Hydrological Analysis of Al-Rafee Watershed for Sustainable Rainwater Harvesting

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Abstract

This study aimed to conduct a hydrological analysis and assess the potential for rainwater harvesting using GIS-AL technologies for the Al-Rafee' watershed, located in the eastern part of Iraq within the governorates of Salah Al-Din and Diyala Provinces. The total area of the basin is 212.19 km², lying between latitudes (34°33'18"–34°33,49"N) and longitudes (44°35'22"–44°46'17"E). The study relied on the SCS-CV model to estimate surface water runoff volume. The findings indicated the presence of three hydrological soil groups: B, C, and D. The land cover was found to be diverse, with agricultural lands occupying the largest area (91.12 km²), while barren lands had the smallest coverage (0.22 km²). The study also showed high Curve Number (CN) values and low retention (S) values. Furthermore, it concluded that it is possible to establish reservoirs to collect rainwater at the identified locations, with the aim of developing the studied region for future investment opportunities.

I. INTRODUCTION

Water basins in arid and semi-arid environments have received significant attention from hydrological studies due to the scarcity of water resources in these environments. Rainfall is the primary water resource in these environments, causing surface runoff and replenishing groundwater reserves during rainfall [1,2]. To understand hydrological characteristics and the potential for utilizing them and constructing dams for water harvesting purposes, we relied on artificial intelligence (AI) and geographic information systems (GIS) techniques [3,4]. These techniques are effective tools for analyzing hydrological variables and selecting suitable sites for constructing dams, whether earth or concrete [5,6].

GIS techniques form the foundation for integrated and visualized spatial and non-spatial dataset. The comprehensive set of GIS layers was essential for defined the physical environment, and monitoring infrastructures [7]. These layers include details on physical infrastructures such as pit boundary, tailing storage facility, process water impoundment, and haul road. They also have covered hydrogeology, incorporating drainage network (surface water pathway), Digital Elevation Model, and groundwater well location. GIS spatial database serves as computational domains for physically based distributed hydrologic model [8]. The facilitates the integration of layer (DEMs, the soil, and land cover) with hydrogeological

model to simulate complex process including evapotranspirations, snowmelts, infiltrations, aquifer recharges, groundwater flows, and overland runoffs [9]. This coupling between GIS, and the AI allows operators to predict fate and transport of contaminant under various operational, and climatic scenarios, far exceeding the capability of simple map overlay. These spatial dataset support rigorous water quality risk assessments by facilitated the analysis of runoff pattern, contaminant migrations, and groundwater vulnerability [10].

Al-Adhari[11] has been studied that dealt with the hydrogeomorphology of the valleys region west of the Euphrates north of the western Iraqi plateau. Its chapters included the natural components of the region, landforms, as well as the hydrological analysis and the hydrogeomorphological and morphotectonic relationships of the study region. Al-Jubouri[12] has been addressed that water harvesting in the Wadi Al-Mubaddad Basin in Salah Al-Din Governorate, analyzing all the physical and morphometric characteristics of the area and estimating the surface runoff volume using the SCS-CN method, which proved effective in estimating the water runoff volume. The study concluded that water harvesting techniques can be applied in the studied basin. Al-Zarfi[13] found that the hydrological evaluation of the possibility of rainwater harvesting in Al-Ghadhari Valley and concluded that geographical techniques can predict the selection of the best suitable locations for establishing water harvesting methods in

order to benefit from rainwater collection. Four locations were chosen for small dams to control the expected flash floods and to store and utilize the water for restoring plant life and cultivating pasture plants.

The research problem is summarized in the following questions: Do the hydrological characteristics of the Wadi Al-Rafi' Basin support water harvesting and AI and GIS techniques select the best sites for constructing dams in the Wadi Al-Rafi' Basin.

The hydrological characteristics of the Wadi Al-Rafi' Basin provide suitable conditions for water harvesting operations. Artificial intelligence and geographic information systems (GIS) techniques can be used to identify the best locations for dam construction. The study aims to exploit the wasted water in the Wadi Al-Rafi' Basin for future investments as well as to use the best methods for water containment by determining the amount of surface water runoff and working to conserve this water and utilize it more effectively.

II. STUDY METHODOLOGY

The study relied on an analytical approach to analyze data related to these characteristics, based on the use of artificial intelligence and modern geographic information systems techniques for mapping, graphical representation, and equation analysis, as well as selecting the best and most suitable locations for water harvesting projects in the study area.

