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Pavithra V
Ph.D. Scholar, Department of Agricultural Statistics, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India

Vinay HT
Ph.D. Scholar, Department of Agricultural Statistics, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India

Cheela Soumya
Ph.D. Scholar, Division of Agricultural Economics, ICAR-IARI, New Delhi, India

Corresponding Author:
Pavithra V
Ph.D. Scholar, Department of Agricultural Statistics, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India

A statistical approach to forecasting potato price in Kolar market of Karnataka

Pavithra V, Vinay HT and Cheela Soumya

Abstract
The price of potato fluctuates primarily due to variations in production and market arrival, making price forecasting essential for helping producers in decisions regarding acreage allocation and timing of sale. The present study aimed to forecast the price of potato in Kolar market of Karnataka state using the statistical techniques like Single Exponential Smoothing, Double Exponential Smoothing, Triple Exponential Smoothing and Autoregressive integrated moving average (ARIMA). The study was based on the secondary data of potato price from January 2010 to December 2023. The results demonstrate that the Holt-Winters Exponential Smoothing method or Triple Exponential Smoothing model achieves a high level of accuracy in price forecasting, with a Mean Absolute Percentage Error (MAPE) of 0.12% and a Root Mean Square Error (RMSE) of 207.18 Hence, it was employed to forecast potato price from January 2024 to December 2024.

Keywords: Exponential smoothing methods, Autoregressive integrated moving average (ARIMA), price forecasting

1. Introduction

Potato holds significant importance as the world's foremost crop, ranking as the fifth largest agricultural commodity. It has a huge potential to increase farmers income due to its wide market demand nationally and internationally [10]. India is the third largest potato producing country with an area of 2.23 million ha and production of 59.74 million MT during 2023 (statista.com). The state, Karnataka contributes significantly to the potato production in India and provides substantial income for farmers in Karnataka. It is a highly recommended food security crop that can help low-earning farmers and vulnerable consumers ride out extreme events in world food supply and demand. Consumer prices are crucial elements of macroeconomic indicators because households in an economy follow these indicators.

In Karnataka state, sowing of potato was observed during the months of May to July while harvesting period varied from September to November. However, arrivals in the market continue all over the year gradually. Thus, model building and forecasting the monthly price behavior of potato over the years is of much practical importance.

Forecasting involves making estimates of the future values of variables of interest using past and current information. It is a risky venture for semi-perishable commodities like potato. The demand for potato will be driven mainly by the processing industry and the need of consumers for daily consumption. The price instability and uncertainty pose a significant challenge to decision makers in coming up with proper production and marketing plans to minimize risk. Price fluctuations are a matter of concern among consumers, farmers, and policymakers. The government can play an important role in trying to maintain stability in potato production and prices by implementing suitable policies. Price forecast therefore, is vital to facilitate efficient decisions and it plays a major role in coordinating the supply and demand of these products. Thus, an exact and accurate forecasting strategy for potato price via a forecasting technique is necessary to assist the government's decision-making for subsequent months.

Several attempts have been made in the past to develop price forecast models for various commodities [5, 8]. The prices of potato largely fluctuate mainly due to variations in production and market arrival. Thus, the price forecast of potato could help producers in decision making on acreage allocation and time of sale. Naturally, forecasting is one of the main aspects of time series analysis having the art of saying that what will happen in the future. There are various forecasting models in use now-a-days. Analyst can choose their own method of forecasting based on their knowledge and available external information. As the process of development goes on, the forecasting procedure can be modified to meet the specific conditions. Different forecasting models may fit more or less equally well to the data, but they forecast different future values [9].

As recognized in present times, time series data analysis has been an increasingly more important subject in various research areas such as economics, agricultural economics, econometrics, business, psychology, engineering, social sciences and so on. Several Researchers used ARIMA models and ensemble Artificial Neural Networks to forecast the potato prices in different markets [1, 4, 7]. In current study we employed statistical models like Single Exponential Smoothing (SES), Holt's linear method, Holt-Winter's Exponential Smoothing (H-WES) method and ARIMA model to forecast the prices of potato in Kolar market of Karnataka.

2. Methodology

2.1 Data Description

The time series data on potato prices were collected from the AGMARKNET website (http://agmarknet.gov.in) for a period of 14 years, spanning from January 2010 to December 2023, specifically focusing on the Kolar market in Karnataka state. Data on prices refer to modal prices in a month and is considered superior to monthly average price as it represents the major proportion of the commodity marketed during the month.

