




Water Pollution Forecasting in Cengklik Reservoir Using the Triple Exponential Smoothing Method

Nooriza Modistira Sakti¹, Dimara Kusuma Hakim² , Elindra Ambar Pambudi³, Maulida Ayu Fitriani⁴

¹⁻⁴Department of Informatics Engineering, Universitas Muhammadiyah Purwokerto, Indonesia, 153174

 dimarakusuma@gmail.com

 <https://doi.org/10.37339/e-komtek.v9i1.2414>

Published by Politeknik Piksi Ganesha Indonesia

Abstract

Artikel Info

Submitted:

30-04-2025

Revised:

20-05-2025

Accepted:

24-06-2025

Online first :

30-06-2025

Water quality is a crucial element for the sustainability of ecosystems and human life, yet it is often threatened by pollution resulting from human activities. Cengklik Reservoir in Boyolali Regency has shown increasing levels of pollution influenced by domestic waste, agricultural fertilizers, and residual fish feed from Floating Net Cages (KJA). This study aims to predict water pollution levels to support more effective management efforts by applying the Triple Exponential Smoothing (TES) method to pollution index data from 2016 to 2023. The forecasting results reveal a clear seasonal pattern, with a Mean Absolute Percentage Error (MAPE) of 34.36%, indicating a moderately good level of accuracy. These findings suggest that TES is capable of identifying general pollution patterns, although further approaches are needed to fully capture the dynamics of water pollution. As a follow-up, the study recommends optimizing the number and placement of KJA units, improving waste management, and implementing community education programs to preserve water quality and ensure the sustainability of the reservoir ecosystem.

Keywords: water pollution, Triple Exponential Smoothing, reservoir, forecasting, Cengklik, Boyolali.

Abstrak

Kualitas air merupakan elemen krusial bagi keberlangsungan ekosistem dan kehidupan masyarakat, namun sering kali terancam oleh pencemaran akibat aktivitas manusia. Waduk Cengklik di Kabupaten Boyolali menunjukkan peningkatan pencemaran yang dipengaruhi oleh limbah domestik, pupuk pertanian, dan sisa pakan ikan dari Keramba Jaring Apung (KJA). Penelitian ini bertujuan untuk memprediksi tingkat pencemaran air guna mendukung upaya pengelolaan yang lebih efektif, dengan menerapkan metode Triple Exponential Smoothing (TES) terhadap data indeks pencemaran periode 2016 hingga 2023. Hasil peramalan menunjukkan pola musiman yang cukup jelas, dengan nilai Mean Absolute Percentage Error (MAPE) sebesar 34,36%, yang menunjukkan tingkat akurasi yang cukup baik. Temuan ini mengindikasikan bahwa TES mampu mengidentifikasi pola pencemaran secara umum, meskipun pendekatan lanjutan tetap diperlukan untuk menangkap dinamika pencemaran secara lebih menyeluruh. Sebagai tindak lanjut, penelitian ini merekomendasikan optimalisasi jumlah dan tata letak KJA, peningkatan pengelolaan limbah, serta pelaksanaan program edukasi masyarakat untuk menjaga kualitas air dan keberlanjutan ekosistem waduk.

Kata-kata kunci: pencemaran air, Triple Exponential Smoothing, waduk, peramalan, Cengklik, Boyolali.



This work is licensed under a [Creative Commons Attribution-NonCommercial 4.0 International License](https://creativecommons.org/licenses/by-nc/4.0/).

1. Introduction

Water has an important role as a natural resource that supports the sustainability of various forms of life [1]. However, suboptimal management of makes water very vulnerable to pollution due to human activities [2]. Due to its nature as a medium capable of spreading contaminants widely, water pollution has a direct impact on human health, the environment, as well as vital sectors such as agriculture and industry [3]. For example, the increase of BOD (Biochemical Oxygen Demand) levels to 10 mg/L and COD (Chemical Oxygen Demand) of 25 mg/L at several points of the Cengklik Reservoir shows conditions that have exceeded the water quality standards according to PP No. 22 of 2021. KJA waste even increase phosphate levels to 2 mg/L, triggering eutrophication that threatens aquatic biota.

