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CONTENTS

Sr. No.	TITLE & NAME OF THE AUTHOR (S)	Page No.
1.	**FORECASTING FOOD GRAINS PRODUCTION USING ARIMA AND REGRESSION MODEL** *V.KASTHURI*	1
2.	**A COMPARATIVE ANALYSIS OF SELECTED MUTUAL FUND SCHEMES IN BANKING SECTOR** *APOORVA SHUKLA & ISHIKA SRIVASTAVA*	7
	REQUEST FOR FEEDBACK & DISCLAIMER	10

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FORECASTING FOOD GRAINS PRODUCTION USING ARIMA AND REGRESSION MODEL

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ABSTRACT

The Time series is a sequence of values arranged in a specific order of time. Prediction and analysis of food grains are an essential portion in agricultural statistics. Food grain production is a conspicuous portion in Indian agriculture. Agriculture shows the robust part in the Indian economy. The growth rate of agriculture production is usually decided by the show of food grains and non-food grain production. The present research work focused on production of food grains in India using time series data ranging from 1990- 91 to 2018-19. In this paper, Autoregressive Integrated Moving Average Model (ARIMA) and linear regression model for predicting food grain production of India were compared. And also Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) were compared. The results were displayed numerically and graphically.

KEYWORDS

food grains. food grains production forecasting.

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INTRODUCTION

Time series analysis involves methods for analyzing time series data. Crop and land use statistics from the support of the Agricultural Statistics System. Crop production contains grains, cotton, tobacco, fruits, vegetables, nuts and plants. Different crops grow in different areas of the country. LI et.al (2011) predicted air quality using Auto regressive moving average and multiple linear regression (MLR) models. Indian government policies and planning has always given considerable importance to *the production* of food grains due to which India has been achieving the continued growth all the same many restrictions. The free market play has adversely affected the production of food grains and the rate of growth of food *grain* production declined after the introduction of *the New Economic Policy* (NEP) in India. Osman Hegazy et.al (2013) proposed least square support vector machine (LS-SVM) to predict stock market price. Selvin et.al (2017) used an artificial neural network to identify an essential trend from a data. Box et.al (2015) employed Auto regression, moving average method in air quality predictions. Jayanthi Balaji et.al(2018) predicted stock price movement. Hiransha et. al (2018) used four types of deep learning architectures namely, Multilayer Perceptron (MLP), Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM) and Convolutional Neural Network (CNN) for predicting the stock price of a company based on the historical prices available. Athira et.al (2018) predicted pollution and meteorological time series AirNet data using Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM), and Gated Recurrent Unit (GRU). Menon et.al (2016) applied linear models like Auto Regressive (AR), Auto Regressive Moving Average model (ARMA) and Auto Regressive Integrated Moving Average model (ARIMA) have been used for stock market forecasting. Rout et.al (2015) predicted stock market using recurrent neural network. Roman et.al (2016) used Back propagation and Recurrent Neural Network (RNN) for predicting multiple stock market return. Sushant Kumar Pandey et. *al* (2018) employed software bug prediction becomes the vital activity during software development and maintenance. In this paper, Autoregressive Integrated Moving Average Model *(*ARIMA) and Regression model were used for food grains production prediction in India during 1991 to 2019. The performance of these different models was evaluated using the forecasting accuracy criteria namely, the Mean Absolute Error (MAE) and Root Mean Square Error (RMSE).

OBJECTIVES OF THE STUDY

1. To know about the trend lines.
2. To know what the yield will be in the coming seasons.

INTRODUCTION TO TIME SERIES

Time series analysis comprises methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data. Time series forecasting is the use of a model to forecast future events based on known past events to predict data points before they are measured.

REGRESSION MODEL

The term regression was used by biometrician Sir Francis Galton. Regression is the measures of the average relationship between two or more variables in terms of the original units of the data.

Simple Linear Regression

A simple linear regression is carried out to estimate the relationship between a dependent variable, Y and a single explanatory variable, x given a set of data that includes observations for both of these variables for a particular population.

