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# Hydrological Information related Existed Dam Sites Assessment using ArcGIS in Zawita District

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**ABSTRACT**

***One of the critical pillars that sustain human civilization is meeting the water demand for different purposes like storage, electricity, flood control, and others. In another hand, the mismanagement of water resources and unplanned urbanization is denoted as the most obstacles for developing the arid and semi-arid regions. For this, it is important to know the appropriate places to construct such important projects and to evaluate those places if those places are suitable for constructing dams or not. In this paper, a hybrid Geographic information system (ArcGIS) decision-making technology powered by fuzzy logic is molded to assess seven small dams' sites in the Zawita district. Some Hydrological criteria were depended for evaluation like rainfall, geological formations, and types of soil, slope, surface hydrological properties, and drainage density. The results show that all dams within the Zawita district are located in areas with suitable geological formations except Bari bhar which may suffer from sedimentation problems next years. While regarding slope and drainage density criteria; All dams are located in an appropriate site. Finally, by using the fuzzy logic strategy, it turns out that three finished dams were built in relatively suitable places, they are Botiya, Bari bhar, and Bhiri. Finally, As for the unfinished dams, one dam is considered an unsuitable location according to all the criteria used, which is the Talwa dam and one dam within a relatively suitable location, which is the Eminki dam, while the Bisre dam was one of the appropriate dams that have not been built yet. From the result, It should be noted selecting the most suitable site to build dam has a great role in proper management of the limited water resources in Duhok to meet the whole demand especially in recent years it has been considered that water scarcity is the most serious issues due to climate change.***

## 1. INTRODUCTION

Water can be characterized as the foremost important component for surviving life Veldkamp [1]. The scarcity of water has been increased after urban development and growing population which in turn leads to ever-increasing in demand as forwarded by Al-Ruzouq et al. [2]. This postures a major concern which restricting the usage of the plans and programs related to water division improvement as revealed by AlMohseen and Klari [3] in addition, the unplanned urbanization with the mismanagement of the limited resources of water make many obstacles face the developing countries, to manage these resources to fit water supply Al-Ruzouq et al. [4]. Dams are considered one of the greatest and biggest civil facilities ever built by man. These dams have changed the features of human civilization. The construction of dams of various kinds is increasing in all countries of the world. Rather, they invented many different models of dams to resist violent waters, the limits of the water facilities that are established to conserve and store water and prepare it for consumption.

Several studies have been suggested [5, 6, 7]; any breach or break happening in a dam leads to massive losses in the area downstream of it (loss of life and economy) as well as negative effects on the environment could occur. This has. In this manner, the issue of selecting the best appropriate sites to build new dams is pivotal. By and large, dam location choice is conducted by conventional strategies, such as ordinary decision-making strategies or agreeing to a political interface. In recent years, the progression in satellite and computational control has upgraded the opportunity to oversee diverse hydrologic parameters and territory characteristics. RS and ARCGIS offer tall flexibility of joining of spatial data with distinctive progressed numerical, real, and decision-making techniques, such as fuzzy logic, and multi-criteria assessment procedures and counterfeit insights as stated by Kumar, et al. [8]. Several studies have been conducted to evaluate dam sites based on varying criteria. Al-Ruzouq, et al. [4] highlighted some key factors that affect dam location suitability; Table 1 below highlighted the key components that influence dam location propriety within the literature.

Recently, some studies were done in the Kurdistan region of Iraq for assessing Dam sites. Othman and Al-Maamar et al. [33] Determined suitable sites to construct new dams within the Khabur River Basin within the Duhok governorate. They used the fuzzy analytical hierarchy process (AHP) and Weighted Sum Method (WSM) to compare appropriate dam sites. GIS was utilized to generate 14 thematic layers for assessing dam site including lithology, tectonic zones, distance to active faults, distance to lineaments, soil type, land cover, hypsometry, slope gradient, average precipitation, stream width, Curve Number Grid, distance to major roads, distance to towns and cities, and the distance to villages. Also, Ali, et al. [9] used Geographical Information Systems (GIS) with Remote Sensing (RS) through satellite images and Digital Elevation Model (DEM). GIS helped to build objective maps of the Garmiyan region located in Iraqi Kurdistan, which are geomorphological, geological, and hydrological maps, as well as hydrogeological maps to determine the appropriateness of the location of the underground dam. Another study was done in Al-Tharthar Basin northern of Iraq by Al-Thanoon and Ahmed [34], to choose the best dam site using GIS. The location of the dam they chose depended on which dam had more lake storage with a lesser length and the existence of substantial foundation materials. The above highlighted the importance of studying the hydrological information and morphology of any catchment before deciding on building dams and how it will affect the expected storage and safety of these dams in the future especially as the water resources are limited and with time while the population and demands are increasing Klari [3]. So the present study adopts six parameters like surface hydrological properties, precipitation, geological formation, type of soil, the density of water pool, slope to assess dam site suitability in Zawita where some are finished, and some are under construction.

**Table1:** Recent dam site suitability studies.

| References | Study Area | Utilized Factors | Utilized Technique |
|---|---|---|---|
| **Mohammed et al. [10]** | Greater Zab river, Northern Iraq | Rainfall, geology, soil type, fault line, tectonic line, altitude, slope, road network, LU/LC, material used for dam construction | Analytical hierarchal processes (AHP) and fuzzy logic |
| **Sayl et al. [11]** | Western desert of Iraq | Western desert of Iraq | Elevation area volume curve method |
| **Jamali et al. [12]** | Northern Pakistan | Northern Pakistan | Analytical hierarchal processes (AHP) and the factor interaction method (FIM) |
| **Jamali et al. [13]** | Boda-Kalvsvik, Sweden | Boda-Kalvsvik, Sweden | Water balance calculations and overlay analysis |
| **Weerasinghe et al. [14]** | Sao-Francisco and Nile catchment | Sao-Francisco and Nile catchment | Soil conservation service curve number (SCS-CN) equation, compound weighted index (CWI) and multi criteria evaluation technique |
| **Pandey et al. [15]** | Karso, Hazaribagh, India | Karso, Hazaribagh, India | Overlay analysis (Integrated Mission for Sustainable development (IMSD) guidelines |
| **Darshdeep and Litoria et al. [16]** | Soankhad watershed, Punjab, India | Soankhad watershed, Punjab, India | Overlay analysis (IMSD guidelines) and Water balance study |
| **Kumar et al. [7]** | Bakhar watershed of Mirzapur District, Uttar Pradesh, Indea | Bakhar watershed of Mirzapur District, Uttar Pradesh, Indea | Overlay analysis (IMSD and Indian National Committee of Hydrology(INCOH) |
| **Das et al. [17]** | Himalayan region, India | Himalayan region, India | Calculation of available flow of water |
| **Rantnam et al. [18]** | Yarafeni watershed in Midnapur District, West Bengal, India | Yarafeni watershed in Midnapur District, West Bengal, India | Sediment yield index (SYI) and weighted overlay analysis |
| **Baban et al. [19]** | Langkawi Island, Malaysia | Langkawi Island, Malaysia | Weighted overlay method |

## 2. STUDY AREA

Duhok is one of the districts of Duhok governorate north of Iraq, as it is located coordinately at 40˚48′00″N, 43˚17′ 30″E and it is located in the center of Duhok governorate with a total area of 1015.02 km². The study focused on Zawita which is the biggest town of Duhok located coordinately at 36˚54′21″N, 43˚08′ 34″E. It is about 16 km away from the city of Duhok having an area of 430 Km² approximately 43 % of Duhok total area (Figure1), and it consists of 71 villages.

