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گۆڤاری کوردستانیی بۆ لێکۆڵینەوەی ستراتیجیی

Application of (SCS-CN) Method in Runoff Estimation in Qoratu Watershed Using (GIS & RS) Techniques

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Abstract

The method of Soil Conservation Service Curve Number (SCS-CN) was applied to assess runoff in Qoratu Watershed, Garmian Administration, (NE-Iraq). Digital Elevation Model (DEM-12.5m) and (Landsat OLI) were both utilized as the stuff of Geographic Information System (GIS) and Remote Sensing (RS) techniques analyzed to obtain accurate hydrological data. Qoratu watershed is a mutual (Iran-Iraq) watershed located within the Iraqi Kurdistan Region adjacent to the Sirwan River. Topographically, the study area is known as the sub-mountain area of the Kurdistan Region. At its sixth order, the watershed drains into the Sirwan River. The total area of the Qoratu watershed Was found to be (808.34 Km2); so, approximately (44.9%) of this area is located within the Iraqi Kurdistan Region. This study aimed to (i) Estimate the Runoff of the Qoratu watershed for dam construction purposes, (ii) estimate the water harvest of the Qoratu sub-watershed to achieve the best state of water management in the study area, (iii) estimate groundwater levels rise, and (iv) to control floods during the rainy season. The study concluded that the water inflow is high; thus, the possibility of constructing a dam and/or ponds in the area is beneficial.

Keywords: (GIS & RS) techniques, LU/LC, Qoratu watershed, Runoff estimation, (SCS-CN) method.

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1. Introduction

Water is the greatest natural gift to humanity; it has become a limited resource that needs to be preserved by water resources management. Precise runoff estimation is essential and critical for water resource management. Runoff is one of the main factors used in watershed control, as it is the drainage of the water precipitated into a stream in the watershed, after achieving the losses of both sub-surface and surface water (Hashim & Sayl, 2022). Runoff is one of the most important hydrological variables that are widely used in most water resource equations and their applications. Its occurrence and quantity are relying on the rainfall event characteristics; for example, the intensity distribution and duration. Regardless of the mentioned characteristics, many catchment-specific factors directly affect the runoff occurrence and its amount. Those factors include vegetation cover, type of soil, slope and the type of watershed (Bansode & Patil, 2014). Nowadays, the method of (SCS-CN) is considered one of the common methods which are used widely to compute the quantity of runoff for a specific rainfall. Independently, the (SCS) is regarded as an experimental model which only needs a parameter - Curve Number which makes up together the land use hydrological effects. Therefore, the structure of the method is simplified, the calibration of the model can be easily obtained and the functions' surface characteristics can be reflected well on the runoff. However, due to its low input data requirements, it can also be applied to hydrological forecasts of ungagged watersheds (Wang et al., 2015). Recently, the water scarcity issue is becoming more serious due to several factors. They include increasing water demand, high population rate, recurrence of drought phenomena, the effect of global warming and lack of management and planning of water resources during the last four decades. Moreover, water policies of the upstream countries enforced another burden where mega water projects and dams have been constructed on the upper parts of the rivers within their borders. Thus, this has led to the reduction of the inflow rate of rivers inside of Iraqi Kurdistan Region. Therefore, it is essential to construct dams in suitable areas to guarantee water reserves for drought seasons.

2. Study Area

The Qoratu watershed extends from Kermanshah Province in the Islamic Republic of Iran to the Kurdistan Region of Iraq, and in the sixth order, it flows into the Sirwan River in the Qoratu Sub-district in Garmian Administration. Also, it is located between the Hawasan watershed in the north and the Alwand watershed in the south. This watershed is one of the permanent sources of feeding the Sirwan River in the sub-mountainous area or the plateaus and hills areas (figure 1). The Qoratu watershed's total area is (808.34 km2); while, about (362.92 km2) or (44.90%) of this area is located within the Iraqi Kurdistan Region. Astronomically, the watershed lies between two latitudes (34° 29’ 55″30 ‹43 34° – ″) north and longitudes (45° 26’ 50″30 ‹04 46° – ″) east.