2.2 Methods

Different time series models such as Simple Exponential Smoothing (SES), Double Exponential Smoothing (DES), Triple Exponential Smoothing (TES), ARIMA were applied to the price data.

2.2.1 Single exponential smoothing

It is a method to estimate future values using a single weight/parameter given by Brown [3]. More weightage is given to recent observations and less weightage is given to distant observations.

$$F_{t+1} = \alpha Y_t + (1-\alpha)F_t$$

Where, α is a smoothing parameter taking values in the interval (0, 1).

F_t = the forecasted price at time t.

Y_t =actual price at time t.

2.2.2 Double Exponential Smoothing (Holt's linear method)

Simple exponential smoothing (SES) is not effective in predicting time series with a local linear trend. Brown [3] demonstrated that SES forecasts for such time series tend to lag behind the actual series. To address this limitation, Holt [6] proposed an extension of SES called Holt's method. This method includes an additional updating equation for the slope (trend), resulting in improved forecasts for time series with a local linear trend.

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

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

$$F_{t+m} = L_t + m b_t$$

Where,

L_t= Level at time t

b_t= Trend at time t

F_{t+m}= Forecast value for m period ahead

α, β = Smoothing parameters ranging from 0 to 1. The combination of these parameters is selected based on minimum RMSE value.

2.2.3 Holt-Winter's Exponential Smoothing (H-WES) method or Triple Exponential Smoothing (TES)

Holt's method was extended by winter to capture seasonality directly. The Holt- Winter's method is based on three smoothing equations, one for level, one for trend, and one for seasonality. It is similar to Holt's method, with an additional equation to deal with seasonality. Holt-Winter's Exponential Smoothing (H-WES) methods are widely used when the data shows trend and seasonality. In this study the multiplicative model is used as the seasonal variation over time is observed. The four equations for the model are given as follows.

$$L_t = \alpha \frac{Y_t}{S_t} + (1-\alpha)(L_{t-1} + b_{t-1})$$

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

$$S_t = \gamma \frac{Y_t}{L_t - Y_t} + (1-\gamma)S_{t-s}$$

$$F_{t+m} = L_t + m b_t + S_{t-s+m}$$

Where, s= length of seasonality

L_t= Level at time t

b_t= Trend at time t

S_t= Seasonal component at time t

F_{t+m}= Forecast value for m period ahead

α, β *and* γ are level, trend and seasonal smoothing constants or the weights respectively, which lies between 0 and 1. The combination of these parameters is selected based on minimum RMSE and MAPE value.

2.2.4 ARIMA model

In an autoregressive integrated moving average model, the future value of a variable is assumed to be a linear function of several past observations and random errors (Box and Jenkins) [3]. Theoretically ARIMA model includes three components: Auto-Regressive (AR), Moving-Average (MA), and Integrated (I) terms. The first two components are expressed in equation.

$$\nabla^d y_t = \emptyset_1 \nabla^d y_{t-1} + \cdots + \emptyset_p \nabla^d y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - -\theta_p \varepsilon_{t-p}$$

AR terms MA terms

Where ϕ is a number strictly between −1 and +1, and θ are the weights, and p is the order of the AR model, and q is the order of the MA model. Here, ε_t's are independently and normally distributed with zero mean and constant variance σ^2 $\forall$ t =1, 2, …, n.

3. Results and Discussion

3.1 Descriptive statistics

The descriptive statistics of potato price in Kolar market of Karnataka is depicted in Table 1. It reveals that the average price of potato is 1217 (Rs/Quintal) and it ranges from 604 to 2410 (Rs/Quintal). The time series data is moderately skewed and platykurtic. 31% CV indicates less variability in the price data. Time plot of the average monthly potato price for the original series is presented in Figure 1.