The model is

$$y = \beta_0 + \beta_1 x + \varepsilon \quad \text{...(1)}$$

Where y is a dependent variable
x is a independent variable
β_0 is intercept
β_1 is slope
ε is stochastic error term

Autoregressive (AR) Model

The model ($Y_t - \delta$) is

$$(Y_t - \delta) = \alpha_1 (Y_{t-1} - \delta) + \alpha_2 (Y_{t-2} - \delta) + \dots + \alpha_p (Y_{t-p} - \delta) + u_t \quad \text{... (2)}$$

Where δ is the mean of Y and u_t is an uncorrelated random error term with zero mean and constant variance σ^2 (i.e., it is white noise),then we say that Y_t is a p^{th} - order autoregressive, or AR(p) process.

Moving Average (MA) Model

The moving average process is simply a linear combination of white noise error terms.

The model Y_t is as follows,

$$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \ldots + \beta_q u_{t-q} \quad \ldots (3)$$

is an MA(q) process. Where μ is a constant and u is the white noise stochastic error term. Here Y at time t is equal to a constant plus a moving average of the current and past error terms.

Autoregressive Moving Average (ARMA) Model

The process has characteristics of both AR and MA and is therefore ARMA. Thus, Y_t follows an ARMA (1,1) process if it can be written as,

$$Y_t = \theta + \alpha_1 Y_{t-1} + \beta_0 u_t + \beta_1 u_{t-1} \quad \ldots (4)$$

Because there is one autoregressive and one moving average term. θ Represents a constant term.

In general, in an ARMA (p, q) process, there will be p autoregressive and q moving average terms.

$$Y_t = \theta + \alpha_1 Y_{t-1} + \beta_0 u_t + \beta_1 u_{t-1} + \alpha_2 Y_{t-2} + \beta_2 u_{t-2} + \cdots + \alpha_p Y_{t-p} + \beta_q u_{t-q} \quad \ldots (5)$$

Autoregressive Integrated Moving Average Model

Autoregressive Integrated Moving Average Model (p, d, q), where p is Autoregressive and q is the Moving Average Model and d is the differencing. If d =0, the data exhibits stationary and the order is denoted as (p, q), which is called ARMA process. If the data does not exhibit stationary, the first order differencing is carried out for converting it into stationary, hence the model is denoted as (p, d, q).

FOUR STAGES OF ARIMA MODELING

Model Identification

This stage involves achieving variance and level stationary, and identifying tentative patterns using graphs, statistics, auto correlation coefficient function (ACF), partial auto correlation co-efficient function (PACF), etc.

Estimation

Determining of model parameters by software applications form this stage and it has to be ensured that the estimation procedure converges as Melard procedure is iterative.

Diagnostic Checking

Bayesian Information criteria (BIC), residual squared error (RSE) provides diagnostics for model fitting. The parameters must be significant and the residuals need to be white noise and normal and Model should be technically defendable.

Forecasting

Forecasts are made after confirming insignificant ACF / PACF's, of the ARIMA process random and normal errors validates model. All the four stages require considerable care and work and they themselves are not exhaustive.

SELECTION OF MODEL CRITERION

Model selection can be made based on the values of certain criteria like log likelihood (log L), Akaike Information Criteria (AIC)/Bayesian Information Criteria (BIC)/ Schwarz-Bayesian Information Criteria (SBC). SBC is used which is given by

SBC=$\log\sigma^2$+ (m logn)/n. …(6)

RESIDUAL ANALYSIS

Residuals are differences between the one-step-predicted output from the model and the measured output from the validation data set. Thus, residuals represent the portion of the validation data not explained by the model. Different types of error measurement namely

1. Mean Absolute Error (MAE)
2. Root Mean Square Error (RMSE)

Mean Absolute Error (MAE)

It is the difference between the measured value and "true" value. The **Mean Absolute Error** (MAE) is the average of all absolute errors. The formula is:

$$\text{MAE} = \frac{1}{n}\sum_{t=1}^{n}|u_t| \quad \ldots (7)$$

Where n is the number of errors and $|u_t| = y_t - \hat{y}_t$.

