A Comparison Between Arima and Ann Models for Guntur Red Chillies Price Forecasting

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Abstract: Red chillies is one of the most important spices produced in Andhra Pradesh. Guntur APMC is the major market that trades red chillies in Andhra Pradesh. The current study is an attempt to forecast red chilli prices in Guntur market. In this study secondary data were used for the purpose of analysis. The price data of red chillies for a period of 10 years were obtained from APMC, Guntur. Training data from July 2013 to December 2022 and testing data from January 2023 to June 2023 was considered for the purpose of study. The red chilli prices of Guntur were forecasted by employing Autoregressive Integrated Moving Average (ARIMA) and Artificial Neural Network (ANN) models. The data analysis software R is used for modelling and forecasting Guntur red chilli prices. The results revealed the superiority of ANN models over ARIMA due to presence of non-linearity in the data. Government should take steps to provide accurate forecasted chilli price data to farmers which result in better price realization by farmers. Government should also frame trade policies in such a way that the country can be benefited through trade by comparing prices of commodity in our country with other countries.

1 INTRODUCTION

Chilli is one of the oldest spices used in almost every cuisine in the world (Sarojam et al., 2020). Red chilli is produced and exported most frequently in the globe by India (Swami et al., 2022). Indian chilli is highly preferred by other countries because of its colour, quality and pungency (Deepthi & Kumar, 2020; Gade et al., 2020). It is one of the most important commercial crops that is being cultivated in India. In the year 2021-22, 18.36 lakh tonnes of red chilli were produced in an area 8.8 lakh ha. in our country. Major chilli producing states in India are Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka and Orissa. These states contribute nearly 90 per cent of chilli production in India. Though the area under chilli crop is largest in Andhra Pradesh, production of chilli crop is highest in Telangana due to highest productivity (4.15 t/ha) of the crop in that state (Spices Board of India, 2022).

Guntur market, which is reputed as Asia's biggest red chilli market draws in produce from throughout the state as well as international purchasers. During peak season lakhs of farmers flood to the Guntur market to sell their produce. The chilli farmers have to sell their produce in Guntur market through e-National Agriculture Market (e-NAM) only. The trading of produce through e-NAM influence the costs and returns of farmers (Malleswari et al., 2023). Though the market yard consists of well-equipped quality assaying laboratory, it is practically impossible to test produce of each and every farmer as the number of farmers coming to market to sell their produce are very high. The place in the market yard is also not sufficient for formation of lots. The lots may be drenched during rainy season. All these problems resulted in decreased efficiency in marketing of chillies through e-NAM.

In general, price of an agricultural commodity influenced by quantity of arrivals. These prices fluctuate more when compared to other commodities due to presence of non-linearity and non-stationarity of data (Vijay & Mishra, 2018; Sun et al., 2023). So, there is presence of risk and uncertainty while

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forecasting prices of these agricultural commodities (Naveena et al., 2017). This affects the policies on price stabilization of agricultural commodities that are framed by the government. This in turn result in loss to the society as well as to the economy of the country (Prasetyo et al., 2023).

Accurate price forecasting of agricultural commodities is vital issue that need to be addressed at present. The importance of price forecasting of agricultural commodities increased recently due to increased price volatility (Rathod et al., 2017). In general, price volatility is high for vegetables but recently volatility of commercial crops has also increased which in turn increase the need for accurate model for price forecasting.

The time series forecasting of agricultural commodities plays a vital role for sustainability of economy for developing countries as the economy of these countries depend on agriculture. The agricultural prices are influenced by many factors such as weather, pests and diseases, political changes etc. The accuracy of a model can be increased if we include all these factors in the forecasting model but in the current study, the forecasting model is built by using only the past price data of the commodity. The primary goal of present study is to assess the forecasting ability of ARIMA and ANN models.

The objectives of the current study are

1. To forecast the red chilli prices in Guntur Market using ARIMA and ANN models
2. To compare the accuracy of both the models

2 MATERIALS AND METHODS

In the current study, secondary data were used for the purpose of analysis. The price data of red chillies were obtained from market yard of Guntur. Monthly price data for a period of 10 years were used for analysis. Of which data from July 2013 to December 2022 were used to derive Autoregressive Integrated Moving Average and Artificial Neural Network models. Chilli prices from January 2023 to June 2023 were forecasted using these models and the forecasted data were compared with actual prices of red chillies. The data analysis software R is used for modelling and forecasting of red chilli prices in Guntur market.

