



Estimating the Volume of Surface Runoff of the Shwan-Kirkuk Basin Using Geospatial Techniques

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Abstract

The Shwan Basin –Kirkuk is considered one of the seasonal valleys, with an area of 1371 km². The research aims to estimate the volume of surface runoff of the basin using the SCS-CN method. This method was implemented within the ArcGIS 10.8 and Landsat 9 OLI satellite data for the basin, which deals with several variables, including land cover, especially vegetation, soil quality and rainfall. The study relied on the highest rainfall intensity during the years 2010-2024, and the soil was classified according to the hydrological soil groups specified by (SCS-CN). The second level of soil moisture, represented by the semi-arid soil condition (AMCII), was chosen according to the tables prepared by (SCS). Based on stream orders, the basin was divided into six sub-basins. The CN values of the basins varied between 62 and 93, main basin dominating the 78 and 85 categories, covering an area of 447.78 and 442.4 km², respectively. The average depth of surface runoff in the main basin was 23 mm, while in the 6.5, 4, 3, 2, and 1 sub-basins, the values were 16.17, 21.27, 21.91, 23.69, 20.40, and 34.50mm, respectively. The highest surface runoff volume for the main basin and sub-basins occurred in 2019, and the lowest was in 2021 during rainfall events of 150 and 36 mm for both years, respectively.

Keywords:

Shwan basin, surface runoff, SCS-CN method, ArcGIS 10.8, landsat 9 OLI, hydrological soil groups, curve number (CN), rainfall-runoff modeling, sub-basin analysis, semi-arid conditions, AMC ii, remote sensing, GIS hydrology, watershed management, kirkuk.

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Introduction

The study of surface runoff is of great importance in hydrological studies, especially in arid and semi-arid regions, as water scarcity is one of the most important challenges in these regions (Vasquez & Mendoza, 2024; Tirmare et al., 2024). Surface runoff carries pollutants from the soil surface, which in turn reaches the groundwater, causing its pollution. (Khazal & Azeez, 2024, Mohammed & Azeez, 2024).

The reasons for these challenges include climate change, resulting lack of rainfall, fluctuations in its spatial and temporal distribution, in addition to the increase in population, which is accompanied by an increase in demand for water (Thamer & Aziz, 2023; Assegid & Ketema 2023). Projections indicate that as the hydrological cycle changes and global temperatures rise, droughts are expected to become more frequent and severe (Mustafa et al., 2024). Estimating surface runoff is an important hydrological factor in rainwater harvesting, reducing the risks of floods and landslides (Halvorsen & Tsvetkova, 2023).

Surface runoff estimation processes are accompanied by some difficulties in obtaining hydrological information specific to dry valleys due to the lack of information represented by the lack of hydrometric stations on valley courses equipped with devices to measure surface runoff in terms of its quantity, speed, and maximum value. In addition, the high cost of establishing and maintaining these stations has prevented the expansion of their establishment (Al Rayani et al., 2019). Surface runoff estimation processes are accompanied by some difficulties in obtaining hydrological information specific to dry valleys due to the lack of information represented by the lack of hydrometric stations in the valleys equipped with devices to measure surface runoff in terms of its quantity, speed, and its highest value. In addition, the high cost of establishing and maintaining these stations has prevented the expansion of their establishment (Al Rayani et al., 2019). Due to the difficulty of estimating surface runoff rates of basins directly, as it requires providing field measuring equipment and devices, in addition to measuring the amount of discharge during a rainstorm, mathematical experimental models were used to calculate the volume of surface runoff and its other characteristics, such as surface runoff speed and depth. The Runoff Curve Number Method, designed by the Soil Conservation Services and known as the SCS-CN method, was relied upon, which relies on the minimum possible information about rainfall, vegetation cover, and hydrological soil type, and with the help of Geographic Information Systems (GIS) and Remote Sensing (RS) technology, through which an integrated database can be built on the hydrological characteristics of the studied basins (Al-Shammari, 2023; (Abioghli, 2016; Vinutha et al., 2024). As a result of the water deficit that characterizes the Shwan basin, and given that it is one of the dry valleys within Kirkuk Governorate, the rain that falls in it is wasted annually, in addition, about 1570 tons of soil are lost per hectare annually (Noori & Azeez, 2023; Sredić et al., 2024), therefore the research aimed to estimate the volume of surface runoff generated within the basin as a result of its exposure to seasonal rain showers, which results in torrential floods and the loss of huge quantities of falling rainwater.

Materials and Methods

Study Area: The study area is located in Kirkuk Governorate, Iraq, located between longitude 44o8'21"-44o48'4" E and latitude 35o27'58"-35o49'53" N (figure 1), at an elevation of 350-800 meters asl. Rainfall data were obtained from the NASA Power website for the years 2010-2024. The basin is characterized by dryness and high temperatures during June, July, and August. This is accompanied by high evaporation rates and low relative humidity. Rainfall (285mm) is characterized by fluctuations in terms of time, location, and quantity, falling suddenly in short, heavy showers that result in flash floods.

