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Forecasting of Cotton Production in Nagpur District of Maharashtra India

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Abstract: ***Agriculture is the backbone of India. Most of population of India's livelihood depends on agriculture. Agricultural crop production depends on several factors including weather nutrients present in the soil, fertilizers used and others. Cotton is one of the most important fiber and cash crop of India. Cotton plays a dominant in the industrial and agricultural economy of the country. In this paper, we tried to forecast cotton production. The data on production, production area, temperature and rainfall for Nagpur district of Maharashtra in India during the year 2000 to 2018 is considered. For forecasting different statistical tools such as descriptive statistics, simple regression, multiple regression, ARIMA as well as ARIMAX model were used. The study reveals that for univariate time series model ARIMA (0, 1, 1) and for multivariate time series model. Arima (0, 1, 1) are the best fitted model.***

Keywords: Cotton forecast, Multiple Regression Analysis, ARIMA, ARIMAX

1. Introduction

Agriculture is known to be one of the most significant economic activities. It has been practiced in India since time immemorial. It involves the production of plants, livestock, fiber, fuel and more by utilizing natural resources such as water and land. It is the most important sector of Indian economy. i.e. It plays a vital role in the economy of India. The agriculture sector of India has occupied almost 43 percent of India's geographical area. Agriculture is still the only largest contributor to India's GDP even after a decline in the same in the agriculture share of India. Agriculture also plays a significant role in the growth of socio-economic sector in India. Indian agriculture sector accounts for 18% of India's gross domestic product (GDP) and provides employment to 50% of the country workers.

1.1 Cotton Crop

Cotton is a tropical and subtropical Kharif crop. It is a dry crop but roots need timely supply of water at maturity. Cotton is one of the most important fiber and cash crop of India. Cotton plays a dominant role in the industrial and agricultural economy of the country. This crop leads to the direct and indirect employment for the country. India is the second largest cotton producing country in the worlds next to china. These two countries accounts 42% of the world's cotton production. Gujrat and Maharashtra are top two major cotton producing states of India.

Cotton requires an average annual temperature of over 16 degree celcius and annual rainfall 50 cm distributed throughout the growing season. A daily minimum temperature of 16 degree Celsius is required for the germination and 21- 27 degree Celsius for proper vegetative growth.

The broucher given by ICAR-CICR Nagpur for PKV 081BT12 cotton seeds, states that the duration/period between 15 June to 15 July is best for sowing . The row spacing should be 60 - 75 cm and the spacing between two plants should be 10 - 15 cm at the time of sowing. It is also instructed that the seeds should be used 3kg/acreages and the use of fertilizers must be proper including its quantity and quality.

1.2 Objective of the study

In this paper, we are forecasting future cotton production. The area we have selected is Nagpur district of state Maharashtra. The farmer, industrialist as well as the government may be more interested about the prediction of crop. Thus it is needed to carry out such studies at micro level also.

The forecasting will be helpful to farmers. This helps in planning of farming operations i.e. whether to undertake or withhold the sowing operations, which directly affects the production rate of crop. This will also give insight about the raw material available in the region for cotton dependent industry. Also government can plan and come out with better policy for the region. Keeping this in view, we have restricted our study to the Nagpur district only.

For the forecasting of cotton production, we have used the time series data of cotton production from www.krishi.maharashtra.gov.in. Weather data is recorded from www.indiawaterportal.org/met_data. Whole data covers the period of 2000-2018, the data consist of Area, Production, Productivity, Rainfall and Temperature data for each particular year.

Many of the statistical tools are helpful in forecasting the yield of the crop. We tried to forecast the crop production using best, commonly used linear regression models and time series models (Autoregressive Integrated Moving Average model and ARIMAX model).

2. Literature Review

Over the years, to forecast the crop production a variety of approaches were used those approaches were based on simulation model, remote sensing, linear regression model, time series model etc. The most used models are regression and time series models.

K.B. Hebbar, and et al (2008) described a methodology in their paper to predict the cotton production on a regional basis using the integrated approach of remote sensing (RS), geographic information system (GIS) and crop simulation model i.e. Infocrop – cotton model.

M.K. Debnath, and et al (2013) attempts to forecast the cultivated area and production of cotton in India using Autoregressive Integrated Moving Average (ARIMA) model. They have considered the time series data for prediction covering the period 1950 – 2010 for their study.

