data points and forecasted based on the best fitted ARIMA models in respective series. In the second step, these forecasted values are used as auxiliary/independent variable in the ARIMAx models of the production and productivity series. All developed ARIMAx models are compared for error diagnostic criteria i.e. RMSE, MAE, MAPE and value of R^2. The method which provides lower value of error diagnostic criteria and maximum value of R^2 is selected as best fitted model for coconut production and productivity forecasting.

Composite forecast

To improve forecasting accuracy, combine forecasts derived from methods that differ substantially and draw from different sources of information. Use formal procedures to combine forecasts: An equal-weights rule offers a reasonable starting point, and a trimmed mean is desirable if you combine forecasts resulting from five or more methods. Combining forecasts is especially useful when you are uncertain about the situation, uncertain about which method is most accurate, and when you want to avoid large errors. Compared with errors of the typical individual forecast, combining reduces errors. Combining should be done mechanically and the procedure should be fully described. Equal weighting is appealing because it is simple and easy to describe and the present investigation used it.

ARIMA models, ARIMAx models and combine forecast are selected as best fit models/ or evaluated based on the criteria of R^2, RMSE, MAE and MAPE.

Results and Discussion

From the table 1, one can find that, during the period under study average production for India under coconut was 9161.757 million nuts, with maximum production recorded 23351.220 million nuts (during the year 2011), while the minimum production was 3147.700 million nuts (during the year 1949). Increase in production of nuts in India is being reflected through simple as well as compound growth rates of 11.848 % and 3.902 % respectively during the period under study. Lepto kurtic and positive skewness clearly indicate that production of coconut showed maximum shift or improvement at early stages. All the states considered showed positively skewed production pattern which clearly indicates that coconut production showed steady changes at early stage commesurating with the changes in pattern of area. This finding of positive growth rates in production of coconut is not in conformity with the findings of Krishnan *et al.,* (1991) who showed negative growth rates production of four major crops including coconut in Kerala, though for a short study period of 1970-71 to 1986-87. Excepting Karnataka, all other states recorded platy kurtic nature of coconut production.

Among the states considered maximum compound growth rate found in West Bengal with 5.691 per cent (accompanied with 31.035 % SGR) followed by Karnataka and Tamil Nadu with 5.463 and 5.214 per cent respectively. Kerala, even with highest average production i.e, 4251.153 million nuts under period considered showed lowest compound growth of 2.688 per cent; a clear cut reflection of change in area under coconut in Kerala. The annual time series of coconut production for Karnataka noticed a gradual increase over the first half of the study period and later noticed rapid increase in recent years.

Test of outliers and randomness for production of coconut

From table 2 the results of both the test of randomness and that of outlier are presented for coconut. A few outliers are detected e.g. in case production of Karnataka, Kerala, Tamil Nadu and India as a whole indicating significant deviation from the aggregate pattern and thereby differential potentialities of growth. These outliers were of high values and kept untouched for the analysis since they were found in recent time and acceptable. From the test of randomness one can see that production of coconut in case of all states considered and whole India have changed with trend.

Modeling and forecasting of coconut production

From stationarity test for the production series of coconut, it is observed that, all the data series are non-stationary in nature (Table 3). The non-stationary data series are made stationary by first order differencing except the case of Kerala where second order differencing is performed to achieve the stationarity. After achieving stationarity, various ARIMA models are tried for each series and only best models among the competitive model for each series is selected based on minimum value of RMSE, MAPE, MAE and maximum value of R^2 and presented in table 4. From the table it is clear that ARIMA (1,1,2), ARIMA(1,1,1), ARIMA (4,2,0), ARIMA (1,1,1) ARIMA (1,1,1) and ARIMA (1,1,2) are found to be best ARIMA model for modeling coconut production in Andhra Pradesh, Karnataka, Kerala, West Bengal, Tamil Nadu and India respectively.

