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Forecasting of pigeon pea yield in Bihar through Auto-Regressive Integrated Moving Average model (ARIMA)

Naveen and Mahesh Kumar

Abstract
This research paper entitled "Forecasting of Pigeon pea yield in Bihar through Auto-Regressive Integrated Moving Average Model (ARIMA)*"* is based on the secondary data. Data was collected for the years 1980 to 2021 from the websites and Department of Economics and Statistics and India Agri. Stat. The different ARIMA models are judged on the basis of Autocorrelation Function (ACF) and Partial autocorrelation Function (PACF) at various lags. The ARIMA models are fitted to the original time series data as well as the first difference data to check the stationarity. The possible ARIMA model are identified on the basis of significant coefficient of autoregressive and moving average components. Data for the year 1980 to 2019 were used for model building and rest two years data i.e. 2020 and 2021 were used for validation of yield forecast model of Pigeon pea.
It was found that the ARIMA (1, 1, 1) model is best fitted for forecasting of Pigeon pea yield in Bihar among all the other models namely ARIMA (0, 0, 1), ARIMA (1,0,1), ARIMA (0, 1, 1), ARIMA (1, 1, 1), ARIMA (0,1, 2), ARIMA (2, 0, 0) and ARIMA (2, 0, 1). The parameters of all these models were computed and tested for their significance. Various statistics were also computed for selecting the adequacy, invertibility, stationarity, Diagnostic checks, % forecast error and parsimonious model with t-test and chi-square test. The low values of MAPE, MAE, RMSE, % forecast error and BIC are good inferences for forecasting of Pigeon pea yield in Bihar. Five years ahead forecasting from 2020 to 2024 for pigeon pea yield were calculated using ARIMA models. The five year ahead yield forecasting of pigeon pea in Bihar for the year 2020, 2021, 2022, 2023 and 2024 are 1723 kg/ha, 1680 kg/ha, 1671kg/ha,1693 and 1707 kg/ha respectively with forecast error for the year 2020 and 2021 are 2.23% and 4.62% respectively.
The ARIMA model for forecasting yield of Pigeon pea in Bihar is as below:
$Z_t – Z_{t-1} = 16.019 + 0.485\ (z_{t-1} - z_{t-2})\ –0.995\ (a_{t-1} - a_{t-2}) + a_t$ (for Bihar)

Keywords: Yield forecasting of Pigeon pea, ARIMA models, Box and Jenkins (1976), time series

Introduction
Pulses are essential components of a human diet and aid in improving the nutritional value of the vast majority of Indians, especially vegetarians, who consume cereal-based diets. Pulses are crucial for reducing the global issues of under nutrition and malnutrition. For the vast majority of people living in developing nations like India, pulses are an essential staple food and one of the richest and cheapest sources of protein (Maphosa and Jideani, 2017). They are also a cheap source of minerals, carbohydrates, and B-complex vitamins (Singh *et al*., 2018). Additionally, they contain anti-nutrients that prevent nutrients from being absorbed into the body, such as tannin, hem agglutinin, cyanogenic glycosides, and alkaloids (Aruna and Devindra, 2016). The most commonly consumed pulses are chickpea pigeon pea, kidney beans, black gram, green gram and lentils (Singhali *et al*., 2014).
One significant legume pulse crop grown throughout the world is the pigeon pea (*Cajanus cajana* (L.) *Mill* sp.), which is a member of the Fabaceae family and falls under the subfamily Papilionaceae (Behera *et al*., 2020; Saxena *et al*., 2020). As well as these names, it is also referred to as red gramme, congo pea, gungo pea, and no-eye pea (Wu, 2009). Because of its deep taproot, tolerance to heat, and rapid growth, the pigeon pea is a tropical and subtropical species that is primarily suitable for rainfed agriculture in semi-arid regions (Mallikarjuna *et al*., 2011). It is a drought-resistant plant that grows quickly and is hardy, versatile, and adaptable (Bekele-Tessema, 2007). Due to its ability to fix nitrogen and flexibility for mixed or intercropping crops, it is an important component of dry land farming systems, particularly those used by small and marginal farmers in many parts of the world (Pandit *et al*., 2015).

