
Prediction Of HIV Case Spread In Sukabumi Using Single Exponential Smoothing Based On Grid Search Optimization

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Abstract

Human Immunodeficiency Virus (HIV) remains a health problem of concern in Sukabumi City. The increase and fluctuation of HIV cases require control efforts through data-based planning. This study aims to analyze the development pattern of HIV cases, apply the Single Exponential Smoothing (SES) method, optimize the alpha parameter using the Grid Search method, and evaluate the accuracy of the prediction model. The data used were monthly HIV cases in the Sukabumi City Health Office area from January 2024 to December 2025. Forecasting was conducted using the SES method and implemented using Microsoft Excel and Python programming language. The alpha parameter was optimized using Grid Search with values ranging from 0.01 to 0.99. Model accuracy was evaluated using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). The results showed that the optimal alpha value was 0.06, with a predicted number of HIV cases in January 2026 of 18.016 cases. The model obtained MAD of 2.597, MSE of 10.383, and MAPE of 13.71%. Based on the MAPE value, the model was categorized as good forecasting and can support planning and decision-making related to HIV case management.

Keywords: Human Immunodeficiency Virus (HIV), Single Exponential Smoothing, Grid Search, forecasting, HIV case prediction

INTRODUCTION

The development of information technology has had a significant impact on various fields, including the health sector (C. S. Anwar and Saiful, 2024). The utilization of information technology enables data processing, storage, and analysis to be carried out more effectively and efficiently (E. Salfitri et al., 2024). In public health, available data can be used as a source of information to support decision-making, policy formulation, and more targeted health program planning (K. Ferawati et al., 2021).

One of the health problems that remains a global concern is Human Immunodeficiency Virus (HIV) (Elfika et al., 2023). HIV is a virus that attacks the human immune system and can develop into Acquired Immunodeficiency Syndrome (AIDS) if not properly treated (E. R. Dewi et al., 2024). The continued spread of HIV in various regions indicates that this disease remains a challenge in efforts to improve public health quality (Farozi et al., 2024). Therefore, various prevention and control measures are needed, supported by accurate information regarding the development of HIV cases (V. D. O. Sumakul et al., 2023).

The Sukabumi City Health Office, as the institution responsible for health data management, plays an important role in monitoring the development of HIV cases in Sukabumi City. Based on HIV case data from 2024–2025, the number of recorded cases showed monthly fluctuations. In 2024, the number of cases ranged from 15 to 21 cases per month, while in 2025, the number of cases ranged from 13 to 24 cases per month. The highest number of cases occurred in June and December 2025, with 24 cases, while the lowest number occurred in July 2025, with 13 cases. These fluctuations indicate that HIV transmission continues to occur and requires particular attention from relevant institutions.

Historical HIV case data are generally used to provide information about conditions that have already occurred. However, such information cannot provide an overview of the possible number of HIV cases in future periods. Predictive information is needed to assist the Sukabumi City Health Office in planning prevention and control programs, as well as providing health resources more effectively. By predicting the number of HIV cases,

anticipatory measures can be taken earlier so that case management can be carried out more optimally.

One method that can be used to predict the number of HIV cases is Single Exponential Smoothing (SES) (L. Setiawati et al., 2026). This method is a forecasting method for time series data that assigns greater weight to recent data, allowing predictions to be generated based on available historical data patterns (L. Maysofa et al., 2023). The SES method has advantages in terms of simple calculations, ease of implementation, and its ability to produce good accuracy for data without strong trend and seasonal patterns (A. Rizka et al., 2026).

In its application, the predictions generated by the SES method are influenced by the alpha parameter used (M. I. Nasution and R. S. Hayati, 2024). Therefore, this study not only uses standard SES but also applies alpha parameter optimization using the grid search method to obtain a parameter that produces the lowest prediction error. The resulting predictions are then evaluated using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) to determine the accuracy of the model used (A. Krisma, et al., 2019).

