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Rainfall Prediction using Backpropagation Method and GIS for Disaster Mitigation Mapping

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Abstract

Frequent weather or climate changes, coupled with the topography of Cirebon and Majalengka which are mostly lowlands and close to the sea, raise concerns that flood disasters can occur if mitigation is not done early. This research aims to predict and map rainfall and runoff discharge as a flood mitigation effort in the Cirebon and Majalengka areas. The method used in this research is the Backpropagation Method, which resembles the way the neuron system works in the human brain to learn patterns, optimize weights and biases, and reduce the error rate (mean square error) so that the predicted value is closer to the actual value. The results showed that Cirebon was predicted to have the highest rainfall of 2471 mm in 2048, based on prediction data from BMKG Penggung Station, while Majalengka was predicted to have the highest rainfall of 2922 mm in 2048, based on prediction data from BMKG Kertajati Station. The largest runoff discharge in the Cirebon region occurred in Susukan District (51.96 km^2) with a discharge of 68.648 m^3/second (Q25), and in the Majalengka region occurred in Lemahsugih District (78.64 km^2) with a discharge of 104.16 m^3/second (Q25). The implications of this research include mitigation efforts that can be carried out, such as reducing development above drainage channels, reforestation, maintaining open areas, reducing land use change, conservation of rivers and catchments, construction of flood embankments, and issuance of related regulations.

Keywords: Rainfall, Area, Discharge, Mapping, Prediction.

INTRODUCTION

Cirebon City has an average elevation of 5 metres above sea level (B. K. Cirebon, 2024). The terrain in Cirebon Regency is divided into lowland areas and partly highland areas (B. P. S. K. Cirebon, 2024). The altitude in Majalengka Regency is between 19 - 857 metres above sea level (Majalengka, 2024). The increase in rainfall is caused by changes in weather patterns due to the ever-changing atmosphere and the presence of cold air flow (Aslim et al., 2023).The problem is that due to changes in weather or climate that often change at this time, coupled with the topographic conditions of Cirebon and Majalengka which are partly low-lying and close to the sea, it is feared that if disaster mitigation is not carried out early on, flood disasters will occur due to lack of early preparation for the prevention of runoff discharge. With the expected results of monthly rainfall values, runoff discharge, and mapping for the next 2, 5, 10, and 25 years. With the research location in Cirebon and Majalengka. This research aims to determine the prediction of rainfall, runoff discharge, and its mapping as a flood mitigation effort in the Cirebon and Majalengka areas.

Figure 1. Research Location
Source: Google Earth

Rainfall is the height of rainwater that falls on a land surface which is considered not to evaporate, not to seep, and not to flow (Triwahyuni et al., 2020). Rain that falls to the ground surface will form a runoff that will eventually flow back to the sea, some will be absorbed into the soil surface (infiltration), and others will continue to flow down (percolation) to go to a saturated place below the groundwater surface (Ikhwan et al., 2022). The origin of incoming flow is from rainfall, and the origin of outgoing flow is from surface runoff, evaporation, and infiltration (Muttaqin & Farhan, 2021). Prediction is a systematic activity in estimating something with the possibility of happening in the future or has been estimated based on pre-existing data (Adiguno et al., 2022). Rainfall prediction is one of the important activities in climate forecasting, because precise and accurate results will greatly help in planning and management for water resources, flood warnings, construction activities, flight operations, and so on (Yusuf et al., 2022). One of the factors included in weather forecasting is water, where water is very important for the survival of living things to meet their needs and activities (Zahran, 2023). Digital mapping is an activity in processing digital format maps, and uses hardware such as computers, as well as related software in processing (Thariq, 2020). Mapping can present information related to a place by displaying location data according to the coordinates on the map. (Sitio et al., 2021). Mitigation is an activity carried out to minimise and reduce the risk of damage caused by disasters (Afrian, 2020). Disaster mitigation is a process to increase community knowledge in understanding and dealing with hazard characteristics, changing actions and mindsets so that the quality of natural resources is maintained (Qurrotaini & Nuryanto, 2020). Mitigation and control of natural disasters related to meteorological forecasts must be carried out from the beginning with high accuracy and in an easy-to-understand delivery (Oktaviani & Afdal, 2013). Examples of mitigation for flood disasters that can be carried out include the construction of flood embankments, and issuing a regulation to minimise the occurrence of disasters (Tribhuwana et al., 2021).