Cengklik Reservoir in Boyolali Regency, Central Java, is a multifunctional reservoir that supplies domestic raw water, agricultural irrigation, and supports aquaculture through KJA (Floating Net Framework) [4]. However, uncontrolled use causes moderate to severe pollution, especially in the dry season. The main pollutant sources consist of internal waste, such as fish feed residu from KJA, as well as external waste in the form of domestic waste, agricultural fertilizers, industrial waste, and flow from upstream [5]. The cumulative impact threatens the sustainability of the reservoir's ecological function and the welfare of the surrounding community [6].

To anticipate pollution exclusion, time series analysis is used to predict trends based on seasonal patterns [7]. This study applied the Triple Exponential Smoothing (TES) method due to its ability to capture trend, seasonal, and fluctuation components of data [8]. The TES model parameters were determined empirically, with smoothing values of $\alpha = 0.7$, $\beta = 0.006$, and $\gamma = 0$ indicating moderate sensitivity to data changes. Visualization of the results showed a pattern of increasing pollution in the middle of the year, which was consistent with the intensity of fish farming activities and low water discharge.

Although it provides a useful baseline, the TES has limitations in dealing with volatile and non-linear pollution data. The study results show large error values, indicating that while the TES can depict seasonal patterns, prediction accuracy requires additional approaches. Complementary methods such as ARIMA (Auto Regressive Integrated Moving Average) can handle non-seasonal components, while machine learning-based models such as LSTM (Long

Short-Term Memory) can learn complex patterns and improve prediction accuracy by utilizing long historical data. To support strategic and sustainable water quality management, several key actions can be implemented to gradually limit the number of KJAs to reduce internal waste load.

Community education is a critical success factor, with community-based training and environmental awareness campaigns that teach the understanding that protecting the reservoir water means protecting their loves [9]. In terms of policy, this strategic recommendation can be integrated in regional regulations such as the Boyolali District regulation on water effluent control and strengthened through the support of ministries such as the MoEF. As a reference, Saguling Reservoir in West Java has successfully reduced eutrophication levels through a combination of technical and social approaches – proving the effectiveness of similar strategies in a tropical reservoir context.

2. Method

This research was conducted using a quantitative approach to predict water quality pollution in Cengklik Reservoir. The research process follows stages that are organized systematically, according to the research flowchart that has been made. The diagram of the research method can be depicted as in [Figure 1](#).

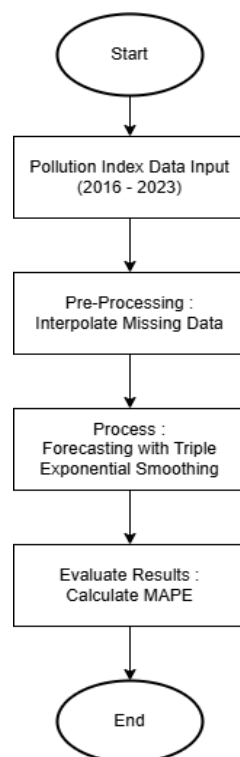


Figure 1. Research Flow Chart

2.1. Pre-Research

The initial stage of the research began with a literature study to deepen the theory related to water quality and relevant forecasting methods, including Triple Exponential Smoothing (TES). Water pollution index data was collected from official sources, namely the website of the Ministry of PUPR Directorate General of Water Resources BBWS Bengawan Solo, covering the period from 2016 to 2023. This data was identified as the main basis for further analysis.

2.2. Data

The data obtained contains monthly water pollution index values during the research method. It was found that there were data gaps in some periods, such as January - April 2019 and April - May 2020, which could affect the analysis process and the accuracy of forecasting. Data gaps are resolved by interpolation. Data interpolation is a method used to estimate new values based on existing data [10]. This method is used to estimate missing values based on data around the blank period, resulting in a complete data set. This step ensures that the analysis can be conducted thoroughly without being interrupted by missing data.

