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Forecasting Rainfall in Planting Onion Crops in Brebes District, Brebes District Using Holt-Winters Exponential Smoothing

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Abstract

Planting shallots is very dependent on rainfall. High rainfall when planting shallots can result in shallot plants not growing well, resulting in reduced selling value at harvest time and low rainfall. Therefore, this study aims to determine the rainfall forecasting process for planting shallot plants in Brebes District, Brebes Regency. The data used in rainfall forecasting is monthly data in Brebes District from January 2019 to December 2023 using the Holt-Winters Exponential Smoothing method. Data sourced from NASA's Power Data Access Viewer. In the surface data, get the MAPE value0.05241. Earth Skin Temperature data gets a MAPE value of 2.34346. Wind Speed data gets a MAPE value of 14.5396. DataPrecipitationgot a value of 138.829583. These findings contribute to further understanding regarding rainfall forecasting in shallot planting, which can support the planting process so that the harvest is good and produces high selling value.

Keywords: Holt-Winters Exponential Smoothing; Rainfall Forecasting; Red Onion

Abstrak

Penanaman bawang merah sangat bergantung pada curah hujan. Curah hujan yang tinggi pada saat penanaman bawang merah dapat mengakibatkan tanaman bawang merah tidak dapat tumbuh dengan baik, sehingga mengakibatkan berkurangnya nilai jual pada saat panen maupun pada saat curah hujan rendah. Oleh karena itu, penelitian ini bertujuan untuk mengetahui proses peramalan curah hujan dalam hal penanaman tanaman bawang merah di Kecamatan Brebes, Kabupaten Brebes. Data yang digunakan dalam peramalan curah hujan adalah data bulanan di Kecamatan Brebes dari bulan Januari 2019 hingga Desember 2023 dengan menggunakan metode Holt-Winters Exponential Smoothing. Data bersumber dari Power Data Access Viewer milik NASA. Pada data permukaan, didapatkan nilai MAPE sebesar 0.05241. Data Suhu Kulit Bumi mendapatkan nilai MAPE sebesar 2.34346. Data Kecepatan Angin mendapatkan nilai MAPE sebesar 14.5396. Data Curah Hujan mendapatkan nilai 138.829583. Temuan ini memberikan kontribusi pemahaman lebih lanjut mengenai peramalan curah hujan pada penanaman bawang merah yang dapat mendukung proses penanaman sehingga hasil panen baik dan menghasilkan nilai jual yang tinggi.

Kata-kata kunci*: Pemulusan Eksponensial Holt-Winters; Peramalan Curah Hujan; Bawang Merah*

1. Introduction

Shallots (Allium cepa L. Aggregatum) are superior vegetables and have long been cultivated intensively by farmers **[1]**. In planting shallots, weather plays a vital role for good growth. The influence of rainfall on shallot planting is significant because sufficient rainfall can significantly influence the development and production of shallots **[2]**. Rainfall in an area can be predicted by considering several factors that influence rainfall during planting shallot plants, which can be seen from air temperature, temperature, wind direction, and rainfall **[3]**. High rainfall can have a significant impact on shallot planting. Waterlogged soil due to excessive rain can cause root rot and affect overall growth **[4]**.

The Holt-Winters Exponential Smoothing technique calculates historical data trends and seasonality in the rainfall forecasting process. This technique is also called the Triple Exponential Smoothing method. The Holt-Winters model is used in an effort to model seasonal pattern data, which may or may not contain a trend **[5]**. A study by **[6]** titled Rainfall Forecasting Using the Holt-Winters Exponential Smoothing Method in North Padang Lawas Regency produces the best prediction score using the smallest MAPE value, 0.3271700. Study by Adindach Syadza Rizkia et al **[7]** shows getting a MAPE forecasting value of 6.507755.

Based on this, this study aims to forecast or estimate rainfall more accurately by combining level, trend, and seasonal components. The Holt-Winters Exponential Smoothing method, which considers seasonal fluctuations and trends over time, can help farmers set planting schedules and irrigation planning.

2. Method

The statistics used in this analysis are monthly rainfall statistics at 5-year intervals starting from January 2019 to December 2023. The data was downloaded from the National Aeronautics and Space Administration website. Data collection uses a non-experimental design because the data is generated by downloading existing data.

This study uses secondary data, which is then processed and analyzed (forecast) to obtain a forecasting score. The rainfall variable is used. Data processing uses the Microsoft Excel application. To see good criteria for forecasting, look at the smallest MAPE value.