A.R.Reddy, Sanchita M. Yelekar and Isabella Agarwal (2013) has done a research on Variations in Cotton Productivity in September 2013. They studied the spatiotemporal variations in cotton yields of India.

Kartik Ingole, Kavita Katole, Ashwin Shinde and Minal Domke (2013) has done Crop Prediction and Detection using Fuzzy Logic in MATLAB in November 2013. In the paper, they explored the dynamics a fuzzy in forecasting the crop (wheat yield) using remote sensing and other. Fuzzy logic has the ability to mimic human being in reasoning. By this it can predict which crop is suitable for the particular condition.

S. Dharamaraja , vidyattama jain , priyanka Anjoy , Hukum chandra (2017) used linear regression models and time series models for yield forecasting of Bajra crop . Author attempts to determine the predictive accuracy in forecasting crop yield. The time series models works in stochastic manner, which is proficient for the study.

S. Poyyamozhi, Dr. A. Kachi Mohideen (2017) studied the forecasting of cultivated area and production of cotton in India using Autoregressive Integrated Moving Average model.

Dr. Atul B. Tekade and et al (2018) studied the marketing of pesticides and its effect on agricultural products in Nagpur district and evaluated the agricultural and farmer development in Nagpur district. The study was carried out during 2000-01 to 2005-06.

Priyanka Mallikarjun Kumbhar (2019) studied Price forecasting and Seasonality of Soybean in Amravati District of Maharashtra India (July 2018). To analyze the data author had used statistical techniques like seasonality and exponential smoothing for price forecasting. The study gives an overview of the different time series analytical methods. The accuracy of proportion among the forecasted and actual price value of soybean was found in between 80.52 to 85.55 %.

S. Dharmaraja, S and et al (2020) in their study mentioned different factors affecting Bajara production. They have used regression models as well as time series model to forecast Bajara production.

3. Methodological Approach

The factors affecting Crop production are rainfall, temperature and nutrition level of soil, quality of fertilizers, quality of seeds, use of pesticides and insecticides and other factors. It is difficult to collect the data on nutrition’s present in the soil, pest and insect outbreaks as there is no such system of collecting this type of data. Hence, we have considered only two factors affecting the cotton production i.e. rainfall and temperature. The data collected were analysed using Statistical Packages SPSS, version 20 and Microsoft Excel. The various descriptive and data analysis techniques such as Multiple Linear Regression and ARIMAX Model were used in this research.

3.1 Methods of Data Collection

This study is based on secondary data. The yearly cotton production data of the Nagpur district is collected from online portal www.krishi.maharashtra.gov.in. Weather is a major factor affecting cotton production. Hence, the rainfall and temperature data is also taken into consideration. Weather data is collected from the online source www.indiawaterportal.org/met_data.

Our data set consists of yearly update of cotton production and the factors affecting cotton production for the period 2000 - 2015. The data contains values for area (Ha), production (Tonnes), temperature (°C) and rainfall (mm).

3.2 Methods of Data Analysis and Interpretation

a) Descriptive Analysis

To analyze the pattern and trend of the data along with their predictions, descriptive analysis was used. Line plots and tables were used to show the results of analysis.

b) Regression Analysis

In statistical modeling, regression analysis is a set of statistical processes for estimating the relationships between a dependent variable and one or more independent variables. The most common form of regression analysis is linear regression, in which a researcher finds the line that most closely fits the data according to a specific mathematical criterion. Regression analysis is used when independent variables are correlated with each other and with dependent variable. Regression equation represents the best way of prediction of dependent variable from various different independent variables.

(i) Simple Linear Regression

The simple linear regression model is

$$Y = \beta_0 + \beta_1 X + \xi$$

Y = response variable

X = Explanatory variable

β_0 = Intercept

β_1 = Regression coefficient

ε = error term , ε ~N (0, 1)

Hypothesis under consideration is
$H_0 : \beta_0 = 0$ vs $H_1 : \beta_1 \neq 0$

(ii) Multiple Linear Regression

The multiple linear regression model I

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... \beta_i X_i + \xi$$

i = 1,2,.........k

Where X_1, X_2 ...X_i = Explanatory variable βi = estimated parameter

ε = error term, ε ~N (0, 1)

Hypothesis under consideration is

H0 : $\beta_0 = \beta_1 = \ldots\ldots \beta_k = 0$

VS

H1 : βi ≠ 0 for at least one i

c) Time Series Analysis

Time series analysis is a technique that deals with time series data i.e. the data collected over time. Time series model works in stochastic manner. It is used to predict the future values on the basis of previously known values while regression analysis is often works in such a way as to test theories that the current values of one or more independent time series effect the current value of another time series.