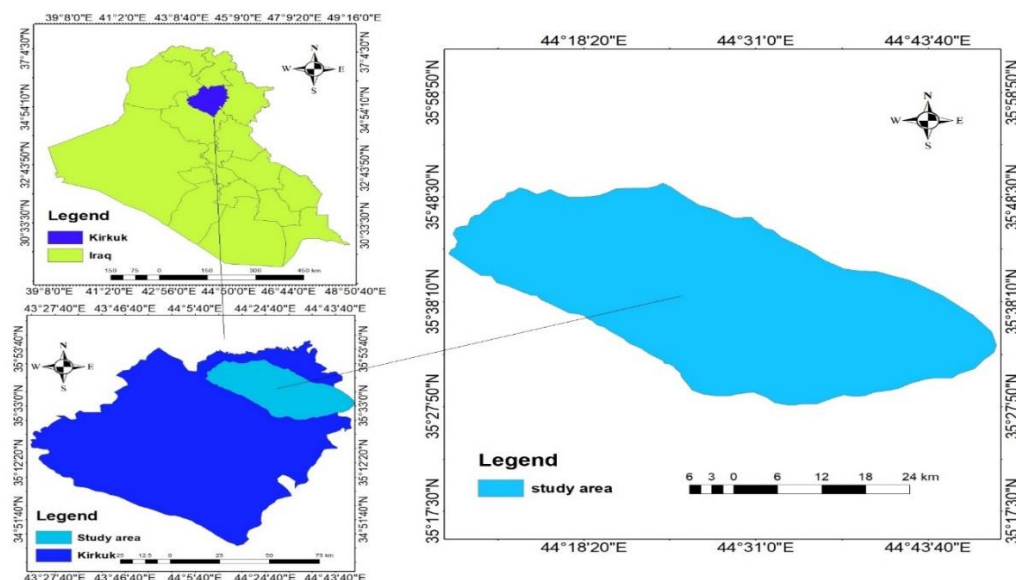


Figure 1. Map of study area

Estimating the Surface Runoff Volume of the Shwan Basin

Shwan basin receives semi-seasonal rainfall, which may not be sufficient to generate significant surface runoff. However, sudden, rainy winter cyclones are capable of generating higher amounts of surface runoff. It was necessary to create a hydrological database for the basin under study, represented by the depth of runoff, its volume, and the factors affecting it. Perhaps the method of the curve number Soil Conservation System- Curve Number (SCS-CN) is one of the most important mathematical methods used in calculating surface runoff.

Stages of Calculating Surface Runoff Volume Using the SCS-CN Method

The SCS-CN method requires several stages, equations, and procedures to obtain accurate surface runoff estimates, as follows:

Mapping of Land Cover Types

The detection of land cover types in the Shwan Basin reflects the basin's ability to generate surface runoff or recharge groundwater. The basin's land cover types were derived from supervised classification for the Landsat 9 OLI satellite image, observed on April 17, 2023, using ArcGIS 10.8

Mapping of Hydrological Soil Groups

Soils were classified into four soil groups (A, B, C, and D) according to the SCS-CN method (Table 1).

Table 1. Soil hydrological groups (USDA,1986)

Groups	Soil Texture
A	Sand, loamy sand or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay Loam, silty clay loam, sandy clay, silty clay, or clay

Forty-six soil samples were collected, covering the entire study area at a depth of 0-30 cm for particle size distribution analysis for hydrological group mapping using ArcGIS 10.8.

Curve Number (CN) Mapping

CN values were extracted by combining land cover and soil hydrological group layers. Using the application raster calculator in ArcGIS 10.8.

Antecedent Moisture Condition (AMC)

In order to calculate the surface runoff volume with results that simulate the basin's reality, it was necessary to adopt the soil moisture variable, which plays a significant and influential role in the surface runoff volume. SCS developed three moisture levels (Table 2), each with its pre-moisture levels. (AMC) refers to the moisture content present in the soil at the beginning of the rainfall-runoff event under consideration. It is well known that initial abstraction and infiltration are governed by AMC. For practical application, three levels of AMC are recognized by SCS as follows:

AMC-I: Soils are dry but not to the wilting point. Satisfactory cultivation has taken place.

AMC-II: Average conditions

AMC-III: Sufficient rainfall has occurred within the immediate past 5 days.

Saturated soil conditions prevail.

Table 2. Antecedent Moisture Conditions (AMC) for Determining the Value of CN. (Govindaraju et al., 2024)

AMC Type	Total Rain in the Previous 5 days		Soil characteristics
	Dormant Season	Growing Season	
I	Less than 13 mm	Less than 36 mm	Dry condition
II	13 to 28 mm	36 to 53 mm	Average condition
III	More than 28 mm	More than 53 mm	Heavy condition

In the current study, the second soil moisture level (AMCII) was determined, represented by the semi-dry soil condition.

For a detailed hydrological study of the basin, it was divided into six sub-basins based on river levels. This was to determine which basins respond most quickly to surface runoff.

Calculating the Surface Runoff Volume

The curve number (CN) is a key factor in determining surface runoff in the SCS method, which takes into account land use, soil quality, geological structure, vegetation cover, and rainfall. The mathematical formula for this method is:

$$Q = (p - I_a)^2 / (p - I_a + s) \dots\dots\dots (1)$$

Where:

Q = depth of surface runoff (mm)

P = amount of rainfall (mm)

Ia = initial intercept before the start of surface runoff, represented by evaporation, infiltration, and vegetation

S = surface collection after the start of surface runoff (mm)

Since Ia is equal to one-fifth of S, Ia becomes:

$$Ia = 0.2S \dots\dots\dots (2)$$

Accordingly, the equation is...

$$Q = (P - 0.2S) / (P + 0.8S) \dots\dots\dots (3)$$

The value of (S) is calculated based on the following mathematical relationship.

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

To convert the units of Equation (4) to mm to conform to metric measurements, it takes the following form.

$$S = 25400 / CN - 254 \dots\dots\dots 5$$

The total value of CN is calculated according to the following equation.

$$= \frac{(A_1 * CN_1) + (A_2 * CN_2) + (A_3 * CN_3) + (A_4 * CN_4) + (A_5 * CN_5)}{A_1 + A_2 + A_3 + A_4 + A_5} \text{ CN composite}$$

Where:

A1....A5=Area of each type of soil cover.

CN1....CN5=Value of each type of soil cover.

