Priority Analysis of Small Dams Construction using Cluster Analysis, AHP and Weighted Average Method Case Study: Small Dams in Semarang District

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Priority analysis of small dams construction using cluster analysis, AHP and weighted average method case study: small dams in Semarang District

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1. Introduction

One of the problem of water resources management is human behavior itself which increasing the change in land use for livings. Changes in land use may affect the availability of water resources. The land use change for people's activities will increase the need for water, reduced the water availability, increase the direct runoff thus incease the floodings, and increased the drought conditions [1,2].

District Semarang is one of the districts that always experiencing high degree of land use change, which also experiencing the water resources severety problems. To overcome this problem, the Balai Besar Wilayah Sungai Pemali-Juana has identified 8 (eight) potential small dams (embung) in Semarang District, i.e., Dadapayam, Mluweh, Lebak, Pakis, Jatikurung, Gogodalem, Kandangan, and Ngrawan [3]. To overcome the problem immediately, ideally these potential small dams must be constructed within 5 year term. However, the government cannot possibly build all these small dams within the 5 year period because of the financial constraints. So the government should determine the priority on which dams to constructed first during the period. The purpose of this study is to determine the sequence of construction of small dams in Semarang District which are more effective and efficient. It uses Cluster Analysis [4,5], AHP (Analytical Hierarchy Process) [6-8], and Weight Average [4,8] methods.

The location of this research is in the administrative area of Semarang District, Central Java Province shown in Figure 1.

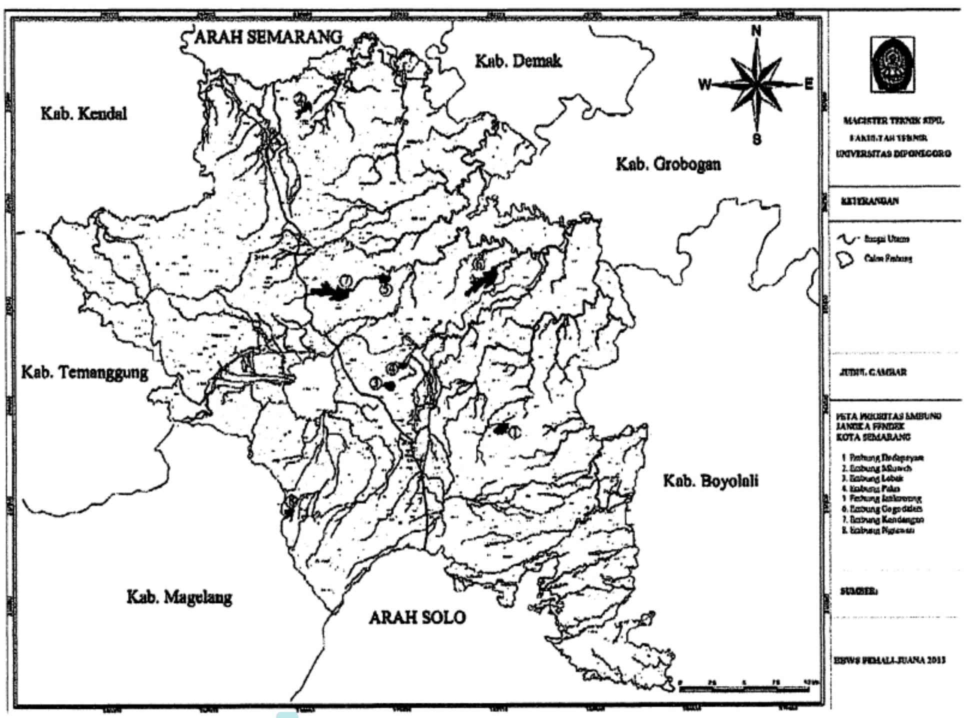

Fig. 1. Map Location potential small dams (Embung) In Semarang District.

The selection on which reservoir to be constructed first will require some criterias. The criterias whould reflect the efficient and effective construction. Therefore, some criterias should reflect both engineering and non-engineering factors. These criterias are selected based on some regulations, standards, and guidance for small dam construction such as SNI 03-1724-1989 [13], PP No. 37. Year 2010 [9], RSNI T-01-2002 [10], Public Work regulation No. 03/PRT/M/2009 (Code of Social Engineering Construction of Dams) and SK. Dams Safety No. 05/Kpts/2003 (General Design Criteria Manual Dam).