In ARIMAx, first all the independent variables are modeled and forecasted up to 2020 using ARIMA technique. Then these forecasted values are used as independent variables in the ARIMAx model. As in case of ARIMA, here also best ARIMAx model has been selected based on minimum value of RMSE, MAPE, MAE and maximum value of R^2 and presented in table 4. It can be noted that ARIMAx(0,1,1) for Andhra Pradesh and Kerala; ARIMAx(3,2,0) for West Bengal and Tamil Nadu; ARIMAx(1,1,2) for Karnataka and ARIMAx(1,1,0) for India respectively are the best ARIMAx models among the various competitive ARIMAx models for modeling coconut production. The results of Ljung–Box test of residuals also reject the presence of significant auto correlation in the residuals of the best fitted ARIMA and ARIMAx model.

Table.1 *Per se* performance of coconut production (in Million Nuts) in major states of India during 1949-2015

Particulars	Andhra Pradesh	Karnataka	Kerala	West Bengal	Tamil Nadu	India
Minimum	157.000	339.400	1920.200	22.000	409.600	3147.700
Maximum	1477.989	6058.860	7429.390	395.280	6917.460	23351.220
Average	597.136	1296.611	4251.153	163.595	2251.715	9161.757
Skewness	0.585	2.501	0.419	0.227	1.056	1.048
Kurtosis	-1.321	5.736	-1.020	-1.720	-0.066	0.144
SE of Mean	56.433	158.695	162.095	18.029	237.814	657.885
SGR (%)	7.006	27.583	5.626	31.035	24.230	11.848
CGR (%)	3.026	5.463	2.688	5.691	5.214	3.902

Table.2 Test of outliers and randomness for production of coconut

Test of randomness	Andhra Pradesh	Karnataka	Kerala	West Bengal	Tamil Nadu	India
No. of Observation	67	67	67	67	67	67
No. of Point (p)	26	19	29	15	30	34
E (P)	44.667	44.667	44.667	44.667	44.667	44.667
V(P)	11.589	11.589	11.589	11.589	11.589	11.589
τ_{cal}	-5.483	-7.540	-4.602	-8.715	-4.308	-3.133
Inference	Trend	Trend	Trend	Trend	Trend	Trend
Outliers Test	No	Yes	Yes	No	Yes	Yes

Table.3 Test of stationarity for production of coconut in India for observed data

State	ADF Value	P-value	Conclusion	KPSS Value	P-value	Conclusion
Andhra Pradesh	-2.658	0.246	Non Stationary	2.356	< 0.001	Non Stationary
Karnataka	-1.710	0.717	Non Stationary	1.515	< 0.001	Non Stationary
Kerala	-1.819	0.667	Non Stationary	2.240	< 0.001	Non Stationary
West Bengal	-1.463	0.808	Non Stationary	2.485	< 0.001	Non Stationary
Tamil Nadu	-1.975	0.588	Non Stationary	2.288	< 0.001	Non Stationary
India	-1.313	0.848	Non Stationary	2.338	< 0.001	Non Stationary

Table.4 ARIMA, ARIMAx and combined model for production of coconut in India

State	Models	Model selection criteria				Ljung-Box test for residuals	
		R^2	RMSE	MAPE	MAE	χ^2	P Value
ARIMA Models							
Andhra Pradesh	(1,1,2)	0.906	147.385	12.338	80.143	14.438	0.493
Karnataka	(1,1,1)	0.763	532.954	7.185	148.534	9.872	0.873
Kerala	(4,2,0)	0.898	387.595	5.701	260.313	7.493	0.914
West Bengal	(1,1,1)	0.971	24.067	5.767	11.968	19.433	0.247
Tamil Nadu	(1,1,1)	0.936	436.806	9.831	274.786	11.287	0.791
India	(1,1,2)	0.939	1188.739	5.886	669.749	11.804	0.694
ARIMAx Models							
Andhra Pradesh	(0,1,1)	0.926	131.994	14.344	77.609	17.648	0.411
Karnataka	(1,1,2)	0.925	314.230	12.518	182.945	7.249	0.950
Kerala	(0,1,1)	0.911	362.844	5.675	257.063	12.355	0.778
West Bengal	(3,2,0)	0.968	26.248	7.253	13.539	14.402	0.495
Tamil Nadu	(3,2,0)	0.928	485.967	11.693	300.139	15.302	0.430
India	(1,1,0)	0.954	1036.952	6.189	677.078	12.958	0.739
ARIMA+ARIMAx							
Andhra Pradesh	-	0.926	128.010	12.528	70.965	-	-
Karnataka	-	0.892	361.714	8.666	150.068	-	-
Kerala	-	0.918	340.828	5.134	234.733	-	-
West Bengal	-	0.972	23.552	6.250	12.216	-	-
Tamil Nadu	-	0.937	429.076	10.557	276.155	-	-
India	-	0.953	1022.757	5.738	640.688	-	-