The objective of the time – series analysis to find out that or those models would better reflect the underlying dynamics and same for the forecasting the series phenomenon. The time series data of cotton product were modeled by Box – Jenkins type stochastic autoregressive integrated moving average (ARIMA) process.

(i) ARIMA

Autoregressive Models (AR) can be effectively coupled by with moving average (MA) model to form a general and useful class of time series model called Autoregressive Moving Average (ARMA) models. However, they can only be used when the data is stationary. This class of models can be extended to non-stationary series by allowing differencing of the data series. These are called Autoregressive 9 Integrated Moving Average (ARIMA) models. Box and Jenkins (1970) popularized ARIMA models. ARIMA models, also called Box-Jenkins models, are models that may possibly include autoregressive terms, moving average terms, and differencing operations. Various abbreviations are used:

- When a model only involves autoregressive terms it may be referred to as an AR model.
- When a model only involves moving average terms, it may be referred to as an MA model.
- When no differencing is involved, the abbreviation ARMA may be used.

Moving Average (MA) models

$$Y_t = C + e_t + \theta_1 e_{t-1} + \theta_2 e_{t-2} + ... + \theta_q e_{t-q}$$

where e_t is white noise. e_t ~ N(0, σ_2). This is a multiple regression with past errors as predictors and the coefficients Θi ; I = 1, 2,…q are to be estimated.

Autoregressive (AR) models

$$Y_t = C + e_t + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + ... + \phi_p Y_{t-p}$$

Where, e_t is white noise. This is a multiple regression with lagged values of Y_t as predictors. Φi ; i=1,2,…p are the coefficients which we wish to estimate.

Autoregressive Moving Average models

$$Y_t = C + e_t + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + ... + \phi_p Y_{t-p} + \theta_1 Y_{t-1} + \theta_2 Y_{t-2} + ... + \theta_q Y_{t-q}$$

Predictors include both lagged values of Y_t and lagged errors. ARMA models can be used for a huge range of stationary time series. An ARMA model applied to differenced data is an ARIMA model. For instance, if Y_t is non-stationary, we take a first-difference of Y_t so that ΔY_t becomes stationary. Autoregressive Integrated Moving Average models

ARIMA (p, d, q) model is given by,

yt = c + φ1yt−1 + · · · + φpyt−p + et+ θ1et−1 + · · · +θqet−q

Where, AR: p = order of the autoregressive part

I: d = degree of first differencing involved

MA: q = order of the moving average part.

(ii) ARIMAX

ARIMAX is related to the ARIMA technique but, while ARIMA is suitable for datasets that are univariate. ARIMAX is suitable for analysis where there are additional explanatory variables (multivariate) in categorical and/or numeric format. The standard ARIMA (autoregressive integrated moving average) model allows to make forecasts based only on the past values of the forecast variable. The model assumes that future values of a variable linearly depend on its past values.

The ARIMAX model is an extended version of the ARIMA model. It includes also other independent (predictor) variables. An Autoregressive Integrated Moving Average with Explanatory Variable (ARIMAX) model can be viewed as a multiple regression model with one or more autoregressive (AR) terms and/or one or more moving average (MA) terms.. Autoregressive terms for a dependent variable are merely lagged values of that dependent variable that have a statistically significant relationship with its most recent value. Moving average terms are nothing more than residuals (i.e. lagged errors) resulting from previously made estimates.

Time-series dependent variable be well estimated by a properly weighted combination of the following right-hand-side (RHS) variables.

1) xt = The value of the independent variable at time t.

2) yt-i = The immediately preceding value of the dependent variable at time t-i ; i= 1,2,…p .

3) et-j =The estimation error produced by the model at time t-j ; j=1,2,…q. The ARIMAX model with one explanatory variable is given by,

yt = βxt + φ1yt−1 + · · · + φpyt−p + et+ θ1et−1 + · · · + θqet−q

This model can be used for the prediction of dependent variable when explanatory variables are given.

4. Results and Discussion

To study the impact of the Area, Temperature and Rainfall on Cotton Production and measure the degree of association among the determinants following techniques were used.

