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Statistical Modeling on Groundnut Prices in Adoni Market using Hybrid Timeseries Models

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ABSTRACT

Present study made an attempt to forecast the Groundnut prices in Adoni market of Andhra Pradesh through a comparative study on models namely ARIMA, GARCH, and hybrid ARIMA-GARCH model. The selection of the appropriate model was done on the basis of diagnostic criterion such as R^2, RMSE and MAPE. Finally, ARIMA (1,1,1) - GARCH (1,1) model emerged as the best model to forecast the groundnut price based on the selected diagnostic criterion and residual correlogram. By using the model, for January 2024, it was estimated at 6984.69 (Rs. Q.).

Keywords: *Groundnut, Price, ARIMA, and GARCH.*

Groundnut (*Arachis hypogaea* L.) king of oil seeds is valued for its high-oil content and edible seeds. It is the fourth most important source of edible oil and the third most important source of vegetable protein in the world. Across the landscape of India-2021, Groundnut was grown in an area of 5.75 million hectares with a production of about 10.11 million tonnes and an average productivity rate of 1795 kg/ha. Notably, Groundnut holds a dual role in India, not only serving as an essential oilseed crop but also playing a pivotal role as a prominent agricultural export commodity, thereby contributing to the nation's trade dynamics and economic growth. India's groundnut exports during (April-August 2022) stood at US$ 223.52 million for the quantity of 177,938.21 MT. Major producing states of India are Gujarat, Rajasthan, Tamilnadu, Andhra Pradesh and Karnataka. In Andhra Pradesh, groundnut is cultivated in an area of 8.2 lakh hectares with a production of 5.2 lakh tonnes, contributing 5.13% to India groundnut production for the year 2021-22

MATERIAL AND METHODS

The Groundnut crop of Adoni market was selected for the study due to its economic importance and availability of secondary data for the period of 147 months during Jan 2011 to Apr 2023 from Agmarknet (agmarknet.gov.in). Various statistical tools namely ARIMA, GARCH and ARIMA-GARCH models were employed in the study, in addition to descriptive statistics and outlier detection techniques.

ARIMA Model

ARIMA (p,d,q) model which is a combination of Auto Regressive (AR) and Moving Average (MA) with an order of integration or differencing (d), where p and q are the order of autocorrelation and moving average respectively (Box and Jenkins, 1976) was selected.

The Auto-regressive model of order p denoted by AR (p) is as follows:

$$Y_t = c + \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \ldots + \emptyset_p Y_{t-p} + e_t$$

The Moving Average (MA) model of order q or MA (q) can be written as:

$$Y_t = c - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \ldots\ldots - \theta_q e_{t-q} + e_t$$

Where c is constant term, $\emptyset_p$ is the p^{th} autoregressive parameter, θ_q is the q^{th} moving average parameter and e_t is the error term at time 't'.

ARIMA in general form is as follows:

$$\Delta^d Y_t = c + (\emptyset_1 \Delta^d Y_{t-1} + \ldots + \emptyset_p \Delta^d Y_{t-p}) - (\theta_1 e_{t-1} + \ldots + \theta_q e_{t-q}) + e_t$$

where Δ denotes difference operator like

$\Delta Y_t = Y_t - Y_{t-1}$ (data form of first order differentiation)

$\Delta^2 Y_{t-1} = \Delta Y_t - \Delta Y_{t-1}$ (data form of second order differentiation)

Here, $Y_{t-1}, \ldots, Y_{t-p}$ are values of past series with lag 1, …, p respectively.

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.

Hybrid Model (ARIMA-GARCH):

Zhang (2001) proposed a hybrid approach that decomposes a time-series process into its linear and nonlinear component. The hybrid model considers the time-series $Y_{5\emptyset a\ddot{U}}$ as a combination of both linear and nonlinear components.

That is, $Y_t = L_t + N_t$; where L_t and N_t represent the linear and nonlinear component present in the given data, respectively, which are to be estimated from the data.

This hybrid method of combining forecasting has following steps:

- First, a linear time-series model, say, ARIMA is to be fitted to the data.
- At the next step, residuals of the fitted linear model, has to be verified for nonlinear component (ARCH effect). Let $e_{5\emptyset a\ddot{U}}$ denotes the residual at the time 5ØaÜ from the linear model, then $e_t = Y_t - L_t$
- Once the residuals of linear model confirm the ARCH effect, then the residuals are modelled using a nonlinear model (GARCH). And also obtain the forecast values, $\hat{N}_t$ for the residual series.
- Finally, the forecasted linear and nonlinear components are combined to obtain the aggregated forecast values as $\hat{Y}_t = \hat{L}_t + \hat{N}_t$

In the present study, hybrid model (ARIMA-GARCH) has been developed, for this ARCH-LM test was applied to the residuals of linear time series model (ARIMA) and if ARCH effect is found to be significant, then only GARCH model has been tried, as explained above.

