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**RESEARCH NOTE**

# Forecasting of Onion Prices in Bangalore Market: An Application of Time Series Models

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ABSTRACT

The present study has made an attempt to identify the best forecasting model to predict the onion prices from January, 2018 to June, 2018. The employed time series models were ARIMA (Box-Jenkins model); Artificial Neural Network (ANN); and Exponential Smoothing Models (Single, Double and Winters) to predict future prices of Bangalore onion market. For ARIMA technique, (1,1,0) (1,1,1) model was selected, the adequacy of the model was judged by maximum R-Square (72.91), minimum MAPE (21.16), RMSE (379.18) and MAE (228.18). In the case of ANN technique, ten best performing neural networks were analysed. Among them $ANN_2$ was found as a good fitted model with high $R^2$ value equal to 0.90 and lowest average absolute error value of 205.63 per cent with highest value of correlation coefficient 0.95. The forecasted values of onion prices are ranging from ₹ 1380 to ₹ 847 per quintal for the months from January to June 2018. Among the different exponential smoothing techniques, the simple exponential smoothing (SES) model was the preferred model for forecasting onion price due to the minimum value of MAPE (21), MAD (231) and MSD (144255). Comparing the actual prices with the predicted prices the results revealed that among different models, ANN model was the most suitable technique to predict future prices accurately for onion in Bangalore market. The identification of the best forecasting model and accurate forecasting of market prices would help the farmers, consumers, wholesalers as well as government in order to take appropriate decisions.

**Keywords: ARIMA, ANN, Exponential smoothing, MAD, MSD and Time series models.**

**JEL: C53, Q02, Q11, Q12**

I

## INTRODUCTION

Onion occupies the largest area under perishable vegetables in India. Total horticulture crops production was 311.7 million tonnes from an area of 25.43 million hectares during 2017-18. Area under vegetables was 10.26 million hectares with a 184.4 million tonnes of production. The share of onion in total vegetables production (23.3 million tonnes) was 12.64 per cent (Reserve Bank of India, 2019). For the present study, onion crop was selected because of huge demand and frequent price variation. Price fluctuations of agricultural commodities directly influence both consumer real income and farmers to access food. Accurate price forecasting is an important component of institutional policy making decisions and trade to stabilise domestic market prices by regulating exports and impose stock limits for local traders. Srikala *et al.* (2018) employed ARIMA, ANN and Exponential smoothing

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models to predict the future prices in Nizamabad paddy market and concluded that ANN model gives relatively closer future prices compared with the actual prices. The objective of present research was to compare the forecasting performances of different time series models, namely, ARIMA, ANN and Exponential smoothing models for forecasting of Bangalore onion market prices.

## II

## MATERIALS AND METHODS

The time series data on monthly prices of onion were collected from the registers maintained by the respective market committee and NHRDF (National Horticulture Research and Development Foundation). The data related to monthly modal prices (Rs./qtl) were collected for the period of January 2003 to December 2017 (15 years) and were used for model fitting. The data for subsequent period i.e., from January 2018 to June 2018 were used for validation for Bangalore market. As elucidated in Srikala *et al.* (2018) the forecasting model details are as follows:

### 1. *Auto Regressive Integrated Moving Average (ARIMA) Model*

In ARIMA model (Box and Jenkins, 1976), the estimated value of a variable is supposed to be a linear combination of the past values and the past errors. Generally a time series can be modelled as a combination of past values and errors, which can be denoted as ARIMA (p,d,q) which is expressed in the following form

$$Y_t = \theta_0 + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + ... + \Phi_p Y_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - ... - \theta e_{t-q} \quad ....(1)$$

where $Y_t$ and $e_t$ are the actual values and random error at time t, respectively, $\Phi_i$ (i = 1,2,……, p) and $\theta_j$ (j = 1,2,……, q) are model parameters, p and q are integers and often referred to as orders of autoregressive and moving average polynomials respectively. Random errors are assumed to be independently and identically distributed with mean zero and constant variance. Similarly, a seasonal model is represented by ARIMA (p, d, q) x (P, D, Q) model, where P = number of seasonal autoregressive (SAR) terms, D = number of seasonal differences, Q = number of seasonal moving average (SMA) terms. The main stages in setting up a forecasting ARIMA model are: (i) Model identification, (ii) Parameters estimation, (iii) Diagnostic checking and (iv) Forecasting. The ARIMA model is basically a data oriented approach that is adopted from the structure of the data itself.