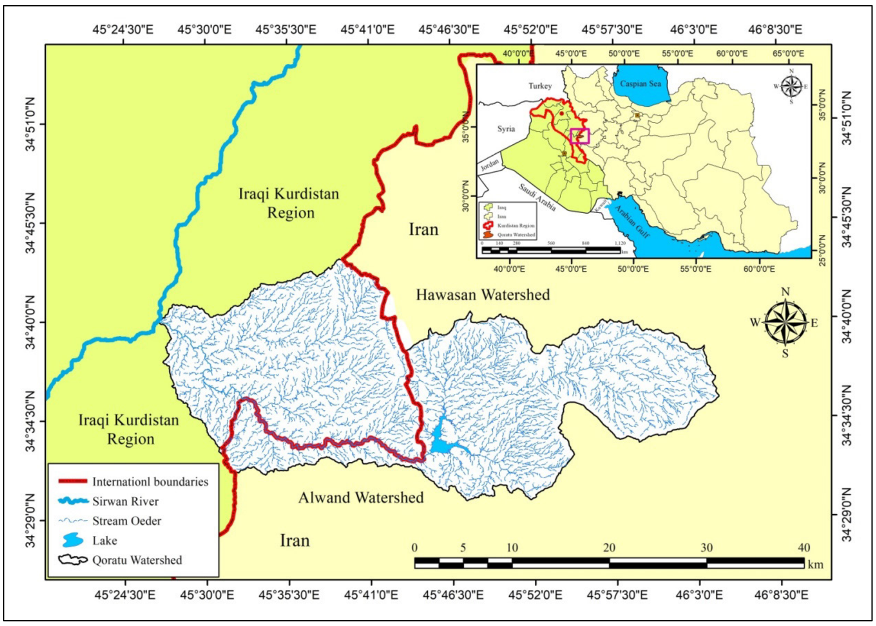

Fig. 1. Location Map of the Qoratu Watershed

3. Methodology and Data Source

The present research relies on the Soil Conservation Service Curve Number (SCS-CN) method, which is regarded as one of the common methods for computing the quantity of water surface coming from rainstorms. The data have been extracted from several sources including (1) Digital Elevation Models (DEM-12.5m) which have been used to retrieve the map of the watershed by using Arc Map GIS (10.8), (2) land cover and land use data which have been obtained from a satellite image by (Landsat8-OLI) with (30 m), this is provided by the United States Geological Survey (USGS), Earth Explorer website (https://earthexplorer.usgs.gov). The spatial resolution was extracted in August 2020 (figure 2).

To obtain accurate results, image pre-processing has been utilized using the (Gram-Schmidt Pan Sharpening) technique to improve spatial resolution from (30m) to (15m) through (A panchromatic Band – 15m). The atmospheric and radiometric correction has been utilized to remove the impacts of the atmosphere and shades that have direct effects on the signal measured by the satellite sensor. Moreover, the type of LULC of the study area has been extracted; then, Hydrologic Soil Groups (HSGs) have been obtained from a Group of Global Hydrological Soil from (NASA): (https://daac.ornl.gov/SOILS/guides/Global_Hydrologic_Soil_Group.html). The curve number (CN) and Antecedent Moisture Condition (AMC) for LULC types (prepared by the United States Department of Agriculture USDA 1956), however, the rainfall data as the most significant parameter in the (SCS-CN) method in (Kalar and Sarpol Zahab) Districts were analyzed (table 1). SCS-CN method does not take evapotranspiration into account, especially at the annual level. Therefore, unlike other research, in this research evapotranspiration was calculated to obtain accurate results. Finally, (Statistical Package for Social Sciences - SPSS-26) was used to show the correlation between rainfall and runoff depth.