2.1 Autoregressive Integrated Moving Average (ARIMA) Model

ARIMA is one of the classical techniques for non-stationary analysis. ARIMA models can be described with historical or lagged values and random error terms. ARIMA models are also known as a family of mixed models. The forecasting process more complicated in mixed models but they result in accurate predictions. A pure model is nothing more than a model that has only AR or MA components but not both. The integration term (I) is the inverse process of variance and is used to generate estimates. ARIMA model stands for ARIMA (p d q). The ARIMA model is shown as follows;

$$\emptyset(B)(1-B)^d Y_t = \theta(B)\varepsilon_t \quad (1)$$

$$Y_t = \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \cdots + \emptyset_p Y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} \quad (2)$$

The model parameters are $\emptyset i$ and θj; the time series is denoted by Yt, random error is represented by εt, the number of autoregressive terms is p, the number of moving terms is q, and the backshift operator is B such that, $BY_t = Y_{t-1}$ (Box & Jenkins 1994; Brockwell & Davis, 1996). In the past, all types of data were exclusively analysed with the ARIMA model. However, as analytical software has advanced, a plethora of new methodologies have emerged that have aided in precise prediction (Abdulali & Masseran, 2021).

2.2 Artificial Neural Network (ANN)

ANN functions just like central nervous system of brain. It's the machine learning technology that's been employed the most in recent years. ANN is often called as regressive neural network because it uses independent observations as inputs (Varshney & Srivastava, 2023). The framework for ANN can be modelled mathematically using neural network as well as physical parameters. The general expression of the final output Y_t of the multi-layer feed forward autoregressive neural network is as follows;

$$Y_t = \alpha_0 + \sum_{j=1}^{q} \alpha_j \, g\left(\beta_{0j} + \sum_{i=1}^{p} \beta_{ij} + Y_{t-p}\right) + \varepsilon_t \quad (3)$$

where, α_j (j = 0,1,2, … , q) and β_{ij}(i = 0,1,2, … , p, j = 0,1,2, . . . , q) are the model parameters, also called as the synopsis weights, p is the number of input nodes, q is the number of hidden nodes and g is the activation function. The difference between real and anticipated values is lessened with ANN training. The following is the autoregressive ANN's error function.

$$E = \frac{1}{N}\sum_{t=1}^{N}(e_t)^2 \quad (4)$$

$$E = \frac{1}{N}\sum_{t=1}^{N}\left\{X_t - \left(w_0 + \left(\sum_{J=1}^{Q} w_J\, g\left(w_{oj} + \sum_{i=1}^{p} w_{ij} X_{t-i}\right)\right)\right)\right\}^2 \quad (5)$$

where, N represented total number of residual terms. The parameters of the neural network w_{ij} change when changes occur in Δw_{ij} as $\Delta w_{ij} = -\eta \partial E / \partial w_{ij}$, where, η represented learning rate.

2.3 Testing Accuracy of the Model

The accuracy of the model used for forecasting is tested with the help of a measure, Mean Absolute Percentage Error (MAPE). MAPE is simple average of absolute percentage errors. It is a relative measure that uses absolute values. It is represented as follows

$$\text{MAPE} = \sum_{j=1}^{n} \frac{\left|\frac{d_j - y_j}{d_j}\right|_{x^k}}{n} \times 100 \quad (6)$$

Where d_j means the actual value of j, y_j represented forecasted value and n represented total number of observations.

Lewis (1982) has categorised the accuracy of forecasting model based on MAPE. If MAPE is ≤ 10% then the accuracy of model considered to be excellent, if it is in the range of 10% to 19% then the model is good and if the range is in between 20% and 49% then the model reasonable. If the value of MAPE is more than 50% then the model is considered as not accurate.

3 RESULTS AND DISCUSSION

The data set of Guntur red chilli prices from July 2013 to December 2022 was used for the purpose of building the model and from January 2023 to June 2023 was used for checking the validation of the model.