### 2. *Artificial Neural Network (ANN) Model*

Neural networks are good at input and output relationship modelling even for noisy data. The greatest advantage of a neural network is its ability to model complex non-linear relationship without a priori assumptions of the nature of the relationship.

The ANN model performs a nonlinear functional mapping from the past observations ($Y_{t-1}$, $Y_{t-2}$ ,……….., $Y_{t-p}$) to the future value $Y_t$ ,i.e.,

$$Y_t = f\,(Y_{t-1}, Y_{t-2},..., Y_{t-p}, w\,) + e_t \qquad ....(2)$$

where 'w' is a vector of all parameters and f is a function determined by the network structure and connection weights. Training of the neural network is essential factor for the success of the neural networks among the several learning algorithms available in which back propagation has been the most popular and most widely implemented learning algorithm of all neural networks paradigms. The important task of the ANN modelling for a time series is to choose an appropriate number of hidden nodes, q, as well as the dimensions of the input vector p (the lagged observations). However, in practice, the choices of q and p are difficult.

3. *Exponential Smoothing Models*

3.1. *Single Exponential Smoothing (SES)*

For the time series $Y_1$, $Y_2$........., $Y_t$, forecast for the next value $Y_{t+1}$ say, $F_{t+1}$, is based on the weights α and (1 – α) to the most recent observation $Y_1$ and recent forecast $F_1$ respectively, where α is a smoothing constant. The form of the model is :

$$F_{t+1} = F_1 + \alpha\,(Y_1 - F_1)$$

The choice of α has considerable impact on the forecast. The optimum value of α corresponding to minimum Mean Square Error (MSE) is then identified.

3.2. *Double Exponential Smoothing (DES)*

The form of the model is:

$$L_t = \alpha\, Y_t + (1-\alpha)\,(L_{t-1} + b_{t-1})$$
$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)\, b_{t-1}$$
$$F_{t+1} = L_t + b_t$$

where, $L_{t-1}$ is level of series at time t
$b_t$ is slope of the series at time t
$Y_t$ is Actual value for period t
$F_{t+1}$ is Forecast value of period t
α and β (= 0.1, 0.2,..........0.9) are the smoothing and trend parameters

The pair values of parameters, α and β, which give minimum MSE are taken.

To assess the prediction accuracy of the models under study, - the following Forecast Evaluation methods were applied: Different criteria were used to make comparisons between the forecasting ability of the models. The first criterion is the

Mean Absolute Deviation (MAD). It is a measure of average error for each point forecast made by the two methods. MAD is given by

$$MAD = (1/T)\ \Sigma\ |P_t - A_t| \qquad ....(3)$$

The second criterion is the mean absolute percent error (MAPE). It is similar to AME except that the error is measured in percentage terms, and so allows comparisons in units which are different. The third criterion is mean square error (MSE), which measures the overall performance of a model. The formula for MSE is

$$MSE = (1/T)\ \Sigma(P_t - A_t)^2 \qquad ....(4)$$

where, $P_t$ is the predicted value for time t, $A_t$ is the actual value at time t and T is the number of predictions.

3.3. *Holt-Winters Multiplicative Model*

To handle seasonality present in the time series data, the third parameter is added. Assuming prices of onion is influenced by seasonal factor, third equation being introduced along with new weight ($W_3$) in order to take care of seasonality and to forecast the prices. The resulting set of equations is called the "Holt-Winters" (HW) method after the names of the inventors. There are two main HW models, depending on the type of seasonality

$$S_t = W_1 \frac{Xt}{SIt-1} + (1 - W_1)(S_{t-1} + b_{t-1})$$

where, $W_1$= level smoothing constant
SI = seasonality estimate
I= length of seasonal cycle.

