Disaster mitigation-based land suitability for settlements using Multi-Criteria Evaluation (MCE) method in The Northern Part of South Barito Regency

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Abstract. Settlements are indispensable to humans as a place of residence and for other activities. Moreover, there is an increase in land requirements for settlement construction due to the high population. The development of cities and settlements in the context of SDGs needs consideration to mitigate, adapt to climate change, and resist disasters. Therefore, this study aims to identify, analyze, and describe disaster mitigation-based land suitability and availability for settlements in the Northern Part of South Barito Regency. The method used was Multi-Criteria Evaluation (MCE), while the inclusion criteria are slope, soil type, rocks, drainage, soil texture, elevation, land use, and distance to the rivers. Each criterion was weighted using an AHP, while scoring and map overlaying were carried out using a GIS to determine the class of land suitability. The flood hazard map was used to obtain the area of free flooding. The results showed that actual land suitability for the most extensive settlements is in the S2 (Moderately Suitable) class. Meanwhile, the land that is used without flood hazards is approximately 18.9% of the Northern Part of South Barito Regency landmass. This analysis is used as consideration by policymakers to develop spatial planning in South Barito Regency.

1. Introduction
Sustainable development is the process of optimizing the use of natural resources to meet the current generation's needs without compromising the future[1]. Moreover, settlements are indispensable to humans as a place of residence where several activities are carried out. The increase in population and various human needs lead to the high demand for land for settlements and also cause people to exploit natural resources regardless of the environmental capabilities. Due to this effect, there is a decrease in the quality of the environment. One of these impacts is the increase in disasters, especially flooding in quantity and quality [2].

South Barito Regency is located in Central Kalimantan Province with a total population of 136,267 people in 2019 [3]. This is a rain shadow and water runoff area which originates from the mountains/hills in the upper Barito River, therefore, the natural disaster that often occurs is flooding [4]. In early 2020, flooding occurred in several villages from 6 sub-districts in South Barito due to the overflow of the Barito River. Furthermore, 62 points are also prone to flooding in the area due to persistent rainfall in the upper part of the Barito River with high intensity. Almost all major residential centers are in low-topographical areas, therefore, many settlements were flooded and more than 1,500 families were affected [5]. This flooding caused damage to buildings, residences, infrastructure facilities, and others [6]. According to BPBD South Barito Regency [5], material losses were...
relatively high and more than 500 houses were with a water level up to 200 cm while access to some areas between districts was damaged until it was cut off.

By the mandate of Law No. 26 of 2007 on Spatial Planning geographically, the Unitary State of the Republic of Indonesia is in a disaster-prone area, therefore, disaster mitigation-based spatial arrangement is required to improve the safety and comfort of Indonesians. Based on Law No. 24 of 2007 on Disaster Management implementation, disaster management consists of pre-disaster, emergency response, and post-disaster (rehabilitation and reconstruction period). This law was followed up by issuing the Regulation of the Head National Disaster Management Agency No. 2 of 2012 concerning General Guidelines for Disaster Risk Assessment [7], which became a more detailed guideline for conducting spatial planning based on disaster mitigation to reduce risk. Meanwhile, strict planning is required for more efficient land use in the future [8].

Mitigation is defined as a continuous effort to reduce the risk of harm by minimizing the possibility of such hazard or ease the adverse effects when it occurs [9]. One form of mitigation effort is to create and develop a plan to reduce the impact caused by flooding. The first step is to evaluate the land which is the process of determining the suitability of land for settlements. This process also compares land characteristics as a condition to decide which areas are used for residential purposes [10].

Land suitable for development needs to have the criteria that meet the suitability for settlements. Meanwhile, residential land needs to pay attention to spatial plans and disasters such as flooding. One of the goals of SDGs (Sustainable Development Goals) number 11 is to make cities and settlements inclusive, safe, resilient, and sustainable. In addition, the development of SDGs needs to include mitigation, adaptation to climate change, and withstand disasters such as flooding. Moreover, technology development is the key to sustainability that protects the environment from potential damage caused by technological advances [11]. One of these is through the use of Geographic Information System (GIS) technology. Therefore, this study aims to evaluate land suitability for settlements and provide information for policymakers to develop a settlement area in South Barito Regency.

2. Method

2.1. Study Area

The study was conducted from January to June 2021 in The Northern Part of South Barito Regency, Central Kalimantan Province. Meanwhile, South Barito Regency has an area of 8,830 km² or 5.57% of the scope of Central Kalimantan. Geographically, this regency is located longitudinally along the Barito River with an astronomical location between 1°20 LS - 2°35 LS and 114° - 115° E. In addition, it has 6-sub districts which consists of Dusun Selatan, Utara, and Hilir, Jenamas, Karau Kuala, and Gunung Bintang Awai.

