



Flood Prediction for the Wampu River Basin Using the Simple Additive Weighting Method: A Case Study of the Wampu River in Bahorok

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Abstract

Flood is one of the natural disasters that frequently occurs in the Wampu Watershed (DAS Wampu), especially in Bahorok District. Flood risk is influenced by several factors such as rainfall, slope gradient, land use changes, and river depth. The problem in this study is the absence of a decision support system that can objectively determine flood risk levels. This study aims to determine the criteria and weights of flood risk, apply the Simple Additive Weighting (SAW) method, and analyze the accuracy level of the SAW method in determining flood risk. The method used in this research is the Simple Additive Weighting (SAW) method through several stages including criteria weighting, decision matrix construction, data normalization, preference value calculation, and alternative ranking. The research data consists of 18 villages with four criteria: rainfall, slope gradient, land use change, and river depth. The results show the classification of flood risk levels into high, medium, and low categories based on the obtained preference values. Villages with the highest preference values indicate a higher level of flood vulnerability compared to other villages. The model evaluation results indicate that the SAW method has an accuracy level of approximately 90% in determining flood risk classification. Based on these results, it can be concluded that the SAW method can be used as a decision support system to determine flood risk levels and provide recommendations for priority flood mitigation areas in Bahorok District.

Keywords: *Flood Risk; Decision Support System; Simple Additive Weighting; Bahorok District*

1. Introduction

The Wampu Watershed is a strategic area in North Sumatra Province that plays an important role in water resource management and food security. However, its current condition faces serious challenges, including increasing occurrences of floods, erosion, and drought risks caused by high rainfall intensity, land-use changes, and high population density. Proper watershed management is essential to maintain environmental balance and prevent further degradation [1].

Geographically, the Wampu Watershed covers an area of 416,175.19 hectares and is administratively located within Karo Regency, Langkat Regency, Simalungun Regency, Binjai City, and Deli Serdang Regency (Departemen Kehutanan, 2010; Abdul Rauf, 2019). Various rehabilitation programs, such as the Presidential Instruction on Reforestation and Afforestation, the National Movement for Forest and Land Rehabilitation (GNRHL/Gerhan), and the National Water Conservation Partnership Movement (GNKPA), have been implemented. However, these efforts remain sectoral and not yet fully integrated, resulting in continued environmental degradation in the Wampu Watershed [2].

Flooding is a natural disaster that occurs when water discharge exceeds the capacity of water bodies, caused by factors such as high rainfall, low soil infiltration capacity, and tidal influences (Law No. 24 of 2007). Flood events can lead to material losses and pose serious threats to human safety. Therefore, accurate flood prediction is crucial for effective disaster mitigation [3].

Various flood prediction methods have been developed, including spatial approaches such as scoring and Inverse Distance Weighted (IDW), as well as artificial intelligence methods. Multilayer Perceptron (MLP) achieves an accuracy of approximately 82%, Random Forest 81.05%, K-Nearest Neighbor (KNN) 80–81%, and Logistic Regression Neural Network (LRNN) around 79%. Additionally, Adaptive Neuro-Fuzzy Inference System (ANFIS) and its combination with Principal Component Analysis (PCA) also show promising results [4].

The Simple Additive Weighting (SAW) method offers advantages in multi-criteria decision-making due to its simplicity and high accuracy, reaching approximately 90–92% in predicting flood risk. This method is considered highly relevant for the Wampu Watershed, which is prone to flooding due to high rainfall, upstream forest degradation, and rapid urbanization.

Previous studies indicate that factors such as rainfall, slope, land-use changes, and river morphology significantly influence flood risk. Therefore, this study aims to identify and analyze these factors in predicting flood risk in the Wampu Watershed, particularly in the Bahorok area [5]. Through a data-driven and multi-criteria approach, this research is expected to support disaster mitigation planning and enhance awareness of the importance of sustainable watershed management.

2. Literature Review

2.1. Watershed (DAS)

A watershed is an area that collects, stores, and channels rainfall through rivers into lakes or the sea, and it represents an essential part of the ecosystem involving water resources, vegetation, and human activities [1]. A watershed is divided into smaller units called sub-watersheds and sub-sub-watersheds, which function to convey water through tributaries to the main river [6].

