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Use of Machine Learning Technique in Forecasting the Price and Arrival of Onion in Important Markets of Anugul District of Odisha, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Price fluctuations in onion crop of Odisha, is due to variation in production and market arrival. Study of the market arrival and market price of onion in important and efficient markets of Anugul district of Odisha is conducted in the study. The study can help policymakers create effective agricultural policies to reduce price volatility and provide timely information to the farmers to adopt best cropping pattern and sell their product in market at appropriate time and obtain adequate profit.
Data pertaining to arrival and price of onion crop in market of Anugul district has been collected for the period from April 2022 to March 2024. The traditional ARIMA model can take care of only

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linearity in the data. Since data on price and arrivals of crops are usually nonlinear in nature, the modern technique of models i.e Machine Learning models are fitted to the data on arrival and prices of onion. These modern models would fit the data having non-linearity nature. ANN models with different nodes at hidden layer are fitted to the data. The best fit model selected by appropriate model diagnostic tests and model fit such as, Root Mean Square Error (RMSE) and Mean Absolute Percent Error (MAPE) are cross validated and finally used for prediction purpose.
Neural Network Auto Regressive models at different nodes and hidden layers are fitted separately to the data for arrival and for price in Anugual, Athamalik and Jarapada market of Anugul district are found to be the best fit models for forecasting. The forecasted values of onion price of Anugul and Athmalik markets are found to be stable and in Jarapada, market it is found to be increasing and then stable with time. The forecasted values of arrivals of onion are found to be stable in Jarapada market. In Anugul market arrivals of onion is found to be decreasing and then stable while in the Athmalik market the forecasted values of arrivals of onion are found to be fluctuating with alternative increase and decrease.

Keywords: ANN; fluctuation; MAPE; model diagnostics test; RMSE.

1. INTRODUCTION

Onion is a very important food item in Odisha. Price fluctuations can cause instability in budget, where the accurate price forecasting helps in stabilizing the market by providing timely information to both producers and consumers. Farmers can use price forecasts for onions to guide their decisions on crop planning, or when to plant their crops to maximize profits while harvesting them. Additionally, they can choose whether to cultivate onions or switch to another crop in accordance with market expectations. If the crop is harvested early, they can store and sell it in accordance with those projections. By doing this, they can increase their revenue, lower their chance of suffering losses as a result of unanticipated price reductions, preserve their purchasing power, and guarantee affordability.

“Price projections can be used by policymakers to create more effective intervention plans, such as import-export policies with subsidies and market controls to limit sharp price swings and guarantee food security. Frequent price projections promote fairness in the market by increasing market transparency, lowering the likelihood of speculative trading, and preventing price manipulation” (Thowseaf, 2024).

The classical statistical model for forecasting has a great limitation of assuming linear relationship of the data series which may not be possible most of the times. Modern and advanced Neural network models can take care of non-linearity and noise in the data. “The greatest advantage of a neural network is the ability to model complex nonlinear relationship without assuming any kind of pattern in the data series. Due to great rely on biological processes, agriculture price forecasting is one of the more difficult time series analytic applications” (Choudhury, et al., 2019). “The price behavior of agricultural products is significantly influenced by the biological aspects of crop production” (Jha and Sinha, 2013).

“Time series modeling builds a model that describes the underlying relationship by gathering and analyzing historical observations of the same variable. The classical Auto Regressive model is one of the most significant and frequently applied time series models” (Dash, et al., 2020). Dash et al. 2020 fitted different ARIMA models to the stationary data on kharif cereals of Odisha. The assumption of a linear relationship between the data series, which is typically unknown, is the greatest drawback of ARIMA model. When the assumed relationship for the process of creating data is incorrect, the forecasting results and their economic implications are likely to be erroneous. Artificial neural networks (ANNs), in particular, have become a viable alternative to conventional statistical models in machine learning approaches to get over this restriction (Darbellay and Slama, 2000). ANNs are a data-driven, self-adaptive, non-linear, and nonparametric technique.

2. METHODOLOGY

The period of research study has been considered for two financial years i.e. 2022-23 and 2023-24. The data pertaining to the arrival of onion and price of onion in the selected markets of Anugul districts of Odisha are collected at weekly intervals from the agricultural marketing information network (AGMARKNET) website (http://agmarknet.gov.in)

The t series (Trapletti and Hornik, 2022) and forecast (Hyndman and Khandakar, 2008) packages of R software are used for data analysis. The Artificial Neural Network (ANN) is a data-driven, self-adaptive, nonlinear and non-parametric statistical method.

