WEIGHING FACTORS IN AN ANALITICAL HIERARCY PROCESS (AHP) FOR DETERMINING POTENTIAL LOCATION FOR DAM CONSTRUCTION IN POGRAXHË IN KOSOVO

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SUMMARY

Nowadays, the collection of geospatial data and analysis through Geographic Information System (GIS) can provide a very valuable analysis which narrows down the most suitable locations for the dam construction. There are no fixed conditions to be used for the Determining of potential location for dam construction. Based on results and solutions presented in many scientific papers, there are some main factors that should be considered in order to obtain the result of analysis in determining the potential location for a dam construction. The number of factors and the priority rank as well are not fixed, and it might change depending on the collected data, study area and priorities that experts recommend to be considered for the analysis. According to Saaty (1977) in analytical hierarchy process (AHP) where in the basis of their significance, factors are weighed and compared to each other. In this case, the result of the analysis will be provided after a multicriteria decision making. An important part of the selected criteria and its priority weight to one another, it is the Determining of random consistency index (RI). According to Saaty (1977) consistency index shows weather the pair wise comparison between criteria used in analysis, are acceptable in AHP.

Key words: Criteria, AHP (Analytical Hierarchy Process), GIS, Location, Dam.

INTRODUCTION

Water is a crucial element for the survival of life on earth (Veldkamp 2017). A dam is a barrier that stops or restricts the flow of water or underground

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streams. Reservoirs created by dams not only suppress floods but also provide water for activities such as irrigation, human consumption, industrial use, aquaculture, and navigability.

A dam is by nature linked to an environment. The morphology of the river valley therefore plays a vital role in the choice of a dam site and the most suitable type of dam (Becue 2002). The selection of Dam site for constructing a dam should be governed by the following factors: Suitable foundation must be available; For economy, the length of the dam should be as small as possible, and for a given height, it should store the maximum volume of water; The general bed level at dam site should preferably be higher than that of the river basin. This will reduce the height of the dam; A suitable site for the spillway should be available in the near vicinity; Materials required for the construction of dam should be easily available, either locally or in the near vicinity; The value of land and property submerged by the proposed dam should be as low as possible; The dam site should be easily accessible, so that it can be economically connected to important towns and cities; and Site for establishing labor colonies and a healthy environment should be available near the site (Selection of Dam Site 2015).

Geographical information system (GIS) and remote sensing techniques appeared as powerful multidisciplinary science which provides easy data access, large area coverage and frequent temporal capabilities for many of its applications in hydrology (Lehmann et al 2014). Generally, dam site selection is conducted by traditional methods, such as conventional decision-making techniques or according to political interests (Jozaghi et al 2018). However, remote sensing (RS), geographic information systems (GIS) and machine learning (ML) techniques are recently emerging as some of the most appropriate approaches to understand dam sites. In recent years, the advancement in satellite and computational power has enhanced the opportunity to manage different hydrologic parameters and terrain characteristics (Al-Ruzouq et al 2019). Applying the geospatial analyses and techniques for modeling with GIS tools, now it is possible efficient displaying of land surface with Digital Elevation Models, TIN models , and shading relief models (Izeiroski et al, 2016). Using GIS approach an attempt has been made to select suitable sites for checkdams for harvesting rain water (Padmavathy et al 1993). Using different spatial analyses with a set of GIS tools in an efficient way are obtained several raster maps with values of slopes (gradients, inclinations) of the land surfaces, raster maps wih aspect-direction values as well as raster maps with shadow analysis of the surface and others (Izeiroski et al, 2016).

This site suitability was evaluated using geospatial technologies using multi criteria as per available ground information for feasibility of the site. All contributing factors such as Topography, Geology, Catchment size, Precipitation, Distance from roads, Distance from settlements and protected areas, Distance from rivers, and Parcel ownership were studied before selecting a suitable site for the dam, and used in the research based on weigh factors of each criteria related to the case study area characteristics.