The S coefficient values were extracted from equation:

$$S = 1000/CN - 10 \qquad (1)$$

The values of the LA coefficient were extracted from the equation:

$$Q = (P-la)2 / (P-la)+S \qquad (2)$$

The CN values for the Wadi Al-Rafia basin, they are obtained by combining the land cover use map with the hydrological soil types map and multiplying each CN number by the population that represents the area of the basin, then summing them and dividing them by the total area of the basin. All the equations mentioned are dealt with and their values are extracted by dealing with them in the ArcMap 10.8 program.

A. Location of The Study Area

The Wadi Al-Rafi' basin is located in the eastern part of Iraq and it is a basin that shares the geographical area it occupies, meaning that its area is within the administrative borders of the two governorates of Salah Al-Din and Diyala. The total area of the basin was (212.91 km^2), and the largest part of the area was within the governorate of Salah Al-Din and the smaller part is within the governorate of Diyala (Fig. 1). Astronomically, the Wadi Al-Rafi' basin is located between two latitudes (34°33'18"–34°33,49"N) and and longitudes (34°33'18"–34°48'30"N).

B. Calculating the (S) Coefficient, The Maximum Soil Water Retention Capacity at The Start of Water Runoff

The (S) coefficient indicates the soil's ability to retain water during rainfall and surface runoff. The (S) coefficient has values with specific hydrological implications. Values of (S) close to (0) indicate the soil's weak ability to retain water running on the surface after the start of water runoff. This causes an increase in the amount of water running on the soil's surface. High (S) values, close to (254 mm), represent the median values of the (S) coefficient. Thus, the soil's ability to retain water on the surface increases. The higher the (S) coefficient values are above the median values (254 mm), the lower the amount of surface runoff [14].

C. Calculating the (LA) Coefficient, The Initial Extraction Coefficient for The Wadi Al-Rafi' Basin:

The (LA) coefficient is another criterion that helps in estimating and calculating the amount of surface runoff and provides an image of the amount of rainwater lost before the surface runoff occurs due to various processes, including plant obstruction of water movement, infiltration, and evaporation. If the (LA) coefficient values are low and close to (0), they indicate a small amount of rainwater lost and a high surface runoff. Conversely, high (LA) coefficient values that exceed (0) indicate a high amount of rainwater lost and a high surface runoff. Conversely, high (LA) coefficient values that exceed (0) indicate a high amount of rainwater lost after the surface runoff occurs [15].

D. Calculating (CN) Values for The Wadi Al-Rafi' Basin

The (CN) values are estimated numbers starting from (0-100). If the value approaches (0), the permeability of the surfaces to water increases or decreases. The ability to generate surface runoff decreases, but if the value is closer to the number (100), then the surfaces are impermeable to water and all the rain that falls on them is converted into surface runoff [8].

E. Mathematical Formulas for Calculating The Values of (CN), (QV), (S), (La) and (Q)

The (SCS-CN) model is considered one of the most important mathematical methods used to calculate and estimate surface runoff for hydrological studies. The (SCS-CN) model is a series of equations that can be expressed mathematically using the following formulas [16]:

$$Q = (P-la)2 / (P-la)+S \qquad (3)$$

Where:

Q = Depth of surface runoff (inches)

P = Amount of rainfall (inches)

LA = Initial losses before the start of surface runoff due to evaporation, infiltration, and vegetation, and inches

S = Surface water accumulation after the start of surface runoff (inches)

The values of the (S) coefficient are calculated according to the following equation:

$$S = 1000/CN - 10 \qquad (4)$$

Since the (La) values are equivalent to five (S) values, (La) is calculated using the following mathematical formula Equation (3)(5) La=0.25

Since the inputs for this model are in inches, we multiply the constants in Equation (2) by the value (25.4) and convert them from inches to millimeters to conform to metric measurements. The equation is then given the following mathematical formula:

$$S=25400/CN-254 \qquad (5)$$

To calculate the volume of surface runoff according to the SCS-N model, we use the following mathematical equation:

$$QV=Q*A/1000 \qquad (6)$$

Where:

QV = volume of surface runoff

Q = depth of surface runoff

A = area of the drainage basin (km²)

Conversion factor = 1000

F. Calculating The Surface Runoff Depth (Q) for The Wadi Al-Rafi' Basin

The surface runoff depth is another measure of the amount of water flowing across the soil surface during rainfall, regardless of the water accumulation area in the basin (11). The purpose of calculating (Q) is to determine the highest depth reached by surface runoff. The (Q) values were calculated based on the (LA- S- CN) values and daily rainfall data for January 14, 2024. From observations in Table (III), it was shown that the (Q) values in the Wadi Al-Rafi' Basin ranged from (4.83 mm) to (40.46 mm), and the average surface runoff depth reached (25.7 mm). This corresponds to the values of (LA -S -CN), confirming the possibility of surface runoff occurring and continuing in the basin.