According to McCulloch and Pitts (1990), "Artificial Neural Network are made up of interconnected basic processing neurons which are designed to emulate the functioning of the central nervous system of human brain". The output y_t and the inputs (y_{t-1}, $y_{t-2,\ \dots}$ y_{t-p}) relationship can be mathematically represented as

$$y_t = f\left(\sum_{j=0}^{q} w_j g\left(\sum_{i=0}^{p} w_{ij}\, y_{t-i}\right)\right)$$

The entire data set is divided to Training set and testing set. The first 90% of the data are utilized as training data to develop the model. "Test data is made up about 10 percent of the total data during the last period. The nonlinearity in the data series is tested using Terasvirta neural network test for nonlinearity for the time series data. In Terasvirta test the parameter values of the neural network model are based on Taylor expansion" (Mahdiloo, *et al.*, 2018). The significant p – value in the Terasvirta test indicates non-linearity in the data.

Following model diagnostic test are used for testing the independency and normality assumption of residuals.

2.1 Box-Pierce Test

Box-Pierce test is used to test the independence of the residuals obtained from the fitted model. The following provides the Box-Pierce Q-statistics:

$$BP\ (k) = \sum_{k=1}^{n} \rho^2\ a.k$$

Where, ρ^2 denotes the coefficient of autocorrelation in lag k of the residuals a_t, n is the number of terms in differenced series and k is the maximum lag.

2.2 Shapiro-Wilk Test

The Shapiro-Wilk test is used for testing normality of the residuals obtained from the fitted model. The hypothesis are the following:

H_0: The residuals are normally distributed.
H_1: The residuals are not normally distributed.

The test statistic is

$$W = \frac{\left(\sum_i^n q_i y_i\right)^2}{\sum_i^n (q_i - \bar{y})^2}$$ (Dash *et a.l*, 2023)

Where y_i's are the sample values, q_i's are coefficients and $\bar{y}$ is the sample mean. Data sets with p-value higher than 0.05 denotes that the data are from a normally distributed population.

2.3 Model Evaluation

The model fit statistics used for evaluation of non-linear models are Root mean squared error (RMSE) (Dash *et al.* 2016), Mean Absolute Percentage Error (MAPE) (Dash and Mahapatra, 2020). RMSE, MAPE.

2.4 Root Mean Square Error (RMSE)

RMSE is computed as the square root of the residuals' variance. Lower value of Root Mean Square Error (RMSE) denotes the improved ability of a model to fit the data.

Mathematically RMSE = $\sqrt{\frac{\sum_{i=1}^{n}(y_t - \hat{y}_t)^2}{n-2}}$ (Rout and Abhiram, 2021)

Where, y_t denotes the actual value and $\hat{y}_t$ denotes the estimated value, n – no. of observations

2.5 Mean Absolute Percentage Error (MAPE)

Mean Absolute Percentage Error (MAPE) shows the accuracy in forecasting. It is the average of the absolute percentage deviation between the actual and predicted values at various points of observation.

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n} \frac{|y_t - \hat{y}_t|}{y_t} \times 100$$

Where $y_t\ and\ \hat{y}_t$ and y are respectively the actual value and predicted value respectively, n is the no. of observations.

3. RESULTS AND DISCUSSION

Machine learning (ML) method to onion demand prediction has been done by Babu and Rao (2022) in which Machine Learning models for prediction are used which is tested and evaluated for figuring out strategies that gives the greatest precision efficiency.

