Jurnal E-Komtek
Vol. 8 No. 1 (2024) pp. 1-9
https://jurnal.politeknik-kebumen.ac.id/index.php/E-KOMTEK
p-ISSN : 2580-3719 e-ISSN : 2622-3066

Forecasting Air Temperature Using the Triple Exponential Smoothing Method

Heri Susanto[1], Dimara Kusuma Hakim[2]
[1,2]Department of Informatics Engineering, Universitas Muhamadiyah Purwokerto, Indonesia, 53182

dimarakusumahakim@gmail.com

https://doi.org/10.37339/e-komtek.v8i1.1723

Published by Politeknik Piksi Ganesha Indonesia

Artikel Info
Submitted:
22-04-2024
Revised:
15-05-2024
Accepted:
20-05-2024
Online first :
21-06-2024

Abstract

Changes in air temperature are a major challenge in Indonesian agriculture. Erratic air temperatures hurt plant growth, so farmers must adjust planting schedules and plant selection according to the air temperature at a certain period. The author aims to predict minimum and maximum air temperatures in Temanggung district in 2024 using the Triple Exponential Smoothing (TES) method. Monthly air temperature data in Temanggung district for the period 2020 to 2023 is used for air temperature forecasting using the TES method. The analysis results show that the TES model can predict air temperature with fairly good accuracy. The minimum temperature is expected to be 23°C, maximum 26-27°C. The research results provide benefits for the agricultural sector in Temanggung. Farmers can use the results of air temperature predictions to adjust planting schedules based on crops that suit the air temperature to minimize the negative impact of air temperature on plant growth and agricultural yields.

Keywords: *Forecasting, Air Temperature, Triple Exponential Smoothing*

Abstrak

Perubahan suhu udara jadi tantangan utama di pertanian Indonesia. Suhu udara tidak menentu berdampak negatif terhadap pertumbuhan tanaman, sehingga petani harus menyesuaikan jadwal penanaman dan pemilihan tanaman yang sesuai dengan suhu udara pada periode waktu tertentu. Penulis bertujuan untuk memprediksi suhu udara minimum dan maksimum di kabupaten Temanggung pada tahun 2024 menggunakan metode Triple Exponential Smoothing (TES). Data suhu udara bulanan di kabupaten Temanggung selama periode 2020 hingga 2023 digunakan untuk peramalan suhu udara menggunakan metode TES. Hasil analisis menunjukkan bahwa model TES dapat memprediksi suhu udara dengan akurasi yang cukup baik. Suhu minimum diperkirakan 23°C, maksimum 26-27°C. Hasil penelitian memberikan manfaat bagi sektor pertanian di Temanggung. Petani dapat menggunakan hasil prediksi suhu udara untuk menyesuaikan jadwal penanaman berdasarkan tanaman yang sesuai dengan suhu udara sehingga dapat meminimalkan dampak negatif suhu udara terhadap pertumbuhan tanaman dan hasil pertanian.

Kata-kata kunci: *Peramalan, Suhu Udara, Pemulusan Eksponensial Tiga Kali Lipat*

1. Introduction

Climate change is a long-term change in climate elements or fluctuations that occur over time. This change in climate patterns has existed since the start of the Industrial Revolution 1.0 in 1750 [1]. One sector that is very sensitive to climate change is agriculture, especially in tropical regions where rice plants are a staple food source for the population and greatly influence cropping patterns, planting time, production, and quality of produce [2].

One of the elements that influence climate change in the agricultural sector is air temperature. Air temperature affects plant growth, resulting in crop failure or poor production quality. Air temperature affects plant life activities, including the processes of photosynthesis, respiration, transpiration, growth, pollination, fertilization, and fruit loss [3]. Plants need ideal temperatures so they can be utilized optimally. Excessive temperatures, whether too high or too low, can inhibit growth and cause plant death. High air temperatures can inhibit photosynthesis, a vital process for plants to produce energy and biomass [4]. A report published by the Intergovernmental Panel on Climate Change (IPCC) in 2001 stated that there had been an increase in global air temperature of 33 degrees Fahrenheit since 1861. The report also predicted that there would be an increase in global average temperature of 1.1 to 6.4 degrees Celsius from 1990 to 2100 [5].

In 2022, Central Java province recorded an agricultural sector export value of 8.3 trillion rupiah (Central Java Provincial Government, 2021). This achievement makes Central Java the province with the highest agricultural export value. Temanggung Regency, the majority of which is dominated by agricultural land and has great potential [6]. Based on data from the Department of Food Security, Agriculture and Fisheries (DKPPP) Temanggung District 2021, the agricultural land area of 48,669 hectares means Temanggung District has great potential so efforts are needed to optimize production results to prevent crop failure.

