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Modeling and Forecasting of Arecanut Production in India-Vision 2020

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A B S T R A C T

Arecanut is an important plantation crop which India holds number one position in area and production. Arecanut has the never ending list of uses i.e. for chewing purpose, as medicine, as vegetable, as stimulant, fuel wood, lubricant, tannin, wrapping, clothing etc.,(Aman, 1969). Arecanut is facing numerous hurdles adding pressure to the mere survival of the sector not only in domestic but also in international sector. Forecasting methods can help estimate many such future aspects of any business operation and so also in agriculture. ARIMA, ARIMAx and Combined forecast techniques used to model and forecast the area, production and productivity of arecanut until 2020 using time series data for a period of 1965 to 2015. Area of India under arecanut for the year 2020 is forecasted to be 447.581 thousand hectares by the best fitted ARIMA (1,1,1). The estimate of production for arecanut by 2020 found to be 723.834, 975.452 and 849.643 metric tonnes by the best fitted ARIMA (0,1,2), ARIMAx (1,1,0) and combined forecast methods respectively. Similarly productivity by the end of 2020 found to be 1595.966, 1576.010 and 1585.988 kg per hectare using the best fitted ARIMA (0,1,1), ARIMAx (0,1,1) and combined forecast respectively.

Introduction

Arecanut (*Areca catechu*) is a plantation crop. India holds number one position both in areca nut area and production. Arecanut also popular by name *supari* or *betelnut*, is used for chewing purpose. It is one of important commercial crop in South East Asia. Arecanut has the never ending list of uses i.e. for chewing purpose, as medicine, as vegetable, as stimulant, fuel wood, lubricant, tannin, wrapping, clothing etc., Medicinal properties of areca nut which are helpful to cure ailments such as dysentery, diarrhea, heart burn, urinary stones, etc., (Aman, 1969).

Indian plantation 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.

Planning for the future is a critical aspect of managing any organization, and agricultural enterprises are no exception. Forecasting methods can help estimate many such future aspects of any business operation and so also in agriculture. With the above backdrop there is great need for developing suitable and reliable models using information from different sources like agricultural inputs, meteorological information for providing the reliable and timely forecast of crop production which in turn helps for suitable policy making. The present work is an attempt carried out to study the area, production and productivity which in turn have a motto to foresee what could be the future behavior of arecanut in India.

Materials and Methods

Depending upon the production performance of the major growing states for arecanut and scrutinizing the data for each state, it was noticed that continuous and quality data were available for Karnataka, Kerala and Assam (produces more than 87% together) of total Indian arecanut production respective. State wise time series data on area, production and productivity of arecanut and also state-wise NPK fertilizer consumption data for the period of 1965-2015 was collected from Ministry of Agriculture and Farmers Welfare, Govt. of India 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 arecanut 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 arecanut 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

Per se performance of arecanut production in India

Table 1 provides the *per se* performance of arecanut in India during 1965-2015. From the table one can find that, during the period under study country's average area under arecanut is 256.45 thousand hectares; the maximum area covered was 463.89 thousand hectares, while the minimum area covered was noted to be 131 thousand hectares. Increase in area under arecanut is being reflected in terms of simple growth rate 4.756% accompanied with a compound growth rate of 2.423 percent per annum. Platykurtic and positive nature of skewness clearly indicates that area under arecanut showed steady changes at early stage and remained almost same during later part of study. Among the major nut growing states in India, the maximum growth in area was observed in Karnataka with a SGR of 9.211% and CGR of 3.435%, followed by Assam SGR-4.154% and CGR- 2.237% and Kerala SGR-1.250% and CGR- 0.968 %. In support of the above, average area under arecanut in Karnataka is more compared to all other states, followed by Kerala and Assam. The positive value skewness and negative kurtosis for all states reveals steady changes in area under arecanut has taken place during initial period under study and remained almost same during later part of the study. While in case of Kerala negative value of skewness and platykurtic nature reveals that there has been marginal shift in recent years of the study.