4.1 Descriptive statistic

Table 4.1 gives the descriptive statistics the variable under consideration. From the table 4.2, average area used for cotton production in Nagpur district is 94136.58 Ha, average production of cotton is 166726.32 Tonnes, average temperature is 27.82°C and average rainfall is 88.95 mm for the year 2000 to 2018.

Table 4.1: Descriptive statistic for cotton production, temperature, rainfall and area

	Area (in Ha)	Production (in Tonnes)	Temperature (in °C)	Rainfall (in mm)
N	19	19	19	19
Mean	94164	166726	27.82	88.95
Median	80100	115400	27.50	88.53
SD	40160	140252	0.84	15.81
Variance	1612838190	19670728713	0.71	249.88
Skewness	2	2	0.83	0.36
Kurtosis	4	3	-0.34	0.08
Minimum	44300	63100	26.80	62.61
Maximum	219040	550200	29.50	124.20

4.2 Regression Analysis

(a) The fitted simple linear regression model is,
$Y^{\wedge} = \beta 0 + \beta 1X$
Production = $\beta 0 + \beta 1$ (area)

Table 4.3: Regression analysis

Model	R	R^2	Adj. R^2	Std. error of estimate
	0.784	0.614	0.586	23407.914

From the table 4.3, the value of coefficient of determination R2 = 0.586. This indicate that there is 58.6% of the variance in cotton production is predicted from the independent variable 'area'.

Table 4.4: ANOVA for Regression Model

Model	S. S.	DF	M. S. S.	F	Sig
Regression	12204303359.512	1	12204303359.512	22.27	0.0
Residual	7671026015.488	14	547930429.678		
Total	19875329375.000	15			

From the table 4.4, the regression sum of square is 12204303359.512, the residual sum of square is 7671026015.488 and the total sum of square is 19875329375.000. Since Cal F (22.273) > Tab F (4.6001), we reject the null hypothesis at 5% level of significance and conclude that $\beta 1 \neq 0$

Table 4.5: Coefficient of Regressors

Model	Coefficient		T	Sig
	B	Std. Error		
Constant	-3015.507	24897.078	-0.121	0.905
Area	1.418	0.301	4.719	0.000

From the table 4.5, the values of coefficients are -3015.507 and 1.418 for β0 and β1 respectively. The table also shows that the variable is statistically significant as the p-value is less than 0.05.

(b) The fitted multiple regression model is
$Y1^{\wedge} = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3$

Table 4.6: Regression Analysis

Model	R	R^2	Adj. R^2	Std. error of estimate
	0.879	0.772	0.715	19429.294

From the table 4.6, the value of coefficient of determination R2 = 0.715. This indicate that there is 71.5% of the variance in cotton production is predicted from the independent variable area, rainfall and temperature.

Table 4.7: ANOVA for Regression

Model	S. S.	DF	M. S. S.	F	Sig
Regression	15345359752.678	3	5115119917.559	13.550	0.000
Residual	4529969622.322	12	377497468.527		
Total	19875329375.000	15			

From the table 4.7, The regression sum of square is 15345359752.678, the residual sum of square is 452996922.322 and the total sum of square is 19875329375.000. Since, Cal F (13.550) >Tab F (3.490295), we reject the null hypothesis at 5% level of significance and conclude that $\beta i \neq 0$ for at least one i , where i =1,2,3.

Table 4.8: Coefficients of Regressors

Model	Coefficient		T	sig
	B	Std. error		
Constant	-508426.484	215759.854	-2.356	.036
Area	1.757	.299	5.876	.000
Temperature	14929.831	6972.505	2.141	.050
Rainfall	689.952	296.491	2.327	.038

From the table 4.8, the values of coefficients are -508426.484, 1.757, 14929.831 and 689.952 for β0, β1, β2 and β3 respectively. The table also shows that the variables are statistically significant as the p-value for all the variables are less than or equal to 0.05.

4.3 Time Series Analysis

(a) ARIMA methodology for Forecasting of Cotton Production

The ARIMA (0,1,1) model is considered for forecasting cotton production , as the normalized BIC value for ARIMA (0,1,1) is 20.571 which is smaller as compared to other ARIMA (1,1,1) model having normalized BIC equal to 20.673 as shown in table 4.9. Using ARIMA (0,1,1), forecast of cotton production in Nagpur district for the year is 309900 Tonnes.