Table 1. Terasvirta test of non- linearity for arrival and price data of onion in important markets of Anugul District of Odisha

Market	Arrival		Price	
	Chi-square value	p- value	Chi-square value	p- value
Anugul	1.2075	0.047	15.621	0.041
Athamalik	4.3822	0.012	12.725	0.017
Jarapada	33.325	<0.001	10.531	0.005

Table 2. Model diagnostic test and model fit statistics of ANN models fitted to arrival of onion (quintal) in Anugul market of Anugul District of Odisha

Model	Model diagnostic test				Model fit statistics			
	Box-Pierce test		Shapiro wilks test		RSME		MAPE	
	Chi-Square value	p- value	w value	p-value	Training data	Testing data	Training data	Testing data
NNAR (1,1)	0.0521	0.819	0.391	0,482	299.813	118.844	25.5442	25.271
NNAR (1,2)	0.029	0.865	0.411	0.231	296.416	136.130	25.8044	26.955
NNAR (1,3)	0.064	0.801	0.416	0.012	296.358	136.907	25.8650	27.077
NNAR (1,4)	0.064	0.801	0.41	0.187	296.350	136.180	25.8536	27.352

Table 1 depicts the Terasvirta test of non-linearity for arrival and price data series. The significant χ^2 value confirms the non-linearity of both arrival and price data which suggest that ANN model are to be fitted for efficient forecasting of arrival and price data for future period.

The result of Table 2 shows that NNAR (1,1), NNAR (1,2) and NNAR (1,4) models satisfy the test of independence and normality of residuals due to which the three models qualify for being selected on basis of model diagnostic criteria. Out of the three models NNAR (1,1) model is selected on account of lowest RMSE and MAPE. Thus the model NNAR (1,1) is used for forecasting the arrival of onion in Anugul market of Anugul district.

The result of Table 3 shows that NNAR (3,2), NNAR (3,4) and NNAR (3,5) models satisfy the test of independence and normality of residuals due to which the three models qualify for being selected on basis of model diagnostic criteria. Out of the three models NNAR (3,5) model is selected on account of lowest RMSE and MAPE. Thus the model NNAR (3,5) is used for forecasting the arrival of onion in Athamalik market of Anugul district.

Table 3. Model diagnostic test and model fit statistics of ANN models fitted to arrival of onion (quintal) in Athmalik market of Anugul District of Odisha

Model	Model diagnostic test				Model fit statistics			
	Box-Pierce test		Shapiro-Wilk'stest		RSME		MAPE	
	Chi-Square value	p-value	w value	p- value	Training data	Testing data	Training data	Testing data
NNAR (3,1)	0.284	0.594	0.959	0.046	83.615	269.183	7.659	18.458
NNAR (3,2)	0.039	0.842	0.984	0.618	65.837	284.557	6.220	20.800
NNAR (3,3)	0.320	0.571	0.977	0.305	62.940	256.878	5.681	16.224
NNAR (3,4)	0.089	0.764	0.987	0.767	51.966	296.305	4.936	24.711
NNAR (3,5)	0.263	0.607	0.985	0.635	45.065	270.323	4.255	17.437

Table 4. Model diagnostic and model fit statistics test of ANN models fitted to arrival of onion (Quintal) in Jarapada market of Anugul District of Odisha

Model	Model diagnostic test				Model fit statistics			
	Box-Pierce test		Shapiro-Wilk's test		RSME		MAPE	
	Chi-Square value	p- value	w value	p- value	Training data	Testing data	Training data	Testing data
NNAR (1,1)	0.849	0.3566	0.470	0.2176	316.456	248.268	27.134	100.160
NNAR (1,2)	0.583	0.4452	0.456	0.2341	294.841	239.008	25.157	96.592
NNAR (1,3)	0.090	0.763	0.429	0.3745	274.487	238.942	23.764	96.485
NNAR (1,4)	0.066	0.796	0.425	0.7461	274.318	250.142	24.475	101.093

Table 5. Model diagnostic and model fit statistics test of ANN models fitted to Price of onion (Rs/Quintal) in Anugul market of Anugul District of Odisha

Model	Model diagnostic test				Model fit statistics			
	Box-Pierce test		Shapiro-Wilk's test		RSME		MAPE	
	χ^2 value	p- value	w value	p- value	Training data	Testing data	Training data	Testing data
NNAR (2,1)	0.5489	0.458	0.751	4.026	143.538	441.252	3.347	8.259
NNAR (2,2)	0.0123	0.912	0.746	2.728	136.146	441.927	3.161	7.311
NNAR (2,3)	0.0489	0.825	0.754	4.891	134.239	438.357	3.105	6.962
NNAR (2,4)	0.0637	0.800	0.749	3.425	133.283	431.319	3.043	7.293

Table 6. Model diagnostic and model fit statistics test of ANN models fitted to Price of onion (Rs/Quintal) in Athmalik market of Anugul District of Odisha