Calculating Total Surface Runoff Volume

The total surface runoff volume is calculated using the runoff depth obtained from Equations 3 and 5. The mathematical relationship becomes as follows:

$$Q_v = Q * A * (1000)$$

Where:

Qv = runoff volume (m³)

Q = runoff depth/mm

A = drainage basin area / km²

1000 = conversion factor

Results and Discussion

Morphometric studies of river basins are a modern trend that focuses on the use of hydrological and geomorphological methods and techniques to study the characteristics of river basins, both descriptively and

quantitatively. This helps understand the general characteristics of their basins and valleys, and the nature of their geomorphological function in terms of erosion, transport, and sedimentation, as well as the resulting phenomena that affect the surface runoff of these basins. The study of morphometric characteristics is of great importance, as it helps understand the relationship between the elements of the morphological characteristics of these basins, on the one hand, and the relationship between the movement of running water and the development of geomorphological features within these basins, on the other hand, by measuring and analyzing the spatial, morphological, topographic, and drainage characteristics, as well as the influencing factors.

The focus in studying the morphometric characteristics of the basins was on relying on a digital elevation model (DEM) with an accuracy of 30 meters and ArcGIS 10.8, through which the spatial characteristics and basin dimensions of the area are found using the tool. (Arc Hydrology Tools).

Catchment Properties

It includes the basin area, basin lengths, basin widths, and basin perimeter. These can be discussed as follows:

Basin Area

The importance of the river basin area as a variable lies in its impact on the volume of water discharge within the basin. The discharge volume and max flow rate of rainfall increase with increasing basin area. The basin area is affected by the prevailing climate and geological structure.

It is noted from Table 3 that the total area of the Shwan Basin is 1,371 km² and consists of six secondary basins of varying sizes. The main Basin 1 is the largest in area, at 734.4 km², while the Basin 6 is the smallest, at 19 km². This variation in basin area is due to the varying effects of erosion and weathering on exposed rocks, as well as the varying slopes of the study area.

Table 3. Spatial characteristics of the Shwan Basin

Basins	Area km²	%	Perimeter	Length km	Width
1	734.4	53.6	134.5	41.3	3.3
2	404.4	29.5	110.8	26.2	4.2
3	54.3	4.0	54.3	15.4	3.5
4	46.0	3.4	47.8	10.2	4.7
5	34.2	2.5	32	7.2	4.4
6	19.0	1.3	28.6	7.8	3.7
Shared basins	78.7	5.7			
Total Area	1371	100%	161	62.55	21.92

The larger the basin area, the greater the amount of rainfall it receives, which leads to an increased likelihood of flooding. The larger the basin area, the more active the geomorphological processes of rainfall. This helps in the formation of high water flows, as the larger the basin area, the more rainstorms cover it. This contributes to the rapid formation of water flow in most of the tributaries that feed the basin, which in turn increases the amount of water discharge. Also, the greater the slope, the greater the speed of rainwater flow, which is reflected in the increased activity of water erosion. Meanwhile, the presence of vegetation in the area reduces water erosion processes and thus helps in the infiltration of rainwater into the ground.

Basins Lengths

Basin length plays a significant role in determining the likelihood of flooding, as short basins facilitate flooding due to low evaporation and seepage losses and low discharge. The basin length is defined as the line extending from the valley mouth to the farthest point at the watershed area in the upper basin (Schumm, 1956). From Table (3), noted that the length of the main Shawan basin (study area) reached 62.55 km, and that the secondary basins vary in length. The smallest length was 7.8 km (Basin 6), while the highest length was 41.3 km (Basin 1).

Basin Average Width

It is the straight transverse distance between the two farthest points on the basin's circumference. It was found that the width of the main Shwan basin was 21.92 km, but the secondary basins varied in average width. The lowest width was 3.3 km (basin 1), while the highest width was 4.7 km (Basin 4).

Basin Perimeter

The basin perimeter is represented by the watershed line that forms the outer frame of the basins and separates each basin from the other basins (1). It appears from Table (3) that the perimeter of the Shwan Basin reached 161 km. It is also possible to observe the variation in the secondary basins in their perimeters, as the lowest value reached 28.6 km (Basin 6), while the highest value reached 134.5 km (Basin 1). This variation indicates the existence of a direct relationship between the area of the basin and its perimeter.

Land use\Landcover

The land cover classification process is concerned with clarifying the types that exist within the secondary basins of the region. Six land covers were found to be distinguished in the main basin and the secondary basins, as follows:

Water

This cover was represented by the presence of some water bodies spread throughout the study area, most notably the waters of the Khasah Dam Lake, which were concentrated in Basin 2, covering an area of 3.3 km², representing a total percentage of 0.8 and 0.24 of the area of Basin 2 and the main basin, respectively (Table 4),(Figure.2).

Agricultural Land Abandoned

This class includes all agricultural lands covering certain areas of the basins planted primarily with winter crops, such as wheat, which rely on rainfall. The total cultivated area was 821 km² (59.89%). The highest percentage of this category was in Basin 1, which covered an area of 508.7 km² (69.3%), and the lowest was in Basin 6, which covered 13.8 km² (72.5%).

Urban Lands

This class represents areas with urban uses, including residential areas, civil facilities, roads and transportation networks spread throughout the study area. This category covers an area of 36.20 km² (2.64%) of the total study area. The highest area was in Basin 1, which reached 20.5 km² (2.8%), while the lowest was in Basins 6 and 7, which reached 0.7 km².

Non-Plowed Soil Pasture

This category included seasonal, perennial, and annual grasses covering the area throughout the year. Total area was estimated at 54.31 km², occupying 3.96% of the study area. Basin 2 excelled in this cover, with an area of 32.8 km², while basins 3, 5, and 6 were devoid of this cover.

Orchards

This category includes orchards and scattered shrubs that are found on the edges of seasonal valleys that vary in size and density. This cover occupied 2.82% of the study area (38.62 km²), and Basin 2 excelled in its content of this cover, which amounted to 27.9 km², while Basins 3 and 6 were devoid of this cover.

