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Assessment of the possibility of water harvesting for the Al-Labad Basin - west of Samarra, using artificial intelligence technology, watershed modeling (WMS)

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***Abstract*---**Rainwater harvesting is a critical issue and process to address water shortages at the global and regional levels. The effects of drought on Iraq in recent years have been exacerbated by climate change. Water resource management has become vital to solving this challenge. The study aimed to use GIS technology to study the best dam construction sites in the study area, and the basin is located in Samarra, Salah al-Din Governorate. The area of the basin is (5379.8) square kilometers at an altitude ranging between (23-144) meters above sea level, and the study used the natural criteria as a better suggestion is to use the integrated GIS programs in (3. ArcGIS10) and (AHP). The study showed that there are 7 sites for constructing dams with varying storage capacities. One of the dams in the felt basin was chosen to have the largest water storage capacity. The water capacity of the reservoir was 7.3 m 3 with an area of 144.2 km 2. The study recommended the establishment of water catchments to store rainwater for purposes that serve the region during the drought period, and good planning is to invest in water in various areas of water resource management and employ other skills for environmental planning.

***Keywords*---**Water harvesting for Al-labad basin, Al-labad basin using Artificial intelligence, WMS.

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Introduction

The term water harvesting is used to refer to any morphological, chemical, or physical process that is carried out on the ground to benefit from rainwater, whether directly or indirectly, by enabling the soil to store the largest possible amount of rainwater falling on it and reducing the speed of excess runoff on it. That would contribute to preventing erosion, or indirectly, by collecting the runoff water in a drainage and storage area that is not susceptible to erosion and using it to irrigate crops, drink water from animals, or feed groundwater[1]. The right choice of the proper rainwater system is not obvious. Many factors and conditions must be taken into account during the selection. The choice of the RHW system depends on topography, land use, rainfall as well as the development of demand and economy [2]. Sometimes, due to the small area of the land, we are unable to implement a new investment. In such cases, we try to adapt to already existing facilities for harvesting water This study uses a combination of geospatial and statistical methods to achieve this goal. To construct a model to discover suitable candidates, use the analysis and analytical hierarchy process (AHP)[3].

Sites for water harvesting AHP tries to generate a consensus on .a single, unified decision-making model This method incorporates a three-step process that includes decomposing the problem into multiple criteria, prioritizing the importance of the criteria, and finally resolving the problem. combining the facts into a model of suitability Water harvesting was decomposed in this investigation. Suitability is divided into Ten key criteria: Elevation, Topographic Wetness Index, slope, land use, runoff, Drainage density, Distance from the river, soil drainage, and Distance from the road. [4]According to the literature analysis, these criteria were chosen based on water harvesting design recommendations and studies. [5].Geographical Information Systems (GIS) are being integrated in this way AHP has been widely employed in natural and environmental decision-making studies. Through pairwise comparisons, this study develops a model that may find highly favorable water areas.

Study Area

The study area is located in Samarra, Salah al-Din Governorate, on the eastern bank of the Tigris River, between latitude 33 36 0 - 34 35 0 and longitude 43 0 79 0 - 44 45 0It is surrounded by Tikrit on the north, Lake Tharthar on the east, Fallujah on the south, and Yathrib on the west. According to Figure 1, the basin has an area of 5379.8 km2, with a topography ranging from 23 to 144 meters above sea level. The soil texture consists of a medium texture of alluvial clay or alluvial clay (1). This soil is characterized by being poorly drained and thus helps in the emergence of high surface runoff in the basin Al-labad.

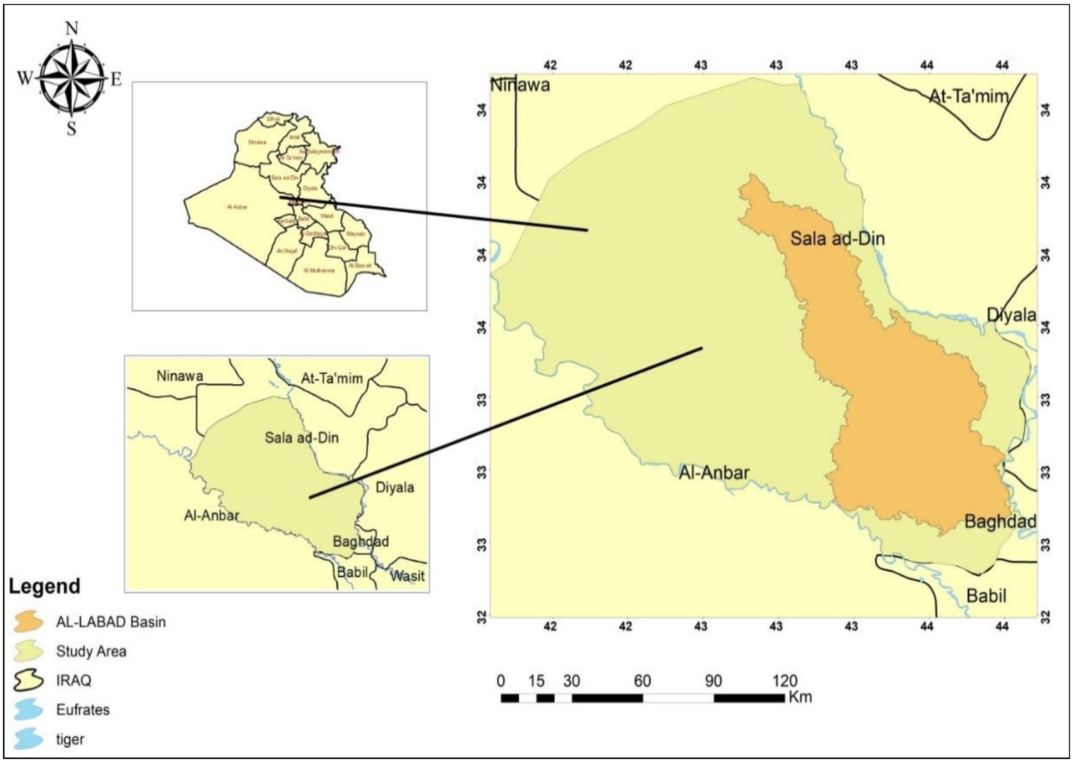
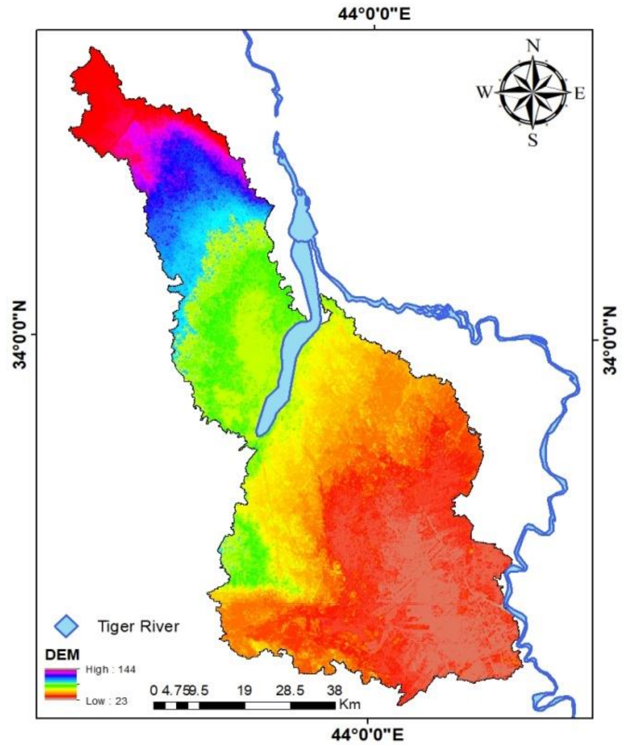


