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Spatial analysis methodologies using multicriteria evaluation approaches

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Abstract. Water needs for human and agricultural consumption have increased due to an increase in population and human activities. Identifying potential rainwater harvesting sites (RWHS) is an important step towards maximizing water availability for agriculture and other uses. The selection of suitable sites using computational techniques presents a great challenge, so the present study aimed to examine from a critical approach the different approaches reported, as well as the theoretical references of the topic addressed. Computational spatial analysis methodologies were analyzed using multicriteria evaluation (MCDA) approaches as well as computational technologies such as AHP and WLC supported by GIS). As a result of the study carried out, it was concluded that the identification of areas suitable for certain RWH techniques using improved geomatics techniques remains one of the important purposes of development and research. In addition, the MCDA -GIS combination has the potential to provide a rational, objective and non-biased approach to decision-making in locating potential sites for dam construction.

1. Introduction

Over time the identification of hydrological uses has been carried out through procedures that involve a large amount of time and resources. These procedures are focused on the search for geographical areas which allow the development of a jump, either through projects with derivation or projects with dam, and that, in turn, these sites have significant water availability, and available and favorable infrastructural conditions. This search should seek to find efficient projects, with short conduits or narrow canyons [1]. Once a possible site with attractive characteristics is identified, takes place a prefeasibility level analysis, whose main purpose is to make preliminary calculations regarding energy production, the identification of the main technical, environmental and social restrictions, as well as the prior quantification of the investment costs of the evaluated alternative. A good search process guarantees that the obtained benefits justify the future environmental and social impacts to which the area of influence would be subject.

Mwenge et al. [2], Durga et al. [3], Baban et al. [4] agree that, when analyzing the land's suitability or its capacity for the feasibility study and for the selection of potential areas. For the construction of dams it is important to take into account within the selection criteria:

- weather (rain);
- hydrology (rain-runoff relationship and intermittent water courses);
- topography (pending);
- agronomy (crop characteristics);
- soils (texture, structure and depth);
- socioeconomic criteria (population density, workforce, priority of people, experience);
- land tenure;
- water laws;
- accessibility;

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- related costs.

Arango [1], Petheram et al. [5], Peng et al. [6] do not consider environmental and social factors within the development of their research, despite this, they recognize their importance in their final recommendations. Failure to consider such factors at the time of the development of decision-making support systems in the selection of potential sites for water collection would result in harmful damages not only at the economic level but also at the social level.

Although criteria have been established for the design of dams, general guidelines and recommended considerations, as well as technical knowledge and experience, there is no certainty that the resulting design criteria can be applied to other reservoir sites with similar conditions [7]. These requirements and pressures have made it necessary to develop a clear criterion to locate the reservoir sites in addition to a more effective system in decision-making, that is, one that can handle a large number of data sets and provide assistance to the decision makers [8].

From the beginning the engineers have carried out the studies of definition of the hydrological potential by analyzing the cartographic, topographic information, among others available in the area of interest. Through the traditional approach, this available information is processed and analyzed independently, thus drawing isolated conclusions that are then contrasted and allow, in some way, to define the potential of the area. The research process of a potential dam site usually involves an iterative process of increasingly detailed studies, which sometimes occurs in just 2 or 3 years, but often in 10 or more years [5], this considering the volume of information that needs to be analyzed manually, which makes it an inefficient and complex process. On the other hand, the fact that the analyzes are carried out independently makes the results obtained rigid and often do not allow analyzing all the possibilities and getting the most out of the processed information.