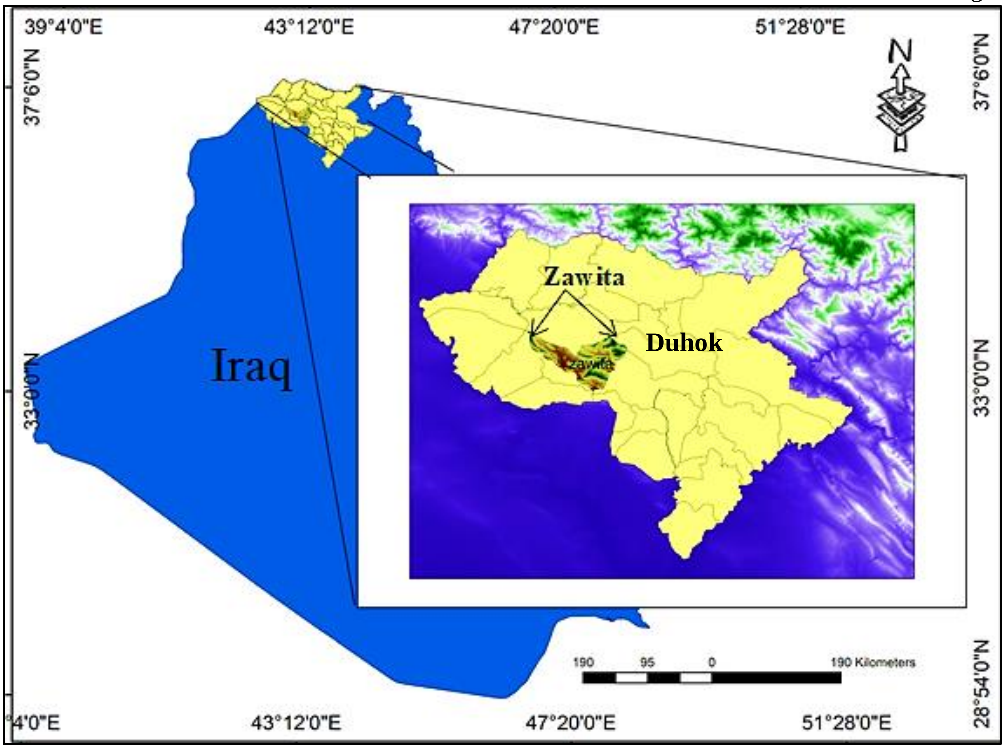



**Figure 1**: Location of Zawita.

Duhok is located in a semi-arid region; the average monthly rainfall is 88.76 m while the mean yearly rainfall is 798.7 mm between the years 2000 and 2015. Monthly and yearly rainfall in Zawita rainfall station is shown in (Table 2) from the Ministry of Agriculture and Water Resource [21].

**Table 2**: The average monthly and yearly rainfall (mm) of Zawita station between 2000 and 2015.

| Station | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Yearly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Zawita rainfall (mm)** | 180.1 | 137.5 | 85 | 86.6 | 0 | 0 | 0 | 30.9 | 15.7 | 39.5 | 81.17 | 142.4 | 798.7 |

Figure (2) show the natural vegetation in Zawita district is classified between pine and oak trees with only 2.9% of the total area of the area while the rest is herbs and shrubs. The mentioned percentage of vegetation cover was found after classifying the area using GIS according to the satellite image (Landsat 8 Oli) downloaded from the USGS website on 10/20/2019. Tables (3) show the land use classification of Zawita using the same procedure for vegetation cover. This meant that curve number may be between 70 to 85 as can be assumed depending on land use/vegetation cover from many previous studies, so runoff occurring is predicted well

**Table 3**: Land use classification in Zawita District

| Land Use | Area ($Km^2$) | Percentage (%) |
|---|---|---|
| **Pine and Oak Trees** | 9.25 | 2.2 |
| **Herbs and Shrubs** | 170.57 | 41 |
| **Weed** | 137.01 | 33 |
| **Orchards** | 1.89 | 0.5 |
| **Residential** | 23.87 | 5.7 |
| **Rocks** | 36.92 | 8.9 |
| **Waters** | 1.78 | 0.4 |
| **Soil** | 29.14 | 7 |
| **Burnt** | 5.35 | 1.3 |
| **Total** | 415.76 | 100 |