Figure (1): location of the Al-labad basin

Study Methodology

Multi-Criteria Decision Making (MCDM) enables the selection of the optimal solution in a wide variety of domains, including economics, environmental engineering, and business. It is used, among other things, to determine the flood risk of places[6].

In a GIS environment, the study approach to determine the optimal sites for potential water harvesting is based on assembling and preparing layers for calibration and entering them into a program. Determine the functions of ambiguous affiliation around each of the stage requirements. layers and data corresponding to the standards and inserting them into the information systems environment geographical. As in Figure (2), then define the functions of the fuzzy affiliations according to the conditions such as The step of reclassifying the data and this process is done in order to facilitate the process of reading the stored data in Raster format by changing the original values with other new values, Then extract the weights for each layer by an Analytic Process HierarchyIt is possible to choose from among many options (taking into account all the factors) on which the selection process depends., which may not be digital Easily measured. and dependent Hierarchical process on the relationship between Standards and a relationship between the alternatives for each standard(Bahrmes 2004.)


44°0'0"E
34°0'0"N
N
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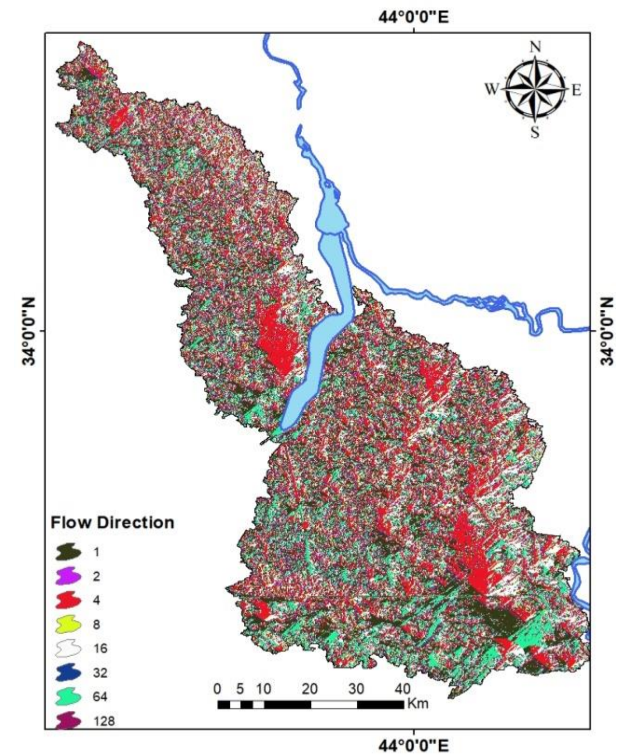
E
S
Tiger River
DEM
High : 144
Low : 23
0 4.759.5 19 28.5 38
Km