2.3. Testing and Analysis

The data that has been collected is processed using the Triple Exponential Smoothing (TES) method. Triple Exponential Smoothing is an exponential smoothing-based data smoothing method specifically designed to process data that shows trend patterns and seasonal variations [11]. This method uses three parameters, namely alpha, beta, and gamma, each of which serves to adjust the smoothing rate of actual data, trend patterns, and seasonal patterns [12]. The advantage of Triple Exponential Smoothing lies in its ability to capture complex dynamics in time series data, making it very effective in producing accurate forecasts for short-term periods, especially when data has significant seasonal fluctuations [13].

The forecasting process using the Triple Exponential Smoothing method begins with the determination of the parameter values α , β , and γ , which can be determined through optimization methods or based on experience. The α parameter controls how quickly the model responds to changes in actual data, while β and γ serve to capture changes in trends and seasonal patterns, respectively. By inputting these parameters, the data is initialized for the calculation of single, trend, and seasonal smoothing values through a series of mathematical equations [14].

The formula used in Triple Exponential Smoothing includes several steps, where each step contributes to the update of the smoothing, trend, and seasonal values.

- a. Exponential Smoothing

$$St = \alpha \frac{xt}{lt-L} (1 - \alpha)(St - 1 + Tt - 1) \quad (1)$$

- b. Trend Smoothing

$$Tt = \beta(St - St - 1) + (1 - \beta)Tt - 1 \quad (2)$$

- c. Seasonal Smoothing

$$lt = \gamma \frac{xt}{St} (1 - \gamma)lt - t \quad (3)$$

- d. Period Forecast

$$Ft + m = (St + mTt) + lt - L + m \quad (4)$$

Where:

α = Actual data smoothing parameters.

β = Smoothing parameters for trend patterns.

γ = Smoothing parameters for seasonal patterns.

X_t = Actual value or statistic at period t .

S_t = Value of the seasonal exponential smoothing at period t .

L_t = Value of the level smoothing at period t .

T_t = Value of the trend smoothing at period t .

k = Number of future periods to be forecasted.

F_{t+m} = Forecasted value at period $t+m$.

The parameters α , β , and γ , are optimized using the Solver tool in Microsoft Excel to produce more accurate forecasts.

2.4. Results

The analysis process with the TES method provides a basis for forecasting water quality in Cengklik Reservoir by considering seasonal patterns, trends, and data fluctuations. The results of data processing are continued to the accuracy evaluation process through error calculation.

2.5. Water Quality Prediction with the Smallest MAPE

Forecasting accuracy is evaluated using Mean Absolute Percentage Error (MAPE). MAPE is a method of measuring the level of error value based on the difference between predicted and actual values in percentage form [15].

The MAPE calculation formula is as follows [16] :

$$MAPE = \left(\frac{100\%}{n}\right) \sum_{t=1}^n \left|\frac{X_t - F_t}{X_t}\right| \quad (6)$$

Where:

X_t = actual value at time t

F_t = forecasted value at time t

n = total number of observations

MAPE helps evaluate the accuracy of the prediction results produced by the forecasting method. The MAPE value criteria are shown in the following Table 1 [17].

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

3. Results and Discussion

The graph in Figure 2 shows the comparison between actual data (in blue) and predicted or forecast data (in orange) for the period 2016 to 2024.

