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Rainfall Analysis at Klang District in December 2021

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Abstract. In December 2021, the worst flood outbreak in Malaysia occurred in Selangor and Pahang States. Focused on the Klang district, the rainfall amount during the flooding month, which happened in December, has been analyzed. This study aims to examine the rainfall data in this area during the occurrence of the flood. Hourly rainfall data were obtained from four rainfall stations: JPS Pulau Lumut station, Kg. Sg. Kembong station, Pintu Kawalan P/S Telok Gong station, and Ladang Sg. Kapar station has been computed to daily rainfall data by using averaging formula and analyzed using Pearson's correlation formula. The result shows that the highest amount of rainfall occurred on December 17, 2021, with 18.4 mm at JPS Pulau Lumut station. The correlation analysis values between each station show a good correlation since they exceed the value of 0.650. A strong correlation is indicated by JPS Pulau Lumut and Ladang Sg. Kapar with 0.893. Rainfall analysis and accurate rainfall measurement are important for a wide spectrum of assessments, such as flood forecasting, effective water resources management, and agriculture.

1. Introduction
The Earth's system is influenced by the global circulation of precipitation and it helps to regulate the Earth's temperature by transferring heat from the tropics to higher latitudes [1]. Rainfall is a series of 1 to 5 mm-diameter drops of liquid water that descend from the atmosphere to the Earth's surface and it is a type of precipitation that occurs frequently in tropical areas of the world [2]. Located in the Southeast Asia region, Malaysia has a hot, humid climate throughout the year [3][4]. Rainfall in Malaysia is influenced by the monsoon seasons. There are two monsoon seasons in Malaysia which are the Northeast monsoon (NEM) and Southwest monsoon (SWM). NEM occur between November to March, while SEM is from May to September. On top of that, inter-monsoon is expected in April and October [4]. During these monsoon seasons, the nation has significant yearly rainfall, between 2000 and 4000 mm with 150 to 200 wet days [5]. Extreme rainfall is one of the primary contributors to natural catastrophes like floods [6] and landslide occurrences [7]. IPCC claims that severe precipitation events are anticipated to increase worldwide precipitation in the future, presumably intensifying and occurring more often throughout much of the wet tropical zone [8]. According to the Department of Irrigation and Drainage of Malaysia, the categorization of rainfall intensity (in one hour) has been divided into 4 types. Table 1 shows the rainfall categorization.

Table 1. The categorization of rainfall intensity (in one hour) [9]

No.	Category	Amount	Indicator
1.	Light	1 – 10 mm	Green
2.	Moderate	11 – 30 mm	Yellow
3.	Heavy	31 – 60 mm	Orange
4.	Very Heavy	> 60 mm	Red

Flash floods can occur when convective rain falls for more than 60 mm in 2 to 4 hours (typically). The intensity of monsoon rains can occasionally surpass several hundred millimetres in 24 hours, and long duration with intermittent heavy bursts [9]. Information on variations in rainfall distribution in a region is crucial and helpful for planning water resources, spotting droughts and floods, and monitoring economic activities. It may also serve as a reference for other planning tactics involving water sources [10].

According to a study conducted by [11], extreme rainfall activities in Peninsular Malaysia show an increasing trend based on the data analysis from the year 1975 until 2010. On the other hand, this paper highlighted the precipitation amount for December 2021 in the Klang district due to the worsts flood disaster. Figure 1 shows the map of the flooded area in Pahang and Selangor on December 2021.