2. Research methods

Based on regulatory guidelines and regulations, some criterias for selecting the priority of small dams can be identified. Additional criteria's is defined based on some consultation with experts and from review on the influence of criteria to the efficiency and effectiveness of small dams construction [3,11,12].

The following are some variables that will be used in the determination of priority for small dam construction. The variables that will be used in the analysis are : 1) Vegetation cover in the inundation area, 2) The slope and stability of the abutment, 3) Volume of embankment material, 4) The area to be acquired, 5) type of subgrade foundation, 6) design discharge Q50yr, 7) Effective storage, 8) Sediment storage, 9) catchment area, 10) Duration of operation, 11) Equivalent Cost of water/m^3, 12) Distance of quarry from the site of the dam, 13) access road to the site of the dam, 14) the population needs to be evacuated, 15) Status of land in site, 16) Response from surrounding communities, 17) Infrastructure to be re-aligned/ re-placed, 18) Cost of land acquisition, 19) Cost of construction, 20) operating costs and maintenance, 21) Coverage of irrigation areas, and 22) The benefits of raw water. These variables are comprehensive and covering aspects of engineering, operational, economic, and social. Using these variables, it requires to collect data and information related to these variables for each potential small dams.

In principle, the research uses secondary dan primary data in order to quantify all the variables involved. The raw data for each variables are standardized [14] and ranged into 5 category. Based on these standardized variables, the analysis of cluster analysis is conducted to 1) the grouping of the variables and 2) the priority of the construction. Furthermore, based on the variables grouping, it can be determined up to nine selected representative variables. Based on these representative variables, it can be analyzed further using AHP [6], [7], [8] and weighted method [4], [8] to determine the priority for the small dam construction.

2.1. Cluster analysis method

Cluster Analysis is an analysis to classify or to group "similar" elements such that the variables of the research can be grouped (clustered) into less variables. It is useful to summarize the data with the grouping of objects based on certain characteristics in common between the objects to be studied. It is also useful to "reduce" the variables in the research. Some variables which are in similar class or group, which therefore has similarity, can then be represented by one representing variable.

In cluster analysis, one class has principally similarity between the members in the class and has dis-similarity with the members from other class. The most commonly used similarity index is the Euclidian distant. The measure of dissimilarity between objects all objects i with j, can be symbolized by d_{ij} . The d_{ij} value obtained through the calculation of distance squared as follows [4] and [5]:

$$d_{ij} = \sqrt{\sum_{k-1}^{p}\{x_{ik} - x_{jk}\}^2} \quad (1)$$

Where :

d_{ij} = quadratic of distance Euclidian between object i with object j
p = sum of variable cluster
x_{ik} = value of object i on variable of k
x_{jk} = value of object j on variable of k

Based on this index, it can be used to determine which object is more belongs (similar) to which group. The analysis uses K-Means method as follow:

a) Determine the magnitude of k, namely from the amount of cluster and determine the centroid (average) in each cluster.
b) Calculate the distance of each object to every centroid.
c) Form a new cluster based on the calculated distances.
d) Recalculating the average (centroid) of the newly formed cluster.
e) Repeat step b) until no further transfer of objects between clusters.

2.2. Analytical Hierarchy Process (AHP) Method

According to Saaty [7], the decision-making process is basically to select an alternative. The main tool is AHP (Analytical Hierarchy Process) which is a functional hierarchy of human perception with its main input. With a hierarchy, a complex and unstructured problems resolved into their groups and then the groups are arranged into a form of hierarchy. Basically the steps in the method of AHP include [6-8]:

a) Define the problem and determine the desired solution.
b) Create a hierarchical structure that begins with a common goal, followed by sub-objectives, criteria and possible alternatives.
c) Make a pairwise comparison matrix that depicts the relative contribution or influence of each element on each criterion of interest or a level above it. Comparisons are made based on the judgment of the decision makers to judge the importance of an element compared to other elements.
d) Perform a pairing comparison in order to obtain judgment on n [(n-1)/2] results, where n is the number of elements being compared.
e) Compute eigenvalues and test consistency. If it is not consistence, then repeat from data retrieval.
f) Repeat steps c, d, and e for all levels of hierarchy.
g) Calculating the eigenvectors of each pairwise comparison matrix. Value eigenvector is the weight of each element. This step is to synthesize the judgment in the prioritization of the elements on the lowest hierarchy level to achieving goals.
h) Check the consistency of the hierarchy. If the value is more than 10 percent, the judgment should check the data.