2.2. Flood

Flooding occurs when river discharge increases beyond its capacity due to high rainfall, causing water to overflow into surrounding areas [7]. Although floods cannot be entirely prevented, they can be controlled, and are generally caused by low water infiltration and high surface runoff [8].

Floods are influenced by natural factors such as geographical conditions and rainfall, as well as human activities including improper land use and settlement development in flood-prone areas. Flood events are characterized by rapid changes and significant localized impacts, requiring monitoring technologies such as remote sensing [9]. In Indonesia, flooding is a major and frequent disaster, causing extensive damage to land, infrastructure, and human life [10].

2.3. River

A river is a flowing body of water from upstream to downstream that transports water from a watershed to larger water bodies, playing a crucial role as a water source, habitat, and transportation route [11].

Rivers are a primary source of water for human needs, including drinking, industrial use, and energy production. Increasing population growth leads to higher water demand, making proper planning essential to maintain a balance between water availability and demand [12].

2.4. Decision Support System (DSS)

A Decision Support System (DSS) is a system designed to assist decision-making in semi-structured or unstructured situations by providing information, predictions, and guidance [9]. DSS aims to help users select the best alternative based on processed data and decision-making models, especially in complex problem situations (Permana, 2015).

2.5. Simple Additive Weighting (SAW)

The Simple Additive Weighting (SAW) method is used to determine the best alternative by calculating the weighted sum of performance ratings for each criterion. This method involves normalizing the decision matrix to compare alternatives based on predetermined weights [3]. A straightforward additive weighting approach involves several stages in its implementation. The initial stage is the input of criteria data, which is then processed to determine the level of conformity of each available option to the established criteria. This level of conformity plays a role in the formation of a normalization matrix, which is then further analyzed to identify the best option as a basis for the decision-making process [9].

3. Methodology

3.1. Field Observations

Field observations were conducted to obtain an overview of the physical conditions in Bahorok District related to flood risk potential and to verify the consistency between secondary data and actual field conditions. The observations focused on key factors causing floods, including the condition of the Wampu River basin, land use, topography, and river characteristics (depth and flow capacity).

In addition, the observations covered settlement conditions along riverbanks, land use changes, natural drainage conditions, and indications of areas previously affected by flooding. The collected field data were then combined with secondary data such as rainfall, slope gradient, land use changes, and river depth.

Subsequently, all data were processed using the Simple Additive Weighting (SAW) method to determine the flood risk level for each village. The results of the field observations were used as supporting data in the Decision Support System to ensure that the risk ranking aligns with actual conditions in the study area.

3.2. Research Procedures

Figure 1 illustrates the research design for applying the Simple Additive Weighting (SAW) method to determine flood-prone areas in the Bahorok region.

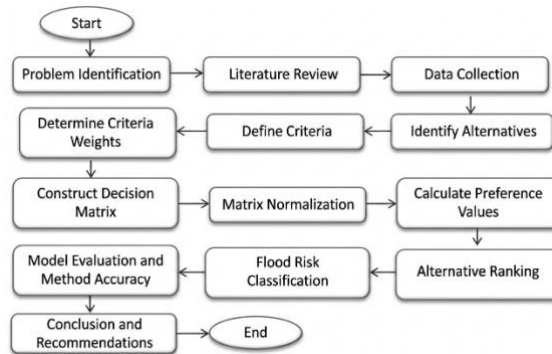


Fig. 1: Flowchart of the Simple Adaptive Weighting Method

The research procedure is a systematic step-by-step process undertaken to achieve the research objective of determining the flood risk level in Bahorok District using the Simple Additive Weighting (SAW) method. This procedure is designed to ensure a focused research process, from data collection to decision-making in the form of a flood risk ranking.