Therefore, we need a model that can be used to forecast air temperature in the future. Forecasting is estimating the size or amount of something in the future using data that existed in the previous period and then analyzing it naturally especially using statistical methods. The purpose of forecasting is to reduce uncertainty in the future [7].

Research on air temperature forecasting in Cilacap district using the Triple Exponential Smoothing method using monthly minimum and maximum air temperature data in Cilacap from 2017 to 2018. The results of the research show that maximum temperature forecasting with $\alpha = 0.4$, $\delta = 0.1$, and $\gamma = 0.1$ obtained a MAPE value of 1.62917%, and forecasting the minimum

temperature with α = 0.7, δ = 0.1, and γ = 0.1 obtained a MAPE value of 1.92473%. Because the MAPE value is in the range 0 < x < 10, the forecasting results are said to be accurate **[8]**.

The expected research result is that air temperature forecasting using the Triple Exponential Smoothing method in Temanggung district can provide information about minimum and maximum air temperatures to farmers in Temanggung district for planting planning based on the predicted air temperature.

2. Method

This research uses quantitative methods, which focus on historical data patterns. The forecasting method applied is the time series forecasting method **[9]**. The time series method is a statistical technique that utilizes historical data collected over a certain period. The time series approach assumes that what happened in the past will continue in the future **[10]**. In other words, time series forecasting is based on past data. This method is an approach that uses exponentially decreasing weighting **[11]**. One of the methods used for time series forecasting is the Triple Exponential Smoothing method.

The Triple Exponential Smoothing method is an approach to time series forecasting that expands the simple Exponential Smoothing concept by including trend and seasonal elements **[12]**. Triple Exponential Smoothing (TES) is a technique that can forecast several periods at once. The main advantage of Triple Exponential Smoothing lies in the use of triple smoothing, which produces more precise predictions **[13]**. Triple Exponential Smoothing involves three main elements, namely smoothing elements, trend elements, and seasonality for each period, using three different weightings in the forecasting process. These three weightings consist of alpha (α), beta (β), and gamma (γ). Alpha (α) controls the degree of smoothing relative to the most recent observations. Beta (β) controls the level of relative smoothing for evaluating trends in the forecasting process, with a value between 0 and 1. Gamma controls the relative smoothing for estimating seasonal elements and has a value between 0 and 1 **[14]**.

The statistical method used in forecasting air temperature in Temanggung district is the Triple Exponential Smoothing (TES) forecasting method. The aim of using the Triple Exponential Smoothing forecasting method is to predict monthly minimum and maximum air temperatures in Temanggung district, which is an area that is primarily agricultural. Forecasting calculations using the Triple Exponential Smoothing method:

$S'^{t} = \alpha X_t + (1 - \alpha)\, S'_{t-1}$

$S''_t = \alpha S'_t + (1 - \alpha) S''_{t-1}$

$S'''_t = \alpha S''_t + (1 - \alpha) S'''_{t-1}$

$\alpha_t = 3S'_t - 3S''_t S'''_t$

$b_t = \frac{\alpha}{2}(1 - \alpha)(6 - 5\alpha)S'_t - (10 - 8\alpha)S''_t + (4 - 3\alpha)S'''_t$

$c_t = \alpha^2 (1 - a)^2 (S'_t - 2S''_t + S'''_t$

$F_{t+m} = \alpha_t + b_t + 1/2c_t$

namely:

a. S'_t =Single smoothing value,

b. S''_t =Double smoothing value,

c. S'''_t =Seasonal smoothing values,

d. α_p =Exponential smoothing parameters (0 < < 1),α_p

e. F_{t+m} = Forecast value at time t + m.

After obtaining the forecast value, the next step is to test the accuracy of the forecast results using the Mean Absolute Percentage Error (MAPE), calculated from the difference between the forecast value and the actual value.

$$MAPE = \frac{1}{n}\sum_{i=0}^{n} \left|\frac{F_t - yi}{yi}\right| \times 100\%$$

Namely:

a. F_t =Forecasting value

b. yi =Actual value

c. n = lots of data

The smaller the MAPE value, the better or more accurate the forecasting results; the MAPE value criteria can be seen in Table 1 **[15]**.

d. F_t =Forecasting value

e. yi =Actual value

f. n = lots of data

The smaller the MAPE value, the better or more accurate the forecasting results; the MAPE value criteria can be seen on **Table 1 [15]**.