Authors such as [9], [10], [11], address the need to examine both the location of the reservoir and the site of the dam, because it is important to know the capabilities of the foundations to support the weight of both the volume of water in the reservoir as of the materials for the construction of the dam. Therefore, choosing a suitable site is a crucial phase in the construction of the site. A well-selected site will not only provide the best benefits, but will also allow the acquisition of aesthetic values that contribute to the creation of a recreational area around the reservoir. On the contrary, a poorly selected site or an incorrect decision at the time of building dams in unsuitable areas can cause flooding and therefore damage to industrial, crop or populated areas. In 1963, for example, more than 300 million meters of rock slipped into the reservoir site of the San Vaiont dam in Italy. This generated flood waves, which exceeded the dam crest by 100 m causing the death of 3,000 people downstream [12]. An investigation, at a later date, established that the rocky material on the lateral slope of the reservoir became saturated due to the water deposit and, as a result, the slope became unstable and began to slide towards the reservoir [13]. This example shows the importance of preliminary investigations and recognition in the selection and location of reservoir sites. Before the United Nations Conference on Environment and Development in 1972, the economic importance of a reservoir project preceded all other considerations [4]. Since then, environmental awareness and concern have steadily increased, therefore, decision makers have had to take into account not only technical design and economic factors, but also local and regional environmental and social impacts of a proposed reservoir.

This paper aims to carry out a study of current trends in the use of spatial analysis methodologies for the selection of potential sites for the construction of dams, as well as evaluate the criteria to identify suitable reservoir sites in order to meet future demands of water. In addition, some approaches to multiple criteria analysis techniques and their integration in a GIS context are analyzed and described, with the aim of developing in future research a specialized instrument to accelerate decision-making and planning in hydrological use.

2. Methods

Remote sensing and GIS have the ability to manage, analyze and manipulate all relevant layers of information involved, such as topography, economic and environmental data, in relation to the selection of the reservoir site. In addition, remote sensing data can allow decision makers to investigate a wider area of potential sites in a shorter period of time and at a lower cost [14]. It can also delineate areas of structural weakness by mapping the scope of the main geological lines related to failures and strikes [15], [16]. Since site selection of the site involves large data sets, GIS can be used to maintain and manipulate data in order to extract the necessary information and use the information in the decision-making process [17]. Another important advantage of using GIS in site selection is its ability to display [18].

The digital elevation models (DEM) Fig. 1, allow to obtain much of the information necessary for the definition of the potential and are fundamental at the time of generating the hydrological information, since it is from this information that the morphology of the basins of the territory, which obviously represents primary information for the estimation of the water supply.

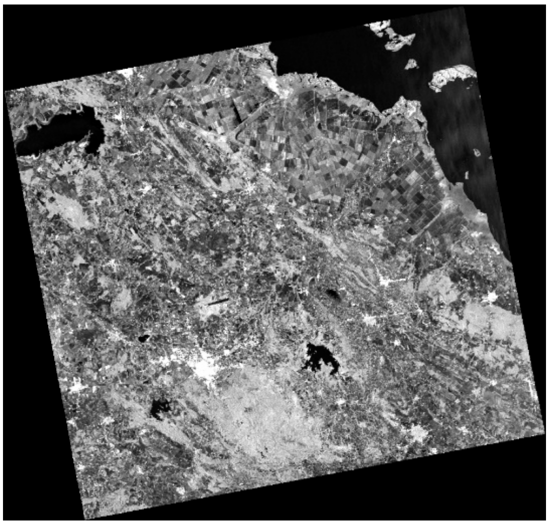


Figure 1. Example of a Digital Elevation Model (DEM).

Various methodologies have been developed for the selection of sites and techniques suitable for water collection. Mbilinyi et al. [19] applied the multi-criteria techniques (MCDA) approach to identify areas for water collection technologies within a GIS context. The approach had been used in some studies in other countries. However, in Tanzania, the approach was new in the field of rainwater harvesting (RWH), because it had not been used to identify suitable areas for such technologies. The combination was useful for evaluating multiple criteria and expert opinion consistently in order to obtain suitability maps and tabular data. He demonstrated that the MCDA-GIS combination has the potential to provide a rational, objective and unbiased approach to making decisions in the identification of potential sites for RWH technologies. Although effective, its methodology could be improved with, for example, the consideration of other factors such as social economy.