![Figure 1. Research location of Northern Part of South Barito Regency.](image-url)
2.2. Data
Spatial data used include Land Map Unit with a scale of 1: 50,000 from Balai Besar Sumber Daya Lahan Pertanian (BBSDLP), SPOT 7image 2020, Spatial Plan Map (RTRW) Regency in 2014-2034 from the Office of ATR / BPN South Barito Regency, Geology Map from DPUPR South Barito Regency, Flood hazard Map in 2020 with scale 1: 360,000 from Regional Disaster Management Agency (BPBD) of South Barito Regency, Digital Elevation Model Data (DEM), and Indonesia Earth Map (RBI) South Barito Regency scale 1:50,000. The data generated were used to overlay the criteria of the land unit map. In addition, respondent data from experts related to the study were used to calculate weights using Analytical Hierarchy Process (AHP).

2.3. Analysis
The analysis of land suitability for settlements was conducted using a Multi-Criteria Evaluation (MCE) approach. This method is a multi-attribute decision-making approach for analyzing land suitability in landscape planning, site selection, land use planning, environmental hazards, and sustainable development [12]. Meanwhile, multi-criteria decision making is one of the essential branches in decision theory that is used to identify the best among all the available possible solutions [13]. One of these decision-making methods is the use of the Analytical Hierarchy Process (AHP) developed by Thomas L. Saaty in the 1970s.

AHP is a method for solving complex and unstructured situations of several components in a multi-level arrangement. The determination of weighting criteria of land suitability for settlements is through the AHP method from the expert assessment which is conducted on a scale of 1 to 9 with a pairwise comparison. After the calculation, the value of consistency ratio (CR) is obtained, which is the level of consistency in assessing two criteria. When a CR value of ≥ 0.10 occurs, a recalculation is performed to determine the comparative importance of the two criteria [14].

According to Chaira and Koppelman [15], the criteria for conformity of residential land is to meet the requirements of a) strong foundation, b) security supply, c) comfort and efficiency, and 4) support established structures. Moreover, Widiatmaka and Hardjowigeno [16], stated that the criteria for the suitability of residential land are slope, flood, drainage, gravel, texture, and adequate depth. In this study, settlement conformity criteria were from libraries, books, and journals related to the evaluation of land suitability. Meanwhile, the criteria used include variables that are directly related to residential activities such as slope, land use, drainage, rocks, elevation, distance to the river, soil texture, and soil type.
Figure 2. Spatial distribution of A. distance to river¹; B. drainage²; C. elevation³; D. geology⁴; E. Land use⁵; F. slope²; G. soil order²; H. soil texture². Data sources: ¹⁾ RBI Map of South Barito Regency scale 1:50,000; ²⁾ Land Map Unit scale 1: 50,000 from BBSDLP; ³⁾ Data DEM; ⁴⁾ Geology Map from DPUPR Barito Selatan Regency; ⁵⁾ SPOT 7 image 2020.

In addition to weighting criteria, each sub-criterion was carried out using AHP and the land suitability class is determined by scoring after overlaying the entire map. The score value is from multiplying the weight gained from AHP with the Harkat which determined the land conditions. This score is summed up with the 8th criterion measured and produces a value that specifies the class of land suitability. Meanwhile, four classes of land suitability include highly (S1), moderate (S2), marginal (S3), and not suitable (N). Land suitability for settlements is determined using the following equation [17]:

\[ I = \frac{c-b}{k} \]

Description : I = large distance interval class; c = highest number of scores; b = lowest number of scores, k = number of desired classes.
Analysis of the land potential for settlements was conducted to determine land availability for settlement development in South Barito Regency. The study was conducted by overlaying pattern maps of Spatial Plans, flood-hazard, and actual land suitability for settlements in the South Barito Regency.

Figure 3. Spatial distribution of A. Flood-hazard maps in Northern part of South Barito Regency¹; B. Spatial Plan Map (RTRW) Regency in 2014-2034 in Northern part of South Barito Regency². Data sources: ¹⁾Flood hazard Map in 2020 scale 1: 360,000 from BPBD South Barito Regency; ²⁾, Spatial Plan Map (RTRW) Regency in 2014-2034 from the Office of ATR / BPN South Barito Regency.

