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Mining Zone Determination of Natural Sandy Gravel using Fuzzy AHP and SAW, MOORA and COPRAS Methods

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Abstract: Indonesia is one country that is rich in natural resources, both natural, marine and air resources. The existence of abundant resources is not properly utilized by the people of Indonesia. Improper use of resources will cause environmental damage. One form of environmental destruction is natural Sandy Gravel (Sirtu) mining activities in Kediri Regency. This study aims to map potential place for mining areas assessed using Geographic information system (GIS) and Multi criteria choice Making (MCDM) using Simple Additive Weighting Method (SAW), Multi Objective Optimization on the basis of Ratio Analysis Method (MOORA) and Complex Proportional Assessment Method (COPRAS). The weighting of the criteria used in this study is based on the Fuzzy Analytical Hierarchy Process (F-AHP) method. GIS is used to score the criteria and build the decision matrix needed by the MCDM method. The criteria used in this study are based on UU Republik Indonesia 4/2009. Those criteria are grouped into 3 categories which are natural factors, environmental factors, and aesthetic factors. Natural Factors have sub-criteria such as geomorphology, lithology, and hydrology. Environmental factors are comprised of vegetation, wildlife, distance from main road, distance from settlements, and population density. While aesthetic factors consist of natural features and touristic places. The results showed that from the three methods used which are SAW, MOORA and COPRAS methods, the most suitable method was the COPRAS method with 19/19 aggregation values. The order of sub-districts in Kediri Regency with the most suitable potential for Natural Sandy Gravel (Sirtu) is as follows: Kras, Bulan, Papar, Tarokan, Purwoasri, Mojo, Pare, Ngadiluwih, Kukung, Kandatel, Gampengrejo, Semen, Grogol, Plosoklaten, Ngancar, Puncu, Wates, Kepung, Kandangan.

Keywords: MCDM, Fuzzy AHP, GIS, COPRAS, MOORA, SAW, Mining zone.

1. Introduction

Indonesia is a country comprised of many islands which contains enormous natural resources. Some of those natural resources can be gathered by mining activities. Some regions in Indonesia are famous for natural resources produced from mining activities. Those natural resources Is then can be utilized for various things to improve our lives. Unfortunately, Natural Resources such as natural sandy gravel is limited so that their use needs some considerations. Natural sandy gravel (Sirtu) in Gunung Kelud are a product of active volcanic activity. Thus, places in the Kediri Regency are ideal for the mining location of these resources. There are numerous mining activities which reduce the potential held of natural sandy gravel after mining activities. Thus, mining in the same location for a long time would reduce the profit yield from the natural resource. Hence, determine the zone which the mining activities should be held is important.

To determine the location for natural sandy gravel mining, there are several factors that needs considerations. Those factors are natural factors, environmental factors, and aesthetic factors. Since there are multiple factors that is needed for considerations, Multi Criteria Decision Making (MCDM) method can be utilized. MCDM method is used to determine the best suited alternatives based on given criteria [1]. Thus, the location of the mining activities will be the best suited to the criteria.

The MCDM method that we utilize in this study are Simple Additive Weighting (SAW), Multi Objective Optimization on the Basis of Ratio Analysis (MOORA), and Complex Proportional Assessment (COPRAS). SAW have been used in several studies ranging from singer selection based on vowel intonation and several other criteria [2], and second-hand motorcycle [3]. MOORA have also been used in decision making system for building location [4], [5], and some production decision making process [6–8]. While, COPRAS has also performed good in several studies such as Building refurbishment decision support[9], Selection of low-e windows [10], optimizing blind spot of heavy vehicles [11], and material selection problem [12]. Using the mentioned methods, this study tries to determine the most suitable location for mining natural sandy gravel.

The main contribution of this paper is the MCDM method that is most suitable for this case with Fuzzy Analytic Hierarchy Process (AHP) to determine the weight of each criteria. By utilizing fuzzy AHP as a criterion weighting method, the result can reflect the actual importance of each criterion compared to the previous research where the weight of each criterion was not known [1]. This research is comprised of as follows: section 2 which explains the related theory to support this research, section 3 shows the proposed method, section 4 describes the results and analysis of the experiment, and section 5 concludes the research.

2. Related theory

Multi Criteria Decision Making (MCDM) method have been used to solve which alternative that should be used based on 2 or more criteria. MCDM have been employed in various research with various problems such as Multi-objective problem considering user preference [13], selecting Serbian banks [14], machine tool selection [15], supplier of healthcare selection [16], port choice [17], selection of clustering methods [18].

Simple Additive Weighting (SAW) have been implemented to select singers based on some criteria [2]. In the study, using SAW and Analytic Hierarchy Process (AHP) shows that compared to expert judgements, the result of the MCDM method achieve 84.61% accuracy. Another research using SAW shows a promising result in selecting a second-hand motorcycle based on some criteria [3]. Thus, shows the capability of SAW method in multi criteria decision making process.

Multi Objective Optimization on the Basis of Ratio Analysis (MOORA) have been implemented in several studies. MOORA shows a great result on its accuracy compared to several other MCDM method [1]. Other research using MOORA as the MCDM method shows that MOORA can handle MCDM problem on many case studies. MOORA have been used for selecting the best cutting parameters in milling process [7]. Other research on warehouse location selection shows that even if MOORA is more simple the performance of MOORA is similar to Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [5]. On welding process, MOORA have been successfully determine the optimal welding parameter such as the voltage, electricity current, electrode diameter, and welding speed for the best welding result [8].