MATERIALS AND METHODS

Weighing the factors that are part of analysis for choosing the most suitable location for the dam construction, shows the importance that each of factors have. 8 factors have been included in this study. By classifying how much each factor weighs, the importance of them is determined because not all of them are of the same importance in determining the most suitable location.
There are a few methods that can be utilized to weigh the factors as part of the analysis. One of the most widely-used methods is comparing factors against one-another, according to the so-called Analytical Hierarchy Process (AHP) compiled by Saaty (1977). Based on their importance, factors are compared against one-another.
The matrix of weights has been set following Njiru and Siriba (2018), where every criteria is compared to another in relation to its importance, on a scale of 1 to 8. The most suitable locations have been ascertained as a result of the sum-up of the criteria. Next, the structure of the Analytical Hierarchy Process has been presented for making the decision for the study area (figure 1).

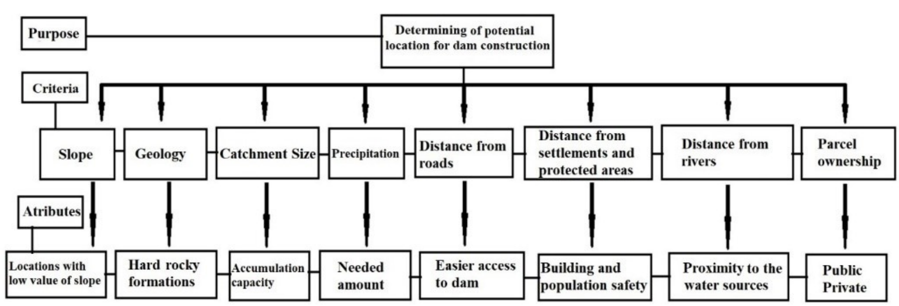

Figure 1. The structure of the Analytical Hierarchy Process (AHP) for making the decisions for the study area.

EVALUATING THE RELATIVE IMPORTANCE OF THE CRITERIA IN RELATION TO ONE-ANOTHER

According to Saaty (1977) in Analytical Hierarchy Process (AHP), determining the importance of the criteria is ascertained trough relating them against one-another. According to Njiru (2017) the form of listing the criteria and how they are valued is done on a scale of 1 to 8. Value 1 is for factors that share the same importance, whereas value 8 is for the factor that is way more important in comparison to others.

In Table 1 the criteria listed according to their importance they carry have been shown. The scale from 1 to 7 has been presented following Njiru (2017), Al-Adamat (2012) and Law NO. 03/1-039. The land ownership criteria determined by representatives of Ministry of Infrastructure – MI (2019), has been listed number 8, and is linked with the expropriation of properties. The costs of the construction of dams has not been taken into consideration in this paper. Therefore, this factor will be of the least prioritized.

Table 1: Factors according to the order of importance

Factor	Order of importance	Description
Slope (Topography)	1	Slope affects dam safety, thus large slope values increase the danger of landslides, and give a pressure to the dam.
Geology	2	The harder rocky formations are considered more suitable for the dam construction.
Catchment size	3	A bigger basin in study area provides a bigger value of water accumulation for the dam.
Precipitation	4	Large values of precipitation in study area provides a bigger value of water accumulation for the dam.
Distance from roads	5	Because of economical purposes for easier access to the dam, small distances from roads are considered more suitable.
Distance from settlements and protected areas	6	Due to safety of settlements and population, distance from dam site should be considered in order to provide safety.
Distance from rivers	7	Proximity of the rivers is considered economically more suitable.
Parcel ownership	8	Public parcel ownership in study area, is considered more suitable because of economical purposes.

CALCULATION OF THE WEIGHT OF FACTORS IN RATIO WITH ONE - ANOTHER

Having evaluated the factors according to their importance, following Njiru (2018) a comparison has been drawn between each and every factor. The comparison between the factors (table 2) has been done on a scale of 1 to 8 following the matrix of Saaty (1977) so that the weight of every factor can be measured against others.

1 = two factors share the same importance
8 = One factor is way more important than another.

Table 2: The matrix of the comparison of the factors with one-another

Factor	Slope (Topography)	Geology	Catchment size	Precipitation	Distance from roads	Distance from settlements and protected areas	Distance from rivers	Parcel ownership
Slope (Topography)	1	2	3	4	5	6	7	8
Geology	1/2	1	2	3	4	5	6	7
Catchment size	1/3	1/2	1	2	3	4	5	6
Precipitation	1/4	1/3	1/2	1	2	3	4	5
Distance from roads	1/5	1/4	1/3	1/2	1	2	3	4
Distance from settlements and protected areas	1/6	1/5	1/4	1/3	1/2	1	2	3
Distance from rivers	1/7	1/6	1/5	1/4	1/3	1/2	1	2
Parcel ownership	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1
Total	3	5	7	11	16	22	29	36

For evaluating the weights of the factors in relation to one-another the following equation has been utilized following Saaty (1997):

$$Wi = \sum_{j=1}^{n} Pij / (\sum_{i=1}^{n} \sum_{j=1}^{n} Pij) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where: *Pij* – is ratio between factors,
i & j – is factor, and
W – is primary weight.

