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

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Abstract

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.

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

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 which in turn have a motto to foresee what could be the future behavior of coconut in India.

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

\[ X_t = c + \sum_{i=1}^{p} \rho_i X_{t-i} + \varepsilon_t \]

Where \( \rho_1, \rho_2, \ldots, \rho_p \) are the parameters of the model, \( c \) is a constant and \( \varepsilon_t \) 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, \(\mu\) 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. Leptokurtic 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.
commensurating 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 platykurtic 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 ARIMA, 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 ARIMA model. As in case of ARIMA, here also best ARIMA 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 ARIMA(0,1,1) for Andhra Pradesh and Kerala; ARIMA(3,2,0) for West Bengal and Tamil Nadu; ARIMA(1,1,2) for Karnataka and ARIMA(1,1,0) for India respectively are the best ARIMA models among the various competitive ARIMA 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 ARIMA 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    | 0.675   | 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   | $\chi^2$ | $P$ 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       | 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   |
|             | ARIMA(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   |
|             | ARIMA(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   |
|             | ARIMA(0,1,1) | 6159.900  | 6126.398  | 6231.953   | 7107.499   | 7181.716   | 7241.266   | 7289.932   | 7325.968   |
|             | Combined   | 6086.255  | 6068.788  | 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    | 375.776    | 377.881    | 379.899    | 381.832    | 383.685    |
|             | ARIMA(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    | 369.474    | 369.634    |
| Tamil Nadu  | ARIMA(1,1,1) | 6917.250  | 6917.460  | 6171.060   | 6968.132   | 6917.350   | 6917.475   | 6118.106   | 6114.246   | 6113.944   | 6113.942   |
|             | ARIMA(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 | 20898.808 | 22294.709 | 22570.546 | 22846.061 | 23121.253 | 23396.122 |
|             | ARIMA(1,1,0) | 23348.609 | 22176.424 | 22211.060 | 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 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 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 indicate 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 indicate 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.

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