The application of a decision support system in predicting flood hazard using the analytical hierarchy process method

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Abstract. Flood disasters are natural disasters that often occur in Indonesia because of the tropics. There are many flood-prone areas that have high population density, due to lack of understanding of the community regarding flood-prone areas and many people choose settlements in a flood area without prior knowledge of the territory. These are flood-prone areas. For that purpose a built Prediction Decision Support System using Flood Vulnerability the Analytical Hierarchy Process method where on this system has five criteria, namely land slope, landform, bulk rain, land use, and soil texture. The results of this study are: the slope of land is flat, which is the criteria for the slope of the land is flat. with the results of 11.33.

1. Introduction
Flooding is a natural disaster that can be dangerous human life so it must be avoided. Indonesia is a country which is very vulnerable to various natural disasters, such as droughts, floods, land slides, volcanic eruptions, and earthquakes and tsunamis. Flooding is the biggest disaster which ranks first in Indonesia. Various triggers can cause flooding such as land changes in the upstream area with forest clearing which causes rainwater not to be absorbed by the land so that the water directly flows into the river as well development of urban areas that are not accompanied by management goodwill cause the urban drainage system to deteriorate so that the water does not flow properly so that it causes puddles. This study we took a case study in the city of Merauke. Flood disaster in general caused by the amount of rainfall that occurred in Merauke city and not accommodated surface flow discharge in existing drainage channels. This condition is exacerbated by the blockage of the channels leading to drainage. Momentary floods in general caused by the amount of rainfall that occurred in Merauke City and not accommodated surface flow discharge in existing drainage channels. This condition is exacerbated by the blockage of the channels leading to drainage. Based on these problems, this research will be carried out by implementing the AHP Analytic Hierarchy Process method. Because AHP uses the judgment of the decision supporter to structure the problem into a hierarchy [1]. AHP utilizes comparisons between each pair of items formed as a matrix. Matching comparisons produce weighting scores used to measure the number of important items and criteria for each other. Matrix calculations are then used to sort the variables to the best decisions.
2. Literature review
AHP method is able to discuss modeling problems, pair comparisons, rating scales, consistency indices, comparisons between matrices, weighting parameters, sensitivity analysis and decisions between groups [1]. The AHP method can also be used very well in evaluating a more objective problem. AHP can be a valuable tool in prioritizing an indicator. Decision-makers can use priority assessments from this study as determined by AHP. AHP has been widely used in evaluating and selecting medical technology, agriculture, capital and information system projects, project evaluation and technology [3]. AHP is a theory of measurement that is carried out through pairwise comparisons between criteria and depends on expert judgment for weighting priority scales [4]. AHP is a decision-making model that can be conceptualized and is a structured model [5]. This method has been used in a variety of decision-making problems such as: measuring individual weights from the principles of medical ethics, examining the importance of health information systems for patients with rare diseases, solving environmental impact problems, for selecting suppliers [6,7]; for to support decision making in groups [8]; and to determine and evaluate a performance [9]. AHP is a decision-making model that can be conceptualized and is a structured model [5]. This method has been used in a variety of decision-making problems such as: measuring individual weights from the principles of medical ethics, examining the importance of health information systems for patients with rare diseases, solving environmental impact problems, for selecting suppliers [6,7]; for to support decision making in groups [8]; and to determine and evaluate a performance [9].

3. Methodology
AHP is a decision-making method proposed by Saaty [1] AHP is a decision-making method proposed by Saaty [1] AHP is a decision-making method proposed by Saaty [1]. the application of the AHP method has been applied to various problems that involve planning decision making, the resource requirements needed for the application of this method, determining the various priorities needed, and determining the right decision alternatives [13]. The AHP implementation model requires 4 steps:

3.1. Step 1 : Analyzing problem objects:
The first stage is to build a structured hierarchy to make it easier to solve decision-making problems. This hierarchical structure includes criteria that are objective, multiple or singular, grading scale for each criterion, and requiring experts to suit the object under study used to evaluate. Basically, the application of the AHP method has three principles, the first requires a hierarchical framework, analyzes the priority scale on each criterion, and calculates the consistency ratio value. Building a framework and formulating it into hierarchies is the first step that must be made in the implementation of the AHP method, with the highest levels in the hierarchy being the goals of the whole, the intermediate levels in the hierarchy representing each criterion, and the lowest levels in the hierarchy is an alternative decision. After the hierarchical framework is created, then the user is asked to create a paired comparison matrix obtained from each hierarchy and to compare the pairwise comparison matrices between each user the user must use a paired comparison scale. the last step, each paired comparison matrix is then calculated to produce an eigenvector value to determine the importance of each criterion and each alternative. Pairwise comparison matrices (whose columns and rows are the contents of alternative decisions) must be formed based on the number of criteria. After determining alternatives for each matrix is formed, then the user must calculate the overall importance of each alternative. The matrix scheme is shown in figure. 1. This matrix shows the importance between criteria. In special cases, such as in currency exchanges, this matrix model matrix cannot be used [14].
Pairwise comparison calculations begin by comparing the interests between criteria. Is \( n \times (n - 1) / 2 \) which is needed in the calculation of each set of matrices. Decision-makers must assess and compare each element of the matrix using a scale of pairwise comparison. The final results of implementing decision making are returned to decision-makers.

### 3.2 Step 2: Assessment between groups:

This step has three stages. The first step, pairwise comparisons for each group must be done to determine the value of each criterion’s weight. The second step, pairwise comparisons between other groups is used to obtain the relative values obtained from the rating scale. In the application of the AHP method, verbal statements are obtained through a fundamental scale with values from one to nine. Although verbal gradation is not an important concern, there are several other numerical scales that have been proposed, see fig. 3 [15].

| Scale type                  | Mathematical description | Parameters | Approx. scale values |
|-----------------------------|--------------------------|------------|----------------------|
| Linear (Saaty, 1977)        | \( S = X \)              | \( x = \{1, 2, ..., 9\} \) | 1;2;3;4;5;6;7;8;9 |
| Power (Harker, Vargas, 1987) | \( S = X^2 \)            | \( x = \{1, 2, ..., 9\} \) | 1;4;9;16;25;36;49;64;81 |
| Root square (Harker, Vargas, 1987) | \( S = \sqrt{X} \)         | \( x = \{1, 2, ..., 9\} \) | 1;\(\sqrt{9};\sqrt{8};\sqrt{7};\sqrt{6};\sqrt{5};\sqrt{4};\sqrt{3} \) |
| Geometric (Lootsma, 1989)   | \( S = 2^{x-1} \)        | \( x = \{1, 2, ..., 9\} \) | 1;2;4;8;16;32;64;128;256 |
| Inverse linear (Ma, Zheng, 1991) | \( S = \frac{9}{(9-x)} \) | \( x = \{1, 2, ..., 9\} \) | 1;1.13;1.29;1.5;1.82;2.25;3;4.5;9 |
| Asymptotical (Dodd, Donegan, 1995) | \( S = \tanh \left( \frac{\sqrt{(x-1)}}{14} \right) \) | \( x = \{1, 2, ..., 9\} \) | 0.0;0.12;0.24;0.36;0.46;0.55;0.63;0.7;0.76 |
| Balanced (Sal Hamalainen, 1997) | \( S = \frac{w}{(1-w)} \) | \( w = \{0.5, 0.55, 0.6, ..., 9\} \) | 1;1.22;1.51;1.86;2.33;4.5;67.9 |
| Logarithmic (Ishizuka, Balkenberg, Kaplan, 2010) | \( S = \log_2(x + 1) \) | \( x = \{1, 2, ..., 9\} \) | 1;1.58;2.2;2.58;2.81;3.3;17.32 |