Trend estimate is given by:

$$b_t = W_2 (S_t - S_{t-1}) + (1 - W_2) b_{t-1}$$

Seasonality estimate given by:

$$SI_t = W_3 \frac{Xt}{St} + (1 - W_3)\ SI_{t-l}$$

where, $W_3$= seasonal smoothing constant
Then m - Period ahead forecast is given by:

$$F_{t+m} = (S_t + mb_t) SI_{t-l+m}$$

Holt-winters additive model: Smoothing equation is given by:

$$S_t = W_1(X_t - SI_{t-l}) + (1 - W_1)(S_{t-1} + b_{t-1})$$

Trend estimate given by:

$$b_t = W_2 (S_t - S_{t-1}) + (1 - W_2) b_{t-1}$$

Seasonality estimate given by:

$$SI_t = W_3 (X_t - S_t) + (1 - W_3) SI_{t-1}$$

Forecast equation for additive seasonality:

$$F_{t+m} = S_t + mb_t + SI_{t-l+m}$$

This particular model is known as the additive model (seasonality factor is added to forecast).

*Selection of Weights ($W_1$, $W_2$, $W_3$)*

Values of all three smoothing constant/weights were obtained by trial and error method. Different onion time series were analyzed by giving different weights and the best H-WMM model in each case was selected based on the minimum MAPE and MSD value under different weights. The best price forecasting technique was selected based on the higher $R^2$ and least Mean Absolute Percentage Error (MAPE) value of all the price forecasting techniques used for predicting the future prices of onion. Deviations of predicted prices from the actual prices were calculated using the formula

$$\text{Deviation (per cent)} = \frac{\text{Actual value- Forecasted value}}{\text{Actual value}} * 100$$

The accuracy of fitted models has been tested by computing MAPE, RMSE and MAE using the formulae given below.

1. For Mean Average percentage error (MAPE) formula is

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{|X_t - \hat{X}_t|}{\hat{X}_t} \text{ x } 100$$

2. For Mean Square Error (MSE) the formula is

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(X_t - \hat{X}_t)^2$$

3. For Root Mean Square Error (RMSE) the formula is $\sqrt{MSE}$
4. For Mean Absolute Error (MAE) formula is

$$MAE = \frac{1}{n}\sum_{t=1}^{n}|X_t - \hat{X}_t|$$

where $X_t$=Actual value and $\hat{X}_t$ = predicted values

III

RESULTS AND DISCUSSION

1) *ARIMA Model*

1.1. *Identification of the Model*

Identification of the model was concerned with deciding the appropriate values of (p,d,q) (P,D,Q). It was done by observing Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) values illustrated in Figure 1. ARIMA model was estimated after transforming the price data of onion in Bangalore market into stationary series. Based on the maximum R-Square, minimum MAPE (Mean Absolute Percentage Error), minimum RMSE (Root Mean Square Error) and minimum MAE (Mean Absolute Error) the model (1,1,0) (1,1,1) was found to fit the series suitably to forecast prices in Bangalore market. The results of these coefficients are given in Table 1, from the results we conclude that the model (1,1,0) (1,1,1) is better than the other models because this model satisfied maximum R-Square, and minimum MAPE,RMSE and MAE criteria.