G. Calculating The Surface Runoff Volume (QV) for The Wadi Al-Rafi' Basin

Calculating the QV is one of the basic priorities upon which many hydrological studies concerned with water resources management depend, such as dam and reservoir construction projects, flood monitoring, and water harvesting. The QV expresses the amount of running water per unit area of the basin (12). Since the study area lacks a hydrological monitoring station, the QV was calculated and relied upon in the current study of the Wadi Al-Rafi' Basin, based on the previously obtained Q calculation. Table (III) shows that the lowest surface runoff volume recorded in the Wadi Al-Rafi' Basin was (4,046 m3) with an area of (0.10 km2), while the highest surface runoff volume in the basin was (1,427,610.6 m3) with an area of (64.22 km2). The total surface runoff volume for the Wadi Al-Rafi' Basin was (4,031,010 m3) and this changes during rainfall and the continuity of surface runoff in the basin.
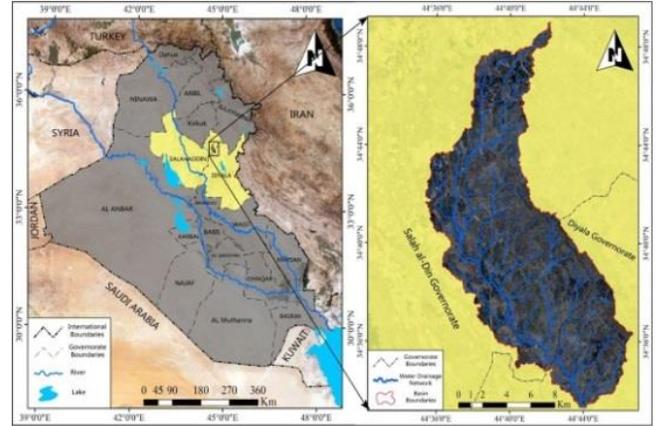

Fig. 1.   Location of the study area.
Source: Republic of Iraq, Ministry of Water Resources, General Authority for Survey, Administrative Map of Iraq, 2016; Digital Elevation Model (DEM) with a resolution of 12.5 meters, using Arc Map 10.8 software.

III. RESULTS AND DISCUISSION

A. Stages of Extracting The Curve Number (CN) Values for The Wadi Al-Rafi' Basin

CN values reflect the land cover types and the hydrological group to which the soil of the study area belongs, as well as the pre-wet state of the soil. CN values in the study area were extracted by combining land cover uses with the hydrological soil group prepared by the Food and Agriculture Organization of the United Nations (FAO), using the Combine tool in the Arc Map 10.8 program, and conducting some values to obtain these CN values.

B. Classification of Land Use Land Covers Uses

Land cover refers to the natural or human features or phenomena found on the Earth's surface [1]. The satellite image of the Sentinel 2 satellite, dated February 25, 2025, was used to classify the land cover of the study area with a resolution of 10 m and according to the Supervised Classification, using the ENVI 5.3 program. Thus, the satellite data passed through several treatments, it was possible to identify four types of land cover uses in the Wadi Al-Rafi' Basin, as follows:

This type of land is very widespread and is the most widespread in most parts of the study area, with the exception of the eastern and southeastern parts, in addition to other scattered areas [16]. It is the largest type in area, covering an area of 114.9 km², representing 42.80% of the total area of the basin (Fig. 2 and Table I). Agricultural crops impede surface water flow and increase water infiltration into the ground from the time of their growth during the rainy season until the winter. This causes a decrease in the ability to generate surface water flow, which reduces the degree of hydrological risk [17].

This type of land includes land that is bare of vegetation and is found in small parts andin various regions of the basin, namely in the northern and northern parts. The eastern part as well as the western and southwestern parts, where this type covers an area of 0.22 km², represents 0.10% of the total basin area, as shown in (Fig. 2 and Table I). Despite the small area of this type, fallow

or barren lands generally contribute to the rapid surface runoff during rainfall. This is because they are devoid of vegetation, which impedes and reduces the speed of water flow. This type of land increases the degree of hydrological risk [18].

This type of land occupies an area of 114.9 km^2, representing 53.97% of the total basin area. It is widespread in the eastern and southeastern parts, in addition to other scattered areas of the study area, as shown in (Fig. 2 and Table I). Vegetation cover is characterized by its direct impact on surface runoff. The greater the area of land covered by grass, the less the amount and speed of surface runoff, thus reducing the resulting hydrological risks.

