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Comparing Two Exponential Models for Predicting Yearly Cocoa Bean Yield in Ghana

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Abstract: In this study, two exponential models, the Simple Exponential model and Holt's Linear Exponential model were used. The two models are compared in order to determine which of the two models the better one is. Ghana's annual cocoa bean yield for the past 60 years is used as the input characteristics and it is gathered from the "Food and Agriculture Organization of the United Nations," a secondary source. To determine the goal of the current study, error metrics such Mean Absolute Error and Root Mean Squared Error were employed. In conclusion, the Holt's Linear Exponential model appears to be a more accurate model for forecasting Ghana's annual cocoa bean yield. This study aids in timely decision-making for farmers, the chocolate industries, and cocoa bean producers.

Keywords: Yearly cocoa bean yield, RMSE, MAE, Simple Exponential Model, Holt's Linear Exponential Model

Introduction

Ghana is one of the top producers of cocoa beans in the world, and the economy of the nation heavily depends on cocoa cultivation. A sizeable section of the population receives work and income from the cocoa business, which has been a major engine of economic progress. The following are some important facets of Ghanaian cocoa farming,

Historical Importance

Ghana has a long history of growing cocoa, having been brought to the country by the blacksmith Tetteh Quarshie in the late 1800s.Cocoa has developed into a significant export good and an essential part of Ghana's agriculture industry throughout time.

Significance to the Economy

Ghana's economy is built on cocoa, which also makes up a sizable portion of the nation's export revenue.In Ghana, millions of smallholder farmers depend on the cocoa industry as a primary source of income for their families.

Top Producer Worldwide

Ghana is one of the world's leading producers of cocoa on a regular basis. Ghana and Ivory Coast together produce a significant amount of the world's cocoa.Cocoa is cultivated in the southern sections of the country because of the ideal climatic and soil conditions, especially in the Ashanti, Brong-Ahafo, Western, and Central regions.

Agriculture by Smallholders

Ghanaian smallholder farmers, who usually own tiny parcels of land, are the main producers of cocoa.Since these farmers are essential to the production of cocoa, attempts have been undertaken to assist them by providing resources, better agricultural techniques, and training programs.

Difficulties

Concerns about sustainability, low production, and aged cocoa plants are some of the issues facing Ghana's cocoa business.Initiatives aiming at revitalizing cocoa fields, encouraging sustainable farming methods, and addressing problems like deforestation and child labour are being implemented in an attempt to address these difficulties.

Regulating Organization

The government organization in charge of managing and policing the cocoa industry is the Ghana Cocoa Board (COCOBOD). In determining cocoa pricing, helping farmers, and overseeing the sale and export of cocoa, COCOBOD is essential.

Profile of Flavour and Quality

Ghanaian cocoa is well known for having a unique flavour profile, which is frequently defined by a rich, full-bodied flavour with hints of acidity and red fruit flavours.In the international chocolate market, Ghanaian cocoa is highly prized for its quality and frequently sought after for high-end chocolate goods.

Green Projects

The cocoa sector has placed a greater emphasis on sustainability in recent years. Ghana has taken part in a number of sustainability projects and certification schemes aimed at addressing social and environmental issues, such as attempts to stop deforestation and raise the standard of living for cocoa growers.

To summarize, Ghana's history, culture, and economics are intricately linked to the cultivation of cocoa. Despite obstacles, the sector is developing and placing more of an emphasis on quality, sustainability, and the welfare of the farmers who produce this highly valued commodity worldwide.

Review of Literature

The following section discusses the relevant studies for the current work.

Boken (2000), outlines a process for prediction yield using time series analysis. The average spring wheat yield series for Saskatchewan, Canada was modelled using a few different approaches, including linear trend, quadratic trend, simple exponential smoothing, double exponential smoothing, simple moving averaging, and double moving averaging. Yields for 1994, 1995, and 1996 were predicted using spring wheat yield data from 1975–1993, 1975–1994, and 1975–1995, respectively.The quadratic model generated the best accurate forecast during the model development (1975–1993, 1975–1994, and 1975–1995) and testing (1994, 1995, and 1996) periods, according to a deterministic metric (i.e., mean squared error, or MSE). Additionally, a discussion is given about how to improve the forecast by projecting the yield for the homogenous subareas (within Saskatchewan) as opposed to the province as a whole. Using a geographic information system, the subareas could be created based on yield fluctuation or soil-climatic variables.

