

## **BACKPROPAGATION METHOD TO PREDICT RAINFALL LEVELS IN ROKAN HULU DISTRICT**

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**Abstract:** Rokan Hulu Regency is one of the regencies in Riau Province and has 2 large rivers, namely the Rokan Kanan River and the Rokan Kiri River. When the level of rainfall is high, the river flow overflows and causes flooding in several sub-districts. Climate change that is happening has an impact on changes in rainfall patterns, to overcome the impacts of climate change Rokan Hulu Regency needs to take early steps before a flood disaster occurs. The method used in processing the data is the backpropagation method and data processing using the Matlab software. Data processing was carried out on rainfall data for the last 6 years, from 2015 to 2020, which was sourced from the Rokan Hulu Regency Statistics Agency. Rainfall data from 2015 to 2019 is used as input data, while 2020 is the target. The data processing stage begins with data normalization and determining network training parameters. Artificial neural network research was carried out on rainfall data with a 5-5-1 architecture. The results of testing the rainfall data show prediction results with high accuracy, where the average accuracy rate reaches 98.17% with the highest accuracy of 99.99% while the lowest accuracy is 91.53%. The prediction results show a fairly high level of accuracy so that they can be used as evaluation material.

**Keywords:** artificial neural network; backpropagation; prediction; rainfall

**Abstrak:** Kabupaten Rokan Hulu merupakan salah satu kabupaten yang berada di Provinsi Riau dan memiliki 2 aliran sungai besar yaitu sungai rokan kanan dan sungai rokan kiri. Ketika tingkat curah hujan tinggi aliran sungai meluap dan menyebabkan banjir beberapa kecamatan. Perubahan iklim yang terjadi memberikan dampak pada perubahan pola curah hujan, untuk menanggulangi dampak perubahan iklim Kabupaten Rokan Hulu perlu melakukan langkah-langkah dini sebelum terjadi bencana banjir. Metode yang digunakan dalam mengolah data yaitu metode backpropagation dan pengolahan data menggunakan software Matlab. Pengolahan data dilakukan pada data curah hujan selama 6 tahun terakhir yaitu dari tahun 2015 sampai dengan 2020 yang bersumber dari Badan Statistik Kabupaten Rokan Hulu. Data curah hujan tahun 2015 sampai dengan tahun 2019 sebagai data input sedangkan tahun 2020 sebagai target. Tahapan pengolahan data diawali dengan melakukan normalisasi data dan menentukan parameter pelatihan jaringan. Penelitian jaringan saraf tiruan dilakukan pada data curah hujan dengan arsitektur 5-5-1. Hasil pengujian terhadap data curah hujan menunjukkan hasil prediksi dengan akurasi yang tinggi, dimana tingkat akurasi rata-rata mencapai 98,17% dengan akurasi tertinggi sebesar 99,99% sedang akurasi terendah sebesar 91,53%. Hasil prediksi menunjukkan tingkat akurasi yang cukup tinggi sehingga dapat digunakan sebagai bahan evaluasi.

**Kata kunci:** backpropagation; curah hujan; jaringan saraf tiruan; prediksi

## INTRODUCTION

In today's development, technology has become something that is familiar to the community, all activities are carried out using existing technology. The purpose of developing a technology is to facilitate and assist in carrying out various human activities and activities, such as technology at the Meteorology, Climatology and Geophysics Agency (BMKG) which records rainfall levels to make it easier to find out the high and low levels of rainfall that occur. Rain is very useful in the continuity of human life and in various agricultural sectors that require water at normal intensity. When the intensity of rainfall is high, it can cause natural disasters, one of which is flooding.

Rokan Hulu Regency is one of the regencies in Riau Province and has 2 large rivers, namely the Rokan Kanan River and the Rokan Kiri River. When there is high rainfall, the rivers in Rokan Hulu Regency overflow and cause flooding in various sub-districts. The floods that occurred in Rokan Hulu Regency not only caused material losses but also claimed lives, such as the 2019 flood which caused the death of a toddler girl to be found dead in the flood currents.