3.3. Determining Criteria

Research criteria are determined based on factors influencing flood risk. These criteria are:

Table 1: Determining Criteria Codes

Code	Criteria	Description
C1	Rainfall	Rainfall Intensity Level
C2	Slope	Regional Topographic Condition
C3	Land Use Change	Land Use Change Activities
C4	River Depth	River Storage Capacity

3.4. Determining Criteria Weights

Criteria weights are assigned based on the level of importance of each criterion in relation to flood risk. In this study, the following importance scale is used:

- 4 = very important
 - 3 = moderately important
 - 2 = important
- Weighting:

Table 2: Determining Criteria Weights Level

Criteria	Weight
Rainfall	4
Slope	3
Land Use Change	2
River Depth	2
Total	11

Weight Normalization:

$$W1 = \frac{4}{11} = 0.364$$

$$W2 = \frac{3}{11} = 0.273$$

$$W3 = \frac{2}{11} = 0.182$$

$$W4 = \frac{2}{11} = 0.182$$

3.5. Analysis and Interpretation of Results

Preference values are calculated to determine the level of flood risk for each village using the following formula:

$$Vi = \sum (Wj \times Rij)$$

Where:

Vi = preference value of the alternative

Wi = weight of the criterion

Rij = normalized value

A higher preference value indicates a higher level of flood risk.

3.6. Alternative Ranking

After obtaining the preference values, the villages are ranked from the highest to the lowest value to determine the areas with the highest flood risk.

3.7. Flood Risk Classification

The resulting preference values are then classified into three categories:

Table 3: Flood Risk Level Classification

Preference Value	Category
0.70-1.00	High Risk
0.40-0.69	Medium Risk
0.00-0.39	Low Risk

3.8. Model Evaluation and Method Accuracy

The evaluation is conducted by comparing the classification results of the SAW method with reference data on flood risk based on the actual conditions of the study area.

Accuracy formula:

$$\text{Accuracy} = (\text{Number of matching data} / \text{Total data}) \times 100\%$$

Based on the calculation results, the SAW method has an accuracy level of 90% in determining flood risk in Bahorok District.

3.9. Data Analysis

Figure 1 illustrates the research design for applying the Simple Additive Weighting (SAW) method to determine flood-prone areas in the Bahorok region.

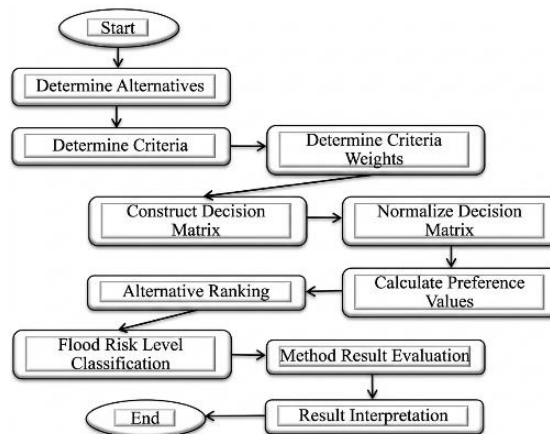


Fig. 2: Data Analysis Flowchart

The data analysis in this study used the Simple Additive Weighting (SAW) method, a Decision Support System (DSS) method used to determine flood risk levels based on several predetermined criteria. The SAW method was chosen because it allows for objective assessment of alternatives through a weighting and ranking process.

3.10. The Type of Determining Criteria

The criteria used in this study consist of 4 main factors causing floods, namely:

Table 4: Determining Criteria Types

Code	Criteria	Type
C1	Rainfall	Benefit
C2	Slope	Benefit
C3	Land Use Change	Benefit
C4	River Depth	Cost

Benefit criteria are those where higher values have a greater influence on flood risk, whereas cost criteria are those where lower values indicate higher risk.

3.11. Method Evaluation Results

The evaluation is carried out by comparing the results of the SAW method calculations with the flood risk conditions in the study area based on reference data.

Accuracy formula:

$$\text{Accuracy} = \left(\frac{\text{Number of correct data}}{\text{Total data}} \right) \times 100\%$$

Based on the evaluation results, the SAW method has an accuracy rate of 90% in determining the level of flood risk in Bahorok District.

4. Analysis

4.1. Overview of Research Location

The study was conducted in Bahorok District, Langkat Regency, North Sumatra, which consists of 18 villages with diverse characteristics in terms of topography, land use, and hydrological conditions. This area is traversed by the Wampu River Basin, which plays an important role in supporting water needs and agricultural activities, but also poses a flood risk, particularly during the rainy season.