From the table one can find that, during the period under study average production of Indian arecanut was 295.797 thousand tons, with maximum production recorded 746.110 thousand tons, while the minimum production was 113.00 thousand tons. Increase in production of nuts in India is being reflected through simple as well as compound growth rates of 4.73% and 2.415% respectively during the period under study. Leptokurtic and positive skewness clearly indicate that production of arecanut showed maximum shift or improvement at early stages.

Among the states considered maximum compound growth rate found in Karnataka with 4.617 (accompanied with SGR-18.182%) per cent followed by Kerala and Assam with 2.415 and 2.190 per cent respectively. Karnataka even with highest average production i.e., 136.916 thousand tons followed by Kerala 75.163 thousand tons and Assam 51.831 thousand tons.

Arecanut yield of India is varied from 831.461 Kg/ha to 1658.470 Kg./ha with an annual simple and compound growth rate of 1.435 percent and 1.075 percent respectively. On average arecanut yield remained 1099.678 Kg/ha during the study period. In similarity with area and production Karnataka has recorded the highest average highest yield (1417.49 Kg/ha) followed by Assam (949.817 Kg/ha) while Kerala with lowest yield (943.046 Kg/ha). Kerala has the highest CGR and SGR have both highest whereas negative growth is seen in case of Assam. Among the states considered Assam and Karnataka are positively skewed whereas Kerala shows negative skewness. Karnataka shows only leptokurtic behavior which tells the story of presence of higher proportion of places with maximum yield.

Test of outliers and randomness for area, production and yield of arecanut

In table 2 the results of both the test of randomness and that of outlier are presented for arecanut. No outlier was detected in all data series of arecanut. From the test of randomness one can see that except the yield of arecanut in India area, production and yield of arecanut in Assam, Kerala, Karnataka and India follow some trends.

Modeling and forecasting of arecanut area

First order differencing was necessary for the series to make it stationary except for area of arecanut in Kerala which required second order differencing. Once the data series are made stationary, 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. Developed models are also put under diagnostic checking through Ljung–Box test of residuals.

From the Table 3, for area under arecanut in Assam, Karnataka, Kerala and India, the best fitted ARIMA models are respectively

ARIMA (1,1,0), ARIMA (3,1,0), ARIMA (0,2,1) and ARIMA (1,1,1). The results of Ljung–Box test of residuals also reject the presence of significant auto correlation in the residuals for the best fitted model in ARIMA. These models are used for forecasting arecanut area 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 4 for the states of Assam, Karnataka, Kerala and India as a whole respectively.

From the forecasted values obtained, it can be noted that area of arecanut in Assam, Karnataka, Kerala and India would be 80.512, 219.156, 101.351 and 447.581 thousand hectares respectively in 2020. The forecasted figures compared with the year 2015 indicate that area under arecanut in case of Assam and Kerala would increase in future, whereas area in Karnataka and India as a whole would decrease in future. Thus proper measures should be taken to arrest the decrease in area under arecanut in future.

ARIMA, ARIMAx and Combined model for production of arecanut in India

When the production of arecanut is considered, from the Table 5, it can be observed that combined forecasting performed better compared with ARIMA in all cases considering the criteria of R^2, RMSE, MAE and MAPE. In case of Assam ARIMAx performed better.

Combined forecasting performed better in case of Kerala and India as compared with ARIMAx. In case of Karnataka both combined forecast and ARIMAx is found completing as R^2 is high in ARIMAx and in all the other criteria combined forecast found with improved performance. The combined forecast values of the same can be found in Table 6.

ARIMA, ARIMAx and Combined model for yield of arecanut in India

When the yield of arecanut is considered, from the Table 7, it can be observed that combined forecasting performed better compared with ARIMA in all cases considering the criteria of R^2, RMSE, MAE and MAPE except India where ARIMA performed better compared with combined forecast. Combined forecasting performed better in case of Assam and Kerala as compared with ARIMAx. In case of Karnataka and India both combined forecast and ARIMAx is found completing with each other as per the criteria considered. The combined forecast values of the same can be found in Table 8.

From the study of past production behavior of areca nut, it is found that for India, increase in area, production and productivity are being reflected in terms of simple growth rates and compound growth rates. Platykurtic and positive nature of skewness clearly indicates that area under areca nut showed steady changes at early stage and remained almost same during later part of study. Among the major nut growing states in India, the maximum growth in area was observed in Karnataka followed by Assam and Kerala. In support of the above, average area under areca nut in Karnataka is more compared to all other states, followed by Kerala and Assam.