Table 1. MAPE Value Criteria

MAPE value	Interpretation
<10%	The forecasting results are very accurate
10% - 20%	Accurate forecasting results
20% - 50%	The forecasting results are quite accurate
>50%	Inaccurate forecasting results

This research was conducted for one year, 2024. Data processing was done using the Microsoft Excel application. The criteria used to determine the best model were the smallest MAPE value. The data used in this research is secondary data. Secondary data is obtained from other parties in this research, such as NASA (National et al. Administration) satellites. The data used is monthly air temperature data with a time interval of 5 years, namely 2019–2023. The research procedure for forecasting air temperature using the Triple Exponential Smoothing method is as follows:

a. Literature Study: Look for literature references related to research, such as air temperature forecasting and time series methods (Triple et al.), through journals, articles, books, and previous research. The literature study results will help researchers choose a suitable method for predicting air temperature and analyzing data using this method.
b. Data collection: Research on air temperature forecasting needs to collect research data such as maximum temperature, minimum temperature, air humidity, and wind speed. In this research, data obtained from NASA's Power satellite will be used for air temperature forecasting analysis using the Triple Exponential Smoothing method.
c. Data Analysis: The analysis stages in this research were carried out using the Microsoft Excel application. Data obtained from NASA satellites was then analyzed using the Triple Exponential Smoothing method. The following are the analysis steps using the Triple Exponential Smoothing method:
    1. Model Identification: Determining the model that fits the data
    2. Parameter Estimation: Determine the values of α, β, and γ.
    3. Initial Value Calculation: Calculates initial values for data, trends, and seasonality.
    4. Error Value Calculation: Measures prediction error with metrics such as MAPE (Mean et al.) and RMSE (Root Mean Squared Error).
    5. Conclusion: The conclusion is an explanation of the results of the research that has been carried out.

3. Results and Discussion

Forecasting air temperature using the Triple Exponential Smoothing method in Temanggung district uses monthly minimum and maximum temperature data from 2021 to 2023. Based on the output data, as in **Figures 1** and **Figure 2** shows that the minimum and maximum air temperatures have a seasonal pattern. Hence, the Triple Exponential Smoothing or Holt-Winters method is suitable for data with seasonal patterns like this. This method smoothes three components of the data: level (or average), trend, and seasonality. By using smoothing parameters alpha for level, beta for trend, and gamma for seasonality, this method can capture seasonal patterns in data and forecast future air temperatures.

In **Figures 3** and **Figure 4,** IDW interpolation (Inverse Distance Weighted) is used. IDW (Inverse Distance Weighted) interpolation is a spatial method that assumes that each input point has a local influence that decreases as the distance increases. The power value in IDW interpolation determines how much influence the input points have. The higher the power value, the greater the influence of closer points, resulting in a more detailed surface **[16]**.

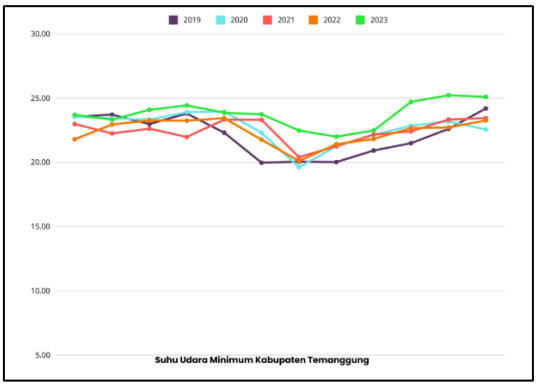

Figure 1. Minimum Air Temperature

Figure 1 plots monthly minimum air temperature data from 2019 to 2023. The minimum air temperature in Temanggung district from 2020 to 2023 ranges from 20 degrees Celsius to 25 degrees Celsius. Maximum air temperature in **Figure 2.**

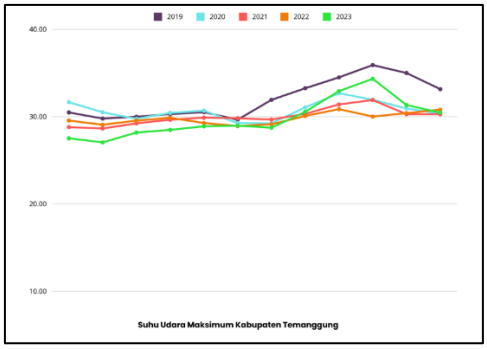

Figure 2. Maximum Air Temperature

Figure 2 shows a monthly air temperature graph for the maximum temperature from 2020 to 2023. The maximum air temperature in the Temanggung district from 2020 to 2023 ranged from 27 degrees Celsius to 34 degrees Celsius. Minimum air temperature with IDW interpolation is presented in **Figure 3.**