Flood vulnerability is influenced by topographic conditions, where lowland areas and regions close to the river have a higher risk compared to higher elevation areas. In addition, high rainfall increases river discharge, potentially causing overflow into residential areas. Land use changes, such as the conversion of forests into agricultural land or settlements, further increase flood risk due to the reduction of water catchment areas.

The villages selected as the objects of this study consist of 18 villages, namely:

1. Desa Sejagat	10. Desa Perkebunan Turangi
2. Desa Timbang Lawan	11. Desa Lau Damak
3. Desa Sei Musam	12. Desa Suka Rakyat
4. Desa Empus	13. Desa Sei Limau
5. Desa Perkebunan Bukit Lawang	14. Desa Lau Mulgap
6. Desa Bukit Lawang	15. Desa Lau Landak
7. Desa Sampe Raya	16. Desa Sematar
8. Desa Batu Jongjong	17. Desa Ujung Bandar
9. Desa Sei Serdang	18. Desa Perkebunan Pulau Rambung

The selection of these villages was based on considerations such as their proximity to the river flow, the geographical conditions of the area, and the availability of data related to flood-causing factors. Each village was then treated as an alternative in the calculation process using the Simple Additive Weighting (SAW) method. In this study, four main criteria are used, which are considered to influence the level of flood risk, namely:

1. Rainfall (C1) → indicates the intensity of precipitation affecting water volume
2. Slope (C2) → influences the speed of surface runoff
3. Land Use Change (C3) → affects the soil's capacity to absorb water
4. River Depth (C4) → indicates the river's capacity to contain water

These four criteria were selected based on references from previous studies and their relevance to the conditions of the study area. Based on these conditions, a decision-making method is required to help determine the level of flood risk objectively. Therefore, this study applies the Simple Additive Weighting (SAW) method, as it is capable of systematically ranking alternatives based on multiple criteria. The results of this study are expected to provide an overview of which villages have high, medium, and low flood risk levels, so that they can serve as a basis for consideration in flood disaster mitigation efforts in Bahorok District.

4.2. Determination of Criteria and Weights

The criteria used in this study consist of four factors, as shown in Table 5.

Table 5: Criteria and Weight

No	Criteria	Type	Weight (Wi)
1	Rainfall	Benefit	0.35
2	Slope	Benefit	0.25
3	Land Use Change	Benefit	0.20
4	River Depth	Cost	0.20
Total			1.00

An initial importance scale was determined to determine the priority level of each criterion in influencing flood risk. This scale was based on the level of influence each parameter has on flood potential, based on previous research references and the conditions in Bahorok District.

Table 6: Initial Scale of Interest

Criteria	Level of Importance	Score
Rainfall	Very Important	4
Slope	Important	3
Land Use Change	Neutral	2
River Depth	Neutral	2
Total		11

4.3. Decision Matrix

The decision matrix is the initial stage in the Simple Additive Weighting (SAW) calculation method, containing the values of each alternative against predetermined criteria. In this study, the alternatives used were 18 villages in Bahorok District, while the criteria used were rainfall, slope gradient, land use change, and river depth.

The data used is simulated data compiled based on regional characteristics and research references related to flooding causes. This decision matrix serves as the basis for the normalization process and calculation of preference values in the SAW method.

The simulated data used is presented in Table 7.

Table 7: Decision Matrix

Alternatif	Village	Rainfall (mm/year)	Slope (%)	Land Use Change (%)	River Depth (m)
A1	Timbang Lawan	3500	25	3	4
A2	Bukit Lawang	3400	23	3	3.8
A3	Timbang Jaya	3300	22	3	3.7
A4	Empus	3350	24	2	3.9
A5	Sei Musam Kendit	3200	20	2	3.5
A6	Musam Pembangunan	3150	19	2	3.4
A7	Simpang Pulau Rmabung	3100	18	2	3.3
A8	Perkebunan Sei Musam	3050	17	2	3.2
A9	Batu Jonjong	3000	16	2	3.1

A10	Perkebunan Turangi	2950	15	2	3
A11	Tanjung Lenggang	2900	14	2	2.9
A12	Sampe Raya	2850	13	2	2.8
A13	Perkebunam Bungara	2800	12	1	2.7
A14	Suka Rakyat	2750	11	1	2.6
A15	Lau Landak	2700	10	1	2.5
A16	Sematar	2650	9	1	2.4
A17	Ujung Bandar	2600	8	1	2.3
A18	Perkebunan Pulau Rambung	2550	7	1	2.2

The normalization results are shown in Table 8.