Bare Soil

This category represents the unexploited barren lands in all basin lands, as well as the stony and rocky lands that are not suitable for human or agricultural uses due to the presence of several rocky exposures of layers of anticlines and exposed due to erosion, which were mainly concentrated in the northern parts of the study area. This occupied 338.79 km² (24.71% of the study area). Basin 1 excelled in this cover, which amounted to an area of 181 km², while Basin 5 occupied the lowest content, which amounted to 4.6 km².

Table 4. Land use/land cover for the study area

Basins	Basin1		Basin2		Basin3		Basin4		Basin5		Basin6		Main Basin	
Class	Area Km ²	%	Area Km ²	%	Area Km ²	%	Area Km ²	%	Area Km ²	%	Area Km ²	%	Total	%
Water	0.0	0.0	3.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.30	0.24
Agricultural Land Abandoned	508.8	69.3	209.5	51.8	38.2	70.3	25.8	56.1	25.0	73.0	13.8	72.5	821.08	59.89
Urban lands	20.5	2.8	8.9	2.2	1.1	2.0	4.3	9.3	0.7	2.1	0.7	3.8	36.20	2.64
Non Plowed Soil Pasture	19.2	2.6	32.8	8.1	0.0	0.0	2.3	5.0	0.0	0.0	0.0	0.0	54.31	3.96
Orchards	4.9	0.7	27.9	6.9	0.0	0.0	1.9	4.1	3.9	11.5	0.0	0.0	38.62	2.82
Bare Soil (Crop Residue cover)	181.0	24.6	122.0	30.2	15.0	27.6	11.7	25.4	4.6	13.4	4.5	23.7	338.79	24.71
Total	734.4	100	404.4	100	54.3	100	46	100	34.2	100	19	100		

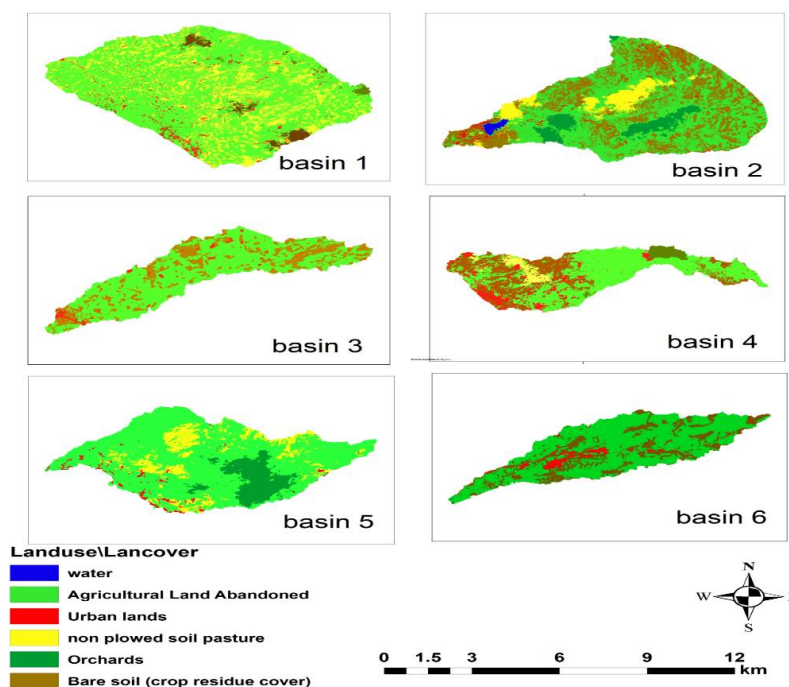


Figure 2. Land use/land cover for the study area

Soil Hydrological Group

The U.S. Soil Conservation Service (SCS) classified soils into four soil hydrological groups based on the rate of water transpiration and water infiltration within the soil. Four classes (A, B, C, and D) were identified as mentioned in Table 5.

Table 5. Soil hydrological group classes

class	Clay%	Silt%	Sand%	texture
A	Less than 10%	-----	More than 90%	Sandy
				(Loamy sand, Sandy loam, Loam or Silt loam)
B	%20 – 10	-----	%90 – 50	Loamy sand or Sandy loam
				(Loam, Silt loam, Silt, or Sandy clay loam)
C	%40 – 20	-----	Less than 50%	Loam, Silt loam, Sandy clay loam, Clay loam, and Silt clay loam
				(Clay, Silt clay, or Sandy clay)
				Clayey
D	More than 40%	-----	Less than 50%	

All hydrological soil types were observed, distributed over the secondary basins (Table 6) and (Figure.3)

Hydrological Group (A):

This represents floodplain sediments, which are coarse-textured sandy soils with a high water absorption capacity. This group covers an area of 125.9 km² (9.2% of the total study area). The highest percentages were found in Basin 1, which occupied 100.5 km². This group did not appear in Basins 3 and 6.

2- Hydrological Group (B):

These soils have a coarse texture and are mostly shallow in depth. They are a mixture of boulders, gravel, and rock fragments bound together by cementing materials composed of silt. They are found in the upper reaches of the basins between the anticlines from which the valleys descend. This category covered an area of 638.8 km², representing 46.6% of the study area.

The highest percentages were in Basin 1, at 479 km², and the lowest in Basin 6, at 0.3 km².

3 - Hydrological Group (C):

The soils in this group have medium runoff potential and low infiltration rates when fully moist. Water transport through the soil is somewhat restricted. These soils were formed by seasonal river flooding and are mostly composed of silt and sand.

The total area of this type was 434.5 km², representing 31.70% of the total area. The highest percentage was in Basin 2, at 218.4 km², followed by Basin 1 and finally Basin 6, at 6.3 km².

4 - Hydrological Group (D):

The soils in this group are responsible for most of the surface runoff in the region. They are characterized by a very low rate of water infiltration. The area of this group reached 91.5 km² (6.7%). Basin 2 outperformed the other basins with an area of 41.7 km². Basins 3 and 4 did not contain this type.