Root Mean Square Error (RMSE)

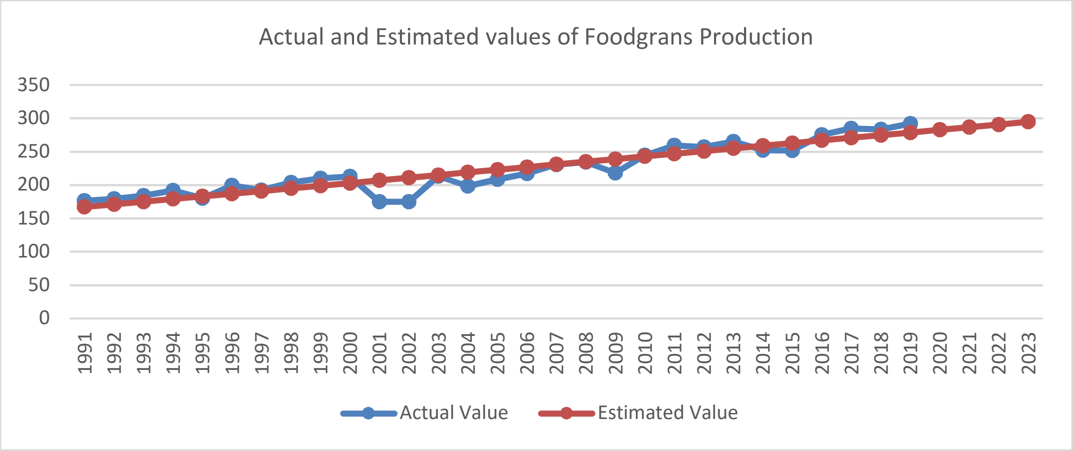
Root Mean Square Error (RMSE) measures how much error there is between two data sets.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_t - \hat{y}_t)^2}{n}} \quad \ldots (8)$$

RESULTS AND DISCUSSION

For the analysis data from 1991 - 2019 is considered. The data consist of the food grains production of India. In this work we have considered food grains production of prediction for ARIMA and regression models. The data is taken from www.Agricoop.co.nic.in. The results obtained are as follows:

FIGURE 1: ACTUAL AND ESTIMATED VALUES OF FOOD GRAINS PRODUCTION USING REGRESSION MODEL



In figure 1 shows that actual and estimated values of food grains production using Regression model.

ANALYSIS OF FOOD GRAINS PRODUCTION USING ARIMA

Here the ARIMA model seems to be the best fit and also forecasting has been done. The Non-stationary of the data is viewed from the following line graph.