RESULTS AND DISCUSSION

From Table-1, it was confirmed that there were no outliers detected from the Grubb's test during the period. It was also observed that the prices of groundnut during the study period had varied from 2600 to 7202 (Rs. /Q.) with an average of 4908.01 (Rs. /Q.). Standard Deviation was recorded as 872.08, which indicated that the prices were dispersed highly over the months.

Table 1 Descriptive Statistics for Prices of Groundnut in Adoni Market

Groundnut Prices (Rs. /Q.)	Adoni
Mean	4908.01
Minimum	2600
Maximum	7202
Standard deviation	872.08
utliers detected (Grubbs tes	No

To employ the selected linear time series model (ARIMA), stationary of data series had to be examined first. For this, Augmented Dickey Fuller (ADF) test was applied to the market prices of Adoni as to verify the stationary 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).

From Table 3, based on selected diagnostic criterion i.e., highest R^2 (0.778) and least AIC (2172.10), RMSE (437.67), MAPE (6.78) values and significance of all estimated parameters at 5% LOS, the model ARIMA (1,1,1) was identified as one of the appropriate models to forecast the Prices of Groundnut in Adoni market. Similar kind of model was found to be appropriate to forecast the coconut production in India, as per the report of Naveena *et*

al., (2014). Singh *et al.* (2013) also identified the model as appropriate to forecast the Paddy production in Bastar.

Later, the basic 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 were 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 (0.009) at 5% LOS. Hence GARCH (1,1) model was developed by using AR (1) model and their model fit statistics were depicted in Table 4. As per the report of GARCH model was found to be appropriate to forecast Prices of Vegetables in Egypt.

Table 2 Result of ADF test for the Prices of Groundnut in Adoni Market

Groundnut	Data type	ADF statistic	Critical value (P value)	Decision
Adoni	ADF at level	-2.94	0.18	Data Non-Stationary
	ADF at 1st difference	-6.73	0.01	Data became Stationary

Table 3 ARIMA Model fit Statistics for Adoni Market Prices of Groundnut

ARIMA Model	Parameter Estimates						Goodness of Fit			
	Constant	Autoregressive Coefficient		Moving Average Coefficient		R^2	RMSE	MAPE	AIC	BIC
		AR1	AR2	MA1	MA2					
(0,1,1)	22.63			-0.20**		0.771	440.21	6.87	2180.12	2189.03
(1,1,1)	**13.98**	**0.76****		**-1.00****		**0.778**	**437.67**	**6.78**	**2172.1**	**2183.98**
(1,1,2)	14.13	0.79**		-1.06**	0.06	0.768	441.32	6.91	2184.77	2192.62
(2,1,1)	14.11	0.73**	0.04	-0.99**		0.763	443.33	7.01	2194.79	2201.64
(2,1,0)	22.4	-0.17**	-0.11			0.763	446.52	7.15	2194.29	2202.17
** Significant at 1% level, * Significant at 5% level										

Table 4 Model fit Statistics for GARCH & ARIMA-GARCH for Adoni Market Prices of Groundnut

Model	Model form	RMSE	MAPE	R^2
GARCH	AR (1) - GARCH (1,1)	430.85	6.65	0.791
ARIMA-GARCH	ARIMA (1,1,1) - GARCH (1,1)	428.04	6.5	0.812
ARIMA	ARIMA (1,1,1)	437.67	6.78	0.778

Table 5 Estimated Parameters for ARIMA-GARCH for Adoni Market Prices of Groundnut

Type of model	Model form	Mean Equation			Variance Equation		
		Constant	AR1	MA1	Constant	ARCH effect (α_1)	GARCH effect ($\beta 1$)
Hybrid model	ARIMA (1,1,1) - GARCH (1,1)	52.27	0.20**	-170.67**	5.60**	0.90**	0.07*
** Significant at 1% level, * Significant at 5% level							

Now, residuals of the selected ARIMA model i.e., ARIMA (1,1,1) was also further verified for ARCH effect through ARCH-LM test. By this test, it was concluded that residuals of ARIMA (1,1,1) model also had heteroskedastic nature, as due to the significant prob. value (0.013) at 5% LOS. Hence, in addition to AR (1)-GARCH (1,1) model, ARIMA (1,1,1)-GARCH (1,1) model was also tried and compared with each other, as represented in Table 4.

