Correlation Study of The Number of Cloud to Ground Lightning Strikes With Rainfall in The City of Pontianak

Tegar Pujianda¹, Usman A Gani², Danial¹

¹Undergraduate Program Electrical Engineering, Faculty of Engineering, Universitas Tanjungpura, Pontianak, Indonesia
²Department of Electrical Engineering, Faculty of Engineering, Universitas Tanjungpura, Pontianak, Indonesia

ABSTRACT

Research has been conducted on lightning strikes with rainfall to determine the relationship between the two. The problem in this study is how the relationship between lightning clouds to the ground with rainfall in Pontianak City. The lightning data used is lightning detector data originating from the BMKG Supadio Station and rainfall on the BMKG website. The method used in this study performed a linear regression test and a correlation test. The results obtained show a relationship between rainfall and cloud lightning to the ground daily with a Spearman correlation of 0.2237 which means that the relationship between the two variables has weak strength. The strength of the relationship between the number of cloud lightning strikes to the ground with low rain intensity and the 22.37% relationship between rainfall intensity and the number of cloud lightning to the ground. The correlation coefficient obtained is positive. The relationship between the two variables is unidirectional and can be interpreted that high rain intensity will cause the number of lightning strikes to increase. The intensity of rainfall determines less the size of the number of cloud lightning strikes to the ground. The correlation value between the number of cloud lightning strikes to the ground and the intensity of rainfall in Pontianak City in the weak correlation category with a small value ($R^2$) close to zero. The coefficient of determination is 0.088. This means that 8.8% of the variation from lightning strikes can be explained by variable variations in rainfall.

Keywords: Correlation Rainfall Cloud Lightning to the ground Pontianak City Lightning

1. INTRODUCTION

Indonesia is a country that is crossed by the world's equator so that Indonesia is an area that is easy to grow convective clouds. In addition, Indonesia also has a large area of water that can produce clouds including cumulonimbus clouds which are the main cause of rain and lightning.

Lightning occurs because there is a potential difference between clouds and the ground. The process of charge occurs on the cloud because it continues to move continuously in a regular manner and during its movement with which it interacts other clouds, so that negative charges will gather on one side (up or down) while positive charges accumulate on the bottom side. If the potential difference between the cloud and the ground is large enough, it will cause the scattering of negative charges (electrons) from the cloud to the ground or vice versa to achieve equilibrium.

Pontianak City is the capital of West Kalimantan province. Pontianak City is located on the equator because it is traversed by latitude 0o earth and is located on the west coast of the island of Kalimantan. This geographical location makes Pontianak City receive high solar irradiation so that the level of evaporation humidity is also high. This triggers the easy growth of convective clouds that can cause heavy rain and lightning. Pontianak City and its surroundings are potentially prone to lightning strikes due to the easy growth
of convective clouds. Bad weather such as heavy rain and strong winds are strongly associated with thunderstorms originating from Cumulonimbus clouds that have a strong convection system.

Lightning strikes that occur are often associated with rain. If there is rain, it can cause lightning, but when lightning occurs, it does not necessarily rain. For this reason, studies are needed to determine the relationship between lightning and rainfall.

2. LITERATURE REVIEW

2.1 Previous research

There are several previous studies or similar research that has existed before which became the material for the preparation of this thesis.

Previous research conducted by Fitridayanti Hidayat (2018) in her research entitled "Characteristics and Relationship of Cloud to Ground Lightning Activities with Rainfall (Case Study of Pontianak City and its Surroundings)". His study used the Spearman correlation method to determine the relationship between rainfall and lightning activity. The results of his research showed the highest correlation value with a value of \( r = 0.417 \). Fitridayanti's conclusion is that the correlation of rainfall and lightning at stations (Supadio, Mempawah, Maritim and Segedong) tends to be low. This is due to several factors, including not every rain accompanied by lightning and vice versa and the influence of weather conditions and convective clouds that produce rainfall and lightning [1].

Research conducted by Deka Agung Pratama, Rosi Budi Kurniawan, and Octadini Rahma Dica (2016) with the title "Correlation of Lightning Strike Frequency to Rainfall Intensity in Manado City in 2016". This study aims to determine the correlation between the frequency of lightning strikes with the amount of rain intensity. Lightning strike frequency data is taken by the Lightning Detector sensor. The calculation of lightning strike frequency was calculated using the Arawan to tanahis 10.2.2 application and using the Pearson Correlation Coefficient method. After calculation, a value of Rs of 0.674 was obtained which means that between variable X (frequency of strike) and variable Y (rain intensity) there is a moderate positive linear relationship of 0.674 [2].

