CIVED Journal of Civil Engineering and Vocational Education

EISSN: 2622-6774
Vol 11 No.3 September 2024
http://cived.ppj.unp.ac.id/index.php/CIVED

Comparison of Gumbel Method and Log Pearson Method in Flood Control in Konto River Jombang

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Received 17th August 2024; Revision 30th August 2024; Accepted 29th September 2024

ABSTRACT

This study aims to analyze the potential for flooding in the Konto River, Gudo District, Jombang Regency, this study uses the Gumbel and Log Pearson III statistical methods. Floods in this area often occur due to rainwater flow from the surrounding mountains which causes damage to infrastructure and settlements. Maximum daily rainfall data from 2013 to 2023 are used in this analysis. The Gumbel method is a statistical technique that is often used to analyze extreme rainfall data. The Gumbel and Log Pearson III methods are applied to estimate the design rainfall based on the flood return period, which is useful in infrastructure planning and flood mitigation. The calculation results show that the design rainfall increases with the increase in the return period. Compared to the Log Pearson III method, the Gumbel method provides higher design rainfall results, making it more suitable for estimating extreme rainfall in this area. These results are important in efforts to manage water resources and control flooding in the Konto River. The design rainfall will increase with the longer return period. This means that the higher the design rainfall, the smaller the possibility of it happening again. The results of the calculations show that the three methods can be used to calculate the planned rainfall, because the differences between one method and another are not much different, but the most suitable method to use is the gumbell method because the planned rainfall value is greater.

Keywords: *Gumbel Method; Log Person; Konto River.*

INTRODUCTION

Mount Kelud is one of the active volcanoes in East Java. Geographically, Mount Kelud is located on the border between Kediri Regency, Blitar Regency and Malang Regency. Mount Kelud has erupted more than 30 times since 1000 AD. Mount Kelud last erupted in 2014, which was the largest eruption since 1990.[1] The eruption threw volcanic material and also flowed cold lava towards the river flow, one of which is the Konto River in Jombang Regency. The Konto River, formerly called the Nilakanta River, has a Brantas watershed system of 568 km2 with a total length of the river network of 168.34 km. The flow of the Konto River is a mixed flow where there are three mountains that supply it, namely Mount Kawi, Mount Anjasmoro, and Mount Kelud. This causes the river to overflow into settlements during the extreme rainy season.[2]

In 2013, the Konto River flooded thousands of houses in Jombang District with a water level reaching 1.5 meters. This happened because the flow of rainwater from the slopes of Mount Kelud increased and caused a number of embankments to be damaged because they were unable to withstand the heavy flow. In addition, in 2023, a second flood occurred on the Konto River caused by the failure of infrastructure on the river which caused the water to overflow and inundate the Kediri-Jombang route. In general, heavy and prolonged rainfall is the main cause of flooding in the Konto River.[3]

The way to overcome the flood problem is by using flood frequency analysis. There are several strategic steps taken to reduce flood losses, but the design of hydraulic structures largely depends on the behavior of river flow [1][2]. River discharge can be well understood using frequency analysis. Flood frequency analysis is a dimensionless method used to link extreme events with the frequency of occurrence or return period through the use of probability distributions based on peak discharge data recorded at several measuring stations [3]. Flood frequency analysis was carried out on the Konto River, Jombang because the river often receives water supply from the mountains which causes damage to both building infrastructure and building edges.[4][5]

The purpose of this study is to prevent future flooding that will occur on the Konto River, Jombang. By expanding the understanding of flood frequency analysis using the Gumbel and Log Pearson type III methods to analyze extremes in hydrology. Both methods allow estimation of flood peak height and frequency of occurrence based on historical data.[6] The Gumbel method and the log person method are two statistical methods used to analyze and predict extreme floods based on historical data.[7]

METHOD

Gumbel Method

The Gumbel method is one of the methods used for extreme analysis in hydrology. This method is based on the assumption that the distribution of extreme rainfall or peak flow can be approximated by the Gumbel distribution [7]. The Gumbel method is usually used to predict extreme rainfall in an area by estimating the parameters of the Gumbel distribution.[8] The Gumbel method is also known as the Type I extreme distribution or Gumbel Extreme distribution is one of the methods commonly used in hydrological analysis to model the extreme distribution of rainfall or peak flow. This method is based on the assumption that extreme rainfall or peak flow can be approximated by the Gumbel distribution[8]. Gumbel probability distribution is expressed as:[4][9]

$$QT = Q(1 + KCv) \quad \text{...} \quad (2.1)$$

where, QT = Probability of Discharge in Return Period T Years

Cv = Coefficient of Variation (a/O) Q = Average Flood
K = Frequency Factor = (yT . yn) / an an = Data Standard Deviation
yT = - Mn . (T/ T - 1)

yn = Expected Average

Log Pearson method

The Log Pearson method is another method that is also used in hydrological analysis to predict extreme rainfall or peak flow. This method is based on the assumption that the Pearson Type III logarithmic distribution can be used to analyze extreme data in hydrology [9][10][9].

