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An empirical investigation on turmeric prices of Duggirala market using machine learning model

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ABSTRACT

This study is an attempt to model and forecast the Turmeric prices in Duggirala market of Andhra Pradesh by using secondary monthly time series data from Jan10 to Apr 2025. A comparision study was made between Generalized Autoregressive Conditional Heteroskedasticity (GARCH) and Artificial Neural Network models (ANN). The Box-pierce test was also verified to know the adequacy of the model. The selection of the appropriate model was done on the basis of diagnostic criterion such as RMSE, MAPE and MAE. Finally, NNAR (3-6-1) model was recognised as the best model to forecast the turmeric prices based on the diagnostic criterion.

Keywords: *Duggirala, Model, Price and Turmaric*

Turmeric is also an important commercial spice crop grown in India, popularly known as "Indian saffron." It is also called the "Golden Spice of India" and has been used since antiquity as a spice, dye and aromatic stimulant in several medicines. For the year 2023-24, India's production was recorded as 10.63 lakh tonnes under cultivated over an area of 2.92 lakh hectares. The major turmeric-producing states in India are Maharashtra, Tamil Nadu, Telangana, Karnataka, Madhya Pradesh and Andhra Pradesh. In Andhra Pradesh, 0.38 lakh tonnes of turmeric was produced under an area of 0.22 lakh hectares for the year 2023-24. India exported 1.62 lakh tonnes of turmeric in 2023-24, valued at Rs. 1875.86 in Crores.

MATERIAL AND METHODS

The Turmeric crop of Duggirala was selected for the study due to its economic importance and the availability of secondary data for the period of 184 months during Jan 2010 to Apr 2025 from Agmarket (agmarket.gov.in). In this study 178 data points used for model building and 6 data points used for model validation. Statistical tools namely ADF test, Box-pierce test, ARCH-LM test, GARCH and ANN models were employed in the study, in addition to descriptive statistics and outlier detection techniques.

Test for Outlier

For detecting the outlier in the time series, Grubbs' test was used in the current scenario as the test is particularly useful in case of large sample and easy to follow. *Graph pad* software was employed in the present study to identify the existence of outliers (Sahu, 2010).

GARCH Model

GARCH is a mechanism that includes past variances in the explanation of future variances. More specifically, GARCH is a time series technique that allows users to model and forecast the data series by considering conditional variance of the errors. If an ARMA model is assumed for the error variance, the model is called GARCH (Muanenda, 2018).

The basic GARCH model has two equations; one equation is to describe the behaviour of the mean and another to describe the behaviour of the variance. Here, mean equation (Y_t) is a stationary time series which may be either from a linear regression function that contains a constant or possibly some explanatory variables or it may be from AR model.

Artificial Neural Network model (ANN)

The ANNs are generally constructed by layers of units i.e., artificial neurons or nodes, hence termed as multilayer ANNs, such that each unit in a layer performs a similar task. The very first layer consists of the input units, which are statistically known as the independent variables. Similarly, the last layer contains the output units, statistically known as the response or dependent variables. The rest of units in

the model are known as the hidden units and constitute the hidden layers.

In the present study, single hidden layer with multilayer feed forward network was employed in developing ANN model, which is considered as the most popular for time series modeling and forecasting (Rathod *et al.,* 2017). This model is characterized by a network of three layers of simple processing units. The first layer is input layer, the middle layer is the hidden layer and the last layer is output layer, as shown in the Figure 1.

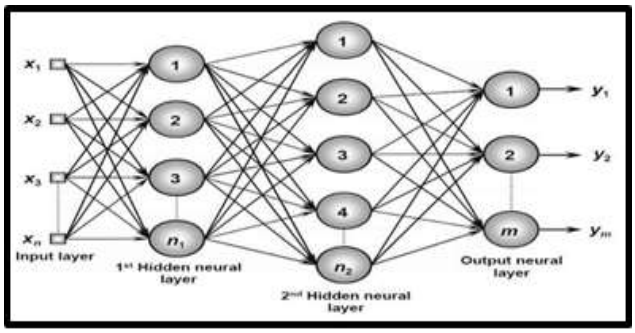

Figure 1: Architecture of Multilayer feed for ward networks

In this study, model performance among the selected ANN models was verified by diagnostic criterion namely MAPE, MAE and RMSE. In addition to this diagnostics, Box-Pierce test was also employed to verify weather the residual of series were independently distributed or not.