Isioye et al. [20] in another study they used Remote Sensing, a limited field survey to identify potential sites for RWH technologies. The entrance to the Decision Support System (DSS) included maps of rainfall, slope, soil texture, soil depth, drainage and land use / coverage, and the exits are maps showing potential sites of water storage systems, stone terraces, bench terraces and borders and Model Builder in ArcView was used as a platform for the DSS. Munyao [21] used GIS and Remote Sensing with primary rainfall data sets, runoff coefficient, soil, slope, land use / coverage and socio-economic aspects of the area under consideration to access the potential for water collection using the software GIS ILWIS and ArcGIS to obtain all the key spatial layers that were used for various analyzes and weighted overlays were made to produce maps showing potential sites for water collection. Weerasinghe et al. [22] focused on the use of a GIS and remote sensing. They developed an integrated methodology to evaluate water management. Consequently, the model specifies the possible water collection and storage sites for water storage and soil moisture conservation on farms [22].

Şen & Al-Suba'I [23] identified and evaluated the factors that could affect the location of the dam in the basins and, therefore, the planning of the water resources of the proposed reservoirs. These authors studied the effects of sedimentation and flooding on the location and construction of dams in Saudi Arabia. Forzieri et al. [24] presented a methodology to assess the suitability of sites for dams. The selection criteria were defined both qualitatively and quantitatively and were based on a territorial analysis using satellite data in combination with hydrological and climatological information. The methodology is particularly useful in areas where there is very little territorial information available, such as most developing countries, and it has been applied in the Kidal region of Mali, where 66 sites were evaluated, of which only 17 complied with the proposed selection criteria. The authors selected suitable construction sites from the predominant technical and engineering perspectives and neglected others, such as socio-political perspectives [24].

Ammar et al. [25] reviewed the methodologies and main criteria that have been applied in arid and semi-arid regions (ASARs) during the past three decades. They classified and compared four main site selection methodologies, identified three main sets of criteria for selecting RWH locations and identified the main characteristics of the most common water collection techniques used in ASARs. The methods were diverse, from those based only on biophysical criteria to more integrated approaches, including the use of socio-economic criteria, especially after 2000. Most studies now select water collection sites using GIS in combination with hydrological models and/or multiple criteria analysis.

In the scientific literature, several studies detail methods for the identification at regional level of promising areas for the collection and storage of water in micro and small farms or to optimize the location and size of storage units in urban drainage environments (by example, Behera et al. [26]; Zoppou [27]; Travis et al. [28], Marques et al. [29]).

In [20], a methodology is proposed in which the first stage consists in identifying and deciding which RWH technologies would be mapped. For this, a field study must be carried out in which the technologies must be defined, examples of which are:

- Collection of surface runoff from open areas and storage in terrestrial structures (ponds).
- RWH in situ and storage in soil profile for crop production.
- Other methods of groundwater recharge, such as sand dams (dam walls and dam reservoirs).
- Rock basin.

Then the criteria to be evaluated are selected and the criteria maps are created, which will be reclassified into five comparable units, that is, suitability classes: 5 (very high suitability), 4 (high suitability), 3 (medium suitability), 2 (low suitability) and 1 (very low suitability). Subsequently, it proposes the suitability model (S), through which suitability maps for water collection are generated by integrating different factor criteria maps using the Weighted Overlay Process (WOP) for the MCDA.

The MCDA was achieved through a weighted linear combination (WLC) in which the continuous criteria (factors) are standardized in a common numerical range and then combined by a weighted average. With a weighted linear combination, the criteria are combined by applying a weight to each, followed by a sum of the results to obtain a suitability map using the following equation:

$$S=(RIWS\times SS_i)+(RIWD\times SD_i)+(RIWL\times SL_i)+W \quad (1)$$

where:

$RIWS$ is relative importance weight for slope layer;

$RIWD$ is relative importance weight for drainage layer;

$RIWL$ is relative importance weight for land cover/use layer;

SS_i is suitability level of cell i in the slope layer;

SD_i is suitability level of cell i in the drainage layer;

SL_i is suitability level of cell i in the land cover/use layer;

W is buffer union of roads settlement and drainage;

i is represents the type of water collection technology to use;

The higher the suitability number of a given site criterion, the more suitable it will be for water collection technologies. The weighting assigned to each of the site selection criteria represents the importance of that criterion for the decision-making process for site selection in this project. The importance was thought in terms of "Would the identification of one aspect of these criteria alter the decision to build river basins?". A weighting of 1 was assigned to the criteria with little importance, a weighting of 2 to those criteria with little significance, 3 to a moderate significance and a weighting of 4 and 5 to the criteria with a significant impact on the site selection decision.