It is among the most generally consumed legume in the semiarid tropics (Maphosa and Jideani, 2017). It is generally grown by less land holding farmers with minimum input under rainfed conditions (Khoury *et al*., 2015, Saxena *et al*., 2018; Zavinon *et al*., 2019).

The *Cajanus cajanifolia,* the closest wild relative of the pigeon pea, is indigenous to peninsular India and grows in tropical deciduous woodlands (Van der Maeson., 1995). Other viewpoints, however, contend that India or North Eastern Africa served as *Cajanus cajan's* original habitat (Van der Maesen, 1989).

Sharma *et al.* (2018) [3] conducted the study using ARIMA models to predict the production of maize in India over the next four years, from 2018 to 2022. For the purpose of choosing a more appropriate model, they examined the Auto-Correlation Function and Partial Auto-Correlation Function of different series.

Biswas *et al.* (2019) [2] Sunflower seed price forecasting for the market Kadiri in the district of Anantapur in the state of Andhra Pradesh was done using the ARIMA model. For the chosen model ARIMA (1, 1, 2), the mean average percent error and root mean square percent error were 2.30 and 3.44 percent, respectively.

Kumar and Verma (2020) [6] used ARIMA techniques to predict the mustard production five years in advance in the study areas of Haryana's Bhiwani and Hisar districts. MAPE, Akaike Information Criterion, and Bayesian Information Criterion are used to evaluate the validity of models.

Yadav *et al.* (2020) [9] used the compound growth rate to calculate the growth in Assam's fish production during the previous ten years. They have tried utilising the ARIMA methodology to develop models and predict fish production in the state of Assam. The Directorate of Fisheries, Government of Assam, site provided the time-series statistics on fish production in Assam from 1980 to 2018. In order to create an ARIMA model, fish production data from 1980 to 2014 were employed. Utilizing the remaining fish production data from 2015 to 2018, these created models were verified. They discovered the ideal model to forecast Assam's fish production. For the purpose of forecasting Assam's fish production, the discovered model ARIMA (1,1,0) was employed. The reports generated showed a strong pattern of growth from 336.97 to 358.21.

Wankhade and Kale (2021) [4, 8] Using Auto-Regressive Integrated Moving Average (ARIMA) models in the statistical software MINITAB19, predictions of the area and yield of the groundnut crop (in q/ha) in India were made, along with 95 percent confidence intervals. They obtained annual data from the Directorate of Economics and Statistics, GOI, for the years 1970 through 2017, and they used the Ljung-Box Chi-Square Statistic, Auto-Correlation Function, and Partial Auto-Correlation Functions to test the randomness of the error factors in the model. They noticed that even though groundnut planting area is trending downward for the next 15 years, from 2018–19 to 2032–33, groundnut yield is trending upward.

Materials and Methods

The current study is being conducted in order to investigate the yield forecasting of pigeon pea in the Indian states of Bihar.

The methodology is outlined below

1. Description of the research area
2. Data source
3. Techniques and tools used in the analysis

1.1 Description of the research area

The state Bihar is located between the latitudes of 24°-20'-10" and 27°-31'-15" North and the longitudes of 83°-19'-50" and 88°-17'-40" East. Bihar is located in the subtropical to tropical zone, bordering the Ganga delta and Assam. The Himalayan Mountains to the north of Bihar play an important role in precipitation. The state covers an area of 93.6 lakh hectares. That is roughly 3% of India's total geographical area. It is located in Eastern India and has a subtropical climate. During the peak summer months of March and May, the average temperature will be close to 40 degrees Celsius. The temperature would drop to 8 degrees Celsius in the winter, from December to January. Bihar has a total area of approximately 94,163 square km and is located 173 feet above sea level. The state has an average of 52.5 rainy days per year, with precipitation totalling 976 mm.

2. Source of the data

The present study is based on the secondary data on area, production and productivity of pigeon pea. These data will be collected from the authenticated portals like Directorate of Pigeon pea Research and India Agri stat. etc.

3. Techniques and tools used in the analysis

3.1 ARIMA models for forecasting of yield

The Box and Jenkins (1976) model will be used for yield forecasting. The basic group of models for forecasting a time series is Auto Regressive Integrated Moving Average (ARIMA). The "Auto-Regressive" process refers to the various series that appear in forecasting equations. The "Moving Average" process is used to demonstrate the lags of forecast errors in the model. ARIMA (p, d,q) denotes the ARIMA model, where 'p' is the order of the auto regressive process, 'd' is the order of the data stationary process, and 'q' is the order of the moving average process.