FIGURE 2: LINE GRAPH OF FOOD GRAINS PRODUCTION

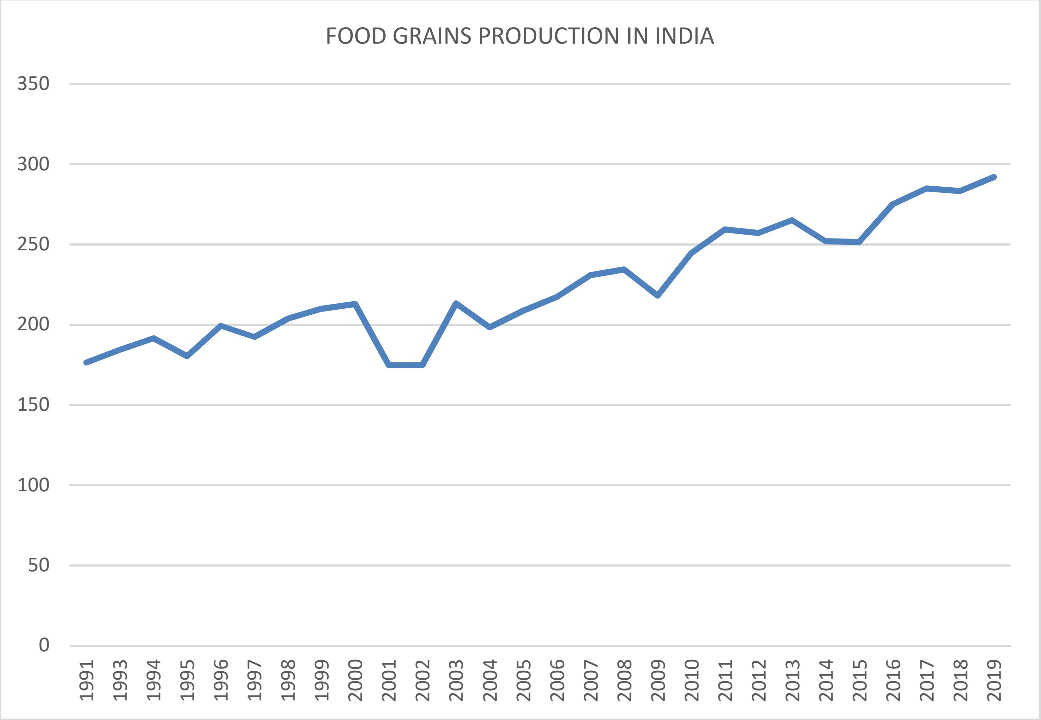


TABLE 1: ACF AND PACF OF FOOD GRAINS PRODUCTION

Autocorrelation Functions of Food grains Production					
			Box-Ljung Statistic		
Lag	Autocorrelation	Std. Error[a]	Value	df	Sig.[b]
1	-.242	.179	1.827	1	.176
2	-.312	.176	4.971	2	.083
3	.098	.173	5.291	3	.152
4	.014	.169	5.298	4	.258
5	.042	.165	5.363	5	.373
6	-.124	.162	5.950	6	.429
7	.136	.158	6.691	7	.462
8	.017	.154	6.703	8	.569
9	-.073	.150	6.941	9	.643
10	-.030	.146	6.982	10	.727
11	-.038	.142	7.055	11	.795
12	-.043	.138	7.152	12	.847
13	.139	.134	8.229	13	.828
14	.157	.129	9.715	14	.783
15	-.218	.124	12.797	15	.618
16	-.076	.120	13.204	16	.658

Table 1 shows that the Q value is 13.204 for k=16. We compare this to the Chi square distribution with 16-2=14 degrees of freedom. Here the calculated value is less than the table value, i.e., 13.204 < 23.68. It concluded that Q is not significant. The residuals can consider as a white noise series.

ACF AND PACF FOOD GRAINS PRODUCTION

In order to make the points stationary, first order differencing carried out. Below the graphs give the details on the first order differencing.

