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Research Article

Rainfall Variability and Its Influence on P Palm Oil Productivity (Elaeis Guineensis Jacq.): Case Study at PT. Nusaina Group Seram Island Province Maluku

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ABSTRACT

Rainfall variability significantly influences plant productivity; including palm oil. This research aims to describe rainfall variability and its influence on oil palm productivity on Seram Island, Maluku Province. The data collected consists of rainfall, palm oil production data and supporting data. The analytical method used consists of generating rainfall data, analyzing extreme rainfall conditions and regression analysis to see the relationship between rainfall and palm oil productivity. The research results show that the El Nino rainfall anomaly at the research location in the 1992-2021 period occurred 8 times with a frequency of once every 2 - 6 years or an average of once every 3 years. La Nina occurs 7 times with a frequency of 1 – 10 years or an average of once every 4 years. The very extreme El Nino caused a reduction in rainfall at the research location by 888 mm or 40% of normal conditions, whereas the very extreme La Nina event resulted in an increase in rainfall of 1491 mm or 58% of normal conditions. Rainfall variability is very closely related to oil palm productivity with the regression equation $Y = 94.05 – 0.1558x + 0.000083x^2 – 10^{-8}x^3$ and the accuracy level R^2 is 98.6%.

Keywords: *Oil palm, Productivity, Seram Island, Rainfall variability*

Introduction

Oil palm (Ela e is guinennsis J ac q) is one of the important commodities in Indonesia and has quite bright development prospects. Indonesia is the first palm oil producer in the world with a total land area of 14.68 million ha and an average productivity level of 3,702 tonnes/ha (MPASSI et al., 2023). As Indonesia's mainstay plantation crop, this commodity can generate quite a large amount of foreign exchange because it has large business opportunities and can create employment opportunities that lead to community welfare (Rabha, 2021).

Indonesia's palm oil production throughout 2019 reached 51.8 million tons of CPO. This amount increased by around 9 percent from

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production in 2018 of 47.43 million tons (Mariuzza et al., 2022). The high demand for palm oil from developing economies in Asia such as India and China as well as the high level of domestic consumption are the main driving forces behind the growth of the palm oil industry in Indonesia. Therefore, attention must be paid to the development of the palm oil industry in Indonesia so that the increase in palm oil production remains consistent throughout Indonesia. So far the largest palm oil industry is in the western region of Indonesia and is only starting to be developed in the eastern region of Indonesia ; including Maluku (Racha et al., 2022).

Under certain conditions, the influence of climate on the vegetation that grows in a place is much stronger than the influence of soil. Knowledge regarding how plants can live in a particular climate requires more detailed climate information from several decades which includes monthly average values and distribution patterns throughout the year, while to estimate plant diversity requires daily weather information (Setiawan, 2009). Rainfall can be considered as the main factor that limits the yield potential of oil palm and because it is difficult to change, to adapt it to existing climatic conditions it is more practical to modify agronomic measures so that it can support the achievement of good yield potential. on palm oil (Chaves et al., 2018).

Halofsky et al. (2015) explained that climate variability that can have an impact on oil palm growth is drought stress and excess water stress (rainfall, rainy days, wet months, dry months, humid months, water deficit) and heat stress (air temperature index). According to Hartley (1988), good rainfall for oil palm land suitability ranges from 2000 - 2500 mm per year and there is no monthly rainfall below 100 mm (Lake-Thompson, 2018). The high and low levels of rainfall can be used as evaluation material for production achievements in the coming years. Insufficient rainfall distribution has an impact on flower development in oil palm plants and increases miscarriage, failed or rotten bunches, low productivity and long inflorescences of around 8-9 months. Lack of water in oil palms can cause nutrient deficiencies in oil palm plants. Excessive rainfall also damages fresh fruit bunches (FFB), reduces road quality, hampers harvest activities, and flood.