44°0'0"E
34°0'0"N
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W
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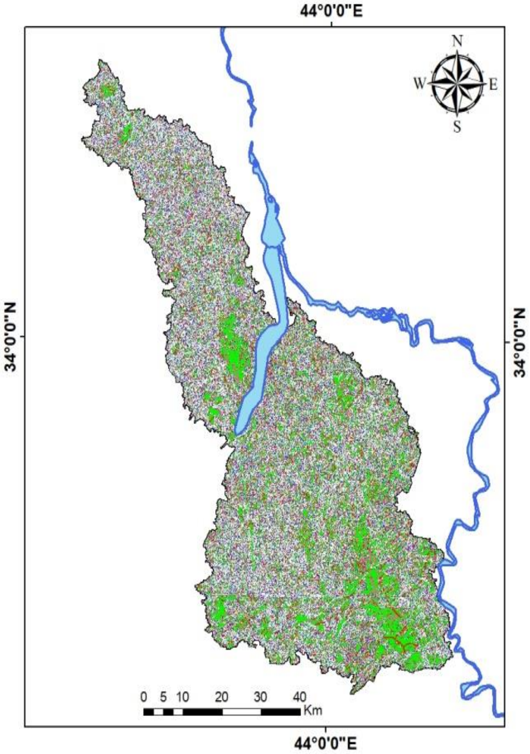
Flow Direction
1
2
4
8
16
32
64
128
0 5 10 20 30 40
Km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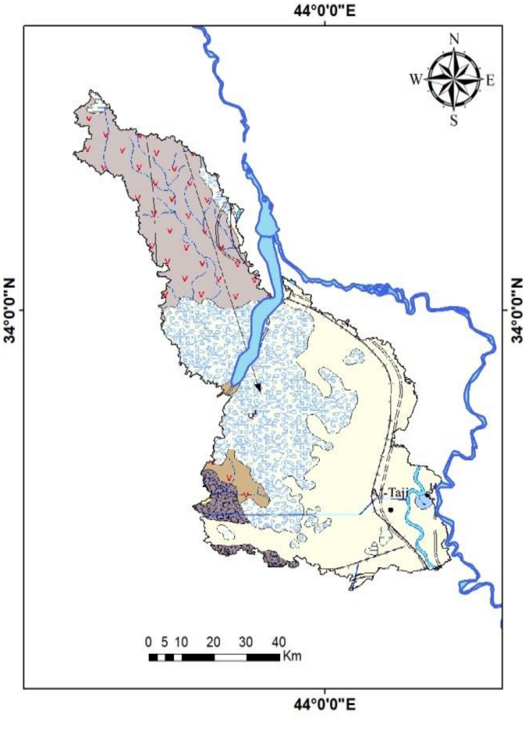
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Al-Taji
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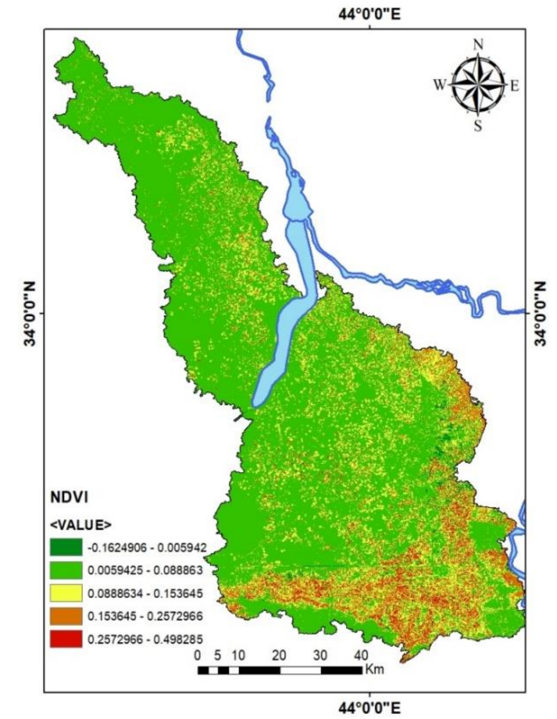
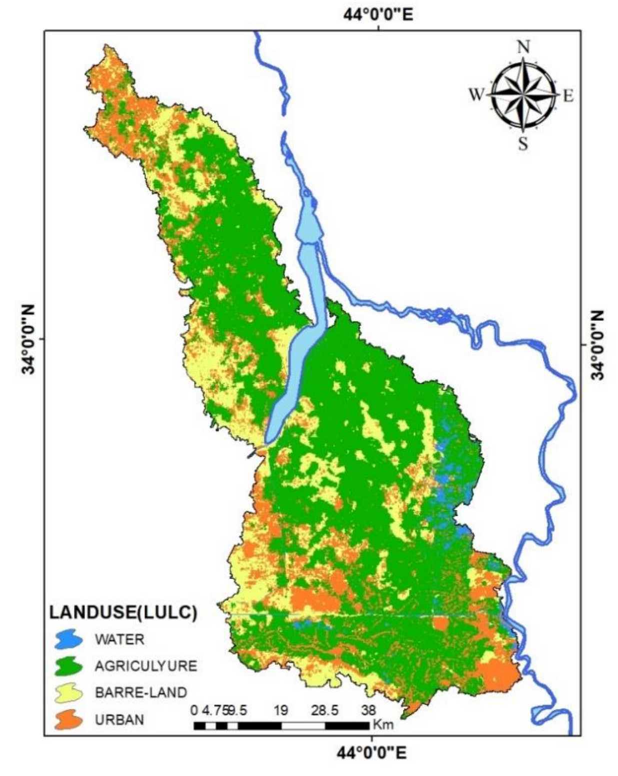
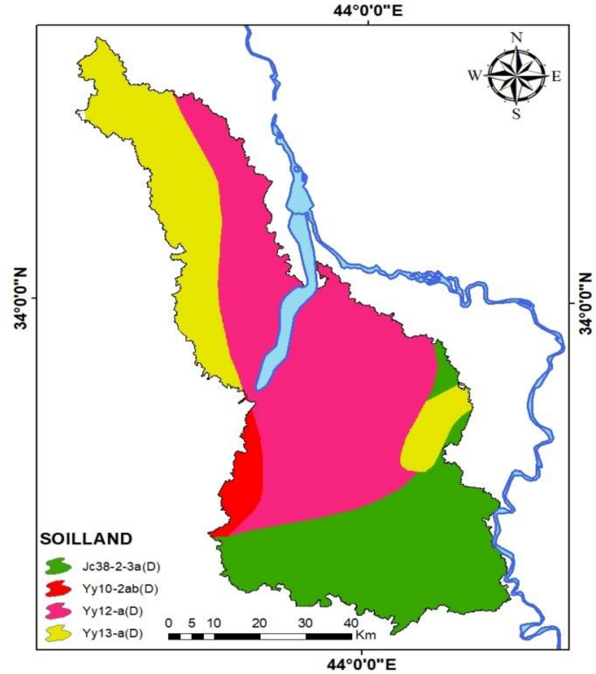
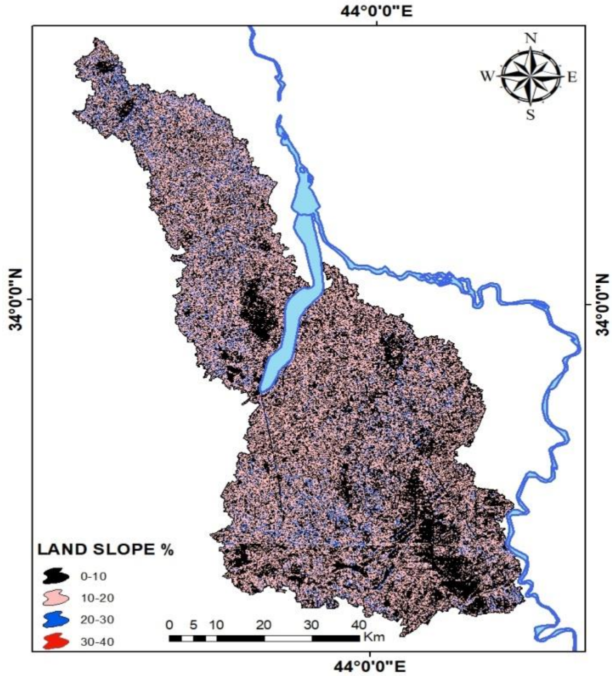
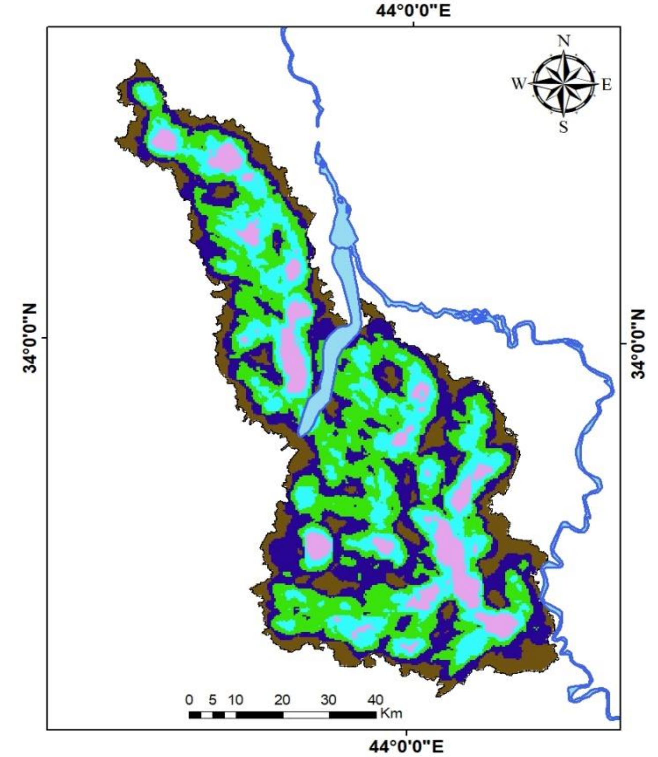