Model	Model diagnostic test				Model fit statistics			
	Box-Pierce test		Shapiro-Wilk's test		RSME		MAPE	
	χ^2 value	p- value	W value	p- value	Training data	Testing data	Training data	Testing data
NNAR (1,1)	0.986	0.320	0.795	6.083	402.315	241.648	7.639	9.493
NNAR (1,2)	1.239	0.266	0.736	2.549	375.952	146.586	6.239	5.729
NNAR (1,3)	1.167	0.279	0.711	7.635	370.900	102.483	5.653	3.892
NNAR (1,4)	1.176	0.278	0.710	7.516	369.801	91.8464	5.589	3.357

The result of Table 4 shows that NNAR (1,1), NNAR (1,2) NNAR (1,3) and NNAR (1,4) models satisfy the test of independence and normality of residuals due to which the three models qualify for being selected on basis of model diagnostic criteria. Out of the three models NNAR (1,3) model is selected on account of lowest RMSE and MAPE. Thus the model NNAR (1,3) is used for forecasting the arrival of onion in Jarapada market of Anugul district.

The result of Table 5 shows that all fitted models satisfy the test of independence and normality of residuals due to which all the models qualify for

being selected on basis of model diagnostic criteria. Out of these models NNAR (2,4) model is selected on account of lowest RMSE and MAPE. Thus the model NNAR (2,4) is used for forecasting the arrival of onion in Anugul market of Anugul district.

The result of Table 6 shows that all fitted models satisfy the test of independence and normality of residuals due to which all the models qualify for being selected on basis of model diagnostic criteria. Out of these models NNAR (1,4) model is selected on account of lowest RMSE and MAPE. Thus the model NNAR (1,4) is used for forecasting the arrival of onion in Athamalik market of Anugul district.

The result of Table 7 shows that all fitted models satisfy the test of independence and normality of residuals due to which all the models qualify for being selected on basis of model diagnostic criteria. Out of these models NNAR (1,3) model is selected on account of lowest RMSE and MAPE. Thus the model NNAR (1,3) is used for forecasting the arrival of onion in Jarapada market of Anugul district.

Forecast values of arrivals and prices of onion crop at Five-day interval in Anugul market given in Table 8 show a stable phase while price shows decline with ups and downs in some phases.

Forecast values of arrivals and prices of onion crop at Ten-day interval in Athmalik market given in Table 9 show an incline phase while arrivals show decline with ups and downs in some phases.

Table 7. Model diagnostic and model fit statistics test of ANN models fitted to price of onion (Rs/Quintal) in Jarapada market of Anugul District of Odisha

Model	Model diagnostic test				Model fit statistics			
	Box-Pierce test		Shapiro-Wilk's test		RSME		MAPE	
	χ^2 value	p- value	w value	p- value	Training data	Testing data	Training data	Testing data
NNAR (1,1)	3.750	0.053	0.429	0.063	551.159	271.902	9.561	8.448
NNAR (1,2)	1.865	0.172	0.479	0.065	433.201	409.907	8.028	19.649
NNAR (1,3)	0.516	0.473	0.433	0.213	413.158	301.905	7.161	13.146
NNAR (1,4)	0.272	0.602	0.428	0.274	419.611	305.605	7.416	14.834

Table 8. Five-days interval forecast of wholesale onion price and arrival of Anugul market from April, 2024 to September,2024

Date	Price (in Rs./q)	Arrival (in Quintals)	Date	Price (in Rs./q)	Arrival (in Quintals)
01/04/2024	1986.939	473.8937	20/07/2024	2000.616	473.8937
06/04/2024	1998.635	473.8937	25/07/2024	1984.936	473.8937
11/04/2024	1985.651	473.8937	30/07/2024	2002.743	473.8937
16/04/2024	2000.616	473.8937	04/08/2024	1985.039	473.8937
21/04/2024	1984.936	473.8937	09/08/2024	2004.646	473.8937
26/04/2024	2002.743	473.8937	14/08/2024	1985.850	473.8937
01/05/2024	1985.039	473.8937	19/08/2024	2006.122	473.8937
06/05/2024	2004.646	473.8937	24/08/2024	1987.003	473.8937
11/05/2024	1985.850	473.8937	29/08/2024	2007.164	473.8937
16/06/2024	2006.122	473.8937	03/09/2024	2018.224	473.8937
21/06/2024	1987.003	473.8937	08/09/2024	1996.180	473.8937
26/06/2024	2007.164	473.8937	13/09/2024	2018.235	473.8937
31/06/2024	1989.341	473.8937	18/09/2024	1996.221	473.8937
05/07/2024	1986.939	473.8937	23/09/2024	2018.241	473.8937
10/07/2024	1998.635	473.8937	28/09/2024	1996.245	473.8937
15/07/2024	1985.651	473.8937			