The Log Pearson method estimates the parameters of the Pearson Type III logarithmic distribution to predict extreme rainfall or peak flow. The Log Pearson method, also known as the Pearson Logarithmic Moments method, is one of the methods commonly used in hydrological analysis to model the distribution of extreme rainfall or peak flow [10]. This method differs from most other distributions in that three parameters, mean (Za), standard deviation (SDV), and skew coefficient (k), are required to describe the distribution. In the log-Pearson type-III probability distribution, the variates are first transformed into logarithmic form (base 10) and the transformed data are analyzed for random hydrological series. Then the Z series is varied, where Z = log x is obtained first. For this Z series, for each recurrence interval T from the equation:

$xT = \dot{x} + K\sigma \text{ gives}$

$ZT = z + Kz.\,\sigma z$

where, Kz is the frequency factor which is a function of the recurrence interval (T), and Cs is the skewness coefficient.σz is the standard deviation of the sample variation

Research Location

The location to be studied is the Konto River, Gudo District, Jombang Regency.

Figure 1. Konto River, Gudo District, Jombang Regency

Research Stages

This study uses a data analysis approach based on the Gumbel and Log Pearson methods. The location used is on the Konto River in Gudo District, Jombang Regency, East Java. Several stages to obtain the research results are as follows:

1. Data Collection

   Collection of complete hydrological data such as rainfall or peak flow that is relevant to the area studied, such as collecting rainfall data from the last 10 years, namely 2013 to 2022 at the Konto River location. The data obtained must be adequate and cover significant flood periods, including historical rainfall data, river flow data, topographic maps and previous measurement or research results related to the area.

2. Data Analysis

   Data analysis using the Gumbel method and the Log Pearson method using the data that has been collected. Estimating and comparing the Gumbel and logarithmic Pearson type III distribution parameters using existing data. The steps for analyzing data using the Gumbel method are:

EISSN: 2622-6774
Vol 11 No.3 September 2024
http://cived.ppj.unp.ac.id/index.php/CIVED

a) Collect rainfall data. Collection of rainfall data that is relevant to the area or location to be analyzed. The data should cover a sufficient and representative period to allow for accurate analysis.
b) Identify extreme periods. Identify extreme periods in the rainfall data that will be used for analysis. These periods can be daily, monthly, or annual rainfall with high intensity or significant peak flows.
c) Rank the data. Rank the extreme rainfall data from highest to lowest. This ranking will help in calculating the frequency of extreme events.
d) Calculate the Probability of Occurrence. Calculate the probability of occurrence associated with extreme rainfall using the Gumbel distribution. The Gumbel distribution has two parameters, namely location (μ) and scale (σ), which need to be estimated from the data.
e) Estimate the distribution parameters. Use estimation methods such as the method of moments, maximum likelihood method, or best fit method (e.g., L-moment method) to estimate the Gumbel distribution parameters from the ranked data.

RESULTS AND DISCUSSION

Rainfall Data

The rainfall data used for the analysis is the maximum daily rainfall data for 10 years, starting from 2014-2023. The rainfall data can be seen in the following table**:**

Table 1. Maximum daily rainfall data

No.	Year	Maximum Rainfall (mm)
1	2014	81
2	2015	118
3	2016	131,3
4	2017	85,3
5	2018	73
6	2019	123
7	2020	164,1
8	2021	85
9	2022	170,6
10	2023	105,6