Auto Regressive process of order (p) is,

$$Y_t = \mu + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \cdots + \varphi_p Y_{t-p} + \varepsilon_t$$

Moving Average process of order (q) is,

$$Y_t = \mu - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} + \varepsilon_t$$

The basic formulation of ARIMA (p, d,q) could be described as,

$$Y_t = \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \cdots + \varphi_p Y_{t-p} + \mu - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} + \varepsilon_t$$

Where

Y_t= yield (dependent variable) of groundnut at year t

Y_{t-1}, Y_{t-2}..., Y_{t-p} = response variable at time lags t-1, t-2..., t-p respectively

μ = constant mean of the process
$\varepsilon_{t-1}, \varepsilon_{t-2}, \ldots, \varepsilon_{t-q}$ = errors in the previous time periods
φ_s=coefficients to be estimated of AR process
θ_s = coefficients to be estimated of MA process
ε_t= forecast error, independently and normally distributed with zero mean & constant variance for t = 1, 2,…, n
d = fraction differenced during the interpretation of AR and MA

3.2 The Box-Jenkins modelling procedure

For forecasting, the mathematically sound and reliable Box-Jenkins method is used instead of any other traditional econometric methods. To create a model, this method employs a series of stages in the ARIMA modelling procedure. The built models were then tested for accuracy using historical data. The model fits better if the residues are small, contain useless information, and are distributed irregularly. If the model is not satisfactory, the entire process should be repeated to improve on the basic model using the new available model. This procedure is repeated until the best-fitting model is found. The following are the iterative phases (Fig-3.2) in developing an ARIMA forecasting technique are found as below,

1. Model specification
2. Model estimation
3. Diagnostic checking
4. Forecasting

3.2.1 Model specification

The primary goal of ARIMA modelling is to find the best values for p, d, and q. This could be partially resolved by examining the time series data's Auto Correlation Function (ACF) and Partial Auto Correlation Functions (PACF) (Pindyk & Rubinfeld, 1991). The ACF indicates the order of the model's autoregressive component 'q,' whereas the PACF indicates the component 'p.' The first step is to determine whether the data are stationary. The degree of homogeneity, (d), i.e., the number of time series data to be differenced to produce a stationary series. It is determined by where the ACF fall out to zero. After deciding ‘d’, a stationary series, its ACF and PACF are analysed to determine the suitable values of p and q.

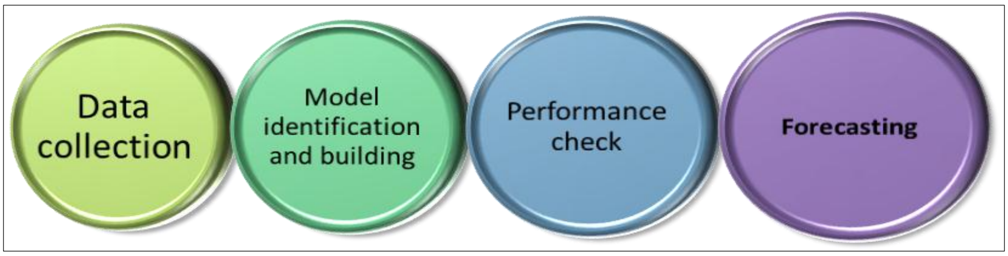

Fig 1: Steps in ARIMA forecasting

3.2.2 Model estimation

The model is then estimated using a computer package. In step 1, the goal is to obtain estimates of the ARIMA model parameters that were tentatively constructed. The ARIMA coefficients (φ's and θ's) should be calculated using a nonlinear least squares method. The most important method for estimating ARIMA models is known as "Marquardt's compromise."

3.2.3 Diagnostic checking

The output is obtained through diagnostic checks. The first diagnostic check is residual analysis, which involves creating a graph of a time series plot of residuals. If the plot produces a rectangular scatter around a zero-horizontal level with no trend, the applied model is declared normal. Normality testing is the second diagnostic check. Normal scores are compared to residuals in the first normality test. If it formed a straight line, the applied model is declared to be a good fit. The residuals histogram is plotted as the second normality test. The third check is determining the fitness of the good. The residuals are marked against the corresponding fitted values for this purpose. When the plot shows no pattern, the model is declared to be a perfect fit.