Fig.1 ACF and PACF graphs of residuals for the best fitted ARIMA models of production of coconut in India

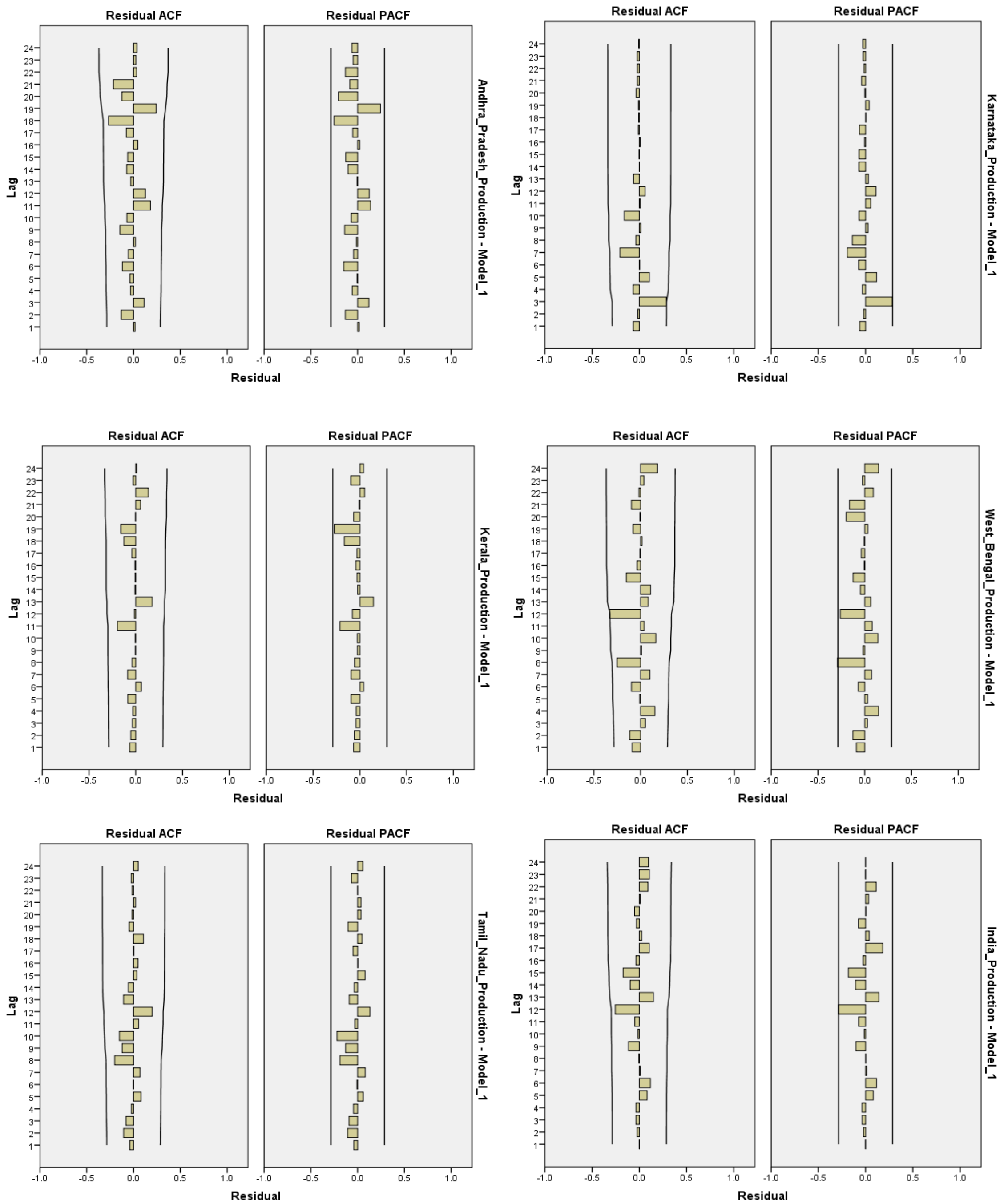

Fig.2 ACF and PACF graphs of residuals for the best fitted ARIMAx models of production of coconut in India