In the research conducted (Sheikhi et al., 2023) The content of the discussion is to compare six hybrid artificial intelligent models developed to predict daily rainfall in urban areas, by combining the firefly optimisation algorithm (FA), invasive weed optimisation algorithm (IWO), genetic particle swarm optimisation algorithm (GAPSO), neural network (ANN), group method of data handling (GMDH), and wavelet transformation. Research (Kyojo et al., 2024) discussed the analysis of annual maximum rainfall data for 31 years, starting from 1990 to 2020, and the Generalised Extreme Value (GEV) model proved to be the best for modelling extreme rainfall at all stations. Using three methods to estimate it, namely L-moments method, Maximum Likelihood Estimation (MLE), and Bayesian Markov chain Monte Carlo (MCMC) are used to estimate GEV parameters and future return rates. The content of the discussion in the research (Silva et al., 2023) was to predict monthly rainfall, one month in advance, in four municipalities in the Belo Horizonte City region using ANNs trained with different climate variables. (Aslim et al., 2023) discusses the identification of the right combination of network architecture, learning rate, and epoch in predicting each rainfall post in Maros Regency. And also predicts the monthly rainfall profile in 2021 - 2025 in Maros Regency. Other research by (Setiawan & Barokah, 2022) which predicts rainfall using the auto correlation function in artificial neural networks with the backpropagation method to deal with the impact caused by high rainfall such as hampering population mobility and distribution of goods, especially in the port area.

Based on the above background, the purpose of this research is to predict rainfall, runoff discharge, and map the potential for flooding in the Cirebon and Majalengka areas as a disaster mitigation effort. This research is expected to provide accurate information about rainfall and runoff discharge predictions for the next 2, 5, 10, and 25 years. This information will be useful in assisting regional spatial planning, infrastructure development that is more resilient to floods, and minimizing the risk of damage due to natural disasters in the research area. The benefit of this research is to make an important contribution to water resources management and flood disaster mitigation efforts. With accurate prediction results, local governments and related agencies can formulate more effective policies in reducing flood risks, such as building embankments, improving drainage systems, and controlling uncontrolled land use changes.

METHOD

The method used is the Backpropagation Method. The backpropagation method is a method that resembles the way the neurons system works in the brain of humans to learn patterns and is used to optimise weights and refractions, then the error rate (mean square error) gets smaller, saying that the estimated value better represents the actual value (Siregar, 2019). For the stages of predicting rainfall in this research, it starts from inputting the original data, namely entering the monthly rainfall amount data that has been obtained for the three rainfall posts, namely BMKG Jatiwangi, BMKG Kertajati, and BMKG Penggung. This rainfall amount data is entered and arranged in different excel or each for each rainfall post which is used as initial data or original data. Next, normalise the original data, namely creating and compiling the amount of rainfall data in excel, select one of the rainfall station excel first to be entered into the programming with the help of Matlab 2021a software to get the normalisation value. When determining the training data and training target data, we first test the accuracy of the prediction results with existing data. In the neural network programme, the artificial neural network design that will be used is 12-1000-1, meaning that the network starts with 12 values for the input layer (rainfall data for 12 months), 1000 neurons in the hidden layer, and only one value for the output layer, which is the rainfall data in the target year. Finally, test and predict by inputting the test target data in the form of rainfall data that has been pre-selected from the beginning. Then calculate the RMSE (Root Mean Square Error) value to determine the prediction validation level of the rainfall pattern.

In this research, quantitative research methods are used because they focus on collecting numerical data and statistical analysis to objectively measure and analyse phenomena. This method is used to analyse data and problems using sources that can be considered in writing articles**.** In this research, the type of data used is secondary data, namely data obtained from related agencies, namely BMKG Kertajati, Jatiwangi, and Penggung Stations, as well as from some literature such as BMKG Online related to rainfall data. For the stages of data analysis in this research such as predicting rainfall, calculating rainfall runoff discharge, and map modelling.

In the backpropagation artificial neural network (JST), which is used is a binary sigmoid activation function (valued between 0 and 1), can use the formula (Tamaji et al., 2022):

$$\mathbf{X'} = \frac{\mathbf{0{,}8\ (X - b)}}{\mathbf{(a - b)}} + \mathbf{0{,}1} \quad (1)$$

Calculating the RMSE (Root Mean Square Error) value to determine the level of validation of predictions of rainfall patterns, with the formula:

$$\mathbf{RMSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \bar{Y}_i)^2 \quad (2)$$

There are several methods that can be used to calculate rainfall for return periods, such as:

Gumbel Method

$$\mathbf{X_T = \bar{X} + K.S_x} \quad (3)$$

Iwai Kadoya Method

$$\boldsymbol{\xi} = \mathbf{c\ .\log\frac{R + b}{R_0 + b}} \quad (4)$$

Log Pearson III Method

$$\mathbf{\log X_t = \overline{\log x} + (K_T\ x\ S\log x)} \quad (5)$$

Rainfall intensity is the amount of rainfall that occurs in a period and the rainwater is concentrated. (Tribhuwana & Prasetyo, 2020). The intensity formula is:

$$\mathbf{I} = \frac{\mathbf{R_{24}}}{\mathbf{24}}\ \mathbf{x}\left[\frac{\mathbf{24}}{\mathbf{t}}\right]^{\frac{2}{3}} \quad (6)$$

Runoff water discharge is the amount of rainwater per unit time that does not absorb into the soil (infiltration), so that it is carried out by drainage channels. (RAMDHANI & YUSTIANA, 2023). The formula used is the rational method discharge formula:

Rational Method

$$\mathbf{Q = 0{,}278\ x\ C\ x\ I\ x\ A} \quad (7)$$

RESULT AND DISCUSSION

The results of the sum of rainfall prediction values as shown in tables 1, 2, and 3 per month for the years 2025, 2028, 2033, and 2048 at BMKG Kertajati, BMKG Jatiwangi, and BMKG Penggung stations.

Table 1. Recapitulation of Predicted Monthly Rainfall Amount at BMKG Kertajati Station (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DES
2025	375	474	322	326	221	85	18	29	34	83	143	248
2028	338	364	378	307	257	109	40	18	42	56	112	173
2033	192	334	372	373	317	262	114	39	18	37	54	109
2048	368	367	521	394	162	65	11	49	93	280	318	294

Source: Calculation Result

Table 2. Recapitulation of Predicted Monthly Rainfall Amount at BMKG Jatiwangi Station (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DES
2025	427	489	342	358	222	78	17	26	30	74	138	293
2028	425	410	413	334	255	86	30	14	44	57	114	223
2033	464	419	491	347	329	109	47	8	57	36	103	209
2048	630	331	567	232	332	28	67	2	153	71	225	212

Source: Calculation Result

Table 3. Recapitulation of Predicted Monthly Rainfall Amount at BMKG Penggung Station (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DES
2025	436	487	506	326	215	54	21	9	33	37	79	191
2028	428	492	487	378	252	62	21	8	25	37	72	155
2033	422	481	529	378	285	69	24	6	25	29	67	141
2048	440	484	531	378	276	62	22	5	25	29	68	151