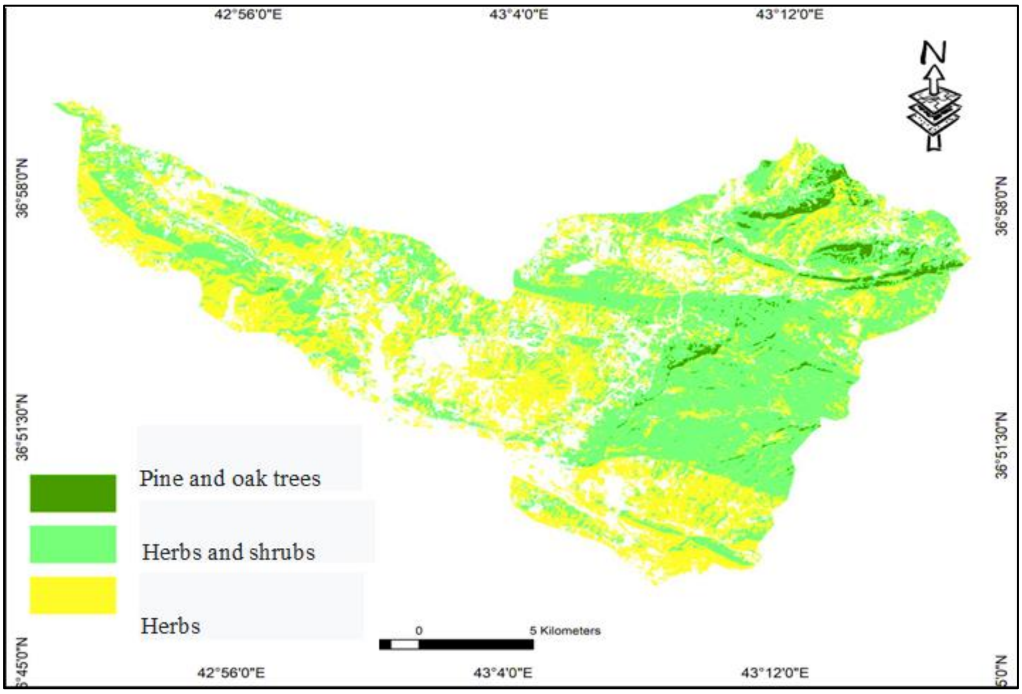


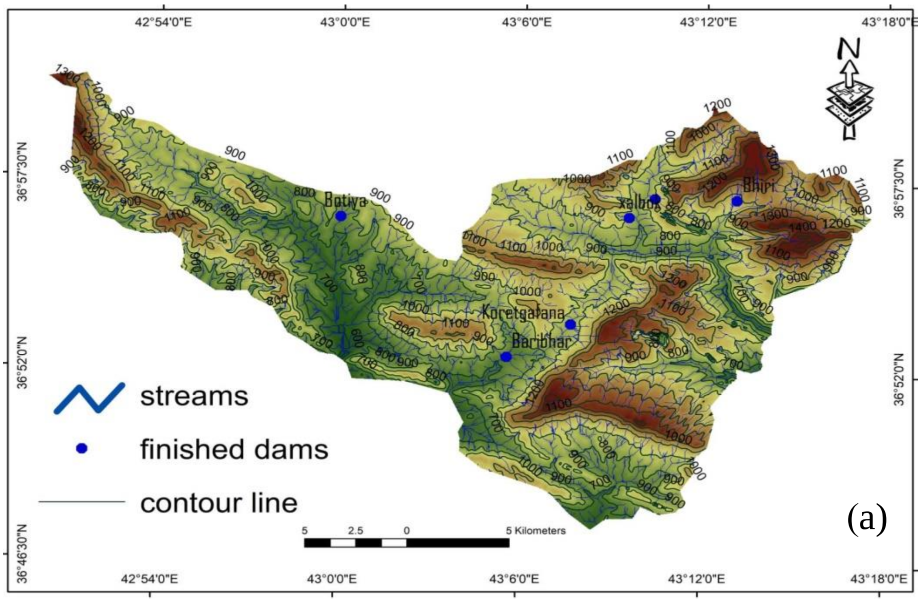

**Figure 2**: The vegetation cover in the Zawita District.

In Zawita, there are six finished dams, with a total storage capacity of 843,000 m3 of water and this is very good if it is used in dry years to meet the water needs of the district. The number of unfinished planned dams will reach three dams where they can store water with a volume of 375805 m3. If these dams are built with the volume of water in the finished dams, the volume of water that can be absorbed by all dams within the district will reach 1218805 m3; Dams are divided into two main parts, namely, finished and actually existing dams and the other part is under construction i.e. unfinished (Figure3). Most of these dams are used for irrigation purposes. More detailed information on dams was obtained from Dams Directorate in Duhok (Unpublished data, Table4).

**Table 4**: Dams in Zawita district.

| Finished Dams | Longitude | latitude | Storage ($m^3$) | Dam Height | Execution Year |
|---|---|---|---|---|---|
| **Xalbok** | 43°10′22″ | 36°57′04″ | 30,000 | 6 | 2001 |
| **Bhiri** | 43°13′04″ | 36°57′03″ | 380,000 | 18 | 2005 |
| **Kurt Kavanagh** | 43°09′31″ | 36°56′31″ | 45,000 | 10 | 2006 |
| **Botiya** | 43°00′00″ | 36°56′25″ | 230,000 | 16 | 2007 |
| **Bari bhar** | 43°05′33″ | 36°52′26″ | 120,000 | 13 | 2009 |
| **Zawita** | 43°07′39″ | 36°53′24″ | 38,000 | 12 | 2009 |
| **Talwa** | 43°10′21″ | 36°49′22″ | 149,513 | 16.5 | Under construction |
| **Bisre** | 43°3′47″ | 36°51′31″ | 142,395 | 10 | Under construction |
| **Eminki** | 43°5′28″ | 36°52′46″ | 83,897 | 10 | Under construction |

ArcGIS program was used to create the spatial, slope, basins, and drainage density maps of these dams. Then re-referencing other maps like geological and soil type maps were created by other researchers as will be explained later. The next step is extracting the referenced map according to the study area required for the study which is Zawita to make the thematic layers that would be used for assessment of the dam site.



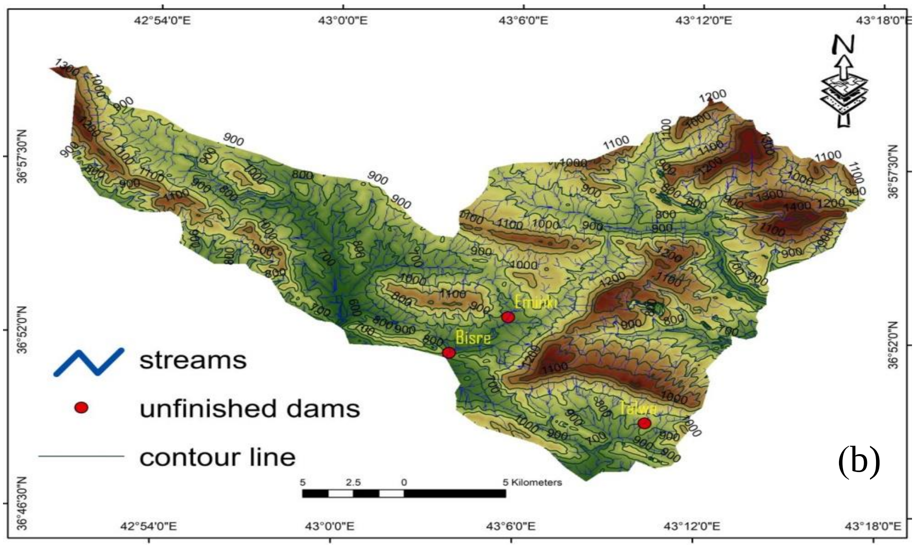



**Figure 3** (a, b): The Spatial Distribution of Dams in the Zawita District.

## 3. METHODS AND MATERIALS

### *3.1 Methods*

It is known that the process of evaluating dam sites is not an easy matter at present if it follows the correct scientific foundations and in the light of modern software and technologies, as it requires an extensive reading of all the factors controlling them, so it must be set as basic criteria: Binary and the fuzzy logic system. In the binary system, two values (0-1) were used to give weight to the properties of some variables, the value (0) was given for the Unsuitable positions and the value (1) for the appropriate positions, while the fuzzy logic system was used for the variables whose regions were divided To degrees in terms of relevance according to the variable, and then the final result was categorized into three degrees that included the positions (appropriate, relatively appropriate, and unsuitable).