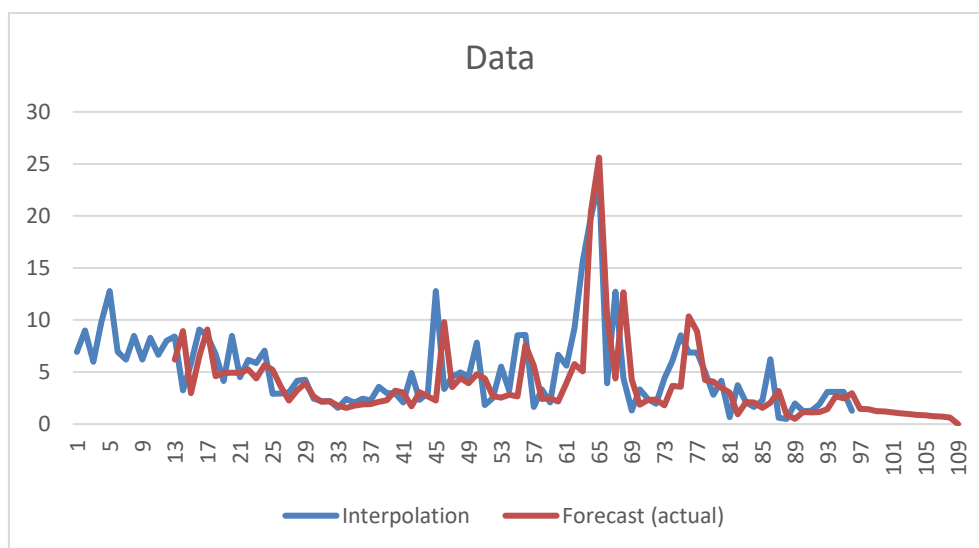


Figure 2. Comparison Chart Between Actual and Predicted Data

Figure 2 shows that the predictions follow the fluctuation pattern of the actual data, but there are some significant deviations in some periods. This graph illustrates that while the prediction model provides a general overview, its accuracy can vary depending on the data conditions and other influencing factors. The results of the data analysis of water quality pollution index values obtained from 2016 to 2023. The data used includes monthly pollution index values, which are presented in **Table 2**.

Table 2. Data on Water Pollution Index Values in Cengklik Reservoir

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	6.94	9	5.98	9.81	12.78	6.93	6.21	8.48	6.2	8.3	6.65	8.03
2017	8.43	3.26	5.84	9.08	8.48	6.71	4.14	8.47	4.51	6.17	5.85	7.06
2018	2.9	2.93	3.02	4.16	4.27	2.45	2.19	2.2	1.55	2.43	2.05	2.45
2019	-	-	-	-	2.08	4.9	2.34	3.01	12.77	3.36	4.54	4.97
2020	4.55	7.84	1.84	-	-	3.21	8.55	8.56	1.64	3.36	4.54	4.97
2021	5.63	9.21	15.68	19.83	23.4	3.94	12.72	4.41	1.32	3.33	2.39	1.95
2022	4.4	6.09	8.55	6.88	6.87	5.02	2.81	4.17	0.66	3.75	2.08	1.64
2023	2.25	6.24	0.6	0.5	2	1.24	1.27	1.88	3.1	3.1	3.08	1.29

There are data gaps from January to April 2019 and April to May 2020. To overcome this problem, interpolation was carried out so that the data could be processed thoroughly. This interpolation process is important to ensure that the analysis is not affected by data gaps, so that the results obtained are more accurate [17]. The data that has been interpolated can be presented in **Table 3**.

Table 3. Interpolated Data of Water Pollution Index Values in Cengklik Reservoir.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	6.94	9	5.98	9.81	12.78	6.93	6.21	8.48	6.2	8.3	6.65	8.03
2017	8.43	3.26	5.84	9.08	8.48	6.71	4.14	8.47	4.51	6.17	5.85	7.06
2018	2.9	2.93	3.02	4.16	4.27	2.45	2.19	2.2	1.55	2.43	2.05	2.45
2019	2.27	3.58	2.96	2.99	2.08	4.9	2.34	3.01	12.77	3.36	4.54	4.97
2020	4.55	7.84	1.84	2.53	5.54	3.21	8.55	8.56	1.64	3.36	4.54	4.97
2021	5.63	9.21	15.68	19.83	23.4	3.94	12.72	4.41	1.32	3.33	2.39	1.95
2022	4.4	6.09	8.55	6.88	6.87	5.02	2.81	4.17	0.66	3.75	2.08	1.64
2023	2.25	6.24	0.6	0.5	2	1.24	1.27	1.88	3.1	3.1	3.08	1.29

After the interpolation process, the data is then normalized by applying the transpose technique to adjust the scale of the values so that they are not too high or vary in extremes. This process helps to stabilize the distribution of the data so as improve accuracy in the next stage of analysis or forecasting. The interpolation results that have gone through the normalization process are presented in Table 4.