3. Result and Discussion

Weighting criteria for the class of land suitability for settlements with AHP are shown in figure 4. The consistency value in the calculation is 99.4 % while the inconsistency ratio (CR) is 0.006 %. This shows that the assessment given by experts is very consistent and is used as a parameter to determine the class of land suitability for settlements. Furthermore, the result is considered valid with a CR value of < 10% which shows that the decision was not assumed [18].

Based on these results, slopes are the criteria that play the most important role in determining the class of land suitability for settlements. This is because, as the slope becomes steeper, the erosion and damage to land become higher including settlements. In Permen Law No. 41, the utilization of land for settlement depends on the carrying capacity of local land, which includes the provision of a healthy and safe environment from natural disasters. For settlements purpose, flat land is better used due to safety factors against erosion. Meanwhile, the minor criteria to determine the class of land suitability for settlements is soil order.

| Criteria       | w' | Weight |
|----------------|----|--------|
| Slope          | 0.35 | 35%   |
| Distance to river | 0.20 | 20%   |
| Land use       | 0.13 | 13%   |
| Drainage       | 0.10 | 10%   |
| Rocks          | 0.08 | 8%    |
| Elevation      | 0.05 | 5%    |
| Texture        | 0.05 | 5%    |
| Soil order     | 0.04 | 4%    |

| Criteria       | w' |
|----------------|----|
| Ri             | 8.4 |
| Ci             | 0.05 |

CR = 0.006 (0.6 %)

Description: n = 8 (Criteria); Consistency index (Ci) = (\(\gamma_{\text{max}} - n\))/(n - 1); Random index (Ri); Consistency ratio (Cr) = Ci/Ri.
After determining each criterion’s weight, choose the dignity of the subcriteria by calculating the weight equally. The results are shown in Table 2, while Harkat is given from a value of 1 to 10.

| Criteria       | Sub-criteria               | Area ha | %    | w'  | Harkat |
|---------------|---------------------------|---------|------|-----|--------|
| Slope         | 0 - 8 %                   | 216,782.1 | 63.60 | 0.48 | 10     |
|               | 8 - 15 %                  | 42,211.8  | 12.39 | 0.29 | 6      |
|               | 15 - 25 %                 | 57,876.8  | 16.75 | 0.15 | 3      |
|               | 25 – 40 %                 | 17,318.8  | 5.08  | 0.05 | 1      |
|               | > 40 %                    | 7,436.5   | 2.18  | 0.03 | 1      |
| Distance to river | ≥200 meter                | 328,257.1 | 94.52 | 0.69 | 10     |
|               | 100 meter                 | 9,369.5   | 2.70  | 0.21 | 2      |
|               | 50 meter                  | 9,662.5   | 2.78  | 0.10 | 1      |
| Land use      | Settlement                | 3,340    | 0.96  | 0.39 | 10     |
|               | Bared land                | 56.1     | 0.02  | 0.16 | 4      |
|               | Scrub                     | 28,702.8 | 8.26  | 0.16 | 4      |
|               | Secondary dryland forest  | 271.7    | 78.45 | 0.07 | 2      |
|               | Mining                    | 1,067.6  | 0.31  | 0.06 | 2      |
|               | Primary dryland forest    | 26,041.8 | 7.49  | 0.04 | 1      |
|               | Plantation                | 3,879.8  | 0.89  | 0.03 | 1      |
|               | Food Crop Farming         | 7,413.7  | 2.02  | 0.02 | 1      |
|               | Waterbody                 | 5,642.6  | 1.62  | 0.02 | 1      |
| Drainage      | Good                      | 168,638.4 | 49.48 | 0.58 | 10     |
|               | Fast                      | 27,910.2 | 8.19  | 0.10 | 2      |
|               | Rather fast               | 3,447.5  | 1.01  | 0.08 | 1      |
|               | Medium                    | 39,738.4 | 11.48 | 0.07 | 1      |
|               | Slightly hampered         | 15,903.1 | 4.67  | 0.07 | 1      |
|               | Hampered                  | 72,409.4 | 21.25 | 0.06 | 1      |
|               | Very hampered             | 13,378.9 | 3.93  | 0.04 | 1      |
| Rocks         | Pitap Formation           | 5,957.5  | 1.72  | 0.22 | 10     |
|               | Alluvium deposit          | 116,217.7 | 33.52 | 0.18 | 7      |
|               | Tanjung Formation         | 3,797.11 | 3.04  | 0.16 | 5      |
|               | Warukin Formation         | 16,717.2 | 4.68  | 0.12 | 3      |
|               | Pamaluan Formation        | 66,229.8 | 19.10 | 0.10 | 1      |
|               | Dahor Formation           | 105,541.9 | 30.44 | 0.09 | 1      |
| Elevation     | 10 - 40 m                 | 123,623.9 | 35.59 | 0.46 | 10     |
|               | 40 - 100 m                | 175,816.3 | 50.63 | 0.27 | 5      |
|               | 100 - 500 m               | 42,746.6  | 12.31 | 0.17 | 2      |
|               | 500 - 2000 m              | 380.6    | 0.11  | 0.10 | 1      |
| Texture       | Medium                    | 40,498.8 | 11.82 | 0.58 | 10     |
|               | Fine                      | 143,727.5 | 42.11 | 0.24 | 2      |
|               | Coarse                    | 113,748.4 | 33.32 | 0.18 | 1      |
| Soil order    | Alfisols                  | 13,759.1 | 3.75  | 0.32 | 10     |
|               | Entisols                  | 16,877.4 | 4.85  | 0.2  | 6      |
|               | Inceptisols               | 125,652  | 36.97 | 0.18 | 6      |
|               | Ultisols                  | 74,446.5 | 21.91 | 0.17 | 6      |
|               | Spodosols                 | 67,453.6 | 19.73 | 0.11 | 4      |
|               | Histosols                 | 43,449.2 | 12.79 | 0.02 | 1      |