Table 9. Ten-days interval forecast of wholesale onion price and arrival of Athmalik market from April, 2024 to September,2024

Date	Price (in Rs./q)	Arrival (in Quintals)	Date	Price (in Rs./q)	Arrival (in Quintals)
01/04/2024	2566.217	919.332	11/07/2024	2564.725	793.357
11/04/2024	2563.703	867.058	21/07/2024	2564.686	798.664
21/04/2024	2565.360	867.995	31/07/2024	2564.712	697.973
01/05/2024	2564.267	853.473	10/08/2024	2564.695	799.733
11/05/2024	2564.988	833.634	20/08/2024	2564.706	819.177
21/05/2024	2564.512	817.748	30/08/2024	2564.698	688.236
31/05/2024	2564.826	837.692	09/09/2024	2564.703	786.695
11/06/2024	2564.619	773.746	19/09/2024	2564.700	755.008
21/06/2024	2564.756	749.280	29/09/2024	2564.725	793.357
01/07/2024	2564.666	764.149			

Table 10. Five-days interval forecast of wholesale onion price and arrival of Jarapada market from April, 2024 to September,2024

Date	Price (in Rs./q)	Arrival (in Quintals)	Date	Price (in Rs./q)	Arrival (in Quintals)
01/04/2024	2235.186	521.0266	20/07/2024	2235.187	521.0266
06/04/2024	2235.186	521.0266	25/07/2024	2235.187	521.0266
11/04/2024	2235.186	521.0266	30/07/2024	2235.187	521.0266
16/04/2024	2235.186	521.0266	04/08/2024	2235.187	521.0266
21/04/2024	2235.186	521.0266	09/08/2024	2235.187	521.0266
26/04/2024	2235.186	521.0266	14/08/2024	2235.187	521.0266
01/05/2024	2235.186	521.0266	19/08/2024	2235.187	521.0266
06/05/2024	2235.187	521.0266	24/08/2024	2235.187	521.0266
11/05/2024	2235.187	521.0266	29/08/2024	2235.187	521.0266
16/06/2024	2235.187	521.0266	03/09/2024	2235.187	521.0266
21/06/2024	2235.187	521.0266	08/09/2024	2235.187	521.0266
26/06/2024	2235.187	521.0266	13/09/2024	2235.187	521.0266
31/06/2024	2235.187	521.0266	18/09/2024	2235.187	521.0266
05/07/2024	2235.187	521.0266	23/09/2024	2235.187	521.0266
10/07/2024	2235.187	521.0266	28/09/2024	2235.187	521.0266
15/07/2024	2235.187	521.0266			

Forecast values of arrivals and prices of onion crop at Five-day interval in Jarapada market given in Table 10 shows a stable phase.

Fig. 1 shows the actual, fitted and forecast values of arrivals of onion in Anugul market. The fitted values are seen to be very close to actual values which shows that the selected best fit ANN model is appropriate. The forecast values are found to show decreasing and then stable trend.

Fig. 2 shows the observed, model fit and predicted values of arrivals of onion in Athmalik market of Anugul district. The model fit values are seen to be very close to actual values which shows that the selected best fit ANN model is appropriate. The predicted values are found to be increasing and then decreasing trend with fluctuations at different intervals of time.

Fig. 3 shows the observed, model fit and predicted values of arrivals of onion in Jarapada market of Anugul district. The model fit values are seen to be very close to actual values which shows that the selected best fit ANN model is correct and the forecast values are found to show stable trend.

Fig. 4 shows the observed, model fit and predicted values of price of onion in Anugul market. The model fir values are seen to be very close to actual values which shows that the selected best fit ANN model is adequate. The forecast values are found to show decreasing and then stable trend with fluctuations at different points of time period.