2.3. Weighted Average Method

Weighted Average Method is a method by taking the average value based on the average calculation by giving weight to each value to be taken the average value. The weight of each are not the same, if all the weights are equal then the calculation is the average of ordinary arithmetic [4,13].

Average calculation with this method is with a few additions to the weight calculation. It is similar to the calculation of average ordinary arithmetic. Data elements are taken into weight beforehand, in which the data has more weight will be more influential than the data with less weight. With the provision of the weights which cannot be negative, some of which may be zero, but it is impossible if all the weight is zero, because if it did so then the calculation is not possible to do. This method is widely used in the data analysis system, the calculation of differential and integral calculus.

In general, the calculation method of Weighted Average may be made to the existing data contents, $\{x_1, x_2, x_3, \ldots, x_n\}$, using weights, $\{w_1, w_2, w_3, \ldots, w_n\}$, to obtain the average with the formulation as following.

$$X = \frac{w_1.x_1 + w_2.x_2 + w_3.x_3 + \cdots + w_n.x_n}{w_1 + w_2 + w_3 + \cdots + w_n} \quad (2)$$

Rules of the use of variable / fittings that must be considered every element of data and weights4:

$\{wi|i = 1,2,\ldots,n\} > 0$

w is the weighting, on the basis of preference (interest/the preferred option) but the decision maker in this case using the results of the questionnaire.

In certain circumstances where the weights are normalized so that the accrual overall weight equal to one, then the formula above can be more concise becomes.

$$X = \sum_{i=0}^{n} w_i . x_i \quad (3)$$

3. Analysis and Discussion

The data analyzed is the data of each reservoir to each of the variables that they are quantitative and qualitative. Where the data has been standardized or transformation of the relevant variables into scoring form of variable data. The scoring scale assessment data is put on a scale of 1 to 5 scale, where 5 is the scale with the highest weight value (most favorable), while 1 is the lowest weighting scale value (least favorable). A1 to A8 are alternatives for reservoir 1 to reservoir 8 (see Table 2.). The variables K1 to K22 are the variables used in the analysis [3].

Table 1. Summary of Data Standards

	A1	A2	A3	A4	A5	A6	A7	A8
K1	2	5	2	2	5	5	3	3
K2	5	2	2	3	2	3	4	2
K3	5	1	3	5	5	4	4	5
K4	4	5	5	4	3	2	5	4
K5	5	1	5	5	3	1	1	1
K6	2	2	4	3	2	3	5	3
K7	3	5	4	4	1	2	1	1
K8	2	3	2	3	5	3	5	1
K9	2	1	5	4	3	1	2	2
K10	2	5	2	2	1	3	1	1
K11	5	5	3	4	1	1	1	1
K12	5	3	3	3	3	3	3	1
K13	3	4	3	3	3	3	3	4
K14	5	5	5	4	5	5	5	4
K15	4	2	4	4	3	4	4	4
K16	4	5	4	4	4	5	5	4
K17	5	1	5	1	5	5	5	1
K18	3	5	4	4	3	1	3	4
K19	4	1	3	5	4	4	4	4
K20	3	1	2	1	4	4	4	5
K21	3	5	2	3	2	2	3	2
K22	2	2	5	5	2	3	5	1

Information:

K1=Vegetation cover in the inundation area, K2=The slope and stability of the abutment, K3=Volume of embankment material, K4=The area to be acquired, K5= Type of subgrade foundation, K6= design discharge Q50yr, K7= Effective storage, K8= Sediment storage, K9= catchment area, K10= Duration of operation, K11= Equivalent Cost of water/m³, K12= Distance of quarry from the site of the dam, K13= access road to the site of the dam, K14= the population needs to be evacuated, K15= Status of land in site, K16= Response from surrounding communities, K17= Infrastructure to be re-aligned/ re-placed, K18= Cost of land acquisition, K19= Cost of construction, K20= operating costs and maintenance, K21= Coverage of irrigation areas, and K22= The benefits of raw water.