This type of land cover use appears clearly in various parts of the study area, including the northern and northwestern parts, as well as the western parts. It occupies an area of (6.67 km^2), representing (3.13%) of the total area (Fig. 2 and Table I), shown in red. This type is considered the most closely associated with hydrological risks, as its surfaces are solid and impermeable to water, thus helping to support water flows, which increases hydrological risks.
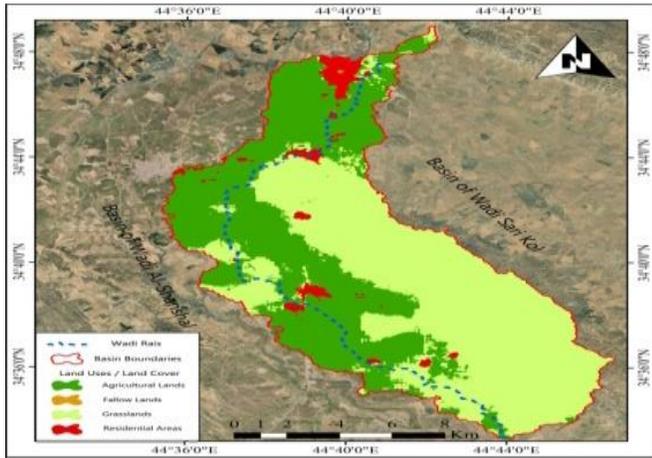

Fig. 2. Typea of land cover uses Based on the satellite image of the satellite (Sentinel 2) and using the program (ArcGIS 10.8 software).

TABLE I. TYPES OF LAND COVER USES

Land Cover Use Types	Area (km)	Percentage (%)
Agricultural Land	91.12	42.80
Fallow Land	0.22	0.10
Grassland	114.9	53.94
Residential Areas	6.67	3.13
Total	212.91	100

C. Hydrological Soil Groups (HSGs)

The U.S. Soil Conservation Service (SCS) has developed a special classification for soils worldwide. Soils are classified into four hydrological groups (A, B, C, and D) based on the rate of water infiltration and transfer within the soil. Each of these groups has its own numerical meaning, distinguishing it from the others and expressing a specific hydrological condition. Class (A) represents low surface runoff, while Class (D) represents high surface runoff. Classes (B and C) represent two intermediate conditions of surface runoff (Table II).

TABLE II. HYDROLOGICAL SOIL CLASSES ACCORDING TO THE SCS METHOD

Class	Flow Depth	Soil Types
A	Low	A deep sandy layer with very little silt and clay
B	Average	A sandy layer shallower than Class A and with an average percolation rate after wetting
C	Above Average	A clay layer with a specified depth and a below-average percolation rate before reaching the soil
D	High	A thick clay layer with a shallow layer of fine soil or rocky layer

After matching the two maps, the hydrological soil map according to the SCS method and the soil classification map according to Buringh [19] classification of Iraqi soils, in the GIS program, it became clear that there are three soil types in the study area, as follows:

This soil is widespread in the eastern and southern parts of the study area. This group of soils includes areas with moderate surface runoff, as its soil has a moderate infiltration rate and consists of a medium-depth sandy layer that occupies a large area of the study area, amounting to (65.52 km^2), representing (30.37%) of the total area of the basin (Fig. 3 and Table III). This group of hydrological soils is characterized by moderate water runoff due to the high infiltration rate resulting from the presence of coarse particles in its components.
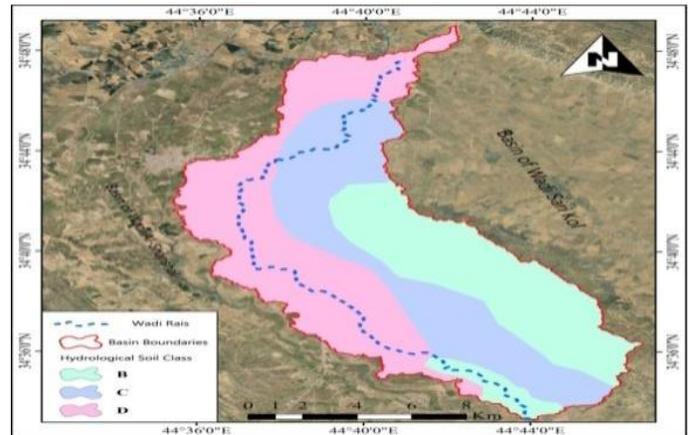

Fig. 3. Hydrological soil classifications based on the unified soil classification (HWSD), using the program (ArcGIS 10.8 software).

TABLE III. HYDROLOGICAL SOIL TYPES IN WADI AL-RAFI' BASIN

Hydrological Classifications	Area (Km^2)	Percentage (%)
B	65.52	30.77
C	63.79	29.96
D	83.6	39.27
Total	212.91	100

The area covered by this group of hydrological soils is (63.79 km^2), representing (29.96%) of the total area of the basin (Fig. 3 and Table III). This group of soils extends in the form of a longitudinal strip extending from the northeastern parts to the southeastern parts of the basin. Hydrologically, this soil is characterized by a limited-depth clay layer, and its infiltration

rate is below average. This allows for medium to high surface water flow due to the presence of a layer of fine and medium clay or silt, which in turn achieves the downward movement of water.