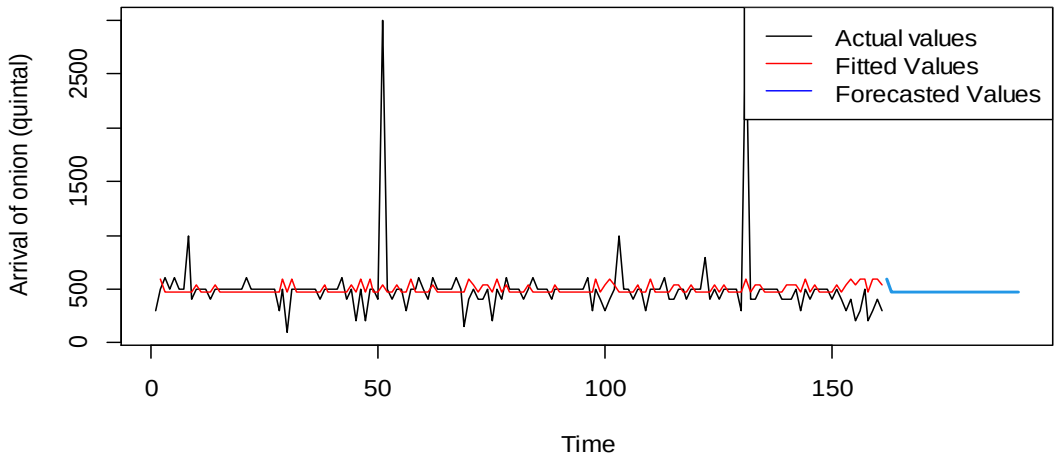

Fig. 1. Observed, model fit and predicted values of arrivals of onion (in quintal) in Anugul market of Anugul district of Odisha

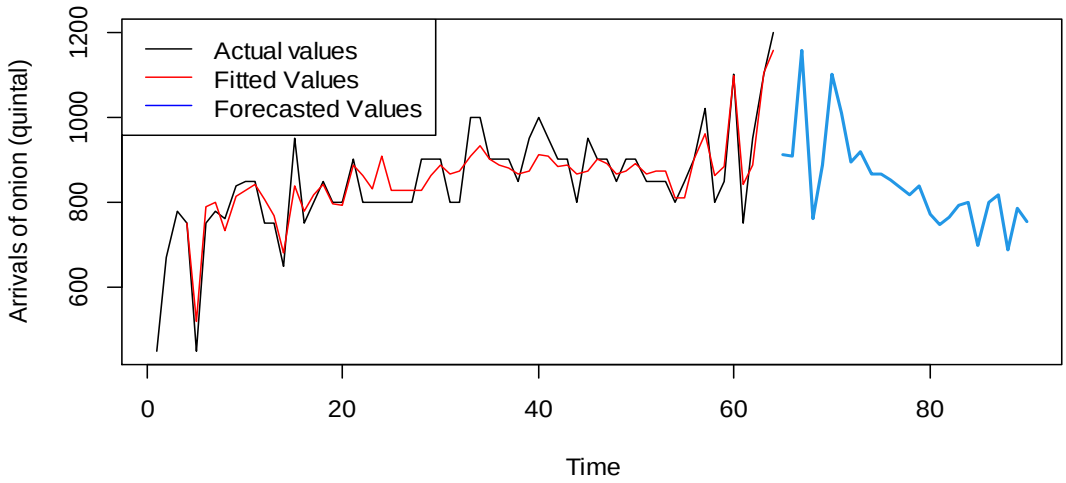

Fig. 2. Observed, model fit and predicted values of arrivals of onion (in Quintal) in Athamalik market of Anugul district of Odisha