Complex Proportional Assessment (COPRAS) have been favoured along with TOPSIS for material selection [12]. Based on the research, COPRAS is a simple MCDM method that can be implemented for real problem. Other research using COPRAS as an MCDM method to select low-e windows in a building retrofit [10]. COPRAS shows its capabilities to select windows and cut the window replacement costs.

AHP have been employed in various research for different purposes. AHP have been used to determine which criteria gives more contribution in a case compared to other criteria [19]. Fuzzy AHP as a method to determine the weight of criteria for MCDM method have been done in the past[20]. Based on the research, Fuzzy AHP have been successfully utilized to determine the weight of the criteria for optimization of solar farm site in Bali, Indonesia.

To select the best MCDM method, other research uses aggregation to show which method is the most suitable for the given case. A research uses the method sensitivity to criteria weight [21], while other research uses both sensitivity and accuracy[1]. However, the previously mentioned research tests the effect of weight change to the methods result. This research aims to simplify the process using method that is used to determine the suitable weight for each criterion.

3. Research method

This study combines the Fuzzy AHP process for weighting criteria and the spatial data analysis process using ArcMap 10.2.2. The ranking order of each alternative is determine using the SAW, MOORA and COPRAS methods. The results of the three ranking sequences are then compared.

Fig. 1 shows the whole proposed method of this study. First, we create a questionnaire to share to the experts which determine each criteria weight. Fuzzy

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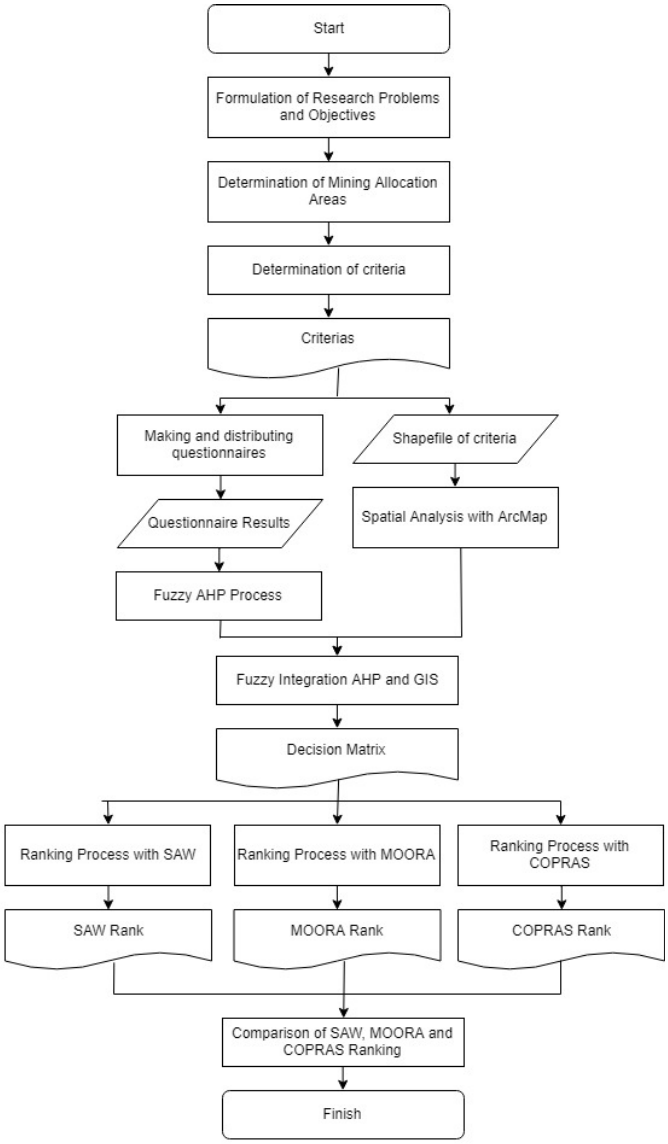

Figure 1. Research methodology

AHP is then employed to generalize the weight that is needed for MCDM method later. Since we already got the weight for each criterion, MCDM methods are then employed and produce rank of its own. The results of the MCDM methods are then compared using the accuracy based on recent studies[1].

3.1 Determination of mining areas

Determination of Mining Allocation Areas is based on local regulations governing Spatial and Regional Plans in Kediri District and Kediri City. There are 2 Regional Planning and Spatial Planning Regulations in Kabupaten Kediri, namely:

1. Peraturan Bupati Kediri No. 50 Year 2015 about mining allocation areas in Kediri Regency)
2. Peraturan Bupati Kediri No. 57 Year 2015 about allotment areas for Minerals and Non-Metallic Rocks in Kediri Regency.

While the Regional Plan and Spatial Planning in the City of Kediri is Peraturan Daerah Kota Kediri Number 1 Year 2012 about spatial planning of the City of Kediri in 2011 – 2030, based on these three basic regulations, the regions that are not intended for the mining area is not included in this study.

3.2 Determination of criteria

Determination of criteria is done by the Delphi Method, but the basis for determining the proposed criteria is the development of the definition contained in Law No. 4 year 2009 concerning Mineral and Coal Mining.