3.1. Selection priority small dam (Embung) with non-hierarchical cluster analysis method

This method starts with the process of determining the number of class, and the method used is non- hierarchical. After the standardization of data and have obtained the recapitulation of data of each reservoir, the next step is to enter the recapitulation data into the program Statistical Package for Social Science (SPSS) 17. Results of the analysis of non-hierarchical cluster method of SPSS 17 is in the form of each grouping of small dams and within each reservoir towards the center of the cluster.

Table 2. Distance to cluster center

No.	Small dams name	QCL_1	QCL_2
A1	Dadapayam	3	4,589
A2	Mluweh	2	0,000
A3	Lebak	3	3,816
A4	Pakis	3	4,308
A5	Jatikurung	1	3,415
A6	Gogodalem	1	3,606
A7	Kandangan	3	5,706
A8	Ngrawan	1	4,619

QCL_1 is the cluster/grouping number, and QCL_2 is the distant between reservoirs to the center's cluster.

- Cluster – 1 : Jatikurung , Gogodalem and Ngrawan.
- Cluster – 2 : Mluweh
- Cluster – 3 : Dadapayam, Lebak, Pakis and Kandangan
- To see if the variables have formed clusters are variables that influence the development of reservoirs it is necessary to test its validity using Variance Hypothesis testing. This test is used to determine the relative value of each variable and the usual more effective to test the number of variables and a population of more than one.

Additionally, from the F count it can be used as the determining more significant variables. From the 22 (twenty two) variables, there are twelve (12) variables whose Fcount > 2.747. They are 1) Vegetation cover in the inundation area, 2) Volume of embankment material, 3) The area to be acquired , 4) effective storage, 5) Duration of operation , 6) equivalent cost of water/m³ , 7) access the entrance to the site of the dam, 8) Status of land at the site, 9) construction costs, 10) Cost of OM, 11) Coverage of irrigation areas and 12) Benefits of raw water. Therefore, it can be inferred that in this case, these twelve variables are variables that has significant influence in the efficiency and effectiveness of construction of reservoirs. These 12 variables are then used in the AHP and Weighted methods.

3.2. Small dams priority selection method of AHP based questionnaire data

The process of priority selection using AHP (Analytical Hierarchy Process) aims to provide an assessment of the alternatives which is more favorable compared to the others. It uses 12 selected variables to determine the priority. The comparison for each variables are obtained from questionnaire. The result of AHP in the form of a ranking based on the assessment of priority weighting of each of the alternatives available.

1) Criteria weighting calculation for purpose

From the results of the questionnaire obtained by the comparison results in a matrix form pairwise comparison between the criteria used in this study, as in Table 3.

Table 3. Pairwise comparison matrix criteria for purpose

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
K1	1,000	2,690	0,386	0,771	0,430	0,865	2,122	0,335	0,489	1,820	1,093	0,393
K2	0,372	1,000	0,627	0,779	0,792	0,578	1,000	0,541	1,000	1,000	1,364	0,590

K3	2,589	1,594	1,000	2,073	2,455	1,377	2,532	1,000	1,000	1,828	4,138	1,000
K4	1,297	1,283	0,482	1,000	1,000	1,000	1,093	1,062	1,000	1,000	1,000	1,000
K5	2,326	1,263	0,407	1,000	1,000	1,000	2,552	0,455	2,293	2,304	1,000	2,333
K6	1,156	1,730	0,726	1,000	1,000	1,000	0,498	0,399	1,000	1,000	1,000	1,000
K7	1,000	1,000	0,395	0,915	0,392	2,007	1,000	1,790	1,000	1,000	1,135	0,473
K8	1,849	1,849	1,000	0,942	2,196	2,504	0,559	1,000	2,539	2,422	2,541	0,272
K9	2,047	1,000	1,000	1,000	0,436	1,000	1,000	0,394	1,000	1,000	0,406	0,632
K10	0,549	1,000	0,547	1,000	0,434	1,000	1,000	0,413	1,000	1,000	0,385	1,427
K11	0,915	0,733	0,242	1,000	1,000	1,000	0,881	0,500	2,462	2,600	1,000	1,000
K12	2,544	1,696	1,000	1,000	0,429	1,000	2,114	3,681	1,582	0,701	1,000	1,000

To model the Analytical Hierarchy Process (AHP) comparison matrix can be accepted if the value of a consistent ratio of not more than 10% or equal to 0.1. Because the value of $CR = 0.0011 \leq 0.1$ the comparison matrix can be received / consistent.