Based on these problems, this study aims to analyze the development pattern of HIV cases in the Sukabumi City Health Office area based on historical data, apply the Single Exponential Smoothing method to predict the number of HIV cases, and compare the prediction results of standard Single Exponential Smoothing with Single Exponential Smoothing using alpha parameter optimization through the grid search method. In addition, this study aims to analyze the accuracy of the prediction results using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). The data used are monthly HIV case data in the Sukabumi City Health Office area from January 2024 to December 2025.

RESEARCH METHODS

This study uses a quantitative approach with a time series forecasting design to predict the number of Human Immunodeficiency Virus (HIV) cases in the Sukabumi City Health Office area. The subject of this study is monthly HIV case data obtained from the Sukabumi City Health Office for the period January 2024 to December 2025, consisting of 24 monthly observations. The data were obtained through documentation and secondary data collection from the Sukabumi City Health Office. The sampling technique used was total sampling, in which all available monthly HIV case data during the study period were used as the research data.

The variable analyzed in this study is the monthly number of HIV cases, with the observation period as the time variable. Data analysis consisted of data identification, time series pattern analysis, data preparation, forecasting, and model evaluation. The forecasting method used was Single Exponential Smoothing (SES), which was selected based on the characteristics of the historical data. Standard SES was applied to obtain the initial forecasting results. Furthermore, optimization of the alpha parameter was performed using the Grid Search method with alpha values ranging from 0.01 to 0.99. Each alpha value was evaluated based on its prediction error, and the alpha value producing the lowest error was selected as the optimal parameter.

The accuracy of the forecasting models was evaluated using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). The analysis was implemented using Microsoft Excel and the Python programming language. The final stage involved generating the HIV case prediction for the subsequent period and comparing the forecasting results with the actual historical data to support the interpretation of model performance.

RESULTS AND DISCUSSION

Application of Single Exponential Smoothing (SES)

Based on calculations using the Single Exponential Smoothing (SES) method, prediction results for the number of Human Immunodeficiency Virus (HIV) cases were obtained for the period from January 2024 to December 2025. In January 2024, the predicted value was 16.000, equal to the actual number of 16 cases. When the number of cases increased to 21 cases in June 2024, the predicted value gradually increased to 16.896. Conversely, when cases decreased to 15 in July 2024, the predicted value remained at 17.306. This demonstrates the smoothing characteristic of SES, where predictions do not immediately follow drastic changes in the actual data.

In 2025, the number of cases fluctuated between 13 and 24 cases, while the predicted values adjusted gradually and reached 18.037 in December 2025. The prediction for the following period was 18.633, or approximately 19 cases. Overall, SES was able to follow the pattern of the actual data, although it required time to adjust to sharp changes.

Table 1. Standard SES Forecasting Results

No	Period	Actual	Forecast
1	Jan-24	16	16,000
2	Feb-24	17	16,000
3	Mar-24	19	16,100
4	Apr-24	18	16,390
5	May-24	20	16,551
6	Jun-24	21	16,896
7	Jul-24	15	17,306
8	Aug-24	16	17,076
9	Sep-24	17	16,968
10	Oct-24	18	16,971
11	Nov-24	20	17,074
12	Dec-24	21	17,367
13	Jan-25	14	17,730
14	Feb-25	16	17,357
15	Mar-25	17	17,221
16	Apr-25	20	17,199
17	May-25	21	17,479
18	Jun-25	24	17,831
19	Jul-25	13	18,448
20	Aug-25	15	17,903
21	Sep-25	17	17,613
22	Oct-25	18	17,552
23	Nov-25	22	17,597
24	Dec-25	24	18,037
25	Prediction		18,633

Comparison of Actual Data and Forecast Results

Based on the comparison graph between the actual data and forecast results, the Single Exponential Smoothing (SES) method was able to represent the general pattern of HIV case movements, although differences between actual and predicted values remained in several periods.