The Delphi method in this study was conducted in several rounds. In the first round, the questionnaire was distributed to respondents which are the expert of the field of work. From this round, the expected criteria were obtained. Then, the identified criteria were reassessed by respondents in the second round and the agreed criteria is then retrieved. These criteria were included in the third round and the following rounds until all respondents agreed to all the criteria.

3.3 Fuzzy AHP process

Fuzzy AHP (FAHP) is a ranking method. FAHP is a combination of AHP method and fuzzy concept approach. F-AHP covers the weaknesses found in the AHP, namely the problem with criteria that have more subjective traits. The uncertainty of numbers is represented by a sequence of scales [22]. Fuzzy AHP utilizes Triangular Fuzzy Number (TFN) to determine the degree of membership of each criterion. So, the number at the level of intensity of interest in the AHP is transformed into the TFN scale. Chang (1996) defines the value of AHP intensity into a fuzzy triangle scale which divides each fuzzy set by 2, except for intensity of interest 1 [22].

In this study, the Fuzzy AHP method was used as an attempt to answer the sequence of potential zones of Sirtu mining in Kediri Regency including the weight of every criteria.

3.4 Spatial analysis with arcmap

In this study the data in the form of maps are converted into digital format and are combined to produce a map overlaying the order of importance of a criterion. Based on the consideration of the analysis a decision system matrix was produced on all criteria and each alternative sub-district.

3.5 SAW, MOORA and COPRAS ranking process

3.5.1. Simple additive weighting (SAW)

The SAW method requires the procedure of normalizing the decision matrix to a scale that can be compared with all available opportunity scores. This SAW technique also requires decision makers to decide the weight for every characteristic. The overall score for options is received through summing all of the multiplication results among the ratings and the weight of each attribute.

3.5.2. 3.5.2. Multi-objective optimization by ratio analysis (MOORA)

MOORA method categorize the criteria of an MCDM problem into criteria that would need to be maximized or minimized. Then, includes the weight of each criterion. This method can determine the objectives of the opposing criteria. Thus, it can give rank to each of the criteria based on the categories.

3.5.3. Complex proportional assessment (COPRAS)

COPRAS is one of the Multi Attribute Decision Making methods (MADM) for decision making in various fields of science. The COPRAS method uses stepwise sorting and evaluates the procedures of alternatives in terms of significance and utility degrees [21].

3.5.4. Comparison of SAW, MOORA and COPRAS ranking

After the ranking of each sub-district with those 3 methods, then we can compare each method and get the most suitable sub-district for mining activities. The choice of the most suitable method is done by first determining the aggregate value based on the SAW, MOORA and COPRAS methods. The order of each method is then compared to the collective aggregate sequence. Thus, methods with the highest score is the most suitable method.

4. Result and discussion

In this sub-chapter, we discuss the classification testing on each data that has been obtained from electronic nose and evaluation of results

4.1 Determination of criteria

The Delphi method is done by using a questionnaire that is filled separately between participants. Opinion screening will be stopped after the answers from participants lead to convergent answers. The Delphi method in this study was conducted in 3 rounds. Then, based on the questionnaire, we assign Triangular Fuzzy Number (TFN) and Reciprocal value for each criterion. Table 1 shows the Reciprocal value of the criteria based on Delphi method.

Based on Table 1, the criteria that will be used in this study is comprised of 10 criteria and 3 groups of criteria. The first group is Natural Factors that holds the criteria which is naturally occur on the location such as geomorphology, lithology, hydrology. The second group of criteria contains Environmental Factors such as the vegetation, wildlife, distance of the location to the main road, distance of the location to the nearest settlement, and population density of the given location. The last group weights the location aesthetic if it is used as the mining location with criteria such as natural features and touristic places that will be affected.

Table 1. Questionnaire results and fuzzy calculations

Criteria	Natural Factors			Environmental Factors			Aesthetic Factors			Fuzzy Geometric Mean ($\tilde{r}_i$)			Fuzzy Weights ($\widetilde{w_i}$)			Defuzzification Weights	Normalized Weights
Natural Factors	1	1	1	1	2	3	1	2	3	1.00	1.59	2.08	0.22	0.48	0.90	0.54	46.63
Environmental Factors	1/3	1/2	1	1	1	1	2	3	4	0.87	1.14	1.59	0.20	0.35	0.69	0.41	35.71
Aesthetic Factors	1/3	1/2	1	1/4	1/3	1/2	1	1	1	0.44	0.55	0.79	0.10	0.17	0.34	0.20	17.66

Since we got the reciprocal value of the fuzzy AHP, we can calculate the Fuzzy Geometric Mean ($\tilde{r}_i$), Fuzzy Weights ($\widetilde{w_i}$), Defuzzification Weight (w_i), and Normalized Weight of the criteria.