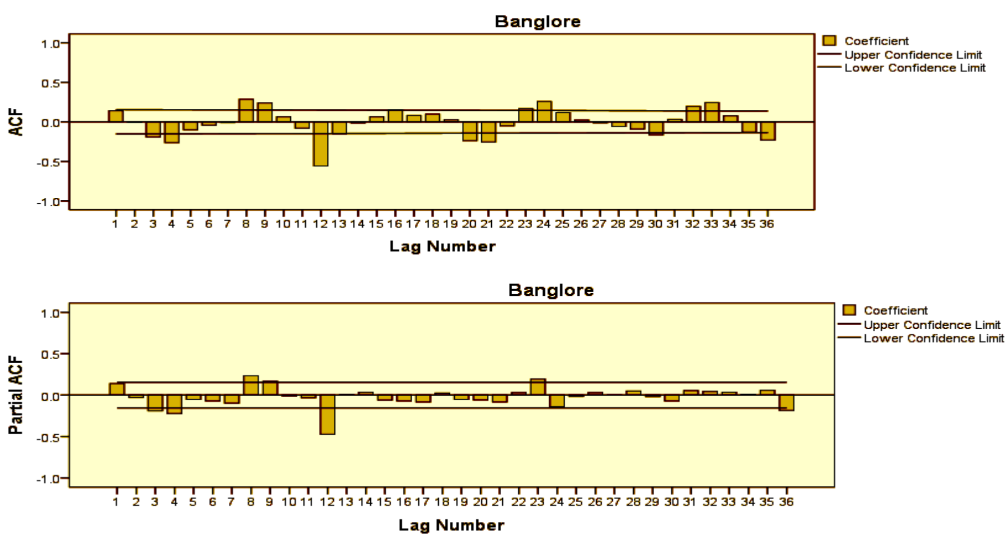


Figure 1. Autocorrelation and Partial Autocorrelation coefficients of Onion Prices in Bangalore Market.

TABLE 1. RESIDUAL ANALYSIS OF MONTHLY PRICES OF ONION IN BANGALORE MARKET

| Sr. No. (1) | Model (2) | R-square (3) | MAPE (4) | RMSE (5) | MAE (6) |
|---|---|---|---|---|---|
| 1. | (0,1,0) (2,1,1) | 72.10 | 21.64 | 385.04 | 231.47 |
| 2. | (0,1,1) (0,1,1) | 72.52 | 21.57 | 380.68 | 231.27 |
| 3. | (1,1,1) (0,1,1) | 72.63 | 21.55 | 381.60 | 231.09 |
| 4. | (1,1,0) (1,1,1) | 72.91 | 21.16 | 379.18 | 228.18 |

*Source*: Estimated by authors.

1.2. *Diagnostic Checking*

The parameters of the tentatively identified model were estimated and are presented in the Table 2. The adequacy of the model was judged by maximum R-Square (72.91), minimum MAPE (21.16), minimum RMSE (379.18) and minimum MAE (228.18). The model (1,1,0) (1,1,1) was found to be the best as to forecast onion prices in Bangalore market. The autocorrelation and partial autocorrelations of various orders of the residuals of ARIMA (1,1,0) (1.1,1) up to 36 lags were computed and shown in Figure 2. The figures showed that, the autocorrelation at lag 4 and 36 and partial autocorrelation functions at lag 4, 19 and 36 were significantly different from zero and fell slightly outside the 95 per cent confidence interval, which indicated the presence of white noise error in the residuals. Hence, except for lag 4, 19 and 36 autocorrelation was absent in the residuals. This showed that the selected ARIMA model was appropriate for forecasting the price of onion during the period under study.

TABLE 2. CONDITIONAL LEAST SQUARE ESTIMATES OF ONION PRICES IN BANGALORE MARKET

| (1) | Estimate (2) | SE (3) | t (4) | P value (5) |
|---|---|---|---|---|
| AR (1) | 0.187 | 0.079 | 2.372 | 0.019 |
| Seasonal AR (1) | - 0.083 | 0.100 | - 0.833 | 0.406 |
| Seasonal MA (1) | 0.953 | 0.214 | 4.454 | 0.000 |