As mentioned by Al-Kofari [32], Based on the needs of the study area, the geographical location and the population distribution, a specific mechanism was reached regarding the criteria chosen to determine the optimal sites for water harvesting; for example, the dam should be built on a solid ground. The land on which the specified site is located must be flat or with gentle slopes, because if the slope exceeds a specific value, it will lead to soil erosion processes. The acceptable slopes should be within the range (0° to 11°). In other side, soil types have a great influence on dam site selection. If the soil type is a clayey, it is most suitable, but with soil having a high permeability like sandy soil then it considered as unsuitable. Moreover, as the greater the percentage of accumulation of runoff (drainage density) indicates the increase in the area of the feeding basin

Finally, the process of fuzzy method in evaluating the locations of dams in this study depends on the integration of the previous criteria depending on the degree of importance of the criteria used in the matching process within the ArcGIS 10.5 program (Table 5).

**Table 5**: is the percentage of criteria used in the spatial assessment process for the locations of small dams in the Zawita district.

| Criteria | Percentage (%) |
|---|---|
| **Drainage density** | 40 |
| **Slope** | 20 |
| **Geology** | 20 |
| **The soil** | 20 |
| **Total** | 100 |

### 3.2 Materials

Towards assessing the dam site, six parameters were adopted as criteria: Precipitation, surface hydrological properties, geological formation, soil type, drainage density, and slope. A brief description of each parameter is indicated as shown below:

**Precipitation:** The climatic criterion is one of the important criteria that have a direct impact on the process of water harvesting. High rainfall zones are considered appropriate for dam construction Al-Ruzouq, et al. [4]. The areas suitable for water harvesting must have an annual rainfall of not less than 50 mm as shown by Awawdeh, et al. [20].

**Slope:** The slope is defined as a surface of the earth that descends from the horizontal plane of the surface by a degree not exceeding (90) degrees, and the slope or slope is defined according to ArcGIS as the amount of change in height between each cell and the adjacent cell, as each cell is surrounded by eight neighboring cells The greater the slope, the greater the elevation in the area, and the smaller the slope, the closer the area is to a flat shape. The slope is defined by DEM 30 m from the usgs.gov site using ArcGIS Table 6 illustrates the degree and area of the slope in Zawita.

**Table 6**: Slopes degree, area and percentage of Zawita District.

| Description | Slope Degree | Area ($Km^2$) | Percentage (%) |
|---|---|---|---|
| **Flat-Level** | 0-1.9 | 8.6 | 2.1 |
| **Slight wave** | 2-7.9 | 113.6 | 27.8 |
| **Wavy** | 8-15.9 | 150.4 | 36.8 |
| **Intermittent** | 16-29.9 | 118 | 28.8 |
| **Severely Choppy** | More than 30 | 17.8 | 4.3 |
| **Total** | | 408.4 | 100 |

**Geological formations:** When choosing sites for water harvesting, geological studies of the study basin must be conducted because of their importance in knowing the types and characteristics of rocks and the extent of their hardness or porosity, as this reflects on the economic nature of the construction of dam sites and the provision of materials needed for construction. Some types of geologic formation are described in Table7.

**Table 7**: Geological formations in the study area.

| Geologic formation | Description |
|---|---|
| **Sharnish** | The composition consists of two units, the lower one consisting of marl limestone and marline shale in abundance, and the cans unit consisting of blue marl with little resistance to force factors as classified by Al-Hidan and Al-Samraai [22] |
| **Belaspi** | The rock consists mainly of limestone, diolamine, clay and dolmen white to cream and light gray white miniature, respectively, and well-layered by Hasan [23] |
| **JRX** | It is characterized by its red sequences, which consist of successive folds interspersed with sand and silt stones and queens tide with the presence of layers of gypsum in the upper parts as reported by Al-Brefkani, et al. [24]. This formation is spread within the upper folds in (Gali Kabirka) and in the areas surrounding Mount (Zarwa) in the north and northwest and in Eastern parts of the side. |
| **Khurmalah** | Its rocks are composed of finely stratified limestone (smaller and paler) and limestone referenced by Hsasn, et al. [25] |
| **Kolosh** | Abdel-Aziz [26] classified Kolosh as a formation consisting of igneous rocks, represented by shale rocks, mudstones, sand and others, ranging in color, between gray and black This formation is spread along the feet of the mountains. |

| | |
|---|---|
| **Anjana** | It represents the transitional phase between marine environments and aquatic environments, and that the igneous rocks of this formation are clayey, alluvial and sandy rocks as denoted by Al-Mufti [27] |
| **Slot** | Its rocks are composed of limestone, gypsum, marl, a little sand, alpha, and anhydrite |
| **Sediments of the slopes** | It appears on a large scale in areas of gradient change and increases towards low and flat lands, and includes the northwestern part Abdel-Hakim [28] |
| **Sediments of the sedimentary plain** | Khidir [29] stated that Sediments of the sedimentary plain is represented by the sedimentation resulting from floods and the repetition of these sediments secreted by the formation of plain lands on the side of the two valleys with varying areas, increasing in breadth in the areas of twists and turns ranging in width from several meters to reach about (50) meters and rarely up to (100) meters (, 2001) |

**Types of soil:** Soil means the crumbled surface layer of the earth's crust above its surface, in which the plant grows by its roots and derives its water from it Abdel-Hakim [28]. Soil is one of the natural factors affecting the surface drainage process because there is a reciprocal relationship between surface runoff and soil texture as explained in several studies [29, 30]. Three types of soil were found in the study area as shown in Table 8.

**Table 8**: Type of Soil within Zaweta district.

| Soil Type | Description |
|---|---|
| **Clayey soil** | Also called heavy soil, it has a smooth texture when it is dry, while its texture becomes sticky when it is wet, and although it contains many nutrients; it does not allow water and air molecules to pass through it. |
| **Side panels- clay mixture** | Soft soils of clay textures, including soils containing (40%) or more by weight of clay. |
| **Sandy Loamy Soil** | It is the soil that has more sand than clay and has good permeability due to the presence of sand |

**Surface hydrological properties:** The hydrological standard determines the amount of surface water that flows into the drainage basin and the volume of storage in the dam lake in rainy years, as this is related to the amount of rainfall, the coefficient of surface runoff, and the area of the drainage basin, which must be sufficient to fill the storage lake, and then the locations of the constructed dams must be within a network The water bodies in the drainage basins Al Sulaiman [31].

On this basis, the criterion of accumulation of runoff was used, as the greater, the percentage of accumulation of runoff indicates the increase in the area of the feeding basin. So it represented the surface hydrological characteristics of the river basins, the drainage network, and the aggregate density of water, as each of the mentioned characteristics have a role in determining and evaluating the optimal sites for the small dam and can be studied as follows:

**The main basins of the study area:** The study area has three main basins, which are Komel Basin, Hashkerou, and Baidawa. Figure4, Table 9 shows that the Hashkerou basin has the highest area among the basins of the Zawita district, with an estimated area of (166.4) km², and the lowest of the Baidawa River basin with an area of (36.5) km².