Table 4. Interpolated data after data normalization.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	1.94	2.20	1.79	2.28	2.55	1.94	1.83	2.14	1.82	2.12	1.89	2.08
2017	2.13	1.18	1.76	2.21	2.14	1.90	1.42	2.14	1.51	1.82	1.77	1.95
2018	1.06	1.08	1.11	1.43	1.45	0.90	0.78	0.79	0.44	0.89	0.72	0.90
2019	0.82	1.28	1.09	1.09	0.73	1.59	0.85	1.10	2.55	1.21	1.51	1.60
2020	1.52	2.06	0.61	0.93	1.71	1.17	2.15	2.15	0.49	1.21	0.74	1.89
2021	1.73	2.22	2.75	2.99	3.15	1.37	2.54	1.48	0.28	1.20	0.87	0.67
2022	1.48	1.81	2.15	1.93	1.93	1.61	1.03	1.43	-0.42	1.32	0.73	0.49
2023	0.81	1.83	-0.51	-0.69	0.69	0.22	0.24	0.63	1.13	1.13	1.12	0.25

The next step is to perform calculations to determine the level, trend and seasonal values of the processed data. The results of this calculation provide a clearer picture of the pattern of water quality pollution from year to year. The data that has been analyzed is presented in **Table 5**.

Table 5. Data on Level, Trend and Seasonal Values of Water Pollution in Cengklik Reservoir.

Month	Pollution	Level	Tren	Seasonal
Jan-16	1.94			0.95
Feb-16	2.20			1.07
Mar-16	1.79			0.87
Apr-16	2.28			1.11
May-16	2.55			1.24
Jun-16	1.94			0.94
Jul-16	1.83			0.89
Aug-16	2.14			1.04
Sep-16	1.82			0.89
Oct-16	2.12			1.04
Nov-16	1.89			0.92
Dec-16	2.08	2.05	-0.12	1.02

Further analysis was conducted to compare the actual data with the predictions generated.

Table 6 shows the comparison between actual and predicted data, as well as the difference, absolute error, squared error, and absolute percent error (APE) for 2017 to 2023.

Table 6. Comparison of Actual and Predicted Data, Difference, Absolute Error, Squared Error, and Absolute Percent Error 2017- 2023.

Year	Month	Actual Data	Prediction	Difference	Absolute Error	Squared Error	Absolute Persen Error (APE)
2017	January	2.13	1.82	0.31	0.31	0.09	14.45
2017	February	1.18	2.19	-1.01	1.01	1.02	85.34
2017	March	1.76	1.09	0.67	0.67	0.45	38.22
2017	April	2.21	1.87	0.33	0.33	0.11	15.11
2017	May	2.14	2.21	-0.07	0.07	0.00	3.29
2017	June	1.90	1.53	0.38	0.38	0.14	19.74
2017	July	1.42	1.59	-0.17	0.17	0.03	11.93
2017	August	2.14	1.60	0.54	0.54	0.29	25.22
2017	September	1.51	1.59	-0.08	0.08	0.01	5.51
2017	October	1.82	1.66	0.16	0.16	0.03	9.01
2017	November	1.77	1.48	0.29	0.29	0.08	16.15
2017	December	1,95	0.22	0.22	0.22	0.05	11.11
2018	...	...	...	...	...	...	...
2019	...	...	...	...	...	...	...
2020	...	...	...	...	...	...	...
2021	...	...	...	...	...	...	...
2022	...	...	...	...	...	...	...
2023	January	0.81	0.44	0.37	0.37	0.13	45.17
2023	February	1.83	0.71	1.12	1.12	1.25	61.00
2023	March	-0.51	1.16	-1.67	1.67	2.80	-327.71
2023	April	-0.69	-0.13	-0.56	0.56	0.31	-80.86
2023	May	0.69	-0.70	1.40	1.40	1.95	201.29
2023	June	0.22	0.14	0.07	0.07	0.00	32.66
2023	July	0.24	0.11	0.13	0.13	0.02	53.42
2023	August	0.63	0.15	0.48	0.48	0.23	75.82
2023	September	1.13	0.35	0.78	0.78	0.61	68.93
2023	October	1.13	0.98	0.16	0.16	0.02	13.77
2023	November	1.12	0.90	0.22	0.22	0.05	19.57
2023	December	0.25	1.90	-0.84	0.84	0.70	329.49

Forecasting Water Quality Pollution Data for 2024 based on the analyzed data. **Table 7** below shows the predicted pollution values for each month, along with the difference, absolute error, and squared error.