The area of this group is (83.6 km^2), representing (39.27%) of the total basin area, as shown in Fig. 3 and Table III. It ranks first in terms of its spatial extent, extending in the form of a longitudinal strip from north to south. The soil of this group consists of a clay layer, a hard, bare rock layer, or a shallow layer of soft soil that prevents water from seeping into the soil. Its hydrological importance is highlighted by the fact that it is the weakest of the hydrological groups in terms of its ability to absorb water, which results in high water flow [20].

D. Rainfall Intensity and Pre-Existing Soil Moisture Conditions

Rainfall, in terms of its intensity and abundance, represents the primary source of surface runoff in the aquifer environment. Rainfall in Iraq is generally classified as irregular in its abundance, precipitation, and quantity. Rainfall may fall in a single day in quantities that are almost equal to or greater than the rainfall that falls over an entire month (3). To calculate the values of CN and Q, the daily rainfall intensity was used on January 14, 2024, according to the climatic data on the website (https://chrsdata-en8.4ci.edu). We note from Fig. 4 that there is a variation in rainfall values in the study area, as its quantity ranges between (103-14 mm), and its intensity varies from one place to another in the study area [21].The hydrological analysis results indicated that the studied area includes four main land use classes, along with three hydrological soil types (B, C, and D). The previous soil moisture status was at the second level. These characteristics highlight the importance of rational land management to enhance the efficiency of agricultural use and help reduce the risks of water erosion and the loss of natural resources.
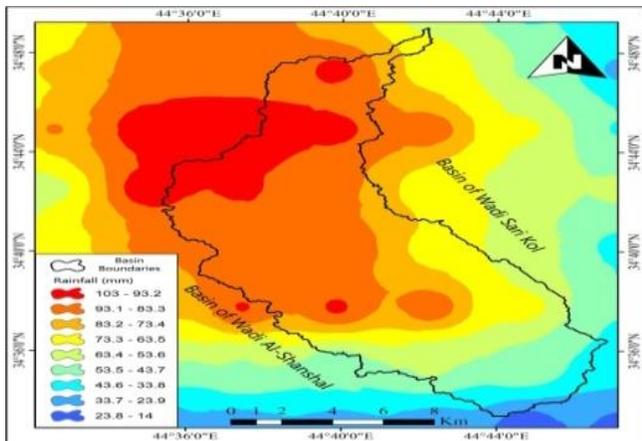

Fig. 4. The adopted intensity in the study area (https://chrsdata-en8.4ci.edu).

E. Pre-Condition of Soil Moisture

It is an indicator that shows the soil moisture content before the rainstorm occurs. To determine the values of (CN), specialists developed the SCS method. Three pre-conditions for soil moisture were determined. The first condition (AMC I)

represents dry soils, with values ranging from (0-35 mm). The second condition (AMC II) represents moderate semi-arid areas, with values ranging from (35-5.52 mm). The third condition (AMC III) represents humid areas, with values ranging from (100-52.5 mm). Temperatures are low and rainfall is heavy for the five days preceding the calculation of surface runoff [4]. The second condition (AMC II) was determined, which represents the moderate (normal) condition, to calculate the characteristics of surface runoff for the Wadi Al-Rafi'a basin. This was based on soil moisture, which reached (49.5 mm) for the five days preceding the approved rainfall, which was determined based on the website. (https://chrsdata-en8.4ci.edu).

Fig. 5 shows that that the number of (CN) values in the Wadi Al-Rafi' basin reached (10) values, and these values range between (61), which represents the lowest value of (CN) values, with an area of (13.77 km^2), as shown in Fig. 5 and Table IV, which includes grasslands and agricultural lands with a group of soils of class (D), which is an average value indicating that the surface has average permeability, meaning that it has the ability to generate average surface runoff. As for the highest value of (CN) values, it reached (91) with an area of (0.10) km^2, which includes fallow (barren) lands and the hydrological group of soil (C) (20), which is a high value indicating the speed of response of the study area (basin) to surface runoff after rain falls on it because it is characterized by low permeability. It is clear from the above that most of the basin areas fall within the high values of the variable (CN), indicating that a high percentage of the basin area can support and sustain surface water runoff [21].
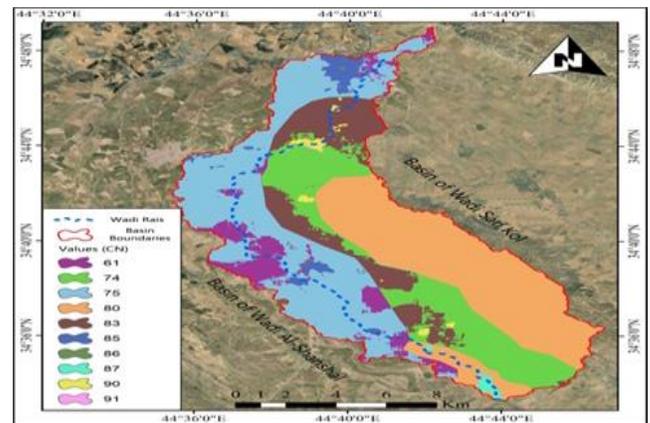

