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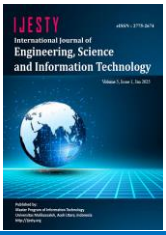

Prediction of Plantation Crop Production Based on Environment Using Linear Regression and Single Exponential Smoothing Methods

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Abstract

As an agrarian country, Indonesia heavily relies on the plantation sector as a key driver of its national economy. One significant region contributing to this sector is West Aceh Regency, which comprises 12 districts and is renowned for cultivating five primary plantation commodities: oil palm, coconut, rubber, coffee, and cocoa. This research aims to develop a plantation crop production prediction system to support efficient resource planning and management in this sector. The system employs Linear Regression and Single Exponential Smoothing (SES) with a smoothing constant (alpha) of 0.2. The system's primary objective is to analyze historical production data at the district level and generate reliable predictions of future production trends. Linear regression models the relationship between time (independent variable) and production volume (dependent variable), effectively capturing long-term trends. SES complements this by addressing short-term fluctuations and applying a weighted average where recent data carries greater importance. Prediction accuracy is evaluated using the Mean Absolute Percentage Error (MAPE). Findings reveal that Linear Regression consistently achieves high precision, with MAPE values below 20% in most districts, particularly for coffee and cocoa. Conversely, SES demonstrates varying results, performing well in some cases, such as coconut production in Arongan Lambalek (MAPE < 20%), but poorly in others, such as oil palm in Bubon (MAPE = 91.06%). In comparison, Linear Regression in Bubon yields a more moderate MAPE of 35.16%. The system is integrated into a user-friendly, web-based platform accessible to stakeholders like farmers, policymakers, and government agencies. Offering actionable insights into production trends aids in mitigating risks, optimizing resource allocation, and enhancing plantation management efficiency. This research underscores the importance of predictive analytics in agricultural planning, with potential applications in other agrarian regions.

Keywords: *Production Prediction, Plantation Crop, Linear Regression, Single Exponential Smoothing, MAPE*

1. Introduction

Indonesia is known as an agrarian country, meaning that most of its population relies on the agricultural and plantation sectors as their primary livelihood. Plantation crops in Indonesia are highly diverse and form a critical component of the nation's agricultural industry [1]. Plantation production is vital to the economy as a significant portion of the population works as farmers [2]. Crops such as oil palm, coconut, rubber, coffee, cocoa, and others are major export commodities due to their economic importance. The development of plantations can be observed from a regional perspective, such as provinces, regencies/cities, and sub-districts [3] [4]. The plantation subsector is a significant component of the agricultural sector, contributing to regional income and providing employment opportunities [5] [6] [7] [8].
According to the Central Bureau of Statistics of West Aceh Regency, this region has five active plantation crops: oil palm, coconut, rubber, coffee, and cocoa. These crops thrive in the environment of West Aceh Regency, where the term "environment" in this context refers to each sub-district in the area. Each sub-district has unique geographical and economic conditions, contributing to the variation in production.
Sub-districts are essential administrative units for managing local-level plantations. West Aceh Regency consists of 12 sub-districts, with most of the population relying on the agricultural sector, particularly plantations, for their livelihood. Plantation crops play a crucial role in the economy of such regions, especially in areas like West Aceh, which have significant agricultural potential.

Plantation crop production refers to cultivating and managing commercial crops on a large scale, aimed at enhancing the economy of farmers or plantation workers. In West Aceh, plantation production varies across different areas due to differing geographical and economic conditions. Although the types of plantation crops in West Aceh may be similar, it cannot be assumed that production levels are uniform across all regions. These conditions underline the importance of information in supporting plantation crop risk management programs and improving the welfare of farmers and plantation workers in West Aceh. With this information, farmers can anticipate future production increases or decreases in various environments.