Although the proposal is good, it is only aimed at finding the place for water collection and does not include the possibility of finding the location of potential sites for the location of dams, as well as for the prevention of natural hazards. In addition, it does not take into account factors such as the social economy, the runoff coefficient of the soil map and the rain map.

The investigation [30] proposes, as in the previous investigation, a methodology of 4 basic steps: selection of RWH technologies, selection of criteria to evaluate, classification of the criteria according to the determined suitability and subsequently the construction of the suitability map integrated by combining criteria layers using a raster calculator. The GIS database required to identify potential sites for RWH was developed using ArcGIS with vector and raster databases. A suitability model was developed using ModelBuilder in ArcGIS 10.2 to implement all processes to identify sites suitable for RWH. Areas suitable for dams were identified by reclassifying layers of biophysical criteria and combining them using the raster calculation tool in the ArcGIS 10.2 space analyst module. Each criterion was cut in the study area, reclassified to numerical values and suitability classifications for dams were assigned. Finally, the most suitable sites for dams were identified by visual interpretation of satellite images and large-scale mapping analysis.

The proposal offers a map of suitability that will be useful for hydrologists, decision makers and planners to quickly determine areas that have RWH potential. Despite these, the work is carried out using components that will only provide a map that is as appropriate as possible so that experts can identify the sites visually and not automatically providing the proposal of said potential sites. In addition, social and environmental factors are not taken into account.

As in the previous cases [4], it makes a selection of the criteria to be taken into account and then makes a reclassification of the criteria creating a suitability map for later evaluation. To make use of GIS, create layers of information corresponding to each restriction. The relevant information obtained was converted into the required restriction layers using IDRISI, a raster-based GIS. The restriction layers needed for the study area were derived from several sources, including a land use/coverage map produced from satellite data and field data [31]. This map was used to extract information and build layers of information for defined restrictions, that is, to identify urban areas, to protect agricultural and forestry areas, respectively. The topography was derived from a DEM digitized from a topographic map at a scale of 1:50 000 [4]. Similarly, geology was also derived from the digitization of a geological map at a scale of 1: 200,000 [4]. This process is usually followed by assigning weights to each restriction layer, multiplying each layer by its weight and then successively multiplying the result by each of the restrictions to combine all layers. For them, the authors of this research considered two MCDA approaches to combine the information layers of the Boolean and WLC methods.

Using the Boolean method, all criteria are reduced to restrict Boolean images of areas, which are adequate and not adequate. In addition, all layers are considered equally important and given the same weight [18]. This procedure was applied to all layers of information using the MCDA function in IDRISI to produce the necessary restriction images. For example, Fig. 2 marks the reserved forest areas, which are clearly defined (in black) as not suitable for consideration based on the criteria developed. To obtain the locations of the potential sites, the functions OVERPLAY, GROUP, AREA and RECLASS of the IDRISI tool are used.

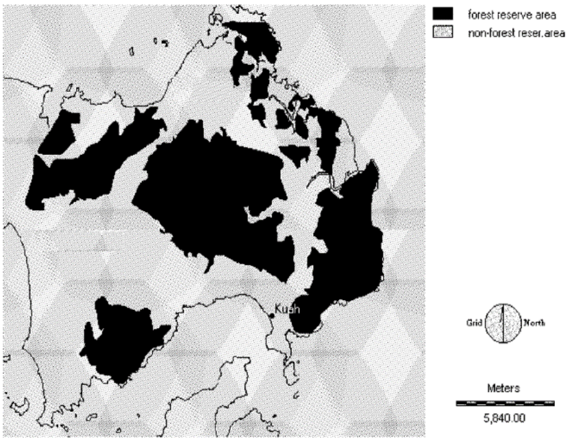


Figure 2. Forest Reserve Areas [4].