Murat et al., (2016) used meteorological time series for employing in scenarios involving climate change. Forecasting or projecting meteorological factors, such as the likelihood of extreme events occurring, is frequently necessary for these kinds of studies. The article's goal was to identify the best exponential smoothing models for producing forecasts utilizing information from time series data on precipitation, wind speed, and air temperature at Jokioinen (Finland), Dikopshof (Germany), Lleida (Spain), and Lublin (Poland).These series' autocorrelation functions and partial autocorrelation functions support their regular additive seasonality or non-seasonality in the absence of any trend. The models with the smallest mean absolute error and the smallest root mean squared error were the most appropriate ones.

Karadas et al., (2017) used annual production data from 1950 to 2015 to anticipate the annual output of a few oil seed crops (sesame, sunflower, and soybean) in Turkey for the years 2016 through 2025. It also aimed to provide farmers, consumers, and input suppliers with sound production recommendations.To economically model the time series data, three exponential smoothing techniques - Holt, Brown, and Damped Trend were used to achieve this goal. These exponential smoothing techniques were compared using goodness of fit metrics including stationary R2, R2, and BIC criteria. The best result among exponential smoothing methods was obtained by utilizing the Holt exponential smoothing approach with two parameters to forecast the amounts of soybean, sunflower, and sesame produced between 2016 and 2025 with high accuracy.

Hartomo et al., (2019) the exponential smoothing method to determine cropping patterns in a widely used rainfall prediction model suffered from inconsistent short-term forecasting and inaccurate long-term forecasting which is recommended The Food and Agriculture Organization (FAO)'s. In order to determine planting pattern, the authors of this study created a novel rainfall prediction model by applying exponential smoothing to the seasonal planting index. The model provides greater accuracy than the original exponential smoothing model, according to the results.

Silvaet al., (2020) performs analysis of the yield and potential for storage of corn and soybeans in MatoGrosso, Brazil, with forecasts until 2022. Data from 1995 to 2018 were arranged according to the following categories: area planted, yield capacity, storage capacity, and production of soy and corn in MatoGrosso.Following that, exponential smoothing methods were employed to provide an early look at the grainstorage balance for the years 2019–2022. It is anticipated that although storage capacity will expand by 9.7%, grain production will increase by 11.9%. The findings so indicated that between the harvests of 2017–18 and 2021/22, there may be a 118% increase in the difference between output and storage. Furthermore, in 2021–2022, the shortfall in storage capacity will account for 53% of the entire harvest. Limitations and implications of the research: Events in the economy, environment, or technology that interfere with the factors being studied could have an impact on the predictions results.The estimation uses a nonparametric resampling technique in conjunction with exponential smoothing models.