Climate change has many impacts on changes in rainfall patterns, to overcome the impacts of climate change, Rokan Hulu Regency needs to take early steps before a flood disaster occurs by managing sewers, water management, and a flood forecasting system. Disasters can be anticipated with accurate information about the level of rainfall that will occur within a certain period of time.

Thus a prediction system for future rainfall levels is needed. The resulting prediction of rainfall levels can be used as material for anticipation and reference

for the Rokan Hulu Regency government in evaluating the impact of greater losses due to flooding. The resulting level of prediction accuracy is determined by the method, in this case a suitable and accurate method for predicting rainfall levels is a backpropagation artificial neural network.

Rainfall prediction is the use of science and technology to predict the future state of the earth's atmosphere at a certain place. Rainfall prediction is done with the help of a computer or certain software in the modeling system [1][2].

Backpropagation is a multi-layer feed forward training method that has been proposed by Rumelhart and McClelland [3][4]. Backpropagation is included in the popular category of artificial neural networks and has advantages in the learning or training process, the training or learning process is repeated by having good computation, especially when data is presented on a large and complex scale [5].

Previous backpropagation research has been carried out by Setti and Wanto. Research predicts the number of internet users in 25 countries with the highest level of internet usage and produces the best network architecture 3-50-1 with an accuracy rate of 92% [6]. Furthermore, Lesnussaa et al also conducted research on the backpropagation method and produced an accuracy rate of 80% [7]. Sovia et al researched backpropagation to predict bitcoin price movements and were able to conduct training and data testing based on network patterns that had been formed [8]. Purnawansyah et al used backpropagation to predict the inflation rate in Samarinda City, architectural parameters 5-5-5-1 produced a good prediction error rate [9]. Muflih et al used backpropagation to predict rainfall in Wonosobo Regency, resulting in an MSE of

0.17042 when testing the network [10]. Saragih et al conducted research on predicting the value of exports in North Sumatra with backpropagation. The study uses 5 architectural models namely 4-5-1, 4-7-1, 4-9-1, 4-10-1 and 4-11-1. The best model of these 5 models is 4-7-1 with a 100% accuracy rate, with a time of 27 seconds. The error rate used is 0.001 – 0.05 [11].

Based on the background that has been described, the researchers conducted a study entitled "Backpropagation Method for Predicting Rainfall Levels in Rokan Hulu Regency"

## METODE

The framework for the research conducted can be seen in Image 1.

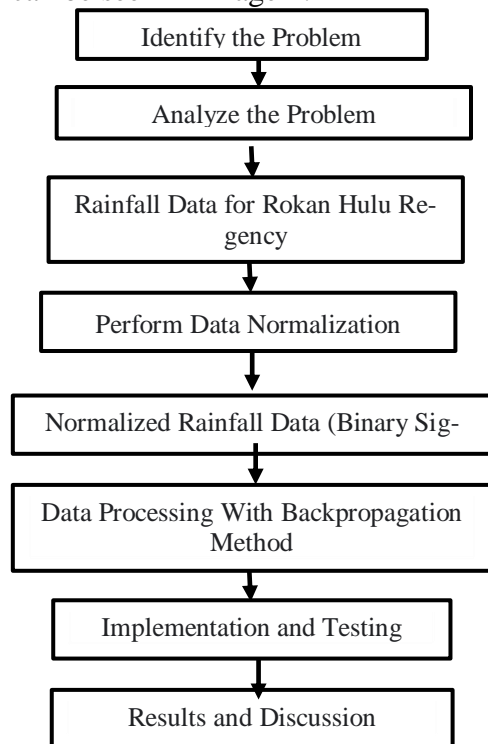


Image 1. Research Framework

Description of the steps in the research framework Image 1 is:

### Identify the Problem

Identifying the problem is the initial stage that is carried out to determine the formulation of the problem that occurs in Rokan Hulu Regency.

### Analyze the Problem

Analysis of the problems that have been determined so that the problems that occur can be well understood.

### Rainfall Data for Rokan Hulu Regency

The data used in this study are rainfall data in Rokan Hulu Regency for the last 6 years from 2015 to 2020 obtained from the Central Bureau of Statistics for Rokan Hulu Regency.