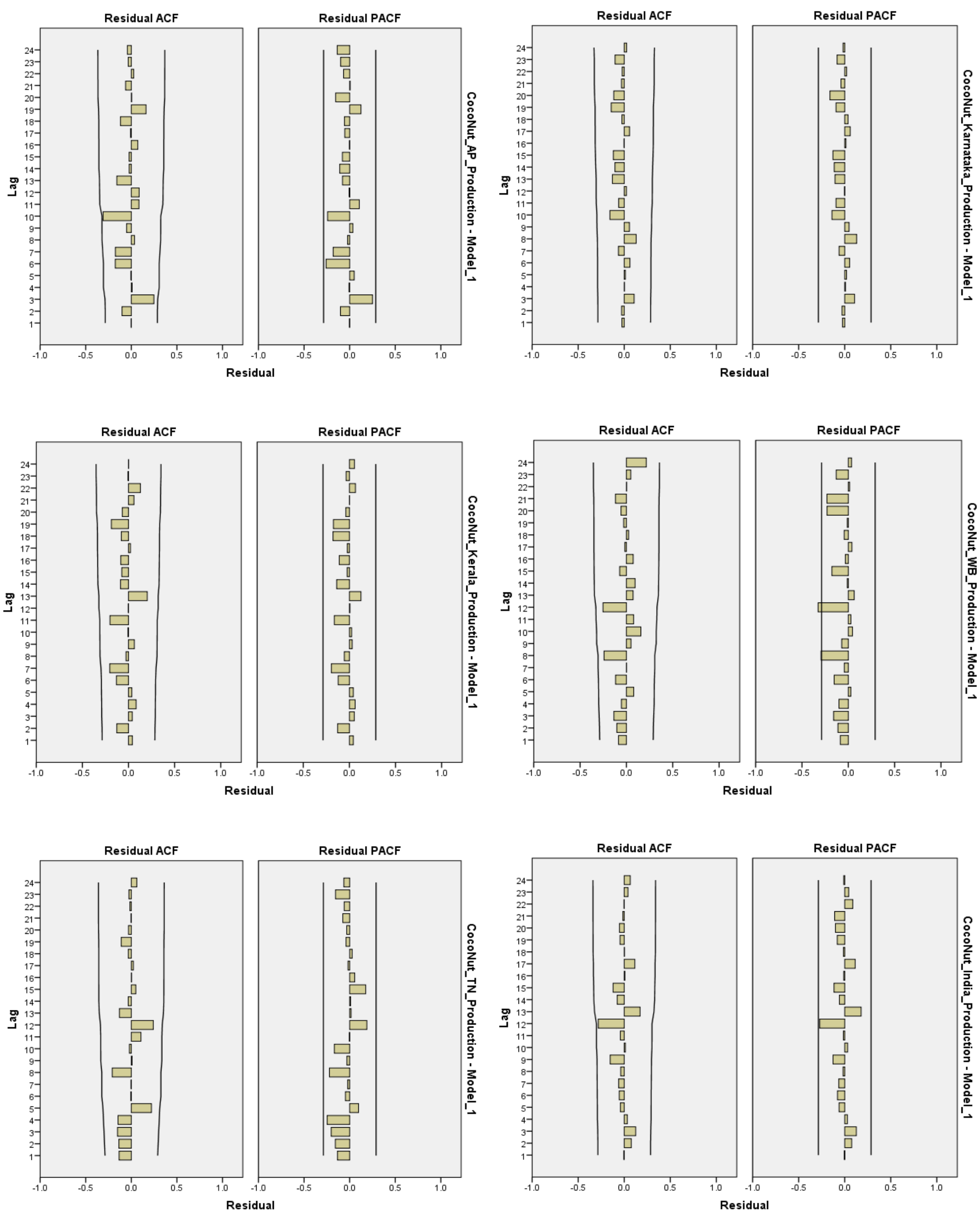

Table.5 Observed and forecasted production (in Million nuts) of coconut in India

State	Model	Observed			Predicted			Forecasted				
		2013	2014	2015	2013	2014	2015	2016	2017	2018	2019	2020
Andhra Pradesh	ARIMA(1,1,2)	1410.005	1447.900	1427.745	1583.412	1526.393	1496.881	1461.755	1472.996	1500.674	1540.913	1590.656
	ARIMAx(0,1,1)				1458.761	1387.487	1501.751	1627.853	1841.932	2053.902	2284.651	2583.720
	Combined				1521.087	1456.940	1499.316	1544.804	1657.464	1777.288	1912.782	2087.188
Karnataka	ARIMA(1,1,1)	5041.150	5141.150	5128.840	5162.665	5715.289	4683.520	5752.955	5476.976	5826.980	5748.332	5968.878
	ARIMAx(1,1,2)				5558.918	5452.224	5658.067	5874.485	5966.541	6219.989	6248.045	6290.812
	Combined				5360.792	5583.757	5170.794	5813.720	5721.759	6023.485	5998.189	6129.845
Kerala	ARIMA(4,2,0)	5968.010	5947.000	7429.390	6012.609	6047.178	5841.009	7274.257	7352.468	7783.640	8261.794	8701.108
	ARIMAx(0,1,1)				6159.900	6126.398	6231.953	7107.499	7181.716	7241.266	7289.932	7325.968
	Combined				6086.255	6086.788	6036.481	7190.878	7267.092	7512.453	7775.863	8013.538