4.2 Calculation of fuzzy AHP

Fuzzy AHP needs to calculate Fuzzy Geometric Mean, Fuzzy Weights, Defuzzification Weights, and Normalized Weights. To calculate Fuzzy Geometric Mean Value ($\tilde{r}_i$), we used Eq. (1).

$$(\tilde{r}_i) = \widetilde{A_1} \otimes \widetilde{A_2} \otimes \widetilde{A_{\dots}} \otimes \widetilde{A_n} \quad (1)$$

where,

$\widetilde{A_n}$ = sub-criteria of n

Then, we calculate the Fuzzy weight using Eq. (2).

$$(\widetilde{w_i}) = \tilde{r}_i \text{ x } (\tilde{r}_1 \, x \, \tilde{r}_2 \, x \dots x \, \tilde{r}_n)^{-1} \quad (2)$$

The resulting Fuzzy weights is then used for defuzzification weight calculation using Eq. (3).

$$w_i = \left(\frac{l+m+u}{3}\right) \quad (3)$$

To calculate the Normalized weight, each defuzzification weight of the criteria is divided by the sum of defuzzification weight of all criteria as shown in Eq. (4).

$$W = \frac{w_i}{\sum w} \cdot 100 \quad (4)$$

The calculation result of the normalized weight of each criterion and sub criterion is shown in Table 2.

4.3 Spatial analysis with arcmap

The criteria we gathered are grouped into 3 categories; natural factors, environmental factors, and aesthetic factors. These are the explanations.

4.3.1. Natural factors

Morphology; mining activities and worker safety and security factors will be better if the mining location is located in lower slope. Based on this criterion, the mining location might be more secure. In this study, hills with steep slopes scored 1, moderate hill slope scored 2 and the slopes of the hills scored 3.

Lithology; The most important material in Sirtu mining is alluvial lithology, these materials can be excavated easier than other materials. The other material that is one of the easier materials to excavate are sediment. Thus, Alluvial lithology scored 3 in this study, sediment lithology scored 2 and other lithologies scored 1.

Hydrology; The activity of Sirtu Mining are greatly affected by how often rain occur on site, especially when excavation process is underway. In this study, sub-district with rainfall capacity of more than 15 mm/day are given score of 1, while rainfall capacity between 15-20 mm/day scored 2, and area with rainfall capacity less than 15 mm/day are given score of 3.

Table 2. Weighted index of fuzzy AHP

Criteria	Criteria Weight	Sub Criteria		Sub Criteria Weight	Final Weight
Natural Factors	46.63	C1	Geomorphology	7.59	3.54
		C2	Lithology	77.72	36.24
		C3	Hidrology	14.69	6.85
Environmental Factors	35.71	C4	Vegetation	4.49	1.60
		C5	Wildlife	5.81	2.08
		C6	Distance from Mainroad	42.11	15.04
		C7	Distance from Settlement	33.10	11.82
		C8	Population Density	14.49	5.17
Aesthetic Factors	17.66	C9	Natural Features	35.61	6.29
		C10	Touristic Places	64.39	11.37

4.3.2. Environmental factors

Vegetation; Mining activities needs to minimizes the damage to the surrounding vegetation. Area with low vegetation is better. In this study, location with 60% or more vegetation area got 1 for this criteria score, while location with 30-60% vegetation scored 2. Area with vegetation area of 30% or below scored 3.

Wildlife; Mining activities should not disturb the habitat of any wild animals. Thus, minimal interruption of the animal habitat is better. In this study, location with more than 50% wildlife area got a scored 1, while location with 25-50% wildlife area scored 2. Area with wildlife area less than 25% scored 3.

Distance from the main road; Mining activities that is closer to the primary highway will lessen the transport expenses. Therefore, mining site that is closer to the highway will be better. Hence, this might have a bad impact on social and environmental factors. In this research, sub-district with main road access of more than 5 km are given a score of 1, while the sub-district of 2.5 km-5 km radius are scored 2. Area with less than 2.5 km radius of the main road scored 3.

Distance from the settlement; The closer the settlement's mine site, the smaller the negative affect on the environment. In this study, the if a sub district have a settlement in 1 km radius from the mining location, the sub district will be scored 1 in this criteria, while if the settlement is in 1-2 km radius of the mining location, It will be given a score of 2. Mining location in more than 2 km radius of settlement will be given a score of 3.

Population density; the less population near the mining area is better since the smaller negative effect could happens to the people. Subdistrict with more than 1.5 million people per km2 scored 1 in this study, while sub-district scored 2 with 1-1.5 million people per km2. The district with less than one million people per km2 is given the score of 3.

4.3.3. Aesthetic factors

Natural Features; Mining activities should not damage natural environments such as forests, mountains, waterfalls, landscapes, caves, and springs. Sub-district with 3 or more natural features is given a score of 1, while location with 2-3 natural features got score 2. Location with no natural features is scored 3.

Touristic Places; Mining activities should try to avoid touristic places since it can disturb the tourists. Location with more than 10 touristic places got a score of 1, while location with 5-10 touristic places got score 2. The highest score is the location with less than 5 or no touristic places.

Then based on GIS analysis, the Table 3 is obtained.