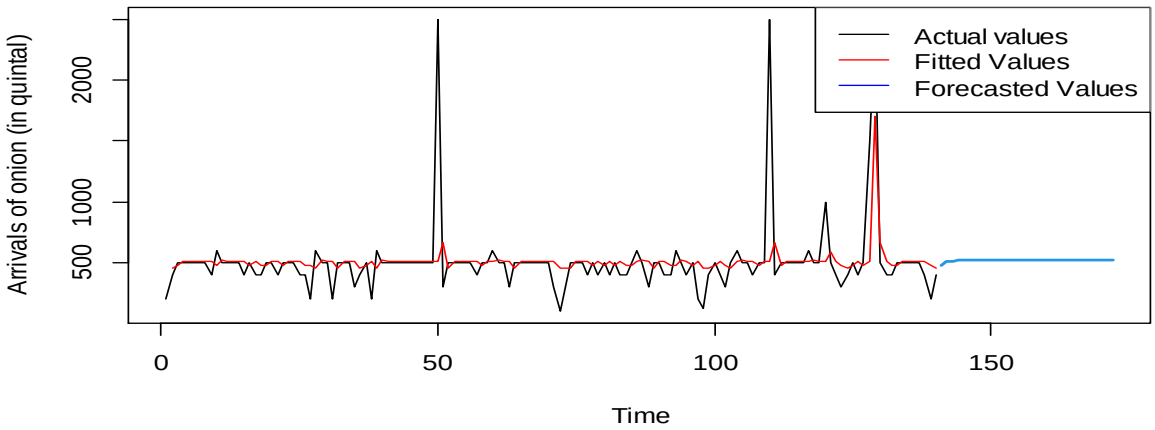

Fig. 3. Observed, model fit and predicted values of arrivals of onion (in quintal) in Jarapada market of Anugul district of Odisha

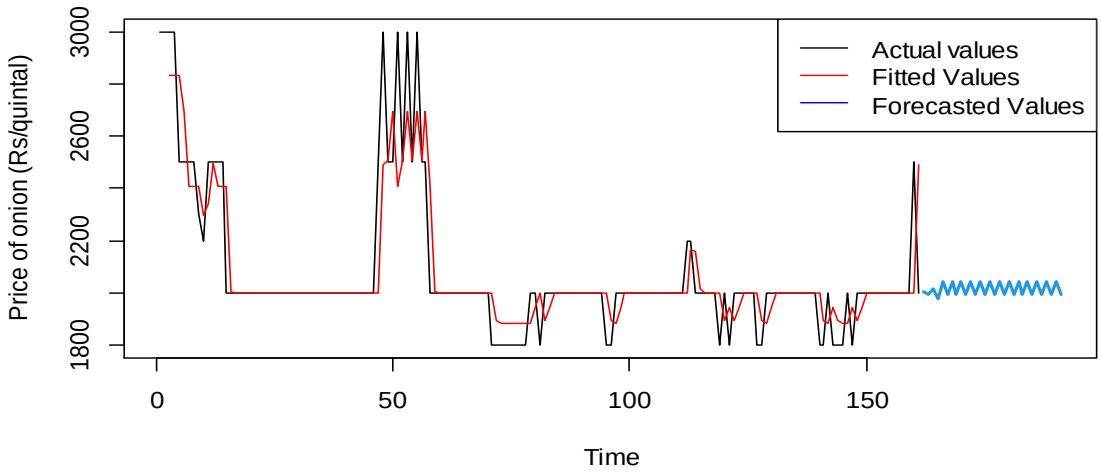

Fig. 4. Observed, model fit and predicted values of prices of onion (Rs/quintal) in Anugul market of Anugul district of Odisha

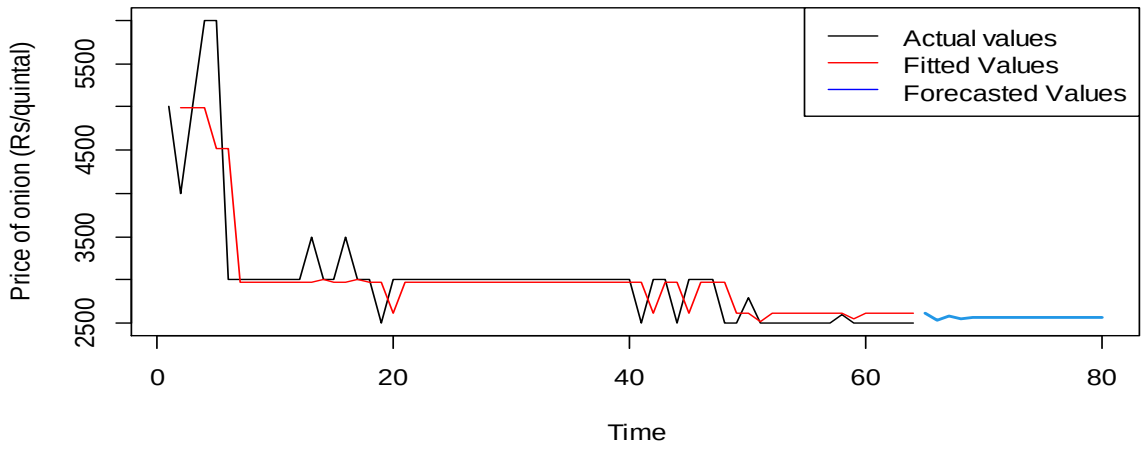

Fig. 5. Observed, model fit and predicted values of prices of onion (Rs/quintal) in Athamalik market of Anugul district of Odisha