44°0'0"E
34°0'0"N
N
S
W
E
NDVI
<VALUE>
-0.1624906 - 0.005942
0.0059425 - 0.088863
0.0888634 - 0.153645
0.153645 - 0.2572966
0.2572966 - 0.498285
0 5 10 20 30 40
Km


44°0'0"E
34°0'0"N
N
S
W
E
LANDUSE(LULC)
WATER
AGRICULYURE
BARRE-LAND
URBAN
0 4.75 9.5 19 28.5 38
Km


44°0'0"E
N
W
E
S
34°0'0"N
34°0'0"N
SOILLAND
Jc38-2-3a(D)
Yy10-2ab(D)
Yy12-a(D)
Yy13-a(D)
0 5 10 20 30 40
Km
44°0'0"E


44°0'0"E
N
W
E
S
34°0'0"N
34°0'0"N
LAND SLOPE %
0-10
10-20
20-30
30-40
0 5 10 20 30 40
Km
44°0'0"E



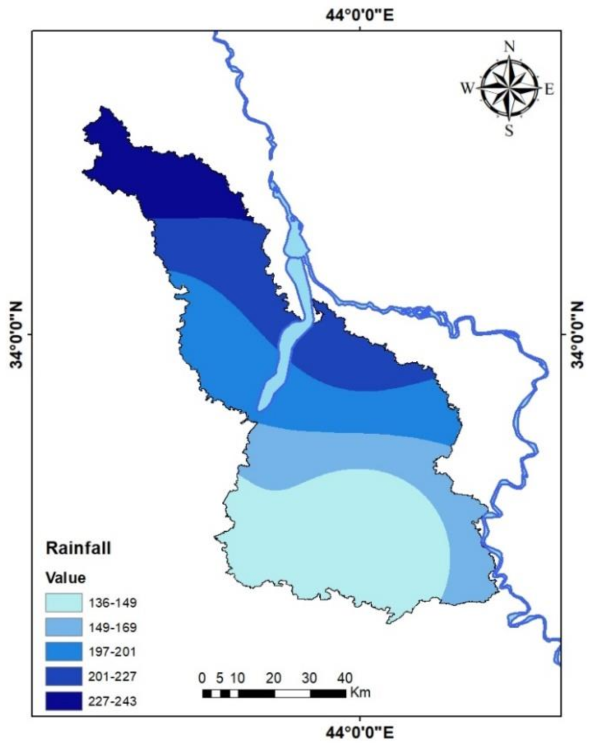


Figure 2 The layers that were relied upon in the research topic

Criteria for selection

The choice of criteria depends on the availability of data for the research area. This study included modeling of rainfall-runoff, DEM and slope, soil type, area geology, rivers, and land cover. Features, curvature, and runoff depth at each pixel are critical in determining whether sites get the most rainfall. The runoff depth at each pixel was determined using a model developed by the Soil Conservation Service (SCS)[8].

The SCS curve number approach is used to predict basin runoff relationships. When hydrologic modeling is used in conjunction with remote sensing data in a GIS setting, a runoff model of the SCS curve is generally appropriate because it depends on land cover characteristics that can be classified by remote sensing software [9].

Geology area The importance of defining the criterion for geological formations, taking into account that the sites chosen for the construction of dams are It is located on solid rocky lands so that they can withstand the construction of engineering facilities for the dam, and be resistant to The pressure is generated as a result of the weight of the stored harvest water, and it is preferable to avoid sites with The fragile rocky nature that may form The accumulation of the stored harvest water may cause an imbalance in the rocky layers. Due to the accumulation of large quantities of water, which represent an additional artificial weight, on the surface of the earth, This weight may lead to the occurrence of mild earthquakes. due to water pressure, which sometimes causes a slump in the crust land at the dam site [10].

Curvature is the concavity or concavity of an area on the Earth's surface. It is derived from the elevation model. Digital (DEM) By entering the digital elevation model maps that are in (Raster) format, and the amount of The curvature of the study area for each cell of the cellular form and knead to know the convex areas of the concave areas, and also know the direction of the surface runoff, And knowing the direction of sedimentation (deposition) and known drainage pattern quality.

NDVI The presence of plants is related to factors Natural environments, such as climate, topography, and soil, are considered These factors are among the most important determinants of plant diversity natural and its density from one region to another, The vegetation protects the soil from rain and reduces drought, and that the system of smallpox and matter Organic matter increases the soil area and thus Increasing the porosity, in turn, leads to an increase in the water tip in the soil vegetation affects In water harvesting at dam sites by increasing hydraulic conductivity, and increase the formation of spots water and leads to an increase in the evaporation process, as it forms The vegetation cover is a barrier to water, thus increasing the amount of water evaporative water.

The slope of the earth's surface has an important effect on water harvesting and the positions of dams are clear between the heights and the slopes Very steep and between depressions and regions temperate, where the soil is thin and stony in The slopes and steep areas, where they are exposed to The upper layer of slope soil to erosion affected Water run-off, while the soil is thick and soft in the declining areas. The slope of the surface as a matter of course One of the topographic criteria based on the stratum Regressions, and criteria were defined. Regressions The surface of the land within which the dam sites are locatedWith regressions ranging between (0 - 2) degrees according to international standards, so that the land is On which the dam sites are flat or self-sufficient gentle slopes [11]. The slope map of the study area watershed was derived from the digital elevation map in Arc GIS. The slope of the area was classified into very low (0-10%), low (10- 20%), medium (20-30%), Steep (30-40%), and very steep (>40%).