Having used the above-mentioned equation for all of the factors, the weights of each factors in relation to one-another has been ascertained. The values of such weights have been presented in the Weights Factors Matrix in table 3:

Table 3: Weight Factors Matrix

Factor	Slope (Topography)	Geology	Catchment size	Precipitation	Distance from roads	Distance from settlements and protected areas	Distance from rivers	Parcel ownership	**Primary Weight W**
Slope (Topography)	0.368	0.435	0.403	0.355	0.311	0.275	0.246	0.222	**0.327**
Geology	0.184	0.218	0.268	0.266	0.249	0.229	0.211	0.194	**0.227**
Catchment size	0.123	0.109	0.134	0.177	0.187	0.183	0.175	0.167	**0.157**
Precipitation	0.092	0.073	0.067	0.089	0.124	0.137	0.140	0.139	**0.108**
Distance from roads	0.074	0.054	0.045	0.044	0.062	0.092	0.105	0.111	**0.073**
Distance from settlements and protected areas	0.061	0.044	0.034	0.030	0.031	0.046	0.070	0.083	**0.050**
Distance from rivers	0.053	0.036	0.027	0.022	0.021	0.023	0.035	0.056	**0.034**
Parcel ownership	0.046	0.031	0.022	0.018	0.016	0.015	0.018	0.028	**0.024**
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**

The consistency of the factors in relation to one-another as part of this analysis will be evaluated following the equation of consistency ratio calculation (Saaty 1977). There will be an evaluation of the relation of Consistency Index CI and Random Index RI (table 4) for the eight above-mentioned factors. The value of CR is compared to 0.1 and this is the maximum CR value for the acceptable pair-wise comparison (Saaty 1977)

Table 4: Values for random index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Equation of Consistency ratio: CR = CI/RI ....(2)

where: $CI = (\lambda max – n) / n\text{-}1$

n – is number of factors in this analysis = 8

λmax – is the sum of the multiplication between each primary vector elements (*Total* column in table 3 and *primary weight* column W).

Having calculated the CI value **(0.06)** and the given value RI (1.41) from table 4, the consistency ratio CR is **0.04**. The calculated value is below the maximum acceptable value **(0.1)**, and in light of the Analytical Hierarchy Process (AHP), which means that the consistency among the factors used in this analysis is acceptable.

STANDARDIZATION PROCESS OF THE PRIORITIZED FEATURES OF THE GIVEN FACTOR

According to Njiru (2018), after selecting the features for the analysis and the evaluation of the weights in relation to one-another, it is necessary to perform data reclassification according to the feature priority. It is necessary due to the selected features can contain data that is regarded as primary as well as data that is not regarded as primary and as such not necessary to achieve at the desirable results as part of the geospatial analysis.
The data reclassification as part of this paper is based on literature that illustrates the opinions of the experts of relevant fields accordingly in regards to every factor used in the analysis, as well as the legislation in force in the Republic of Kosovo.

Values from 1 to 5 will be used for the reclassification of data for one feature according to priority order (Njiru et al 2018). Number 5 will be for data with the highest influence, whereas number 1 for data with the lowest influence. This has been done through the ArcMAP software, using the Reclassify option for each feature.

The reclassification of data of the Slope was performed on a scale of 5, and according to Njiru et al (2018) the surfaces with the lowest value of slope are considered as the most suitable areas. That is so because the pressure against the dam is lower and that the construction is cheaper. Thus, low value of slopes are regarded as highly suitable and primary. For example, the terrain slopes with the value 0-9% have been given the number five value. On the other hand, the high value of slopes is 1 and is considered to be unsuitable.