Table 6. Soil hydrological groups for the study area

Class	A		B		C		D	
Basins	Area Km ²	%	Area Km ²	%	Area Km ²	%	Area Km ²	%
Basin1	100.5	13.7	479.0	65.2	128.9	17.6	25.7	3.5
Basin2	20.5	5.1	123.0	30.5	218.4	54.1	41.7	10.3
Basin3	—	—	24.1	44.5	30.1	55.5	—	—
Basin4	3.3	7.2	6.8	14.9	35.8	77.9	—	—
Basin5	1.6	4.7	5.6	16.4	15.0	44.3	11.7	34.6
Basin6	—	—	0.3	1.9	6.3	33.1	12.4	65.3
Total	125.9	9.2	638.8	46.6	434.5	31.70	91.5	6.70

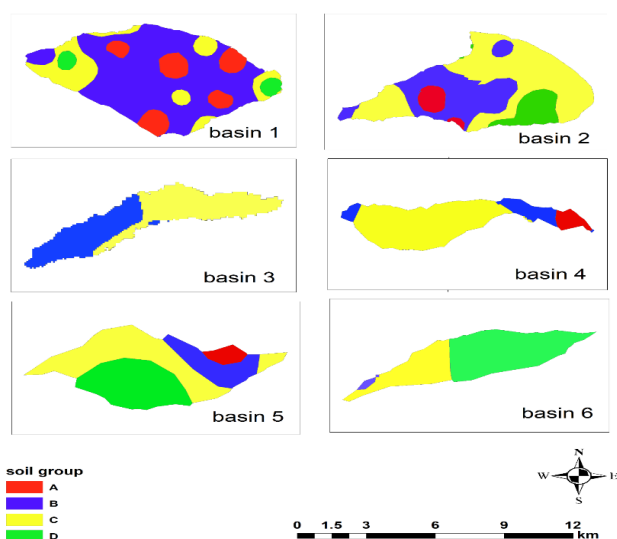


Figure 3. Soil hydrological group map for study area

Curve Number (CN) for Basins

CN values represent the state of the land cover and soil hydrology through their ability to absorb water, and indicate the basin's ability to generate surface runoff. CN values range from 0-100, where high CN values indicate impervious surfaces, which are more capable of generating high surface runoff, while low CN values indicate permeable or less permeable surfaces, and thus their ability to generate surface runoff is reduced, while the value between the two limits represents surfaces with medium permeability (Table 7).

Table 7: CN values represent the state of the land cover and soil hydrology (USDA, 1986)

Land Use/ Land Cover	Soil Hydrological Group Curve Numbers			
	A	B	C	D
Water	100	100	100	100
Agricultural Land Abandoned	67	78	85	89
Urban lands	77	85	90	92
Non Plowed Soil Pasture	68	79	86	89
Orchards	62	71	78	81
Bare Soil (Crop Residue cover)	76	85	90	93

The values mentioned in (Table 8) and Figure (4) showed variations in the areas occupied by the main and the secondary basins, ranging between (93 - 62). Classes 78 and 85 are dominate, covering an area of 447.78 and 442.4 km², respectively. These two classes are relatively impermeable and have the potential to generate moderate surface runoff. As for the secondary basins, most of the values were found in Basins 1 and 2, while the other basins were limited to containing some of them. Classes 78 and 85 also dominated in Basins 1 and 2, occupying 344.2 and 221.4 km², representing 46.8 and 30.2%, respectively. Basin 2 was characterized by its narrow water area, namely the Khasah Dam, with an area of 3.4 km².

Table 8. CN number for study area

Basins	Basin1		Basin2		Basin3		Basin4		Basin5		Basin6		Total	%
CN Value	Area Km ²	%	Area Km ²	%	Area Km ²	%	Area Km ²	%	Area Km ²	%	Area Km ²	%		
62	0.1	0.0	7.9	2.0									8	0.46
67	64.6	8.8	10.9	2.7			2.5	5.4	1.05	3.1			79.05	4.57
68	1.2	0.2											1.2	0.07
71	1.4	0.2	10.7	2.6			1.7	3.8	0.45	1.3			14.25	0.82
76	31	4.2	1.5	0.4			0.8	1.8	0.5	1.5			33.8	1.95
77	3.4	0.5	0.2	0.04									3.6	0.21
78	344.2	46.8	65.5	16.2	18	33	3.5	7.7	7.1	21.0	0.2	1.1	447.78	25.87
79	13.7	1.9	15.1	3.7									28.8	1.66
81	0.32	0.0	2.5	0.6					0.8	2.4			3.62	0.21
85	221.4	30.2	155.9	38.5	27.3	51	21.3	46.0	11.5	33.2	4.3	22.7	442.4	25.56
86	3.4	0.5	17.7	4.4			2.4	5.2					23.5	1.36
89	19.1	2.6	27.2	6.7					8.9	26.2	9.9	52.1	65.1	3.76
90	24.3	3.3	73.8	18.3	9	16	13.8	30.1	1.9	5.5	2.0	10	124.8	7.21
92	0.3	0.0	0.2	0.03					0.5	1.4	0.2	0.9	1.2	0.07
93	6	0.1	11.9	2.9					1.5	4.3	2.4	12.5	21.8	1.26
100			3.4	0.8									3.4	0.20
Total	734.4	100	404.4	100	54.3	100	46.0	100	34.2	100	19.0	100		