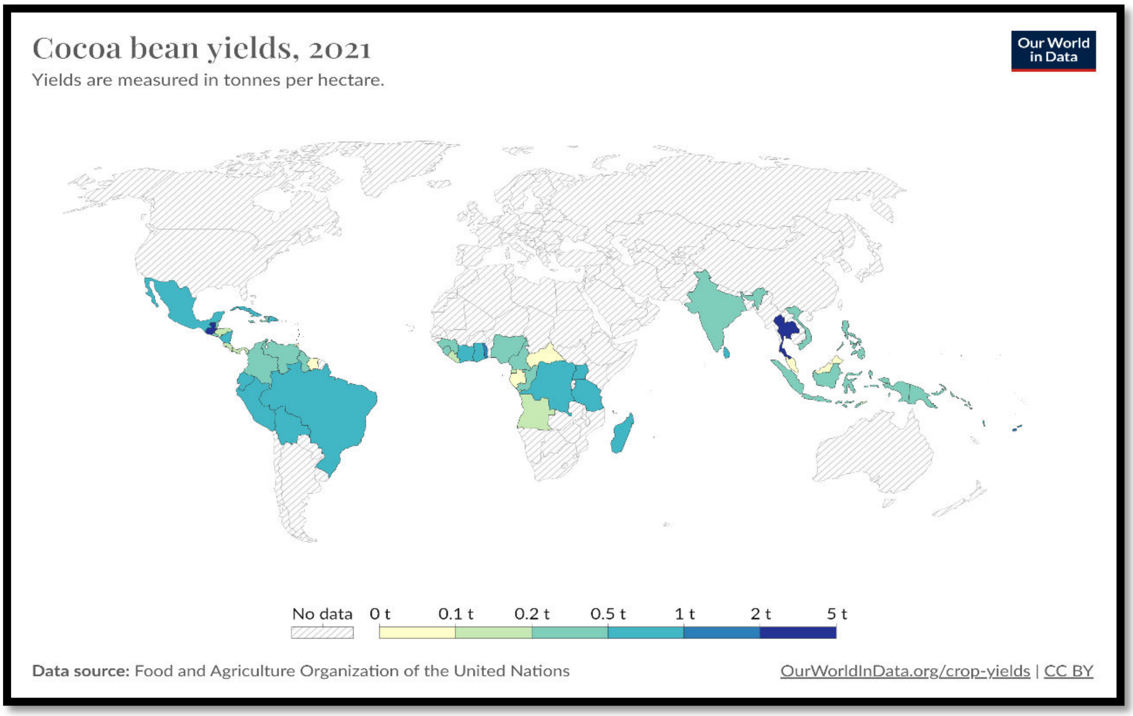
Research Methodology

The objective of the Study

Using 60 years of input data from 1961 to 2021, the goal of the current work is to find which Exponential model is the better fit for predicting Ghana's cocoa bean yield for the next ten years between 2022 and 2031.

Data Source

The "Food and Agriculture Organization of the United Nations" is the source of the secondary data, which was gathered between 1961 and 2021.



Exponential Smoothing Model

Exponential smoothing is a time series forecasting method that assigns exponentially decreasing weights to past observations. It is widely used for forecasting in various fields, including finance, inventory management, and demand forecasting. Here's a general procedure for implementing exponential smoothing,

- Time series data, which are collections of observations gathered over time, are suited for exponential smoothing. Make that the time gap between observations in your data is regular and constant.
- The smoothing parameter, commonly represented as α (alpha), is the most important parameter in exponential smoothing. The weight assigned to recent observations is controlled by this parameter. Based on the properties of your data, choose a suitable value for α. Elevating the α value makes the forecast more sensitive to changes by emphasizing recent observations; but, it may also increase its susceptibility to noise.
- Set the initial forecast for the first period to start the exponential smoothing process. The first few observations can be averaged to achieve this.Assign the first observed value (Y1) to the initial smoothed value (S1).
- For each subsequent period (t), calculate the smoothed value (St) using the exponential smoothing formula:

$$S_t = \alpha * Y_t + (1 - \alpha) * S_{t-1}$$

  Where Y_t is the observed value at time t and S_{t-1} is the smoothed value from the previous period.
- Once you have the smoothed values, you can use them to generate forecasts for future periods. The forecast for the next period *(t+1)* is simply the smoothed value for the current period *(St).*
- Continue the process for each subsequent period in your time series.
- If your data exhibits a seasonal pattern, you may need to consider additional adjustments. Seasonal adjustments involve modifying the forecast based on the seasonal component observed in the data.

- ❖ Assess the accuracy of the model using appropriate evaluation metrics such as Mean Squared Error (MSE) or Mean Absolute Error (MAE). Adjust the smoothing parameter or other components of the model if needed.
- ❖ If the model performance is satisfied, it can use it to make forecasts for future periods.

The properties of your data will determine how successful exponential smoothing is, and you may need to experiment a little to determine the best smoothing parameter and model setup for your particular use case.

Holt's Linear Exponential Model

The Holt Linear Exponential Smoothing model, which is often referred to as double exponential smoothing, is a time series data handling technique. This model consists of a trend component as well as a level component that functions similarly to basic exponential smoothing. The Holt Linear Exponential Smoothing model uses the level and trend values as the basis for its forecast.