Fig. 5. Values of (CN) in the Wadi Al-Rafi' Basin Based on (hydrological soil types, and land cover uses map), using the program (ArcGIS 10.8 software).

The study indicated that the surface runoff coefficient (CN) values were high in all areas of the basin, ranging from 61 to 91. This reinforces the high potential for surface runoff generation, which calls for the adoption of effective water harvesting plans that, in turn, support agricultural stability and ensure the sustainability of these water resources.

Table IV and Fig. 6 show that that the (S) coefficient values in the Wadi Al-Rafi' basin range between (25.12) mm and (162.39) mm. The sum of these values is low and close to (0), which indicates a rapid increase in the amount of water running on the soil's surface. The relationship between (S) and (CN) values is close in terms of their response to surface runoff. The

areas that recorded the lowest value for the (S) coefficient also recorded the highest value for (CN), indicating their impermeability. All of these areas were fall within the hydrological soil group (B, C, D), which is characterized by moderate water infiltration. We conclude from this that the large parts of the Wadi Al-Rafi' Basin have the ability to sustain surface runoff. The study confirmed that the SCS-CN method is one of the effective methods for hydrological analysis of water basins, integrating AL and GIS techniques to obtain accurate estimates of surface runoff. The results demonstrated the effectiveness of these techniques in supporting water planning linked to resource management to serve sustainable development goals.
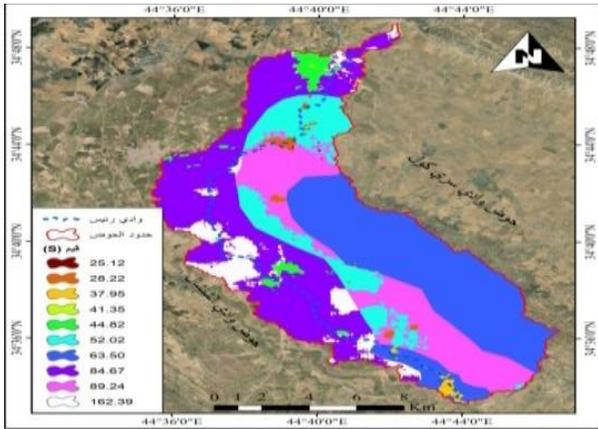

Fig. 6. Values of the (S) coefficient in the Wadi Al-Rafi' Basin based on (hydrological soil types, and land cover uses map), using the program (ArcGIS 10.8 software).

It is clear that the (LA) coefficient values for the Wadi Al-Rafi' Basin range between (5.02) and (32.48 mm), and that all values of this coefficient are low and close to From (0) and also consistent with the values of (CN) and values of (S), and all of these values indicate the generation of high surface water flow in the Wadi Al-Rafi' Basin, because the surface of the basin is characterized by low initial loss of rainwater falling on it (Table IV and Fig. 7).

The results confirmed that the surface runoff depth (Q) values ranged between 4.83–40.46 mm, while the total surface runoff volume (QV) for the Wadi Al-Rafi' Basin amounted to approximately 4,031,010 m³, based on the approved daily rainfall. This reflects a relative abundance of water resources that can be invested in sustainable agriculture projects and the development of human settlements.
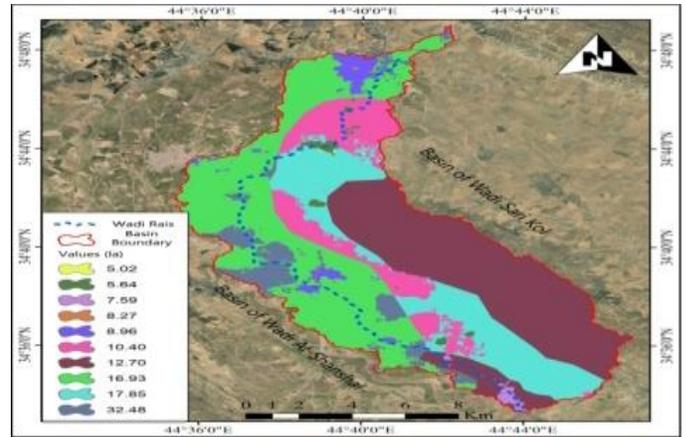

Fig. 7. Values of the coefficient (LA) for the Wadi Al-Rafi' Basin based on (hydrological soil types, and land cover uses map), using the program (ArcGIS 10.8 software).