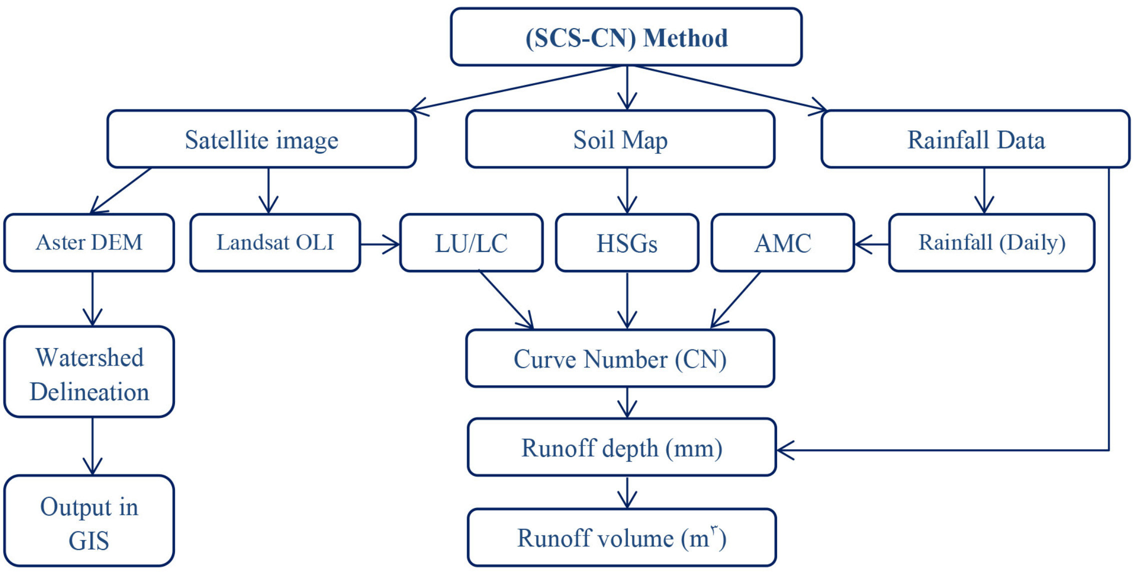

Fig. 2. Flowchart in Methodology

Table 1. Detailed data used from the Qoratu watershed

Data	Type of data	Date	Spatial Resolution	Band used	Definition of satellite images
Landsat8-OLI	Raster	August 2020	m 30	& (1-4) (8) & (6)	LC08_L1TP_168036_20200814_20200822_01_T1
Aster DEM	Raster	2020	m 12.5	1	
Study Area	Vector ((Polygon	2020			
Climatic data of Kalar and Sarpol Zahab stations					
Climate Data	Rainfall ((mm	-2020 2000			

4. (SCS-CN) Method Application

As mentioned before, the (SCS-CN) method is common because it is easy, simple, and understandable, its stability, as well as takes into account most of the characteristics of runoff-producing watersheds including the type of soil, land use, hydrological condition and past moisture condition. Originally, the (SCS-CN) was applied to small watersheds; subsequently, it was developed and used for both rural and urban forest watersheds. Also, this method recently received more concern, especially in the hydrological aspects. (Mishra & Singh, 2003). The presumption of proportion between retention and surface water flow in a form is the factor on which this method is based. The (SCS) normally computes direct runoff by using the following equations: (Pathan & Joshi, 2019).

$$Q = \frac{(P-Ia)^2}{P-Ia+s} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

P: precipitation (mm).

Ia: (initial abstraction) or all the losses before the runoff begins and is given by the following (empirical) equation:

Ia = 0.2S ……………. (2)

So equation (1) changes to this form:

$$Q = \frac{(P-0.2S)^2}{P+0.8\,S} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

S: the (potential infiltration) after the runoff begins given by the following equation.

$$S = \frac{25400}{CN} - 254 \quad \ldots\ldots\ldots\ldots\ldots (4)$$

4. 1. Curve Number (CN)

The Curve Number (CN) is a dimensionless number ranging from '0 to 100' that can be determined according to land use and land cover from a given table. Based on values of CN were applied, hydrologic soil groups (HSGs), land use and land cover types (LU/LC) and antecedent moisture condition (AMC). The equation of Weighted CN is given in the following (Tailor & Shrimali, 2016).

$$Q = \frac{(P-0.2S)^2}{P+0.8\,S} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

CNw: weighted curve number.

CNi: curve the number from 1 to any number.

Ai: area with curve number CNi.

4. 1. 1. Hydrologic Soil Groups (HSGs)

The hydrologic soil conditions were classified by the soil scientists into four categories including (A, B, C, and D) depending on runoff and storage capacity (table 2). The runoff features of each soil type can be described as the following: (A): strong permeability, low runoff potential, high infiltration rate and hydraulic conductivity when fully saturated. (B): relatively strong infiltration capacity or an impermeable layer in a certain depth of the soil profile, high penetration rate when fully saturated. (C): moderate permeability, sandy soil with an impermeable layer in a certain part of the soil profile, secondary infiltration average that wetted. (D): weak permeability, and high runoff (Wang et al., 2015; Askar, 2013; Satheeshkumar, et al., 2017; Ross, et al., 2018). To determine the hydrological soil groups of the Qoratu watershed, the soil classification system developed by (SCS-CN), showed two (HSGs) in the studied area including (C and D) (figure 3).