Drought and excessive rainfall due to the El Nino and La Nina rainfall anomalies as a result of global warming and the accompanying climate change have had a further impact on decreasing agricultural production (Padata et al., 2022; Sitorus et al., 2023). Several studies conducted in the Maluku region show that drought events due to El Nino have had an impact on decreasing nutmeg production on Saparua Island, peanut production on Kei Kecil Island, and clove production on Haruku Island (Rehatta et al., 2021; Kelbulan et al.., 2021; Lawalata et al., 2023;). Manulang et al. (2023) reported that the reduction in rainfall below 1,500 mm/year due to El Nino had an impact on decreasing clove production, and the increase in rainfall above 4,000 mm/year due to La Nina also had an impact on decreasing clove production on Nusalaut Island, Maluku Province. A different thing happened in the Airbuaya area of Buru Island, where the increase in rainfall during La Nina increased clove production because rainfall in the area when La Nina was still within the plant's tolerance interval, namely less than 4,000 mm/year (Awere et al., 2023). The impacts mentioned above can also occur on oil palm plants when this climate anomaly phenomenon occurs (Ahmed et al., 2022).

Based on the various things stated above, research has been carried out which aims to describe variability rainfall and its influence on the productivity of oil palm plants on Seram Island, Maluku Province (Nascimento et al., 2018).

Methods

This research is a case study carried out at PT Nusa Ina Group, northern part of Seram Island which is the central producer of palm oil commodities in Maluku Province. The materials used in this research are : (1) rainfall data, (2) ENSO History NINO 3.4 Zone data (NOAA, 2022), (3) palm oil production data, and (4) other supporting data. The tools used are: Laptop (MS Word 2010, MS Excel 2010), Minitab 18 program packaging, and stationery (Sabin, 2021).

The data collected is in the form of: rainfall data from the Meteorological Station Namlea for the last 30 years (1992-2021), rainfall data from the PT Rain Station. Nusaina Group for the last 8 year period (2014-2021), agricultural data in the form of palm oil production data at PT. Nusaina Group (precisely in Afdeling VI; Figure 1), and the cultivation technology developed as well as other supporting data (Chen et al., 2019).

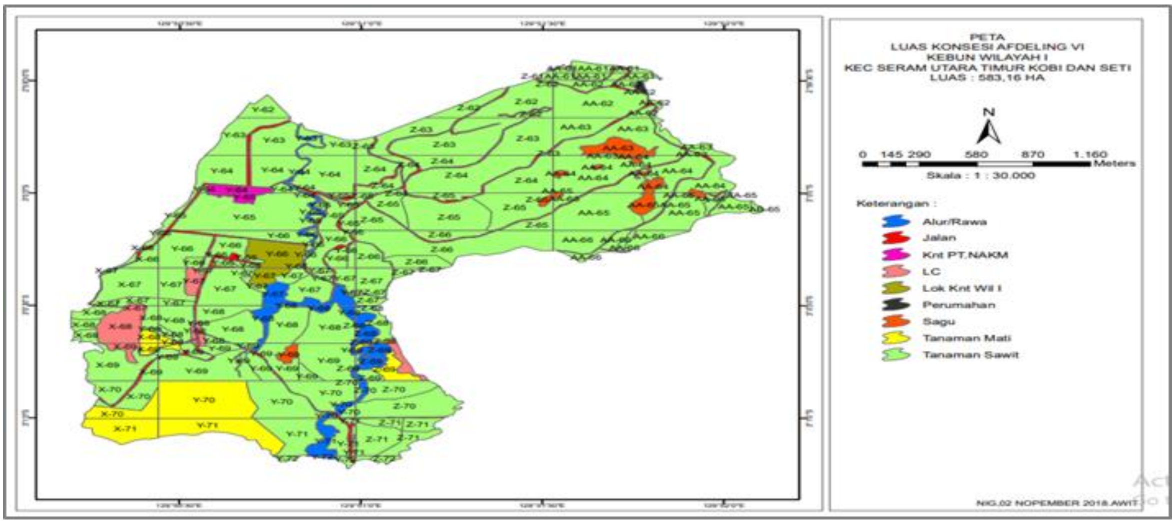

Figure 1. Oil palm plantation area (Afdeling VI) PT. Nusaina Group

The research location does not have a station that records complete rainfall data (especially trace data long-term rainfall for the period 1992-2013, so it needs to be generated using rainfall data from the nearest climate station, namely the Namlea Meteorological Station. Namlea Meteorological Station is an area close to the research location and has the same rainfall pattern, namely the monsoon rain pattern (Syeda et al., 2022).