In today's era, agriculture has undergone significant transformation driven by technological advancements, such as web- or mobile-based applications, data analysis, and artificial intelligence. These technologies enable farmers to easily access data on their plantation crop production over a specific period. One crucial application of this technology is predicting plantation crop production in the West Aceh Regency. This data includes information on the types of crops grown and their output over time.

Predicting plantation crop production plays a vital role in plantation planning. Prediction involves reducing errors by using current and past data to forecast what might happen in the future [9]. By predicting production based on crop type and sub-district, farmers or plantation workers can determine whether production levels are increasing or decreasing over time. Linear regression and single exponential smoothing are widely used prediction techniques in data analysis for various purposes. Linear regression is a method for predicting and optimizing production in the plantation sector by identifying the relationship between independent and dependent variables. On the other hand, single exponential smoothing is a simple yet effective forecasting method that uses weighted averages of historical data to predict future values [10].

Therefore, the author is interested in conducting a study on predicting plantation crop production based on the environment using the Linear Regression and Single Exponential Smoothing methods. This study aims to provide more reliable and accurate estimates of plantation crop production, potentially offering broader insights to stakeholders, including farmers, producers, government, and industry stakeholders, regarding production planning and resource management [11].

2. Literature Review

2.1. Previous Research

Research conducted by Ryan Novanda Putra, Abdul Aziz, and Akhmad Zaini (2023) entitled "Implementation of Simple Linear Regression and Single Exponential Smoothing Methods to Predict Production in East Java" based on the research results, the author would like to convey that the implementation of these methods yields results consistent with previous studies and is equivalent to manual calculations. Using the Simple Linear Regression method, the prediction quality tested with actual data for the 2021 period resulted in an MSE of 4,704,630,020.41, MAD of 48,740.17, and MAPE of 20.95%. For the SES method with an alpha of 0.8, the MSE was 551,565,962.11, MAD was 14,701.98, and MAPE was 6.45%. Based on these results, it can be concluded that the Single Exponential Smoothing method can be categorized as providing excellent prediction results, as the MAPE value is less than 10% [12].

Research conducted by Husdi and Hastuti Dalai (2023) entitled "Application of Linear Regression Method for Predicting the Amount of Raw Materials for Bilfagi Jam Production" based on the research findings, the author aims to assist the Bilfagi Jam Production House in forecasting the amount of pineapple raw materials needed for jam production in the upcoming month, preventing shortages or excess inventory. In 2021, the Mean Absolute Percentage Error (MAPE) testing for applying the linear regression method was 18.897%, which falls under the good forecasting category. From the accuracy of the results, it can be concluded that the prediction system is effective [13].

Research conducted by Nardha Livia Salsavira and Evi Yuliawati (2023) entitled "Forecasting Raw Material Supply Using Linear Regression and Exponential Smoothing Methods" based on the research results and processing conducted by the researcher, the exponential smoothing approach proved to be more optimal than the linear regression method, with a lower error rate. The researcher also used the POM QM software, where the forecast results using the linear regression method were 120,157.5 tons, with an error rate (MAPE) of 23.13%. Meanwhile, the forecast results using the exponential smoothing method were 103,516.2 tons, with a lower error rate (MAPE) of 21.29% [14].

Research conducted by Catherine Intanadya Ilhamti Resista Vikaliana (2024) entitled "Analysis of Crude Palm Oil (CPO) Demand Forecasting Using the Single Exponential Smoothing, Moving Average, and Holt-Winter's Methods at a Palm Oil Plantation Company" This study analyzed the future demand for CPO using three forecasting methods: Single Exponential Smoothing (SES), Moving Average (MA), and Holt-Winter's. The aim was to find the method that provided the best accuracy using Mean Absolute Percentage Error (MAPE). The results show that Holt-Winter's method provided the highest accuracy, with 8.6% and 4.4% MAPE values. In period 13, Company A is forecasted to purchase 2,780.08 MT of CPO, while Company B is expected to buy 4,496.10 MT. These predictions provide valuable insights into the palm oil industry's supply chain and production planning [15].