Table 3. Decision matrix

		Max	Max	Min	Min	Min	Min	Max	Min	Min	Min
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
No.	Sub. District	Geomorphology	Lithology	Hydrology	Vegetation	Wildlife	Distance from Main Road	Distance from Settlements	Population Density	Natural Features	Touristic Places
1	Banyakan	2.58	2.39	1.00	3.00	3.00	2.17	2.24	1.00	1.00	1.00
2	Gampengrejo	1.00	2.80	2.00	2.00	1.00	1.19	1.59	3.00	1.00	3.00
3	Grogol	1.90	2.83	3.00	2.00	1.00	1.98	1.54	2.00	3.00	2.00
4	Kandangan	1.00	1.41	2.00	2.00	1.00	2.88	1.69	2.00	2.00	3.00
5	Kandat	1.00	2.24	3.00	2.00	1.00	1.44	1.44	2.00	1.00	1.00
6	Kepung	2.27	1.48	1.00	2.00	2.00	2.95	1.82	1.00	2.00	3.00
7	Kras	1.00	2.90	2.00	1.00	1.00	1.42	1.35	2.00	1.00	1.00
8	Kunjang	1.00	2.88	3.00	1.00	1.00	2.91	1.24	1.00	1.00	1.00
9	Mojo	2.69	2.76	3.00	3.00	2.00	2.61	2.49	1.00	3.00	1.00
10	Ngadiluwih	1.00	2.79	2.00	1.00	1.00	1.05	1.12	3.00	1.00	2.00
11	Ngancar	2.40	1.05	1.00	3.00	1.00	3.00	2.01	1.00	2.00	1.00
12	Papar	1.00	3.00	3.00	1.00	1.00	1.43	1.20	2.00	1.00	1.00
13	Pare	1.00	2.83	2.00	2.00	1.00	1.38	1.59	3.00	1.00	2.00
14	Plosoklaten	1.85	1.48	1.00	2.00	1.00	2.93	1.74	1.00	2.00	1.00
15	Puncu	2.24	1.21	1.00	2.00	3.00	2.91	1.75	1.00	2.00	1.00
16	Purwoasri	1.00	3.00	3.00	2.00	1.00	1.91	1.56	3.00	1.00	1.00
17	Semen	2.80	2.40	2.00	3.00	3.00	2.70	2.48	1.00	3.00	2.00
18	Tarokan	1.98	3.00	2.00	2.00	1.00	1.55	1.51	2.00	3.00	1.00
19	Wates	1.00	1.53	2.00	2.00	1.00	2.73	1.70	2.00	1.00	2.00

Table 4. SAW rank results

		Max	Max	Min	Min	Min	Min	Max	Min	Min	Min		
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10		
No.	Sub. District	Geomorphology	Lithology	Hydrology	Vegetation	Wildlife	Distance from Main Road	Distance from Settlements	Population Density	Natural Features	Touristic Places	Ui	MOORA Rank
1	Banyakan	0.86	0.80	1.00	0.33	0.33	0.46	1.12	1.00	1.00	1.00	0.83	1
2	Gampengrejo	0.33	0.93	0.50	0.50	1.00	0.84	0.79	0.33	1.00	0.33	0.75	10
3	Grogol	0.63	0.94	0.33	0.50	1.00	0.50	0.77	0.50	0.33	0.50	0.69	13
4	Kandangan	0.33	0.47	0.50	0.50	1.00	0.35	0.84	0.50	0.50	0.33	0.49	19
5	Kandat	0.33	0.75	0.33	0.50	1.00	0.70	0.72	0.50	1.00	1.00	0.73	11
6	Kepung	0.76	0.49	1.00	0.50	0.50	0.34	0.91	1.00	0.50	0.33	0.57	17
7	Kras	0.33	0.97	0.50	1.00	1.00	0.71	0.67	0.50	1.00	1.00	0.82	2
8	Kunjang	0.33	0.96	0.33	1.00	1.00	0.34	0.62	1.00	1.00	1.00	0.77	7
9	Mojo	0.90	0.92	0.33	0.33	0.50	0.38	1.25	1.00	0.33	1.00	0.80	4
10	Ngadiluwih	0.33	0.93	0.50	1.00	1.00	0.95	0.56	0.33	1.00	0.50	0.77	8
11	Ngancar	0.80	0.35	1.00	0.33	1.00	0.33	1.01	1.00	0.50	1.00	0.62	15
12	Papar	0.33	1.00	0.33	1.00	1.00	0.70	0.60	0.50	1.00	1.00	0.81	3
13	Pare	0.33	0.94	0.50	0.50	1.00	0.72	0.80	0.33	1.00	0.50	0.76	9
14	Plosoklaten	0.62	0.49	1.00	0.50	1.00	0.34	0.87	1.00	0.50	1.00	0.65	14
15	Puncu	0.75	0.40	1.00	0.50	0.33	0.34	0.88	1.00	0.50	1.00	0.61	16
16	Purwoasri	0.33	1.00	0.33	0.50	1.00	0.52	0.78	0.33	1.00	1.00	0.79	6
17	Semen	0.93	0.80	0.50	0.33	0.33	0.37	1.24	1.00	0.33	0.50	0.70	12
18	Tarokan	0.66	1.00	0.50	0.50	1.00	0.64	0.75	0.50	0.33	1.00	0.80	5
19	Wates	0.33	0.51	0.50	0.50	1.00	0.37	0.85	0.50	1.00	0.50	0.56	18

4.4 SAW ranking process

At the stage of identification of potential zone sequences using SAW Method, the input data used is data on the Decision Matrix and the criteria weight that has been calculated from the Fuzzy AHP Method. To get the order of sub-districts with the most suitable potential based on the SAW Method, the sequence of calculations is as follows:

a) Normalization matrix, carried out in the following ways:

- For maximized criteria in C1, C2 and C7, we used Eq. (5).

$$r_{ij}(x) = x_{ij} / max\{x_j\} \quad (5)$$

where the value of x_{ij} is the alternative value i in the criteria j based on Table 3. While the value of max $\{x_j\}$ is the maximum value of in criteria j.