Comparison among the Selected Models

The appropriate model between the GARCH and ANN model were further compared by the diagnostic criterion (RMSE, MAPE and MAE).

RESULTS AND DISCUSSION

From Table-1, it was confirmed that there were no outliers detected from the Grubbs' test during the study period. It was observed that the prices of Turmeric during the study period had varied from 2901.80 to 12850.00 Rs. /Q. with an average of 6941.03 (Rs. /Q.). Standard deviation was recorded as 2345.74, which indicated that the prices were dispersed highly over the months.

GARCH

To employ the selected nonlinear time series model (GARCH), stationary of data series had to be examined first. For this, Augmented Dickey Fuller

Table 1. Descriptive statistics for prices of turmeric in Duggirala market

Turmeric	Prices (Rs. / Quintal)
Mean	6941.03
Maximum	12850
Minimum	2901.8
Standard deviation	2345.74
Outlier detected (Grubbs test)	No
QS test	0.85

(ADF) test was applied to the market prices of Adoni as to verify the stationarity of data series. From Table 2, it was also concluded that the data series was non stationary and became stationary at first difference as the null hypothesis was not accepted at 5% LOS as p-value was 0.01 (<0.05).

Later, the GARCH model was developed by using mean equation (Y_t), as a stationary time series of Autoregressive (AR) model. Before employing the GARCH model, residuals of AR (1) model was

Table 2. Result of ADF test for the prices of Tur meric in Duggirala market

Turmeric	Data type	ADF statistic	Critical value (P value)	Decision
Duggirala	ADF at level	-2.5	0.36	Data Non-Stationary
	ADF at 1st difference	-5.52	0.01	Data became Stationary

verified for existence of ARCH effect. From ARCH-LM test, it was found that the residuals of mean equation model had heteroskedastic nature, as due to significant prob. value (0.04) at 5% LOS. Hence GARCH (1,1) model was developed by using AR (1) model [as mean equation model $(Y_t = 22.37+0.84Y_{t-1+} e_t)$] and their model fit statistics were depicted in Table 3.

GARCH model for Turmeric Prices at Duggirala Market (Y_t)

Mean Equation $(Y_t) = 22.37+0.84Y_{t-1+} e_t$ .....(1)

Where $e_t = v_t \sqrt{h_t}$ and h_t satisfies the variance equation

Variance equation $(h_t) = 2141+ 0.74\, \varepsilon^2_{t-1} + 0.18\, h_{t-1}$.....(2)

Table 3. Estimated parameters and model fit statistics by GARCH model for the prices of Turmeric in Duggirala market

Model form	Mean Equation		Variance Equation		
	Constant	AR1	Constant	ARCH effect (α1)	GARCH effect (β1)
AR(1)-GARCH (1,1)	22.37	0.84**	2141.00**	0.74**	0.18**
** Significant at 1% level, * Significant at 5% level					

Model Diagnostics	R-square	RMSE	MAPE	MAE	AIC
	0.81	992.14	8.34	561.72	16.27
	Box – Pierce test for residuals (Prob.) 0.26				
	LM test for residuals (Prob.): 0.15				

From Table 3, the selected model was identified with the diagnostic criterion i.e., RMSE (992.14), MAPE (8.34) and MAE (561.72). Later, residual analysis was also carried out to check the adequacy of the selected model through ARCH-LM test, which further confirmed that the residuals had no heteroskedastic nature, as due to non-significant prob. value (0.15) at 5% LOS.

Artificial Neural Network (ANN) model:

A multilayer feed forward neural network architect with back propagation was considered for the Turmeric prices of Duggirala market during the study period. As a result, 3 lags were identified as optimal for network as input nodes. Now various network topologies were trained by increasing the number of hidden nodes from 1 to 25, by using the sigmoid function as an activation function in the hidden layer. Among several tentative models, the top performing models were listed in Table 4., based on RMSE, MAE and MAPE. A neural network model with 3-6-1 was outperformed among all other neural networks with lower RMSE (669.89), MAE (421.26) and MAPE (6.44) values.