Research conducted by Tri Novriza Putri, Adam Yordan, and Dara Havisha Lamkaruna (2019) entitled "Forecasting New Student Enrollment at Samudra University Using the Simple Linear Regression Method" the results of this study indicate that the use of the simple linear regression method can be considered reliable, as the error in the prediction of new student enrollment for the next year is relatively small, with a difference of 21 students out of 1,428 predicted students. The data used in this study includes new student enrollment data from 2014 to 2019. The test data for 2018, when expected, was 1,449 students [16].

Research conducted by Muh Alwy Yusuf, Herman, and Trisnawati. H, Ardy Abraham, and Hardianti Rukmana (2024) entitled "Simple and Multiple Linear Regression Analysis and Its Applications" in the simple regression analysis, the online learning model explains 47.5% of the variation in student learning outcomes. The remaining 52.5% can be attributed to unexamined factors potentially impacting educational performance. Similarly, in the multiple regression analysis, the Coefficient of determination (R2) showed that the variables of education and free association collectively account for 40.7% of the variance in early marriage occurrences. Consequently, 59.3% of the variability remains influenced by other factors not captured within the current research scope [17].

Research conducted by Deni Reskianto, Mula Agung Barata, and Sahri (2023) entitled "Forecasting Using the Single Exponential Smoothing Method for Predicting Product Sales" in making this Forecast, sales data is used from January 2019 to January 2023. One method that can be used to make forecasts is single exponential smoothing. Single exponential smoothing is a method that focuses on finding stability values that take existing data and give it an exponential function. When using this method, you must provide an alpha parameter. The MAPE method is used to measure the error value to find the best accuracy value for this method. This MAPE will later help determine the number of goods sold in the next period. Based on the results, the conclusion that can be drawn from this research is that this method can be applied well. The results of the calculation of the single exponential smoothing method in predicting sales of goods for the next period in the sale of mattresses, the alpha value of 0.3 is 23.65 with MAD 3.18, MSE 18.97, MAPE 14.68%, wardrobes, the alpha value of 0.2 is 18, 35 with MAD 2.90 MSE 12.35 MAPE 16.60%, table alpha value 0.3 of 25.80 with MAD 3.04 MSE 14.20 MAPE 17.44% [18].

2.2. Data Mining

Data mining is extracting and analyzing large volumes of data to identify patterns, relationships, or valuable information to stakeholders. Through this process, individuals who can analyze and identify unexpected relationships between data can use it for decision-making. Data mining is a term used to explain extracting information from a database. It is also known as Knowledge Discovery in Database (KDD). Data mining is a set of methods automatically used in the overall analysis to reveal complex relationships within massive datasets [19]. Each stage in the data mining process is an integral part of the overall process, and these stages are often iterative, with the analysis continuously being refined and adjusted over time [20].

2.3. Prediction

Prediction, or forecasting, is the art of predicting future events based on the data and information available today and from the past. Forecasting is a science that helps predict or estimate and is the basis for planning, monitoring, and systematic decision-making about what will happen in the future based on known values from past data [21]. Prediction is an effort to reduce errors by using current and past data to forecast what might happen in the future [9].

2.4. Linear Regression

Linear regression is one of the statistics algorithms that use mathematical relationships between variables, namely the independent and dependent variables [22]. Linear regression is a statistical quantitative forecasting technique [23]. Simple linear regression is a type of regression analysis that describes the relationship between one dependent variable and one independent variable, represented by a straight line that indicates how changes in the independent variable affect the dependent variable. This method assumes a linear relationship between the variables, where the independent variable is used to predict or estimate the value of the dependent variable based on a fitted regression line derived from the given data points. [19].

$$Y = a + b(X) \quad (1)$$

$$a = \frac{(\sum Y)(\sum X^2) - (\sum X).(\sum XY)}{(n)(\sum X^2) - (\sum X)^2} \quad (2)$$

$$b = \frac{n(\sum XY) - (\sum X).(\sum Y)}{n(\sum X^2) - (\sum X)^2} \quad (3)$$