Source: Calculation Result

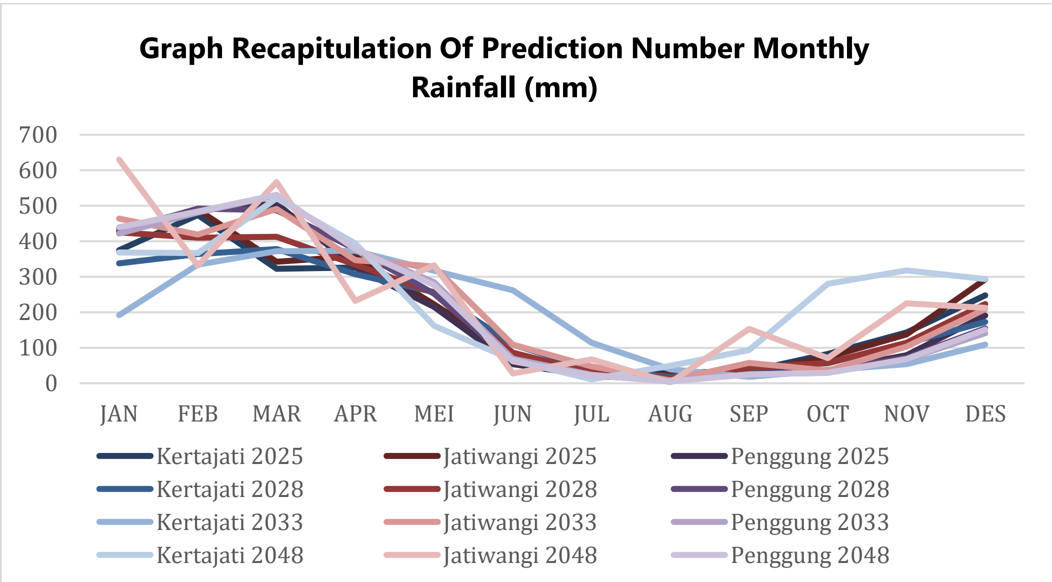

Figure 2 Rainfall Prediction Chart

Source: Calculation Result

It can be seen from the recapitulation table of rainfall prediction results above, at BMKG Kertajati Station in 2025 the highest amount of rainfall occurred in February (474 mm), in 2028 the highest in February (364 mm), in 2033 the highest in April (373 mm), and in 2048 the highest in March (521 mm). At BMKG Jatiwangi Station in 2025 the highest amount of rainfall occurred in February (489 mm), in 2028 the highest in January (425 mm), in 2033 the highest in March (491 mm), and in 2048 the highest in January (630 mm). And at BMKG Penggung Station in 2025 the highest amount of rainfall occurred in March (506 mm), in 2028 the highest in February (492 mm), in 2033 the highest in March (529 mm), and in 2048 the highest in March (531 mm).

Mapping of monthly rainfall prediction results for 2025, 2028, 2033, and 2048 at BMKG Kertajati, BMKG Jatiwangi, and BMKG Penggung stations.

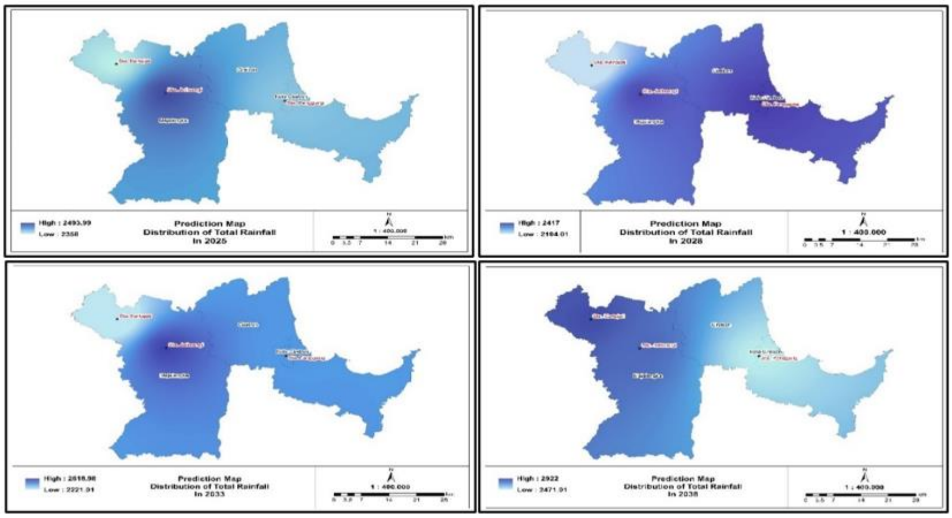

Figure 3 Rainfall Prediction Map
Source: Calculation Result

It can be seen in Figure 3, for the distribution of the amount of rainfall prediction results in 2025, with a maximum rainfall amount of 2494 mm and a minimum of 2358 mm. In 2028, the maximum rainfall amount will be 2417 mm, and the minimum will be 2194 mm. In 2033, the maximum rainfall amount will be 2619 mm and the minimum will be 2221 mm. And in 2048 with a maximum rainfall amount of 2922 mm and a minimum of 2471 mm.

There are several conditions that must be met before choosing a rainfall distribution method.

Table 4. Type and Condition of Rainfall Distribution

Distributin Type	Terms
Gumbel	Cs ≤ 1.1396
	Ck ≤ 5.4002
Iwai Kadoya & Log Pearson III	Cs ≠ 0

Source: Calculation Result

Since the methods used in the calculation of rainfall distribution are the Gumbel, Iwai Kadoya, and Log Pearson III methods, only eligible methods can be used for further calculations before using any of the methods for rainfall distribution.

The results of the calculation of rainfall distribution at BMKG Kertajati, BMKG Jatiwangi, and BMKG Penggung stations against the type and conditions of rainfall distribution can be seen in Table 5.

Table 5. Results of Rainfall Distribution Calculation

Calculation Result				Description			
Kertajati	**Jatiwangi**	**Penggung**	**Maksimum**	**Kertajati**	**Jatiwangi**	**Penggung**	**Maksimum**
3.551	0.388	-1.415	0.546	Unqualified	Qualified	Unqualified	Qualified
15.829	2.371	5.576	2.589				
3.551	0.388	-1.415	0.546	Qualified	Unqualified	Memenuhi	Unqualified

Source: Calculation Result

It can be seen in Table 5, that the results of the calculation of the Cs and Ck values at each station, for stations that qualify using the Gumbel Method are the Jatiwangi BMKG Station and the maximum average of the three BMKG stations. While those that qualify using the Iwai Kadoya and Log Pearson III methods are Kertajati BMKG Station and Penggung BMKG Station.