Further, residual analysis was also carried out to check the adequacy of the selected neural network model and it was discovered that none of the lags of residual ACF chart were found to be significant as per Figure 2 and the Box-Pierce test was also confirmed the same as its p-value was 0.50 (>0.05), hence null hypothesis was accepted as residuals were independently distributed, which also indicated good fit of the selected model i.e., NNAR (3-6-1).

Table 4. Performance of different Neural Network models

Network structure (Turmeric in Duggirala)	RMSE	MAE	MAPE
03-01-2001	961.58	566.42	8.47
03-02-2001	870.11	545.74	8.2
03-03-2001	791.47	494.15	7.5
03-04-2001	746.25	462.78	7.03
03-05-2001	705.91	445.62	6.82
03-06-2001	669.89	421.26	6.44
03-07-2001	673.13	425.13	6.56
03-08-2001	679.16	430.18	6.63

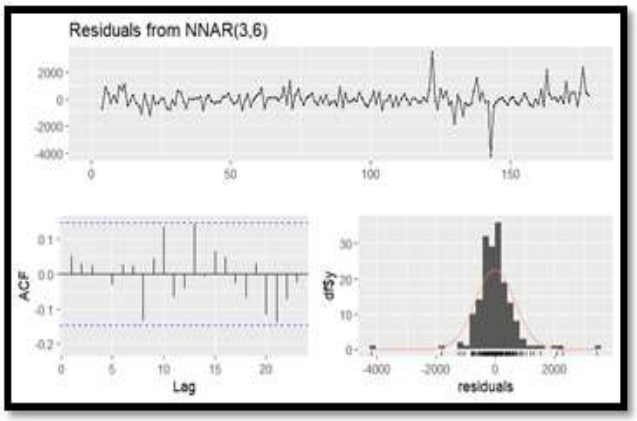

Figure 2. Residual plots for the prices of Turmeric in Duggirala market

Table 5. Model fit statistics between the selected time series models (GARCH, ANN) to the prices of Turmeric in Duggirala market

Criterion\ Model	GARCH	ANN
RMSE	992.14	669.89
MAPE	8.34	6.44
MAE	561.72	421.26

From Table 5, it was revealed that between the selected time series models [GARCH, ANN], the most plausible model was recognised as NNAR (3-6-1) due to the better diagnostic criterion i.e., RMSE (669.89), MAPE (6.44) and MAE (421.26). Similar kind of ANN model was obtained as adequate over ARIMA, GARCH by Badal *et al*. (2023), for forecasting the tomato prices in Varanasi.

Table 6. Predicted values of ANN for the prices of Turmeric in Duggirala market

Period	Actual	Forecasted	Forecast Error (%)
Nov-24	11075.60	11027.22	0.44
Dec-24	10970.30	10230.91	6.74
Jan-25	11075.00	9750.01	11.96
Feb-25	10472.60	9458.56	9.68
Mar-25	10446.30	9053.96	13.33
Apr-25	11300.40	8376.24	25.88

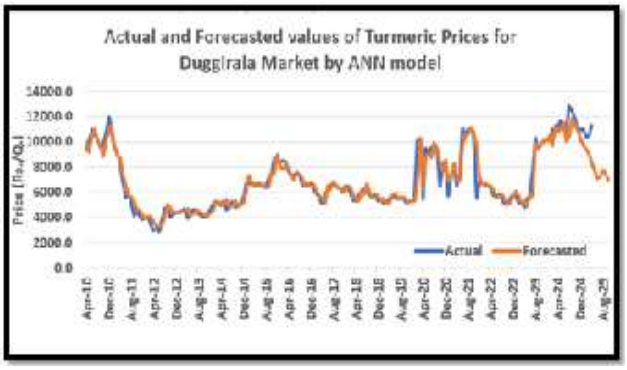

Figure 3. Actual and fitted graph of ANN for the prices of Turmeric in Duggirala market

CONCLUSION

The average price of Turmeric in Duggirala market during the study period (Jan 2010 to Apr 2025) was obtained as 6941.03 (Rs. /Q.) with a simple growth rate (SGR) of 0.10% per month and Standard Deviation was recorded as 2345.74, which indicated that the prices were dispersed highly over the months. Further it was informed as the there was no significant outlier was found during the study period. After conducting a comparative study between the selected models GARCH and ANN in that ANN (3-6-1) outperformed the GARCH model by obtained low diagnostic criterion i.e., RMSE, MAPE and MAE obtaining.

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