FIGURE 3: AUTOCORRELATION AND PARTIAL AUTOCORRELATION GRAPH FOR FIRST ORDER DIFFERENCING

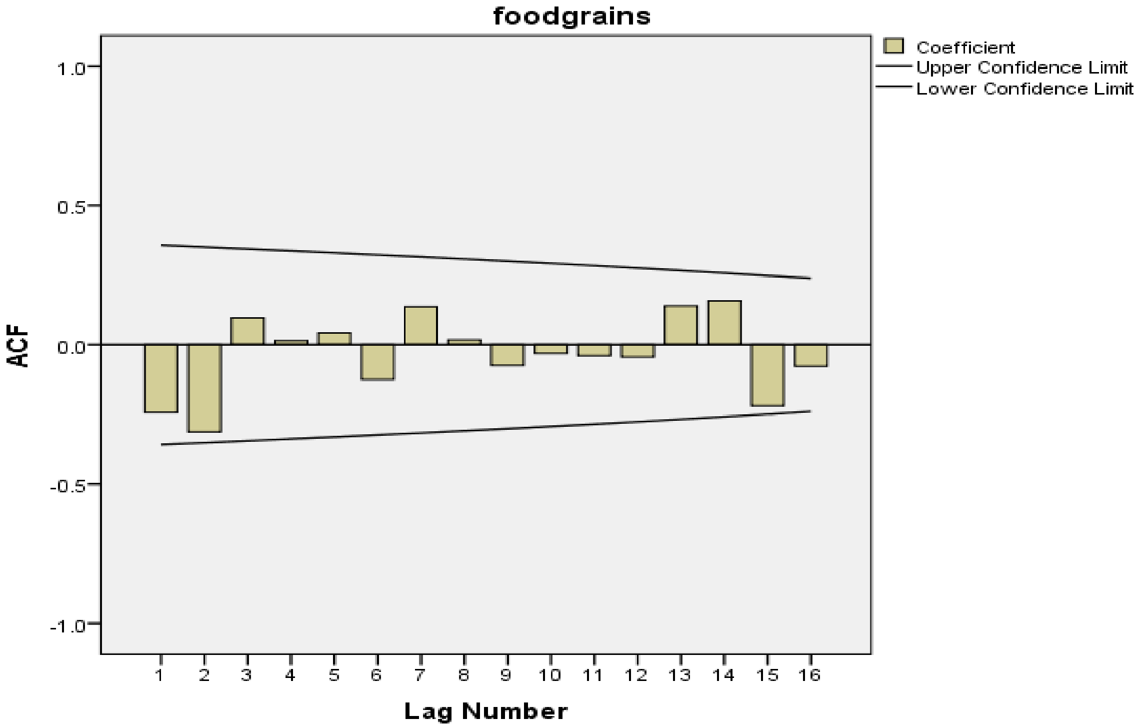


FIGURE 4

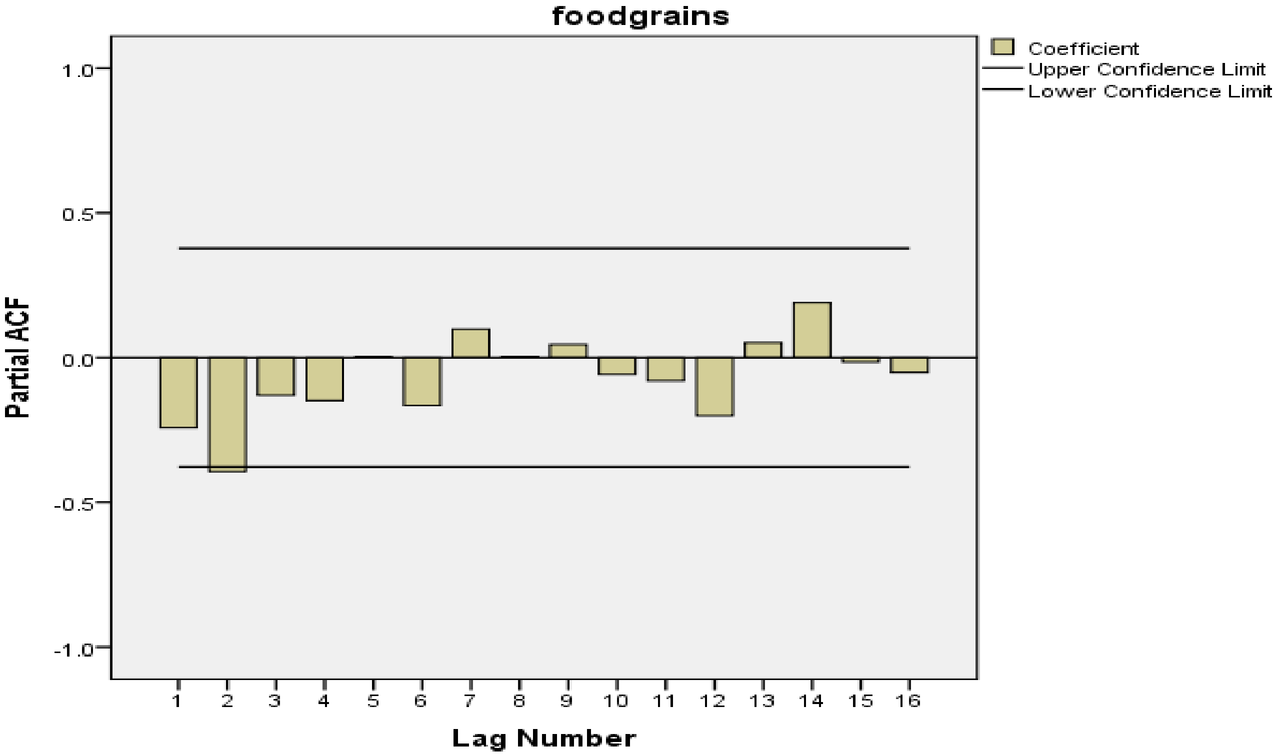


TABLE 2: BIC VALUES OF ARIMA (p, d, q)