**Figure 2. Judgement scales used in AHP**

Harker and Vargas (1987) have conducted a quadratic scale trial and tested square roots using one simple example and debated in favor of a scale of 1 to 9 [16]. However, using one example for a quadratic scale trial, seems insufficient to conclude the use of linear scales 1–9. Lootsma (1989) argues that geometric scale is better in its use than using linear scale 1–9 [17].
Table 1. The 1-9 Fundamental Scales

| Intensity of Importance | Definition                                      |
|-------------------------|------------------------------------------------|
| 1                       | Equal Importance                               |
| 2                       | weak                                           |
| 3                       | Moderate importance                            |
| 4                       | Moderate plus                                  |
| 5                       | Strong Importance                              |
| 6                       | Strong plus                                    |
| 7                       | Very strong or demonstrated importance         |
| 8                       | Very, very strong                              |
| 9                       | Extreme importance                             |

3.3 Step 3: Assessment validation process:
The consistency ratio is obtained by comparing the consistency index with the random index (table 1, Saaty, 2005) [1]. CR has the form:

\[
\text{Consistency ratio} = \frac{\text{Consistency Index}}{\text{Random Index}}
\]  

Table 2. Random Index [18]

| n=3  | n=4  | n=5  | n=6  | n=7  | n=8  | n=9  | n=10 |
|------|------|------|------|------|------|------|------|
| Indice | 0.58 | 0.9  | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

where the value of the consistency index is obtained using equations

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]  

where the RI value is obtained from the average value of CI obtained from the random pair comparison simulation. A good CR value is not higher than 0.1.

\[
\lambda_{\text{max}} \quad \text{is the eigenvalue symbol of the pairwise comparison matrix so} \quad \lambda_{\text{max}} \gg n. \text{This equation is very good for measuring the level of consistency using the Eigen value equation. An alternative method to obtain the } \lambda_{\text{max}} \text{ value is } [14]:
\]

\[
\lambda_{\text{max}} = \sum_{j=1}^{n} \frac{(s-v)_{j}}{m-v_{j}}
\]  

4. Experimental and result

4.1. Hierarchy structure of flood vulnerability

The hierarchical structure consists of desired objectives, internal criteria achieve goals and alternatives as a result of recommendations for decisions of objectives. The following is the hierarchy structure of vulnerability decision support systems flood shown by figure 4:
4.2. Normalization of pairwise comparison matrices

After compiling the required hierarchy, then do it comparison matrix paired with Saaty scale to get weight criteria to use equation (1). the results of the calculation of the matrix are shown in the table 3.

**Table 3. The result of a pairwise comparison count**

| Criteria        | Slope of Land | Land Use | Soil Texture | landform | Rainfall |
|-----------------|---------------|----------|--------------|----------|----------|
| Slope of Land   | 1             | 3        | 3            | 1        | 1        |
| Land Use        | 0.33          | 1        | 1            | 0.33     | 0.33     |
| Soil Texture    | 0.33          | 1        | 1            | 0.33     | 0.33     |
| landform        | 1             | 3        | 3            | 1        | 1        |
| Rainfall        | 1             | 3        | 3            | 1        | 1        |
| **Total**       | **3.67**      | **11**   | **11**       | **3.67** | **3.67** |

4.3. Normalized matrix pairwise comparison criteria

After knowing the number of each column in the matrix pairwise comparison, then is to divide each element in the normalized matrix with each number of columns. The result is as follows on table 4:
4.4. Calculation of consistency ratio
This equation is used to ensure that the value of the consistency ratio (CR) <= 0.1, if the CR value is greater than 0.1 then the pairwise comparison matrix must be re-evaluated and corrected. To calculate the consistency ratio value, a table is created as below:

| Criteria       | Slope of Land | Land Use | Soil Texture | Landform | Rainfall |
|----------------|---------------|----------|--------------|----------|----------|
| Land Use       | 0.273         | 0.273    | 0.273        | 0.273    | 0.273    |
| Soil Texture   | 0.091         | 0.091    | 0.091        | 0.091    | 0.091    |
| Landform       | 0.273         | 0.273    | 0.273        | 0.273    | 0.273    |
| Rainfall       | 0.273         | 0.273    | 0.273        | 0.273    | 0.273    |