Description:

a = Constant

b = Coefficient

Y = Dependent Variable

X = Independent Variable

2.5. Single Exponential Smoothing

The single exponential smoothing method is used for prediction with the value of (α) as the smoothing parameter. This method requires the alpha (α) value as a smoothing parameter, typically ranging from 0.1 to 0.9 [12]. Single Exponential Smoothing is used for short-term predictions. This model assumes that the data fluctuates around a constant average, with no consistent trends or growth patterns [24]. To obtain the correct α value, it is generally calculated for all possible α values to determine which one provides the most accurate prediction.

$$F_{t+1} = \alpha Y_t + (1 - \alpha) F_t \quad (4)$$

Description:

F_{t+1} = Forecast for period t+1 (the next period)

Y_t = Actual value for period t

F_t = Forecast for time period t-1 (the previous period)

α = Smoothing parameter, with a value between 0.1 and 0.9

2.6. Error Analysis

The magnitude of the error or discrepancy between the predicted data and the actual data determines the accuracy of a prediction. This error is caused by unexpected factors [22]. One standard method to calculate this error's size is MAPE (Mean Absolute Percentage Error). MAPE is a method used to measure the accuracy of a prediction model or the mistake of forecast calculations per period, especially in forecasting [25]. MAPE provides information about the error in a prediction output over several periods, offering insights into the magnitude of percentage errors [26].

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{|y-y_i|}{y} \; x \; 100\% \quad (5)$$

Description:

y = Actual data

y_i = Forecasted data for period i

n = Total number of data points

MAPE measures the average percentage difference between predicted and actual values. A lower MAPE indicates greater accuracy in the model's predictions, reflecting better alignment with actual outcomes [27]. The smaller the MAPE value, the better the forecasting model is considered. A MAPE value is generally considered good if it is less than 10% [13].

Table 1. MAPE Range

MAPE Range	Description
<10%	Very Accurate Accuracy Level
10 – 20%	Good Accuracy Level
20 – 50%	Fair/Acceptable Accuracy Level
>50%	Inaccurate Accuracy Level

3. Research Methods

The research conducted by the author focuses on the stages involved in predicting the production of plantation crops in Aceh Barat. The author uses the research stages as a guideline to ensure that the results stay aligned with the established objectives and do not deviate from the intended purpose.

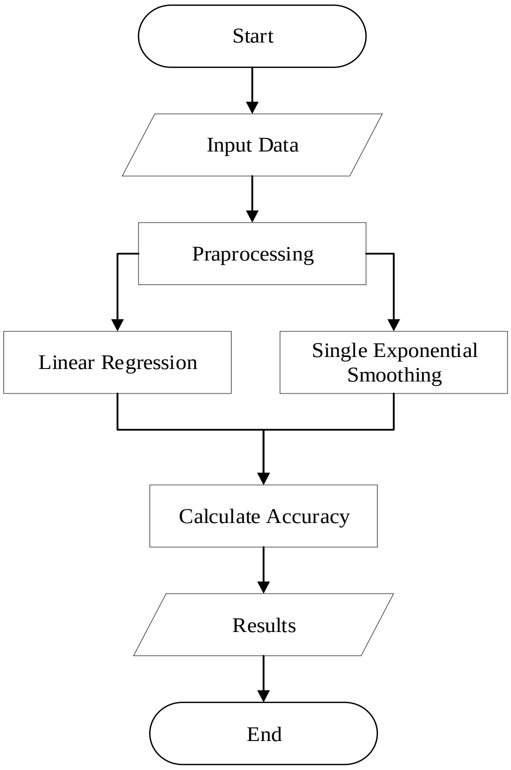

Fig 1. Flowchart System

Each stage will be explained as follows based on the system framework above.

a. Input Data
   Enter the period and production data from the Central Statistics Agency of Aceh Barat Regency, taking data from the last 6 years, 2018–2023.
b. Preprocessing
   The initial stage in data analysis involves data preparation and cleaning before being used in further modelling or analysis.
c. Linear Regression
   Prediction using the linear regression method.