Table 7. Predicted Pollution Value for Each Month

Month	Prediction	Difference	Absolute Error	Squared Error
January	0.39	-0.39	0.39	0.15
February	0.36	-0.36	0.36	0.13
March	0.23	-0.23	0.23	0.05
April	0.20	-0.20	0.20	0.04
May	0.13	-0.23	0.23	0.02
June	0.03	-0.03	0.03	0.00
July	-0.04	0.04	0.04	0.00
August	-0.13	0.13	0.13	0.02
September	-0.18	0.18	0.18	0.03
October	-0.29	0.29	0.29	0.08
November	-0.33	0.33	0.33	0.11
December	-0.44	0.44	0.44	0.19

Next, calculate the error value using the MAPE formula:

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

$$MAPE = \left(\frac{100\%}{84}\right) * (2886.91)$$

$$= 34.36\%$$

Based on the calculation of the MAPE value above, the MAPE value for water pollution is 34.36%. The MAPE value of 34.36% indicates that the forecasting model has a fairly good level of accuracy in capturing water pollution patterns. The Triple Exponential Smoothing (TES) method successfully identifies trends and seasonal patterns in general, as shown in the comparison graph between actual and predicted data. Although there are still some deviations, they are likely influenced by high variability in pollution data, changing environmental conditions, and external factors such as human activities and reservoir management policies. To further improve the prediction accuracy, additional approaches such as optimization of TES parameters or application of other forecasting methods that are more adaptive to environmental dynamics are recommended. In addition, management strategies such as structuring the number of floating net cages (KJA), improving domestic and industrial waste management

systems, and community education programs play an important role in maintaining water quality and supporting the sustainability of the reservoir ecosystem and the welfare of the surrounding community.

4. Conclusion

This research aims to forecast water quality pollution in Cengklik Reservoir using the Triple Exponential Smoothing (TES) method. The analysis results show that the water pollution index experiences significant fluctuations, influenced by various factors such as domestic waste, the use of agricultural fertilizers, as well as fish feed residues from floating net cages (KJA). The prediction model was able to capture the seasonal pattern in the pollution data, and the accuracy evaluation using Mean Absolute Percentage Error (MAPE) resulted in a value of 34.36%, which is in the moderately accurate category. This shows that the TES method is quite reliable in identifying pollution trends and patterns, although there is still room for improvement in accuracy.

To optimize future forecasting results, it is recommended to re-evaluate the TES parameters or combine them with other methods that are more responsive to complex environmental dynamics. In addition, concrete efforts in environmental management need to be strengthened. Strategic steps such as regulating the number and layout of KJAs, managing domestic and industrial waste in a more integrated manner, and involving the community in education and environmental awareness campaigns are very important. With the implementation of the right policies and approaches, the water quality of Cengklik Reservoir can be improved sustainably, maintaining ecological balance and supporting the welfare of the surrounding communities.

References

- [1] M. Fida, P. Li, Y. Wang, S. M. K. Alam, and A. Nsabimana, "Water Contamination and Human Health Risks in Pakistan: A Review," *Exposure and Health*, vol. 15, no. 3. Springer Science and Business Media B.V., pp. 619–639, Sep. 2023. doi: 10.1007/s12403-022-00512-1.
- [2] U. Ahmed, R. Mumtaz, H. Anwar, A. A. Shah, R. Irfan, and J. García-Nieto, "Efficient water quality prediction using supervised machine learning," *Water (Switzerland)*, vol. 11, no. 11, Nov. 2019, doi: 10.3390/w11112210.
- [3] A. H. Haghiabi, A. H. Nasrolahi, and A. Parsaie, "Water quality prediction using machine learning methods," *Water Qual. Res. J.*, vol. 53, no. 1, pp. 3–13, Feb. 2018, doi: 10.2166/wqrj.2018.025.
- [4] "Naskah Publikasi RISKI".