3.1 Price Movement of Dry Chillies in Guntur Market

Chilli prices obtained from Guntur market for the period from July 2013 to June 2023 and found to be varied from Rs.7300 in 2013 (July) to Rs. 20500 in 2023 (June). In the span of 10 years chilli prices have increased more than double in the Guntur market. The average price recorded for the period from 2006 to 2016 was Rs. 11637 and in that period the prices of chilli per quintal was at its minimum in June 2017 i.e., Rs. 3200 and maximum price was realized in July of 2022 i.e., Rs. 24000 which was presented in Figure 1. It can be clearly observed from the graph that prices of chilli in Guntur market yard are increasing over the years. The maximum price in the year 2022 is because failure of crop due to black thrip infestation.

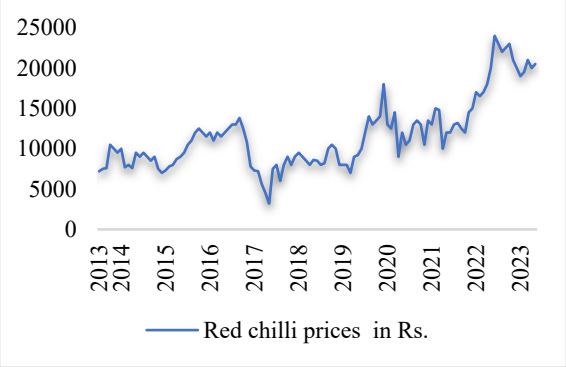

Figure 1: Time series data of red chilli prices in Guntur market

3.2 ARIMA Model Building

ARIMA model is built in statistical software R with the help of tseries and forecast packages. The best ARIMA model is ARIMA (2,1,1) out of all the models. The parameters pertaining to this model are tabulated and represented in Table 1. The coefficients of all the parameters in ARIMA model are found to be significant at 1 per cent probability level.

Table 1: Estimation of parameter for ARIMA (2,1,1) model for Guntur red chilli prices

	Estimate	Std. Error	Z value	Sig.
AR Lag 1	-1.1103	0.1019	-10.8899	0.00
AR Lag 2	-0.2797	0.0923	-3.0309	0.00
MA Lag 1	0.9579	0.0623	15.3694	0.00

The ARIMA model is best model if the data is linear. But if the data is non-linear then this model is not suitable. So, with the help of Brock, Dechert and Scheinkman (BDS) test the non-linearity of data is checked. The results of the BDS test were presented in Table 2. Non-linearity checked for both 2 and 3 dimensions. The results reveal that data is non-linear in nature.

Table 2: Test of non-linearity for residuals ARIMA for Guntur red chilli prices

Parameter	m=2		m=3	
	Statistic	Prob.	Statistic	Prob.
2169.953	35.7509	0.000	51.7245	0.000
4339.905	19.0427	0.000	21.5662	0.000
6509.858	16.2100	0.000	16.2278	0.000
8679.811	16.0743	0.000	15.5886	0.000

3.3 Building of ANN Model

The neural network is shown to have an input layer with an input node and hidden layer with a single hidden node and output layer with an output node. The software showed the best ANN model is NNAR (1,1).

3.4 Evaluation of Models

The MAPE values of both the models are presented in Table 3. The MAPE value of ARIMA model and ANN model are 11.12 and 9.36 respectively. According to Lewis, ARIMA model is good and ANN model is excellent based upon the MAPE values. This is due to non-linearity nature of data.

Table 3: Results of accuracy test for forecasted models of Guntur red chilli prices

	ARIMA fitted	ANN fitted
MAPE	11.12	9.36

In Table 4, the forecasted prices red chillies of Guntur market are presented. The prices are forecasted for a period of six months i.e., from January 2023 to June 2023. The actual prices of chillies in these six months lies within the range of Rs. 19000 per quintal to Rs. 21000 per quintal. The forecasted chilli price values through ARIMA model lies in the range of Rs. 21406.43 to Rs. 21555.47 per quintal. Whereas through ANN model the predicted prices of chillies have shown a gradual decrease and the prices decreased from Rs. 20842.91 per quintal in January 2023 to Rs. 20266.72 per quintal in June 2023. The errors in ARIMA model are from Rs. 524 to Rs. 2498 per quintal. The errors in ANN model are from Rs. 233 to Rs. 1703 per quintal. The errors in ARIMA model in forecasted values are huge when compared to errors in ANN models (Mohammad et al., 2024). It can be clearly observed that the forecasted prices through ANN model are nearer to actual values when compared to forecasted prices through ARIMA model (Kumar et al., 2018).