### Perform Data Normalization

The data normalization stage is the stage of transforming the rainfall data that has been obtained so that the distribution of the data becomes new data that is more normal and does not occur anomalies. Data normalization is performed using a binary sigmoid activation function (never reaches 0 or 1).

### Normalized Rainfall Data (Binary Sigmoid)

Normalized rainfall data contains rainfall data for 2015 to 2020 with values never reaching 0 or 1.

### Data Processing With Backpropagation Method

Data processing is based on the stages of the backpropagation method as follows:

- a. Perform random initial weight initialization

Initialize the initial weights which are determined randomly, namely from the input layer to the hidden layer and from the hidden layer to the output layer.

- b. Setting ANN Parameters (learning rate, epoch and architecture)  
Artificial Neural Network (ANN) training has parameters that greatly affect the results of network training. Parameter settings must be made to achieve training objectives efficiently so as to produce good training.

- c. Doing the Feedforward Stage  
The feedforward stage is the forward propagation flow stage where each input layer neuron receives a signal from the input data which is then forwarded to the hidden layer neurons and from the hidden layer neurons it is forwarded back to the output layer neurons.

- d. Doing the Backpropagation Stage  
The backpropagation stage is the backward propagation flow stage where each neuron of the output layer with the input pattern is then forwarded to the hidden layer neurons and from the hidden layer neurons it is forwarded back to the input layer neurons. The backpropagation stage will calculate any weight changes that go to the hidden layer and the output layer.

- e. Calculates the minimum error value  
Calculating the minimum error is used to see the conditions for stopping the learning process. The termination of the learning process is

determined by the maximum number of iterations or the minimum error (target) value in determining the learning termination process.

### **Implementation and Testing**

The implementation phase is carried out by building a GUI-based system using matlab software to facilitate the process of processing rainfall data into useful information. Furthermore, testing the system is it feasible to use to predict rainfall that will occur in the future and manual calculations with the system are valid or appropriate.

### **Results and Discussion**

The results and discussion will describe the results of the processing and testing of the data that has been carried out. The results obtained are in the form of predictions of rainfall levels and the accuracy of predictions in the future with the aim of being used as a policy reference in managing the impact of changes in rainfall disasters in the future.

## **RESULT ANF DISCUSSION**

This research uses rainfall data for the last 6 years, from 2015 to 2020. Furthermore, rainfall data is divided into 2, namely training data and test data. There is also rainfall data in Table 1.

Table 1. Rainfall Data

Month	Year (mm <sup>3</sup> )					
	2015	2016	2017	2018	2019	2020
January	191	370,3	260	165,29	249,28	164,3
February	143,5	210,4	334,3	98,9	178,3	135,5
March	216,38	153	301	172,7	126,7	205
April	261,22	206,7	272,6	193,4	189,1	223,1
Mey	200	218,2	173,1	282,7	177,8	126,6
June	170,22	70,6	112,3	213,2	203,9	185,3
July	80,78	203	105,2	86,7	203,6	132,3
Augustus	171	41,1	201,3	63,57	221,8	101,8
September	88,44	109	81	172,9	177,8	220,6
Oktober	168	65,8	102,8	338	368,1	101,2
November	365,33	336	331	280,9	527,3	341,1
December	305	108,1	327,5	329,8	387,1	276,3

(Source: BPS Kabupaten Rokan Hulu)

Rainfall data in Table 1 will be analyzed using the backpropagation method to predict future rainfall levels with the following stages of the backpropagation process:

#### 1. Input data

The input data is in the form of rainfall data that occurred in Rokan Hulu Regency. Initialize the input data in Table 2.

Table 2. Initialize the input data

No	Variable	Initialize
1	2015	X1
2	2016	X2
3	2017	X3
4	2018	X4
5	2019	X5
6	2020	Target

#### 2. Data Normalization

Normalization uses the binary sigmoid activation function by changing the data to a range of 0.1 to 0.9 using the equation:

$$x' = \frac{0.8(x-x_{min})}{(x_{max}-x_{min})} + 0.1 \quad (1)$$

The normalization results of rainfall data presented in Table 1 can be seen in Table 3.