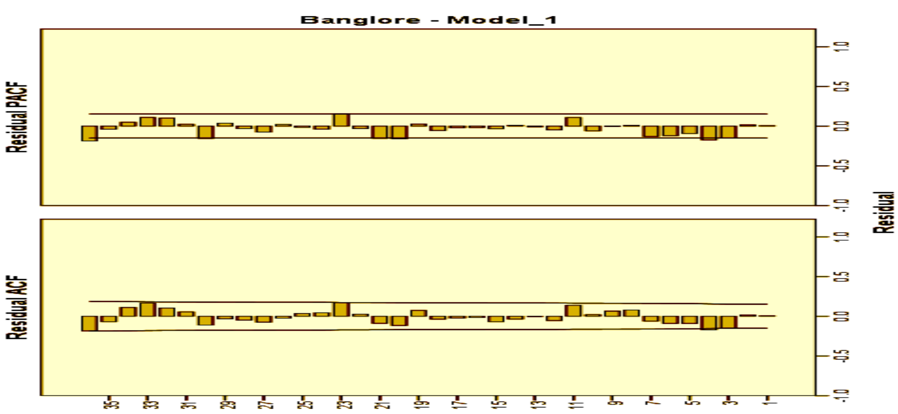


Figure 2. Autocorrelation and Partial Autocorrelation Coefficients of Residual of ARIMA (1,1,0) (1,1,1) Model for the Onion Prices.

1.3. *Forecasting Prices of Onion in Bangalore Market*

Both ex-ante and ex-post forecasting were done and it was compared with actual observations. The prices were forecasted up to June, 2018. The results of ex-ante and ex-post forecasted prices are illustrated in Figure 3. The forecast depicted that there is narrow variations in between the actual and forecasted values of prices of onion and the prices are ranging from Rs.3495 to Rs.3395 per quintal for the months from January to June 2018.

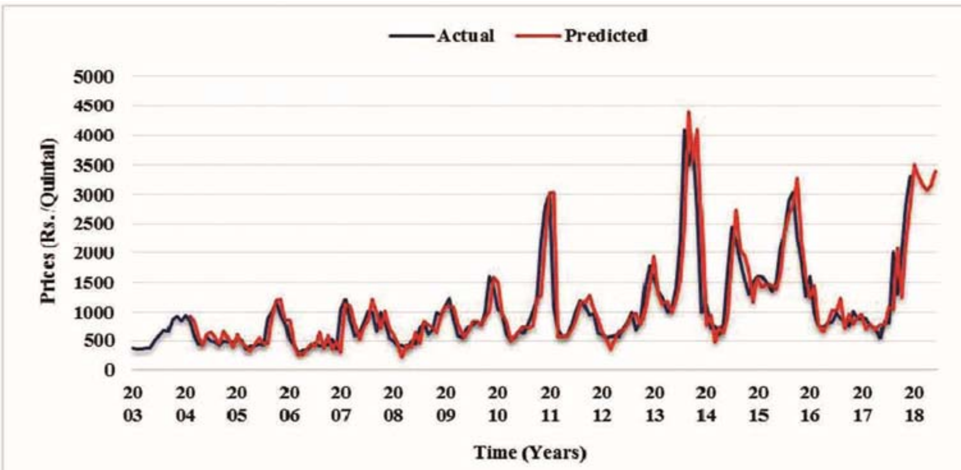


Figure 3. Actual and Predicted Prices of Bangalore Onion Market using ARIMA Technique.

2) *Artificial Neural Network (ANN) Model*

The ANN model was applied to forecast the onion prices for Bangalore market. Different numbers of neural networks were tried for the same data sets and the best performing 10 networks from each data set were selected based on minimum average absolute error, higher $R^2$ and per cent of good forecast. Table 3 and Figure 4 represent the actual and forecasted prices. In the case of price forecasting, 145 data points were considered as training set and 29 data points were considered as testing set. $ANN_2$ method was found better fitted model with $R^2$ equal to 0.90 and lowest average absolute error value of 205.63 per cent with the highest value of correlation