The method using the weighted linear combination requires that the main own vector of the pairwise comparison matrix be calculated to produce the best set of weights. Subsequently, the best acceptable adjustment of the respective weights is used in the MCDA function to calculate the WLC using the constraints in the criteria. The main eigenvector was calculated by taking the square reciprocal matrix of pairwise comparisons between the criteria and these weights would add 1. This result could be achieved by calculating the weights with each column and then averaging all the columns [4]. The WEIGHT function in IDRISI, which operates according to this principle, was used to determine the best fit of the weight factors. The consistency index (CI) was also determined. The CI indicates the probability that the matrix classifications are generated randomly and the value should be less than 0.10; otherwise, the classification of the matrix must be reevaluated [32]. Subsequently, the best acceptable adjustment of the respective weights was used in the MCDA function to calculate the weighted linear combination using the defined factors and constraints. To select only those areas (groups) that can meet the specified surface areas, the IDRISI GROUP, AREA and RECLASS functions were used.

At the conclusion of the investigation, the authors define that both methods provide satisfactory results, it would only depend on the expert to define which of the sites provided by both methods are the most suitable according to the needs and expectations. Although the GIS methodology makes the decision-making process more objective, there is still an element of subjectivity associated with the assignment of weights and map scales. This also allows planners flexibility to incorporate varying degrees of importance to each criterion based on their experience. Through experience, a good judgment in the evaluation of environmental, social and political limitations could produce the best alternative decisions.

The progress of the analytical hierarchy (AHP) is a model that can express a complex problem as an ordered hierarchical structure, and can order the schemes by decision of the people. This method can handle qualitative and quantitative factors in decision making, and has the advantages of systematization, simplicity, practicability and effectiveness. This method was used in article [6] to build dams in the middle and upper sections, middle sections and lower sections. They list a table according to the criteria and sub-criteria that restrict the location of the series of dams. Then, they build the AHP site selection evaluation system consisting of the subsequent objective, the criteria layer, the sub-criteria layer and the scheme layer and as shown in Fig. 3.

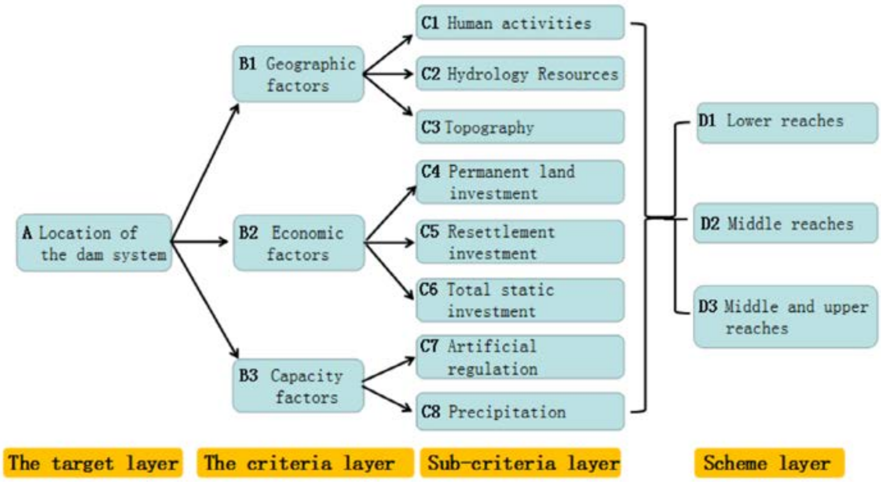


Figure 3. Structure Diagram [6].

Although the criterion in this model is not independent, it is not related to all the elements. In the Table 1 it is clearly described the connection between the factors.