Land cover encompasses the soil, material, vegetation, and water quality, defining the biophysical state of the earth's surface and immediate subsurface. Land use, on the other hand, refers to how people use land and engage in socio-economic activities[12]. The ground cover standard is one of the important criteria in The process of evaluating the positions of dams for the purpose of harvesting the water in the felt basin, The dam sites must be constructed For the purpose of harvesting water away from the network Roads, residential areas, agricultural areas, and areas Pastures, industrial and touristic areas and uses, In particular, the logic may be suitable for the construction of dams In mountainous regions and regions Lakes and desert lands And the barren lands, as the study area was divided into four divisions based on directed classification there are four distinct types of land use/cover(Al-labad basin): Water (19.1km2), Agriculture (1136km2), urban (5.7km2), and barren terrain (4192km2) make up the first four parts of LULC.

Decision analysis with multiple factors

Current research mostly focuses on the performance of existing systems, and it is necessary to gain a better understanding of where new systems can be deployed [13]. The purpose of this study is to discover the potential sites for water collection in the felt basin. To achieve this goal, this study uses geospatial analysis and the Analytical Hierarchy Process (AHP) to build a model for determining optimal water harvesting sites. The AHP seeks to create a single, coherent decision model. This approach includes a three-step procedure that begins by breaking down the issue into distinct criteria, prioritizing the appropriateness of criteria, and ending with compiling the data into an appropriate form. This research classifies the suitability of water harvesting and determines the best locations for dam construction [14].

Weighing factors while making a decision

In this study, a method called the Analytical Hierarchy Process (AHP) was used to compare pairs of objects. This method was made by Saaty (1977). We employed the Analytical Hierarchical Process (AHP) as a multi-criteria analysis approach in conjunction with GIS tools in this work to determine potential rainwater collecting zones. The AHP comparison matrices include ten rows and ten columns since the comparison matrix has ten criteria[15]. The pairwise comparison is constructed in this manner. Each subcategory was rated relative to the others in the matrix by applying an overwhelming relative scale someplace. between 1 and 9 (Table1). Following the construction of the pairwise comparison matrix, this stage requires that To get the optimal set of weights, the major eigenvalue of the pairwise comparison matrix must be identified.

Table 1
The summing of each column's values

Intensity of importance	Definition
1	Equal importance
2	Equal To moderately importance
3	Moderate importance
4	Moderate To strong importance
5	strong importance
6	Moderate To Very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	extreme importance

We must enter values for pairwise comparisons. The bottom left diagonal of the matrix. The cells in the upper right diagonal of the matrix correspond to the inverse values of the triangle in the lower-left corner. To get the optimal set of weights, this basic eigenvector technique should use the pairwise comparison matrix. The following graph shows the process of calculating the total values included in each column of the pairwise comparison matrix. for each cell in a row (see Table 3).

Table 2
The summing of each column's values From Mkiramwinyi 2007

Factor	Landsat	Curvature	Slop	Runoff	LULU	NDVI	River	Lineament	Order	soil
Landsat	1	1	1	1	3	5	1	3	1	1
Curvatures	1	1	1	1	2	3	1	3	1	1
Slop	1	1	1	1	3	1	0.5	1	1	1
Runoff	1	1	1	1	3	2	2	3	1	1
LULC	0.33	0.5	0.33	0.33	1	1	0.33	3	1	1
NDVI	0.2	0.33	1	0.5	1	1	0.2	1	1	1
River	1	1	2	0.5	3	5	1	3	1	1
Lineament	0.33	0.33	1	0.33	0.33	1	0.33	1	1	1
Order	1	1	1	1	1	1	1	1	1	1
soil	1	1	1	1	1	1	1	1	1	1
Sum	7.86	8.16	10.33	7.66	18.3	21	8.36	20	10	10

Table 3
Matrix of pairwise comparisons for macro catchment areas

Factor	Landsat	Curvature	Slop	Runoff	LULC	NDVI	River	Lineament	Order	soil	Critera Weights
Landsat	0.13	0.12	0.1	0.13	0.16	0.24	0.12	0.15	0.1	0.1	0.134
Curvatures	0.13	0.12	0.1	0.13	0.11	0.14	0.12	0.15	0.1	0.1	0.12
Slop	0.13	0.12	0.1	0.13	0.16	0.05	0.06	0.05	0.1	0.1	0.1
Runoff	0.13	0.12	0.1	0.13	0.16	0.1	0.24	0.15	0.1	0.1	0.133
LULC	0.04	0.06	0.03	0.04	0.05	0.05	0.04	0.15	0.1	0.1	0.066
NDVI	0.03	0.04	0.1	0.07	0.05	0.05	0.02	0.05	0.1	0.1	0.061
River	0.13	0.12	0.19	0.07	0.16	0.24	0.12	0.15	0.1	0.1	0.138
Lineament	0.04	0.04	0.1	0.04	0.02	0.05	0.04	0.05	0.1	0.1	0.058
Order	0.13	0.12	0.1	0.13	0.05	0.05	0.12	0.05	0.1	0.1	0.095
soil	0.13	0.12	0.1	0.13	0.05	0.05	0.12	0.05	0.1	0.1	0.095

Estimating pairwise comparability

The consistency ratio (CR) was determined to determine whether or not the relative priority assigned to the parameters was consistent [83,99]. That should be addressed; Satty proposes that if the CR rating exceeds 0.10, it should be re-evaluated [83,99].

$$CR=CI/RI \qquad \text{------------ (1)}$$

The random index (RI) can be found in the table published by Saaty (1977). Set up the matrix, this search employed ten criteria, thus Table 4 gives random values for the indicator by criteria.

Table 4
Random index for different number of criteria From Drobne et al 2009

Number of criteria	1	2	3	4	5	6	7	8	9	10
Random Index	0.00	0.00	0.6	1	1	1.2	1.3	1	1.5	1.49

The following steps may be used to calculate the consistency index (CI): Multiply the weight assigned to the first parameter in Table 3 (area geology = 0.134) by the total number of parameters. Table 2 includes the first column from the original 7.86 pairwise comparison matrix. Then increase the weight of the second parameter (curvature) by the total of the original pairwise comparison matrix's second column. This technique should be repeated for each weighting system parameter. Finally, by adding these values together, we get a consistency vector (10.47). This consistency vector is used to get the equation's consistency index.

$$CI= \lambda\text{-}n/n\text{-}1 \qquad \text{------------------ (2)}$$

Where,λ max is the Principal Eigenvalue, n is the number of criteria
The value of the consistency index of the matrix is 0.052, that is, the consistency of this study is 5%, which is a quantity less than 10%, so the comparison between factors is acceptable.