Table 2. Hydrologic Soil Groups

Soil Group	**Runoff potential**	**Infiltration rate**	**The Minimum Infiltration rate ((mm/h**	**Soil texture**
A	Low	High	7.26 <	.Sand, loamy sand and sandy loam (sand and <10% clay 90%<)
B	Moderately low	Moderately high	7.26 - 3.81	Powder sand and loam (sand and 10-20% clay 50-90%)
C	Moderately high	Moderately low	3.80 - 1.27	.Sandy clay loam (sand and 20-40% clay 50%>)
D	High	Low	1.26 >	Clay loam, silty clay loam, sandy .clay, silty clay and clay (sand and >40% clay 50%>)

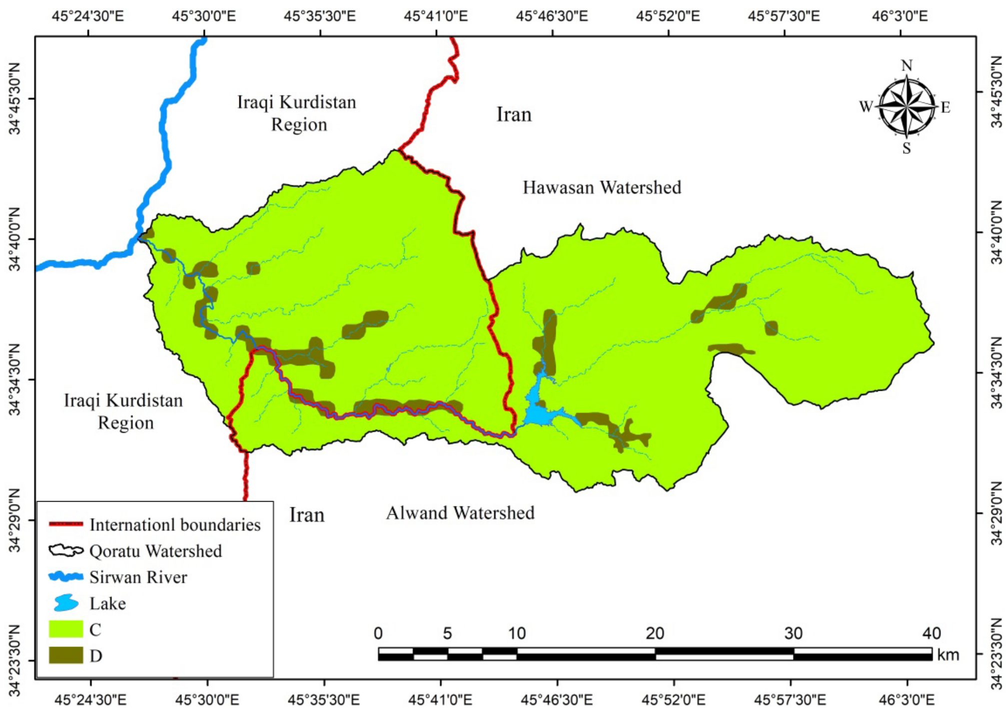

Fig. 3. Hydrologic Soil Groups in Qoratu Watershed

4. 1. 2. Land use and land cover (LU/LC)

LU/LC types influence the hydrological function of the watershed, particularly concerning the runoff (Sujarwo, et al., 2022). To obtain the LU/LC types of Qoratu Watershed, an image of (Landsat8-OLI) for August 2020 with a spatial resolution of 30m was used. The accuracy assessment of the result is 92.4% which is higher than acceptable standards (85%). The Qoratu Watershed LU/LC is classified into 13 classes as shown in (figure 4) and (table 3).