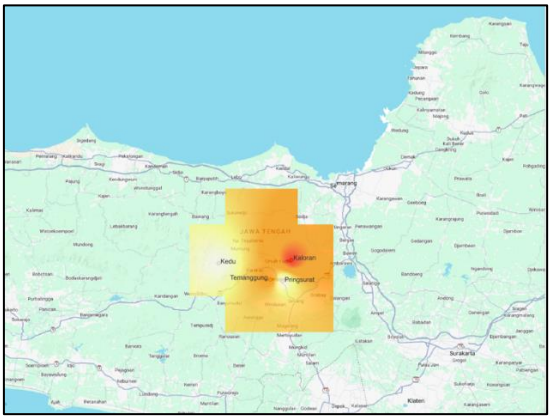

Figure 3. Minimum Air Temperature with IDW Interpolation

Figure 3 shows images of the minimum air temperature at four points: Temanggung sub-district, Kedu sub-district, Pringsurat sub-district, and Kaloran sub-district, using IDW (Inverse Distance Weighted) interpolation. The minimum air temperature is lower in the Kedu and Pringsurat sub-districts, at 21.28 degrees Celsius, while the highest is in the Kaloran sub-district, at 27.78 degrees Celsius.

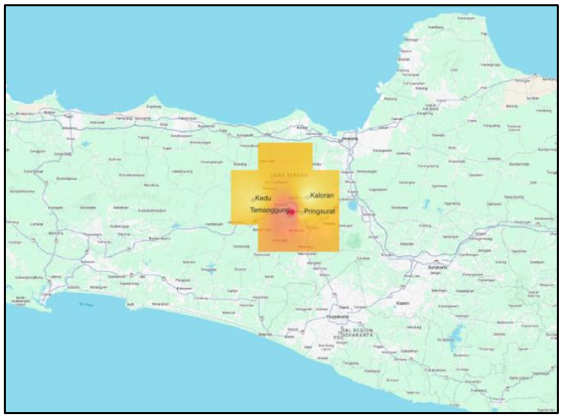

Figure 4. Maximum Air Temperature with IDW Interpolation

Figure 4 shows an interpolated image with IDW (Inverse Distance Weighted) of the maximum air temperature at four points: Temanggung sub-district, Kedu sub-district, Pringsurat sub-district, and Kaloran sub-district. The maximum air temperature is lower in the Kaloran sub-district, at 28.29 degrees Celsius, while the highest is in the Kaloran sub-district, at 30.46 degrees Celsius.

The next step is to forecast a minimum air temperature of 22 degrees Celsius and a maximum of 27 degrees Celsius in 2024 using the Triple Exponential Smoothing method in Temanggung district using the Microsoft Excel application. The air temperature forecasting results for the Temanggung Regency are presented in **Table 2.**

Table 2. 2024 Air Temperature Forecasting Results for Temanggung Regency

Year	Month	Temperature (°C)	
		Minimum	Maximum
2024	January	24.04	26.01
	February	23.75	26.72
	March	23.71	27.41
	April	24.18	28.53
	May	24.23	28.89
	June	22.78	28.61
	July	22.04	29.82
	August	22.37	30.31
	September	22.68	31.76
	October	23.46	33.31
	November	25.09	33.26
	December	25.56	29.16

Table 2 shows the results of air temperature forecasting using the Triple Exponential Smoothing method in Temanggung Regency in 2024. Based on Table 2, the minimum air temperature has an average of 22.04°C and a maximum of 33.31°C.

4. Conclusion

The results of this research show that forecasting minimum air temperature with α = 0.69, β= 0, and γ = 1 obtained a MAPE value amounting to 1.9033% and forecasting maximum air temperature with α = 0.89, β = 0.006, and γ = 1 obtained a MAPE value of 2.409%. Because the MAPE value is in the range $0 < x < 10$, the forecasting results are said to be accurate. The results of air temperature forecasting in Temanggung district are expected to provide an overview regarding the selection and planting schedule of vegetables**.**

References

[1] PP Simanjuntakand A. Safril, "FUTURE TRENDS OF RAINFALL AND EXTREME AIR TEMPERATURES (PERIOD 2021-2030) BASED ON REPRESENTATIVE CONCENTRATION PATHWAY (RCP) 4.5 IN PALU CITY," 2020. [Online]. Available: http://cordex-ea.climate.go.kr/

[2] A. Nurhidayat, AKT Difa, F. Nasrullah, FH Anwar,and DO Radianto, "THE INFLUENCE OF CLIMATE CHANGE ON RICE AGRICULTURE PRODUCTIVITY IN TROPICAL REGIONS".