Table 1: Descriptive Statistics of potato price in Kolar market of Karnataka

Statistics	Price
Observations	168
Mean (Rs/quintal)	1217
Minimum	604
Median	1141
Maximum	2410
SD	386.64
CV	31.78
Skewness	0.89
Kurtosis	0.14

Note: SD: Standard Deviation: CV: Coefficient of Variation

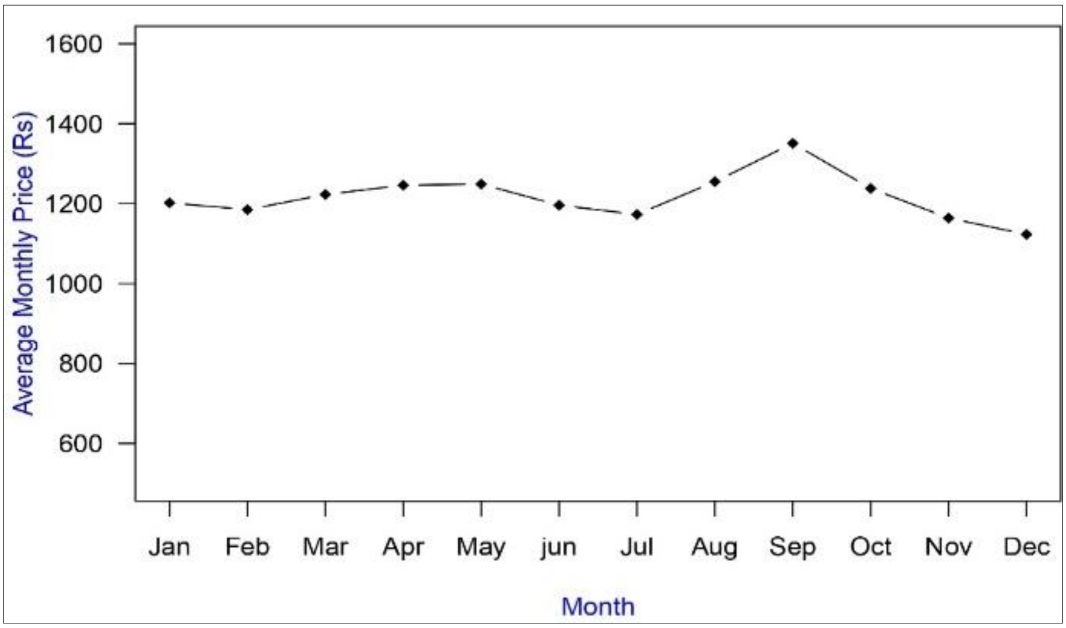

Fig 1: Monthly average wholesale price of Potato in Kolar market, Karnataka

3.2 Fitting of Exponential Smoothing models

All three techniques (Single, Double and Triple) of exponential smoothing methods were considered for modelling potato prices and the values of smoothing parameters are presented in Table 2.

Table 2: Estimated parameter of SES, DES and TES model

Models	Parameters	Estimates	AIC
SES	Alpha (Level)	0.9386	2277.994
DES	Alpha (Level)	0.9352	2281.879
	Beta (Trend)	0.00001	
TES	Alpha (Level)	0.6547	2250.443
	Beta (Trend)	0.00002	
	Gamma (Seasonal)	0.00001	

3.3 Fitting of ARIMA model

To check the stationarity of price series of potato, the Augmented Dickey-Fuller unit root tests used and data was found to be non-stationary hence first differencing was used to transform non-stationary to stationary data and the results were presented in Table 3. By using the "auto. ARIMA" function in R software we found that ARIMA (2, 1, 1) where order of AR is 2 and order of MA is 1, was the best fit model having lower AIC and SBC value. The parameter estimates of ARIMA (2, 1, 1) model along with their significance level are presented in Table 4.

Table 3: Results of Augmented Dicky Fuller test

Data	ADF test	Lag order	P-value
Original	-2.48	5	0.3765
First Differenced	-7.45	5	0.01

Table 4: Parameter estimates of ARIMA (2, 1, 1) model

Parameters	Estimate	S.E.	p-value
AR1	0.55	0.11	0.000 ***
AR2	-0.32	0.09	0.000 ***
MA1	-0.71	0.10	0.000***

***: Significant at 0.1%

3.4 Evaluation of Model Accuracy

The RMSE and MAPE values for training and testing data set for Single, Double, Triple exponential smoothing and ARIMA models are given in Table 5. The results indicates that the Triple exponential smoothing performed better than the remaining model with lower RMSE of 204.33 and 207.18 and Mean Absolute Percent Error of 0.12% and 0.08% for training and testing data set respectively. Therefore, The monthly wholesale prices of potato was forecasted using TES for the year 2024 and the plot showing observed and fitted values is depicted in Figure 2.