3.2.4 Forecasting

Following an evaluation of the fitted ARIMA model's predictive capability, along with 95 percent confidence interval values. Forecasting is done for five years or less because forecasting errors increase rapidly if we go too far into the future.

Results and Discussion

Data on pigeonpea production, area, and yield in the states of Bihar were gathered to help with the research's stated aims. In this section, the findings of the statistical analysis, the methods of which were covered. The secondary data for the years 1980 to 2021 was collected from reliable websites like the Department of Economics and Statistics and India Agri Stat. For the purpose of forecasting pigeonpea yield, data up to the year 2019 were used to build the prediction model, and data from the following two years were retained for the forecast model's validation.

4. Forecasting the yield of pigeon pea in Bihar through ARIMA models

In this study, we have used different models to find out the perfect model for the forecast of pigeon pea yield in Bihar. For the model comparison, yearly yield of pigeon pea was taken into consideration.

4.1 Model Identification

The crucial first step in an ARIMA's discovery process is evaluating the stationary behaviour of the underlying process. The data are non-stationary, that is, they don't have a constant mean and variance, as can be seen from the original plot of pigeon pea yield data in figure 4.1. so that in figure 4.2, the first order difference is plotted and displayed. The first order difference of the data was found to be stationary, that is, to have a constant mean and variance, as shown by this plot.