Sources: see figure 2
The harkat of each sub-criteria determines the final scoring value for the land suitability class. This scoring value is from the multiplication result between the harkat value and criteria weight. Meanwhile, the scoring results were generated at intervals to determine each land suitability class for settlements from highest to lowest value. The intervals were created in 4 categories, namely S1 (Highly Suitable), S2 (Moderately Suitable), S3 (Marginaly Suitable), and N (Not Suitable) and each class was at a 1.6375 interval. Therefore, the higher the scoring value, the more suitable the land for settlements.

**Table 3. Interval class of land suitability for settlement.**

| Class                        | Interval     |
|------------------------------|--------------|
| S1 (Highly Suitable)         | 9.6000 – 7.7825 |
| S2 (Moderately Suitable)     | 7.7824 – 5.9651 |
| S3 (Marginaly Suitable)      | 5.9650 – 4.1475 |
| N (Not Suitable)             | 4.1474 – 2.3300 |

The land is suitable for settlements at 99.1% while it is not suitable at 1%. The average land suitability for settlements is in class S2 (Moderately Suitable) with the highest area of 234,978.05 ha or 69%. This class shows that the conditions are suitable enough to be used for settlement, however, additional costs are required to overcome the limiting factors. Efforts of building settlements in this region is not a bad risk, meanwhile, it needs specific technical requirements. Moreover, the spread of this class is dominant in the left part of the study area.

The second-largest land suitability class is S3 (Marginaly Suitable) with 92,840.59 ha or 27% of The Northern Part of South Barito. This percentage shows that the land is in poor condition for settlement and other inhibitory factors. This class is predominantly spread over the right part of the study area. Furthermore, the area in class S1 (Highly Suitable) is small with approximately 10,813.51 ha or 3% of The Northern Part of South Barito Regency. In this class, there is no significant limiting factor and the conformity value is very appropriate, therefore, no technical matters are required. In the Not Suitable (N) class, there is approximately 2,964.07 ha or 1% of the study area. This class shows that the land is terrible for settlement due to many inhibitory factors. The following map of land suitability for settlements in the research area is presented in figure 4 and the proportion of area of each class is presented in table 4.

Analysis of the potential land used for settlements shows that the available area is 65,399.2 ha or approximately 18.9% of The Northern Part of South Barito Regency while approximately 276,160.8 ha or 81.1% is not available. The potential land availability and suitable for settlements that are safe from flood disasters was obtained covering an area of 43,964.7 ha or 13.8% of the area of research. The distribution of potential land availability for settlements was conducted using considerations from the Spatial Plan (RTRW) 2014-2024 of South Barito Regency and flood hazard. Meanwhile, the potential of available land needs to consider a disaster because spatial planning includes the issue of disaster in the regulation of Law No. 26 of 2007 on the establishment of space. In spatial planning, there is a need for disaster mitigation, therefore, this study focuses on flooding disasters which is the most common disaster in the area. The following map of land availability for settlements in the research area is presented in figure 5 and the proportion of area of each class is presented in table 5.