[3] N. Herlinaand A. Prasetyorini, "Effect of Climate Change on Planting Season and Productivity of Maize (Zea mays L.) in Malang Regency," Indonesian Journal of Agricultural Sciences, vol. 25, no. 1, pp. 118–128, Jan. 2020, doi: 10.18343/jipi.25.1.118.

[4] I.TAyankojo and KT Morgan, "Increasing air temperatures and its effects on growth and productivity of tomatoes in south Florida," Plants, vol. 9, no. 9, pp. 1–16, Sep. 2020, doi: 10.3390/plants9091245.

[5] F.Rozci, "The Impact of Climate Change on the Rice Agriculture Sector," Socio Agribusiness Scientific Journal (JISA), vol. 23, pp. 108–116, 2023.

[6] G. Handoyo, PB Santosa,and Darmawanto, "OPTIMIZATION OF AGRICULTURAL POTENTIAL BASED ON APPROPRIATE AND DIGITAL TECHNOLOGY IN TEMANGGUNG DISTRICT," 2023. [Online]. Available: http://ejournal2.undip.ac.id/index.php/pasopati

[7] mNu, E. Nur Rizki, A. Alimul Karim, and R. Kumala Sari, "Forecasting the Number of Domestic Passengers at Sultan Syarif Kasim II Airport Using the Winter's Exponential Smoothing Method," Journal of Applied Industrial Technology and Management (JTMIT), vol. 3, no. 1, pp. 57–66, 2024.

[8] R. Indriani, A. Sugandha, A. Tripena, N. Larasati, A. Fatkhur Rokhman,and A. Talib Bon, "Forecasting of Air Temperature in Cilacap Regency with Triple Exponential Smoothing (Holt-Winter) Method," 2020.

[9] A. Hajjahand NM Yulvia, "Error Analysis Toward Sales Data Forecasting Error Analysis Toward Sales Data Forecasting," 2021.

[10] L. Yuliana, "SALES PLANNING ANALYSIS USING THE TIME SERIES METHOD (CASE STUDY ON PD. SUMBER JAYA ALUMINUM) Lingga Yuliana STIE Media Nusantara Citra ARTICLE INFORMATION ABSTRACT Mitra Management Journal (JMM Online)," Jul. 2019.

[11] AhmadNurfaizi and Dimara Kusuma Hakim, "Rainfall Frequency Analysis in Nusawungu District Using the Gumbel Method and Forecasting Using Exponential Smoothing," Pratama Media Journal, vol. 17, no. 2, pp. 125–139, 2023.

[12] D. Kusuma Hakim, R.Gernowo, and A. Widhi Nirwansyah, "Rainfall, Wind Speed, and Temperature Forecast Using Triple Exponential Smoothing and Gradient Descent," KnE Social Sciences, Mar. 2024, doi: 10.18502/kss.v9i6.15311.

[13] R. Saputro Bayu, K.Paranita Kartika, and W. Dwi Puspitasari, "Implementation of the Triple Exponential Smoothing Method for Predicting Helmet Sales. Implementation of the Triple Exponential Smoothing Method for Predicting Helmet Sales," 2022.

[14] IWAS Darma, IPEG Gunawan,and NP Sutramiani, "Forecasting the Number of Tourist Visits Using Triple Exponential Smoothing," Bali, 2020.

[15] RN Puspita, "FORCECASTING THE LEVEL OF OPEN UNEMPLOYMENT IN BANTEN PROVINCE USING THE TRIPLE EXPONENTIAL SMOOTHING METHOD," vol. 3, no. 2,Aug. 2022, doi: 10.46306/lb.v3i2.

[16] R.AYudanegara, D. Astutik, A. Hernandi, TP Soedarmodjo, and E. Alexander, "USE OF THE INVERSE DISTANCE WEIGHTED (IDW) METHOD FOR LAND VALUE ZONE MAPPING (CASE STUDY: GEDONG MENENG DISTRICT, BANDAR LAMPUNG)," Journal of Geodesy and Geomatics, vol. 04, pp. 85–90, 2021.