- For the minimized criteria for C3, C4, C4, C6, C8, C9 and C10, use Eq. (6).

$$r_{ij}(x) = min\{x_j\}/ x_{ij} \quad (6)$$

where the value of min x_{ij} is the minimum value in the criteria j.

b) Determine the weight values of each alternative with Eq. (7).

$$U_i(x) = \sum_{j=1}^{n} w_j r_{ij}(x) \quad (7)$$

where w_j is the weight of the criteria j which has been calculated on the weighting of criteria using Fuzzy AHP.

Table 4 shows the results of SAW ranking process based on the above steps. Based on SAW, Banyakan sub district is the most ideal location since it is acquired rank 1. Followed by Kras sub district as the it is acquired rank 2. Thus, if some other obstacles happen and Banyakan cannot be used as a mining location, Kras would be the ideal choice based on SAW.

4.5 MOORA ranking process

MOORA can use the same decision matrix as shown in Table 3 for this case. The difference of this method is the ranking process of MOORA. The calculation process of MOORA method are as follows:

Table 5. MOORA method optimization matrix

		Max	Max	Min	Min	Min	Min	Max	Min	Min	Min		
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10		
No.	Sub. District	Geomorphology	Lithology	Hydrology	Vegetation	Wildlife	Distance from Main Road	Distance from Settlements	Population Density	Natural Features	Touristic Places	Qi	MOORA Rank
1	Banyakan	0.012	0.082	0.007	0.005	0.009	0.033	0.035	0.006	0.008	0.015	0.046	2
2	Gampengrejo	0.005	0.096	0.014	0.003	0.003	0.018	0.025	0.018	0.008	0.045	0.016	11
3	Grogol	0.009	0.098	0.022	0.003	0.003	0.030	0.024	0.012	0.023	0.030	0.007	12
4	Kandangan	0.005	0.049	0.014	0.003	0.003	0.044	0.026	0.012	0.015	0.045	-0.057	19
5	Kandat	0.005	0.077	0.022	0.003	0.003	0.022	0.023	0.012	0.008	0.015	0.020	10
6	Kepung	0.010	0.051	0.007	0.003	0.006	0.045	0.028	0.006	0.015	0.045	-0.038	18
7	Kras	0.005	0.100	0.014	0.002	0.003	0.021	0.021	0.012	0.008	0.015	0.050	1
8	Kunjang	0.005	0.099	0.022	0.002	0.003	0.044	0.019	0.006	0.008	0.015	0.024	9
9	Mojo	0.012	0.095	0.022	0.005	0.006	0.040	0.039	0.006	0.023	0.015	0.030	6
10	Ngadiluwih	0.005	0.096	0.014	0.002	0.003	0.016	0.018	0.018	0.008	0.030	0.027	8
11	Ngancar	0.011	0.036	0.007	0.005	0.003	0.045	0.032	0.006	0.015	0.015	-0.019	15
12	Papar	0.005	0.103	0.022	0.002	0.003	0.022	0.019	0.012	0.008	0.015	0.044	3
13	Pare	0.005	0.097	0.014	0.003	0.003	0.021	0.025	0.018	0.008	0.030	0.029	7
14	Plosoklaten	0.009	0.051	0.007	0.003	0.003	0.044	0.027	0.006	0.015	0.015	-0.008	14
15	Puncu	0.010	0.042	0.007	0.003	0.009	0.044	0.028	0.006	0.015	0.015	-0.021	16
16	Purwoasri	0.005	0.103	0.022	0.003	0.003	0.029	0.024	0.018	0.008	0.015	0.034	5
17	Semen	0.013	0.083	0.014	0.005	0.009	0.041	0.039	0.006	0.023	0.030	0.006	13
18	Tarokan	0.009	0.103	0.014	0.003	0.003	0.024	0.024	0.012	0.023	0.015	0.041	4
19	Wates	0.005	0.053	0.014	0.003	0.003	0.041	0.027	0.012	0.008	0.030	-0.028	17