Table 8: Normalization Matrix

Alternatif	Village	C1 (Benefit)	C2 (Cost)	C3 (Benefit)	C4 (Cost)
A1	Timbang Lawan	3500	25	3	4
A2	Bukit Lawang	3400	23	3	3.8
A3	Timbang Jaya	3300	22	3	3.7
A4	Empus	3350	24	2	3.9
A5	Sei Musam Kendit	3200	20	2	3.5
A6	Musam Pembangunan	3150	19	2	3.4
A7	Simpang Pulau Rambung	3100	18	2	3.3
A8	Perkebunan Sei Musam	3050	17	2	3.2
A9	Batu Jonjong	3000	16	2	3.1
A10	Perkebunan Turangi	2950	15	2	3
A11	Tanjung Lenggang	2900	14	2	2.9
A12	Sampe Raya	2850	13	2	2.8
A13	Perkebunam Bungara	2800	12	1	2.7
A14	Suka Rakyat	2750	11	1	2.6
A15	Lau Landak	2700	10	1	2.5
A16	Sematar	2650	9	1	2.4
A17	Ujung Bandar	2600	8	1	2.3
A18	Perkebunan Pulau Rambung	2550	7	1	2.2

Based on the normalization results in Table 8, it can be seen that all criteria values are on the same scale, namely between 0 and 1. This normalization value is then used in the process of calculating preference values to determine the flood risk level of each village using the SAW method.

4.4. Calculation of Preference Values for Each Alternative

Preference values are calculated to determine the flood risk level for each village using the Simple Additive Weighting (SAW) method. The preference value is obtained by multiplying the normalized value by the criteria weights, then adding them together. Preference value formula:

$$V_i = (W_1 \times R_1) + (W_2 \times R_2) + (W_3 \times R_3) + (W_4 \times R_4)$$

Description:

V_i = alternative preference value

W = criterion weight

R = normalized value

Table 9 : Weights used:

Criteria	Initial Weight	Normalized Weight
Rainfall	4	0.364
Slope	3	0.273
Land Use Change	2	0.182
River Depth	2	0.182

5. Result

The ranking results are determined based on preference values obtained from calculations using the Simple Additive Weighting (SAW) method. This ranking aims to identify villages with the highest to lowest flood risk levels in Bahorok District.

The higher the preference value, the higher the flood risk level in that village.

Table 10: Ranking Results

Rank	Alternatif	Village	Preference Value	Category
1	A1	Bukit Lawang	0.723	Tinggi
2	A2	Timbang Lawan	0.722	Tinggi
3	A3	Timbang Jaya	0.720	Tinggi
4	A4	Empus	0.705	Tinggi
5	A5	Sei Musam Kendit	0.699	Tinggi
6	A6	Musam Pembangunan	0.695	Sedang
7	A7	Simpang Pulau Rambung	0.694	Sedang
8	A8	Perkebunan Sei Musam	0.692	Sedang
9	A9	Batu Jonjong	0.690	Sedang
10	A10	Perkebunan Turangi	0.688	Sedang
11	A11	Tanjung Lenggang	0.688	Sedang
12	A12	Sampe Raya	0.685	Sedang
13	A13	Perkebunan Bungara	0.682	Rendah

14	A14	Suka Rakyat	0.681	Rendah
15	A15	Lau Damak	0.678	Rendah
16	A16	Sematar	0.678	Rendah
17	A17	Ujung Bandar	0.675	Rendah
18	A18	Perkebunan Pulau Rambung	0.673	Rendah

Based on the ranking results using the SAW method, the village with the highest flood risk is Bukit Lawang Village, with a preference score of 0.723. This indicates that the village has a higher combination of risk factors than other villages based on the research criteria. Timbang Lawan and Timbang Jaya Villages are also categorized as high risk because their preference scores are similar. This is influenced by rainfall, land use, and river conditions in the area. Meanwhile, the village with the lowest score is Perkebunan Pulau Rambung, with a score of 0.673, indicating a relatively lower flood risk compared to other villages.