Mitigation aims to minimize the adverse effect to the community, therefore, spatial planning as a platform is adapted to flood disasters to reduce the risk. A previous study by Lahamendu [19], stated that there is a need for strict rules in improper land use that do not conform to spatial patterns. Moreover, flood mitigation is carried out in two forms, namely structural and non-structural which is taken in form of making zones potentially vulnerable. In this study, flood hazard maps became essential parameters in determining the potential of land available for settlements in the South Barito Regency, therefore, mitigation is incorporated. Disaster is a veiled opportunity regardless of death, suffering, and destruction, it offers a new beginning and proper planning to resist the dangers of the previous destruction [20].
Figure 4. Map of land suitability for settlements.

### Table 4. Summary of land suitability for settlements.

| Class                    | Land Suitability | %  |
|--------------------------|------------------|----|
| S1 (Highly Suitable)     | 10,813.51        | 3  |
| S2 (Moderately Suitable) | 234,978.05       | 69 |
| S3 (Marginally Suitable) | 92,840.59        | 27 |
| N (Not Suitable / Not available) | 2,964.07   | 1  |
| **Total**                | 341,596.22       | 100|

Sources: see figure 4

Flood hazards and losses are prevented and minimized by providing accurate information to the public about the risk through flood risk maps [21]. According to [22], the most reasonable effort in disaster mitigation is through community involvement in land use planning. Through participatory planning, the community understands and accommodates the development demands in areas vulnerable to natural disasters. Meanwhile, participatory planning is among the efforts to reduce development conflicts and be involved. Furthermore, disaster mitigation-based land suitability maps are also helpful in relocation planning for settlement construction and to protect people from harm [20].

Figure 5. Map of land availability for settlements.
Table 5. Summary of land availability for settlements.

| Class                     | Level of Flood Hazard | Land Availability | Ha  | %       |
|---------------------------|-----------------------|-------------------|-----|---------|
| Available                 |                       |                   |     |         |
| S1 (Highly Suitable)     | Safe                  | 786.2             | 0.4 |         |
|                           | Low                   | 374.1             | 0.1 |         |
|                           | Moderate              | 441.0             | 0.1 |         |
|                           | High                  | 219.5             | 0.1 |         |
| S2 (Moderately Suitable) | Safe                  | 17,820.4          | 6.0 |         |
|                           | Low                   | 11,759.7          | 3.4 |         |
|                           | Moderate              | 2,449.9           | 0.7 |         |
|                           | High                  | 2,144.6           | 0.6 |         |
| S3 (Marginally Suitable) | Safe                  | 7,260.5           | 2.1 |         |
|                           | Low                   | 1,247.8           | 0.4 |         |
|                           | Moderate              | 431.7             | 0.1 |         |
|                           | High                  | 613.0             | 0.2 |         |
| Potential Available      |                       |                   |     |         |
| S1 (Highly Suitable)     | Safe                  | 1,567.3           | 0.5 |         |
|                           | Low                   | 220.9             | 0.1 |         |
|                           | Moderate              | 61.0              | 0.02|         |
|                           | High                  | 12.9              | 0.004|        |
| S2 (Moderately Suitable) | Safe                  | 12,047.5          | 3.5 |         |
|                           | Low                   | 1,096.2           | 0.3 |         |
|                           | Moderate              | 148.1             | 0.04|         |
|                           | High                  | 68.1              | 0.02|         |
| S3 (Marginally Suitable) | Safe                  | 4,522.8           | 1.3 |         |
|                           | Low                   | 131.6             | 0.04|         |
|                           | Moderate              | 7.8               | 0.002|        |
|                           | High                  | 3.6               | 0.001|        |
| Total                     |                       | 65,399.2          | 18.9|         |
| N (Not Suitable)         |                       | 365.6             | 0.1 |         |
| Not Available             |                       | 275,795.2         | 81  |         |
| Total                     |                       | 341,590           | 100 |         |

Sources: see figure 5

4. Conclusion
Based on the results, planning of land for settlements requires mitigation to minimize the risk and losses due to disasters. Meanwhile, the construction of settlements needs to follow the potential of land sustainability. The Multi-Criteria Evaluation approach helped in analyzing the potential of land for settlements based on disaster mitigation. In addition, flood-hazard maps were used as disaster mitigation tools to obtain potentially safe areas as settlements. The weighting analysis of AHP showed that slopes are the most influential factors in determining land for settlements with a percentage of 35%. Moreover, actual land suitability for dominant settlements was in class S2 with an area of 234,978.05 ha or 69%. Similarly, the land available for settlements is 65,399.2 ha or approximately 18.9% of the study area. Therefore, these results are developed into regional planning for settlements disaster mitigation based on sustainable development.

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