Table 1. The relationship among the criteria and sub-criteria [6].

Sequence	Factors	Relationship between the factors
1	A	determined by B1, B2, B3
	B1	determined by C1, C2, C3
2	B2	determined by C4, C5, C6
	B3	determined by C7, C8
3	C1~C8	All determined by D1, D2, D3

From Table 1 it is necessary to classify the degree of importance of each element that is determined by comparing it with the other elements Table 2.

($X1>X2$) means that factor $X1$ is more important than factor $X2$; $X1=X2$ means that factor $X1$ is as important as factor $X2$).

Depending on the degree of importance, the judgment matrix of each layer is constructed as follows, Fig. 4.

A	B1	B2	B3
B1	1	1/5	3
B2	5	1	7
B3	1/3	1/7	1

B1	C1	C2	C3
C1	1	1/7	1/3
C2	7	1	5
C3	3	1/5	1

B2	C4	C5	C6
C4	1	7	7
C5	1/7	1	1
C6	1/7	1	1

B3	C7	C8
C7	1	7
C8	1/7	1

C1	D1	D2	D3
D1	1	3	5
D2	1/3	1	3
D3	1/5	1/3	1

C2	D1	D2	D3
D1	1	1	1
D2	1	1	1
D3	1	1	1

C3	D1	D2	D3
D1	1	3	5
D2	1/3	1	3
D3	1/5	1/3	1

C4	D1	D2	D3
D1	1	1/3	1/5
D2	3	1	1/3
D3	5	3	1

C5	D1	D2	D3
D1	1	3	5
D2	1/3	1	3
D3	1/5	1/3	1

C6	D1	D2	D3
D1	1	1/3	3
D2	3	1	5
D3	1/3	1/5	1

C7	D1	D2	D3
D1	1	1/3	1/5
D2	3	1	1/3
D3	5	3	1

C8	D1	D2	D3
D1	1	3	5
D2	1/3	1	3
D3	1/5	1/3	1

Figure 4. The judgment matrix of each layer [6].

Table 2. The importance degree among the criteria and sub-criteria [6].

Sequence	Factors	Importance degree
1	A1	B2 > B1 > B3
2	B1	C2 > C3 > C1
	B2	C4 > C5 = C6
	B3	C7 > C8
3	C1	D1 > D2 > D3
	C2	D1 = D2 > D3
	C3	D1 > D2 > D3
	C4	D2 > D1 > D3
	C5	D1 > D2 > D3
	C6	D2 > D1 > D3
	C7	D3 > D2 > D1
	C8	D1 > D2 > D3

Based on the judgment matrix, the proportion of each factor was calculated using the MATLAB programming language. Subsequently, the relative parameters were calculated to test the consistency of each layer to judge the consistency of the judgment matrix.

There are some formulas to calculate CI and CR.

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (2)$$

where:

$\lambda_{\max}$ is the largest eigenvalue of every factor;

n=3 is the number of the factors in the criteria layer;

CI is the consistency indicators of each layer.

$$CR = \frac{CI}{RI} \quad (3)$$

where:

RI = 0.58 is the random consistency index of each layer;

CR is the consistency ratio of each layer;

When proposing the criteria and sub-criteria, it should be taken into account that these should be as complete as possible and refined to obtain the best results in the end, this will greatly improve the objectivity of decision making.

Although the article shows good results, it mentions the criteria to be taken into account for the evaluation and subsequent location of potential sites in the rivers or basins on a map.