The following are the main formulas for the Holt Linear Exponential Smoothing model,

- ❖ Initialization

$$L_0 = Y_0$$
$$T_0 = \frac{1}{2}\left(\frac{Y_1 - Y_0}{1} + \frac{Y_2 - Y_1}{1}\right)$$

- ❖ Smoothing Equations

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1})$$
$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$$

- ❖ Forecast

$$F_{t+h} = L_t + h.T_t$$

Here, Y_t is the observed value at time *t.*
$L_t$is the level at time *t.*
$T_t$is the trend at time *t.*
$\alpha$is the smoothing parameter for the level.
$\beta$is the smoothing parameter for the trend.
$h$is the number of periods into the future of forecasting.

The weighted average of the most recent observation, the previous level, and the prior trend is used to update the level. The weighted average of the difference between the current level and the prior level as well as the prior trend is used to update the trend.This technique works well with time series data that show a linear trend. Selecting suitable values for and β is crucial and frequently necessitates testing to identify the optimal parameters for a particular dataset.

Results and Discussion

The first and foremost step is to plot the raw data.

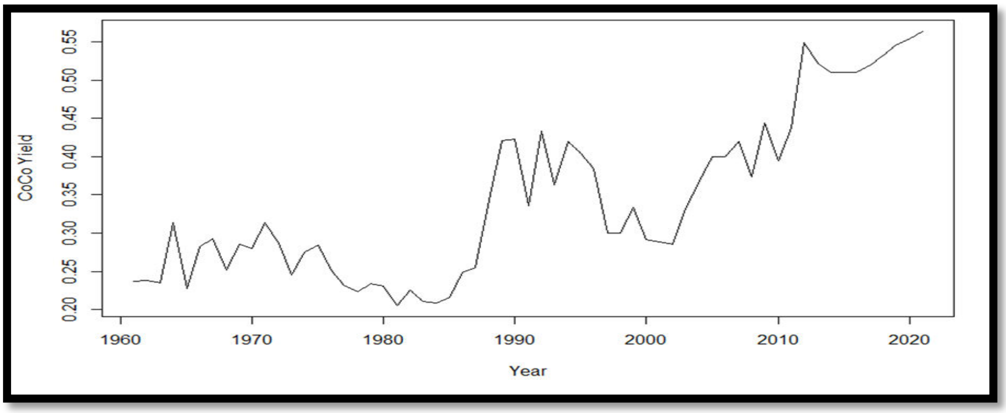


Figure 1. The raw data of yearly cocoa bean yield data from 1961 to 2021.

The raw data, Figure 1shows the no trend and no seasonality. Also, varying with respect to time, confirms the data is not stationary.

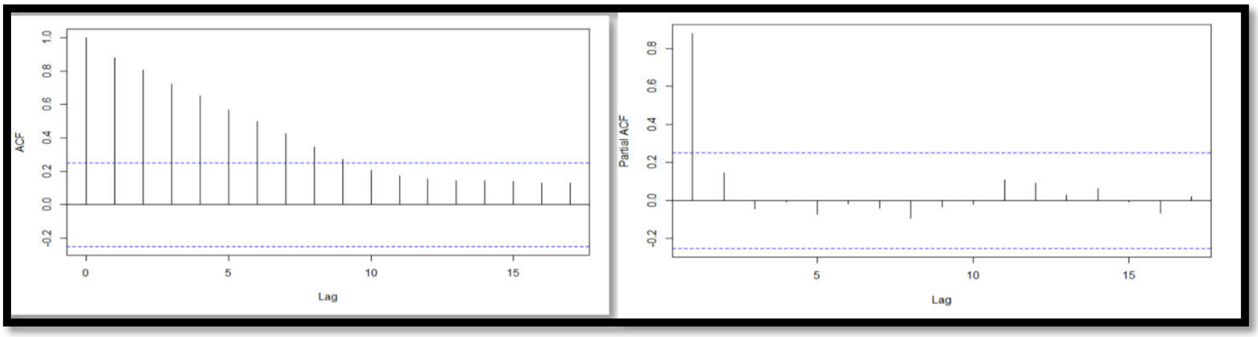


Figure 2. The ACF and PACF plots fortime series data of yearly cocoa bean yield data from 1961 to 2021.