- [5] "admin,+Journal+manager,+Tri+Wahyuni,+Endah+Sih+Prihatini,++Muntalim,+Farid+Wajdi,+Tri+Wahyudi,+Dona+Wahyuning+Laily".
- [6] W. Jurnal *et al.*, "Indonesian Research Journal on Education Persepsi Masyarakat Tentang Limbah B3 PT. Indah Kiat Pulp and Paper di Desa Pinang Sebatang Kecamatan Tualang Kabupaten Siak," 2024. [Online]. Available: <https://irje.org/index.php/irje>
- [7] A. S. Anggraeni, R. Chandra Utama, and D. C. Wati, "PENGHALUSAN EKSPONENSIAL DAN DEKOMPOSISI SAHAM APPLE.INC," 2022. [Online]. Available: <https://doi.org/>
- [8] N. A. 1✉, E. Maharani, F. Nurbaya, P. Studi, K. Masyarakat, and I. Kesehatan, "Nomor 3, Halaman 6-13," *The Indonesian Journal of Public Health*, 2024. [Online]. Available: <https://jurnal.unimus.ac.id/index.php/jkmi,jkmi@unimus.ac.id>
- [9] "5703-17357-1-SM".
- [10] A. Marliyani and E. Hermawan, "Pengembangan Sistem Informasi Manajemen Persuratan di Badan Informasi Geospasial."
- [11] D. Kusuma Hakim, R. Gernowo, and A. Widhi Nirwansyah, "Rainfall, Wind Speed, and Temperature Forecast Using Triple Exponential Smoothing and Gradient Descent," *KnE Soc. Sci.*, Mar. 2024, doi: 10.18502/kss.v9i6.15311.
- [12] A. Yani Dengan Metode, A. Rachman Hakim, I. Tri Utami, and D. Statistika, "PERAMALAN JUMLAH PENUMPANG PESAWAT DI BANDARA INTERNASIONAL DAN METODE EXPONENTIAL SMOOTHING EVENT BASED", [Online]. Available: <https://ejournal3.undip.ac.id/index.php/gaussian/>
- [13] S. Lestari, A. S. Ahmar, and R. Ruliana, "Eksplorasi Metode Triple Exponential Smoothing Pada Peramalan Jumlah Penggunaan Air Bersih di PDAM Kota Makassar," *VARIANSI J. Stat. Its Appl. Teach. Res.*, vol. 2, no. 3, p. 128, Aug. 2020, doi: 10.35580/variasiunm14641.
- [14] R. N. Puspita, D. Kependudukan, P. Sipil, and K. Tangerang, "PERAMALAN TINGKAT PENGANGGURAN TERBUKA PROVINSI BANTEN DENGAN METODE TRIPLE EXPONENTIAL SMOOTHING," vol. 3, no. 2, 2022, doi: 10.46306/lb.v3i2.
- [15] I. Djakaria and S. E. Saleh, "Covid-19 forecast using Holt-Winters exponential smoothing," in *Journal of Physics: Conference Series*, May 2021, vol. 1882, no. 1. doi: 10.1088/1742-6596/1882/1/012033.
- [16] C. V. Hudyanti, F. A. Bachtiar, and B. D. Setiawan, "Perbandingan Double Moving Average dan Double Exponential Smoothing untuk Peramalan Jumlah Kedatangan Wisatawan Mancanegara di Bandara Ngurah Rai," *J. Pengemb. Teknol. Inf. dan Ilmu Komput.*, vol. 3, no. 3, pp. 2667–2672, 2019, [Online]. Available: file:///D:/Donwload/Skripsi/Jurnal/dina_oktavia,%23%23default.groups.name.manager%23%23,+4791-99Z_Artikel-32740-1-2-20190109.pdf
- [17] F. Dhimas Irnawan, I. Hidayah, and L. E. Nugroho, "Metode Imputasi pada Data Debit Daerah Aliran Sungai Opak, Provinsi DI Yogyakarta (Imputation Method on Opak Watershed Data, Special Region of Yogyakarta)," 2021.