Gumbell Distribution

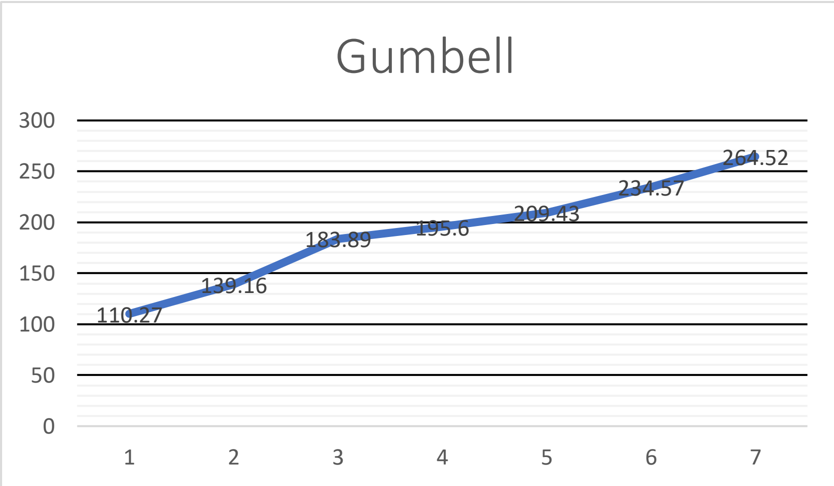
The Gumbell method is a statistical technique that is often used to analyze extreme rainfall data. Based on the type I extreme distribution, this method helps estimate rainfall with a certain return period. Information from this calculation is very important for infrastructure planning, disaster mitigation, and water resource management.

The results of calculating the maximum rainfall return period using the Gumbell method can be seen in the following table:

Table 2. Calculation of rainfall return period

Year	Planned Rainfall (mm/day)
2	110,27
5	139,16

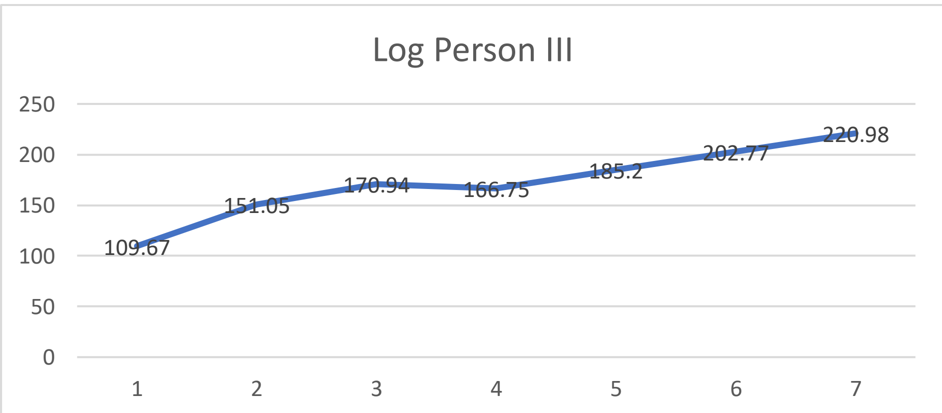
10	183,89
20	195,6
25	209,43
50	234,57
100	264,52



Distribusi Log Pearson
The results of calculating the maximum rainfall recurrence period using the Pearson III log method can be seen in the following table:

Table 3. Design rainfall using the Log Pearson III method

Year	Planned Rainfall (mm/day)
2	109,67
5	151,05
10	170,94
20	166,75
25	185,2
50	202,77
100	220,98



Tabel 4. Log-Pearson Type III Calculator

RANK	YEAR OF PEAK FLOW	PEAK_FLOW_VALUE_Q(cfs)	LOGQ_cfs	(log Q – avg(logQ))^2	(log Q – avg(log Q))^3	Return Period (n+1)/m	Exceedence Probability (1/Tr)
1		120,583	2,081	0,0094	0,0009	21,00	0,048
2		120,333	2,080	0,0093	0,0009	10,50	0,095
3		120,083	2,079	0,0091	0,0009	7,00	0,143
4		115,500	2,063	0,0061	0,0005	5,25	0,190
5		115,500	2,063	0,0061	0,0005	4,20	0,238
6		113,667	2,056	0,0051	0,0004	3,50	0,286
7		109,750	2,040	0,0032	0,0002	3,00	0,333
8		108,333	2,035	0,0026	0,0001	2,63	0,381
9		106,500	2,027	0,0019	0,0001	2,33	0,429
10		103,583	2,015	0,0010	0,0000	2,10	0,476
11		101,417	2,006	0,0005	0,0000	1,91	0,524
12		100,167	2,001	0,0003	0,0000	1,75	0,571
13		91,083	1,959	0,0006	0,0000	1,62	0,619
14		89,417	1,951	0,0011	0,0000	1,50	0,667
15		84,333	1,926	0,0034	-0,0002	1,40	0,714
16		83,083	1,920	0,0042	-0,0003	1,31	0,762
17		80,250	1,904	0,0064	-0,0005	1,24	0,810
18		80,000	1,903	0,0066	-0,0005	1,17	0,857
19		61,333	1,788	0,0386	-0,0076	1,11	0,905
20		61,000	1,785	0,0395	-0,0079	1,05	0,952

Table 5. Comparison of planned rainfall using the Gumbell method, Log Pearson III method,