Table 4. Recapitulation criteria weights

Code	Criteria	Weight
K1	vegetation in the inundated area	6,950%
K2	volume of embankment	6,319%
K3	land acquisition area	12,228%
K4	useful storage	8,500%
K5	reservoir life time	9,431%
K6	water cost/ m³	7,709%
K7	access road to the dam site	7,593%
K8	land status at abutment and inundated area	9,284%
K9	construction cost	7,543%
K10	operation and maintenance cost	6,904%
K11	irrigation service area	6,862%
K12	and raw water benefit	10,678%

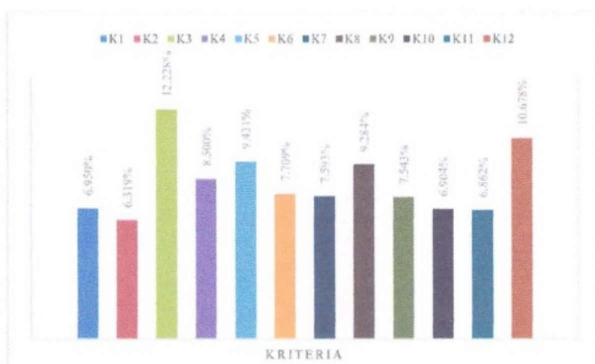

Fig. 2. Criteria quality towards result graph

2) *Alternative weighting calculation against criteria*

The process of calculating the alternative weighting of the criteria is to compare several alternatives to each criterion. Stages of the calculation is equal to the weighting of the criteria of the goal.

Table 5. Alternative weight recapitulation against criteria

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
A1	0,334%	1,353%	0,925%	0,558%	0,925%	1,941%	0,647%	1,589%	1,257%	1,335%	0,913%	1,043%
A2	1,391%	0,300%	3,058%	1,306%	2,667%	1,578%	2,328%	0,357%	0,349%	0,599%	1,794%	0,783%
A3	0,348%	0,382%	2,251%	2,044%	1,171%	1,207%	0,644%	1,428%	0,462%	0,342%	0,578%	2,505%
A4	0,351%	1,182%	1,415%	0,704%	1,234%	0,929%	0,633%	1,438%	1,703%	1,079%	1,323%	2,217%
A5	1,531%	0,795%	0,750%	1,037%	0,680%	0,575%	0,641%	0,411%	1,467%	0,695%	0,383%	0,619%
A6	1,556%	0,521%	0,566%	0,551%	1,809%	0,695%	0,622%	1,349%	0,826%	1,556%	0,604%	1,275%
A7	0,733%	0,690%	1,952%	1,557%	0,357%	0,442%	0,631%	1,347%	0,579%	0,441%	0,983%	1,647%
A8	0,707%	1,095%	1,311%	0,743%	0,589%	0,341%	1,447%	1,365%	0,899%	0,857%	0,286%	0,588%

Information :

A1 = Dadapayam A2 = Mluweh A3 = Lebak A4 = Pakis A5 = Jatikurung A6 = Gogodalem A7 = Kandangan A8 = Ngrawan