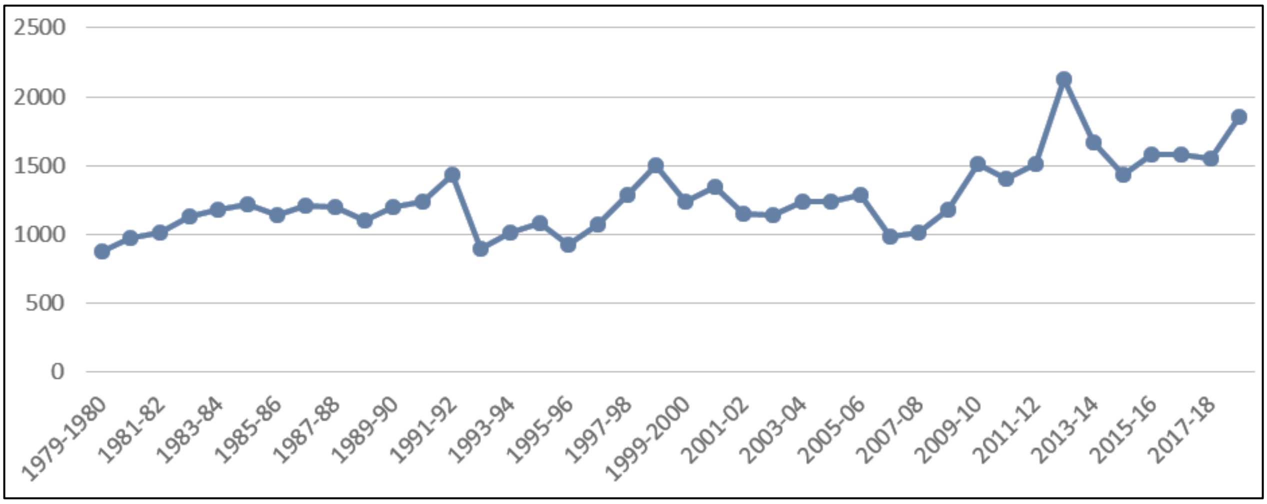

Fig 2: Time series plot of pigeonpea yield in Bihar

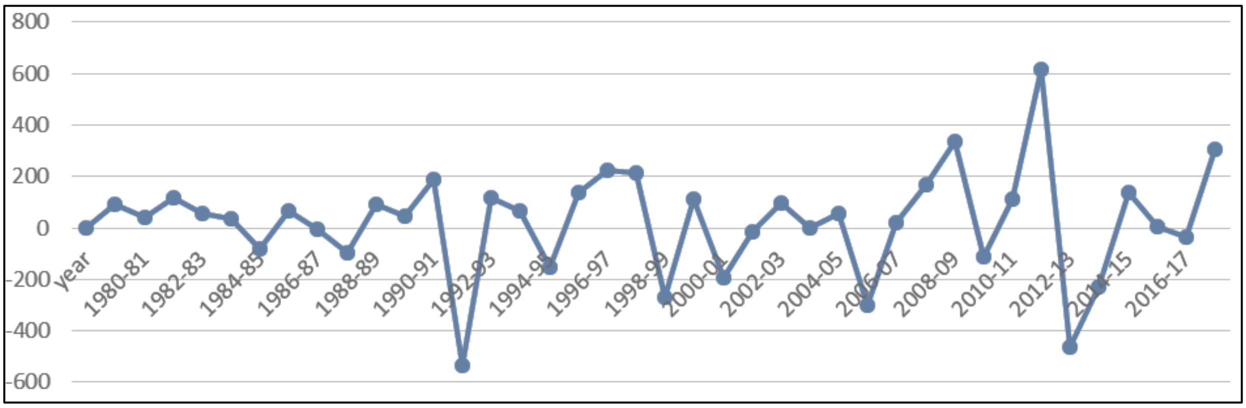

Fig 3: Time series plot of first order difference series of pigeonpea yield in Bihar

The study of table 1 and 2 shows Auto Correlation Function and Partial Auto Correlation Function of original **(Z_t)** and first order difference series (ΔZ_t) for Bihar up to lag 20 (Twenty), respectively.

Table 1: ACF of original (Z_t) and first order difference series (ΔZ_t) for Bihar

Lag	Z_t	t-value	ΔZ_t	Δt-value
1	0.602	3.960	-0.232	-1.506
2	0.417	2.78	-0.237	-1.559
3	0.37	2.5	0.152	1.013
4	0.242	1.657	-0.023	-0.155
5	0.162	1.125	-0.246	-1.684
6	0.183	1.288	-0.098	-0.680
7	0.143	1.021	0.342	2.425
8	0.031	0.224	-0.148	-1.064
9	0.028	0.205	0.091	0.664
10	-0.074	-0.552	-0.13	-0.962
11	-0.013	-0.099	0.041	0.310
12	0.064	0.496	0.037	0.284
13	0.151	1.188	-0.134	-1.046
14	0.173	1.395	0.245	1.960
15	0.069	0.565	0.077	0.626
16	-0.076	-0.633	-0.087	-0.725
17	-0.175	-1.495	-0.263	-2.247
18	-0.103	-0.903	0.192	1.669
19	-0.161	-1.437	-0.05	-0.446
20	-0.136	-1.247	-0.222	-2.036

Table 2: PACF of original (Z_t) and first order difference series (ΔZ_t) for Bihar

Lag	Z_t	t-value	ΔZ_t	Δt-value
1	0.602	3.810	-0.232	-1.45
2	0.086	0.544	-0.307	1.918
3	0.139	0.879	0.011	0.068
4	-0.072	-0.455	-0.054	-0.337
5	-0.008	-0.050	-0.254	-1.587
6	0.095	0.601	-0.324	-2.025
7	-0.01	-0.063	0.123	0.768
8	-0.122	-0.772	-0.103	0.643
9	0.02	0.126	0.179	1.118
10	-0.154	-0.974	-0.32	-2.00
11	0.173	1.094	-0.029	0.181
12	0.077	0.487	-0.023	0.143
13	0.17	1.075	-0.01	-0.062
14	0.019	0.120	0.195	1.218
15	-0.182	-1.151	0.207	1.293
16	-0.231	-1.462	-0.037	0.213
17	-0.155	-0.981	-0.2	-1.250
18	0.122	0.772	-0.01	-0.062
19	-0.065	-0.411	0.071	0.443
20	0.027	0.170	-0.037	0.231

Parameter Estimation

In various output tables the estimates of various parameters from various models were provided. The parameter estimates, standard deviation, and t-ratio have all been calculated for these models. The AR factor and/or MA factor, as well as the appropriate forecast model, are included in the output table.