Result and Discussion

Map of rainwater harvesting

Runoff, slope, ground cover/use, soil texture, and drainage layers should be incorporated. The grid and linear structures (barrier), as well as geology and convexity, provided ideal units for water harvesting. In ArcGIS, layers are grouped using the model builder's rating scores (linear merge weight). An appropriate rainwater harvesting map has been created for the area. View the water collection sites in the Al-labad basin. (see Figure3) The assessment of suitable sites for water harvesting was based on the tripartite system in the distribution of each of the factors, and the value (1) was given for sites suitable for water harvesting, and the value (2) was given for sites that were relatively suitable for water harvesting, while the value (3) was given for non-acceptable purposes. Water harvesting is suitable, and 7 dams have been identified (see Figure 4).

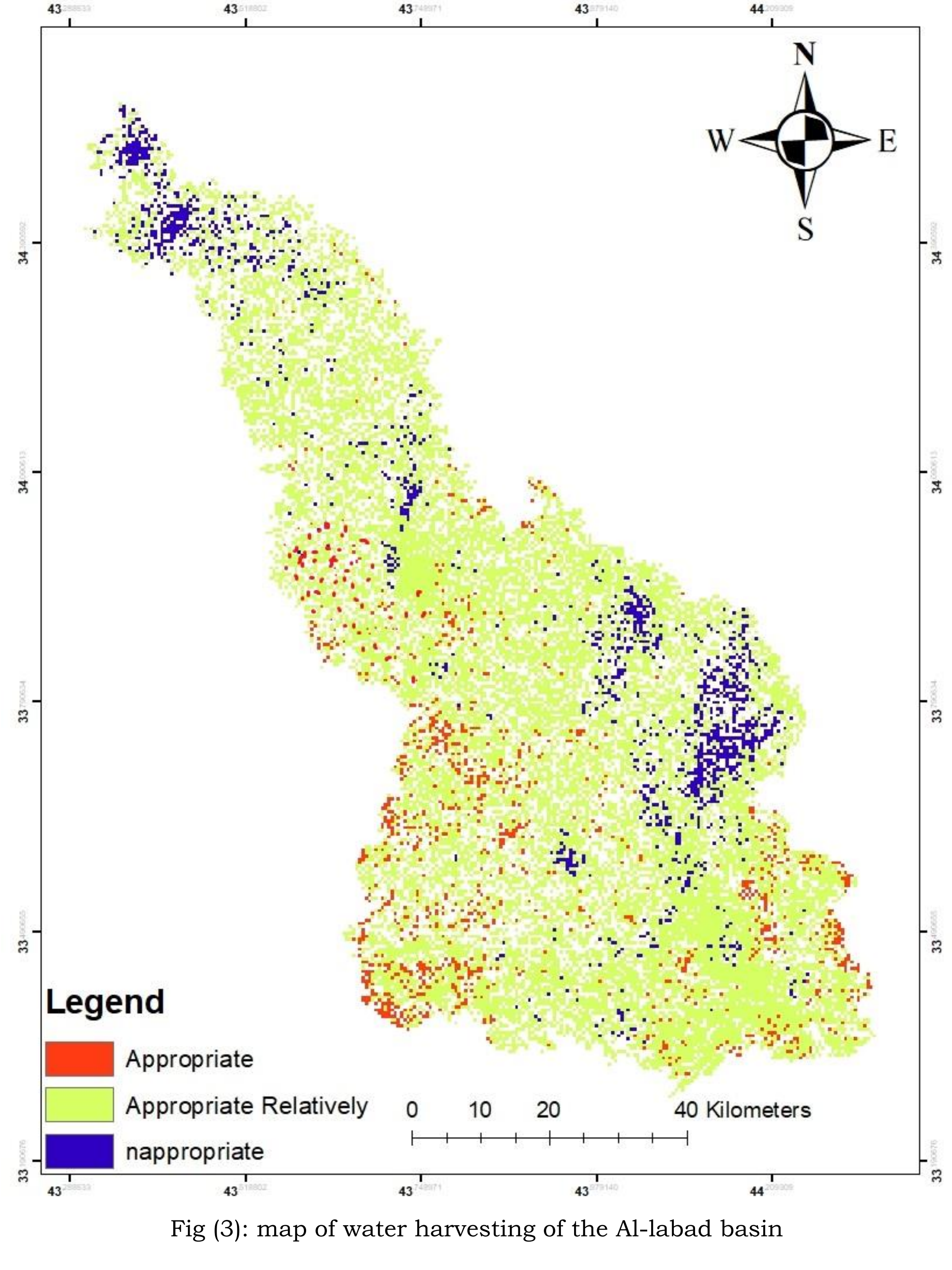


Fig (3): map of water harvesting of the Al-labad basin

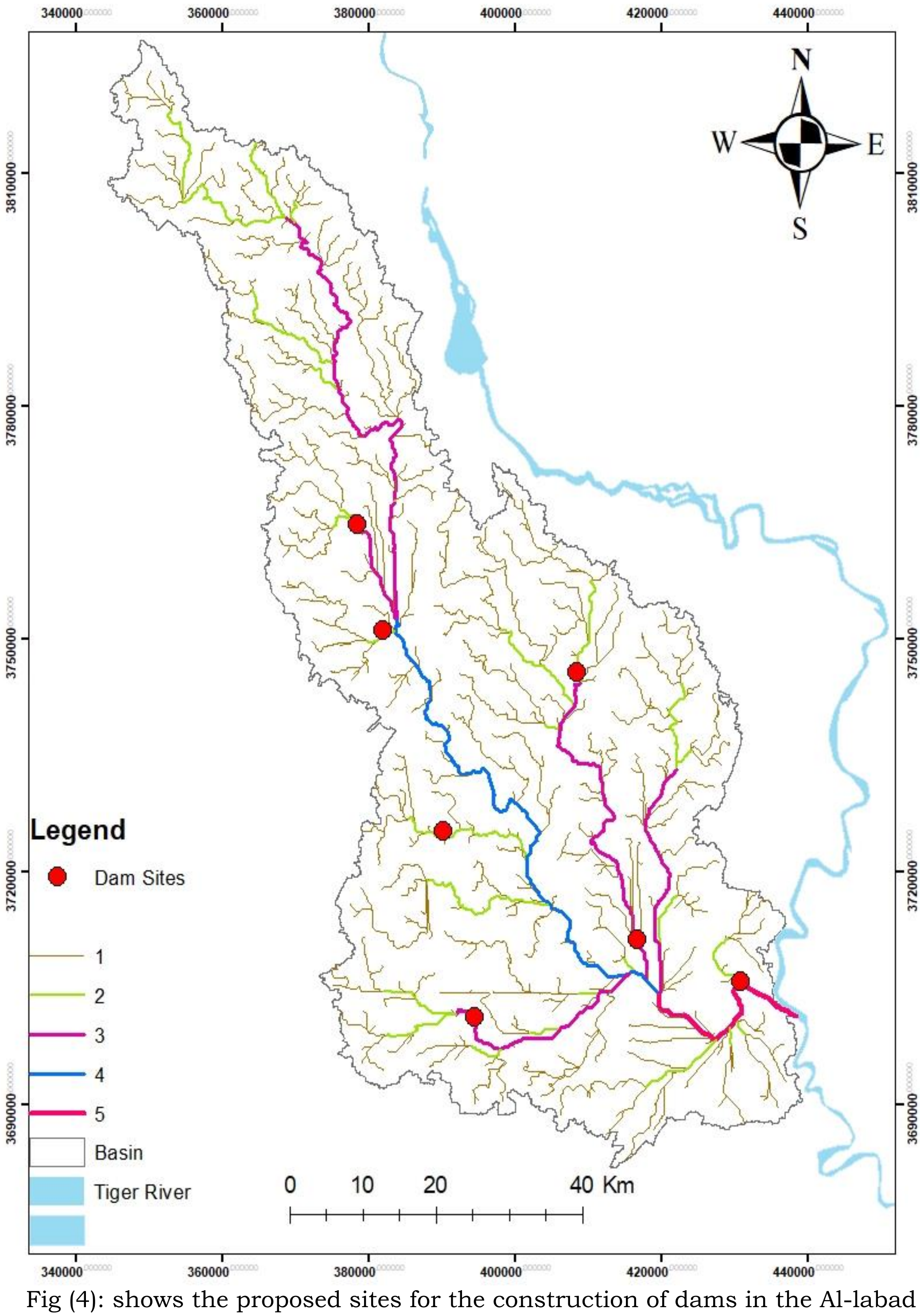


Fig (4): shows the proposed sites for the construction of dams in the Al-labad basin area

The model used to predict the conditions of dams

Surface storage dams are critical water sources because they collect valley flood waters on the earth's surface and between the mountains for home and agricultural usage, as well as flood prevention. Seven dam locations have been suggested using the (WMS) algorithm, which is dependent on a collection of factors having a dimension impact. Spatial considerations in dam site selection.