TABLE 3. DIFFERENT ARTIFICIAL NEURAL NETWORKS CRITERION FOR ONION PRICE FORECAST

| Year/month (1) | ANN1 (2) | ANN2 (3) | ANN3 (4) | ANN4 (5) | ANN5 (6) | ANN6 (7) | ANN7 (8) | ANN8 (9) | ANN9 (10) | ANN10 (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| R square | 0.89 | 0.90 | 0.89 | 0.89 | 0.79 | 0.87 | 0.83 | 0.81 | 0.77 | 0.84 |
| Average AE | 269.38 | 205.63 | 222.72 | 265.59 | 310.00 | 224.11 | 282.90 | 212.65 | 402.00 | 303.52 |
| Correlation Coefficient | 0.95 | 0.95 | 0.95 | 0.95 | 0.89 | 0.94 | 0.92 | 0.90 | 0.88 | 0.93 |
| Per cent of good forecast | 52 | 79 | 69 | 45 | 59 | 55 | 72 | 79 | 62 | 59 |
| Jan, 2018 | 2599 | 1380 | 3889 | 1799 | 1581 | 2259 | 3290 | 2882 | 3398 | 3100 |
| Feb, 2018 | 1293 | 537 | 3272 | 2009 | 910 | 537 | 2712 | 1942 | 2659 | 2260 |
| Mar, 2018 | 1166 | 617 | 2184 | 1094 | 623 | 295 | 1368 | 1159 | 1449 | 769 |
| Apr, 2018 | 1104 | 605 | 1445 | 1141 | 1522 | 227 | 1262 | 1419 | 901 | 1190 |
| May, 2018 | 592 | 635 | 1295 | 910 | 1437 | 533 | 746 | 733 | 518 | 2529 |
| June, 2018 | 99 | 847 | 1204 | 198 | 1507 | 874 | 539 | 821 | 582 | 4444 |

*Source*: Estimated by authors.

coefficient (0.95).The forecasted values of prices of onion and the prices are ranging from  1380 to  847 per quintal for the months from January to June 2018.

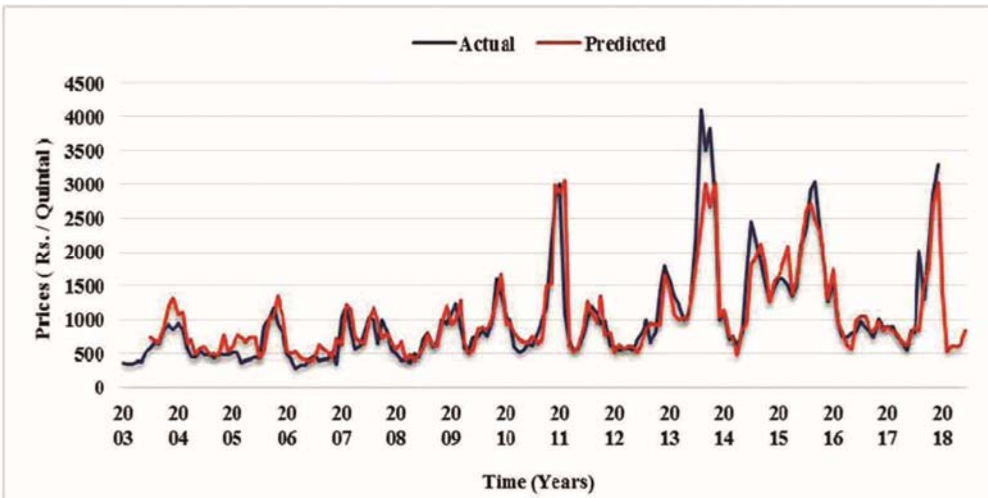


Figure 4. Actual and Predicted Prices of Bangalore Onion Market using ANN Technique

3) *Exponential Smoothing Model*

Under exponential smoothing, the weights ($W_1$,$W_2$,$W_3$) were assigned in geometric progression. Single Exponential Smoothing, Double Exponential Smoothing and Winters Multiplicative Method, all three techniques were considered for forecasting the prices of onion for the selected market. The results are presented in Table 4 and it can be inferred that the SES model is the preferred model for forecasting onion price due to the minimum value of MAPE (21), MAD (231) and MSD (144255) when compared to the other models.