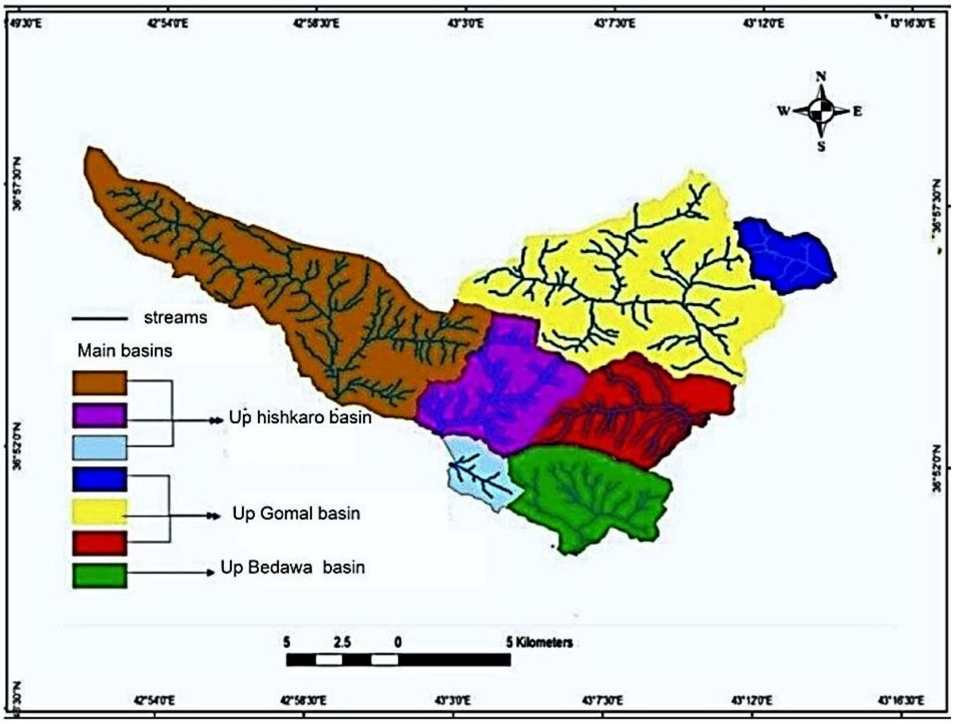


**Figure 4:** The main basins of the study area.

**Table 9**: Area Percent of the Basins.

| River Basin | Area ($Km^2$) | Percentage (%) |
|---|---|---|
| **The upper basins of the Hashkerou River** | 166.4 | 40.74 |
| **The upper basins of the Komel River** | 205.5 | 50.31 |
| **The upper basins of the Bedaoa River** | 36.5 | 8.93 |
| **Total** | 408.4 | 100 |

**Drainage density:** The density of the water gathering is one of the important criteria in evaluating the locations of dams and knowing the places that accumulate the most water at the basin level, where we can determine sites for gathering and whether the dams are built or planned to be built on sites with sufficient water gathering or not.

## 4. RESULT AND DISCUSSION

Zawita rainfall exceeded 50 mm/year, so all dams' sites were located within a suitable area. So by using ARCGIS, as a Beginning to the second Criteria, Water harvesting projects must also be built on the rocks of resistance. Figure5 and Table 10 clarify the geological formation distribution according to the map of the Iraqi Geological Survey, scale of 1:250,000.

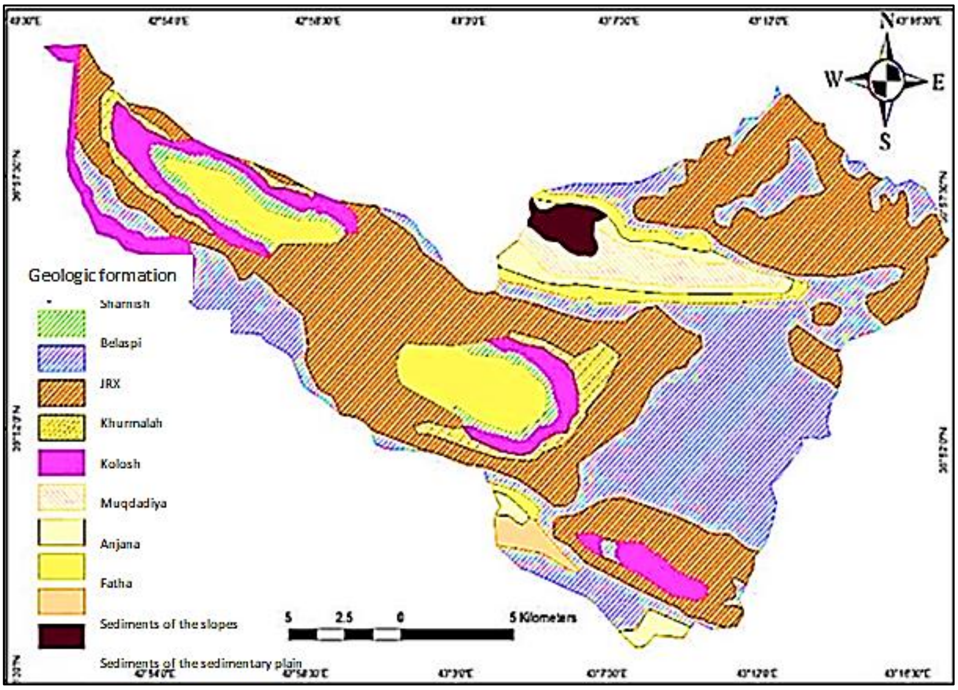



**Figure 5**: Geological formations within Zawita district.

Table 8 represents the areas in kilometers for each type of geological strata that appear in the angular area placed as a percentage. The large layer that appeared in Duhok was JRX, which represents 40.79% and the least formation was sediments of the slopes, which represents 1.22% of the total layers.

**Table 10**: Percentage of the geological formations in Zawita district.

| Geological formations | Area ($Km^2$) | Percentage (%) |
|---|---|---|
| **Sharnish** | 10.4 | 2.54 |
| **Belaspi** | 130.2 | 31.88 |
| **JRX** | 166.6 | 40.79 |
| **Khurmalah** | 13 | 3.18 |
| **Kolosh** | 21.8 | 5.33 |
| **Bakhtiari / Muqdadiya** | 12.6 | 3.08 |
| **Anjana** | 11.4 | 2.79 |
| **Slot** | 34.1 | 8.34 |
| **Sediments of the slopes** | 3.3 | 0.80 |
| **Sediments of the sedimentary plain** | 5 | 1.22 |
| **Total** | 408.4 | 100 |

As cleared in Figure 6 and Table 11, approximately most dams are located within appropriate geologic formations. Except for Bari bhar that located in an Unsuitable dam site, it should be mentioned that this site suffered from this situation right now.