The actual data fluctuated between 13 and 24 cases, while the SES forecast produced a smoother and more stable pattern, ranging from approximately 16 to 18.6 cases. In January 2024, the predicted value was equal to the actual value of 16 cases. However, when actual cases increased to 21 cases in June 2024 and decreased to 15 cases in July 2024, the forecast did not immediately follow these changes due to the smoothing process.

In 2025, the forecast generally followed the direction of the actual data, although noticeable deviations occurred during sharp changes, such as the decrease to 13 cases in July 2025. Overall, the graph indicates that SES can represent the general movement of HIV cases but is less responsive to sudden fluctuations.

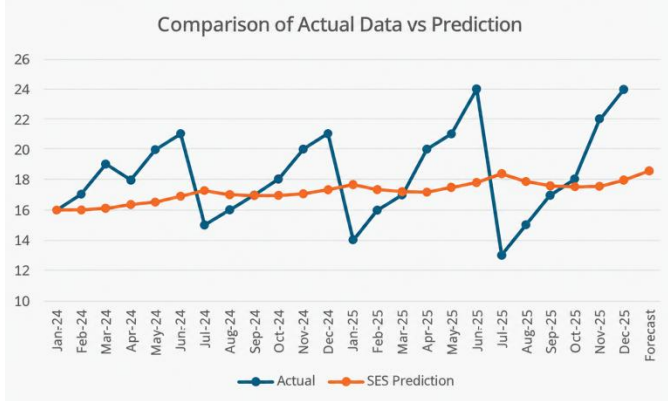


Figure 1. Standard SES Forecasting Chart Using Excel

Model Testing Implementation (MAD, MSE, and MAPE)

Based on the evaluation results, the Single Exponential Smoothing (SES) method produced the best alpha value of 0.1. This value indicates that the model provides greater smoothing to historical data, resulting in a more stable prediction pattern.

The model predicted 18.633 HIV cases for January 2026, indicating that the number of cases is expected to remain relatively stable at around 18–19 cases. Model accuracy was evaluated using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). The results showed a MAD of 2.568, MSE of 9.907, and MAPE of 13.83%.

The MAPE value of 13.83% indicates that the model falls within the good forecasting category, as it is within the 10%–20% range. Overall, the SES method can provide predictions that are relatively close to the actual data and can support the analysis and monitoring of HIV case trends in the Sukabumi City Health Office area.

Table 2. Results of Implementation of Standard SES Model Testing Using Excel

Parameter	Mark
Metode	Single Exponential Smoothing (SES)
Best Alpha	0.1
Prediction Jan-2026	18,633
MAD	2,568
MSE	9,907
MAPE	13,83%

Alpha Optimization Using Grid Search

Based on the forecasting results, the alpha (α) parameter was optimized using the Grid Search method to obtain the value that produced the lowest prediction error. The Single

Exponential Smoothing (SES) method was applied to monthly HIV case data from January 2024 to December 2025, with alpha serving as the smoothing constant that determines the influence of recent data on the forecasting results.

The forecasting results showed that in January 2024, the predicted value was 16.000, equal to the actual data. When the number of cases increased to 21 in June 2024, the predicted value gradually increased to 16.562. In July 2024, when cases decreased to 15, the predicted value remained at 16.828. This indicates that SES applies smoothing, so predictions do not immediately follow drastic changes in the actual data.

In 2025, the number of cases fluctuated between 13 and 24 cases, while the predicted values remained relatively stable at around 17–18 cases. The Grid Search optimization produced a prediction for the following period of 18.016, or approximately 18 cases. Thus, alpha optimization using Grid Search in the SES method can provide a parameter that is appropriate for the characteristics of the data and help produce more optimal forecasting results to support health planning and decision-making.