In Figure 2, it can be seen that the results of yearly coco yield has trend and seasonal pattern based on ACF (Autocorrelation Function) plot where the lag movement is slowly decreasing from 0 to 15 and there are many ACF values outside the interval/ horizontal line and that shows the data is not stationary or has trend.

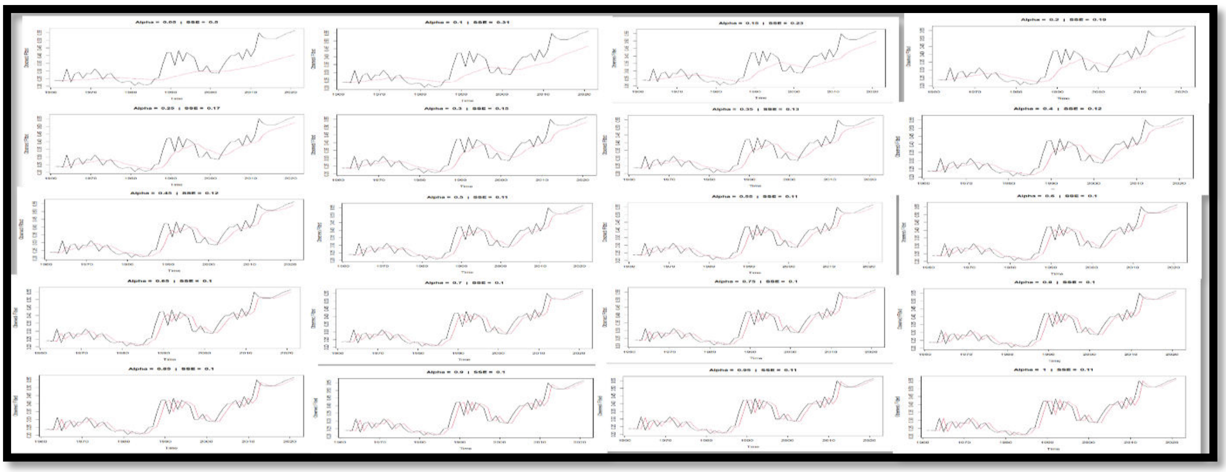


Figure 3. Screening of optimum alpha value by varying alphas from 0.05 to 1.0 at the interval of 0.05 and also compared with actual data.(The black line is actual value and red is fitted value)

The Figure 3,shows the screening of various alphas with the interval from 0.05 to 1.0 with the interval of 0.05. It is well known that the sum of squared error (SSE) is the difference between the actual and fitted values. For all model,SSE value should be low. Among those models, the 0.75 more fitted with the actual data and also less SSE value. Thus, the alpha value 0.75 have been selected to forecast the Simple and Holt's exponential models.

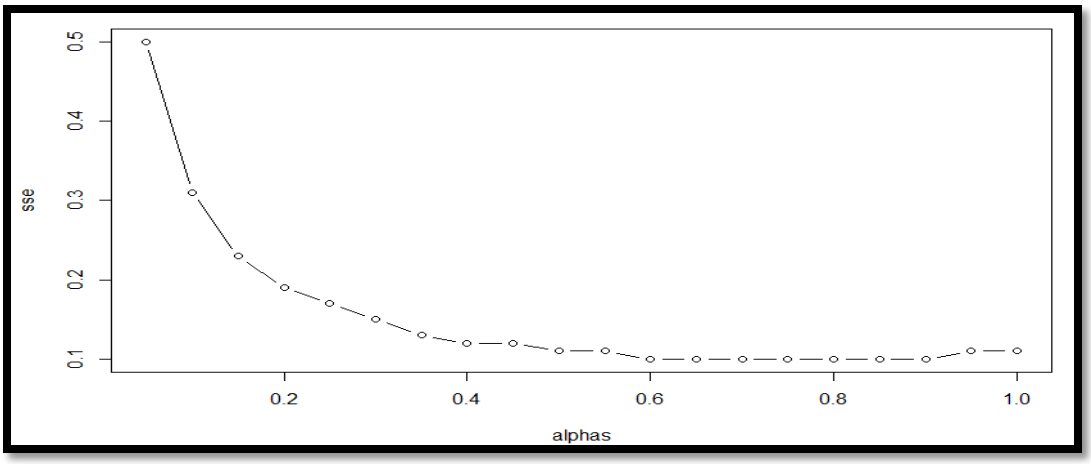


Figure 4. Finding the optimum alpha by comparing alpha value Vs SSE value by varying alphas from 0.05 to 1 and also compared with actual data.