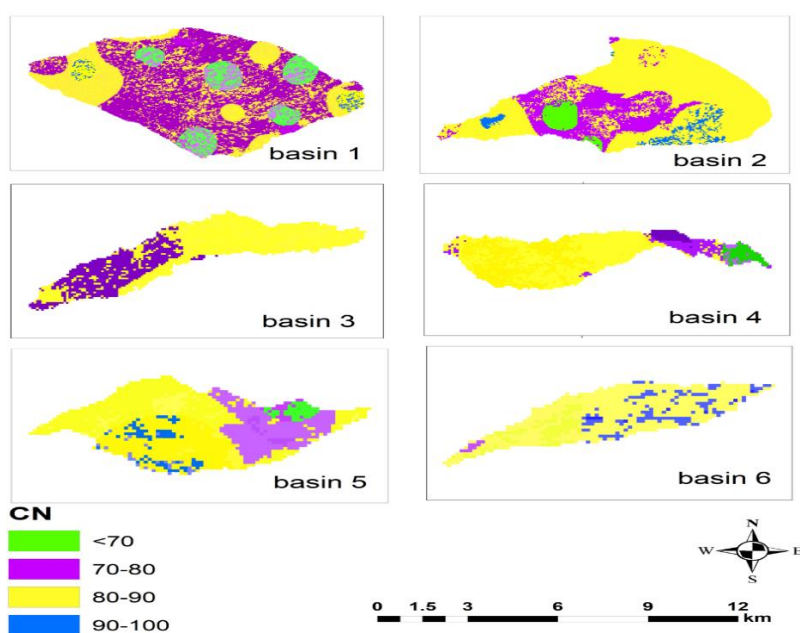


Figure 4. CN map for secondary basins

Run Off Depth

Surface runoff results from the interaction of a specific rainfall event with the characteristics and components of the drainage basin. Therefore, the more the type of ground cover and porosity differ, the depth of the surface runoff that forms on its surface varies. In this case, if the rainfall event is constant across the entire basin, the variable element controlling the variation in runoff depth between basins is the curve number.

In this study, the surface runoff depth of the Shwan Basin was calculated based on the highest rainfall event during a single year over 15 years (Table 9).

Table 9. The highest rainfall in one year for 15 years (2010-2024)

Years	Precipitation (mm/day)
2010	48
2011	51
2012	75
2013	119
2014	55
2015	100
2016	94
2017	63
2018	135
2019	150
2020	100
2021	36
2022	68
2023	71
2024	62

It is noted that there is a fluctuation in rainfall rates in the study area, and this applies to arid and semi-arid regions. The amount of rainfall increased and exceeded 100 mm during the years 2013, 2015, 2018, 2019, and 2020, characterized by more surface runoff than in other years, in which the highest rainfall ranged between 36 and 93 mm. The highest depth of surface runoff was recorded in 2019, reaching 66.64 mm, while the lowest depth value was recorded in 2021, reaching 1.71 mm. (Figure shows the runoff depth curve) (Figure 5).

As noted in Table 10 and Figure 5, the highest surface runoff depths for secondary basins 1, 2, 3, 4, 5, and 6 were also recorded in 2019, reaching 53.68, 64.38, 65.66, 69.16, 58.39, and 88.54 mm, respectively. The lowest were in 2021, reaching 0.24, 1.07, 1.20, 1.61, 1.19, and 4.96 mm, respectively. Table 10 also shows that the average surface runoff depth for the Shwan Basin was 22.99 mm, while in basins 1, 2, 3, 4, 5, and 6, it reached 16.17, 21.27, 21.91, 23.69, 20.40, and 34.50 mm, respectively. This variation in the depth of surface runoff in the basins results from runoff in water flows, which depend mainly on rainfall and the area of the basins.

Table 10. Runoff depth for secondary basins

Year	Basin 1	Basin 2	Basin 3	Basin 4	basin 5	Basin 6	Average
2010	2.00	4.00	4.28	5.08	5.50	10.74	5.27
2011	2.70	5.01	5.33	6.24	9.05	12.48	6.80
2012	10.58	15.21	15.80	17.46	13.76	27.79	16.77
2013	33.62	42.09	43.12	45.96	37.93	62.22	44.15
2014	3.64	6.31	6.67	7.70	5.88	14.61	7.47
2015	22.47	29.35	30.20	32.56	26.39	46.46	31.24
2016	19.16	25.49	26.28	28.47	22.93	41.52	27.31
2017	6.25	9.76	10.23	11.53	8.94	19.96	11.11
2018	43.70	53.37	54.54	57.73	48.25	75.70	55.55
2019	53.68	64.38	65.66	69.16	58.39	88.54	66.64
2020	22.42	29.29	30.15	32.50	26.34	46.38	31.18
2021	0.24	1.07	1.20	1.61	1.19	4.96	1.71
2022	7.71	11.63	12.14	13.58	10.59	22.71	13.06
2023	8.80	13.01	13.55	15.08	11.81	24.69	14.49
2024	5.65	9.00	9.44	10.68	19.04	18.80	12.10
Average	16.17	21.27	21.91	23.69	20.40	34.50	22.99