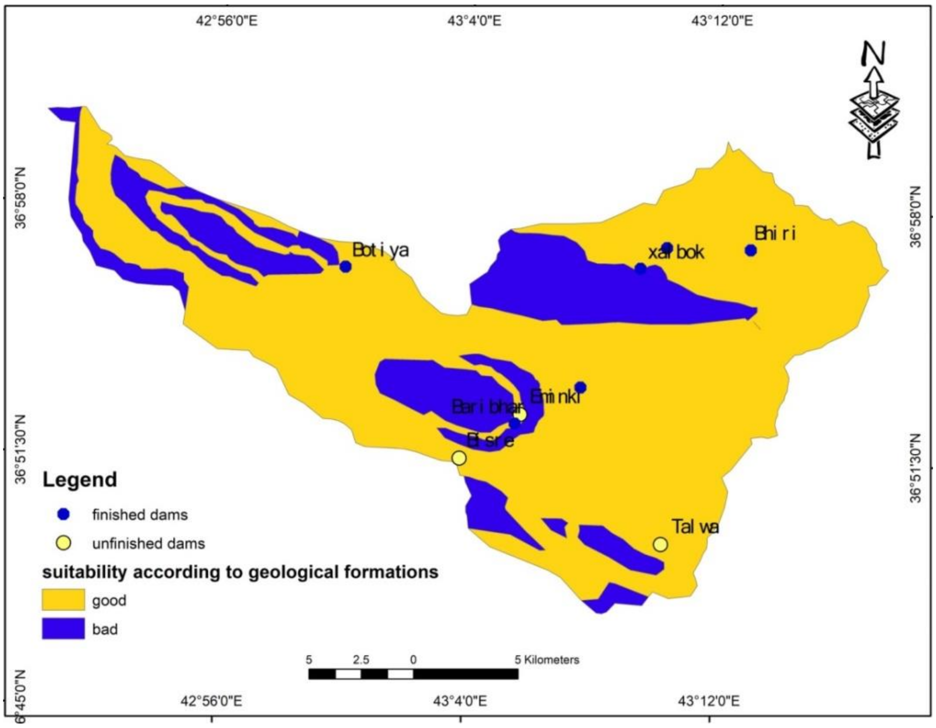



**Figure 6**: Visual Assessment of dam site suitability according to geological formations.

**Table 11:** Degrees of suitability according to the geological formations in the study area.

| Geological formation | Description | Area (Km$^2$) | Percentage (%) |
|---|---|---|---|
| **Sharnish, Khurmalah, JRX, Belaspi** | Appropriate | 320.3 | 76.90 |
| **Fatha, Floodplain sediments, Kolosh, Anjana, Muqdadiya, slope sediments** | Unsuitable | 96.2 | 23.09 |
| **Total** | | 516.4 | 100 |

By the way, Soil type map of Zawita was extracted from soil type map of Duhok generated by Ameen [35] Figure 7 and Table 12 represents the areas of the soil types that appear in its corner, where the most visible are clay soils with an area estimated at (160.3) km², and the least visible are sandy-clay soils with an area of (120.9) km².

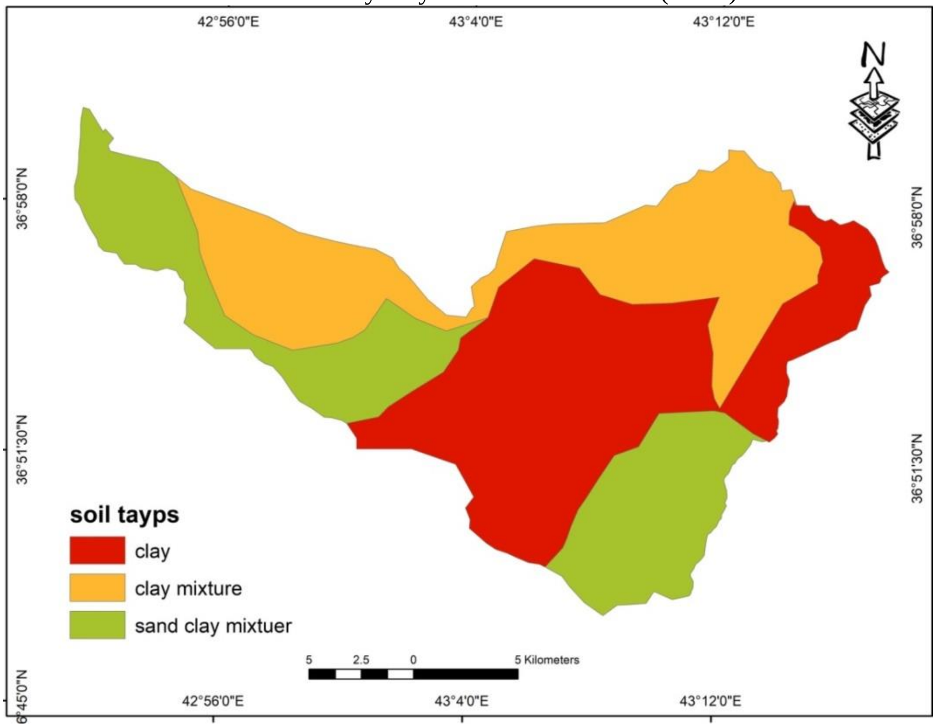



**Figure 7:** Soil types within Zawita district.

**Table 12:** Type and Percent of Soil in Zawita District

| Soil Type | Area ($Km^2$) | Percentage (%) |
|---|---|---|
| **Clayey soil** | 160.3 | 39.25 |
| **Side panels- Clay mixture** | 127.2 | 31.14 |
| **Sandy loamy soil** | 120.9 | 29.60 |
| **Total** | 408.4 | 100 |

Relying on the characteristics of each type of soil that was previously mentioned in the second section of the study, the study basin was classified into three types in terms of suitability for evaluating the positions of dams. Sandy) as for the second type of soil within the study basin, it is relatively suitable for the construction of dams, and it is (clay mixture). As for the last type, which is the most suitable, it is (clay) soil (Figure8, Table 13) we can summarize the following:

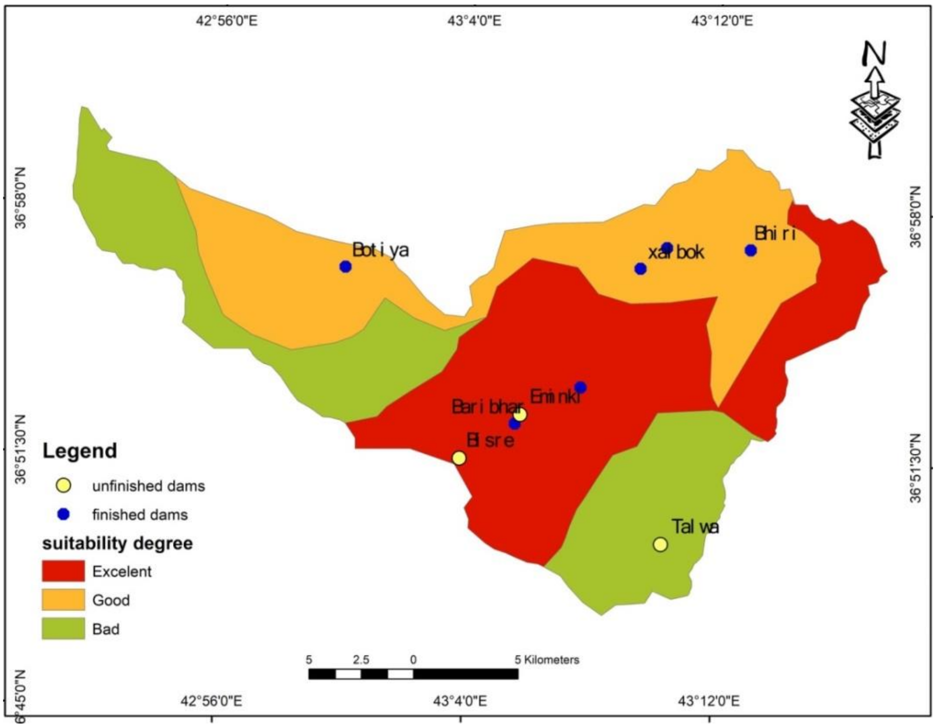



**Figure 8:** Distribution of dams according to soil type in terms of suitability percent.

**Table 13**: Distribution of dams according to soil type in terms of suitability percent.

| Dam | Type | Suitability |
|---|---|---|
| **Xalbok** | Finished | Relatively Appropriate |
| **Bhiri** | Finished | Appropriate |
| **Kurt Kavanagh** | Finished | Appropriate |
| **Botiya** | Finished | Relatively Appropriate |
| **Bari bhar** | Finished | Appropriate |
| **Talwa** | Unfinished | Unsuitable |
| **Bisre** | Unfinished | Appropriate |
| **Eminki** | Unfinished | Appropriate |

Moreover, the surface slope criterion was applied as one of the topographic criteria according to the slope layer. Figure9, Table 14, both of them represent the slope of the land in its angle, which is from flat land to severely interrupted (i.e., steeply sloped), as the flat land in its corner is few, and the undulating land is the most extensive. The acceptable slopes degree within which the dams are located are ranging between (0-11) degrees according to Zing international standards Al-Kofari [32]

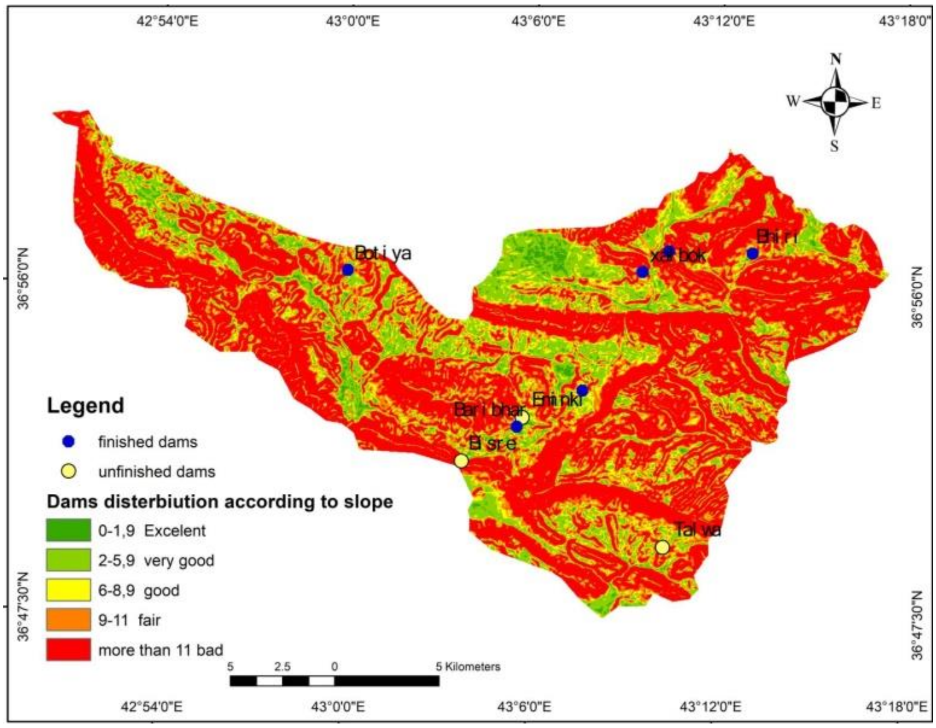



**Figure 9**: Slope according to Zing Specification, Distribution of dams according to the slope criterion.

**Table 14**. Distribution of Finished and unfinished dams according to slope degrees.

| Dam | Type | Slope Degree | Suitability |
|---|---|---|---|
| **Botiya** | Finished | 2-5.9 | Very Good |
| **Bari bhar** | Finished | 6-8.9 | Good |
| **Kurt Kavanagh** | Finished | 2-5.9 | Very Good |
| **Bhiri** | Finished | 6-8.9 | Good |
| **Kerber** | Finished | 9-11 | Fair |
| **Xalbok** | Finished | 2-5.9 | Very Good |
| **Talwa** | Unfinished | 9-11 | Fair |
| **Eminki** | Unfinished | 9-11 | Fair |
| **Bisre** | Unfinished | 0-1.9 | Excellent |

As shown above, it appears that the distribution of dams according to the slope criterion is one of the most important criteria used in evaluating the positions of established and non-finished dams that the positions of three dams among the dams are of medium suitability, two of the dams are good and three Of the dams that are very good in terms of suitability, and one dam was in excellent condition according to this criterion. On another basis, the criterion of drainage density was used, as the greater; the percentage of accumulation of runoff (drainage density) indicates the increase in the area of the feeding basin (Figure10, Table 15)