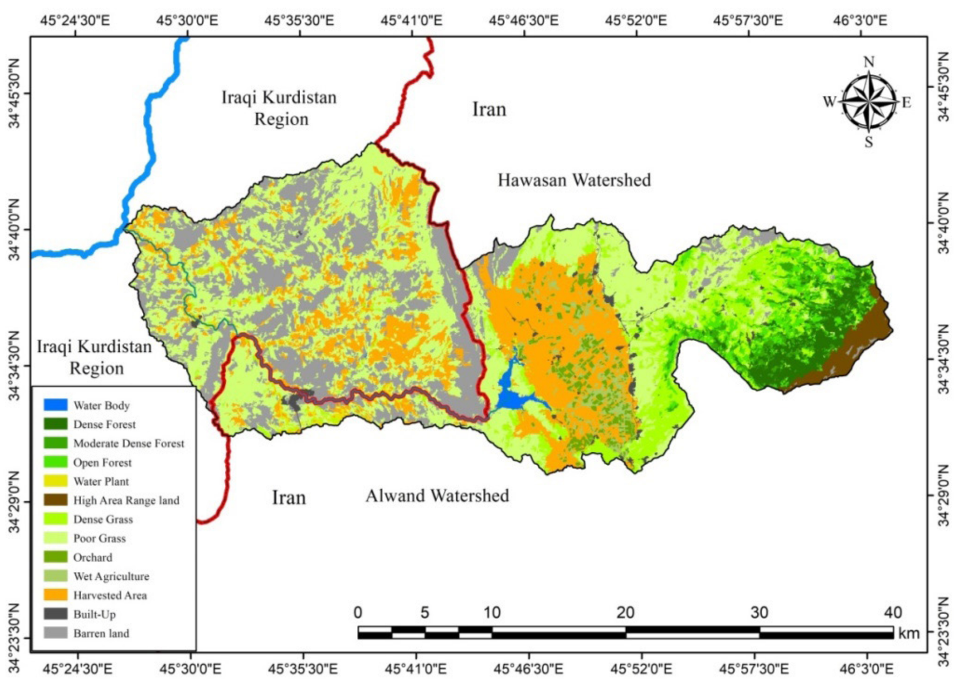

Fig. 4. LU/LC in Qoratu Watershed

Table 3. LU/LC in Qoratu Watershed

Land Use & Land Cover Types	**(Area (Km^2**	**(%) Percentage of Area**
Water Body	4.35	0.54
Dense Forest	25.65	3.17
Moderate Dense Forest	16.58	2.05
Open Forest	25.07	3.10
Water Plant	10.04	1.24
High Area Range land	14.67	1.81
Dense Grass	75.34	9.32
Poor Grass	279.19	34.54
Orchard	14.96	1.85
Wet Agriculture	16.29	2.02
Harvested Area	143.76	17.78
Built-Up	10.57	1.31
Barren land	171.87	21.26
Total Summation	**808.34**	**100**

4. 1. 3. Antecedent Moisture Condition (AMC)

AMC refers to soil moisture content from the beginning of the rainfall/runoff event. The curve number of runoff has three levels of antecedent moisture as shown in (table 4) based on the total rainfall in a period of (5) days. Three classes of AMC are recognized by SCS in terms of practical application uses. For various land conditions, the variation of curve number under AMC II is called CNII. Based on the equations (6, 7), CNII can be converted to the other two AMC (Tailor & Shrimali, 2016; Askar, 2013). Soil moisture variations are noticed in the arid area because of two critical factors; which are environment and structure; the environmental factor includes rainfall, humidity and temperature. This factor has influenced the soil moisture content at the base of the seasonal changes. The structural factor occurs due to topography, soil types, and structures. (Al Jassar & Rao, 2015).

Table 4. Antecedent Moisture Conditions' classification (AMC)

AMC	**Soil characteristics**	**Total (5) day antecedent rainfall ((mm**	
		Dormant season	**Growing season**
I	Soils are dry not to the wilting point, Cultivation has < 13 mm < 36 mm taken place	mm 13 >	mm 36 >
II	Average Condition	mm 28 – 13	mm 53 – 36
III	Heavy or light Rainfall and low temperatures have occurred within the last 5 days; saturated soils	mm 28 <	mm 53 <

$$\text{CNI for AMC} - \text{I} = \frac{CNII}{2.281-(0.01281 * CNII)} \ldots\ldots\ldots\ldots\ldots (6)$$

$$\text{CNIII for AMC} - \text{III} = \frac{CNII}{0.427-(0.00573 * CNII)} \ldots\ldots\ldots\ldots\ldots (7)$$