The positive value of skewness and negative kurtosis for all the states reveal steady changes in area under areca nut has taken place during initial period under study and remained almost same during later part of the study. While in case of Kerala negative value of skewness and platykurtic nature reveals that there has been marginal shift in area in recent years of the study.

Table.1 *Per se* performance of arecanut production in major states of India during 1965-2015

Particulars	Assam	Karnataka	Kerala	India
	Area ('000 hectare)			
Minimum	22.000	35.000	57.000	131.000
Maximum	79.000	236.800	108.600	463.890
Average	56.134	94.782	78.498	256.448
Standard Deviation	19.275	61.279	15.803	101.769
CV	34.337	64.653	20.132	39.684
Skewness	-0.600	1.012	0.205	0.779
Kurtosis	-1.208	-0.372	-1.435	-0.831
SGR%	4.154	9.211	1.250	4.756
CGR %	2.237	3.435	0.968	2.423
	Production ('000 ton)			
Minimum	23.000	44.000	37.000	113.000
Maximum	78.200	460.000	128.000	746.660
Average	51.831	136.913	75.163	295.797
Standard Deviation	15.927	103.325	27.678	163.565
CV	30.729	75.467	36.824	55.296
Skewness	-0.469	1.789	0.433	1.194
Kurtosis	-0.834	2.719	-1.333	0.606
SGR%	4.010	18.182	4.730	9.725
CGR %	2.190	4.617	2.415	3.525
	Yield (kg/ha)			
Minimum	724.758	970.910	609.195	831.461
Maximum	1307.692	2098.803	1302.410	1658.470
Average	949.817	1417.949	943.046	1099.678
Standard Deviation	135.840	192.139	227.035	179.988
CV	14.302	13.550	24.075	16.367
Skewness	0.233	1.252	-0.253	0.702
Kurtosis	-0.134	4.899	-1.327	0.825
SGR%	-0.046	1.550	2.109	1.431
CGR %	-0.046	1.143	1.434	1.075

Table.2 Test of outliers and randomness for area, production and yield of arecanut

Test of randomness	Assam			Karnataka		
	Area	Production	Yield	Area	Production	Yield
No. of Observation	51	51	51	51	51	51
No. of Turning Point (p)	7	21	25	10	15	23
E (P)	32.667	32.667	32.667	32.667	32.667	32.667
V(P)	8.744	8.744	8.744	8.744	8.744	8.744
t_{cal}	8.680	3.945	2.593	7.665	5.974	3.269
Inference	Trend	Trend	Trend	Trend	Trend	Trend
Outliers Test	No	No	No	No	No	No
Test of randomness	**Kerala**			**India**		
	Area	**Production**	**Yield**	**Area**	**Production**	**Yield**
No. of Observation	51	51	51	51	51	51
No. of Turning Point (p)	12	17	25	11	21	27
E (P)	32.667	32.667	32.667	32.667	32.667	32.667
V(P)	8.744	8.744	8.744	8.744	8.744	8.744
t_{cal}	6.989	5.298	2.593	7.327	3.945	1.916
Inference	Trend	Trend	Trend	Trend	Trend	Random
Outliers Test	No	No	No	No	No	No

Table.3 ARIMA models for area under arecanut in India

State	ARIMA Models	Model selection criteria				Ljung-Box test for residuals	
		R^2	RMSE	MAPE	MAE	χ^2	P Value
Assam	(1,1,0)	0.985	2.230	3.576	1.605	17.969	0.391
Karnataka	(3,1,0)	0.974	8.946	3.915	4.362	12.328	0.654
Kerala	(0,2,1)	0.894	5.093	4.478	3.537	8.208	0.962
India	(1,1,1)	0.973	15.037	3.520	9.351	20.520	0.198