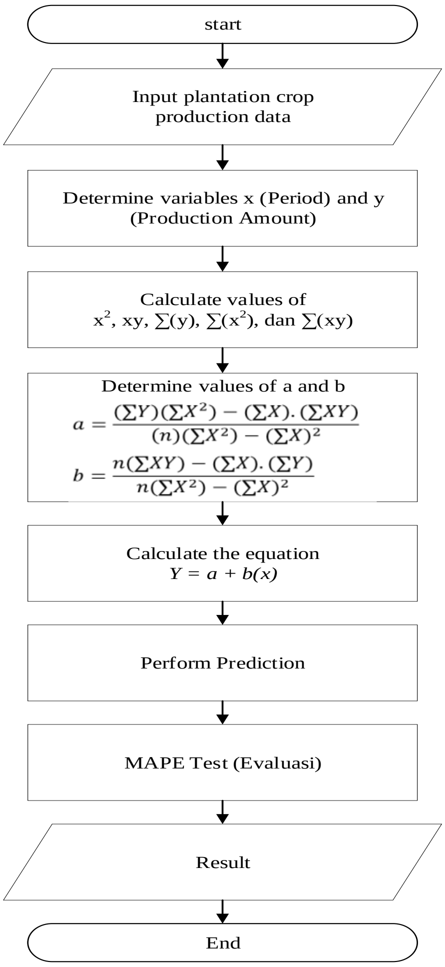

Fig 2. Implementation of the Linear Regression System

d. Single Exponential Smoothing
Prediction using the single exponential smoothing method.

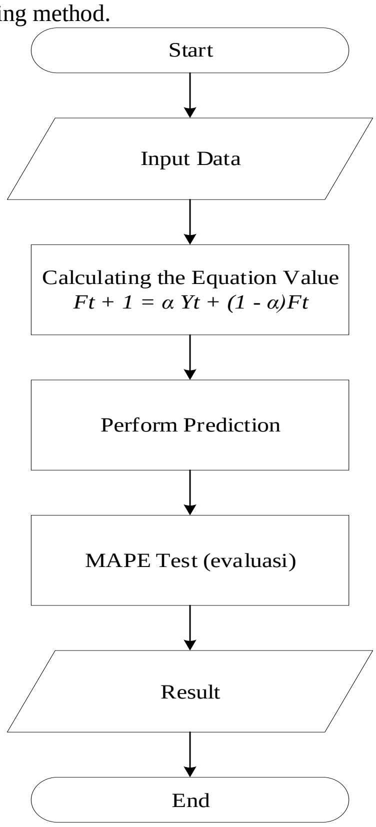

Fig 3. Implementation of the Single Exponential Smoothing System

e. Calculate Accuracy
Accuracy calculation in predicting plantation production in Aceh Barat Regency using MAPE (Mean Absolute Percentage Error).
f. Result
Prediction results and accuracy results.

4. Result and Discussions

4.1. Dataset

The production data of plantation crops provides important information, including the harvest amounts of various commodities such as cocoa, rubber, coconut, coffee, and palm oil. In this study, the data used covers the period from 2018 to 2023, with a scope of 12 locations in Aceh Barat Regency. This data serves as the basis for analyzing production and predicting future trends, thus assisting in decision-making related to the plantation sector. The production data can be seen in Table 2.