2.1 *Holt-Winters Exponential Smoothing*

The Holt-Winters Exponential Smoothing design is a time series design based on three smoothing equations, namely for stationary, trend and seasonal. It uses 3 smoothing benchmarks, namely α, β, γ, each of which has a value between 0 and 1 [8] [9]. The Triple Exponential Smoothing (Winter Mentgod) method has two models, namely the Additive Seasonality model, which is used when the effects are different from time to time. Meanwhile, the Multiplicative Seasonality model is used if the magnitude of the seasonal effect changes over time[10]. In this research, the Holt Winter Multiplicative model is used.

Actions in calculations utilising the Holt-Winters Exponential Smoothing technique:

a) Equations (1), (2), (3) can be used to determine the data smoothing value for the additive model, and for the multiplicative data model, equations (1), (2), and (4) can also be used.
   a. Exponential Smoothing Initial Score (SL)

$$S_L = \frac{1}{L}(. + X_2 + \cdots + X_L) \quad (1)$$

   b. Initial value of trend smoothing (TL)

$$T_L = \frac{1}{L}\left(\frac{X_{L+1} - X_1}{L} + \frac{X_{L+2} - X_2}{L} + \cdots + \frac{X_{L+L} - X_L}{L}\right) \quad (2)$$

   c. Seasonal smoothing start score (It)

   Holt-Winters Additive Design

$$I_t = X_t - S_L \quad (3)$$

   Design *Multiplicative Holt-Winters*

$$I_t = \frac{X_t}{S_L} \quad (4)$$

b) Determine the benchmarks α, β, and γ. To determine the scores α, β, and γ, you can use a solver table in an effort to find the optimal benchmark value. In this case the values of the parameters are 0≤α, β, & γ≤1

c) Recapitulate initial smoothing scores

   The Multiplicative Holt-Winters model is used if the time series data has a seasonal pattern with non-constant seasonal variations.

   a. Exponential smoothing

$$S_t = a\frac{X_1}{I_{t-L}} + (1 - a)(S_{t-1} - T_{t-1}) \quad (5)$$

   b. Trend smoothing

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1} \quad (6)$$

   c. Seasonal smoothing

$$I_t = \gamma\frac{X_t}{S_t} + (1 - \gamma)I_{t-s} \quad (7)$$

d. Period predictions

$$Y_{t+m} = (S_t + mT_t)I_{t-k+m} \quad (8)$$

Where :

α =Single fixed value actual statistical smoothing

β =Single fixed value smoothing trend pattern

γ =Single fixed value smoothing seasonal patterns

X_t =Actual scores/statistics in period t

S_t =Statistical exponential smoothing score in period t

l_t =Seasonal score in period t

T_t =Trend score in period t

m =The total future period that will be predicted

F_{t+m} =Prediction score in period t + m

2.2 **Forecasting**

Forecasting or forecasting is predicting future situations by examining conditions in the past **[11]**. The forecasts aim to minimize uncertainty that can cause problems in the social environment. This uncertainty is usually measured using mean square error (MSE), mean absolute error (MAE), and mean absolute error (MAPE).

2.3 Miming Data

Data mining is also called Knowledge Discovery in Databases (KDD). It is an activity that involves collecting and using historical data to obtain regularities, patterns, or connections in large data sets **[12]**.

2.4 Time Series Data

Time series data is "a number of variable values sequentially in time, for example, day, week, month and year; there are four elements that have an impact on time series statistics **[13]**.

2.5 *Mean Absolute Percentage Error* (MAPE)

The mean absolute percentage is used to find the difference between real data and forecast data. The differences are calculated in the form of percentages on real data **[11]**. In the forecasting or estimating process, finding a 100% accuracy rate is rare. Based on this situation, it is necessary to calculate the error rate in the estimates **[7]**.

$$MAPE = \left(\frac{100\%}{n}\right) \sum_{t=1}^{n} \left| \frac{X_t - F_t}{X_t} \right| \quad (9)$$

Information :

X_t= actual score in period t

F_t= forecasting score in period t

n = total number of statistics

In accordance with the formula above, the smaller the MAPE score, the more accurate the forecasting model. The range scores used to assess the skill of a forecasting model are shown in the table below. MAPE value terms are presented in **Table 1.**

Table 1. MAPE Value Terms

MAPE Score	Parameter
Less than 10 percent	Very good
10 percent – 20 percent	Good
20 percent – 50 percent	Enough
Less than 50 percent	Bad

3. Results and Discussion

The rainfall prediction statistics used as a dataset in this study are precipitation data in the Brebes sub-district, Brebes district. The total rainfall data is 60 from January 2019 to December 2023. Comparison graph of average rainfall is presented in **Figure 1**.