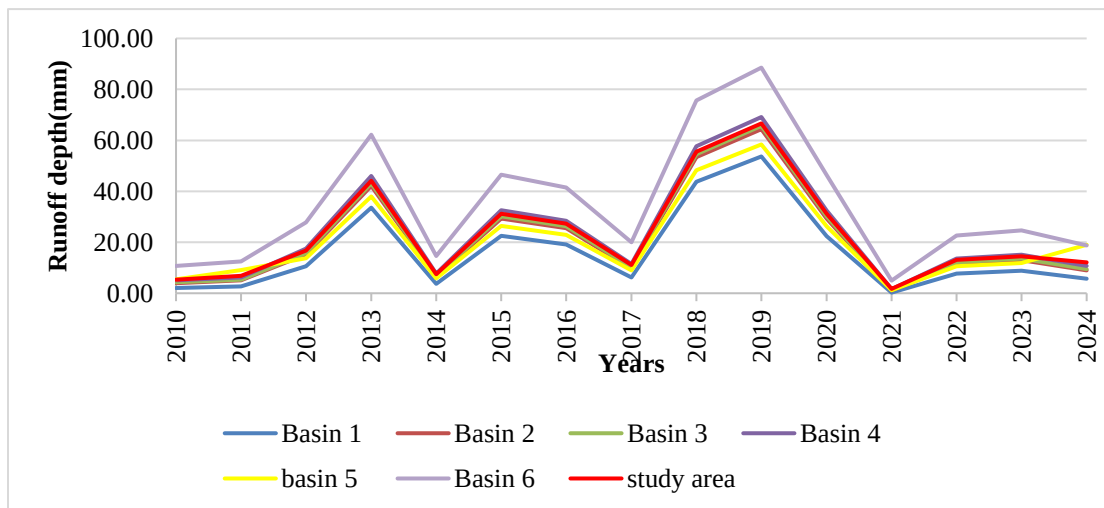


Figure 5. Runoff depth for main and secondary basins in the study area

Runoff Volume

The results in the table (11) and figure (6) show that the average surface runoff volume of the highest rainfall event for the main basin during the study years amounted to 24,107,834 m³. The highest amount was in 2019 (75,872,223 m³), and the lowest amount was in 2021 (884,974 m³) during the rainfall events of 150 and 36 mm for the two years, respectively.

Table 11. Runoff volume for basins

year	Basin 1	Basin 2	Basin 3	Basin 4	basin 5	Basin 6	study area
2010	1470817.13	1616972.82	232188.07	233776.09	187763.13	204080.26	3945598
2011	1985789.84	2026563.85	289213.99	286860.17	309070.05	237115.49	5134613
2012	7769021.66	6151578.93	857886.63	803328.96	469890.87	527916.19	16579623
2013	24683549.98	17020365.97	2340614.01	2114055.09	1295607.11	1182162.96	48636355
2014	2670323.10	2550924.91	361979.90	354048.97	200993.27	277617.22	6415887
2015	16499152.90	11868834.29	1639375.01	1497699.71	901526.81	882649.74	33289238
2016	14071499.95	10309477.20	1426657.72	1309687.25	783165.61	788906.75	28689394
2017	4586535.96	3948742.27	555091.86	530377.06	305237.83	379157.07	10305142
2018	32086589.27	21582814.64	2960273.09	2655518.09	1648063.28	1438206.91	62371465
2019	39413934.18	26035930.41	3564179.88	3181157.37	1994714.89	1682305.98	75872223
2020	16463579.37	11846109.51	1636276.83	1494965.47	899798.65	881295.89	33222026
2021	179368.84	431468.75	65251.39	74065.35	40539.92	94279.64	884974
2022	5660924.63	4704615.25	659157.42	624568.77	361652.46	431408.76	12442327
2023	6465384.19	5261660.62	735729.92	693600.92	403279.02	469044.96	14028700
2024	4151162.97	3637684.44	512202.99	491410.50	650291.17	357186.72	9799939
	11877175.6	8599582.92	1189071.9	1089674.7	696772.94	655555.64	24107834

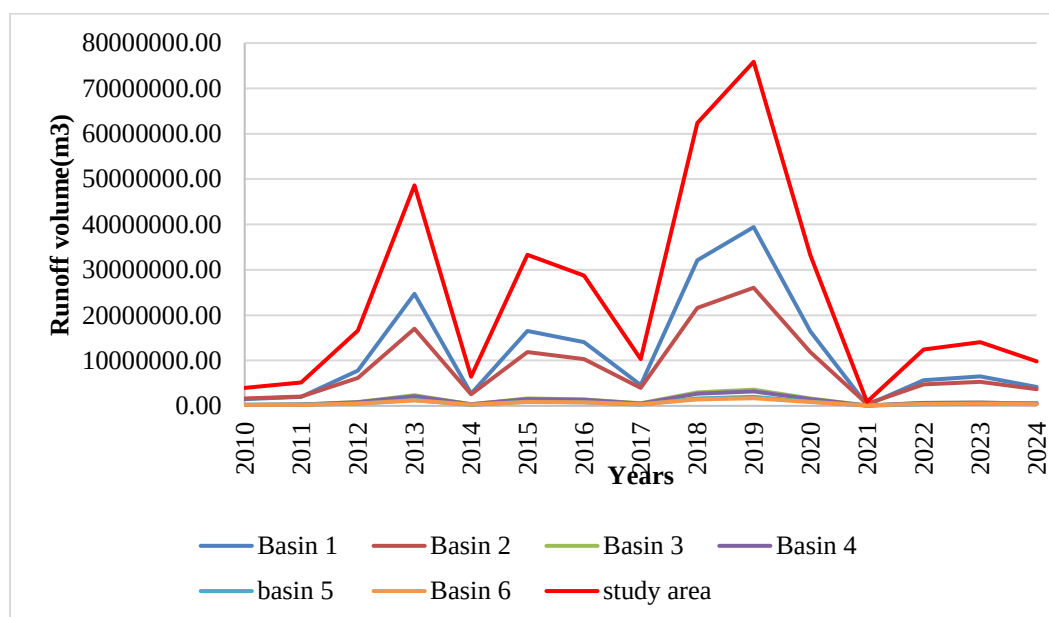


Figure 6. Runoff volume for main and secondary basins

For secondary basins, the volume of surface runoff is consistent with their depth and area, as a strong relationship was found between the area of the basins and the average volume of surface runoff (Figure.7).