Table.4 Observed and forecasted area (in '000 hectare) under arecanut in India

State	ARIMA Models	Observed			Predicted			Forecasted				
		2013	2014	2015	2013	2014	2015	2016	2017	2018	2019	2020
Assam	(1,1,0)	76.570	76.570	79.000	75.800	77.152	76.570	79.937	80.298	80.437	80.491	80.512
Karnataka	(3,1,0)	219.690	218.010	220.000	244.587	222.860	215.260	218.625	219.421	219.043	219.206	219.156
Kerala	(0,2,1)	96.650	96.690	99.000	96.361	96.481	96.572	99.470	99.940	100.410	100.880	101.351
India	(1,1,1)	451.900	450.210	455.000	456.755	442.324	458.746	447.091	454.738	447.344	454.493	447.581

Table.5 ARIMA, ARIMAx and Combined model for production of arecanut in India

State	Models	Model selection criteria				Ljung-Box test for residuals	
		R^2	RMSE	MAPE	MAE	χ^2	P Value
ARIMA Models							
Assam	(4,2,0)	0.782	6.961	8.517	4.598	20.416	0.118
Karnataka	(1,1,1)	0.898	24.503	5.105	8.350	15.195	0.510
Kerala	(1,1,1)	0.940	6.290	5.662	4.118	12.951	0.676
India	(0,1,2)	0.941	32.912	5.601	18.005	9.684	0.883
ARIMAx Models							
Assam	(0,1,1)	0.858	6.007	7.148	3.736	19.675	0.291
Karnataka	(2,2,0)	0.948	25.023	9.517	13.893	9.970	0.868
Kerala	(0,1,1)	0.957	5.921	5.771	4.223	17.018	0.453
India	(1,1,0)	0.958	34.704	5.558	20.582	21.403	0.209
ARIMA+ARIMAx							
Assam	-	0.830	6.040	7.573	4.035	-	-
Karnataka	-	0.930	20.249	6.986	9.805	-	-
Kerala	-	0.965	4.738	5.169	3.594	-	-
India	-	0.956	28.223	4.642	15.138	-	-

Table.6 Observed and forecasted production (in Metric tonnes) of arecanut in India

State	Model	Observed			Predicted			Forecasted				
		2013	2014	2015	2013	2014	2015	2016	2017	2018	2019	2020
Assam	ARIMA(4,2,0)	74.040	74.040	74.040	77.809	77.570	78.214	78.488	79.181	80.907	83.069	86.161
	ARIMAx(0,1,1)				74.521	76.600	78.683	76.641	78.572	80.644	82.852	85.221
	Combined				76.165	77.085	78.449	77.565	78.877	80.776	82.961	85.691
Karnataka	ARIMA(1,1,1)	348.770	457.560	460.000	356.077	354.771	459.645	463.756	466.248	469.814	472.535	475.988
	ARIMAx(2,2,0)				529.500	518.070	688.640	479.830	574.551	589.921	618.772	692.790
	Combined				442.789	436.421	574.143	471.793	520.400	529.868	545.654	584.389
Kerala	ARIMA(1,1,1)	113.360	125.930	128.000	97.767	112.908	125.401	128.146	128.518	128.921	129.330	129.740
	ARIMAx(0,1,1)				105.490	100.291	100.800	125.330	123.941	122.110	119.921	117.341
	Combined				101.629	106.600	113.101	126.738	126.230	125.516	124.626	123.541
India	ARIMA(0,1,2)	622.270	746.660	684.470	689.461	654.315	679.878	721.880	723.834	723.834	723.834	723.834
	ARIMAx(1,1,0)				679.640	659.291	713.842	780.911	812.863	875.510	922.031	975.452
	Combined				684.551	656.803	696.860	751.396	768.349	799.672	822.933	849.643