Figure 4,shows the comparison plot between alphas and SSE the trend is linear after reaching the value of alphas 0.7 with less SSE value, hence this screened value is adopted for further forecast.

Residual Plot for Simple Exponential Model

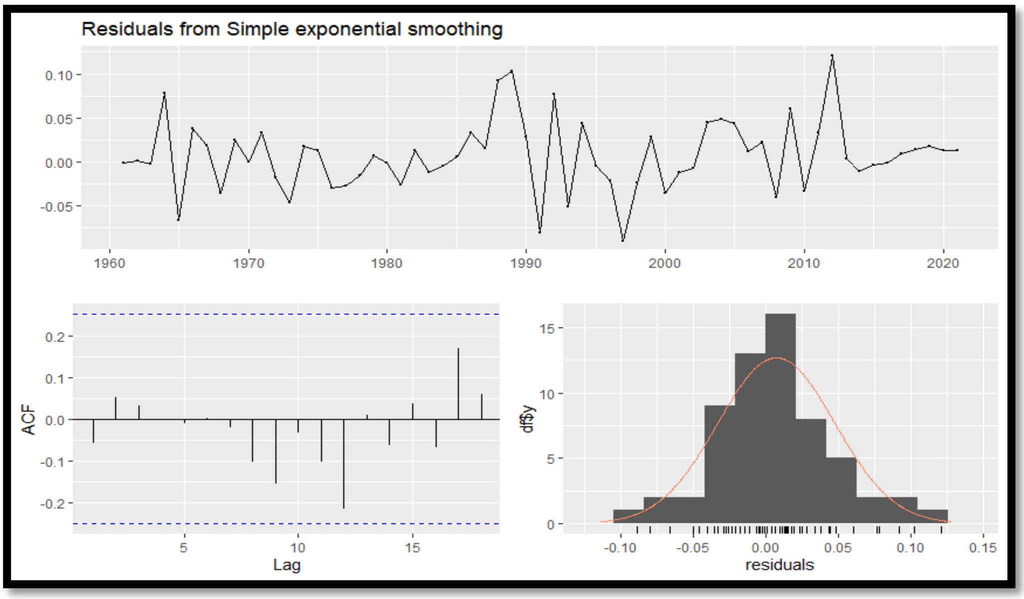


Figure 5. The residual plot for the predicted simple exponential model

Simple Exponential Smoothing Forecasting

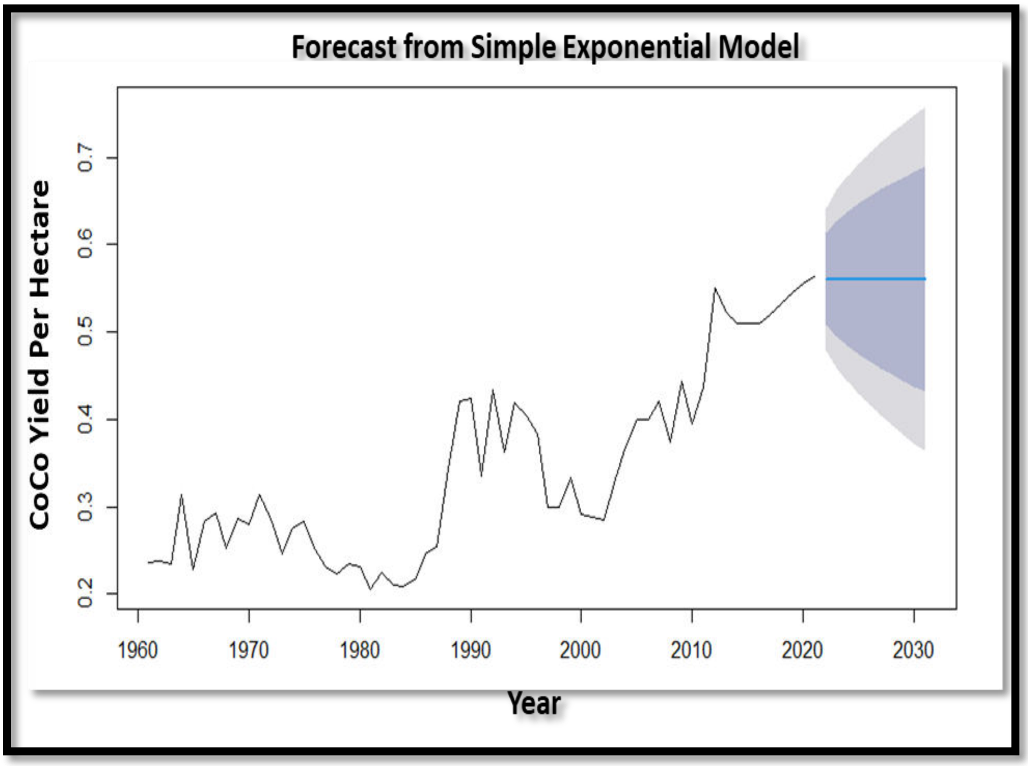