Table 2. Dataset

No	Year	Location	Plantation Crop Production (Tons)				
			Cocoa	Coconut	Rubber	Coffee	Oil Palm
1.	2018	Johan Pahlawan	1.67	50.77	610.00	0.30	246.05
2.	2019		5.20	63.10	691.20	0.35	415.80
3.	2020		1.67	63.10	1070.28	0.35	415.80
4.	2021		1.67	63.10	1070.28	0.30	415.80
5.	2022		1.67	65.00	963.00	0.30	467.00
6.	2023		1.20	65.00	907.00	0.30	546.00
…	…	…	…	…	…	…	…
67.	2018	Sungai Mas	11.99	0.00	869.31	8.60	215.12
68.	2019		19.00	34.90	2507.60	10.50	574.40
69.	2020		15.99	34.90	1214.08	10.50	574.40
70.	2021		15.99	26.50	1214.08	8.60	672.70
71.	2022		18.54	28.70	871.81	8.00	708.12
72.	2023		11.20	26.65	631.00	4.20	1053.00

4.2. Prediction Result

The prediction results using the single exponential smoothing method appear consistent, as the Forecast for future periods is based solely on the previous prediction results. Without actual data for reference, this method relies solely on the previous prediction values to calculate the next period's Forecast. The accuracy level for this period cannot yet be determined, as accuracy calculation requires actual data for comparison. The forecasted production results for the plantation crop types in the subsequent period, from 2024 to 2028, are provided in the table below.

Table 3. Prediction Result (Coffee)

No	Year	Location	Period Number	Simple Linear Regression	*Single Exponential Smoothing*
1.	2024	Johan Pahlawan	7	0.30	0.31
2.	2025		8	0.29	0.31
3.	2026		9	0.29	0.31
4.	2027		10	0.28	0.31
5.	2028		11	0.27	0.31
…	…	…	…	…	…
56.	2024	Sungai Mas	7	5.26	7.97
57.	2025		8	4.36	7.97
58.	2026		9	3.47	7.97
59.	2027		10	2.57	7.97
60.	2028		11	1.67	7.97

Table 4. Prediction Result (Cacao)

No	Year	Location	Period Number	Simple Linear Regression	*Single Exponential Smoothing*
1.	2024	Johan Pahlawan	7	0.89	1.87
2.	2025		8	0.52	1.87
3.	2026		9	0.15	1.87
4.	2027		10	-0.22	1.87
5.	2028		11	-0.59	1.87
…	…	…	…	…	…
56.	2024	Sungai Mas	7	14.92	83.17
57.	2025		8	14.77	83.17
58.	2026		9	14.61	83.17

59.	2027		10	14.46	83.17
60.	2028		11	14.31	83.17

Table 5. Prediction Result (Coconut)

No	Year	Location	Period Number	Simple Linear Regression	*Single Exponential Smoothing*
1.	2024	Johan Pahlawan	7	69.36	59.74
2.	2025		8	71.56	59.74
3.	2026		9	73.75	59.74
4.	2027		10	75.95	59.74
5.	2028		11	78.15	59.74
…	…	…	…	…	…
56.	2024	Sungai Mas	7	35.90	19.75
57.	2025		8	38.94	19.75
58.	2026		9	41.97	19.75
59.	2027		10	45.01	19.75
60.	2028		11	48.04	19.75

Table 6. Prediction Result (Rubber)

No	Year	Location	Period Number	Simple Linear Regression	*Single Exponential Smoothing*
1.	2024	Johan Pahlawan	7	1.115.33	838.58
2.	2025		8	1.181.06	838.58
3.	2026		9	1.246.78	838.58
4.	2027		10	1.312.51	838.58
5.	2028		11	1.378.24	838.58
…	…	…	…	…	…
56.	2024	Sungai Mas	7	608.09	1035.69
57.	2025		8	433.83	1035.69
58.	2026		9	259.58	1035.69
59.	2027		10	85.32	1035.69
60.	2028		11	-88.93	1035.69

Table 7. Prediction Result (Oil Palm)

No	Year	Location	Period Number	Simple Linear Regression	*Single Exponential Smoothing*
1.	2024	Johan Pahlawan	7	583.08	394.41
2.	2025		8	630.32	394.41
3.	2026		9	677.55	394.41
4.	2027		10	724.79	394.41
5.	2028		11	772.03	394.41
…	…	…	…	…	…
56.	2024	Sungai Mas	7	1.101.84	586.37
57.	2025		8	1.235.81	586.37
58.	2026		9	1.369.78	586.37
59.	2027		10	1.503.74	586.37
60.	2028		11	1.637.71	586.37

The table of prediction results above shows the calculated predictions for plantation crop production, which indicates that the production predictions vary. For coffee crops, the projections show a decline each year, while other plantation crops also experience both decreases and increases in predicted production in the coming years.