TABLE IV. VALUES (CN) (S Mм) (LA Mм) (Q Mм) (QV M³)

Area (km)	CN	S (mm)	LA (mm)	Q (mm)	QV (m³)
13.77	61	162.39	32.24	4,83	665091
36.86	74	89.24	17.85	15.17	5591662
64.75	75	84.67	16.93	16.23	10508925
64.22	80	63.50	12,70	22.23	14276106
25.15	83	52.02	10.70	26.45	6652175
4.99	85	44.82	8.96	29,54	1474046
0.12	86	41.35	8.27	31,18	37416
1.26	87	37.95	7.59	32,89	414414
1.69	90	2822	5.64	38,45	649805
0.10	91	2512	5,02	40,46	4,406
212.91					4031010

Source: Based on the application of the previous equations and the outputs of the Arc Map 10.8 program

F. Sustainable Development and Water Harvesting

Water scarcity is one of the most significant problems negatively impacting development in Iraq. What further complicates this problem is the low rainfall rates, high population growth rates, and the expansion of arid and semi-arid regions. This is in addition to the direct reliance on rivers that originate outside Iraqi territory for water resources, as well as the excessive use of water in agriculture and the adoption of primitive irrigation methods. Based on the aforementioned problems, water harvesting is one of the basic requirements that must be implemented in order to create sustainable development and address the shortage in the amount of water required to meet the various requirements of life [23].

Sustainable development refers to the development of resources without causing pollution, imbalance in the environment, or depletion of its resources. It is based on optimal human management of natural resources and encouraging joint action at all stages of development [23, 24]. There are a set of characteristics that must be present in order to create and achieve sustainable development:

1. Regulating the use of natural resources, both renewable and non-renewable, in a fair manner that ensures the interests of future generations.
2. Achieving environmental balance, ensuring the safety of natural life through the balanced use of non-renewable resources and the production of renewable resources, is the governing standard for sustainable development [26-28].

G. The Concept of Water Harvesting

It is the process of harvesting rainwater falling from the atmosphere from the moment it falls on impermeable lands or surfaces and during the surface runoff phase. This is done by capturing and storing it using special means, either as water within special pools for use in various life activities or as moisture in the soil [29].

H. Objectives of Water Harvesting

The objectives of water harvesting are numerous and can be classified into:

First: Strategic Objectives:

1. Ensuring optimal utilization of seasonal water resources in water basins.
2. Developing natural pastures.
3. Contributing to achieving food security through self-sufficiency.

Second: Economic Objectives:

1. Developing agricultural lands, increasing their density, and raising the level of production in arable lands.
2. Optimal use of natural resources, particularly water and land.
3. Enhancing plant and animal wealth in the region (16).

Proposed sites for establishing water reservoirs for water harvesting within the Wadi Al-Rafi' Basin

The process of constructing barriers or dams on watercourses of valleys is considered the optimal method for developing water resources (Fig. 9). This process requires several stages, including the use of a digital elevation model (DEM) of the basin to determine the elevation of the area where water is being held. This process then matches the contour map with the river level map to determine the direction of the slope of the watercourses in the basin [28,29]. This process then selects suitable sites that can be used by the population. Finally, the volume of surface runoff at the appropriate location for the reservoir is estimated to determine the appropriate size of the reservoir or dam. Based on the above, the best locations for the dam were identified within the study area (Fig. 10). The sites were chosen as the best and most hydrologically suitable for constructing the dam and harvesting the surface runoff coming from the area feeding the reservoir area [30, 31]. The first site: The first reservoir is located on the longitude arc (44°38'23") north and latitude (34°44'33") east and extends vertically to a height of approximately (5) m, while the length of the reservoir body is (297) m² and its storage area is (215015) m2. Through this, water can be stored in the lake, which has a storage capacity of (276250) m3, as shown in Fig. 8, Fig. 1, and Table V.
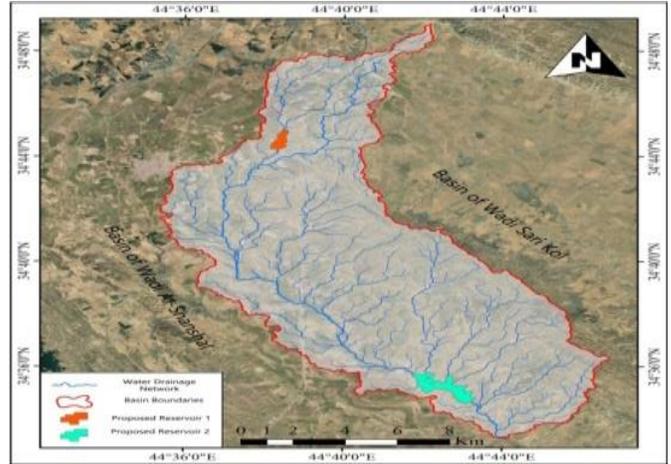