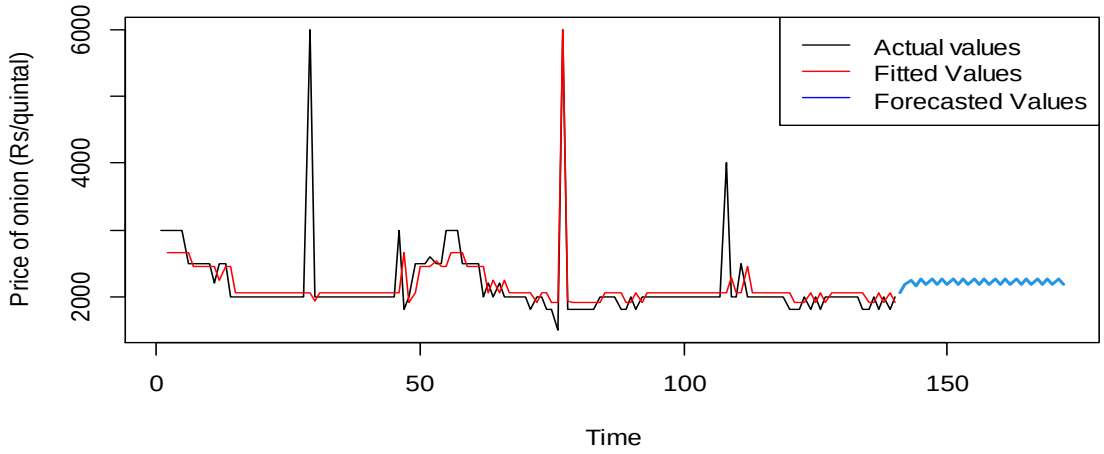

Fig. 6. Observed, model fit and predicted values of prices of onion (Rs/quintal) in Jarapada market of Anugul district of Odisha

Fig. 5 shows the observed, model fit and predicted values of price of onion in Athmalik market of Anugul district. The model fit values are seen to be very close to actual values which shows that the selected best fit ANN model is adequate and the predicted values are shows stable trend.

Fig. 6 shows the observed, model fit and predicted values of price of onion in Jarapada market of Anugul district. The model fit values are seen to be very close to observed values which shows that the selected best fit ANN model is correct. The forecast values are found to show increasing and then stable trend with fluctuations at different intervals.

4. CONCLUSION

In case of arrival data of onion, NNAR (1,1), NNAR (1,2) and NNAR (1,4) models have independent and normally distributed residuals in Anugul market. NNAR (3,2), NNAR (3,4) and NNAR (3,5) models have independent and normally distributed residuals in Athamalik market. All fitted models have independent and normally distributed residuals in Jarapada market of Anugul district. On basis of model diagnostic criteria, these models qualify for being selected. Out of the three qualifies models, NNAR (1,1) in Anugul market, NNAR (3,5) in Athamalik market and NNAR (1,3) in Jarapada market having lowest RMSE and MAPE values and thus regarded as the selected best fit model for forecasting the arrivals of onion in these selective markets of Anugul district. Similarly, in case of price of onion all the fitted ANN models of all the markets satisfy the test of independency and normality of residuals. NNAR (2,4) in Anugul, NNAR (1,4) in Athmalik and NNAR (1,3) in Jarapada market of Anugul having lowest RMSE and MAPE values. Thus they are regarded as the selected best fit model for forecasting the price of onion. The forecasted prices were compared with the actual prices for the given time period. The results revealed that ANN model predicted values were relatively closer to actual prices of onion in the selected markets. The forecasted values show a decreasing trend of both arrivals and prices in the next six months i.e. from April 2024 to September 2024 with ups and downs in some phases.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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