Figure 6. Forecasting for simple exponential smoothing Model for next 10 years

The fitted model in Figure 6, shows the trend is not changing till next 10 years, hence it may not be the good model to predict future forecast.

Residual Plot for Holt's Linear Exponential Model

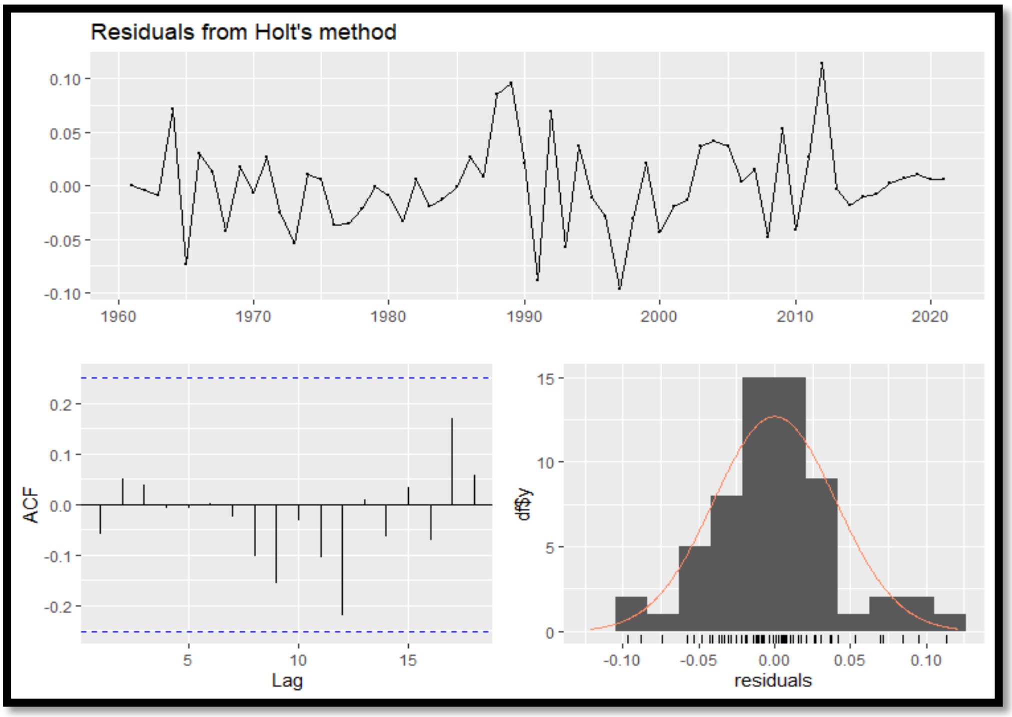


Figure 7. The residual plot for the predicted Holt's linear exponential model.