That study and others like [1], [6], [9], [33], [34], that examined small and large scale water storage on farms, used techniques that involve the spatial overlap of relevant GIS data to produce a summed classified layer. These approaches, instead of identifying specific locations for dam walls, indicate the most appropriate general areas for the construction of water tanks. These techniques work well for criteria that are easily represented in space, such as large-scale geology, runoff generation, social and environmental effects, and proximity to current and future water demands. In the case of [5] it is proposed that, although composite index techniques are useful for capturing large-scale considerations in the location of dams, they do not explicitly model processes and factors relevant to the performance of large individual dams (for example, performance or construction cost), which depend on the complex game between the following factors:

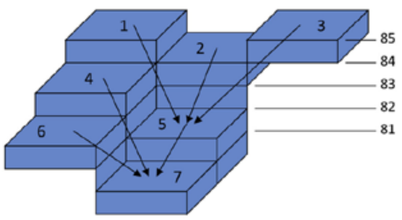
- topography, p. through the dimensions of the dam wall, the volume of the reservoir and the relationship of the surface area with the volume.
- hydroclimatology, p. through the quantity and the inter and intra annual variability of the entrances to the deposit and the net evaporation of the deposit.

- reliability with which a particular performance can be achieved.

Composite index methods have a limited capacity to assess the relative promise of specific sites, mainly because they do not calculate the potential dimensions of the dam and the reservoir and, therefore, the yield, which is generally the key measure of the yield of the dam. To do this [5] describes DamSite, a series of algorithms that provide a flexible means to identify and classify the possible locations of the dam walls in a landscape from the majority to the least promising, by calculating the potential dimensions of the dam and reservoir, and performance calculation at a given reliability for each potential dam within a basin or region.

According to the stages of the proposed methodology, first, it proposes the realization of a spatial analysis to calculate the dimensions of dams and reservoirs and for this it developed a method to automatically calculate the dimensions of dams and reservoirs from a DEM. The geometric parameters are derived from a DEM and its one-way flow network. Plans and depressions should be treated so that there are no interruptions in the flow network. Once the flow paths have been defined, the model rounds the DEM elevations to whole numbers so that the storage and dam dimensions can be calculated efficiently at discrete heights.

The volume and area of a reservoir contained by a dam along the catchment limit is represented by a table of heights and corresponding areas (represented by a DEM cell count). One table is calculated for each cell in the DEM starting at the cells without entrances (hill tops and ridges), and building tables for each cell downstream by combining the tables of the cells that flow into it. Fig. 5 shows a scheme of several cells, the flow paths between them and the resulting tables of heights and cell counts for each cell.



Cell	Height (m)	Count	Depth (m)	Area (m²)	Volume (m³)
1	85	1	0	0	0
2	84	1	0	0	0
3	85	1	0	0	0
4	84	1	0	0	0
5	82	1	0	0	0
	83	0	1	900	900
	84	1	2	900	1800
	85	2	3	1800	3600
6	83	1	0	0	0
7	81	1	0	0	0
	82	1	1	900	900
	83	1	2	1800	2700
	84	2	3	2700	5400
	85	2	4	4500	9900

Figure 5. The construction of the height count table for a small set of cells connected by flow paths. The table for each cell is constructed by combining the tables of each contributing cell. The surface areas and volumes are computed from the counts at each depth using a cell area of 900 m^2 [5].

Given the height count table for a cell, the reservoir area (in m^2) for a given water surface elevation is simply the sum of cell counts with heights less than the water surface elevation, multiplied by The area of the cell. The volume (in m^3) is the sum of areas for heights less than or equal to the height of the water surface (using a 1m elevation increase). The table captures the depth-area-storage relationship in each DEM cell.

Subsequently, the quantification of topographic constrictions and classification of possible sites of dams was carried out in order to penalize walls of higher and longer dams and, therefore, identify economically efficient locations. Performance calculation involved a two-stage approach:

- A quick preliminary performance estimate for each dam height increase m in each pixel along each channel in the study area. The key inputs for this analysis were the annual average runoff raster's and the standard deviation in the annual runoff.
- For a selection of the 'best' potential storage locations identified during the first stage, more robust performance estimates were calculated using the most computational behavior analysis model. For this analysis, the model used squared time series of daily runoff, rain and evaporation.

Alternatively, the method does not use criteria such as minimization of the flooded area (a source of environmental impact), minimum displacement of resident populations, maximization of hydroelectric potential or flood mitigation. All these criteria require an analysis of the basin and the reservoir as an entry in the site selection.