The reclassification of data on the feature of geological layers according to Rusi (2016) mainly relies on the permeability, density and hardness of rock formations. According to Njiru (2017) layers with rock formations that are high in hardness and density will be considered very suitable for reasons of stability for dam construction, with the maximum value of 5. On the other hand, other formations that are softer, which are considered unsuitable, are given the minimum value of 1.

The data reclassification regarding the feature of the catchment area according to Njiru (2017) relies on its size. The larger the catchment area and the more catchment flow it contains, the more suitable it is. That is because this means that the accumulative quantities that will be collected in the reservoir will be larger and thus are given the value of 5. Conversely, smaller-size-catchment areas are given the minimum value of 1 accordingly.

The reclassification of precipitation data according to Al-Adamat et al (2012) is based on the amount of rainfall within the study area. Heavy precipitation areas are considered more suitable as they increase the amount of water in the study area. Therefore, they are given a value of 5. Contrastingly, light precipitation areas are treated as unsuitable and will be evaluated with a value of 1.

Reclassification of data for the settlements feature according to Njiru, F.M. et al. (2018) as well as Law NO. 03 / l-039 protected areas, relies on the distance of settlements and protected areas from the dam site. Taking into consideration the distance for safety reasons, to the appropriate distances will be given a value of 5, whereas to unsuitable distances will be given a value 1.

Reclassification of data for the river feature according to Njiru et al (2018) relies on the proximity of the rivers to the dam site. According to this, a short distance between rivers and planned dam sites are considered as suitable because of economical purposes, to which will be given a value of 5, whereas large distances are considered unsuitable with value 1.

Last is data reclassification of landownership to cadastral parcels. According to the presentation organized by the municipality of Gjilan (2019), the representatives of MI stated that lands of public ownership are very suitable. It was also stated that there is no need for expropriation for these parcels, this way making the lands of public ownership be given a value of 5, whereas private ownership parcels are considered moderately suitable with value of 3. In the following tables are presented the above - mentioned features and reclassification of factors, according to their importance on a scale from 1 to 5: *1 - Not at all suitable, 2 - Slightly suitable, 3 - Moderately suitable, 4 - Suitable, 5 - Very suitable.*

Table 5: Reclassification of Features According to their Importance

Slope (%)	**Value**	**Geology (layers)**	**Value**
0 – 9	5	Amphibolite formations	5
9.1 – 16	4	Quartz formations	4
16.1 – 25	3	Marble and Limestone	3
25.1 – 40	2	/	/
> 40	1	/	/
Catchment size (km^2)	**Value**	**Precipitation (mm)**	**Value**
>2 km	5	>879	5
1.03 – 1.86	4	879- 725	4
0.726 – 1.02	3	724 – 682	3
0.451 – 0.725	2	682 – 600	2
0.02 - 0.45	1	600 <	1
Distance from roads (m)	**Value**	**Distance from settlements and protected areas (m)**	**Value**
0- 1000	5	3001-4000	5
1001-2000	4	2001-3000	4
2001-3000	3	1001-2000	3
3001-4000	2	500-1000	2
>4000	1	500 <	1
Distance from rivers (m)	**Value**	**Parcel ownership**	**Value**
0-500	5	Public property	5
501-1000	4	Private property	3
1001-1500	3	/	/
1501-2000	2	/	/
>2000	1		

For each classification value from 1 to 5, the representation of the classified features is done with the mapping method in 5 layers of different colors where:

- red represents the extreme minimum value of 1, which is considered unsuitable,
- the orange color represents value 2, which is considered slightly suitable,
- yellow represents value 3, which is considered moderately suitable,
- the light green color represents value 4, which is considered suitable, and
- green represents the maximum value 5 which is considered very suitable.

The following figure shows the reclassification of features according to the above-mentioned values related to the table 5, conducted with the Reclassify option within the ArcMAP software.