(WMS) Hydrological Modeling System or the so-called Watershed Modeling System is a solution Effective and accurate for the hydrology problems faced by engineers. It can, if not, save (22%) percent. It may take a lot of time to perform the calculations manually, as well as the results are reproducible which means If the same data is used, the same results will be achieved regardless of performance calculations, and an additional advantage is that the results are more accurate because the chance with little chance of error Accurate hydrography leads to correctly digitized maps that are safer for decision-makers and require less maintenance [16].

WSMv10.1The application, which is built by the American engineering firm Aquaveo, has a window and several toolbars for spatial loading. Statistical and engineering disciplines, with a focus on the research of water networks and the analysis of their hydrological features.

Table (5)
showed the change of information sub-catchment basin Al-labad with different depths

	Elevation m	Dam Height m	Dam Length m	Storage capacity m3
DAM	65	0	0	0
	66	1	52	228.32
	67	2	99	445.674
	68	3	133	893.452
	69	4	200	2,045,324
	70	5	270	2,987,004

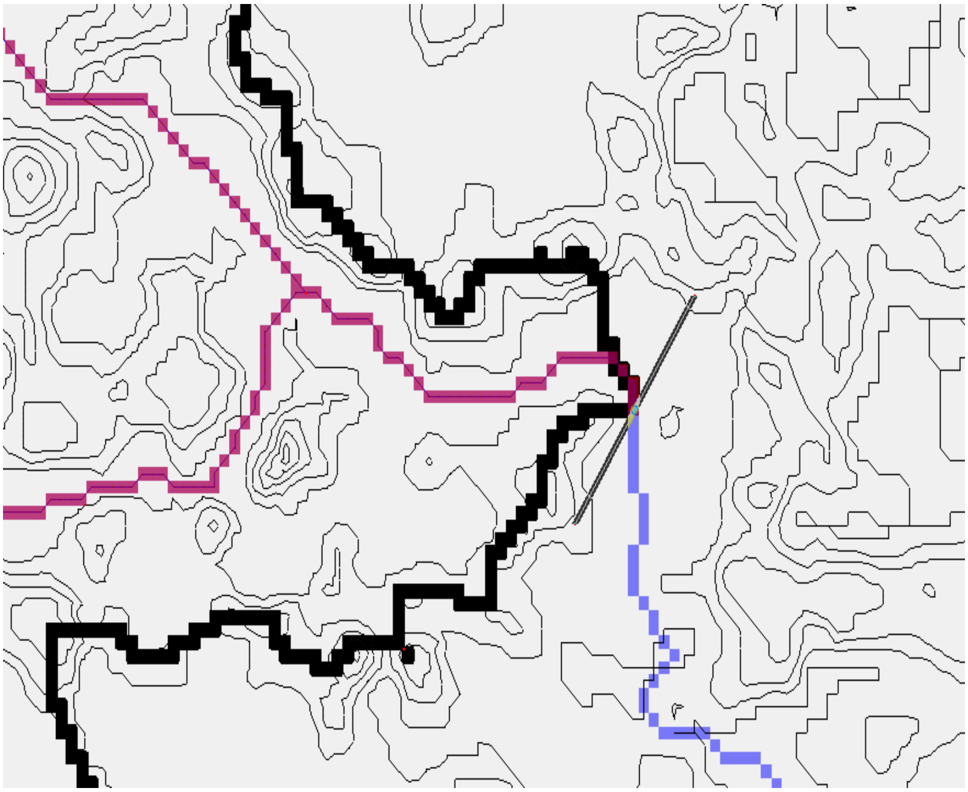


Fig (5): A cross-section for the head of the Al-labad sub-catchment basin (check dams place)