Table 4.9: ARIMA Model statistics

Model	Number of predictors	Model fit statistics	
		Stationary R - squared	Normalized BIC
Production model	0	0.092	20.571

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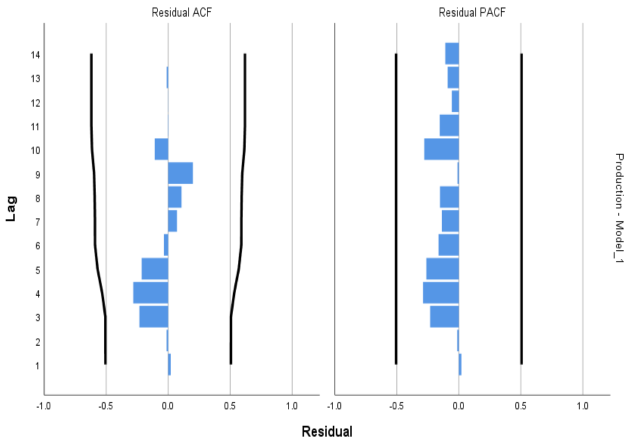

Figure 4.1: ACF and PCF of residuals fitted model for cotton production using ARIMA model

(b) ARIMAX methodology for Forecasting of Cotton Production

The ARIMAX (0,1,1) model is considered for forecasting cotton production , as the normalized BIC value for ARIMAX (0,1,1) is 20.147 which is smaller as compared to other ARIMAX (1,1,1) model having normalized BIC equal to 20.706 as shown in table 4.10

Table 4.10: ARIMAX Model statistics

Model	Number of predictors	Model fit statistics	
		Stationary R - squared	Normalized BIC
Production model	3	0.830	20.147

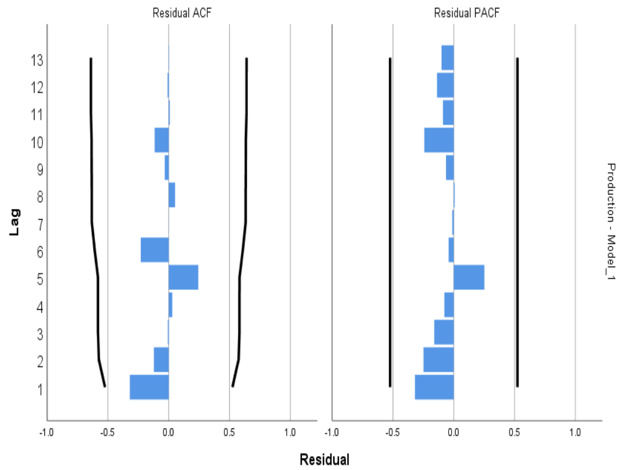

Figure 4.2: ACF and PCF of residuals fitted model for cotton production using ARIMAX model

4.4 Comparison between Regression and Time Series Models

In this section, we compare all the four models i.e. simple linear regression model, multiple linear regression model, ARIMA model and ARIMAX model to identify which model is the best for forecasting

Table 4.11: Actual vs. predicted cotton production in Validation set

Year	Actual	Simple linear regression	Multiple linear regression	ARIMA	ARIMAX
2000	63100	97804.293	75445.81	0	0
2001	76700	110566.2983	106083.97	69500.9225	0
2002	71200	101065.6983	94219.47	80897.7011	71752.7511
2003	115400	102341.8983	132371.77	80875.5342	107781.0959
2004	104300	103759.8983	88906.20	110017.243	96692.95452
2005	98800	100923.8983	104371.99	112654.728	100129.8075
2006	84000	92699.4983	80241.29	101136.312	81461.23585
2007	106600	86460.2983	94472.46	11265.8108	86871.10493
2008	63500	59801.8983	56090.63	110494.132	75937.14698
2009	89000	87169.2983	94504.65	85963.2933	97070.88516
2010	126000	111558.8983	114363.01	94362.9906	117667.7044
2011	141800	141762.2983	142355.91	121587.543	142020.5478
2012	176700	123753.6983	143258.94	141292.401	161592.8506
2013	150400	128007.6983	139731.83	170998.773	170845.0816
2014	150200	154807.8983	130444.98	163841.485	150282.6609
2015	161400	176219.6983	181983.38	161263.517	162681.8388

Table 4.12: Value of RMAE% RMSPE and MAE for the regression and time series models

Validation criteria	Simple linear regression	Multiple linear regression	ARIMA	ARIMAX
RMAE%	16.3015	13.79633	23.11671	18.497
RMSPE	4713.051	2648.67	8941.053	9525.522
MAE	-24.80203	-9.040701	-4134.226	-9769.521

From the above table, it is seen that multiple linear regression model is having less error values as compared to other models. Hence multiple linear regression model is the best model to forecast future production of cotton.