No.	Birthday (Year)	Probabilitas (%)	Planned Rainfall (mm/day)	
			Gumbell	**Log Person III**
1	2	50	110,27	109,67
2	5	20	139,16	151,05
3	10	10	183,89	170,94
4	20	5	195,6	166,75
5	25	4	209,43	185,2
6	50	2	234,57	202,77
7	100	1	264,52	220,98

From the results of the analysis with two methods, namely the Gumbell method, the Log Pearson method, for each return period, the results obtained are not much different. The Gumbell method shows higher results than the other two methods. The comparison table of planned rainfall can be seen in (Table 5). The planned rainfall will be higher along with the longer return period. This means that the higher the planned rainfall, the smaller the possibility of it happening again. For example, from (Table 5) the planned rainfall using the Log Pearson III method with a return period of 100 years and a probability of 1% is 220.98 mm/day, while with a return period of 20 years and a probability of 5% is 176.75 mm/day. This means that the possibility of rain with a magnitude of 219.98 mm/day in 100 years is only 1%, while the possibility of rain with a magnitude of 176.75 mm/day in 20 years is 5%.

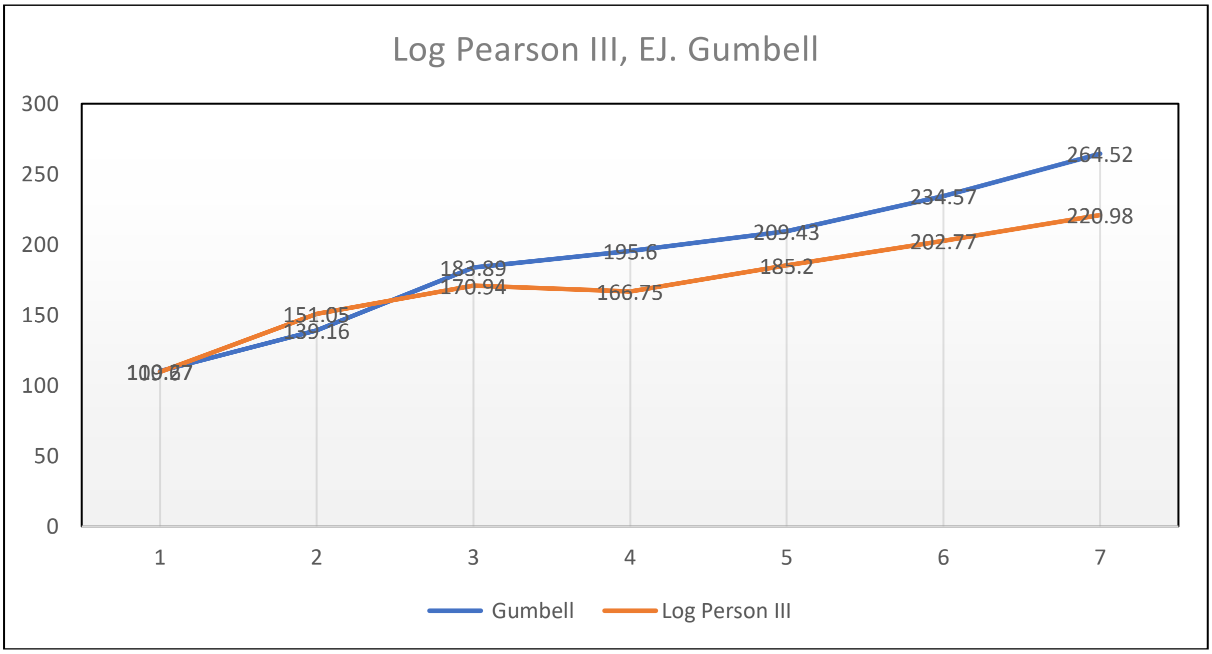


Figure 2. Graph of Planned Rainfall Method Log Pearson III, EJ. Gumbell Method

Based on the graph above, the Iway Kadoya method produces lower values compared to the Log Pearson and Gumbell methods. The difference in value increases in line with the larger recurrence period. The results of the calculation show that the three methods can be used to calculate the planned rainfall, because the difference between one method and another is not much different, but the most suitable method to use is the Gumbell method because the planned CH value is greater**.**

CONCLUSION

The planned rainfall will increase along with the longer recurrence period. This means that the higher the planned rainfall, the smaller the possibility that it will occur again. The results of the calculations show that the three methods can be used to calculate the planned rainfall, because the difference between one method and another is not much different, but the most suitable method to use is the gumbell method because the planned rainfall value is greater.

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