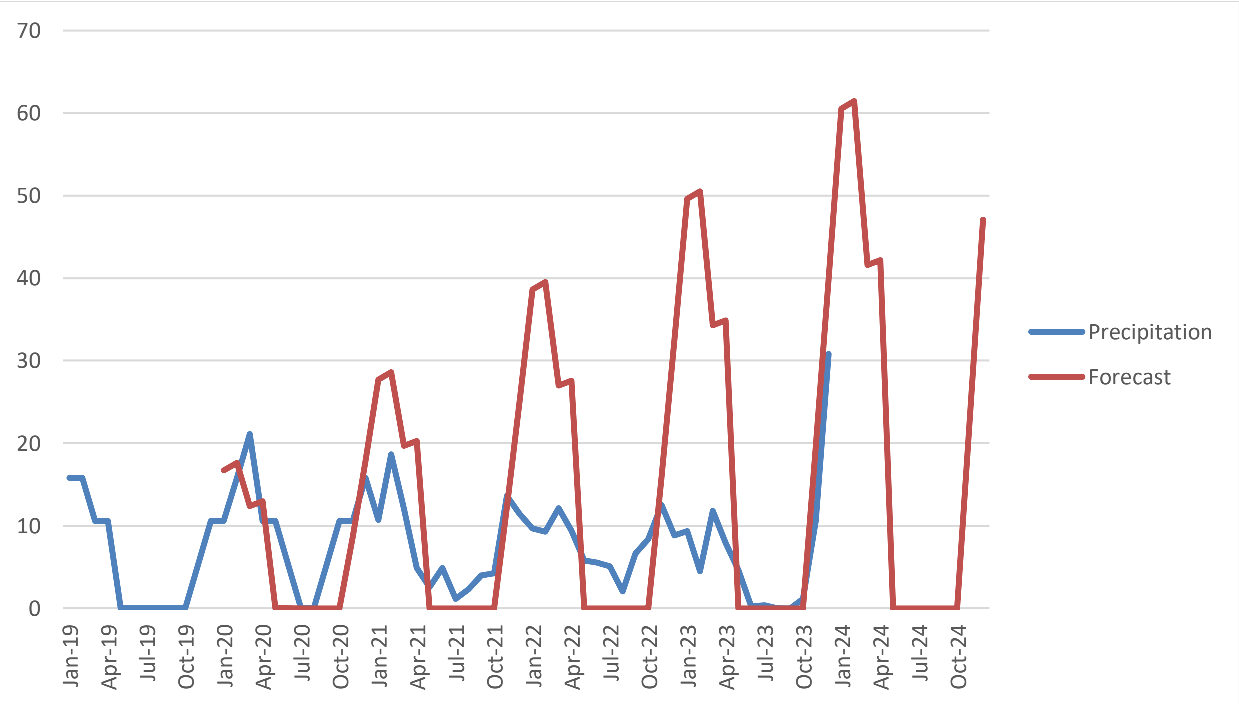

Figure 1. Comparison Graph of Average Rainfall

According to the graph above, the average rainfall model for Brebes District is very diverse. Average rainfall statistics are highest in December 2023 and lowest in July 2019. In the image data, you can see that the data fluctuates every year. The monthly rainfall pattern shown in Figure 1 shows fluctuations each year with a tendency for high rainfall to occur from November to March. In other months, the rainfall in Brebes District, Brebes Regency, is relatively lower. This condition occurs repeatedly yearly, forming a seasonal pattern in rainfall statistics in the Brebes sub-district, Brebes district. Based on rainfall data in the Brebes sub-district Brebes district, it was found that a trend pattern was forming—recapitulation of average rainfall using the Multiplicative method for Holt-Winters Exponential Smoothing.