Table.7 ARIMA, ARIMAx and Combined model for yield of arecanut in India

State	Models	Model selection criteria				Ljung-Box test for residuals	
		R^2	RMSE	MAPE	MAE	χ^2	P Value
ARIMA Models							
Assam	(2,1,0)	0.540	97.899	7.054	66.983	13.531	0.634
Karnataka	(1,1,0)	0.312	120.632	5.721	75.751	8.981	0.702
Kerala	(1,1,2)	0.921	63.344	4.632	43.552	3.201	0.991
India	(0,1,1)	0.783	69.051	4.203	45.981	13.573	0.331
ARIMAx Models							
Assam	(0,1,1)	0.518	100.279	6.545	62.152	19.908	0.279
Karnataka	(1,1,0)	0.492	141.566	6.237	86.122	13.871	0.676
Kerala	(0,1,1)	0.899	73.555	5.145	50.410	6.245	0.991
India	(0,1,1)	0.802	81.421	4.778	54.601	23.939	0.121
ARIMA+ARIMAx							
Assam	-	0.554	95.783	6.747	63.860	-	-
Karnataka	-	0.321	110.480	5.374	70.465	-	-
Kerala	-	0.919	61.086	4.710	44.069	-	-
India	-	0.769	70.353	4.412	48.478	-	-

Table.8 Observed and forecasted yield (in kg/ha) of arecanut in India

State	Model	Observed			Predicted			Forecasted				
		2013	2014	2015	2013	2014	2015	2016	2017	2018	2019	2020
Assam	ARIMA(2,1,0)	966.960	966.960	937.220	934.352	977.226	966.960	946.077	953.938	948.470	947.324	949.596
	ARIMAx(0,1,1)				985.650	1001.850	1017.770	963.840	968.860	973.200	976.281	978.990
	Combined				960.001	989.538	992.365	954.959	961.399	960.835	961.803	964.293
Karnataka	ARIMA(1,1,0)	1587.560	2098.800	2090.910	1628.169	1637.503	1646.490	2115.755	2131.917	2150.382	2168.236	2186.252
	ARIMAx(1,1,0)				1548.311	1428.880	1484.461	1925.272	1824.291	1743.920	1688.681	1644.511
	Combined				1588.240	1533.192	1565.476	2020.514	1978.104	1947.151	1928.459	1915.382
Kerala	ARIMA(1,1,2)	1172.950	1302.410	1292.930	1019.838	1089.890	1053.559	1331.207	1299.281	1347.872	1333.737	1368.467
	ARIMAx(0,1,1)				1023.160	944.741	884.070	1265.711	1241.593	1217.811	1194.074	1170.460
	Combined				1021.499	1017.316	968.815	1298.459	1270.437	1282.842	1263.906	1269.464
India	ARIMA(0,1,1)	1377.010	1658.470	1504.330	1386.859	1397.541	1408.222	1543.605	1556.695	1569.786	1582.876	1595.966
	ARIMAx(0,1,1)				1401.750	1416.250	1586.070	1543.440	1550.160	1558.070	1566.890	1576.010
	Combined				1394.305	1406.896	1497.146	1543.523	1553.428	1563.928	1574.883	1585.988

Leptokurtic and positive skewness clearly indicate that production of areca nut showed maximum shift or improvement at early stages. Among the states considered maximum compound growth rate found in Karnataka followed by Kerala and Assam. Karnataka even with highest average production followed by Kerala and Assam. In similarity with area and production Karnataka has recorded the highest average productivity followed by Assam while Kerala with lowest productivity. Kerala recorded highest CGR and SGR whereas negative growth is seen in case of Assam. Among the states considered, Assam and Karnataka are positively skewed whereas Kerala shows negative skewness. No outlier was detected for the series of areca nut and all series found to have trend except for yield of India. Also found that series of areca nut followed polynomial trend. Thus, it is evident from the study of these three crops, that Kerala is shifting its area from cashew nut in favour of coconut and areca nut.

Modeling and forecasting for area, production and productivity of areca nut indicates that compared to year 2015 area under areca nut in case of Assam, Kerala and whole India would increase in future whereas area in Karnataka would decrease. Thus, proper measures should be taken to arrest the decrease in area under areca nut in future.

Compared to the production of areca nut in 2015, the forecasted figures from ARIMA and ARIMAx models indicate that production of areca nut in Assam, Karnataka, Kerala and India as a whole would increase in future except for production of areca nut in Kerala which decreases slightly as predicted from its ARIMAx model.

The forecasted figures of yield of areca nut using ARIMA models compared with its yield in 2015 indicate possible increase of its yield in future while yield of areca nut in Karnataka and Kerala would decline as predicted by ARIMAx models, may be due to gestation period for new plantations.

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