Table 3. Alpha Optimization Results

No	Period	Actual	Forecast
1	Jan-24	16	16,000
2	Feb-24	17	16,000
3	Mar-24	19	16,060
4	Apr-24	18	16,236
5	May-24	20	16,342
6	Jun-24	21	16,562
7	Jul-24	15	16,828
8	Aug-24	16	16,718
9	Sep-24	17	16,675
10	Oct-24	18	16,695
11	Nov-24	20	16,773
12	Dec-24	21	16,967
13	Jan-25	14	17,209
14	Feb-25	16	17,016
15	Mar-25	17	16,955
16	Apr-25	20	16,958
17	May-25	21	17,140
18	Jun-25	24	17,372
19	Jul-25	13	17,770
20	Aug-25	15	17,483
21	Sep-25	17	17,334
22	Oct-25	18	17,314
23	Nov-25	22	17,356
24	Dec-25	24	17,634
25	Prediction		18,016

Comparison of Actual and Forecast Data

Based on the comparison graph between the actual data and forecast results, the Single Exponential Smoothing (SES) method with Grid Search optimization was able to represent the general pattern of HIV case movements, although differences between actual and predicted values remained in several periods.

The actual data fluctuated between 13 and 24 cases, while the optimized forecast produced a smoother and more stable pattern, ranging from approximately 16 to 18 cases. In January 2024, the predicted value was equal to the actual value of 16 cases. However, when actual cases increased to 21 cases in June 2024 and decreased to 15 cases in July 2024, the forecast did not immediately follow these changes due to the smoothing characteristic of SES.

In 2025, differences between actual and predicted values remained, particularly during sharp fluctuations such as 24 cases in June and 13 cases in July. Nevertheless, the forecast generally followed the overall direction of the actual data. Overall, SES with Grid Search optimization produced a more stable prediction pattern and represented the general trend of HIV cases, although it was less responsive to sudden short-term changes.

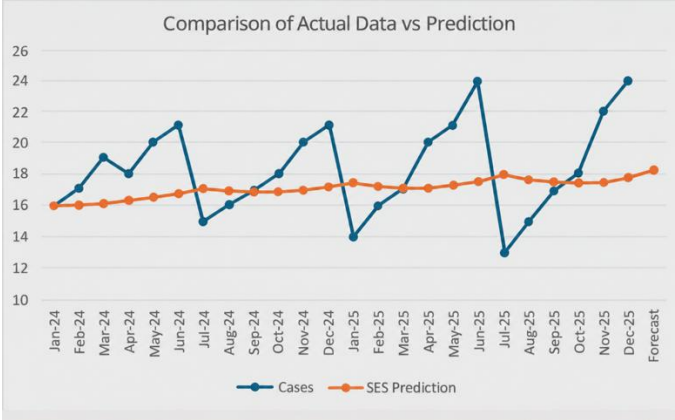


Figure 2. SES Forecasting Graph Optimization of Alpha Value Using Excel Model Testing Implementation (MAD, MSE, and MAPE)

Based on the optimization using the Grid Search method, the optimal alpha value was 0.06. This value produced a predicted number of HIV cases in January 2026 of 18.016 cases, or approximately 18 cases.

Model evaluation using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) resulted in MAD of 2.597, MSE of 10.383, and MAPE of 13.71%. The MAPE value below 20% indicates that the model has good or reasonably accurate forecasting performance.

Overall, alpha optimization using Grid Search in the Single Exponential Smoothing (SES) method produced relatively stable predictions and can be used as supporting information for planning and monitoring HIV cases in the Sukabumi City Health Office area.

Table 4. Results of the Implementation of the SES Model Testing for Alpha Value Optimization

Parameter	Mark
Metode	Single Exponential Smoothing (SES) is a process of optimizing the alpha (α) parameter using the Grid Search method.
Best Alpha	0.06
Jan-2026 Prediction	18,016
MAD	2,597
MSE	10,383
MAPE	13,71%

Implementation of Single Exponential Smoothing (SES) Using Python

In this study, the Single Exponential Smoothing (SES) calculations were implemented using Python to facilitate data processing, forecasting, parameter optimization, and prediction evaluation.