The steps for generating rainfall data using a simple mathematical method were applied by Nangimah et al, Laimeheriwa et al. (2019), and Pattiselanno et al. (2020) with the basic assumption that the percentage/coefficient of change in monthly rainfall is the same in both regions, and the monthly rainfall time series data generated for research locations for which data is not available is proportional compared to the rainfall time series data in the Namlea area. The results of the division in the form of monthly values/coefficients are then multiplied by the bulk time series data rain so that rainfall time series data is produced for the research location for the 1992-2013 period (Ghodszad et al., 2022).

Analysis uses trace data rainfall for the last 30 years (period 1992 -2021 ; consisting of generation data for the period 1992-2013 and data recorded at the research location for the period 2014-2021). Determining extreme rainfall conditions each year in the form of rainfall values above normal and below normal according to BMKG standards (2012), namely: below normal rainfall is rainfall that is less than 0.85 times the average rainfall value (normal) (Silva, 2021), and rainfall above normal is rainfall greater than 1.15 times the average rainfall value (normal). Rainfall events above and below normal each year are then adjusted to the years of El-Nino and La-Nina events in Indonesia (ENSO History Zone NINO 3.4 data) to determine the years of El-Nino and La Nina events at the research location (Ren et al., 2020).

Regression analysis is used to predict the relationship between two functional variables, in this connection the dependent variable (Y : palm oil productivity; tons/ha) and the independent variable (X : rainfall; mm/year). For this purpose, according to available data, rainfall data and palm oil productivity data for 8 (eight) years are used; period 2014-2021.

Because the data type used is numeric (quantitative) in the form of average (Ceron-Martinez, 2019), maximum and minimum values, a regression model test is required with the following stages: (i) data exploration is carried out to understand the data before analysis is carried out. Data is visualized in graphic form (scatter diagram) to determine the characteristics and relationships between attributes and data (Fattah et al., 2019). From the scatter diagram you will see data points that are far apart from other data points due to measurement variability or experimental error, and you can also see whether the regression model trend is linear or curvilinear. Data that is far apart (outliers) is trimmed and then a more appropriate regression model is tested based on minimum S2 variance values and high R2 as well as R2 _adj which is relatively the same or close to R2 (Steel et al., 1997); and (ii) if the regression is curvilinear, continue with the selection of a polynomial (linear, quadratic and cubic) or exponential model. Testing was carried out using the Minitab 18 program (Hamid et al., 2020).

Result and Discussion

Data Analysis

Based on the results of analysis of rainfall data in the last 30 years for the period 1992 – 2021, annual rainfall at the research location ranged from the lowest of 1,333 mm in 2015 to the highest in 2010, namely 4,045 mm with an average annual rainfall value of 2,221 mm (Figure 2) (Gaonkar et al., 2019).