For the purpose of diagnosing the model, the autocorrelation of the residuals has been computed. The significance of residual autocorrelations is examined using the L-Jung Box test as a measure of Q-Statistics. For Bihar, the fitting of ARIMA (1, 1, 1) is displayed in output table 3. Because it has low values for RMSE, MAPE, MAE, and BIC, ARIMA (1, 1, 1) is the best fit model for predicting pigeon pea yield in Bihar. Fig. 3 shows the Residual ACF and PACF plot for ARIMA (1, 1, 1) for yield of pigeon pea and Fig. 4 Graph between time (year) and yield for ARIMA (1, 1, 1) in Bihar

Table 3 Output of fitting ARIMA (1, 1, 1) for pigeon pea yield of Bihar

Model parameters

Parameters	Estimates	SE	t- Value
Constants	16.019	6.685	2.396
φ_1	0.485	0.201	2.414*
θ_1	0.995	1.759	0.566

Auto Regressive Factor: - $\varphi(B) = 1 – 0.485B$

Moving Average Factor: - $\theta(B) = 1 –0.995B$

Forecast Model: - $Z_t – Z_{t-1} = 16.019 + 0.485\ (z_{t-1} - z_{t-2}) – 0.995\ (a_{t-1} - a_{t-2}) + a_t$

Diagnostic Check

Lags	Residual ACF	t-Value
1	-0.011	-0.068
2	-0.094	-0.587
3	0.155	0.959
4	-0.021	-0.127
5	-0.197	-1.193
6	-0.046	-0.269
7	0.252	1.465
8	-0.127	-0.701
9	0.046	0.251
10	-0.154	-0.841
11	-0.019	-0.101
12	-0.002	-0.010
13	-0.081	-0.433
14	0.212	1.127
15	0.062	0.319
16	-0.117	-0.603
17	-0.272	-1.387
18	0.094	0.458
19	-0.099	-0.478
20	-0.203	-0.975