5. Results and Discussions

5.1. CN value in the study area

The CN for the study area is calculated for each pixel, through a combination of LULC and HSG, by using (Arc Map GIS 10.8) (Combines Multiple Raster). Then, the (CN) value for each of the LULC classes in the hydrological soil group of the watershed was obtained from a specific table as shown in (figure 5) and (table 5). The (38mm) rainstorm of (28th-03-2020) was the rainiest rainstorm of the study period of Kalar climatic station used for (AMC) determination. The amount of rainfall 5 days before the rainstorm was less than (13mm); so, the soil condition of the watershed was in a dry state before the rainstorm (AMC-I). The average value of (CNI for AMC-I) for the two groups (C and D) was (60.63) and (67.80) respectively, and their average value was (61.10).

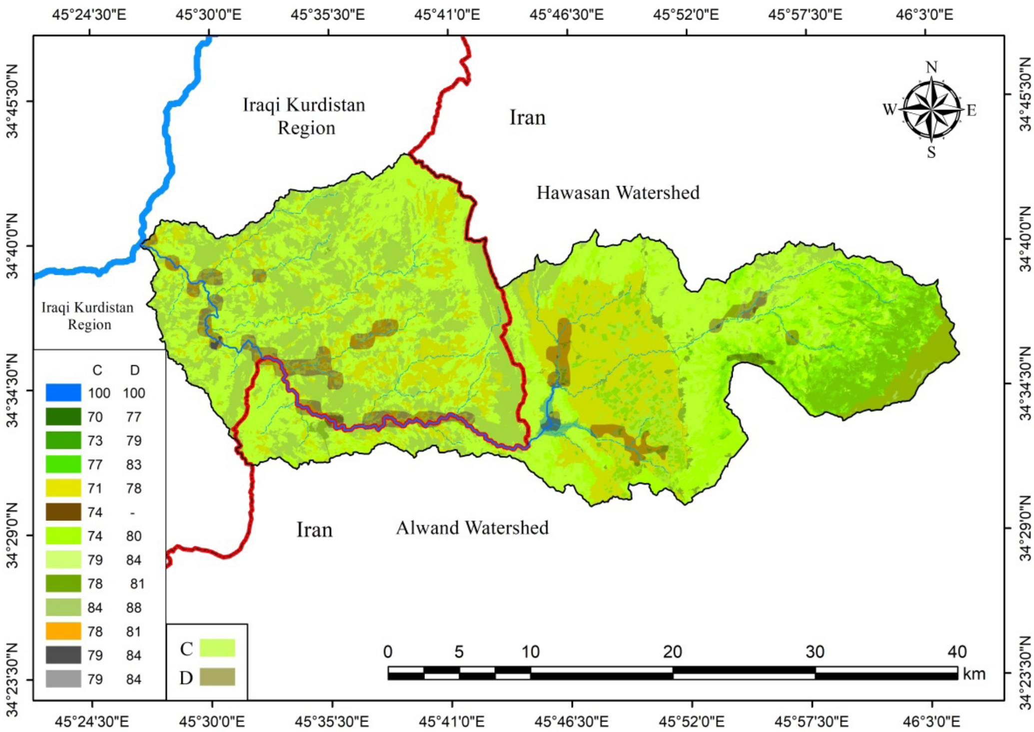

Fig. 5. Values of Curve Number (CN) in Qoratu Watershed

Table 5. (CN) value, (CNw) and (CNI for AMC-I) for each Hydrologic Soil Group in Qoratu watershed

LU/LC Types	C				D			
	Area Km^2	**CN**	**CNw**	**CNI for AMC-I**	**Area Km^2**	**CN**	**CNw**	**CNI for AMC-I**
Water Body	2.85	100			1.50	1.50		
Dense Forest	25.54	70			0.11	0.11		
Moderate Dense Forest	16.04	73			0.54	0.54		
Open Forest	24.05	77			1.02	1.02		
Water Plant	6.31	71			3.73	3.73		
High Area Range land	14.67	74			-	-		
Dense Grass	72.40	74	**77.85**	**60.63**	2.94	2.94	**82.78**	**67.80**
Poor Grass	265.91	79			13.28	13.28		
Orchard	13.82	78			1.14	1.14		
Wet Agriculture	15.04	84			1.25	1.25		
Harvested Area	126.67	78			17.09	17.09		
Built-Up	9.61	79			0.96	0.96		
Barren land	162.88	79			8.99	8.99		
Total Sum	**755.79**				**52.55**			
(S (inch	**6.49**				**4.75**			
(Ia (inch	**1.30**				**0.95**			