Table 4: Forecasted prices of Red Chilli in Guntur market - ARIMA vs ANN

	Actual data	ARIMA fitted	Error in ARIMA
2023-January	20000	21555.47	-1555.47
February	19000	21498.14	-2498.14
March	19500	21406.43	-1906.43
April	21000	21524.30	-524.30
May	20000	21419.08	-1419.08
June	20500	21502.93	-1002.93
	Actual data	ANN fitted	Error in ANN
2023-January	20000	20842.91	-842.91
February	19000	20702.86	-1702.86
March	19500	20577.15	-1077.15
April	21000	20463.65	536.35
May	20000	20360.64	-360.64
June	20500	20266.72	233.28

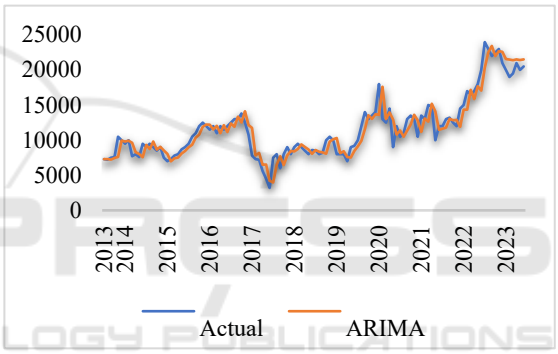

Figure 2: Comparision of Actual and ARIMA fitted red chilli prices

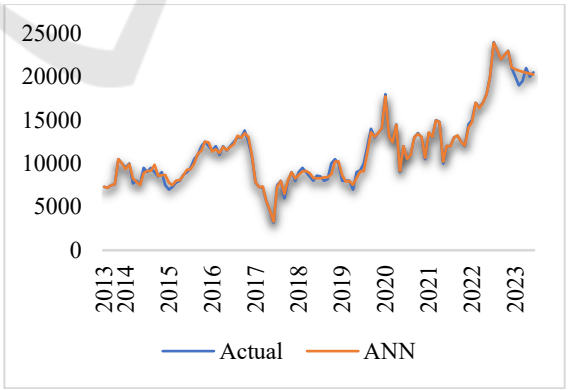

Figure 3: Comparision of Actual and ANN fitted red Chilli price

The same can be depicted in figures. Figure 2 present the comparision of Actual and ARIMA fitted red chilli prices. The graph showed clear demarcation

and there we can able to observe two price lines and there is not much overlapping of lines.

In Figure 3 showed comparision of Actual and ANN fitted red chilli prices. Both the graphs are overlapping and most part of the graph, we can able to observe only single line because of this overlapping.

During 2023, the forecasted red chilli prices are deviating from actual prices because price fluctuations during that particular period were high as a result crop failure due to black thrips infestation.

4 CONCLUSIONS

The nature of data that is considered for the study purpose will determine the model suitable for predicting prices. This is a matter of major concern while predicting agricultural commodity prices. The current analytical study concluded that Artificial Neural Network model is the best model when compared to ARIMA model due to presence of non-linearity nature in the data. The accuracy of the forecasting can still be increased by usage of hybrid models where we can use ARIMA for linear part of data and ANN for non-linear part of data.

Accurate price forecasting of agricultural commodities is vital and helpful for attaining sustainability of an agrarian economy. Accurate price forecasting before the sowing season can help the farmers in taking decision on selection of crop for sowing which in turn result in better returns. If the farmer is informed about the market which provides the best price, then the farmer can plan in advance and sell the produce in that market and get better price realisation.

Government should take steps to inform the accurate prices to farmers which result in better price realization by farmers. Government should also frame trade policies in such a way that the country can be benefited through trade by comparing prices of commodity in our country with other countries.

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