Research conducted by Budi Prasetyo, Yosi Setiawan, and Irwandi (2017) entitled "Analysis of Diurnal Characteristics of Lightning and Rainfall Based on Lightning Detector and Hellmann Data in Medan". This study used lightning detector data and Hellman Rainfall to analyze the characteristics and relationship of the two. In this study, averages, correlations and convectivity activity analysis were used. The results showed that there were 869 times of lightning activity during 2017 consisting of 548 negative CG (CG-) (63.1%) and 309 positive CG (CG+) (36.9%) in Medan City [3].

Research conducted by I Putu Dedy Pratama and Ika Sulfiana Putri (2020) entitled "The Relationship of Cloud Lightning to the Land with Rainfall in Denpasar Using Spearman Correlation and Rain-Yield Value Per Flash". The data used in this study were rainfall data obtained from Automatic Rain Gauges or Automatic Rain Gauge (ARG) and cloud lightning data to the ground from lightning detectors installed at the Denpasar Geophysical Station. The results obtained showed a relationship between rainfall and cloud lightning to the ground daily with a Spearman correlation of 0.453 which means that the relationship between the two variables has moderate strength with a unidirectional correlation where lightning and rainfall do not always occur at the same time. Based on the calculation of Rain-Yield per Flash (RYF), the value of the relationship of cloud lightning to the ground with rainfall is 4.52 x 108 kg/fl [4].

The difference between this research and previous studies is that this research was conducted in Pontianak City in 2021. Previous research the area studied was Pontianak City and its surroundings with a radius of 50 km. What differs from previous research is that this research area specifically discusses the Pontianak city area where secondary data obtained from BMKG is filtered using the arcgis application so that the data obtained is lightning cloud data to the ground in Pontianak City. While the method used is the same as the previous study, namely using the Spearman regression and correlation analysis method. Using regression analysis methods to determine how influential rainfall variables are on cloud lightning strikes to the ground that occur. Meanwhile, the spearman correlation method is to determine the relationship between rainfall and cloud lightning strikes to the ground that occurred in Pontianak City throughout 2021.

2.2 Convective Cloud Formation

Convective clouds are clouds produced by convection processes due to heating solar radiation. Solar radiation energy that heats the ground surface causes the temperature of the ground surface environment to cause the surface environment temperature to rise so that it reaches convection temperature, as a result the temperature of the air mass is higher than the ambient temperature so that the air mass is able to rise to a higher level. Clouds that often produce rain are cumulunimbus clouds where cloud growth is vertical (towering height) or commonly called convective clouds. The characteristic of convective rain is rain in a short time with high

Correlation Study of The Number of Cloud to Ground Lightning Strikes With Rainfall ... (Tegar Pujianda)
Correlation Study of The Number of Cloud to Ground Lightning Strikes With Rainfall … (Tegar Pujianda)

intensity (Widodo, 1998). Clouds that are classified as clouds that cause convective rain are Cb (cumulonimbus) and Cu (cumulus) / Clouds to the ground (cumulus congestus).

2.3 Rainfall
Rainfall (mm) is the height of rainwater that falls on a flat place assuming it does not evaporate, does not permeate and does not flow. Rainfall of 1 mm is rainwater as high as 1 mm that falls (accommodated) on a flat place of 1 m² assuming nothing evaporates, flows and seeps. Rainfall intensity is the amount of rainfall in a certain unit of time, which is usually expressed in mm / hour, mm / day, mm / year, and so on.

2.4 Mechanism of Lightning
Lightning tends to strike areas high on the ground. This is due to the strong terrain around the end or peak of objects above ground level. Lightning is a discharge event due to a potential difference. Lightning can occur due to the presence of lightning clouds or can also be referred to as cumulonimbus clouds. Lightning can occur due to the release of negative or positive charges on clouds and ground surfaces[5].

2.5 Rain Patterns
Indonesia is in a tropical archipelago region, affected by the circulation between the continents of Asia and Australia as well as the Pacific and Atlantic Oceans. Although it is in the tropics, the land is spread from lowlands to mountains. The average annual temperature decreases from lowland to highland. So, the average temperature is relatively high in the lowlands and the low temperatures in the highlands. Because it is in the tropics, the difference in day-night temperatures is greater than the difference in seasonal temperatures (dry season - rainy season)[6].