The length of the season (L) is used in the calculation process, which is 48 because it is used monthly for one year. After that, a recapitulation was carried out for the initial value of data termination using equations (1), (2), and (4), and then the numbers below were obtained. Initial statistical smoothing scores are presented in **Table 2.**

Table 2. Initial Statistical Smoothing Scores

Year	Month	Rainfall	Levels (SL)	Trends (TL)	Seasonal
2019	January	15.82			2.77
2019	February	15.82			2.77
2019	March	10.55			1.85
2019	April	10.55			1.85
2019	May	0.0001			0
2019	June	0.0001			0
2019	July	0.0001			0
2019	August	0.0001			0
2019	September	0.0001			0
2019	October	0.0001			0
2019	November	5.27			0.92
2019	December	10.55	5.71	0.33	1.85

Then, using a solver table, you can get optimal benchmark values for the variables α, β, and γ. In this case, the scores of α=0, β=0, and γ=0 are then recapitulated using the Holt-Winters Exponential Smoothing method. Using the Multiplicative pattern according to the stages in the research methodology, we get the recapitulation results in **Table 3.**

Table 3. Comparison of Actual and Predicted Data

Year	Month	Actual Data	Prediction	Difference	Absolute Error (AE)	Squared Error (SE)	Absolute Percent Error (APE)
2020	January	10.55	16.73	-6.18	6.18	38.22	58.60
2020	February	15.82	17.65	-1.83	1.83	3.33	11.54
2020	March	21.09	12.38	8.71	8.71	75.94	41.32
2020	April	10.55	12.98	-2.43	2.43	5.93	23.07
2020	May	10.55	0.00	10.55	10.55	111.30	100.00
2020	June	5.27	0.00	5.27	5.27	27.77	100.00
2020	July	0.0001	0.00	0.00	0.00	0.00	40.38
2020	August	0.0001	0.00	0.00	0.00	0.00	46.15
2020	September	5.27	0.00	5.27	5.27	27.77	100.00
2020	October	10.55	0.00	10.55	10.55	111.30	100.00
2020	November	10.55	8.61	1.94	1.94	3.75	18.35
2020	December	15.82	17.85	-2.03	2.03	4.13	12.85
2021	…	…	…	…	…	…	…
2022	…	…	…	…	…	…	…
2023	January	9,325	49.59	-40.26	40.26	1620.93	431.75
2023	February	4.47	50.50	-46.03	46.03	2118.61	1029.72
2023	March	11.81	34.28	-22.47	22.47	505.12	190.30
2023	April	7,905	34.89	-26.99	26.99	728.37	341.41
2023	May	4.6	0.00	4.60	4.60	21.16	99.99
2023	June	0.24	0.00	0.24	0.24	0.06	99.86
2023	July	0.335	0.00	0.33	0.33	0.11	99.90
2023	August	0.0001	0.00	0.00	0.00	0.00	253.82
2023	September	0.005	0.00	0.00	0.00	0.00	92.81
2023	October	1,115	0.00	1.11	1.11	1.24	99.97
2023	November	10,545	19.56	-9.01	9.01	81.24	85.47
2023	December	30.82	39.76	-8.94	8.94	79.96	29.01

Forecasting rainfall data for 2024 is presented in **Table 4.**

Table 4. Forecasting Rainfall Data for 2024

Month	Prediction	Difference	Absolute Error (AE)	Squared Error (SE)
January	60.54	-60.54	60.54	3664.70
February	61.45	-61.45	61.45	3776.03
March	41.59	-41.59	41.59	1729.54
April	42.20	-42.20	42.20	1780.53
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	23,21	-23.21	23,21	538.53
December	47.07	-47.07	47.07	2215.12

Next, calculate the error value from the estimates that have been implemented using the MAPE formula based on equation (9):

$$MAPE = \left(\frac{100\%}{n}\right)\sum_{t=1}^{n}\left|\frac{X_t - F_t}{X_t}\right|$$

$$MAPE = \left(\frac{100\%}{48}\right) * (6663{,}82)$$

$$= 138{,}829583$$

Based on the results of calculating the MAPE value above, the MAPE value for Precipitation is 138.829583. The MAPE value for Earth Skin is 2.34346 with the number α equal to 0 β equal to 0.9 γ equal to 0.82634. The MAPE score for Surface is 0.05241 with the number α equal to 0.326014 β equal to 0.140459 γ equal to 0.417165. The MAPE value for Wind Speed is 14.5396 with the number α equal to 0.14853 β equal to 0.05511 γ equal to 1.

4. Conclusion

Implementation of the Holt-Winters Exponential Smoothing method in forecasting rainfall in planting shallots in the Brebes sub-district, Brebes district, using monthly data from January 2019 to December 2023, gave results with rainfall variables with the MAPE value for Precipitation being 138.829583. The MAPE value for Earth Skin is 2.34346 with a score of α equal to 0 β equal to 0.9 γ equal to 0.82634. The MAPE value for Surface is 0.05241 with a score of α equal to 0.326014 β equal to 0.140459 γ equal to 0.417165. The MAPE value for Wind Speed is 14.5396 with a score of α equal to 0.14853 β equal to 0.05511 γ equal to 1.

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