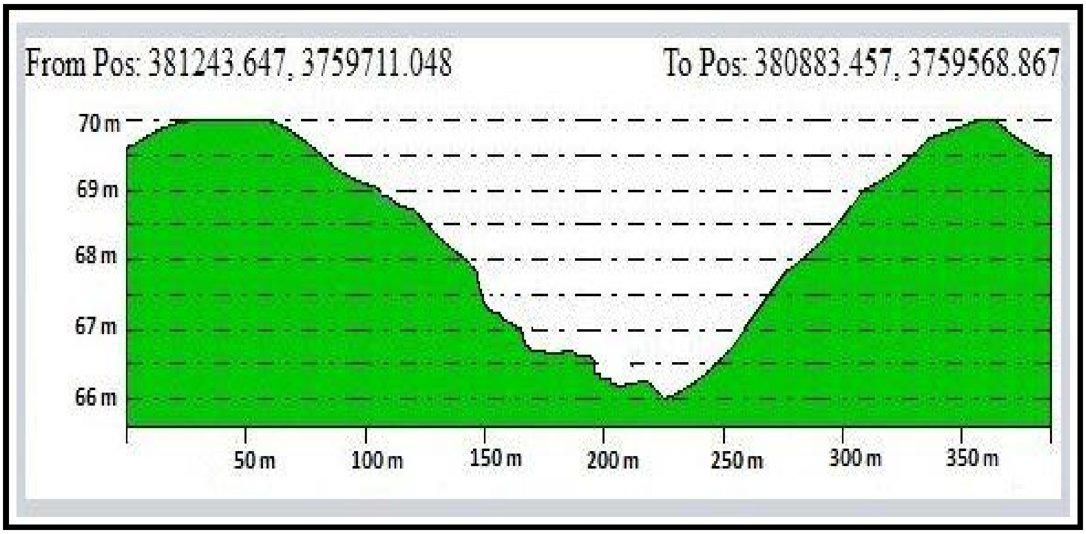
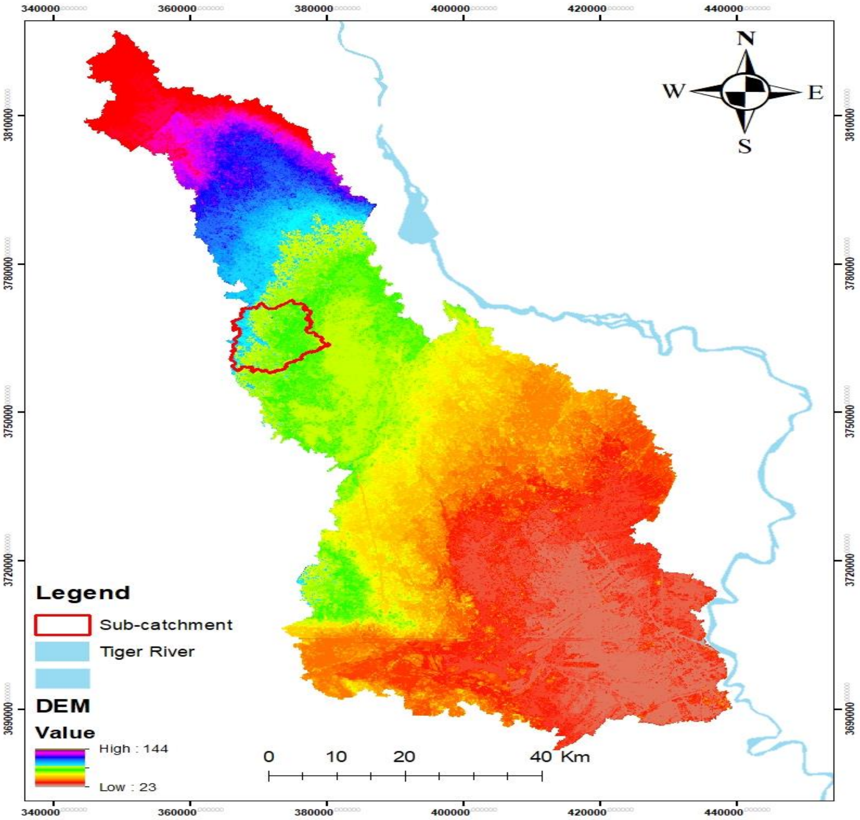


Figure (6): profile of a dam in the sub- catchment



Figure(7): map sub-catchment area for the Al-labad basin

Show the map of the RWH location in the search area. To calculate water depth, sub-catchment area, and sub-catchment volume if the dams achieve constriction at the selection point shown in (Table 6), and use climatic data to calculate mean rainfall and runoff using the SCS method.

Table (6)
Showed averages of runoff and rainfall of sub-catchment basin Al-labad from (1990-to 2019)

n0.	Year	Total rainfall (mm)	Total runoff (mm)	Runoff Volume (m3)
1	1990	301	150	21665996.4
2	1991	308	91	13155997.2
3	1992	209	101	14554713
4	1993	168	51.6	7465264.2
5	1994	164	164	23731029
6	1995	198	46.8	6765834
7	1996	201	17.4	2519799.6
8	1997	311	126	18152361
9	1998	336	57	8245381.2
10	1999	295	38.7	5589802.2

11	2000	209	30.9	4472622.6
12	2001	324	9.65	1395679.2
13	2002	160	39.2	5663548.2
14	2003	167	48.8	7056480
15	2004	272	28	4046920.2
16	2005	194	15	2172036.6
17	2006	129	1.64	236421
18	2007	233	63.3	9146239.2
19	2008	198	28.2	4071357.6
20	2009	161	53	7663655.4
21	2010	154	12	1733031
22	2011	142	41.6	6015360
23	2012	205	83.4	12054289.8
24	2013	182	40.6	5872206
25	2014	170	12.6	1815019.2
26	2015	138	19.6	2829822
27	2016	161	15	2168421.6
28	2017	139	20	2886071.4
29	2018	154	78.7	11381610.6
30	2019	117	36.8	5327064
Avg.		203	50.7	7,328,467.78

Conclusions

Rainwater harvesting is a critical issue and process for addressing water shortages at the global and regional levels. By broadening the horizons of long-term water supply, suitable rainwater harvesting areas have been identified using a geographic information analysis approach and multiple criteria. This process demonstrated that multi-criteria analysis is a cost-effective method and appropriate tool for water management. The multi-criteria evaluation took into account a variety of characteristics, including land cover, soil texture, gradient depth, runoff, rivers, region geology, and linear structures. Ground cover was taken from a 30-meter resolution LANDSAT8 satellite picture. The FAO soil map was used to create the soil map. The digital elevation model was used to create the slope map. In addition, the depth of runoff in the research region was estimated using a soil conservation service model.

Parameter maps were combined using a linear weighted formula to obtain fit The map consists of three comparable categories, Fit High, Moderate Fit, and low fit A simple map enables decision-makers and planners to ascertain which locations have a high rate of speed. Possibility of rainwater gathering from other regions. The Hierarchical Analysis Program (AHP) was utilized to do the analysis. When it comes to assessing the importance of standards and their influence on dam building, The research found that in the al-Labad basin, In terms of impact, the geology criteria, the convexity and concavity criterion, as well as the surface water criterion, take precedence. One of the major influences on the ground being developed is the building of dams .dams along their path, According to the report, the majority of dam locations in The research field are a good fit for the provided criteria. There are seven dams spread over the majority of them. Area for research.

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