2.6 Lightning Clouds to the Ground
Cloud lightning to the ground is the most dangerous type of lightning and damages the ground surface. Cloud lightning to the ground is caused by polarized air. As a result, there is an attraction to negative ions and positive ions. Large water droplets containing negative ions gather at the bottom of the cloud, while at the top of the cloud will gather positively charged ions. If the potential difference between one part and another is large enough, then there will be a negative charge release and vice versa to achieve equilibrium. The flow of electric charge that occurs is caused by a strong electric field, between cloud charge and induced charge on the ground surface whose polarity is opposite[7].

2.7 Effects of Cloud Polarity
The bottom of the cloud is generally negatively charged, but some are positively charged. The polarity of clouds influences the magnitude of the current and the direction of lightning. Charge separation (polarization) occurs due to the presence of strong winds can cause turbulence. Upward strong winds (updraft) carry small liquid water droplets contained in clouds to areas with very low temperatures (freezing level). On the other hand, downdraft winds carry ice floes to lower areas. When the water droplets and ice chunks collide, heat will be released which can make the size of the ice chunks smaller called soft hail/graupels[8].

With the presence of charged clouds, an induced charge will arise on the face of the earth, until an electric field arises. Given its dimensions, the ground is considered flat against clouds. So clouds and ground can be regarded as both condenser plates. If the electric field that occurs exceeds the dielectric strength of air (the strength of air penetration), then a charge release will occur. It was at this moment that lightning occurred.

2.8 Lightning strike density
The density of lightning strikes can be calculated from the number of lightning strikes per area studied. The higher the lightning density, the more frequent and frequent lightning occurs in the area. Lightning density can also be used to determine the factors that influence lightning strikes in a region. By knowing the factors of lightning in an area, the community or government can anticipate so that losses do not occur[9].

2.9 Lightning Detector
The lightning detector system used is a real time system using Lightning/2000 software which is assembled with a Boltek lightning detection system with the type of tool used, namely the Boltek S storm Tracker PCI Lightning detector. The working system of this tool is to capture the frequency of lightning current by a storm tracker antenna which can provide information on the direction and distance of lightning calculated with the strength of the signal received. When lightning activity occurs, the wave frequency of the lightning
wave is captured by the sensor and converted into a database. The correct lightning data will be stored for analysis which is displayed in the form of the direction and strength of the lightning strike[10], [11], [12].

2.10 Regression Test

Regression analysis / test is a study of the relationship between one variable, namely the explained variable (the explained variable) with one or more variables, namely the explanatory variable (the explanatory). If there is only one independent variable, then the regression analysis is called simple regression. If there is more than one independent variable, then the regression analysis is known as multiple linear regression. It is said to be multiple because there are several independent variables that affect the dependent variable.

A simple linear regression equation is an equation model that describes the relationship of one independent variable (X) with one independent variable (Y)[13].

2.11 Correlation Test

The correlation coefficient is a number that expresses the strength of the relationship between two or more variables and can determine the direction of the relationship of the variables. A perfect positive relationship is indicated by $r = +1$, while $r = -1$ indicates a perfect negative relationship. The $r$ value has no units or dimensions. The (+) or (-) sign only indicates the direction of the relationship. The level of relationship or correlation can be seen in Table 1 below:

$$r = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

$r =$ Spearman Rank correlation value
$d_i^2 =$ Finish each rank pair
$n =$ number of rank pairs for spearman ($5 < n < 30$)

<table>
<thead>
<tr>
<th>R value (correlation)</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,00 - 0,199</td>
<td>Very Low</td>
</tr>
<tr>
<td>0,20 - 0,399</td>
<td>Low</td>
</tr>
<tr>
<td>0,40 - 0,599</td>
<td>Strong enough</td>
</tr>
<tr>
<td>0,60 - 0,799</td>
<td>Strong</td>
</tr>
<tr>
<td>0,80 - 1,00</td>
<td>Very Powerful</td>
</tr>
</tbody>
</table>

A positive or negative correlation indicates whether the relationship is unidirectional or opposite. A positive correlation, showing an increase in X followed by an increase in Y. While a negative correlation, indicating an increase in X followed by a decrease in Y.

3. RESEARCH METHODOLOGY

3.1 Place and time of research

This research was conducted in the city of Pontianak, West Kalimantan Province, located on the equator between 0° 02' 24" North Latitude and 0° 05' 37" South Latitude and between 109° 16' 25" East Longitude to 109° 23' 01" East longitude.

Tools and materials
1. Microsoft Word dan Microsoft Excel
2. Arcgis App
3. SPSS Application

3.2 Research methods.
1. Data Collection
   a. Lightning Data
   b. Rainfall Data
2. Perform a Normality Test
   Conducted normality tests using the Kolmogorov-Smirnov and Shapiro-Wilk methods.
3. Perform Regression Tests
Regression tests are performed to study the relationship between two variables, namely the independent variable (free) and the dependent variable (bound).