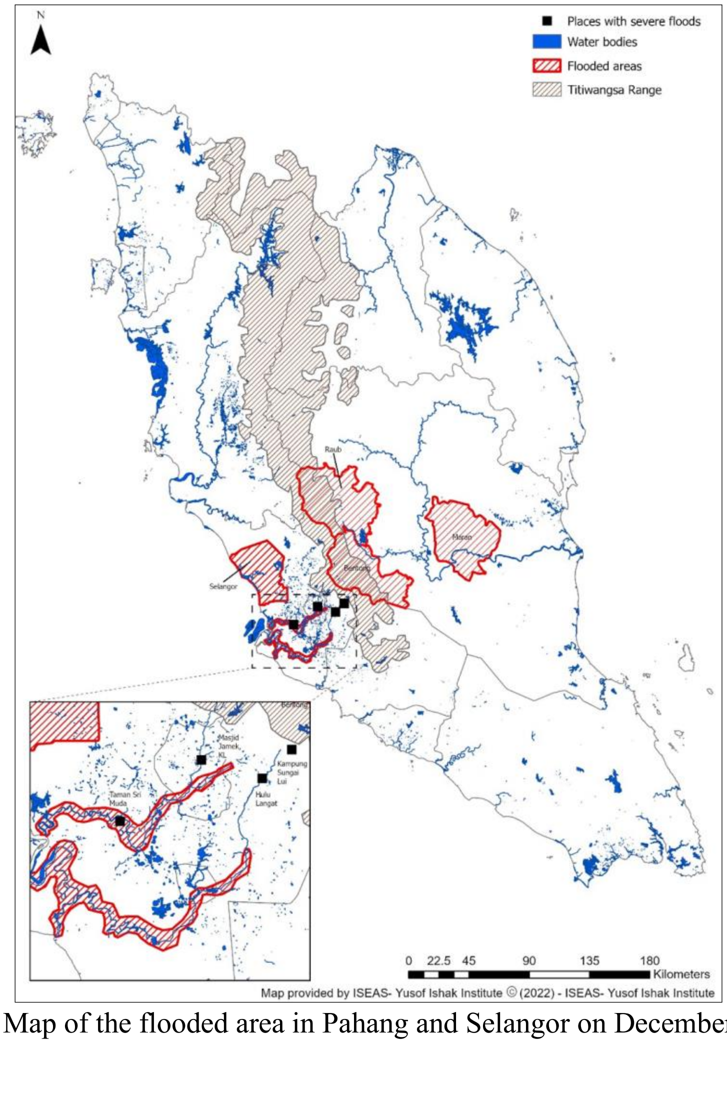

Figure 1. Map of the flooded area in Pahang and Selangor on December 2021 [12]

2. Study Area and Data Used

The Klang Valley is one of Malaysia's most developed areas. The Federal Territory of Kuala Lumpur (the FT Kuala Lumpur); Gombak; Petaling; Klang; and Hulu Langat make up this region. The Klang Valley, which has an area of around 2,832 square kilometres, lies roughly in the middle of Peninsular Malaysia's West Coast [13]. This study focuses on the Klang district. The busiest port in Malaysia is also located in this area which is Port Klang. Moreover, Port Klang is well known as one of the ports with the largest volume of shipments in Malaysia and Southeast Asia [14] and is located at latitude 03°00’N and longitude 101°24’E. Port Klang is the main entry point and the busiest port for Malaysia, which is located at the northern end of the Straits of Malacca on the West Coast of Peninsular Malaysia, about due west of Kuala Lumpur, the country's capital. It is naturally enclosed and well protected by the nearby islands. A network of roads and rail connections connect the port to other regions of the nation, and it is roughly 70 kilometres from Kuala Lumpur International Airport (KLIA) [15].

Four rain gauge stations selected around the Klang district, Selangor, Malaysia in the year 2021 are utilized for the analysis and the data is provided with hourly rainfall data. However, this paper focused on December month because the precipitation is high during this month and it has caused floods in some parts of the Selangor region. The rainfall data is obtained from the Department of Irrigation and Drainage of Malaysia. Figure 2 shows the distribution of four rain gauge stations near Port Klang. According to the labelled numbered of the stations from Figure 2, the station's name is JPS Pulau Lumut, Kg. Sg. Kembong, Pintu Kawalan P/S Telok Gong and Ladang Sg. Kapar rainfall station, respectively. The selection of these stations is based on the availability and readiness of the dataset. Table 2 lists the coordinate of the selected rainfall stations.