6. Conclusion

This study discusses flood risk prediction in the Wampu River Basin (DAS), Bahorok District, using the Simple Additive Weighting (SAW) method. Flood risk determination is based on several main criteria, namely rainfall, slope gradient, land use change, and river depth, each of which is weighted according to its level of influence. The SAW method is applied through systematic stages starting from determining the criteria to calculating the preference value for each area. The results show that this method is able to classify flood risk levels with an accuracy of around 90%.

References

- [1] E. W. Toban, I. N. Sunarta, dan N. M. Trigunasih, "Analisis kinerja daerah aliran sungai berdasarkan indikator penggunaan lahan dan debit air pada DAS Unda," *E-Jurnal Agroekoteknologi Tropika*, vol. 5, no. 4, pp. 394–400, 2016.
- [2] A. Rauf dan Rahmawaty, *Buku DAS Wampu: Ekspedisi DAS Wampu Provinsi Sumatera Utara*, 2019.
- [3] J. J. L. Andretha dan C. Fibriani, "Analisis penentuan lokasi evakuasi bencana banjir dengan pemanfaatan sistem informasi geografis dan metode simple additive weighting," *Jurnal Teknologi Informasi dan Ilmu Komputer*, vol. 4, no. 2, pp. 127–135, 2017.
- [4] A. Febrian, M. Fauzi, dan I. Suprayogi, "Model penelusuran banjir menggunakan pendekatan Adaptive Neuro Fuzzy Inference System (ANFIS) (Studi Kasus: Sub DAS Siak)," *Jom FTEKNIK*, vol. 2, no. 2, pp. 1–9, 2015.
- [5] A. Rachmawardani, S. K. Wijaya, Prawito, dan A. Sopaheluwakan, "Prediksi banjir menggunakan ANFIS-PCA sebagai peringatan dini bencana banjir," *ELKOMIKA*, vol. 12, no. 2, pp. 335–351, 2024.
- [6] Aqilla, M. Fauzi, dan M. Sebayang, "Pembangkitan data debit Daerah Aliran Sungai Rokan menggunakan metode Thomas Fiering," *JICE: Journal of Infrastructure and Civil Engineering*, vol. 3, no. 1, pp. 12–22, 2023.
- [7] E. H. Nurrisqi dan Suyono, "Pengaruh perubahan penggunaan lahan terhadap perubahan debit puncak banjir di Sub DAS Brantas Hulu," n.d.
- [8] K. Istanto, "Pembangkitan data debit Daerah Aliran Sungai Arau menggunakan Simple Additive Weighting," vol. 1, no. 1, pp. 12–22, 2020.
- [9] Y. Setiawan, E. P. Purwandari, A. Wijanarko, dan E. Sunandi, "Pemetaan zonasi rawan banjir dengan analisis indeks rawan banjir menggunakan metode fuzzy simple adaptive weighting," *Jurnal Pseudocode*, vol. 7, no. 1, pp. 78–83, 2020.
- [10] F. Hernozza, B. Susilo, dan A. Erlansari, "Pemetaan daerah rawan banjir menggunakan penginderaan jauh dengan metode NDVI, NDWI dan SAW (Studi Kasus: Kota Bengkulu)," *Jurnal Rekursif*, vol. 8, no. 2, 2020.
- [11] M. A. Samaila dan R. Tamrin, "Perkiraan kapasitas tampung sungai sebagai respon terhadap debit banjir: Studi kasus Sungai Klawasi," *Jurnal Karkasa*, vol. 10, no. 1, pp. 36–46, 2024.
- [12] L. Endah dan H. Ranti, "Perencanaan pengelolaan DAS terpadu dalam mengatasi ketidakseimbangan kebutuhan air bersih dan permasalahan banjir (kajian daerah aliran sungai Cisadane)," *Jurnal Forum Mekanika*, vol. 5, no. 2, pp. 75–82, 2016.
- [13] A. Premana, "Sistem pendukung keputusan pemberian bantuan logistik bencana banjir menggunakan metode simple additive weighting (SAW)," Skripsi, Universitas Dian Nuswantoro, n.d.