ARIMA (p,d,q)	Normalized BIC
ARIMA(1,1,0)	5.759
ARIMA(0,1,1,)	**5.463**
ARIMA(1,1,1)	5.579
ARIMA(2,1,0)	5.725
ARIMA(0,1,2)	5.548

When comparing with other models, *the smaller BIC statistic value* indicates the better fitting model. The specified order is *an ARIMA* (0,1,1) and hence the model is fitted and the forecasting is done.

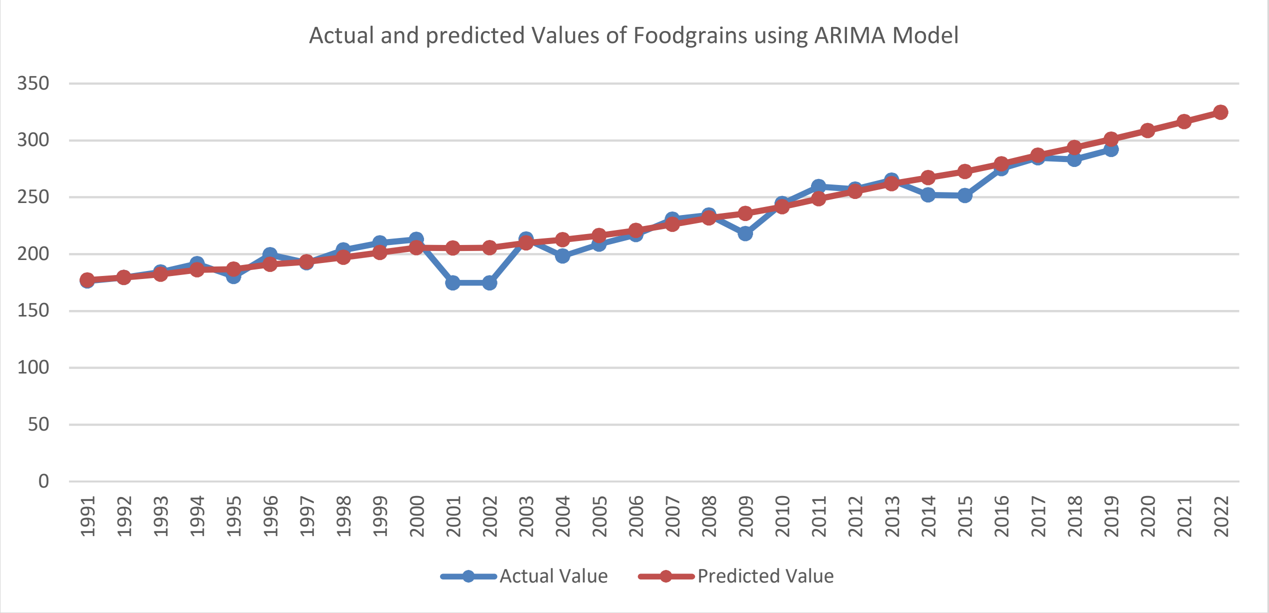
FORECASTED VALUES OF ARIMA (0,1,1)

The table given below shows the details of the forecasted values using the ARIMA (0, 1, 1) model. The range, i.e., the Upper Control Limit (UCL) and the Lower Control Limit (LCL) are also given.