Table 5: Model accuracy evaluation

Models	Training set		Testing set	
	RMSE	MAPE (%)	RMSE	MAPE (%)
SES	222.29	0.12	348.14	0.18
DES	222.20	0.12	348.73	0.18
TES	203.44	0.12	207.18	0.08
ARIMA	200.00	0.12	293.08	0.14

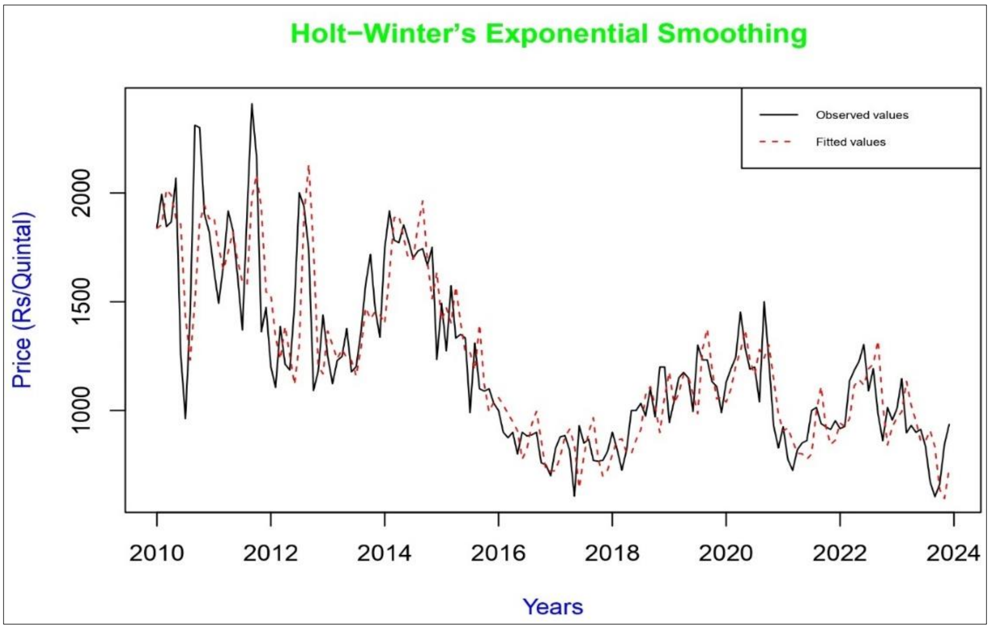

Fig 2: Plot showing observed vs fitted values by Triple Exponential Smoothing model

3.5 Residual diagnostics

The Ljung-Box test was used to diagnose the residual of the triple exponential smoothing model. A perusal of Table 6 reveals that the residuals are random in nature.

Table 6: Residual diagnostics test

Model	Ljung-Box test	
	Test statistic	p-value
TES	1.74	0.19

3.6 Forecasting Monthly price of Potato

TES model was used to forecast the monthly wholesale prices of potato for the year 2024 and the results were depicted in Table 7 which reveals that the price of potato is not fluctuating in the year 2024.

Table 7: Forecasted monthly wholesale price for potato in Kolar market of Karnataka State.

Month	Price (Rs/quintal)
Jan-24	878.61
Feb-24	880.05
Mar-24	911.99
Apr-24	947.60
May-24	934.17
Jun-24	874.17
Jul-24	841.14
Aug-24	901.62
Sep-24	989.13
Oct-24	918.71
Nov-24	843.57
Dec-24	819.28

4. Conclusion

This article explores various models to predict monthly wholesale price of potato, including Single Exponential Smoothing, Double Exponential Smoothing, Triple Exponential Smoothing, and ARIMA. It concludes that Triple Exponential Smoothing, also known as Holt-Winter's Exponential Smoothing (H-WES), performs the best based on evaluation criteria like RMSE and MAPE. Using the TES model we forecasted the monthly potato prices for 2024, suggesting that the prices will remain stable throughout the year. Consequently, producers can either sell their produce at the prevailing marginal price or opt to store the crop in warehouses, given its semi-perishable nature. This information could help Karnataka state farmers optimize their planting schedules for maximum profitability.

5. Conflict of interest: The authors declare that there is no conflict of interest.

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