After determining the method that qualifies the rainfall distribution for each BMKG station, the next step is to conduct a Chi-Square Test to determine which rainfall data or values can be accepted or used.

Table 6. Recap of Chi-Square Test

Chi - Square Test Recap				
Station	**Methods**	**Count**	**Critical**	**Description**
Maximum	Gumbel	4.00	5.991465	Accepted (Result ≤ Critical)
Jatiwangi		4.67		Accepted (Result ≤ Critical)
Kertajati	Iwai Kadoya & Log Pearson III	34.67		Not Accepted (Result ≥ Critical)
Penggung		8.67		Not Accepted (Result ≥ Critical)

Source: Calculation Result

The recapitulation results of the Chi-Square Test on each rainfall data in the Gumbel Method, Iwai Kadoya, and Log Pearson III between the calculated results and the critical value. And rainfall data that can be accepted or used is rainfall data at BMKG Jatiwangi Station and the maximum average of the three BMKG stations.

Because the data can be accepted or used for the calculation of rainfall intensity, the data to be used is the maximum average rainfall data because it is considered to represent all areas in the research area and the highest possible amount of rainfall that occurs. For the calculation of rainfall intensity using the Mononobe Method and the results of the calculation of rainfall intensity can be seen in Table 7.

Table 7. Mononobe Method Rainfall Intensity (mm/h)

t (Minutes)	Rainfall Intensity			
	I2	**I5**	**I10**	**I25**
10	243.516	262.849	275.650	282.872
20	153.405	165.585	173.649	178.198
30	117.070	126.365	132.519	135.991
40	96.639	104.312	109.392	112.258
50	83.281	89.893	94.271	96.741
60	73.750	79.605	83.482	85.669

t (Minutes)	Rainfall Intensity			
	I2	I5	I10	I25
70	66.547	71.830	75.328	77.302
80	60.879	65.712	68.912	70.718
90	56.282	60.750	63.708	65.377
100	52.464	56.629	59.387	60.943
110	49.234	53.143	55.731	57.191
120	46.459	50.148	52.590	53.968

Source: Calculation Result

The time used or planned in the calculation of rainfall intensity is for two hours (120 minutes) for each annual return period of 2, 5, 10, and 25 years. The graph of the calculation results of rainfall intensity values in Table 7 for maximum rainfall data using the Mononobe Method can be seen in Figure 4 below.

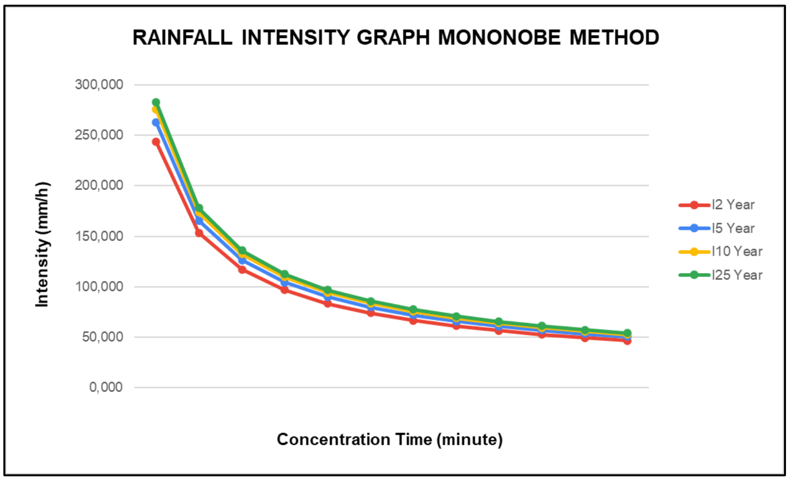

Figure 4. Mononobe Method Rainfall Intensity Chart
Source: Calculation Result

The division of the research area using the thiessen polygon method using three points from the BMKG stations reviewed, namely Kertajati BMKG Station, Jatiwangi BMKG Station, and Penggung BMKG Station located in Cirebon and Majalengka is shown in Figure 5.