TABLE 3: FORECASTED VALUES, LCL AND UCL

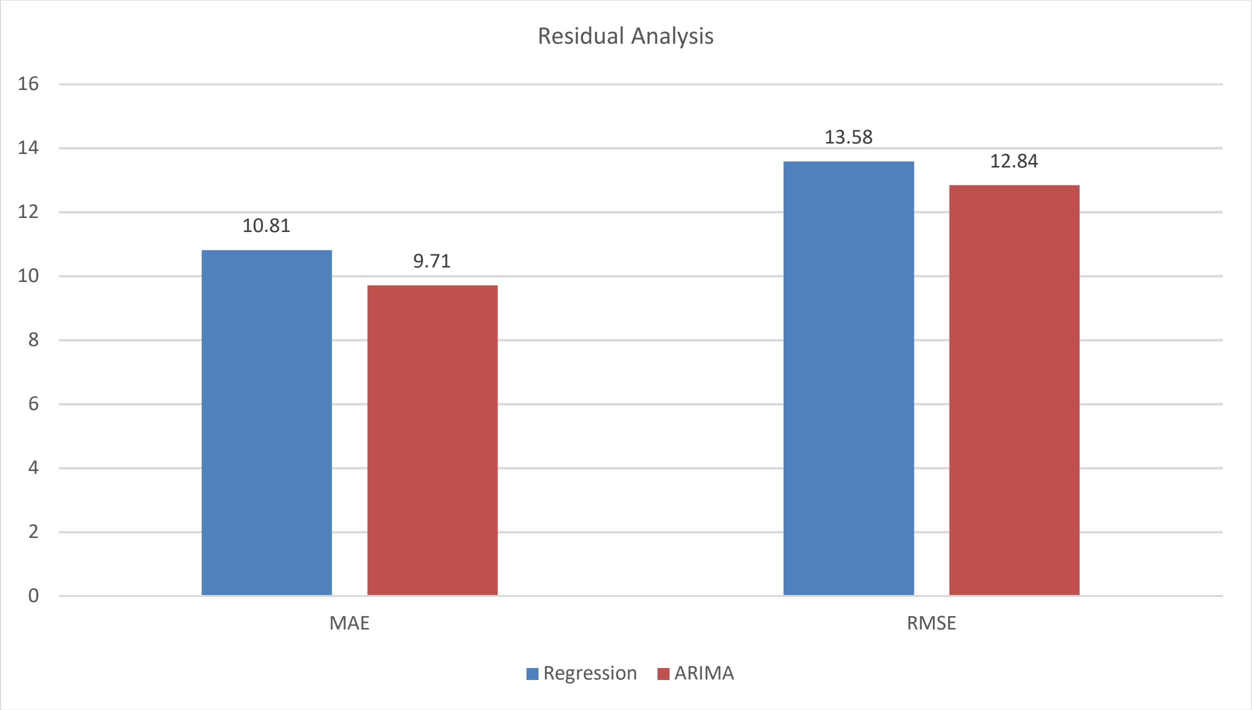
		2020	2021	2022	2023
Food grains production	Forecast	301.00	308.65	316.53	324.66
	UCL	327.02	334.75	342.72	350.92
	LCL	274.98	282.55	290.35	298.39

FIGURE 5: ACTUAL AND PREDICTED VALUES OF FOOD GRAINS USING ARIMA MODEL



In figure 5 shows that actual and predicted values of food grains using ARIMA model

FIGURE 6: RESIDUAL ANALYSIS OF FOOD GRAINS PRODUCTION USING ARIMA AND REGRESSION MODEL



In figure 6 shows that mean absolute error and root mean square error is minimum in ARIMA model when compared to the regression model.

CONCLUSION

Inferences based on the Regression model and Autoregressive Integrated Moving Average (ARIMA) model for the food grains production are given below. From the residual analysis mean absolute error and root mean square error is minimum in ARIMA model when compared to the regression model. So, ARIMA model is best for prediction of food grains production of India. The best model that fit was the ARIMA model and also forecasted. The corresponding Upper limit and the Lower limits are also given for the respective years. The model, ARIMA (0,1,1) was found as the best fit for the food grains with BIC =5.463, when considering the forecasted values, there is an increasing trend pattern from 2020 to 2023 years. The food grains have increased from 301.00 to 324.66.

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