From Table 4, it was revealed that among the selected models, hybrid model namely ARIMA (1,1,1) - GARCH (1,1) was found to be appropriate, due to the better diagnostic criterion i.e., RMSE (428.04), MAPE (6.50) and R^2 (0.812). Later, residual analysis was also carried out to check the adequacy of the selected model and it was discovered that none of the lags of residual were found to be significant as per residual ACF and PACF plot as depicted in Figure 1, hence it was revealed that the residuals were independently distributed, which also indicated good fit of the selected model i.e., ARIMA (1,1,1) - GARCH (1,1). Similar report was given by Dritsaki (2018) that ARIMA-GARCH model was performed better over other models as to estimate the Oil price.

Now by using the best fitted model *i.e.*, ARIMA (1,1,1) - GARCH (1,1), forecasting was done up to the period Jan 2024. As per Table 6, it was revealed that actual and forecasted were close to each other, which also confirmed the appropriateness of the selected model. The prices of Adoni market for the period of January 2024, was forecasted as Rs. 6984.69 per Quintal. As per the report of Ghani and Rahim (2019). Similar kind of Hybrid Model (ARMA-GARCH) was found to be appropriate to forecast rubber prices in Malaysia.

Finally, the actual and fitted graph of Groundnut prices in Adoni market was made by ARIMA (1,1,1) - GARCH (1,1), as depicted in Figure 2, which indicated as there would be slight increasing in the trend of Prices in future.

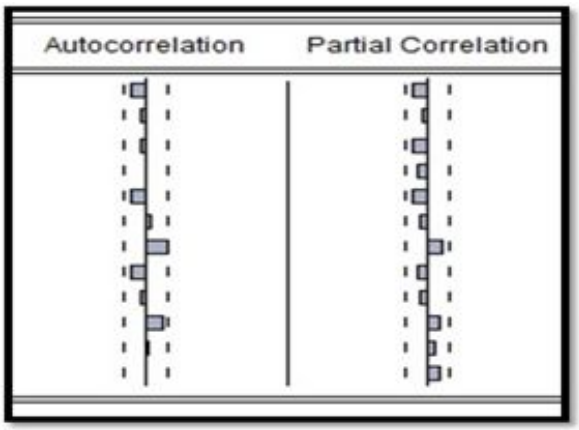

Figure 1 Residual ACF and PACF plot for ARIMA-GARCH model

Table 6 Sample of Predicted values using ARIMA-GARCH model

Period	Actual	Forecasted	Forecast Error (%)
23-Feb	6558.57	6503.98	0.83
23-Mar	6613.38	6660.8	0.72
23-Apr	6734.83	6714	0.31
23-May		6666.46	
23-Jun		6718.78	
23-Jul		6701.06	
23-Aug		6723.33	
23-Sep		6775.6	
23-Oct		6827.87	
23-Nov		6880.14	
23-Dec		6852.41	
24-Jan		6984.69	

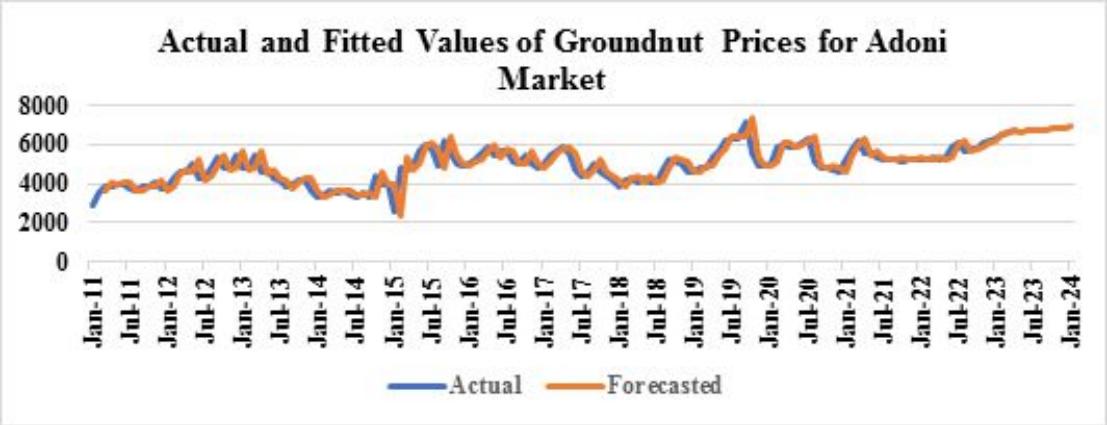

Figure 2 Actual and Fitted Values of Groundnut Prices for Adoni Market

In this study, an attempt was made to forecast the prices of Groundnut in Adoni market by different models namely ARIMA, GARCH and Hybrid (ARIMA-GARCH) model. Among all, the best fitted model was recognized as ARIMA (1,1,1) - GARCH (1,1), due to the better model selection criterion. By using this model Prices of January 2024, was forecasted as Rs. 6984.69 per Quintal. It was concluded as there would be steady increasing trend of Prices in future. This study on forecasting the market prices would help the farmers to market their produce at right time in order to get remunerative prices.

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