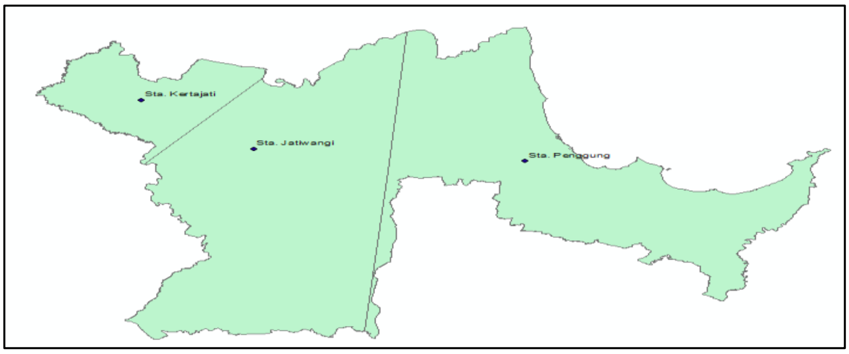

Figure 5. Thiessen Polygon Method Area Division
Source: Calculation Result

After dividing the area in the research area using the Thiessen polygon method, the area value of each cut area was obtained in units of km2, with one BMKG station per area. The data can be seen in Table 8.

Table 8. Area Data

No	Station	Area	Area (Km^2)
1	Kertajati	A1	355.194
2	Jatiwangi	A2	935.136
3	Penggung	A3	1028.284

Source: Calculation Result

In addition to the area within the research area, the area of watersheds included in the research area is needed for further calculations. The watersheds that were selected because they were included in the research area were Cibuaya DAS, Ciwaringin DAS, and Cipager DAS. However, the watershed area used is the only one included in the research area. The watershed area data can be seen in Table 9.

Table 9. DAS Area Data Per Area

No	DAS	Name Area	Area (Km^2)
1	Cibuaya	A1	96.735
2	Cibuaya + Ciwaringin	A2	146.541
3	Ciwaringin + Cipager	A3	117.256

Source: Calculation Result

The coefficient values in Table 10 are derived from the percentage of built and unbuilt area of each research area, and the data is available on the official BPS website of the research area.

Table 10. Coefficient Value Data (C)

Location	Area (Ha)	Area (%)	Coefficient	Coefficient (%)	Coefficient Value (C)
Majalengka	120424.00	51.94	0.53	0.28	0.56
Cirebon	111436.00	48.06	0.59	0.28	
Total	231860.00	100			

Source: Calculation Result

Daily rainfall intensity data used in calculations based on maximum rainfall data per return period of 2, 5, 10, and 25 years can be seen in Table 11.

Table 11. Rainfall Intensity Data

R24	I	PUH
212.731	46.459	2
229.620	50.148	5
240.802	52.590	10
247.111	53.968	25

Source: Calculation Result

Mapping of rainfall runoff discharge values for each cut area of the research area for return periods of 2, 5, 10, and 25 years.

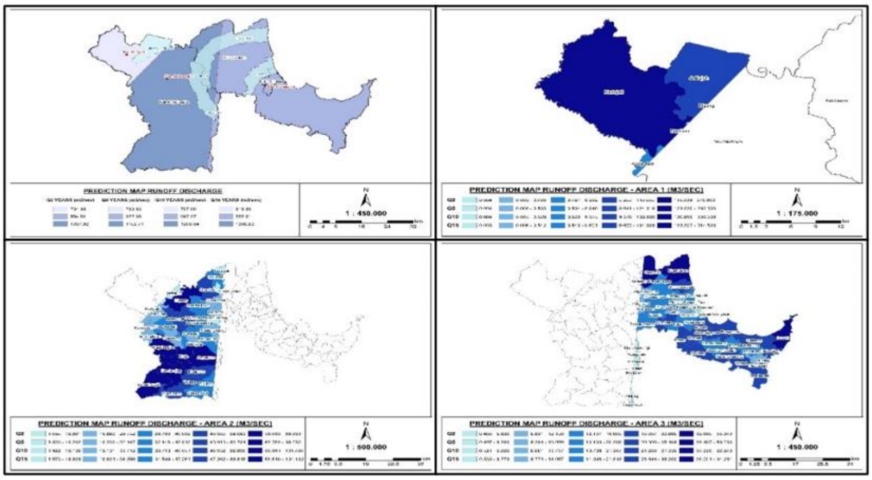

Figure 6. Rainfall Runoff Discharge Distribution Map by Area
Source: Calculation Result

As shown in Figure 6, the first map is a prediction map of the distribution of runoff discharge for return periods of 2, 5, 10, and 25 years in the research area. The second figure is the distribution of runoff discharge for return periods of 2, 5, 10, and 25 years in Area 1. In the third figure is the distribution of runoff discharge for return periods of 2, 5, 10, and 25 years in Area 2. The fourth figure shows the distribution of runoff discharge for return periods of 2, 5, 10, and 25 years in Area 3.