4.3. Evaluation Prediction Result

The prediction evaluation results using MAPE aim to determine how well the method can produce the best predictions. The comparison results of plantation crops are shown in the following table.

Table 8. Evaluation Prediction Result (Coffee)

No	Location	*Mean Absolute Percentage Error*	
		Simple Linear Regression	*Single Exponential Smoothing*
1.	Johan Pahlawan	5.70%	6.73%
2.	Samatiga	11.13%	12.81%
3.	Bubon	7.39%	8.90%
4.	Arongan Lambalek	33.18%	42.22%
5.	Woyla	15.10%	17.03%
6.	Woyla Barat	19.23%	31.14%
7.	Woyla Timur	19.07%	27.55%

8.	Kaway XVI	11.71%	13.43%
9.	Meureubo	14.52%	18.67%
10.	Pante Ceureumen	14.42%	19.96%
11.	Panton Reu	19.35%	27.60%
12.	Sungai Mas	18.77%	27.87%

Table 9. Evaluation Prediction Result (Cacao)

No	Location	*Mean Absolute Percentage Error*	
		Simple Linear Regression	***Single Exponential Smoothing***
1.	Johan Pahlawan	33.61%	40.05%
2.	Samatiga	26.53%	41.92%
3.	Bubon	13.73%	14.49%
4.	Arongan Lambalek	23.67%	23.29%
5.	Woyla	8.34%	11.04%
6.	Woyla Barat	6.93%	20.72%
7.	Woyla Timur	35.96%	27.32%
8.	Kaway XVI	15.27%	13.72%
9.	Meureubo	8.17%	9.63%
10.	Pante Ceureumen	23.89%	22.00%
11.	Panton Reu	15.80%	17.39%
12.	Sungai Mas	18.12%	20.71%

Table 10. Evaluation Prediction Result (Coconut)

No	Location	*Mean Absolute Percentage Error*	
		Simple Linear Regression	***Single Exponential Smoothing***
1.	Johan Pahlawan	4.34%	11.74%
2.	Samatiga	17.11%	44.04%
3.	Bubon	12.18%	13.55%
4.	Arongan Lambalek	2.97%	2.83%
5.	Woyla	22.62%	50.09%
6.	Woyla Barat	20.32%	18.70%
7.	Woyla Timur	20.80%	51.80%
8.	Kaway XVI	37.23%	124.12%
9.	Meureubo	35.00%	79.49%
10.	Pante Ceureumen	15.96%	63.41%
11.	Panton Reu	16.86%	61.59%
12.	Sungai Mas	16.82%	51.91%

Table 11. Evaluation Prediction Result (Rubber)

No	Location	*Mean Absolute Percentage Error*	
		Simple Linear Regression	***Single Exponential Smoothing***
1.	Johan Pahlawan	14.08%	19.04%
2.	Samatiga	21.55%	27.55%
3.	Bubon	26.87%	19.79%
4.	Arongan Lambalek	23.12%	21.19%
5.	Woyla	33.17%	23.03%
6.	Woyla Barat	18.63%	23.05%
7.	Woyla Timur	60.30%	52.19%
8.	Kaway XVI	32.09%	36.49%
9.	Meureubo	27.53%	36.82%
10.	Pante Ceureumen	33.48%	33.04%
11.	Panton Reu	93.99%	94.20%
12.	Sungai Mas	29.88%	31.01%