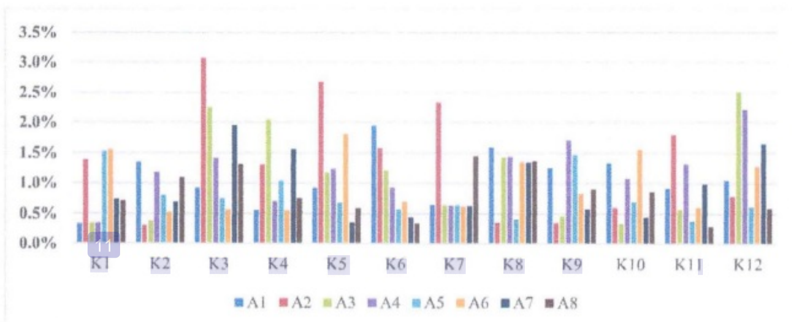

Fig. 3. Alternative weight graph against criteria

Table 6. Total weight alternatives

	Smalldams selection	Weight
A1	Dadapayam	12,820%
A2	Mluweh	16,510%
A3	Lebak	13,365%
A4	Pakis	14,208%
A5	Jatikurung	9,585%
A7	Gogodalem	11,929%
A8	Kandangan	11,357%
A9	Ngrawan	10,227%

Fig. 4. priority ranking chart Embung

3.3. Embung priority selection method of AHP based on data engineering

The decision making process with this method is to compare the technical data of each alternative against each criterion. The value of the interest rate is determined by dividing the interval of the result of each comparison matrix data. The division is divided interval of the level of interest of 1 (one) to 9 (nine). The final result of this method in the form of rankings based on the weighted votes of each alternative.

1) Alternative weighting calculation against criteria

The process of calculating the alternative weighting of the criteria is to compare several alternatives to each criterion. Stages of the calculation is equal to the weighting of the criteria of the goal.

Table 7. Alternative Weight recapitulation Against Criteria

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
A1	0,020	0,271	0,061	0,141	0,127	0,136	0,049	0,227	0,157	0,103	0,139	0,052
A2	0,267	0,042	0,347	0.230	0,240	0,222	0,106	0.105	0,014	0,062	0,305	0,039
A3	0,020	0,065	0,242	0,147	0,127	0,143	0,060	0,129	0,025	0,079	0,104	0,234
A4	0,020	0,187	0,102	0,175	0,127	0,209	0,060	0,129	0,346	0,074	0,147	0,234
A5	0,267	0,124	0,028	0,066	0,094	0,062	0,060	0,026	0,235	0,163	0,049	0,071
A6	0,267	0,094	0,016	0,125	0,169	0,116	0,060	0,129	0,070	0,117	0,064	0,122
A7	0,070	0,094	0,158	0.066	0,028	0,059	0,060	0,129	0,048	0.172	0,144	0,234
A8	0,070	0,124	0,046	0,051	0,088	0,053	0,543	0,129	0,105	0,230	0,048	0,014

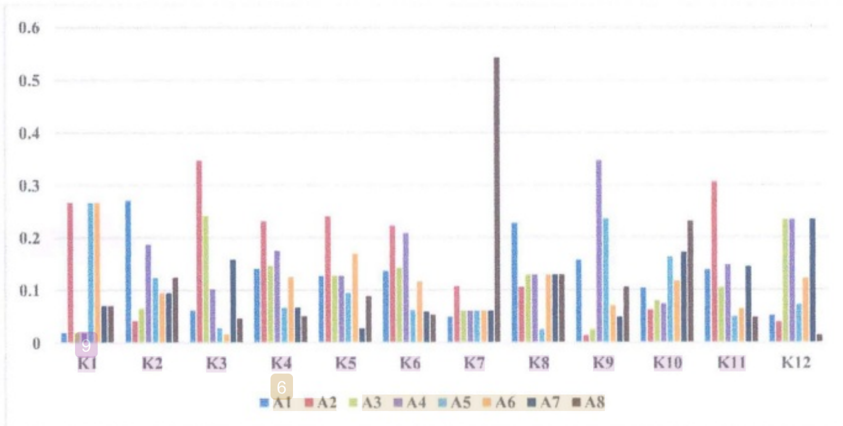

Fig. 5. Alternative weight graph against criteria

Table 8. Alternative weight term

	Alternative	Weight
A1	Dadapayam	1,483
A2	Mluweh	1,978
A3	Lebak	1,375
A4	Pakis	1,808
A5	Jatikurung	1,246
A6	Gogodalem	1,347
A7	Kandangan	1,261
A8	Ngrawan	1,501