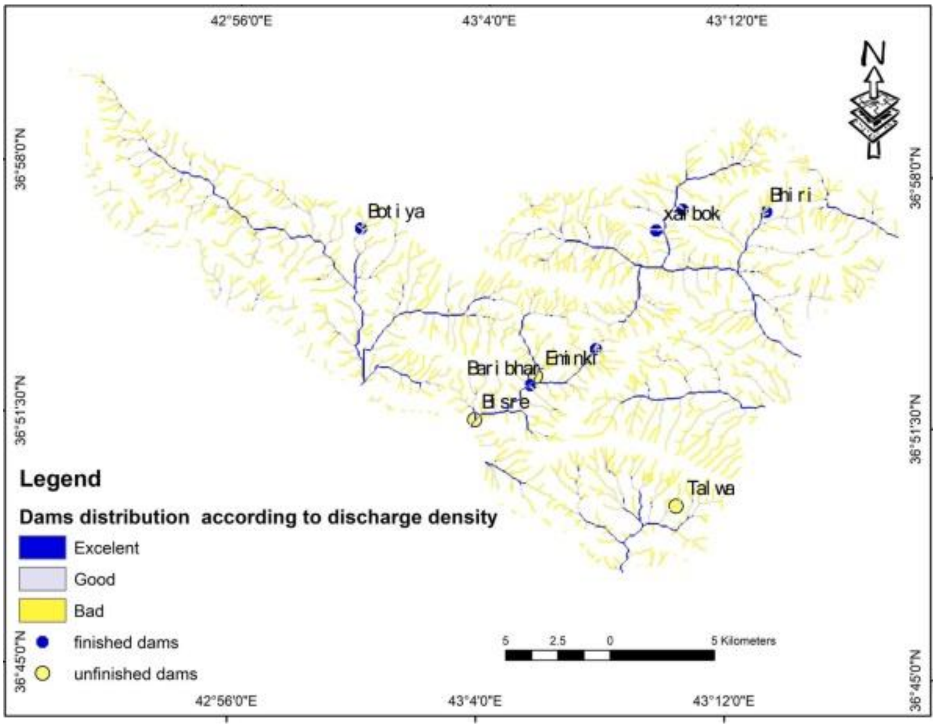



**Figure 10:** Drainage density in Zawita District.

**Table 15**: Distribution of Finished and unfinished dams according to the drainage density.

| Dam | Type | Suitability |
|---|---|---|
| **Botiya** | Finished | Appropriate |
| **Bari bhar** | Finished | Appropriate |
| **Kurt Kavanagh** | Finished | relatively appropriate |
| **Bhiri** | Finished | Appropriate |
| **Kerber** | Finished | relatively appropriate |
| **Xalbok** | Finished | relatively appropriate |
| **Talwa** | unfinished | relatively appropriate |
| **Eminki** | Unfinished | Appropriate |
| **Bisre** | unfinished | Appropriate |

After determining the degree of importance of each criterion, the process of fitting the criteria is carried out within the tool Raster Calculator in ArcGIS (Figure11, Table 16)

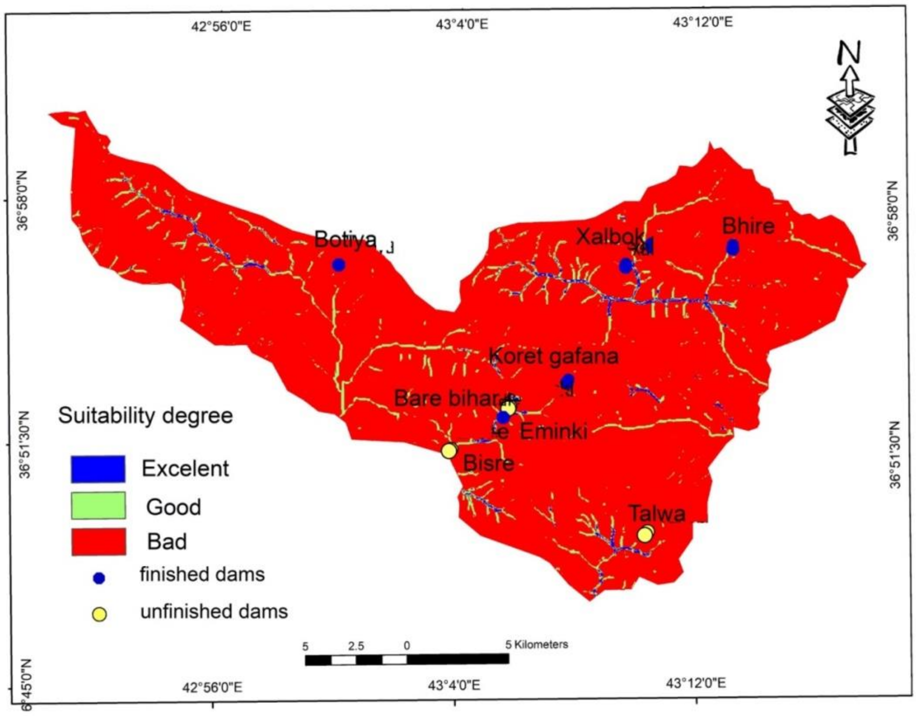



**Figure 11:** Spatial distribution of finished and unfinished dams according to the standard of water collection in the Zawita district.

**Table 16**: Distribution of finished and unfinished dams according to the criteria used.

| Dam | Type | Suitability |
|---|---|---|
| **Botiya** | Finished | Relatively Appropriate |
| **Bari bhar** | Finished | Relatively Appropriate |
| **Kurt Kavanagh** | Finished | Unsuitable |
| **Bhiri** | Finished | Relatively Appropriate |
| **Kharbir** | Finished | Unsuitable |
| **Xalbok** | Finished | Unsuitable |
| **Talwa** | Unfinished | Unsuitable |
| **Eminki** | Unfinished | Relatively Appropriate |
| **Bisre** | Unfinished | Appropriate |

## 5. CONCLUSION

The present study gives clear sights into the importance of selecting the best site for dam construction before making the final decision. The dam location evaluation process depends on the integration of the hydrological standard criteria using binary and fuzzy logic process in the ArcGIS 10. 5 interface. The priority criteria first considered is the drainage density while Geological formation slope and soil type have the same priority after the drainage density.

It should be noted that the study concentrated on existing dams in Zawita to check the suitability of their sites according to the criteria-based. There are nine dams within Zawita some are finished and others are unfinished. GIS was used to introduce a visual and digital view of the results of fuzzy logic methods that were used to assess dam location hydrologically. The criteria depended for assessments were: precipitation, surface hydrological properties, geological formation, type of soil, the density of water pool, and slope.

Firstly, as precipitation within the Zawita district exceeds 50 mm, there is no problem with water harvesting. Secondly, it is found that most dams within the Zawita district are located in areas with suitable slope degrees and good drainage density. Also, all of the dams had appropriate sites according to soil type criteria except Talwa. It is should be noted that all dams sites have a good geological formation except Bari Bhar which located in unsuitable site and the problem of sedimentation was beginning last years and this belongs to the faults of building the dam in this site that will lead to a decrease the efficiency and age of dam. Finally, It turns out that three finished dams were built in relatively suitable places: Botiya and Bhiri, except Bari bhar suffered. While, there are three others in unsuitable places: Kurt Kavanagh, Karbir, and Xalbok. As for the unfinished dams, one dam is considered an unsuitable location according to most of the criteria used, which is Talwa dam and one dam within a relatively suitable location, which is Eminki dam, while the Bisre dam was one of the appropriate dams that have not been built yet.

The conclusion of this study highlights the importance of applying all the hydrological criteria before taking the final decision to build a dam in a particular site, especially in recent times, where the impact of climate change has begun to be evident in the limited water resources, which in turn sheds light on the need to manage water resources in a way that reconciles supply and demand.

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