Table 12. Evaluation Prediction Result (Oil Palm)

No	Location	*Mean Absolute Percentage Error*	
		Simple Linear Regression	***Single Exponential Smoothing***
1.	Johan Pahlawan	9.37%	27.32%
2.	Samatiga	28.67%	39.79%

3.	Bubon	35.16%	91.06%
4.	Arongan Lambalek	8.48%	17.45%
5.	Woyla	42.57%	53.12%
6.	Woyla Barat	16.77%	19.83%
7.	Woyla Timur	34.37%	65.93%
8.	Kaway XVI	15.97%	37.09%
9.	Meureubo	10.30%	32.20%
10.	Pante Ceureumen	11.59%	26.00%
11.	Panton Reu	25.49%	28.71%
12.	Sungai Mas	15.78%	43.14%

The table above shows varying MAPE results, even indicating significant differences. Most MAPE values are below 20%, signifying good prediction accuracy, while some MAPE values range from 20% to 50%, indicating acceptable/sufficient accuracy. Additionally, there are MAPE values above 50%, which suggest low prediction accuracy or results that are less reliable. The following graph presents data on coffee crop production for other crop types. The following is the graph for the coffee plantation at the Johan Pahlawan location.

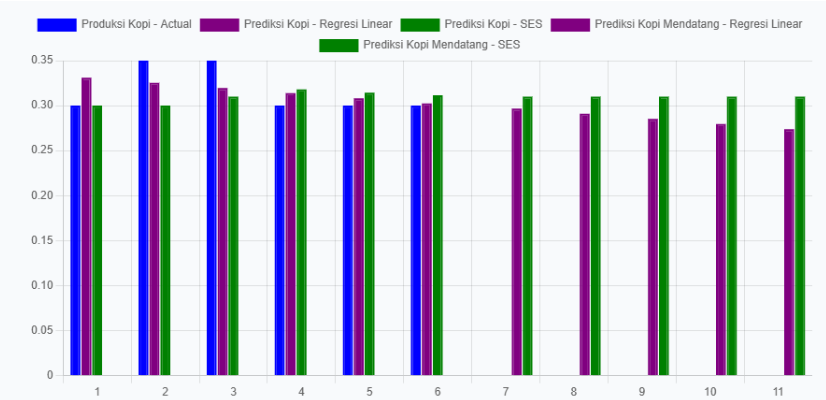

Fig 4. Coffee Production Prediction Graph (Johan Pahlawan)

5. Conclusion

Based on the research conducted, the author concludes the following:

1. The plantation crop production prediction system was successfully developed using linear regression, single exponential smoothing methods, DFD modelling, and a PHP system with Laravel.
2. The linear regression and single exponential smoothing methods with an alpha value of 0.2 were used for predictions, and the Mean Absolute Percentage Error (MAPE) was used to determine the accuracy of the predictions. This study's linear regression method was accurate for specific locations and crop types. For example, the Johan Pahlawan and Bubon locations with coffee crops, the Woyla, Woyla Barat, and Meureubo locations with cocoa crops, and the Johan Pahlawan and Arongan Lambalek locations with oil palm and coconut crops, the predicted results had a MAPE value of less than 10%, indicating perfect forecast accuracy. On the other hand, predictions using single exponential smoothing at several locations also showed MAPE values <10% in some areas, such as Arongan Lambalek with coconut crops and Johan Pahlawan and Bubon with coffee crops.
3. Based on the prediction results, overall, the MAPE value <20% for coffee crops using linear regression indicates that the predictions are accurate. In contrast, the MAPE values ranged from 20% to 50% for the single exponential smoothing method, indicating a moderate or acceptable prediction accuracy. However, at some locations, the MAPE values exceeded 50%. For instance, at the Bubon location for oil palm crops, the single exponential smoothing method produced a MAPE value of 91.06%, while the linear regression method showed a lower MAPE value of 35.16%.

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