5.2. Runoff depth (Q) and Runoff volume (Qv)

As the results of the SCS-CN Method and the annual Runoff depth value (Q/mm) have been calculated by utilizing equations (1 and 3); while runoff volume (Qv/m3) has been found through equation (8) for the study period (2000-2020) as shown in (table 6). The results indicate that the highest (Q) and (Qv) values come with the highest amount of rainfall, which is shown as a scatter plot in (Figure 6). The (R2) value between Rainfall and Runoff depth is (0.9243). Pearson Correlation Coefficient between Rainfall and Runoff depth is (+0.961).

……………. (8) (Hashim & Sayl, 2022).

Qv: Runoff volume (m3).

Q: Runoff depth (mm).

A: Area (m2).

Table 6. Annual average runoff depth (mm) and Runoff volume (m3)

Year	Kalar Station wa-(ter surplus (mm	Sarpel Station water surplus ((mm	Average water surplus of both stations ((mm	Runoff depth (Q) mm	Runoff volume (Qv) m^3
2000	224.41	183.52	203.97	88.37	71430144.15
2001	179.80	222.35	201.08	86.16	69648646.96
2002	288.56	352.32	320.44	184.52	149157365.08
2003	110.38	235.56	172.97	65.41	52873771.61
2004	170.42	185.67	178.05	69.06	55824783.59
2005	165.79	260.08	212.94	95.28	77019207.17
2006	134.25	292.37	213.31	95.57	77251616.47
2007	85.62	185.75	135.69	40.30	32572529.02
2008	56.25	178.48	117.37	29.30	23685100.73
2009	58.60	157.33	107.97	24.10	19479809.16
2010	137.09	188.97	163.03	58.41	47215673.90
2011	81.49	255.56	168.53	62.26	50326810.88
2012	239.79	264.06	251.93	126.46	102221778.72
2013	245.19	247.16	246.18	121.76	98422637.79
2014	141.19	156.68	148.94	48.85	39486191.61
2015	193.06	208.89	200.98	86.09	69587177.15
2016	167.47	274.42	220.95	101.54	82082034.32
2017	172.88	180.51	176.70	68.09	55036816.22
2018	419.18	516.42	467.80	317.54	256677723.96
2019	385.50	478.13	431.82	284.36	229863161.29
2020	139.46	289.39	214.43	96.44	77956000.43
Average	**180.78**	**253.03**	**216.90**	**102.37**	**82753284.77**

Fig. 6. plot showing the rainfall and runoff depth in (2000-2020)

6. Conclusion

The results showed a clear change in a runoff with various land cover - land use/ and soils with certain conditions. The (CNI to AMC-I) ratio calculated in the current study is (61.10). Based on (SCS-CN), the maximum depth of runoff for the Qoratu watershed was speculated by (317.54 mm) and the runoff volume was (256677723.96 m3) in the year (2018); however, the minimum runoff depth of (24.10 mm) and runoff volume (19479809.16 m3) in the year (2009). The Annual total rate in runoff depth in Qoratu watershed is (102.37 mm) and the runoff volume is (82753284.77 m3). For effective watershed management, the (SCS-CN) method can be used in connection with (GIS) technique, as well as this method can be used for unmeasured watersheds. The present study concluded that the water inflow in the study area is high, and the possibility of constructing a dam and water harvesting is a beneficial matter.

جێبەجێکردنی میتۆدی (SCS-CN) بۆ خەمڵاندنی ئاوی ڕۆیشتووی سەر زەوی لەئاوزێڵی دۆڵی قۆرەتوو بە بەکارهێنانی تەکنیکی (GIS & RS)