TABLE 4. DIFFERENT EXPONENTIAL SMOOTHING CRITERION FOR ONION PRICE FORECAST

| Month<br>(1) | Single exponential smoothing<br>(2) | Double exponential smoothing<br>(3) | Winters multiplicative model<br>(4) |
|---|---|---|---|
| MAPE | 21 | 22 | 46 |
| MAD | 231 | 234 | 443 |
| MSD | 144255 | 147621 | 444985 |
| January 2018 | 3343 | 3343 | 2155 |
| February 2018 | 3343 | 3429 | 2642 |
| March 2018 | 3343 | 3465 | 2994 |
| April 2018 | 3343 | 3502 | 3494 |
| May,2018 | 3343 | 3538 | 2882 |
| June,2018 | 3343 | 3575 | 3465 |

*Source*: Estimated by authors.
*Note*: MAD= Mean Absolute Deviation, MSD= Mean Standard Deviation.

*Comparison of Forecasted Values with Real Time Prices for Bangalore Onion Market*

A comparison was made between the forecasted values obtained through various models, viz., ARIMA, Single Exponential Smoothing (SES) and ANN, with those of real time prices for onion in selected market in order to find out the closeness of the forecasted values of different models with real time prices. The results, presented in Table 5, indicated that results obtained through Artificial Neural Networks (ANN) were closer to real time prices over the other time series models. The results concluded that Artificial Neural Networks model shown accurancy to forecast onion prices in Bangalore market but ARIMA model shown accuracy to predict future prices in Tamil Nadu onion market (Amarnath *et al*., 2017), Kolhapur onion market of Western Maharashtra (Darekar *et al*., 2016) and Cotton prices in major producing satates of India (Darekar and Reddy, 2017). Srikala *et al.,* 2018 revealed that ANN model predicted accurate future prices compare with ARIMA and Exponential smoothing models in Nizamabad paddy market.

TABLE 5. COMPARISON OF FORECASTED VALUES WITH REAL TIME PRICES FOR ONION IN BANGALORE MARKET

| Month | Real time prices (Rs./qtl) | Bangalore market | | | | | |
|---|---|---|---|---|---|---|---|
| | | Forecasted Values (Rs./qtl) | | | Deviation (per cent) | | |
| | | ARIMA | S.E.S | ANN | ARIMA | S.E.S | ANN |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| January 2018 | 3170 | 3495 | 3343 | 1380 | -10.25 | -5.47 | 56.46 |
| February 2018 | 1630 | 3294 | 3343 | 537 | -102.09 | -105.11 | 67.08 |
| March 2018 | 840 | 3148 | 3343 | 617 | -274.76 | -298.01 | 26.49 |
| April 2018 | 610 | 3074 | 3343 | 605 | -403.93 | -448.08 | 0.84 |
| May, 2018 | 700 | 3149 | 3343 | 635 | -349.86 | -377.61 | 9.31 |
| June, 2018 | 960 | 3395 | 3343 | 847 | -253.65 | -248.26 | 11.76 |

*Source*: Estimated by authors.
*Notes*: ARIMA = Auto Regressive Integrated Moving Average.
S.E.S = Single Exponential Smoothing Method.
ANN = Artificial Neural Network.

IV

CONCLUSION

The present study employed different time series models in order to know the best model for forecasting onion prices of Bangalore market. The forecasted prices were compared with real time prices. The results revealed that ANN model predicted values were relatively closer to real time prices of onion in Bangalore market. The forecasted values show a decreasing trend of prices in the next ensuing months. The identification of the best forecasting model and accurate forecasting of market prices would help the farmers, consumers, wholesalers as well as government in order to take appropriate decisions. Short-term forecasting future prices is a key issue for the farmers to go for onion crop production in all the seasons, looking into resource availability and profitability compared to the competing crops. It would enable to plan the production in such a way that a good price for the produce could be expected in the near future and facilitate informed decisions before sowing and help in their selection of crop. As per the forecasted prices, farmers can sell the produce immediately or go for storage after harvest to fetch a remunerative price.

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