4.5. Perform pairwise comparison calculations for criteria and sub-criteria
4.5.1. The following is the result of the normalization matrix sub-criteria for slope of land

| Criteria       | Flat     | Small hilly | Hilly  | Steep hilly | Total   | Eigen Vector Priority | Result  |
|----------------|----------|-------------|--------|-------------|---------|------------------------|---------|
| Flat           | 0.522    | 0.522       | 0.522  | 0.522       | 2.087   | 0.522                  | 2.609   |
| Small Hilly    | 0.261    | 0.261       | 0.261  | 0.261       | 1.043   | 0.261                  | 1.304   |
| Hilly          | 0.130    | 0.130       | 0.130  | 0.130       | 0.522   | 0.130                  | 0.652   |
| Steep Hilly    | 0.087    | 0.087       | 0.087  | 0.087       | 0.348   | 0.087                  | 0.435   |
Table 7. The result of the normalization matrix sub-criteria for land use

| Criteria                  | Rice field, Openland | Agriculture, Dry land, Settlements | Shrubs, Grass | Plantation | Forest | Total | Eigen Vector Value | Priority | Result |
|---------------------------|----------------------|-----------------------------------|---------------|------------|--------|-------|---------------------|----------|--------|
| Rice field, Openland      | 0.490                | 0.490                             | 0.490         | 0.490      | 0.490  | 2.449 | 0.490               | 2.939    |        |
| Agriculture, Dry land, Settlements | 0.245          | 0.245                             | 0.245         | 0.245      | 0.245  | 1.224 | 0.245               | 1.469    |        |
| Shrubs, Grass             | 0.122                | 0.122                             | 0.122         | 0.122      | 0.122  | 0.612 | 0.122               | 0.735    |        |
| Plantation                | 0.082                | 0.082                             | 0.082         | 0.082      | 0.082  | 0.408 | 0.082               | 0.490    |        |
| Forest                    | 0.061                | 0.061                             | 0.061         | 0.061      | 0.061  | 0.306 | 0.061               | 0.367    |        |

Table 8. The result of the normalization matrix sub-criteria for soil texture

| Criteria                  | Very Smooth | Smooth | Rough Ground | The Ground is Very rough | Total | Eigen Vector Value | Priority | Result |
|---------------------------|-------------|--------|--------------|--------------------------|-------|---------------------|----------|--------|
| Very Smooth               | 0.558       | 0.558  | 0.558        | 0.558                    | 2.233 | 0.558               | 2.791    |        |
| Smooth                    | 0.279       | 0.279  | 0.279        | 0.279                    | 1.116 | 0.279               | 1.395    |        |
| Rough ground              | 0.093       | 0.093  | 0.093        | 0.093                    | 0.372 | 0.093               | 0.465    |        |
| The ground is very rough  | 0.070       | 0.070  | 0.070        | 0.070                    | 0.279 | 0.070               | 0.349    |        |

Table 9. The result of the normalization matrix sub-criteria for landform

| Criteria                  | Floodplain | Coast | Total | Eigen Vector Value | Result |
|---------------------------|------------|-------|-------|---------------------|--------|
| Floodplain                | 0.875      | 0.875 | 1.75  | 0.875               | 2.625  |
| Coast                     | 0.125      | 0.125 | 0.25  | 0.125               | 0.375  |

Table 10. The result of the normalization matrix sub-criteria for rainfall

| Criteria                  | Very High | High | Medium | Low | Very Low | Total | Eigen Vector Value | Result |
|---------------------------|-----------|------|--------|-----|----------|-------|---------------------|--------|
| Very High                 | 0.490     | 0.490| 0.490  | 0.490| 0.490    | 2.449 | 0.490               | 2.939  |
| High                      | 0.245     | 0.245| 0.245  | 0.245| 0.245    | 1.224 | 0.245               | 1.469  |
| Medium                    | 0.122     | 0.122| 0.122  | 0.122| 0.122    | 0.612 | 0.122               | 0.735  |
| Low                       | 0.082     | 0.082| 0.082  | 0.082| 0.082    | 0.408 | 0.082               | 0.490  |
| Very Low                  | 0.061     | 0.061| 0.061  | 0.061| 0.061    | 0.306 | 0.061               | 0.367  |