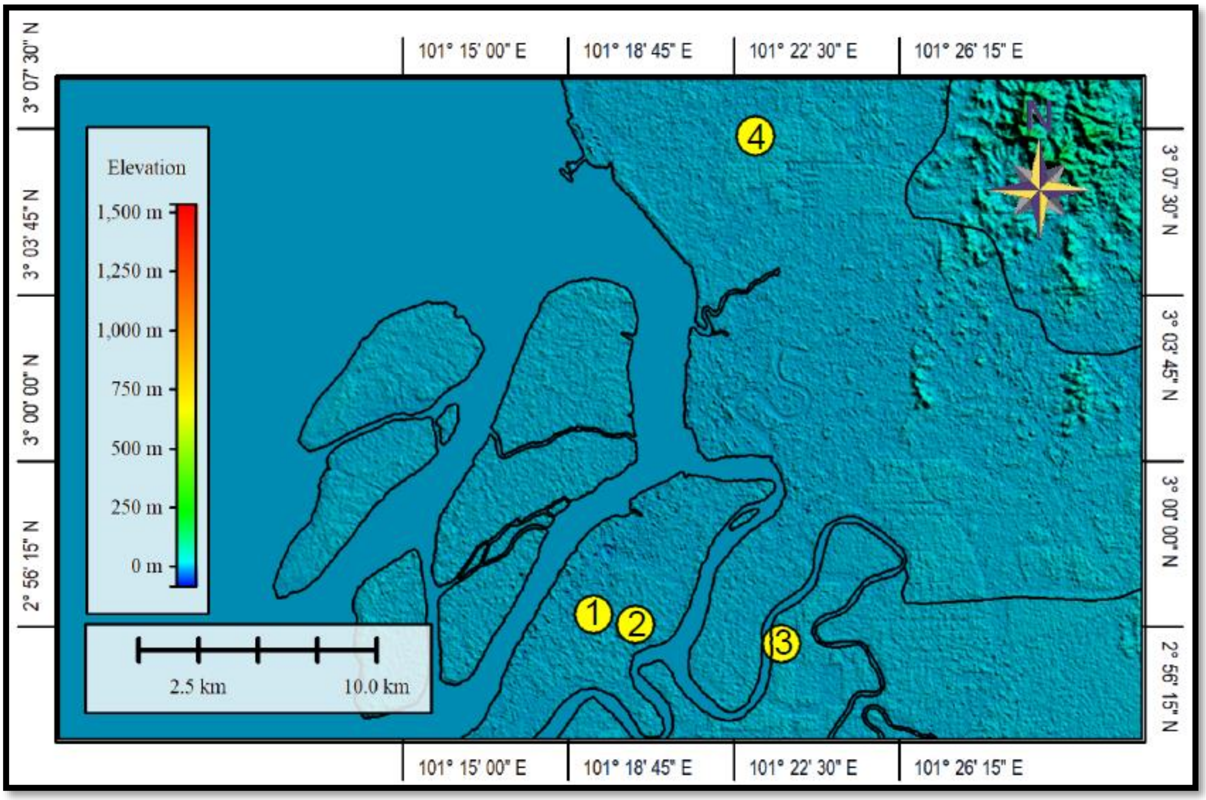

Figure 2. Selected rainfall stations

Table 2. The coordinates of rainfall stations

No.	Station ID	Station Names	Coordinates	
			Latitude	Longitude
1.	2913122	JPS Pulau Lumut	2° 56’ 30”	101° 19’ 20”
2.	2913123	Kg. Sg. Kembong	2° 56’ 17”	101° 20’ 17”
3.	2913001	Pintu Kawalan P/S Telok Gong	2° 55’ 50”	101° 23’ 35”
4.	3113087	Ladang Sg. Kapar	3° 07’ 20”	101° 23’ 00”

2.1. Rain Gauge Stations

The stations are equipped with a 0.5 mm tipping bucket-type rain gauge. Figure 3 and Figure 4 illustrate the tipping bucket used at the rain gauge station. The tipping bucket-style rain gauge is made of a funnel that gathers and directs rainwater into a container resembling a seesaw. After five (5) years, the rainwater tipping bucket needs to be calibrated at the workshop [16].

Figure 3. Tipping bucket used at the rain gauge station [16]

Figure 4. Tipping Bucket installation at the top of the station housing [16]

3. Methodology

The trend of the rainfall has been visualised and the values are highlighted in determining the amount of precipitation in the study area. From the rainfall hourly data, it has been calculated to obtain the daily rainfall data. The calculation has been made by using the averaging approach.

Correlation analysis between each station has been conducted to evaluate the relationship between the data. Pearson's correlation coefficient was used to calculate the correlation (r) between these data sets. The correlation (r) value was divided into intervals of -1 to 1. This range can be understood to mean that the value of r can either be -1 or 1 if y and x have a good relationship or are linear to each other. The Pearson correlation formula and the expansion of the formula are shown in Figure 5 and Figure 6, respectively [17].

$$\mathrm{r} = \frac{C_{xy}}{\sqrt{C_{xx}C_{yy}}} = \frac{C_{xy}}{\sigma_x \sigma_y}$$

Figure 5. Pearson's correlation formula

$$\text{Covariance, } C_{xy} = \frac{1}{N-1}\sum_i (x_i - \bar{x})(y_i - \bar{y})$$

$$\text{Variance of x, } C_{xx} = \sigma_x{}^2 = \frac{1}{N-1}\sum_i (x_i - \bar{x})^2$$

$$\text{Variance of y, } C_{yy} = \sigma_y{}^2 = \frac{1}{N-1}\sum_i (y_i - \bar{y})^2$$

$$\text{Average of x dataset, } \bar{x} = \frac{1}{N}\sum_i x_i$$

$$\text{Average of x dataset, } \bar{y} = \frac{1}{N}\sum_i y_i$$

Figure 6. The expansion of Pearson's correlation formula

4. Result and Discussions

From the data obtained, the values of the rainfall from the selected rainfall stations have been depicted throughout Figure 7, meanwhile, Table 3 shows the statistical value for each of the stations.