West Bengal	ARIMA(1,1,1)	370.830	372.230	373.580	372.002	373.346	374.579	375.776	377.881	379.899	381.832	383.685
	ARIMAx(3,2,0)				374.409	370.179	368.902	364.899	363.316	361.678	359.116	355.583
	Combined				373.206	371.763	371.741	370.338	370.599	370.789	370.474	369.634
Tamil Nadu	ARIMA(1,1,1)	6917.250	6917.460	6171.060	6968.132	6917.350	6917.475	6118.106	6114.246	6113.964	6113.944	6113.942
	ARIMAx(3,2,0)				7265.056	7027.874	6985.918	6014.082	5568.305	4933.696	3990.200	2957.986
	Combined				7116.594	6972.612	6951.697	6066.094	5841.276	5523.830	5052.072	4535.964
India	ARIMA(1,1,2)	21665.190	20439.610	22167.450	23016.087	22105.864	20889.808	22294.709	22570.546	22846.061	23121.253	23396.122
	ARIMAx(1,1,0)				23348.609	22176.424	22121.060	24171.280	26506.199	28715.645	30878.516	33013.792
	Combined				23182.348	22141.144	21505.434	23232.995	24538.373	25780.853	26999.885	28204.957

These selected models are further put under diagnostic checking through ACF and PACF graphs of residuals (Fig. 1 and 2) and found that the residuals of selected models are free from significant correlations and used for forecasting coconut production up to 2020.