Model fit parameter

R-squared	RMSE	MAPE	MAE	BIC
0.503	188.910	10.220	128.833	10.764

Q-Statistics (L-Jung Box Test) = 19.363

D.F. = 16

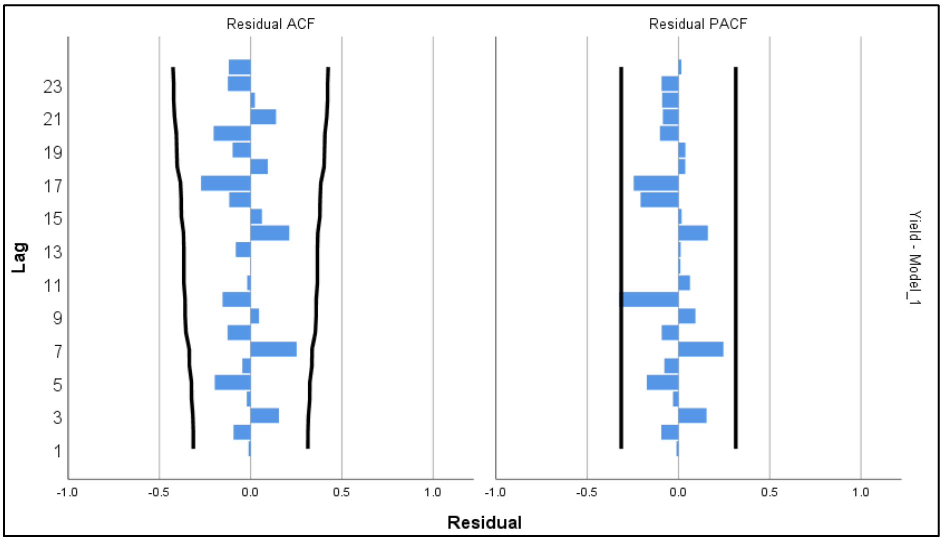

Fig 3: Residual ACF and PACF plot for ARIMA (1, 1, 1) for yield of pigeonpea

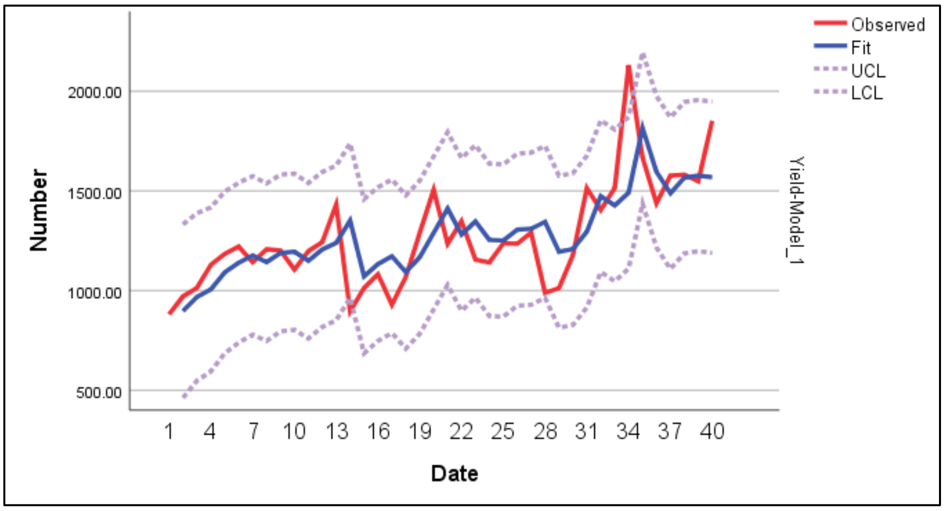

Fig 4: Graph between time (year) and yield for ARIMA (1,1,1) in Bihar

Selection of good model

A good model should be stationary and parsimonious. The estimated coefficients' parameters have been of very high quality and stability. Despite the fact that p=0 for ARIMA (0,0,1), ARIMA (0,1,1), and ARIMA (0,1,2), respectively, they are either pure MA models or a white noise-series. There are no stationarity conditions to test because the literature claims that all pure MA models and white noise are stationary. Similar to this, we have q=0 for the pure AR processes ARIMA (1, 0, 0) and ARIMA (2, 0, 0), also known as a white-noise series. Again, according to the literature, all pure AR processes (or white noise) are invertible and no additional checks are necessary (Box and Jenkins, 1976).Box and Jenkin's suggested guiding principle was applied when choosing a parsimonious model. In contrast to ARIMA (1,1,1), ARIMA (0,1,2), and ARIMA (2,0,1), which each have three parameters and do not satisfy the parsimonious condition, ARIMA (0,0,1), ARIMA (1,0,0), ARIMA (1,0,1), ARIMA (0,1,1), and ARIMA (2,0,0) all have fewer parameters (i.e., two parameters) hence they satisfy parsimonious condition. For each model, the t-test and chi square test have been calculated. The model with the best fit, according to a comparison of different models, is ARIMA (1,1,1). The RMSE, MAPE, MAE, and BIC values are quite low, as shown by the cross validation of the best fit ARIMA (1,0,0) that was chosen to forecast the yield of pigeonpea in Bihar in table 4.4. Thus, the selected model is successfully validated.

4.3 Diagnostic check

A statistically accurate model will have random shocks that are non-autocorrelated and have constant mean and variance. In the result tables for this study mentioned above, the residual ACF were calculated and provided. For each residual autocorrelation coefficient, the null hypothesis Ho: pk(a) = 0 was tested using the t-test. Bartlette's approximation formulas have been used to calculate the respective standard error. The independence of the random shocks is suggested by the fact that all of the t-values of the residual ACF for the model under consideration are non-significant, i.e., less than the critical values. This is further supported by a chi-square test conducted by L-Jung and Box using Q-Statistics. For the chosen model ARIMA (1,1,1), the Q-statistics of L-Jung and Box test is 19.363, which is lower than the chi-square value at 16 degrees of freedom (table 4.3). As a result, the chosen ARIMA model of order (1,1,1) seems appropriate. One step ahead and two steps ahead forecast errors were calculated to be 2.23% and 4.62%, respectively (table 4.5).