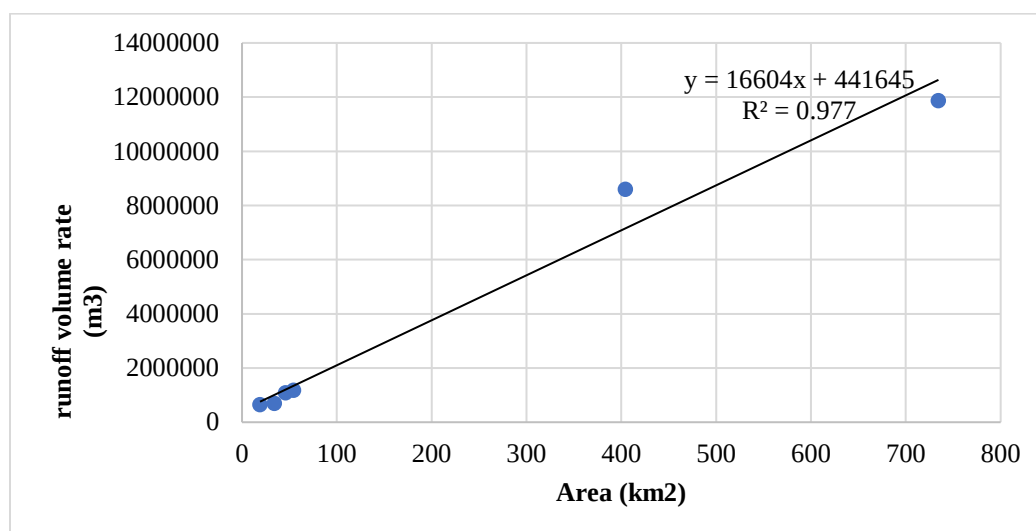


Figure 7. Relationship between runoff volume and basin area

Conclusions

Surface runoff volume was highest in 2019 and lowest in 2021 for all basins. Basin 1 had the highest average surface runoff volume, reaching 11,877,175.6 m³, accounting for 49.26% of the total. This is due to the basin's large area of 734.4 km², the diversity of its land covers, and its geological formations. The basin is characterized by its presence in hard rocks with low porosity and high slopes, which allow for high surface runoff. Accordingly, it is necessary to establish water harvesting sites and dams in order to reduce the risks of floods and water erosion and to benefit from the water retained during dry seasons for drinking purposes and irrigating agricultural lands.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

References

- Abioghli, H. (2016). Numerical Analysis of Reinforced Soil Walls with Finite Element Method. *International Academic Journal of Science and Engineering*, 3(3), 70-76.
- Al Rayani, A. A., Al Madani, A. H. M., & Ekhmaj, A. I. (2019). Analysis of surface Runoff for Some Wadi Basins in Northwest Libya. *The Libyan Journal of Agriculture*, 24(1).
- Al-Shammari, M. A. A. (2023). Characteristics of Runoff in the Ghriba Valley Basin and the Possibility of Investing in Water Harvesting University of Mustansiriyah]. College of Education University of Mustansiriyah.
- Assegid, W., & Ketema, G. (2023). Assessing the Effects of Climate Change on Aquatic Ecosystems. *Aquatic Ecosystems and Environmental Frontiers*, 1(1), 6-10.

- Halvorsen, L. E., & Tsvetkova, M. (2023). Analyzing the Impact of Climate Change on Coastal Infrastructure. *International Academic Journal of Innovative Research*, 10(4), 31–35.
- Khazal, S. S., & Azeez, D. R. (2024). Evaluation the ground water in kirkuk governorate for drinking and irrigation purposes. *Journal of Kirkuk University for Agricultural Sciences*, 15(3).
- Mohammed, A. A., & Azeez, D. R. (2024). Groundwater Quality Assessment for Irrigation purposes in Kirkuk Governorate. *Journal of Kirkuk University for Agricultural Sciences*, 15(3).
- Mustafa, A. R., Ali, D. K., & Azeez, D. R. (2024). Assessment of Hydrological Drought Intensity and Frequency Using SPI in Sulaimanya Province, Iraq. *Journal of Kirkuk University for Agricultural Sciences*, 15(2).
- Noori, N. E., & Azeez, D. R. (2023, December). Soil erosion risk assessment using revised universal soil loss equation RUSLE model: a case study in Shwan Sub basin, Kirkuk, Iraq. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1262, No. 8, p. 082007). IOP Publishing. 10.1088/1755-1315/1262/8/082007
- Schumm, S. A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological society of America bulletin*, 67(5), 597-646. [https://doi.org/10.1130/0016-7606\(1956\)67\[597:EODSAS\]2.0.CO;2](https://doi.org/10.1130/0016-7606(1956)67[597:EODSAS]2.0.CO;2)
- Sredić, S., Knežević, N., & Milunović, I. (2024). Effects of Landfill Leaches on Ground and Surface Waters: A Case Study of A Wild Landfill in Eastern Bosnia and Herzegovina. *Archives for Technical Sciences*, 1, 97. 10.59456/afts.2024.1630.097S
- Thamer, M. B., & Aziz, M. A. (2023). Hydrological assessment of the possibility of rainwater harvesting (Wadi Ghriba case study). *Mustansiriyah Journal of Humanities*, 1(Special Issue/Vol. 1 The 26th Scientific Conference for Humanities and Educational Sciences/College of Education/Al-Mustansiriya University).
- Tirmare, A. H., Mali, P. S., Shirolkar, A. A., Shinde, G. R., Patil, V. D., & Tirmare, H. A. (2024). VLSI architecture-based implementation of motion estimation algorithm for Underwater Robot Vision System. *Journal of VLSI Circuits and Systems*, 6(2), 115-121. <https://doi.org/10.31838/jvcs/06.02.13>
- USDA, (1986). (United States Department of Agriculture), SCS (Soil Conservation Service). (1986). Urban hydrology for small watersheds (Technical Release 55, 2nd ed.). Washington, DC: U.S. Government Printing Office.
- Vasquez, E., & Mendoza, R. (2024). Membrane-Based Separation Methods for Effective Contaminant Removal in Wastewater and Water Systems. *Engineering Perspectives in Filtration and Separation*, 21-27.
- Vinutha, T. Y., Rakesh, C. J., Lokanath, S., & Kumar, A. K. (2024). Surface Runoff Estimation Using SCS-CN Method for Kurumballi Sub-watershed in Shivamogga District, Karnataka, India. *Nature Environment & Pollution Technology*, 23(2). 10.46488/NEPT.2024.v23i02.020