The selected models are also validated for accuracy using last three years and observed that the actual and predicted values are in range and same can be observed from table 5 for the states of Andhra Pradesh, Karnataka, Kerala, West Bengal, Tamil Nadu and India as a whole respectively.

From the selected ARIMA Models the forecasted values obtained, it can be noted that production of coconut in Andhra Pradesh, Karnataka, Kerala, West Bengal, Tamil Nadu and India would be 1590.656, 5968.878, 8701.108, 383.685, 6113.942 and 23396.122 million nuts respectively in 2020. Naveen *et al.*, (2014) found that ARIMA (1, 1, 1) model as an appropriate model to forecast the production of coconut for India and forecasted production for the year 2020 to be 15300.000 million nuts. The difference in the forecasted value between present study and study conducted by Naveen *et al.*, may be attributed to difference in period of data used and also recent data points were found to be high value outliers which is used in the present study. This might be the reason why the presented study forecasted value for coconut production for India is high compared to study conducted by Naveen *et al.*, Similarly, from the selected ARIMAx Models the forecasted values obtained, it can be noted that production of coconut in Andhra Pradesh, Karnataka, Kerala, West Bengal, Tamil Nadu and India would be 2583.720, 6290.812, 7325.968, 355.583, 2957.986 and 33013.792 million nuts respectively in 2020.

Compared to the year 2015, the forecasted figures indicate that production of coconut in the states of Andhra Pradesh, Karnataka and India as a whole would increase in future for both ARIMA and ARIMAx models considered. In case of Kerala and West Bengal the forecasted figures indicates that production would increase in future for the ARIMA models selected and would decrease for ARIMAx models considered. While Tamil Nadu figures indicate would decrease for ARIMA and drastically decrease for ARIMAx models considered.

ARIMA, ARIMAx and combined model for production of coconut in India

When the production of coconut is considered, from the table 4 it can be observed that combined forecasting performed better compared with ARIMA and ARIMAx in all most all cases considering the criteria of R^2, RMSE, MAE and MAPE except few cases as discussed below; In case of Andhra Pradesh combined forecast is best compared to both ARIMA and ARIMAx except having marginal increase in MAPE compared with ARIMA, it can be still noted that ARIMAx and Combined forecast bear same R^2 values. In case of Karnataka when ARIMA, ARIMAx and Combined forecast are compared, each one have two better criteria compared with the other. In case of West Bengal combined is best compared with ARIMA except the criteria of MAPE which is high in case of combined forecasting. In India also Combined forecast is best than ARIMA and ARIMAx even though ARIMAx model have negligible increase in R^2. The combined forecast values of the same can be found in table 5.

Thus Compared to the year 2015, the forecasted figures indicate that production of coconut in the states of Andhra Pradesh, Karnataka and India as a whole would increase in future. In case of Kerala and West Bengal the forecasted figures indicates that production would increase in future for the ARIMA models considered. While Tamil Nadu figures indicates would decrease for both ARIMA and ARIMAx models considered. It is found that combined forecasting performed better compared with ARIMA and ARIMAx in all most all cases considering the criteria of R^2, RMSE, MAE and MAPE. Among the three methods of modeling and forecasting ARIMAx models outperform ARIMA models and combined forecasting method yields better modeling and forecasting accuracy

Acknowledgement

The authors acknowledge and thank Department of Science and Technology for awarding Inspire fellowship for pursuing Doctoral Programme.

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How to cite this article:

Lakshmi Narsimhaiah, P.K. Sahu, Kanchan Sinha, Sh Herojit Singh, Soumik Dey and Pramit Pandit. 2019. Forecasting of Coconut Production in India: An approach with ARIMA, ARIMAx and Combined Forecast Techniques. *Int.J.Curr.Microbiol.App.Sci.* 8(11): 1710-1719.
doi: https://doi.org/10.20546/ijcmas.2019.811.199