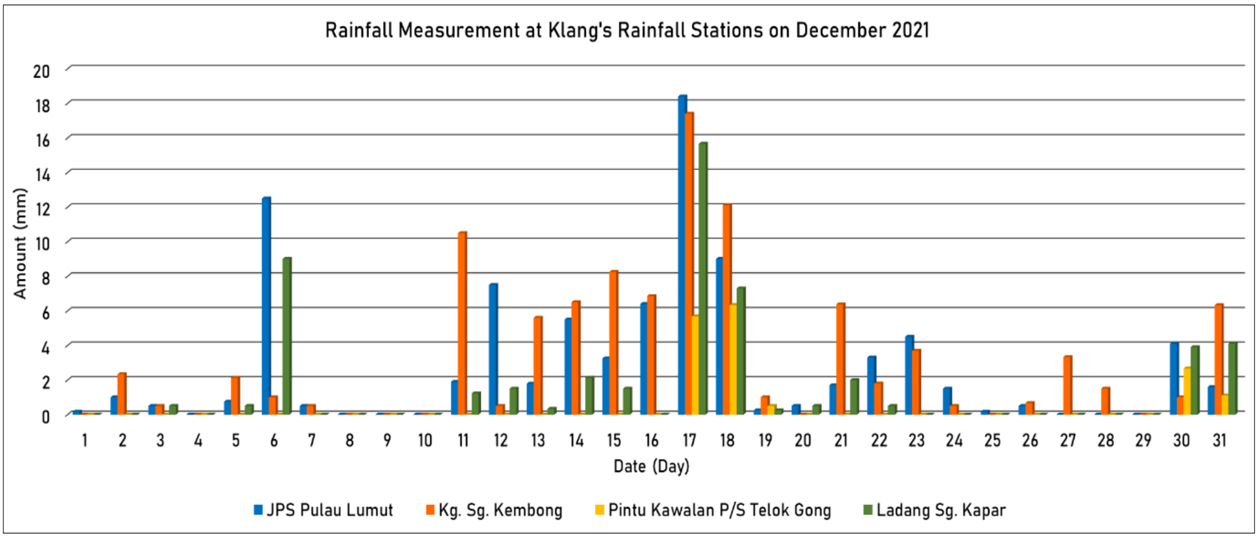

Figure 7. Rainfall Measurement at Klang's Rainfall Stations in December 2021

Table 3. The analysis for the rainfall measurement in December 2021

Station	Highest amount (mm)	Date
JPS Pulau Lumut	18.4	17/12/2021
Kg. Sg. Kembong	17.4	17/12/2021
Pintu Kawalan P/S Telok Gong	6.3	18/12/2021
Ladang Sg. Kapar	15.7	17/12/2021

The highest value of rainfall can be seen coming from the JPS Pulau Lumut station on 17 December 2021, while the lowest value can be seen to occur multiple times for each station with a value of zero. It can be seen that the amount of rainfall from 11 December 2021 until 18 December 2021 varies with each other. According to [12], one of the factors that lead to the flood outbreak in this area on December 2021 is due to Tropical Depression 29W which occurred on 17 December 2021 and heavy rainfall for four days. Moreover, Figure 5, shows that the JPS Pulau Lumut and Kg. Sg. Kembong stations received more than 5 mm amount of rainfall starting 11 December 2021. This rainfall is one of the causes of flooding, in addition to the natural geological processes and anthropogenic impacts [12]. On the other hand, Table 4 highlighted the correlation between each of the rainfall stations to analyse the relationship between them.

Table 4. Correlation analysis of the daily rainfall value

Correlation (r)	JPS Pulau Lumut	Kg. Sg. Kembong	Pintu Kawalan P/S Telok Gong	Ladang Sg. Kapar
JPS Pulau Lumut	1	-	-	-
Kg. Sg. Kembong	0.652	1	-	-
Pintu Kawalan P/S Telok Gong	0.654	0.667	1	-
Ladang Sg. Kapar	0.893	0.672	0.782	1

From Table 4, it can be seen that all of the correlation values exceed 0.5. This indicated that the data have a positive relationship with each other. The data correlation between JPS Pulau Lumut and Ladang Sg. Kapar stations show the highest value with 0.893. This indicates that both of them have a strong correlation with each other compared to the other stations. Moreover, it also can be said that the rainfall activity in this area is correlated with each other since they have moderate and strong r’s values.

5. Conclusion

Amongst the four rainfall stations, it can be concluded that the rainfall amount at JPS Pulau Lumut and Kg. Sg. Kembong station received the most amount of rainfall compared to the other two stations. During the middle of December 2021, the rainfall amount keeps increasing based on the rainfall stations data and this led to flood events in this area. Rainfall analysis is important towards flood forecasting, effective water resources management and agricultural activity. Therefore, this study might aid in the mitigation and adaptation measures towards the vulnerability of future climate change events towards ports and other areas. In future, multiple rainfall stations could be gathered in the analysis procedure to enhance the statistical values and accuracy.

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