Table 6. COPRAS method optimization matrix

		Max	Max	Min	Min	Min	Min	Max	Min	Min	Min		
No.	Sub. District	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Qi	COPRAS Rank
		Geomorphology	Lithology	Hydrology	Vegetation	Wildlife	Distance from Main Road	Distance from Settlements	Population Density	Natural Features	Touristic Places		
1	Banyakan	0.003	0.020	0.002	0.001	0.002	0.008	0.008	0.002	0.002	0.004	0.062	2
2	Gampengrejo	0.001	0.023	0.004	0.001	0.001	0.004	0.006	0.005	0.002	0.011	0.053	11
3	Grogol	0.002	0.023	0.005	0.001	0.001	0.007	0.006	0.003	0.006	0.008	0.052	13
4	Kandangan	0.001	0.012	0.004	0.001	0.001	0.011	0.006	0.003	0.004	0.011	0.038	19
5	Kandat	0.001	0.018	0.005	0.001	0.001	0.005	0.005	0.003	0.002	0.004	0.055	10
6	Kepung	0.003	0.012	0.002	0.001	0.002	0.011	0.007	0.002	0.004	0.011	0.041	18
7	Kras	0.001	0.024	0.004	0.000	0.001	0.005	0.005	0.003	0.002	0.004	0.064	1
8	Kunjang	0.001	0.024	0.005	0.000	0.001	0.011	0.005	0.002	0.002	0.004	0.055	9
9	Mojo	0.003	0.023	0.005	0.001	0.002	0.010	0.009	0.002	0.006	0.004	0.057	6
10	Ngadiluwih	0.001	0.023	0.004	0.000	0.001	0.004	0.004	0.005	0.002	0.008	0.056	8
11	Ngancar	0.003	0.009	0.002	0.001	0.001	0.011	0.007	0.002	0.004	0.004	0.045	15
12	Papar	0.001	0.025	0.005	0.000	0.001	0.005	0.004	0.003	0.002	0.004	0.061	3
13	Pare	0.001	0.023	0.004	0.001	0.001	0.005	0.006	0.005	0.002	0.008	0.056	7
14	Plosoklaten	0.002	0.012	0.002	0.001	0.001	0.011	0.006	0.002	0.004	0.004	0.048	14
15	Puncu	0.003	0.010	0.002	0.001	0.002	0.011	0.006	0.002	0.004	0.004	0.044	16
16	Purwoasri	0.001	0.025	0.005	0.001	0.001	0.007	0.006	0.005	0.002	0.004	0.058	5
17	Semen	0.003	0.020	0.004	0.001	0.002	0.010	0.009	0.002	0.006	0.008	0.052	12
18	Tarokan	0.002	0.025	0.004	0.001	0.001	0.006	0.006	0.003	0.006	0.004	0.059	4
19	Wates	0.001	0.013	0.004	0.001	0.001	0.010	0.006	0.003	0.002	0.008	0.043	17

a) Normalization Matrix, which can be stated in Eq. (8).

$$X_{ij} = \frac{x_{ij}}{\sqrt{[\sum_{j=1}^{m} x_{ij}^2]}} \quad (8)$$

where x_{ij} is the value based on decision matrix of row i .and column j. Therefore, based on Eq. (8), Normalization Matrix produced.

b) To calculate Optimization Values (Q_i), we need to split the criteria into maximized and minimized criteria. Then, subtract the result of the maximized value and the minimized value as shown in Eq. (9).

$$Q_i = \sum_{j=1}^{g} w_j x^*_{ij} - \sum_{j=g+1}^{n} w_j x^*_{ij} \quad (9)$$

$\sum_{j=1}^{g} w_j x^*_{ij}$ is a component of maximized criteria, namely criteria C1, C2 and C7, while $\sum_{j=g+1}^{n} w_j x^*_{ij}$ is a minimized component of criteria C3, C4, C4, C6, C8, C9 and C10.

Table 5 shows the result of MOORA method. Different to the result of SAW method, Kras sub district is the most suitable location based on MOORA. Thus, the result of the most ideal location is shifting. The difference of optimization method results in different ranking result.

4.6 COPRAS ranking process

COPRAS uses the same decision matrix shown on Table 3 for its identification phase. To determine the rank of each criteria, the provided decision matrix is used to create normalization matrix.

a) To create normalization matrix using COPRAS, we used Eq. (10).

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{N} x_{ij}} \quad (10)$$

b) To calculate the optimization values, we do separate calculation for criteria which needs to be maximized and criteria which needs to be minimized. Eq. (11) shows calculation for maximized criteria, while Eq. (12) shows calculation for minimized criteria.

$$S_{+i} = \sum_{j\Omega max} w_j r_{ij} \quad (11)$$

$$S_{-i} = \sum_{j\Omega min} w_j r_{ij} \quad (12)$$

where,

$j\Omega max$ = criteria that needs to be maximized
$j\Omega min$ = criteria that needs to be minimized

c) Based on the optimization values, we can calculate the rank produced by COPRAS method (Q_i) using Eq. (13).

$$Q_i = S_{+i} + [\frac{\sum_{i=1}^{m} S_{-i}}{S_{-i}\sum_{i=1}^{m}\left(\frac{1}{S_{-i}}\right)}] \quad (13)$$

Based on Eq. (13), S_{+i} is the value of the maximized optimization value and S_{-i} as the minimized criteria optimization value. Table 6 shows the ranking result of COPRAS.

As shown in Table 6, the result of COPRAS method is more similar to MOORA method compared to SAW. This is due to the normalization and optimization method that is similar in both methods.

4.7 Comparison of SAW, MOORA and COPRAS ranking

To calculate the accuracy of the method, this study compares the results of the ranking of the aggregation process with the ranking results of each method. The accuracy of this method is then calculated based on the point of each method compared to the total point of all scenarios.

To determine the best alternative sequence, rankings were collected from the SAW, MOORA and COPRAS methods. For 19 sub-districts as the alternative, each best alternative gets 19 points, 19-1 if the alternative is ranked second, and so on for each scenario. The alternative with the highest point is the best overall result. On the Table 7, the total points for each alternative sub-district is shown. The rank of each sub-district based on the aggregation method is shown in Table 8.

Based on Table 8, the result of 3 MCDM method shows that Kras sub district is the most suitable location for mining. Therefore, MOORA and COPRAS got 1 point on the accuracy score while SAW got 0 point.