Fig. 8. Locations of the proposed reservoirs in the Wadi Al-Rafi' Basin based on the digital elevation model (DEM) with a resolution of (12.5) meters and the outputs of the program (ArcGIS 10.8 software).
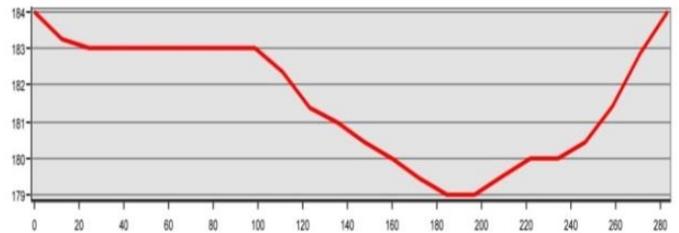

Fig. 9.   Cross section of the first proposed reservoir in Wadi Al-Rafi' Basin
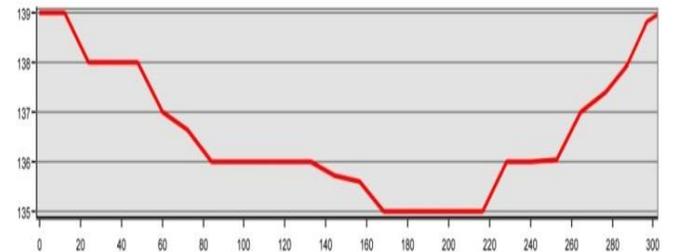

Fig. 10.   Cross section of the second proposed reservoir in Wadi Al-Rafi' Basin

TABLE V.   DESIGN CHARACTERISTIC OF THE TANKS PROPOSED TO BE BUILT ON THE WADI AL-RAFI' BASIN

	Latitude	Arc Length	Dam Length (m)	Dam Height (m)	Storage Area (m²)	Storage Volume (m³)
First proposed tank	44°38'23"	34°44'33"	287	5	215015	276250
Second proposed tank	34°35'12"	44°42'32"	301	4	1229210	2927190

Sources: Based on Fig. (8) and the program (Arc map 10.8)

The second site: This reservoir is located on the longitude arc (44°42'32") north and latitude (34°35'12") east, and its vertical height is (4) m, and the length of the dam body is (301)

m, and its storage area for water is (1229210) m² and its storage capacity is (2927790) m3, as shown in Fig. 8 and Table V. The geographical location and specifications of the dams proposed to be built in the Wadi Al-Rafi' Basin.

The study demonstrated that the construction of water reservoirs in the Wadi Al-Rafi' Basin represents an important strategic option for achieving several goals, including: developing the agricultural sector, enhancing human settlement, providing drinking water for humans and animals, and maintaining the ecological balance in the region. Utilizing these capabilities within the framework of sustainable development plans will contribute to increasing water use efficiency, reducing water waste, and achieving long-term stability for the agricultural and social sectors.

IV. CONCLUSIONS

The study concludes that the SCS-CN method represents one of the most distinctive and effective methods in hydrological studies of water basins. It relied on AI AL and GIS techniques to obtain accurate information for surface runoff estimates for the studied area. These techniques have proven their accuracy in this field. Furthermore, the pre-wet soil condition falls within the second level. The study confirmed that CN values are high in all areas of the basin, ranging from 61 to 91, indicating the potential for surface runoff generation within the basin.The study indicates that the values of the runoff depth (Q) range between (4.83-40.46 mm), while the total surface runoff volume (QV) for the Wadi Al-Rafi'a basin reached (4,031,010 m3) of water, based on the daily rainfall used in the study. This confirms the possibility of surface runoff in the studied basin. This is to achieve sustainable development goals in maintaining ecological balance. This is achieved by utilizing the water storage in these proposed reservoirs. The study confirmed the feasibility of constructing reservoirs in the Wadi Al-Rafi'a basin and developing it from multiple aspects, including developing the agricultural sector, human settlements, and animal watering.

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