A recapitulation of the annual return period plan total runoff discharge for each cut-off area of the research area for the 2, 5, 10, and 25-year return period plans is provided in Table 12.

Table 12. Recapitulation of Runoff Discharge Annual Return Period Plan

Area	Q Return Period (Maximum) m3/sec			
	Q2year	Q5year	Q10year	Q25year
A1	704.96	760.93	797.99	818.89
A2	1067.92	1152.71	1208.84	1240.52
A3	854.51	922.35	967.27	992.61

Source: Calculation Result

Table 12 shows the recapitulation of the total runoff discharge of the annual return period plan in the study area, based on the calculation of the maximum discharge for return periods of 2, 5, 10, and 25 years in three different areas (A1, A2, and A3). The runoff discharge is measured in m^3/second (cubic meters per second) and shows how the runoff discharge is expected to increase with longer return periods.

CONCLUSION

It can be concluded that this research shows that the highest rainfall predicted in 2048 in Cirebon is 2471 mm based on BMKG Penggung Station data, while in Majalengka it is expected to experience the highest rainfall of 2922 mm, based on BMKG Kertajati Station data. In addition, the largest runoff discharge is in Susukan sub-district, Cirebon, with a discharge of 68.648 m^3/second (Q25), while in Majalengka, the highest discharge is in Lemahsugih sub-district at 104.16 m^3/second (Q25). Detailed predictions for the BMKG Kertajati station estimate rainfall of 2358 mm in 2025, 2194 mm in 2028, and 2922 mm in 2048. Similarly, for the Jatiwangi and Penggung BMKG stations, the predicted rainfall shows a consistent trend. Runoff discharge predictions for different districts further highlight areas of concern, such as Kertajati and Lemahsugih, where significant runoff may occur in the coming years. This research provides valuable input to flood mitigation strategies for the Cirebon and Majalengka regions. The findings suggest that efforts such as regulating development over drainage systems, increasing green space, preserving river areas, and building flood embankments are critical to reducing future flood risks. Future research should expand on these results by including additional climate variables such as wind speed, humidity and temperature to improve the accuracy of rainfall predictions. In addition, updating the administrative maps of the study area can improve the accuracy of digital mapping, thus ensuring more effective disaster mitigation planning.

REFERENCES

Adiguno, S., Syahra, Y., & Yetri, M. (2022). Prediksi Peningkatan Omset Penjualan Menggunakan Metode Regresi Linier Berganda. *Jurnal Sistem Informasi Triguna Dharma (JURSI TGD)*, *1*(4), 275–281.

Afrian, R. (2020). Kajian Mitigasi Terhadap Penyebab Bencana Banjir di Desa Sidodadi Kota Langsa. *Jurnal Georafflesia: Artikel Ilmiah Pendidikan Geografi*, *5*(2), 165–169.

Aslim, M. A. F. I., Jasruddin, J., Palloan, P., Helmi, H., Arsyad, M., & Triwibowo, H. (2023). Monthly Rainfall Prediction Using the Backpropagation Neural Network (BPNN) Algorithm in Maros Regency. *Scientific Journal of Informatics*, *10*(1), 13–24.

Cirebon, B. K. (2024). *Kota Cirebon Dalam Angka 2024 (Vol. 49)*. Cirebonkota.Bps.Go.Id. https://cirebonkota.bps.go.id/publication/2024/02/28/f33f29bb47e64e9eeafec39a/kota-cirebon-dalam-angka-2024.html

Cirebon, B. P. S. K. (2024). *Kabupaten Cirebon Dalam Angka 2024 (Vol. 19)*. Cirebonkab.Bps.Go.Id. https://cirebonkab.bps.go.id/publication/2024/02/28/e12c1d992be02c5b2492c646/kabupaten-cirebon-dalam-angka-2024.html

Ikhwan, M., Musa, R., & Mallombassi, A. (2022). Kajian Debit Limpasan Permukaan Akibat Intensitas Curah Hujan Lapangan: Studi Kasus DAS Kiru-Kiru Kab. Barru. *Jurnal Konstruksi: Teknik, Infrastruktur Dan Sains*, *1*(7), 49–56.

Kyojo, E. A., Mirau, S. S., Osima, S. E., & Masanja, V. G. (2024). Frequentist and Bayesian Approaches in Modeling and Prediction of Extreme Rainfall Series: A Case Research from Southern Highlands Region of Tanzania. *Advances in Meteorology*, *2024*(1), 8533930.