Table 9 shows the accuracy point each method get by comparing the result on Table 8 and each method result.

Based on Table 9, the result of all the method is compared to the aggregate results in each scenario. The SAW method gets a total of 8/19 points, while the MOORA 17/19 Method and the highest total points are obtained by the COPRAS Method with 19/19 accuracy.

Table 7. SAW, MOORA and COPRAS final rank

Rank	Score	Methods		
		SAW	MOORA	COPRAS
1	19	Banyakan	Kras	Kras
2	18	Kras	Banyakan	Banyakan
3	17	Papar	Papar	Papar
4	16	Mojo	Tarokan	Tarokan
5	15	Tarokan	Purwosari	Purwosari
6	14	Purwosari	Mojo	Mojo
7	13	Kunjang	Pare	Pare
8	12	Ngadiluwih	Ngadiluwih	Ngadiluwih
9	11	Pare	Kunjang	Kunjang
10	10	Gampengrejo	Kandat	Kandat
11	9	Kandat	Gampengrejo	Gampengrejo
12	8	Semen	Grogol	Semen
13	7	Grogol	Semen	Grogol
14	6	Plosoklaten	Plosoklaten	Plosoklaten
15	5	Ngancar	Ngancar	Ngancar
16	4	Puncu	Puncu	Puncu
17	3	Kepung	Wates	Wates
18	2	Wates	Kepung	Kepung
19	1	Kandangan	Kandangan	Kandangan

Table 8. Calculation of the aggregation method

Sub District	Score	Total Score
Banyakan	19+18+18	55
Gampengrejo	10+9+9	28
Grogol	7+8+7	19
Kandangan	1+1+1	3
Kandat	9+10+10	29
Kepung	3+2+2	7
Kras	18+19+19	56
Kunjang	13+11+11	35
Mojo	16+14+14	44
Ngadiluwih	12+12+12	36
Ngancar	5+5+5	15
Papar	17+17+17	51
Pare	11+13+13	37
Plosoklaten	6+6+6	18
Puncu	4+4+4	12
Purwoasri	14+15+15	44
Semen	8+7+8	26
Tarokan	15+16+16	47
Wates	2+3+3	8

5. Conclusion

To identify the sequence of potential zones of the Natural Sandy Gravel (Sirtu) mining, 3 main criteria were used. Based on the calculation of the Fuzzy AHP Method, the weighting criteria are namely: natural factors consist of geomorphology (3.54%), lithology (36.2%), hydrology (6.85%), vegetation

Table 9. Comparison of results of ranking of each method with aggregation results

Rank	Aggregation Results	Methods			Aggregation Score		
		SAW	MOORA	COPRAS	SAW	MOORA	COPRAS
1	Kras	Banyakan	Kras	Kras	0	1	1
2	Banyakan	Kras	Banyakan	Banyakan	0	1	1
3	Papar	Papar	Papar	Papar	1	1	1
4	Tarokan	Mojo	Tarokan	Tarokan	0	1	1
5	Purwosari	Tarokan	Purwosari	Purwosari	0	1	1
6	Mojo	Purwosari	Mojo	Mojo	0	1	1
7	Pare	Kunjang	Pare	Pare	0	1	1
8	Ngadiluwih	Ngadiluwih	Ngadiluwih	Ngadiluwih	1	1	1
9	Kunjang	Pare	Kunjang	Kunjang	0	1	1
10	Kandat	Gampengrejo	Kandat	Kandat	0	1	1
11	Gampengrejo	Kandat	Gampengrejo	Gampengrejo	0	1	1
12	Semen	Semen	Grogol	Semen	1	0	1
13	Grogol	Grogol	Semen	Grogol	1	0	1
14	Plosoklaten	Plosoklaten	Plosoklaten	Plosoklaten	1	1	1
15	Ngancar	Ngancar	Ngancar	Ngancar	1	1	1
16	Puncu	Puncu	Puncu	Puncu	1	1	1
17	Wates	Kepung	Wates	Wates	0	1	1
18	Kepung	Wates	Kepung	Kepung	0	1	1
19	Kandangan	Kandangan	Kandangan	Kandangan	1	1	1
					8/19	17/19	19/19

(1.6%) and the wildlife (2.08%). Second, environmental factors which contains distance from the main road (15%), distance from the settlement (11.8%) and population density (5.17%). Third, aesthetic factors consist of natural features (6.29%) and touristic places (11.4%). The criteria for Fuzzy AHP and Decision Matrix are used to identify potential zone sequences based on the SAW, MOORA and COPRAS methods. To determine the most appropriate method, the Aggregation Method was used. COPRAS got 19/19 in aggregation

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, Adiba Sabilla Ajrina, Riyanarto Sarno and Aziz Fajar; methodology, Adiba Sabilla Ajrina; software, Adiba Sabilla Ajrina; validation, Riyanarto Sarno and Hari Ginardi; formal analysis, Aziz Fajar; resources, Riyanarto Sarno and Hari Ginardi; writing—original draft preparation, Adiba Sabilla Ajrina; writing—review and editing, Aziz Fajar and Riyanarto Sarno; visualization, Adiba Sabilla Ajrina; supervision, Riayanrto Sarno and Hari Ginardi.

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