Table 4: Selection of good model forpigeonpea yield of Bihar

Models	RMSE	MAPE	MAE	BIC	Stationary	Invertible	Parsimony	Stable/ R^2	Diagnostic Check		% Forecast Error	
									t-test	χ2 test	1st step (2019-20)	2nd step (2020-21)
0,0,1	220.804	12.435	156.158	10.979	NA	✓	✓	0.324	**	NS	6.06	20.72
1,0,0	205.868	10.797	137.102	10.839	✓	NA	✓	0.412	**	NS	0.27	2.42
1,0,1	207.106	10.835	137.095	10.943	✓	✓	✓	0.421	** (For φ_1)	NS	0.88	0.186
0,1,1	199.022	10.676	136.481	10.775	NA	✓	✓	0.433	**	NS	3.67	10.41
1,1,1	188.910	10.220	128.833	10.764	✓	✓	X	0.503	**	NS	2.23	4.62
0,1,2	189.023	10.467	130.294	10.766	NA	✓	X	0.502	NS	NS	2.75	0.373
2,0,0	207.879	10.827	137.272	10.951	✓	NA	✓	0.416	** (For φ_1)	NS	0.582	0.871
2,0,1	208.535	10.602	134.703	11.049	✓	✓	X	0.429	NS	NS	0.635	0.871

✓: Indicates That Condition is satisfied.
X: Indicates That Condition is not satisfied.
NA: Not Applicable. i.e., if p=0 and q=0, for all pure MA and AR processes (or white noise) are respectively stationary and invertible and no further checks are required.
NS: Non-Significant
**: Highly significant

Forecasting the yield of pigeon pea in Bihar through ARIMA models

Computation of forecasts and their confidence intervals

The model has been used to forecast the future yields of the observed time series after its validity has been established. Forecasts would be made for a few years in advance, or "lead time." From the selected model ARIMA (1, 1, 1), the forecasting of next five years yield is done along with its confidence interval. Here we observed that the yield of pigeon pea in Bihar decreased for three years and then increased for the next two years.

Table 5: Forecast along with their confidence interval of ARIMA (1,0,1) for pigeonpea yield of Bihar

Periods	Forecast	95% limits		Actual	% Forecast error
		Lower	Upper		
2019-20	1723	1314	2293	1681	2.23
2020-21	1680	1232	2316	1606	4.62
2021-22	1671	1209	2322		
2022-23	1693	1207	2334		
2023-24	1707	1214	2353		

Summary and Conclusion

Pulses are essential components of a human diet and aid in improving the nutritional value of the vast majority of Indians, especially vegetarians, who consume cereal-based diets. Pigeon pea is second most cultivated pulse crop in India. So, it is important to study the trend of its area, production and yield. In this concern, ARIMA forecasting technique is used forecasting of pigeon pea yield in Bihar.

Instead of conventional or econometric methods, the ARIMA models were used to forecast the yield of pigeon pea in Bihar. The time series data of 40 years were collected from 1980-2019 for the study. As the first step, the yield data is made stationary by the first order differentiation. ACF and PACF of the original and first order difference series were shown in the tables following the differentiation procedure, and both quickly decrease to zero. In order to forecast the yield of pigeon pea in Bihar, separate 8 models were tested. Performance tests were conducted on the models ARIMA (0, 0, 1), ARIMA (1, 0, 0), ARIMA (1, 0, 1), ARIMA (0, 1, 1), ARIMA (1, 1, 1), ARIMA (0, 1, 2), ARIMA (2, 0, 0), and ARIMA (2, 0, 1). The model with the greatest fit for forecasting Bihar's pigeon pea yield among these models was ARIMA (1, 1, 1). Consequently, the pigeon pea yield forecast model in Bihar is,

$$Z_t – Z_{t-1} = 16.019 + 0.485 (z_{t-1} - z_{t-2}) – 0.995 (a_{t-1} - a_{t-2}) + a_t$$

Using the selected ARIMA models, ARIMA (1,1,1) the yield values were forecasted for five years period ahead i.e., from 2020 to 2024 in Bihar. The forecasted values of Bihar are 1723 kg/ ha, 1680 kg/ ha, 1671 kg/ ha, 1693 kg/ ha, 1707kg/ ha, respectively for 2020, 2021, 2022, 2023, 2024.

The forecast values for Bihar decreased for the three years forecast and then increased for the fourth and fifth year. These yield values were presented along with their lower and upper limits with 95% confidence interval. Using the mathematically sound ARIMA models, the pigeon pea yield values were forecasted with 2.23 per cent of one step ahead forecast errors, Bihar. The second steps ahead forecast errors is 4.62 per cent, respectively for Bihar

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