The implementation utilized several Python libraries, including Tkinter for the Graphical User Interface (GUI), Pandas for data management, NumPy for numerical computation, and Matplotlib for visualizing actual and predicted data. Before implementation in Python, SES calculations were performed using Microsoft Excel for initial validation. The results showed identical forecast, Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) values in both platforms, confirming that the Python implementation was consistent with the SES formula.

In addition to standard SES, alpha parameter optimization was performed using Grid Search by testing alpha values from 0.01 to 0.99. The optimization produced an optimal alpha value of 0.06, with MAD of 2.597, MSE of 10.383, and MAPE of 13.71%. The identical results between Python and Microsoft Excel indicate that the SES and Grid Search implementation in the SES.py program was consistent with the theoretical calculations.

Overall, Python not only facilitated faster data processing and analysis but also served as a verification tool for the Microsoft Excel calculations.

Implementasi Metode Single Exponential Smoothing (SES) Standar Menggunakan Python

The standard Single Exponential Smoothing (SES) method was implemented using Python to forecast historical Human Immunodeficiency Virus (HIV) cases from January 2024 to December 2025 using a predetermined alpha value. The program utilized Tkinter as the user interface, Pandas for data processing, NumPy for numerical computation, and Matplotlib to visualize the forecasting results.

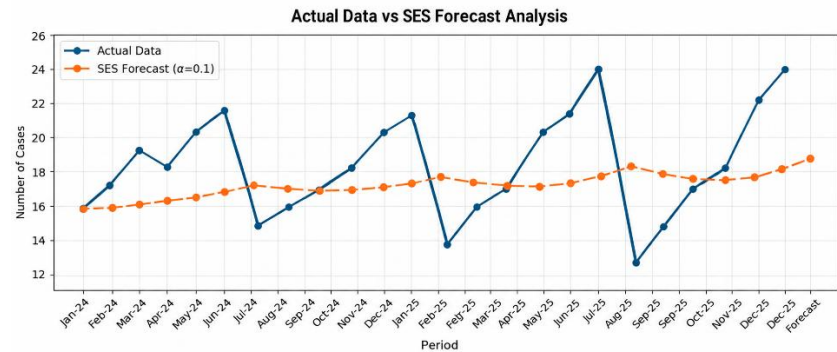


Figure 3. Standard SES Method Graph Using Python

Table 5. Results of Implementation of Standard SES Model Testing Using Python

Parameter	Mark
Metode	Single Exponential Smoothing (SES)
Best Alpha	0.1
Jan-2026 Prediction	18,633
MAD	2,568
MSE	9,907
MAPE	13,83%

At the standard SES stage, the alpha value used was 0.1. Based on the calculations using Python, the predicted number of HIV cases for January 2026 was 18.633 cases, with MAD of 2.568, MSE of 9.907, and MAPE of 13.83%. These results indicate that the standard SES method provides reasonably good forecasting performance, as the MAPE value falls within the 10%–20% range, categorized as good forecasting. The results obtained from

Python were also consistent with those calculated using Microsoft Excel, indicating that the implemented algorithm functioned correctly.

Implementation of the Single Exponential Smoothing (SES) Method for Grid Search Optimization Using Python

After applying the standard Single Exponential Smoothing (SES) method, the study continued with alpha parameter optimization using the Grid Search method. The optimization was implemented using the SES.py program, which automatically tested alpha values ranging from 0.01 to 0.99 to determine the parameter that produced the lowest prediction error.