Table 3. Rainfall Data Analyze

Month	Input Data					
	X1	X2	X3	X4	X5	T
Januari	0,410	0,9	0,665	0,397	0,345	0,310
Februari	0,276	0,511	0,9	0,203	0,203	0,214
Maret	0,481	0,372	0,795	0,418	0,1	0,446
April	0,607	0,502	0,705	0,478	0,225	0,507
Mei	0,435	0,530	0,391	0,739	0,202	0,185
Juni	0,351	0,172	0,199	0,536	0,254	0,380
Juli	0,1	0,493	0,176	0,167	0,254	0,204
Agustus	0,354	0,1	0,480	0,1	0,290	0,102
September	0,122	0,265	0,1	0,419	0,202	0,498
Oktober	0,345	0,160	0,169	0,9	0,582	0,1
November	0,9	0,817	0,890	0,734	0,9	0,9
Desember	0,730	0,263	0,879	0,876	0,620	0,684

#### 3. Set JST Parameters

The ANN parameters used in the learning process of the backpropagation method are:

- Using epoch from 1000-2000.
- The learning rate ( $\alpha$ ) used in the training process is 0.1.
- The minimum error or target output generated is 0.001.
- ANN training uses 5-5-1 architecture, namely 5 input layers, 5 hidden layers and 1 output layer.

#### 4. Initialize Initial Weight

Initial weight initialization by providing a relatively small random value as initial weight and bias in ANN. The following is the initial weight and bias initialization in the ANN training process:

Table 4. Initial Weight from Input to Hidden Layer

Weight	$z_1$	$z_2$	$z_3$	$z_4$	$z_5$
$v_1$	2,278	-2,834	1,171	-0,382	0,053
$v_2$	-1,451	2,511	3,448	-1,454	-3,214
$v_3$	1,166	-0,823	0,752	1,136	1,423
$v_4$	-3,357	0,985	-2,379	2,026	0,193
$v_5$	1,301	1,367	0,214	-5,144	-2,421

Table 5. Initial Weight from Hidden to Output Layer

Bobot	Y
$w_1$	-1,107
$w_2$	0,317
$w_3$	1,174
$w_4$	-2,047
$w_5$	0,746

Table 6. Initial Bias from Input to Hidden Layer

Bias	$v_j$
1	4,735
2	-3,692
3	-5,426
4	6,093
5	3,612

Table 7. Initial Bias from Hidden to Output Layer

Bias	1
$w_k$	3,683

## 5. Feedforward stage

Then carry out the feedforward propagation stage.

Count or add up each hidden layer neuron that receives weight from the input layer by using the equation:

$$z\_in_j = v_j + \sum_{i=1}^n x_i v_{ij} \quad (2)$$

$$z\_in_1 = 4,735 + (0,410 * 2,278) + (0,9 * -2,834) + (0,665 * 1,171) + (0,397 * -0,382) + (0,345 * 0,053) = 3,76401$$

$$z\_in_2 = -3,692 + (0,410 * -1,451) + (0,9 * 2,511) + (0,665 * 3,448) + (0,397 * -1,454) + (0,345 * -3,214) = -1,41747$$

$$z\_in_3 = -4,24735$$

$$z\_in_4 = 4,89061$$

$$z\_in_5 = -2,64345$$

After calculating the weight signal from the input layer to the hidden layer, activate the activation function with the equation:

$$z_j = \frac{1}{1 + e^{-z\_in_j}} \quad (3)$$

$$z_1 = \frac{1}{1 + e^{-(3,76401)}} = 0,97734$$

$$z_2 = \frac{1}{1 + e^{-(-1,41747)}} = 0,19506$$

$$z_3 = 0,01410$$

$$z_4 = 0,99254$$

$$z_5 = 0,93361$$

Then calculate or add up each hidden layer neuron to the output layer using the equation:

$$y\_in_k = w_k + \sum_{j=1}^p z_j w_{jk} \quad (4)$$

$$y\_in_k = 3,683 + (0,97734 * -1,107) + (0,19506 * 0,317) + (0,01410 * 1,174) + (0,99254 * -2,047) + (0,93361 * 0,746) = 1,34422$$