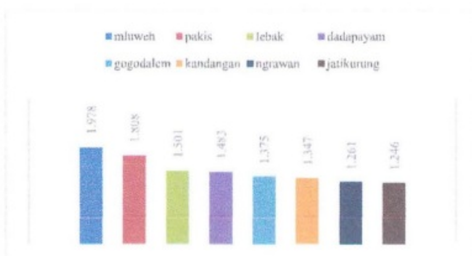

Fig. 6. Priority ranking chart Embung

3.4. Embung priority selection by the weighted average method

The weights of the criteria used is the questionnaire results have been analyzed using AHP questionnaire data. Weighting for alternative locations reservoir was made to all existing criteria. Alternative weighting criteria is based on secondary data from this study. Where data of each reservoir is given in accordance with the ranking of the value of scoring / standardization of data from the previous discussion. Where each alternative against the criteria with greater its value the greater the value of importance. Value ranking of alternatives is then multiplied by the value of the interests of criteria so that the value combinations then summed to obtain the overall value. The result of this final value which will be compared between the alternatives with other alternatives as the basis for determining the selection of priority reservoir.

Table 9. Total weight alternatives

	Criteria	Value Combination
A1	Dadapayam	2,674
A2	Mluweh	2,869
A3	Lebak	2,525
A4	Pakis	2,757
A5	Jatikurung	2,095
A6	Gogodalem	2,276
A7	Kandangan	2,230
A8	Ngrawan	2,247

Figure 7. Priority ranking chart Embung

3.5. *Results Embung priority cluster analysis method , AHP questionnaire data , data engineering and weighted average*

From the analysis that we can know the result of the difference between the reservoir prioritization to three (3) such methods.

Table 10. Results Embung priority cluster analysis method , AHP questionnaire data , data engineering and weighted average

Smalldams selection		AHP Method		Method	Method	
		Cuestionnaire Data	Technique Data	Weighted Average	Analysis Cluster	
A1	Dadapayam	4	4	3	Cluster - 1	Jatikurung
A2	Mluweh	1	1	1		Gogodalem
A3	Lebak	3	6	4		Ngrawan
A4	Pakis	2	2	2	Cluster - 2	Mluweh
A5	Jatikurung	8	8	8	Cluster - 3	Dadapayam
A6	Gogodalem	5	5	5		Lebak
A7	Kandangan	6	7	7		Pakis
A8	Ngrawan	7	3	6		Kandangan

4. Conclusions and recommendations

4.1. Conclusions

From the analysis that has been done in this study, several conclusions can be obtained as follows :

- Variables that influence in the construction of reservoirs using Cluster Analysis Method of non hierarchical method is : 1) vegetation in the inundated area (7,652), 2) volume of embankment (7,744), 3) land acquisition area (4,167), 4) useful storage (4,203), 5) recervoir life time (6,921), 6) water cost/ m³ (4,321), 7) access road to the dam site (3,125), 8) land status at abutment and inundated area (12,031), 9) construction cost (9,844), 10) operation and maintenance cost (4,559), 11) irrigation service area (22,500) dan 12) and raw water benefit (2,893).
- Based on the calculation method of Cluster Analysis, AHP questionnaire data , engineering data and Weighted Average , short-term reservoir development priorities are : 1) Mluweh (0.165) , 2) Pakis (0,142) , 3) (0.134) , 4) Dadapayam (0.128), 5) Gogodalem (0.119) , 6) Kandangan (0.114) , 7) Ngrawan (0.102) and 8) Jatikurung (0.096).

4.2. Recommendation

From the analysis that has been done with the above conclusions, some suggestions can be submitted as follows:

- In this study, administration of the class interval to gain weight at all variables have not been uniform. This means that there are several variables that have different class interval. Suggested for further research using uniform class intervals while providing a source elaboration grade interval of each of the variables to be analyzed.
- For optimal results , the determination of the data relied on respondents' assessment (through interviews / questionnaires), do increase in the number of respondents or experts with increasingly wide resources in order to maintain data consistency.
- To obtain a different result, in the process of standardizing data on Cluster Analysis method can be done by looking for better standards of raw or with standardized/ transformed in SPSS.
- In this study, the scoring scale comparisons on AHP Method engineering data using standard scale of 1-9 according to the method of AHP questionnaire data. Suggested for further research could use a benchmark comparison with the scale of dividing the class interval on the comparative value of the largest and smallest.

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