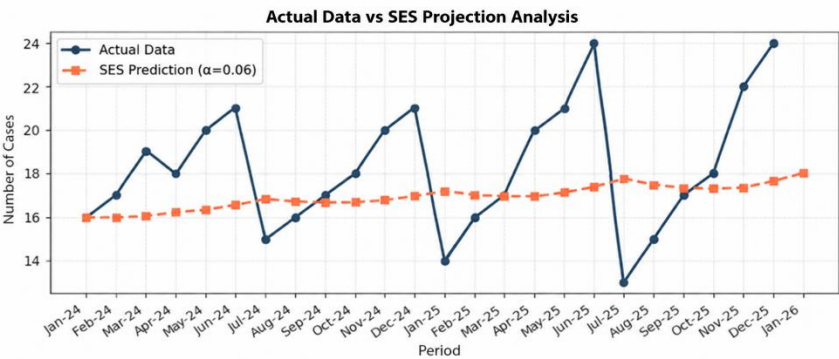


Figure 4. SES Method Graph Alpha Value Optimization Using Python

Table 6. Results of Implementation of SES Model Testing of Alpha Value Optimization Using Python

Parameter	Mark
Metode	Single Exponential Smoothing (SES) dilakukan proses optimasi parameter alpha (α) menggunakan metode Grid Search
Best Terbaik	0.06
Jan-2026 Prediction	18,016
MAD	2,597
MSE	10,383
MAPE	13,71%

Based on the testing using Python, the optimal alpha value was 0.06. Using this value, the model produced a predicted number of HIV cases in January 2026 of 18.016 cases, with MAD of 2.597, MSE of 10.383, and MAPE of 13.71%. These results indicate that the Grid Search optimization successfully identified the parameter that best fits the characteristics of the research data.

The Python implementation also produced prediction, MAD, MSE, and MAPE values consistent with those obtained using Microsoft Excel. This consistency confirms that the Grid Search optimization and Single Exponential Smoothing (SES) algorithm were implemented correctly according to the theoretical calculations. Therefore, the developed Python program can serve as a valid tool for analyzing, evaluating, and predicting the number of Human Immunodeficiency Virus (HIV) cases in Sukabumi City.

Analysis and Discussion of Model Comparison Results

Based on the test results, the standard SES model (α = 0.1) obtained lower MAD and MSE values, at 2.568 and 9.907, respectively, compared with the Grid Search-optimized model (α = 0.06), which obtained MAD of 2.597 and MSE of 10.383. However, the optimized model was selected based on its lower MAPE value of 13.71%, compared with 13.83% for the standard model.

The differences among the evaluation metrics are not mathematically inconsistent, as each metric measures prediction error differently. MAPE evaluates errors relative to the actual values, making it useful for interpreting prediction accuracy across monthly data with

varying case counts. Meanwhile, MSE gives greater weight to larger prediction errors due to its squared-error calculation.

Therefore, although the optimized model has slightly higher MAD and MSE, its lower MAPE indicates a lower average relative prediction error. With a MAPE of 13.71%, the model falls within the 10%–20% good forecasting category. Thus, the Grid Search optimization selected $\alpha = 0.06$ based on the minimum MAPE and provided a suitable model for forecasting HIV cases in Sukabumi City.

CONCLUSION

Based on the research on predicting Human Immunodeficiency Virus (HIV) cases in the Sukabumi City Health Office area using Single Exponential Smoothing (SES), HIV cases from January 2024 to December 2025 showed monthly fluctuations, ranging from 13 to 24 cases. This indicates dynamic changes in the data and the need for forecasting to estimate future cases.

The Single Exponential Smoothing (SES) method can be applied to predict HIV cases using Microsoft Excel and Python. The consistent results obtained from both platforms confirm that the implementation was accurate. The standard SES model with an alpha (α) value of 0.1 produced a prediction of 18.633 cases for January 2026. After optimization using Grid Search, the optimal alpha value was 0.06, producing a prediction of 18.016 cases.

The standard SES model obtained MAD of 2.568, MSE of 9.907, and MAPE of 13.83%, while the optimized SES model obtained MAD of 2.597, MSE of 10.383, and MAPE of 13.71%. The MAPE value of 13.71% falls within the good forecasting category, indicating that the optimized SES model can provide useful predictions to support planning and decision-making related to HIV case management in Sukabumi City.

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