After calculating the weight signal from the hidden layer to the output layer, activate the activation function with the equation:

$$y_k = \frac{1}{1 + e^{-y\_in_k}} \quad (5)$$

$$y_k = \frac{1}{1 + e^{-(1,34422)}} = 0,79318$$

## 6. Backpropagation Stage

Next, do the backward propagation calculation stage, namely from the output layer to the input layer. Calculate the error in the output layer to find out whether the target error has been met or not by using the equation:

$$\delta_k = (t_k - y_k) \left( \frac{1}{1+e^{-y_{ink}}} \right) \left( 1 - \left( \frac{1}{1+e^{-y_{ink}}} \right) \right) \quad (6)$$

$$\delta_k = (0,310 - 0,79318)(0,79318)(1 - 0,79318) = -0,07919$$

When the error value has not reached the target, then it is continued with the calculation of changes in weight values with learning rate ( $\alpha$ ) = 0.1. Use the equation:

$$\Delta w_{jk} = \alpha \delta_k z_j \quad (7)$$

$$\Delta w_{[1,1]} = 0,1 * -0,07919 * 0,97734 = -0,00774$$

$$\Delta w_{[1,2]} = 0,1 * -0,07919 * 0,19506 = -0,00154$$

$$\Delta w_{[1,3]} = -0,00011$$

$$\Delta w_{[1,4]} = -0,00786$$

Table 8. Weight Correction at Each Output Unit

Weight	$z1$	$z2$	$z3$	$z4$	$z5$
$v1$	2,2781	-2,8338	1,1711	-0,3819	0,0531
$v2$	-1,4512	2,5106	3,4477	-1,4542	-3,2141
$v3$	1,1659	-0,8231	0,7519	1,1359	1,4230
$v4$	-3,3570	0,9851	-2,3789	2,0260	0,1930
$v5$	1,3008	1,3667	0,2138	-5,1441	-2,4211

$$\Delta w_{[1,5]} = 0,1 * -0,07919 * 0,93361 = -0,00739$$

$$\Delta w_{[0]} = 0,1 * -0,07919 = -0,00792$$

Next, add up the delta factor in the hidden layer using the equation:

$$\delta_{in_k} = \sum_{k=1}^m \delta_k w_{jk} \quad (8)$$

$$\delta_{in_1} = 0,07919 * -1,107 = 0,08767$$

$$\delta_{in_2} = 0,07919 * 0,317 = -0,02510$$

$$\delta_{in_3} = 0,07919 * 1,174 = -0,09297$$

$$\delta_{in_4} = 0,16211$$

$$\delta_{in_5} = -0,05908$$

Then calculate the error value  $\delta$  in the hidden layer using the equation:

$$\delta_k = \delta_{in_k} \left( \frac{1}{1+e^{-z_{inj}}} \right) \left( 1 - \left( \frac{1}{1+e^{-z_{inj}}} \right) \right) \quad (9)$$

$$\delta_1 = 0,08767 * 0,97734 * (1 - 0,97734) = 0,00194$$

$$\delta_2 = -0,02510 * 0,19506 * (1 - 0,19506) = -0,00394$$

$$\delta_3 = -0,00129$$

$$\delta_4 = 0,00120$$

$$\delta_5 = -0,00366$$

Then calculate the weight correction value for each output unit using the equation:

$$\Delta v_{jk} = \alpha \delta_j x_i \quad (10)$$

Then the results of calculating the weight correction value for each output unit are presented in Table 8.

Next, calculate the corrected bias value from the hidden layer using the equation:

$$\Delta V_{jo} = \alpha * \delta_j \quad (11)$$

$$\Delta V_{j1} = 0,1 * (0,00194) = 0,000194$$

$$\Delta V_{j2} = 0,1 * (-0,00394) = -0,000394$$

$$\Delta V_{j3} = -0,000129$$

$$\Delta V_{j4} = 0,000120$$

$$\Delta V_{j5} = -0,000366$$

## 7. Renewal (Update) Weights and Bias

Calculate the change in weight and bias from the input layer to the hidden layer or from the hidden layer to the output layer from the input layer to the hidden layer.