3. Result and Discussion

One of the main inhibitors identified for the progress and economic development of most urban settlements is the lack of access to adequate water supplies for human consumption and domestic use, irrigation and industrialization [35]. The approaches previously investigated mostly are not based on the identification of potential sites for the construction of dam walls, but rather indicate the general area to locate water deposits.

They propose the use of proprietary tools such as ArcGIS, GISILWIS, ArcView, ArcMap, among others, in which all the work is done manually using a set of functions and components present in them. In some of the cases, the tools developed or the work carried out on the tools are for certain types of dams with specific objectives, as well as environmental or social factors, nor flood prevention.

As he puts it [36] one of the most damaging factors that must be taken into account is flood prevention due to the dangers of unpredictability. Possible causal factors for flash floods include excessive rain, sudden release of water due to a break in the dam or lake bursting. This factor is important because it affects the other factors, say social, environmental, industrial, economic, etc.

These ideas further highlight the importance of applying computational techniques, as well as creating a specialized tool that allows to speed up the process in decision-making and planning in hydrological use. In this way, the potential sites that affect the most important factors in a very low probability can be obtained, which in turn will make it possible to achieve better results in the construction of the dams in their subsequent use. In addition, your employment can provide some of the following advantages:

- The need for micro dams aimed at specific objectives and that, without damaging the environment, allow the possibility of bringing crops or different branches of production towards them would eliminate the cost of taking water to farther places. This allows the dams, made for the population supply, that are the most exploited, to go directly to it without having more purposes or objectives.
- The creation of small dams aimed at specific objectives not only supports the livestock or crop industry, but also supports flood regulation and the collection of these waters.
- The efficiency (in time and/or space) of multicriteria evaluation methods depends on the number of used criteria. Therefore, by selecting the most important set of criteria, the algorithm would work faster, and would provide the potential sites for the construction of dams.
- Have a multicriteria analysis method that allows hydraulic specialists to know through a feasibility study previously carried out and a simulation and representation of the affected areas, which area of the selected river is best suited for the construction of a dam or micro dams.
- Prevention in making incorrect decisions at the time of the construction of dams in unsuitable areas that may cause flooding and therefore damage in industrial, crop or populated areas.

Finally, it can be affirmed that, although the consulted bibliography reports different approaches in order to obtain better locations of potential sites, the existing approaches still have certain limitations and are still inefficient for their application in decision making. This has led the scientific community, recently, to seek new alternatives to improve the selection results [5], [30], such as increasing the degree of abstraction of the base criteria, new methods of coding them [20], [37] or focus on multicriteria evaluation techniques [38], [39].

4. Conclusion

The large number and topicality of proposals for techniques for selecting potential areas, available in the literature, shows that this topic constitutes a very active field of research. The study confirms that:

1. Local selections are characterized by their effectiveness and efficiency in the results that they offer. However, this type of selection has certain limitations - especially related to the loss of context information - that limit its discriminatory power. Therefore, it is necessary to create and update models for selecting potential sites for the construction of dams with a view to improving the results obtained up to now.

2. The integration of mathematical models in GIS facilitates simulation, as it speeds up the spatial analysis of variables and parameters, allowing the combination of aggregated and distributed data.

3. By analyzing the GIS operations of image processing from spatial remote sensing, it's possible to draw conclusions about flood damage and conditions, and prioritize the corrective measures to be applied; and even estimate the probable maximum avenue in a watershed or the meteorological parameters of hydrological interest.

4. Finally, the creation of multicriteria evaluation methods that take into account the improvement of the initial stages of a prefeasibility analysis and that manage to select the sites with the highest discriminatory power, constitutes a current challenge for the scientific community in this field of research. In this sense, the incorporation of techniques for selecting all potential dam sites within a region is vital to guarantee their discriminatory power and, at the same time, to reduce the dimensionality of the data. Its application is possible in order to increase the effectiveness and efficiency in the prevention of decision-making and in the planning of the construction of hydraulic structures.

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