4.6. Calculate results
After calculating each criterion and subcriterion, we must calculate the results of the implementation of the use of the AHP method in the case of flood prediction. For example we use 5 sample data to calculate ranking using the AHP method. Table 11 below is a value from the calculation of criteria and subcriteria.
Table 11. Priority table of criteria and sub criteria

| Slope of land | Land use                  | Soil texture | Landform | Rainfall |
|---------------|---------------------------|--------------|----------|----------|
| Flat (2.609)  | Rice Fields, Open Land    | Very Smooth  | Floodplain| Very High|
| (2.939)       | (2.791)                   | (2.625)      | (2.939)  |
| Small Hilly (1.395) | Agriculture, Dry Land, Settlement | Smooth | Coast | High |
| (1.469)       | (1.395)                   | (0.375)      | (1.469)  |
| Hilly (0.652) | Shrubs, Grass             | Rough Ground | Medium | (0.735)  |
|               | (0.735)                   | (0.465)      | (0.735)  |
| Steep Hilly (0.435) | Plantation | The Ground is Very Rough | Low | (0.490) |
|               | (0.490)                   | (0.349)      | (0.490)  |
|               | Forest                    |              |          | (0.367)  |
|               | Very Low                  |              |          | (0.367)  |

Then given value data for 5 districts, namely district A, district B, district C, district D, and district E as shown in table 12 below

Table 12. Sample data in each district

| Slope of Land | Land use                  | Soil texture | Landform | Rainfall |
|---------------|---------------------------|--------------|----------|----------|
| District A    | Flat                      | Agriculture, Dry Land, Settlement | Smooth | Floodplain | Medium |
| District B    | Small Hilly               | Shrubs, Grass | Rough Ground | Coast | High |
| District C    | Small Hilly               | Agriculture, Dry Land, Settlement | Rough Ground | Floodplain | Medium |
| District D    | Flat                      | Agriculture, Dry Land, Settlement | Rough Ground | Floodplain | Medium |
| District E    | Flat                      | Shrubs, Grass | The Ground is Very Rough | Floodplain | Medium |

The final results are obtained from priority multiplication criteria and subcriteria priority. As seen in the table 13 below:

Table 13. Results table

| Slope of Land | Land use                  | Soil texture | Landform | Rainfall | Total |
|---------------|---------------------------|--------------|----------|----------|-------|
| District A    | 1.636* 2.609 0.545* 1.469 | 0.545* 1.395 | 1.636* 2.625 | 1.64*0.735 | 11.33 |
| District B    | 1.636* 1.395 0.545* 0.735 | 0.545* 0.465 | 1.636* 0.375 | 1.64*1.469 | 5.96  |
| District C    | 1.636* 1.395 0.545* 0.735 | 0.545* 0.465 | 1.636* 2.625 | 1.64*0.735 | 8.83  |
| District D    | 1.636* 2.609 0.545* 1.469 | 0.545* 0.465 | 1.636* 2.625 | 1.64*0.735 | 10.82 |
| District E    | 1.636* 2.609 0.545* 0.735 | 0.545* 0.349 | 1.636* 2.625 | 1.64*0.735 | 10.36 |
5. Conclusion

In this study, we applied the concept of decision making to predict flood-prone areas in the city of Merauke. This study uses 5 samples of data taken in each district. The application of the AHP method in this study is able to provide decision-makers in determining flood-prone areas. The results of the implementation of the AHP method are in the form of ranking obtained from the calculation of pairwise comparisons between criteria and subcriteria that follow the rules of decision making of the AHP method. Then the results were obtained that district A which has the criteria of Slope of land is Flat, Land Use is Agriculture, dry land and settlements, soil texture is smooth, landform is floodplain and rainfall is medium gets the highest order of assessment results of this study with the results of 11.33.

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