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پوختە

لــەم توێژینەوەیــەدا میتــۆدی (SCS-CN) جێبەجێکــراوە بــۆ خەمڵاندنــی قەبــارەی ئــاوی ڕۆیشــتووی ســەر زەوی لەئاوزێڵی دۆڵی قۆرەتوو، کە دەکەوێتە ناوچەی گەرمیان لەباکوری ڕۆژهەڵاتی عێراق، هەریەکە لەفایلی مۆدێلی بەرزی و نزمی (١٢,٥m-DEM) و وێنەی ئاسمانی (Landsat OLI) بەکارهێنراوە، وەکو ڕەگەزی سەرەکی سیستەمی زانیاریە جوگرافییەکان (GIS) و هەستکردن لەدورەوە (RS)، ئەوەش لەپێناو دەستکەوتنی داتای هایدرۆلۆجی ورد لەئاوزێڵەکەدا، ئاوزێڵی دۆڵی قۆرەتوو هاوبەشە لەنێوان (عێراق - ئێران)دا، و لەخاکی هەرێمی کوردستان لەپلەی شەشەمیدا دەڕژێتە ڕووباری سیروانەوە، لەڕووی بەرزی و نزمییەوە ئەم ناوچەیە بە ناوچەی نیمچە شاخاوی هەرێمی کوردستان ناسراوە، ڕووبەری گشتی ئاوزێڵەکە (٨٠٨,٣٤ کم٢) کە ڕێژەی (٤٤,٩٠٪)ی دەکەوێتە خاکی هەرێمی کوردستانەوە، ئامانج لەم توێژینەوەیە خەمڵاندنی قەبارەی ئاوی ڕۆیشتووی سەر زەوییە بەمەبەستی دروستکردنی بەنداو، لەگەڵ خەمڵاندنی ئاوی ساڵانەی ئاوزێڵە لاوەکییەکان بەمەبەستی بەڕێوەبردنێکی تەواوی ئاو لەناوچەکەدا، بەمەش دەبێتە هۆی بەرزبوونەوەی ئاستی ئاوی ژێر زەوی و کۆنترۆڵکردنی لافاو لەوەرزی بارانباریــن لەناوچەکەدا، توێژینەوەکە گەیشتە ئەو ئەنجامەی کە داهاتی ئاوی ساڵانەی ئاوزێڵەکە بەرزە و دروستکردنی بەنداو لەناوچەکەدا سودێکی زۆری دەبێت.

کلیلە وشەکان: تەکنیکی (GIS & RS)، بەکارهێنان و ڕووپۆشی زەوی، ئاوزێڵی قۆرەتوو، خەمڵاندنی ئاوی ڕۆیشتوو، میتۆدی (SCS-CN).

تطبيق طريقة (SCS-CN) لتخمين الجريان السطحي في حوض وادي قورةتوو باستخدام تقنيات (GIS & RS)

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الملخص

تم تطبيق طريقة (SCS-CN) في هذه الدراسة لتخمين حجم الجريان السطحي في حوض وادي قورەتوو، يقع الحوض في منطقة گرميان في شمال شرق عراق ، تم استخدام كل من نماذج ارتفاعات الرقمية (١٢,٥m-DEM) و صور الجوية (Landsat OLI) كأدات رئيسية لبرنامج نظم المعلومات الجغرافية (GIS) والاستشعار عن بعد (RS) و ذلك لأجل حصول على بيانات هيدرولوجية دقيقة في الحوض، يعد حوض وادي قورەتوو حوض مشترك بين (عراق - ايران)، و في مرتبته السادسة في اراضي اقليم كوردستان يصب في نهر سيروان ، ومن ناحية التضاريس تعرف بمنطقة شبه الجبلية في اقليم كوردستان، المساحة الكلية للحوض (٨٠٨,٣٤ كم٢) والنسبة (٤٤,٩٠٪) منها تقع في اراضي اقليم كوردستان، يهدف هذا البحث الى تخمين حجم الجريان السطحي لأجل إنشاء السدود، وايضاً تخمين

الجريان السنوي للأحواض الثانوية لأجل الإدارة المتكاملة للمياه في المنطقة، وفي هذه الحالة يرتفع مستويات المياه الجوفية ويزيد قدرة السيطرة على الفيضان في فترات المطيرة في المنطقة، توصلت الدراسة الى ان الواردات المائية السنوية في الحوض عالي، و بهذا فإن بناء السدود في المنطقة امرُ مفيد.

الكلمات المفتاحية: تقنيات (GIS & RS)، استخدام والغطاء الاراضي، حوض قورەتوو، تخمين الجريان السطحي، طريقة (SCS-CN).

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