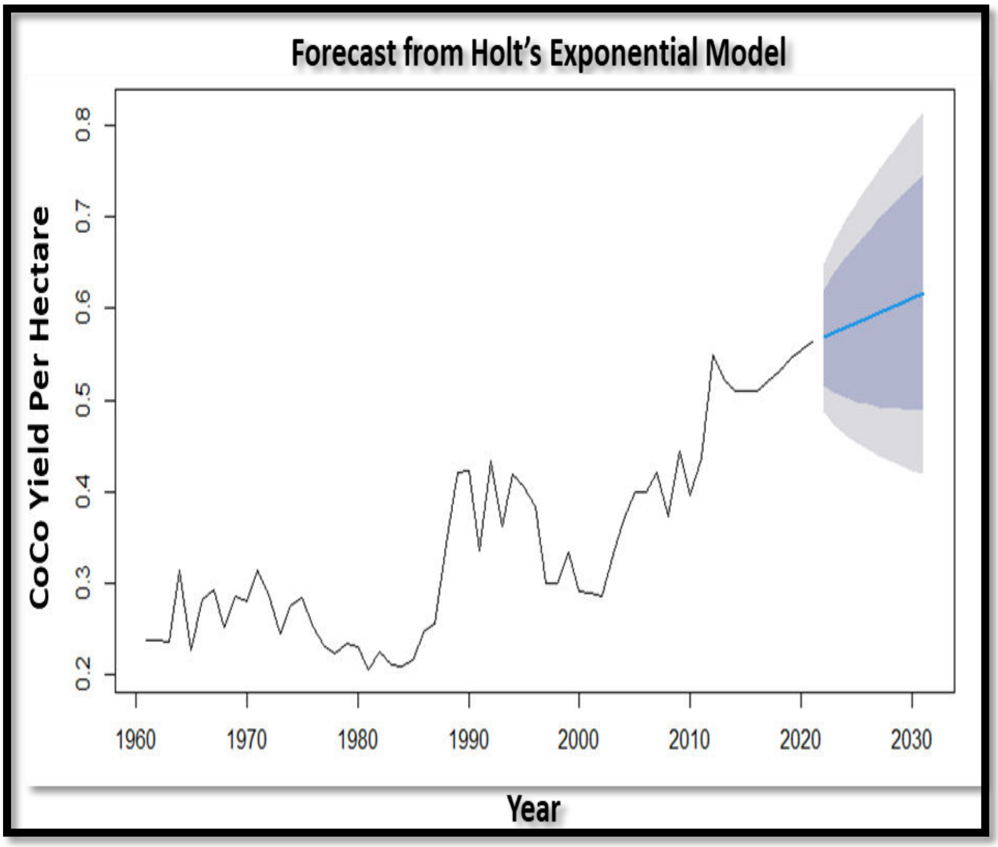


Figure 8. Forecasting plot for Holt's linear exponential smoothing model for next 10 years

Observation and Comparison between the Simple and Holt's linear exponential model

The Holt's linear exponential forecasted model in the figure 8, shows the trend is moving upward however in case of simple exponential model in the figure 6, displaysthe values remains same for next 10 years. This indicates that the Holt's linear exponential may be well suited to forecast the future yearly Cocoa bean yield.

The Table 1, clearly shows the AIC and other paremeter values are less in Holt's linear expnonential model than the simple exponential model except MASE value. This indicates the Holt's linear expnonential model will be more suitable for accurate future forecating yearly Cocoa bean yield.

Table 1. A comparison of various parameters AIC, MASE, RMSE, and MPE for simple and Holt's linear exponential models.

Model Name	AIC	MASE	RMSE	MAE
Simple Exponential Model	-136.0379	8.994544	0.04062839	0.02998603
Holt's Linear Exponential Model	**-134.0037**	9.081863	**0.03997897**	**0.0295601**

Conclusion

This study used the Simple exponential model and Holt's linear exponential smoothing approach to forecast Ghana's yearly cocoa bean yield for the years 2022–2032. Based on error measures such as RMSE, MAE,and the AkaikeInformation Criteria, the Holt's linear exponential modelproduced the best results than simple exponential smoothing model.In the near future, providers of cocoa beans would benefit greatly from the rise in domestic output and the ensuing nominal price range in cocoa beans, which would lead to an increase in exports of cocoa beans and a gain in foreign money. Consequently, in order to boost domestic cocoa bean yield in the future, the appropriate steps must be adopted. Finally, it is believed that the forecasting data generated will serve as a useful future reference for farmers and policymakers.

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