4. Perform a Correlation Test
   Correlation Test using the Spearman correlation method.

3.2 Variables or Research Data
   In this study the variables or data used are as follows:
   1. Data on the number of cloud lightning attacks on the ground in the Pontianak City area throughout 2021.
   2. Data on rainfall intensity in the Pontianak City area in 2021.

3.3 Flowchart

   ![Flowchart](image)

   Figure 1. Flowchart [15]

The research was carried out at the BMKG Supadio office from January 2021 to December 2021. Data obtained from BMKG Supadio Denpasar was in the form of lightning data obtained from LD-2000 and rainfall data obtained from the official BMKG website. First, lightning data and rainfall data were taken, lightning data was taken via the LD-2000 sensor and rainfall data was taken via the official BMKG website. Furthermore, the lightning data that has been obtained is processed by paying attention to time and location. After determining the parameters, the data filtering process was carried out again so that it became lightning data in Pontianak. Then an analysis was carried out using a regression test. Then a normality test is carried out to see whether the data obtained is normally distributed or not. After that, a correlation test was carried out to determine the relationship between the two variables. The correlation test used is the Spearman correlation test.

4. DATA, ANALYSIS, AND CALCULATION

   *Correlation Study of The Number of Cloud to Ground Lightning Strikes With Rainfall*  
   (Tegar Pujianta)
4.1 Lightning Strike Data

Secondary data on lightning strike activity during the year (January 2021 – December 2021) from BMKG Supadio Pontianak can be seen in table 2.

**Table 2. Lightning strike activity based on data obtained from BMKG Supadio Pontianak**

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Strikes</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0</td>
</tr>
<tr>
<td>February</td>
<td>1</td>
</tr>
<tr>
<td>March</td>
<td>42</td>
</tr>
<tr>
<td>April</td>
<td>127</td>
</tr>
<tr>
<td>May</td>
<td>245</td>
</tr>
<tr>
<td>June</td>
<td>115</td>
</tr>
<tr>
<td>July</td>
<td>2</td>
</tr>
<tr>
<td>August</td>
<td>77</td>
</tr>
<tr>
<td>September</td>
<td>171</td>
</tr>
<tr>
<td>October</td>
<td>15</td>
</tr>
<tr>
<td>November</td>
<td>120</td>
</tr>
<tr>
<td>December</td>
<td>181</td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td><strong>1096</strong></td>
</tr>
</tbody>
</table>

4.2 Rainfall Data

Secondary data on rainfall for a year (January 2021 – December 2021) obtained from the official BMKG website.

**Table 3. Rainfall based on data obtained from BMKG Supadio Pontianak (January 2021 – December 2021)**

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>306.4</td>
</tr>
<tr>
<td>February</td>
<td>11.9</td>
</tr>
<tr>
<td>March</td>
<td>226.1</td>
</tr>
<tr>
<td>April</td>
<td>261.4</td>
</tr>
<tr>
<td>May</td>
<td>380</td>
</tr>
<tr>
<td>June</td>
<td>294.5</td>
</tr>
<tr>
<td>July</td>
<td>202.8</td>
</tr>
<tr>
<td>August</td>
<td>633.5</td>
</tr>
<tr>
<td>September</td>
<td>439.5</td>
</tr>
<tr>
<td>October</td>
<td>281.6</td>
</tr>
<tr>
<td>November</td>
<td>211.9</td>
</tr>
<tr>
<td>December</td>
<td>159.8</td>
</tr>
</tbody>
</table>

4.3 Normality Test

Based on the results of the normal distribution test (Table 4.3) between cloud lightning to the ground and daily rainfall in 2021, both are normally distributed (significance > 0.05).

**Table 4. Normality Test Output**

<table>
<thead>
<tr>
<th>Kolmogorov-Smirnov*</th>
<th>Shapiro-Wilk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistic</td>
<td>Df</td>
</tr>
<tr>
<td>CG</td>
<td>.158</td>
</tr>
</tbody>
</table>

*Correlation Study of The Number of Cloud to Ground Lightning Strikes With Rainfall … (Tegar Pujianda)*
distribution if it is greater than 0.05. From the data processing above, 0.261 and 0.561 data were obtained, this shows that the data is normally distributed because it is greater than 0.05. So it can be concluded that the data from cloud values to the ground and rainfall are normally distributed.