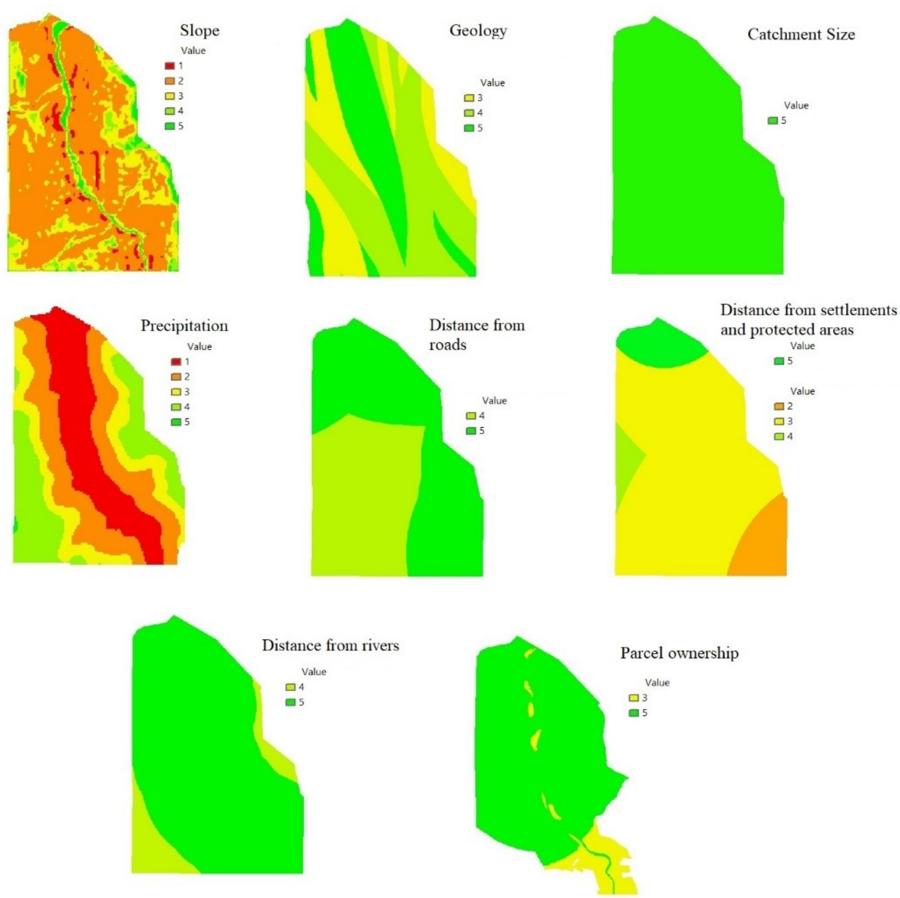

Figure 2. Reclassification of data according to value of importance

ANALYSIS OF THE SUITABILITY OF THE STUDY AREA BY THE WEIGHT OF FACTORS

To create the map of the study area and to analyze the suitability of this area, the primary weights of the -W factors calculated in the matrix of the weights of the factors in table 3 will be used, incorporated in the ArcMAP software for each feature, and expressed in percentage.

Table 6: Matrix of the primary weight W of factors

Factor	Weight W (AHP)	(%)
Slope (Topography)	**0.327**	**33**
Geology	**0.227**	**23**
Catchment size	**0.157**	**16**
Precipitation	**0.108**	**11**
Distance from roads	**0.073**	**7**
Distance from settlements and protected areas	**0.050**	**5**
Distance from rivers	**0.034**	**3**
Parcel ownership	**0.024**	**2**

For each reclassified feature according to the values of importance, through the tool of ArcMAP " Weighted Overlay" , the values of primary weight were used, and as result of their impact, the suitability map of the study area was obtained.

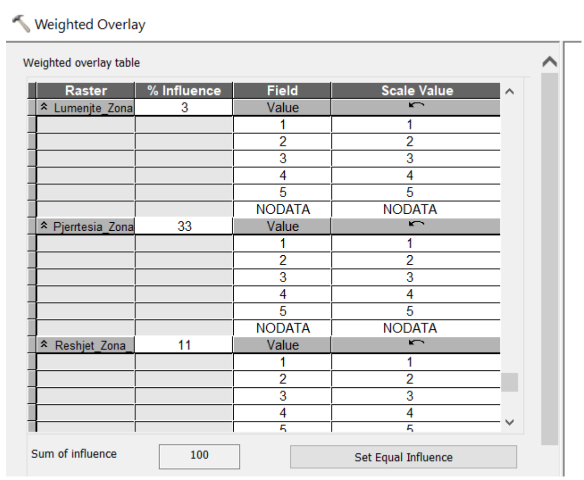

Figure 3. Analysis of suitability of study area according to the weight of factors

RESULTS AND CONCLUSIONS

As a final result of the process of the Analytical Hierarchy Process, and the weighing of the factors used in this process, the layers of features were placed according to their weights and the map of the study area was obtained according to their suitability.