4.5 Cotton Demand

According to several research, the demand for fibers would rise by around 96%. The higher demand for fiber in USA and other developed countries is due to the fashion for carpeted homes, demand for technical textiles, use of filament consumption in many countries' industry and for many others reasons as well.

The majority of fiber is fulfilled by synthetic fiber produced from petroleum. The availability of fossil product is going to decrease. Therefore this deficiency needs to be fulfilled by cotton and other agricultural products. This is the golden opportunity for cotton growing regions.

According to our study, Nagpur district cotton production will rise from 161400 Tonnes in 2015 to 309900 Tonnes in 2030 i.e. rise of 92 %. To maintain current share in cotton production, cotton yield needs to be increased by 4%. This can be achieved by increasing production area. But this approach will have an adverse effect on food security as less land will be available for other crops.

Therefore to fulfill this increase demand, high yielding cotton needs to be developed and used. This will be major challenge to agricultural scientist and policy makers.

5. Conclusions

A) The descriptive statistics of the variable under consideration indicates that average area used for cotton production in Nagpur district is 94136.58 Ha, average production of cotton is 166726.32 Tonnes, average temperature is 27.82°C and average rainfall is 88.95 mm for the year 2000 to 2018.

B)In case of simple linear regression, the value of coefficient of determination, $R2 = 0.586$, which indicates that around 59% of the variance in production is predicted from the variable area under cotton cultivation. The fitted model is $Y^{\wedge} = \beta 0 + \beta 1X$ i.e.

Production = $\beta 0 + \beta 1$ (area) where

a) $\beta 0 = 3015.507$ is a constant.

b) $\beta 1 = 1.418$ implies positive effect of area on cotton production. Our study also shows that variable area has significant impact on cotton production.

c) In case of multiple linear regression, the value of coefficient of determination, $R2 = 0.715$, which indicates that around 72% of the variance in production is predicted from the variable area, rainfall and temperature in the region. The fitted model is

$Y1^{\wedge} = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3$ i.e

$Y1^{\wedge} = \beta 0 + \beta 1$ (Area) + $\beta 2$ (Rainfall)+ $\beta 3$ (Temperature)

a) $\beta 0 = 508426.484$ is a constant.
   $\beta 1 = 1.757$ implies positive effect of area on cotton production.
b) $\beta 2 = 14929.757$ implies positive effect of temperature on cotton production.
c) $\beta 3 = 689.952.757$ implies positive effect of rainfall on cotton production. Our study also shows that variables area, rainfall and temperature has significant impact on cotton production.
d) The ARIMA (0,1,1) model is considered for forecasting cotton production , as the normalized BIC value for ARIMA (0,1,1) is 20.571 which is smaller as compared to other ARIMA (1,1,1) model having normalized BIC equal to 20.67. Using ARIMA (0,1,1), forecast of cotton production in Nagpur district for the year is 309900 Tonnes. The forecasting indicates the increasing trend.
e) The ARIMAX (0,1,1) model is considered for forecasting cotton production , as the normalized BIC value for ARIMAX (0,1,1) is 20.147 which is smaller as compared to other ARIMAX (1,1,1) model having normalized BIC equal to 20.706
f) From our study, it is seen that multiple linear regression model is having less error values as compared to other models. Hence multiple linear regression model is considered to be the best model to forecast future production of cotton.

6. Suggestion

According to Central Institute of Cotton Research, the demand for fibers would rise by 96%. The higher demand for fiber in USA and other developed countries is due to the fashion for carpeted homes, demand for technical textiles, use of filament consumption in many countries' industry and for many others reasons as well. The majority of fiber is fulfilled by synthetic fiber produced from petroleum. The availability of fossil product is going to decrease. Therefore this deficiency needs to be fulfilled by cotton and other agricultural products. This is the golden opportunity for cotton growing regions.

According to our study, Nagpur district cotton production will rise from 161400 Tonnes in 2015 to 309900 Tonnes in 2030 i.e. rise of 92 %. To maintain current share in cotton production, cotton yield needs to be increased by 4 %. This can be achieved by increasing production area. But this approach will have an adverse effect on food security as less land will be available for other crops. Therefore to fulfill this increase demand, high yielding cotton needs to be developed and used. This will be major challenge to agricultural scientist and policy makers.

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