4.4 Regression Test

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.297*</td>
<td>0.088</td>
<td>-0.003</td>
<td>81.919</td>
</tr>
</tbody>
</table>

a. Predictor: (constant), Rainfall
b. Dependent Variable: Cloud to Ground Lightning Strikes

The magnitude of the R correlation value of 0.297 indicates that the correlation between the number of lightning strikes and the independent variable of rainfall intensity is weak (because of the magnitude of < 0.5). The R² number or Coefficient of Determination is 0.088. This means that the effect of the independent variable (rainfall) on the dependent variable is 0.088 or 8.8%.

4.5 Correlation Test

Figure 2. Graph of thunderstorms, clouds to the ground and precipitation in 2021

Figure 4.4 shows that the maximum rainfall occurs in August and the maximum number of lightning strikes in May. In February-May there is an equal increase in the number of lightning strikes and the intensity of rainfall. Then in May-July there is a similar decrease between the intensity of rainfall and lightning. Likewise, in July-August there is an increase in the intensity of rainfall and lightning strikes. This shows that...
in these months there is a relationship between rainfall and lightning. Although in September-December there is a mismatch between rainfall intensity and lightning strikes, lightning and rainfall can be fairly stable. Lightning conditions and rainfall are not balanced because high lightning events are not always related to rain. Usually rain occurs depending on convective clouds that form lightning or precipitation itself.

Table 6. Correlation Test Output Using SPSS

<table>
<thead>
<tr>
<th></th>
<th>Cloud to Ground Lightning Strikes</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman's rho</td>
<td>Correlation Coefficient</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.000</td>
<td>0.224</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-Tailed)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>0.484</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

The correlation value obtained is 0.22377 which means that the correlation value tends to be weak. It states that the intensity of precipitation and the number of lightning strikes have a low relationship or degree of correlation. Thus, every occurrence of cloud lightning to the ground is not necessarily accompanied by rain. Likewise, when rain occurs, it does not necessarily occur rain.

5. CONCLUSION

The conclusions that can be obtained in the results of this study are; the results of research data analysis show a weak influence of rainfall intensity on the occurrence of cloud lightning strikes to the ground in Pontianak City, this can be seen from the correlation test results of 0.224. This means that the intensity of rainfall does not determine the size of the number of cloud lightning strikes to the ground in that place. The correlation value between the number of cloud lightning strikes to the ground and the intensity of rainfall in Pontianak City in the weak correlation category with a very small coefficient of determination value close to zero. The Coefficient of Determination is 0.088. This means that 0.088 or 8.8% of the variation from cloud lightning strikes to the ground can be explained by the variation of the independent variable rainfall. While the rest (100-8.8 = 91.2) or 91.2% is explained by other causes.

ACKNOWLEDGEMENTS

The author would like to thank the chairman and academic community of the Faculty of Engineering, Tanjungpura University who always provide direction and guidance to the author. Hopefully the results of writing from this research can be useful, both for the author and for readers.

REFERENCES


Correlation Study of The Number of Cloud to Ground Lightning Strikes With Rainfall … (Tegar Pujianda)
Correlation Study of The Number of Cloud to Ground Lightning Strikes With Rainfall … (Tegar Pujianda)

Tegar Pujianda

Born in Ketapang on 1 July 2000, studied high school at SMAN 3 Ketapang, Kalimantan Barat from 2015 to 2018, and continued his education at the Electrical Engineering Study Program at Tanjungpura University Pontianak in 2018 and obtained a Bachelor of Engineering degree in 2023.

Usman A Gani

Born in Pontianak on 16 February 1970, pursued his undergraduate education at Tanjungpura University Pontianak and received a bachelor of engineering degree in 1994, then continued his education at the Bandung Institute of Technology and obtained a master's degree in engineering in 2002. Then continued his education at Padjadjaran University and received a doctorate in 2014. Started actively teaching as a lecturer at the Faculty of Engineering, Tanjungpura University from 1995 until now. He is a member of the High Voltage Engineering group at Tanjungpura University, Pontianak, electrical engineering study program. Research topics on High Voltage Engineering, Materials and Manufacturing.

Danial

Born in Sambas on 12 February 1962, pursued his undergraduate education at Tanjungpura University Pontianak and received a bachelor of engineering degree in 1991, then continued his education at the Bandung Institute of Technology and obtained a master's degree in engineering in 1995. Started actively teaching as a lecturer at the Faculty of Engineering, Tanjungpura University from 1992 until now. He is a member of the High Voltage Engineering group at Tanjungpura University, Pontianak, electrical engineering study program. Research topics on Co-firing of Palm Biomass and Coal.