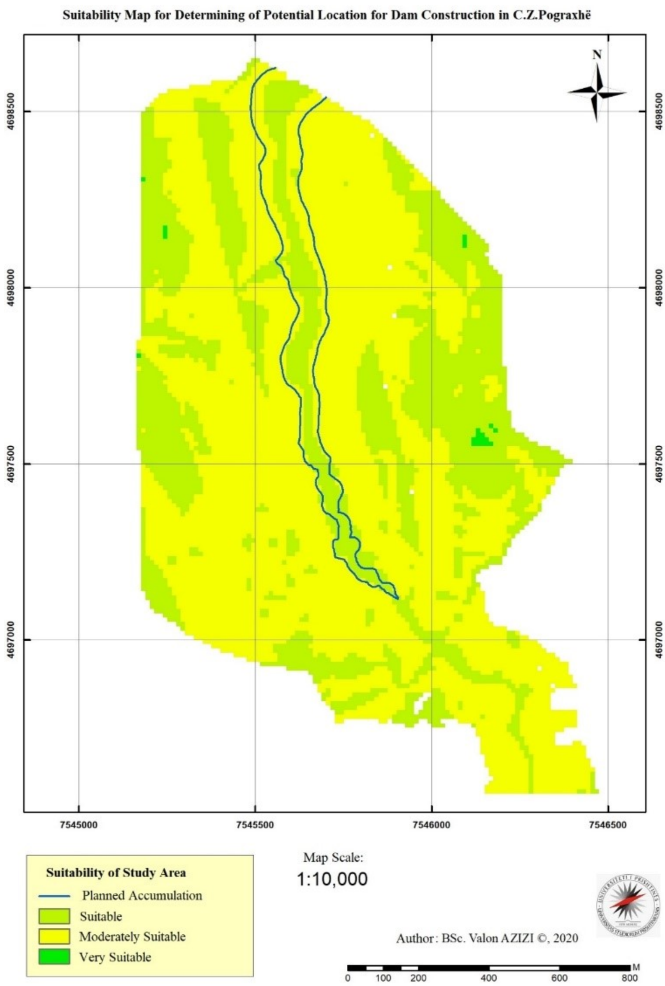

Figure 4. Suitability map of the study area for dam site selection.

The purpose of this paper was identifying the suitability of the study area in order to select the most optimum location for the construction of the dam. This was achieved by utilizing the geospatial analysis using GIS software, based on the Analytical Hierarchy Process (AHP). The weight of deceive factors that are taken into account in doing the analysis and drawing the results.

Results shows that the geospatial analysis done by the GIS software based on PHA, is quite efficient in achieving the results. Research output shows that most of the study area is considered suitable for the construction of the dam, thus answering the research questions posed at the beginning of this paper.

Nonetheless, there are no fixed criteria and no specific factors for selection of the most suitable locations for the dams. Factors that have been considered are those which have been recommended by various local experts and those which have been used more in the literature and the scientific articles which gave this analysis effectiveness and scientific basis in achieving the necessary results. Defined criteria in paper can be used by applying them in various projects aimed for researching suitable areas for the construction of dams.

In addition to the results and conclusions of this paper, it is worth noting that there can be a need to extend and complement such geospatial analysis in the future. The following recommendations would go for any future researches:

- In the Analytical Hierarchy Process implemented as part of the geospatial analysis using ArcGIS software, there are no fixed criteria that are defined to achieve the necessary results in determining the most suitable locations for dam construction. Therefore, in the future, researchers could develop a specific sequence that could clearly define the criteria and weights that would be used in the context of a geospatial analysis for this purpose. Other criteria could also be incorporated, as factors of a certain weights.

- The accuracy of the collected source data has to be defined by a priory accuracy analyses, since it directly affects to the accuracy of the achieved results and the final product of the suitability map of the study area.

- A more thorough geostatistical analysis could be achieved if researchers could extract sufficient data from field studies for each of the factors used in the analysis. That data has to be provided by experts in core fields that would participate in a more detailed analysis of a research area, which would be considered potentially suitable for setting up dams.

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