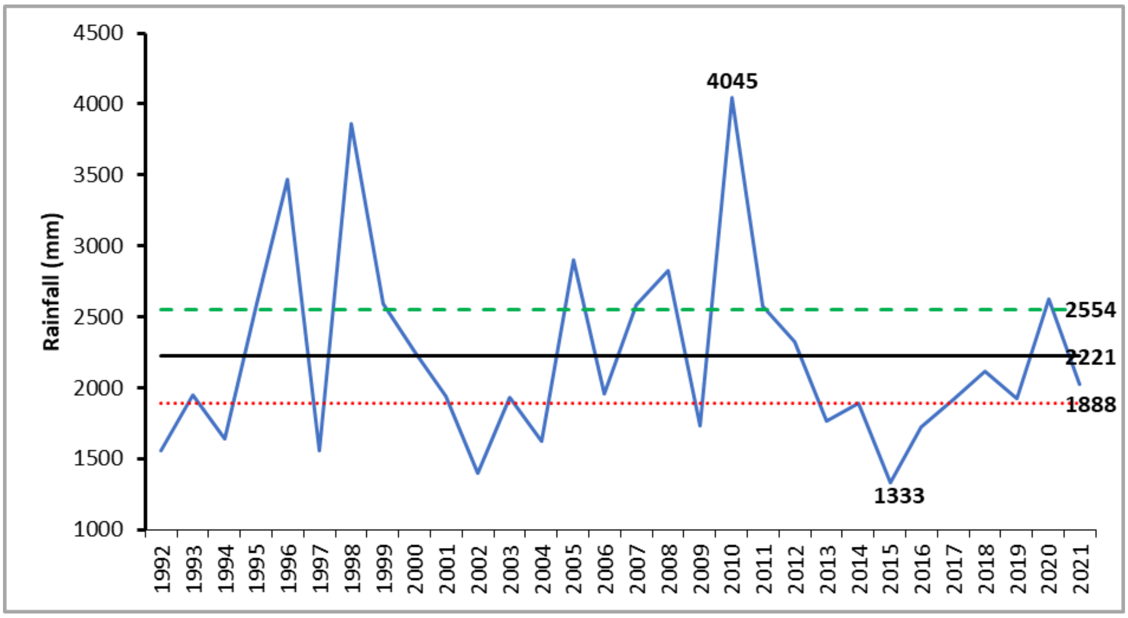

Figure 2. Distribution of annual rainfall at the research location

The rainfall time series data shows that during the 11 years of events, rainfall was at normal conditions, meanwhile for 19 years the rainfall events deviated from normal conditions as shown in Table 1.

Table 1. Rain characteristics at the research location

The Nature of Rain	Year Event
Normal	1993, 2000, 2001, 2003, 2006, 2012, 2014, 2017, 2018, 2019, 2021.
Below Normal	1992, 1994, 1997, 2002, 2004, 2009, 2013, 2015, 2016.
Above normal	1995, 1996, 1998, 1999, 2005, 2007, 2008, 2010, 2011, 2020.

Based on the results of measurements of sea surface temperature (SST) by NOAA in the Nino 3.4 region in the Pacific Ocean, which is indicated by the ONI (Oceanic Nino Index) value, it is clear that from 1992 to 2021 El -Nino events in Indonesia occurred as many as 9 times with a frequency of 2 - 6 years or an average of once every 3 years. Meanwhile,

based on 3 0 year rainfall time series data for the period 19 92 - 20 21 at the research location, of the 9 occurrences of rainfall deviations that were less than normal conditions, 8 of them coincided with El-Nino events in the Indonesian region which were recorded in region Nino 3.4, namely in the years: 19 92, 19 94, 1997, 2002, 2004, 2006, 2009, and 2015; frequency 2 - 6 years or an average of once every 3 years.

The occurrence of below normal rainfall (drought) and the El Nino phenomenon illustrates that drought events at the research location do not always coincide with El Nino events, and El Nino events do not always cause drought or below normal rainfall (Laimeheriwa et al., 2019). In 2013 and 2016, the amount of rainfall at the research location was below normal (< 1,888 mm/year) but these years were not recorded as El Nino years. Furthermore, 2019 was recorded as an El Nino year but did not cause drought or rainfall at the research location under normal conditions (Oda, 2019).

When El Nino intensity is moderate to very strong with ONI values > 1.0, then this rainfall anomaly will continue at the research location. During the last 30 years period, this event occurred 7 times, namely in 1992, 1994, 1997, 2002, 2004, 2006, 2009, and 2015. However, the El Nino intensity was weak with an ONI value of 0.5 to 1. 0, of the 4 years of El Nino events with this intensity, only 3 times this event occurred at the research location, namely in 1992, 2004, and 2006; Meanwhile, in 2019 this incident did not occur because rainfall at the research location was still at its normal interval, namely 1,925 mm/year. The two most extreme El Nino years in the study location when the intensity was strong occurred in 1997 and 2015 with annual rainfall amounts of 1,560 mm and 1,333 mm, respectively; reduced by 661 mm and 888 mm or 26.8 % and 40.0 % from normal conditions.

The conditions above illustrate that when El Nino occurs globally (as recorded in the Nino 3.4 region in the Pacific Ocean) there is a very big chance for this event to occur at the research location which will have a further impact on groundwater shortages and low crop production and even threaten to fail. Harvest (Khatun & Rahman, 2021).

At the research location, during the period 19 82 – 20 21, of the 10 occurrences of deviations in rainfall that exceeded normal conditions, 7 of them coincided with La-Nina events which generally occur in Indonesia, namely in the years: 199 5, 1998, 1999, 200 7, 200 9, 2010, and 20 20 ; frequency 1 – 10 years or an average of once every 4 years (YAKUWA, 2023).

Similar to the El Nino event, high rainfall events (above normal) at the research location does not always coincide with La Nina events, and La Nina events do not always cause above normal rainfall. In 1996, 2005 and 2008, the amount of rainfall at the research location was above normal (> 2,554 mm/year) but these years are not recorded as La Nina years. On the other hand, 2000, 2016, and 2021 which was recorded in the Nino 3.4 region as La Nina years but did not cause rainfall at the research location above normal conditions (Tang et al., 2019).