Calculate the change in weight values from the input layer to the hidden layer using the equation:

$$v_{ij}(\text{New}) = v_{ij}(\text{Long}) + \Delta v_{jk} \quad (12)$$

The following is the result of changing the weight from the input layer to the hidden layer in Table 9.

Table 9. Update the Input Weights to the hidden layer

Bobot	z1	z2	z3	z4	z5
v1	2,2781	-2,8338	1,1711	-0,3819	0,0531
v2	-1,4512	2,5106	3,4477	-1,4542	-3,2141
v3	1,1659	-0,8231	0,7519	1,1359	1,4230
v4	-3,3570	0,9851	-	2,0260	0,1930
v5	1,3008	1,3667	0,2138	-5,1441	-2,4211

Calculate the change in weight from the hidden layer to the output layer using the equation:

$$w_{jk}(new) = w_{jk}(long) + \Delta w_{jk} \quad (13)$$

The following is the result of changing the weight from the hidden layer to the output layer in Table 10.

Table 10. Hidden Weight Updates to Output

Bobot	Y
w1	-1,1149
w2	0,3093
w3	1,1725
w4	-2,0471
w5	0,7381

Next, calculate the change in the new bias value in the output layer using the equation:

$$V_{j0}(baru) = V_{j0}(lama) + \Delta V_{j0} \quad (14)$$

Changes in the new bias values obtained from the calculations are contained in Table 11.

Table 11. Input Bias Update Towards Hidden

Bias	vj
w1	4,7352
w2	-3,6924
w3	-5,4261
w4	6,0931
w5	3,6116

The last step in updating the weights and bias is to calculate the change in the bias value from the hidden layer to the output layer using the equation:

$$W_{j(New Bias)} = w_{0(long)} + \Delta w_0 \quad (15)$$

$$W_{j0(New Bias)} = 3,683 + (-0,00792) = 3,6751$$

8. Stop Condition Test (Is error < min error / epoch < max epoch?)

The ANN training process will stop if it meets one of the two conditions of the ANN training process, namely the output value has reached the target or the epoch has reached the maximum iteration (maximum epoch).

9. Perform Backpropagation Testing

Subsequent network testing used Matlab R2018a Software on rainfall data that occurred in Rokan Hulu Regency from 2015 to 2020, the testing process used the best network training that stopped at epoch 3000. The following results of network testing carried out using Matlab Software are in Table 12.

Table 12. ANN Test Results

Month	Target	Prediction	Accuracy (%)
January	164,3	164,4946	99,88
February	135,5	135,6061	99,92
March	205	205,266	99,87
April	223,1	223,3106	99,91
Mey	126,6	126,5193	99,94
June	185,3	185,5496	99,87
July	132,3	132,3557	99,96
Augustus	101,8	108,8475	93,53
September	220,6	208,4682	94,50
Oktober	101,2	110,5611	91,53
November	341,1	341,1252	99,99
December	276,3	274,0827	99,20
Average Accuracy (%)			98,17

Table 12 is the result of ANN testing of rainfall data that occurred from 2015 to 2020. The results of testing of rainfall data show prediction results with high accuracy, where the average accuracy rate reaches 98.17% with the high-



est accuracy of 99.99% while the lowest accuracy is 91.53%.

Based on these results, it can be concluded that the backpropagation method can be used to predict the level of rainfall that will occur in Rokan Hulu Regency in the future. Predictions of rainfall levels that will occur in the future can be used as a reference material and analysis in handling and overcoming the effects of rainfall from an early age to avoid greater material losses.

## CONCLUSION

The backpropagation method in the network training process uses several parameters, namely using a 5-5-1 network architecture consisting of 5 input layers, 5 hidden layers and 1 output layer, maximum epoch 3000, target error (goal) 0.001, and learning rate 0.1. The network training process stops at a maximum of 3000 epochs. The results of network testing of rainfall data from 2015 to 2020 produce a high level of accuracy, where the average accuracy rate reaches 98.17% with the highest accuracy of 99.99% while the accuracy the lowest of 91.53%.

The results of predicting future rainfall in Rokan Hulu Regency show high accuracy, so that the backpropagation method is quite good at predicting rainfall levels based on past (historical) rainfall data.

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