Majalengka, B. K. (2024). *Kabupaten Majalengka Dalam Angka 2024 (Vol. 39)*. Majalengkakab.Bps.Go.Id. https://majalengkakab.bps.go.id/publication/2024/02/28/4e71313ad18650d50ed2c667/kabupaten-majalengka-dalam-angka-2024.html

Muttaqin, Z., & Farhan, O. (2021). Analysis of Floating Net Cages on The Carrying Capacity of The Darma Reservoir. *Jurnal Teknik Sipil Dan Perencanaan*, *23*(1), 74–82.

Oktaviani, C., & Afdal, A. (2013). Prediksi curah hujan bulanan menggunakan jaringan syaraf tiruan dengan beberapa fungsi pelatihan backpropagation (studi kasus: stasiun meteorologi tabing padang, tahun 2001-2012). *Jurnal Fisika Unand*, *2*(4).

Qurrotaini, L., & Nuryanto, N. (2020). Implementasi pendidikan mitigasi bencana alam gempa bumi dalam pembelajaran IPS SD. *Implementasi Pendidikan Mitigasi Bencana Alam Gempa Bumi Dalam Pembelajaran IPS SD*, *2*(1), 37–44.

Ramdhani, R., & Yustiana, F. (2023). Tinjauan Perhitungan Debit Limpasan Permukaan Dengan Metode Rasional Modifikasi (Studi Kasus Drainase Mikro Kampus Itenas). *Prosiding FTSP Series*, 50–55.

Setiawan, W., & Barokah, A. (2022). Rainfall Prediction Using Backpropagation with Parameter Tuning. *MATEC Web of Conferences*, *372*, 7003.

Sheikhi, Y., Ashrafi, S. M., Nikoo, M. R., & Haghighi, A. (2023). Enhancing daily rainfall prediction in urban areas: a comparative research of hybrid artificial intelligence models with optimization algorithms. *Applied Water Science*, *13*(12), 232.

Silva, M. A. da, Merlo, M. N., Thebaldi, M. S., Ferreira, D. D., Schwerz, F., & Deus, F. P. de. (2023). Climate-related variables may not improve monthly scale rainfall predictions by artificial neural networks for the metropolitan region of Belo Horizonte, Brazil. *Revista Ambiente & Água*, *18*, e2879.

Siregar, E. (2019). *Analisis Metode Backpropagation Dengan Fungsi Aktivasi Sigmoid Bipolar Dan Fungsi Linear Dalam Prediksi Pertumbuhan Penduduk*. Universitas Sumatera Utara.

Sitio, A. S., Poningsih, P., Parlina, I., Gunawan, I., & Sumarno, S. (2021). Analisis Metode Sig (Sistem Informasi Geografis) untuk Pemetaan Klinik Bpjs Dengan Pendekatan Rad (Rapid Application Development). *Jurnal Sosial Teknologi*, *1*(5), 355–365.

Tamaji, T., Utama, Y. A. K., & Sidharta, J. (2022). Jaringan Saraf Tiruan Menggunakan Metode Backpropagation untuk Prediksi Curah Hujan. *Telekontran: Jurnal Ilmiah Telekomunikasi, Kendali Dan Elektronika Terapan*, *10*(1), 30–37.

Thariq, A. (2020). Pemetaan Titik Kelandaian Permukaan Jalan Dengan Memanfaatkan Teknologi Google Maps 3D. *Jurnal Simetrik*, *10*(2), 328–332.

Tribhuwana, A., & Prasetyo, A. (2020). Analysis of Infiltration Relations With Land Physical Properties. *Journal of Green Science and Technology*, *4*(3).

Tribhuwana, A., Rohman, F., & Farhan, O. (2021). Analysis of The Carrying Capacity of Urban Drainage Dimensions. *Journal of Green Science and Technology*, *5*(1).

Triwahyuni, T., Husna, I., & Andesti, M. (2020). Hubungan Curah Hujan dengan Kasus Demam Berdarah Dengue di Bandar Lampung 2016-2018. *ARTERI: Jurnal Ilmu Kesehatan*, *1*(3), 184–189.

Yusuf, M., Setyanto, A., & Aryasa, K. (2022). Analisis Prediksi Curah Hujan Bulanan Wilayah Kota Sorong Menggunakan Metode Multiple Regression. *J-SAKTI (Jurnal Sains Komputer Dan Informatika)*, *6*(1), 405–417.

Zahran, B. (2023). A fuzzy based model for rainfall prediction. *International Journal of Data and Network Science*, *7*(1), 97–106.