When the intensity of La Nin a moderate to very strong with an ONI value < - 1.0, then this phenomenon will continue to occur at the research location (Jacob et al., 2022). During the last 30 years period, this incident occurred 7 times, namely in 1995, 1998, 1999, 2007, 2010, 2011, and 2020. The frequency of La Nina events with this intensity is once every 1 - 9 years or an average of once every 6 years. However, when the La Niña intensity was weak with an ONI value of 0.5 to 1.5, this event did not occur at the research location, namely in 2000, 2016, and 2021. Two years of La-Nina events at the research location with rainfall far above normal (the most extreme) when the intensity was strong occurred in 1998 and 2010 with annual rainfall amounts of 3 respectively. 860 and 4. 0 45mm; increased by 1,360 mm and 1,491 mm or 5 1.1 % and 58.4 % from normal conditions (Jain & Kalamdhad, 2020).

The occurrence of excessive rainfall increasing to more than 4,000 mm/year at the research location during La Nina with strong intensity will have an impact on the risk of floods and landslides (LEÃO, 2020). In the agricultural sector, this incident has an impact on pest attacks and plant diseases, flooding of agricultural land with poor drainage systems, and disruption of the flowering and fruiting processes for several commodities, which will ultimately lead to decreased production and/or crop failure (Siddique et al., 2021).

To see the extent of the relationship between rainfall and oil palm productivity, a regression analysis was carried out using 8 (eight) year data for the 2014-2021 period as shown in Table 2.

Table 2. Rainfall and productivity of oil palm plants

Year	Rainfall (mm)	Productivity tons/ha
2014	1891	2.3932
2015	1333	1.3503
2016	1727	1.5219
2017	1913	3,2013
2018	2113	4.7165
2019	1925	5.4323
2020	2627	5.7115
2021	2022	4.0915

The data in Table 2 above before regression analysis was carried out, data exploration was carried out to find out data that was far apart from other data points due to measurement variability or experimental error. Based on the scatter diagram (Figure 3), it appears that there is a tendency for curved regression with one outlier, namely the 2019 data.

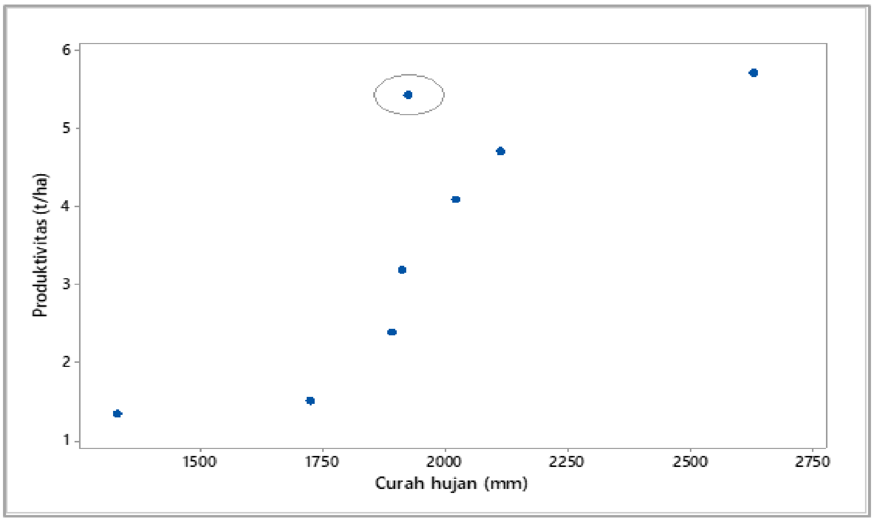

Figure 3. Graph of research data points

From the results of the regression model test, the cubic model was chosen as the best model with the regression equation and graph as follows:

$$\hat{y}_i = 94{,}05 - 0{,}1558x_i \ + 0{,}000083x_i^2 - 10^{-8}x_i^3;\ R^2 = 98{,}6\%$$

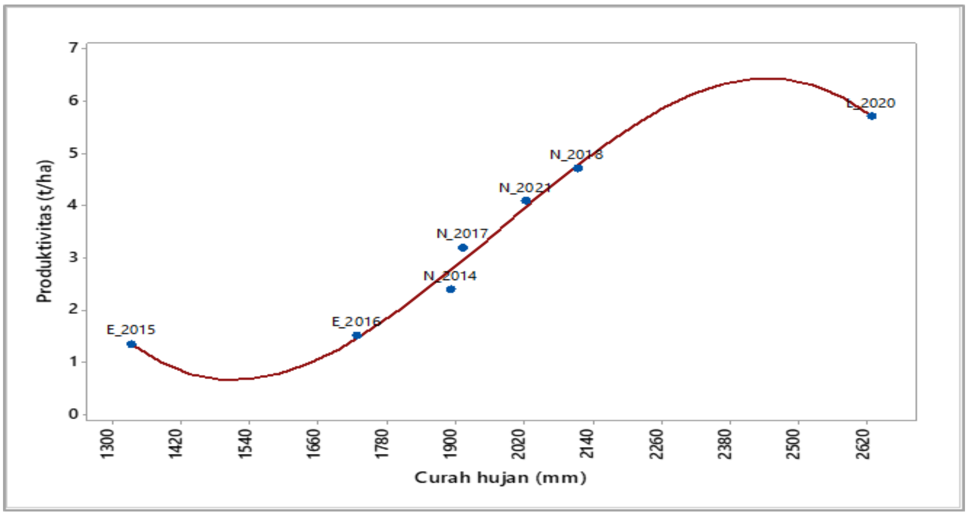

Figure 4. Graph of the relationship between rainfall and palm oil productivity

The graph above illustrates that increasing rainfall (X) will increase palm oil productivity (Y). The coefficient of determination (R^2) value of 98.6% shows that the influence of the dependent variable (rainfall) can explain the dependent variable (oil palm productivity) of 98.6%, the remaining 1.4% of palm oil productivity is explained by other variables not included in model. From the graph it also appears that there is a tendency that if rainfall increases to a certain value, palm oil productivity will decrease (Kar et al., 2021).

If linked to the data in Table 2, when the El Nino event occurred in 2015, which was indicated by low rainfall, namely only 1,333 mm, oil palm productivity was also low, namely only 1.35 tonnes/ha. This low rainfall is not sufficient for the water needs of oil palm plants; especially in the flowering and fruiting phases which are sensitive to water shortages. Similar to the El Nino event in 2016 with rainfall of 1,727 mm, palm oil productivity was also low, although the rainfall was higher than in 2015, the extreme influence of El Nino 2015 had an impact on palm oil production in 2016. Based on monthly rainfall data in 2015, 7 months were classified as dry months according to Schmidt & Ferguson (1951); namely months with rainfall < 60 mm which occurs in April, June to November. This is in accordance with Hidayat & Ando (2014) who concluded that the impact of El Nino on decreasing rainfall in most areas of Indonesia was seen to be dominant in the period June to November, while in the period December to May it had relatively no significant influence on decreasing rainfall. This condition not only caused low oil palm production in 2015 but also continued in 2016. This is also in accordance with what was stated by Hartley (1988) that good rainfall for the suitability of oil palm land ranges from 2000 - 2500 mm per year and there is no monthly rainfall below 100 mm. Meanwhile, the highest oil palm productivity was achieved in 2020 at 5.7115 tonnes/ha. The high production of oil palm is not only due to the increasing age of the plants towards maximum production but also due to sufficient rainfall (2,627 mm/year) and no dry months so that the plants do not lack water (Islam et al., 2020).

Conclusion

1. The El Nino rainfall anomaly at the research location in the 1992-2021 period occurred 8 times with a frequency of once every 2 - 6 years or an average of once every 3 years. La Nina occurs 7 times with a frequency of 1 – 10 years or an average of once every 4 years. The very extreme El Nino caused a reduction in rainfall at the research location by 888 mm or 40% of normal conditions, whereas the very extreme La Nina event resulted in an increase in rainfall of 1491 mm or 58% of normal conditions.

2. Rainfall variability is very closely related to oil palm productivity with the regression equation Y = 94.05 – 0.1558x + 0.000083x 2 – 10 -8 x 3 and the accuracy level R 2 is 98.6%. This shows that the influence of the in dependent variable (rainfall) can explain the dependent variable (oil palm productivity) by 98.6%, the remaining 1.4% of palm oil productivity is explained by other variables not included in the model.

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