HYDROLOGICAL MODELING OF SURFACE RUNOFF OF WATER BASINS IN THE DRY VALLEYS EAST OF LAKE THARTHAR

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Abstract:
The research aims to model the hydrological runoff of the water basins in the dry valleys east of Lake .Tharthar According to the (CN-SCS) equation , which was based on several variables that were used, namely (remote sensing (.data, climate data, hydrological soil data) , in order to provide a clear picture of the hydrological nature of the region In addition, the application of remote sensing data and the GIS environment in identifying locations. The results showed that most of the (CN) values exceed (55), ranging between (30-71). These high values indicate that the soil permeability is low, which was represented by a value of (71) and an area of (7.50) km2, which contributes to the formation of high surface runoff that allows water to carry out erosion processes widely within the basin lands. As for the low values, they indicate high soil permeability, which reached a value of (30) and an area of (100.90) km2 of the total general area in the study area. Development plans were developed to benefit from the natural capabilities that the study area possesses. The study proposes the establishment of hydrological stations to measure the amount .of water flow, especially in areas with water catchments, to benefit from it instead of wasting it

1. The study problem

The problem of the study lies in the fact that the study area suffers from a lack of surface runoff in the dry season and the occurrence of surface water runoff in the wet season, which results in .variability in surface water estimates

2. Study hypothesis

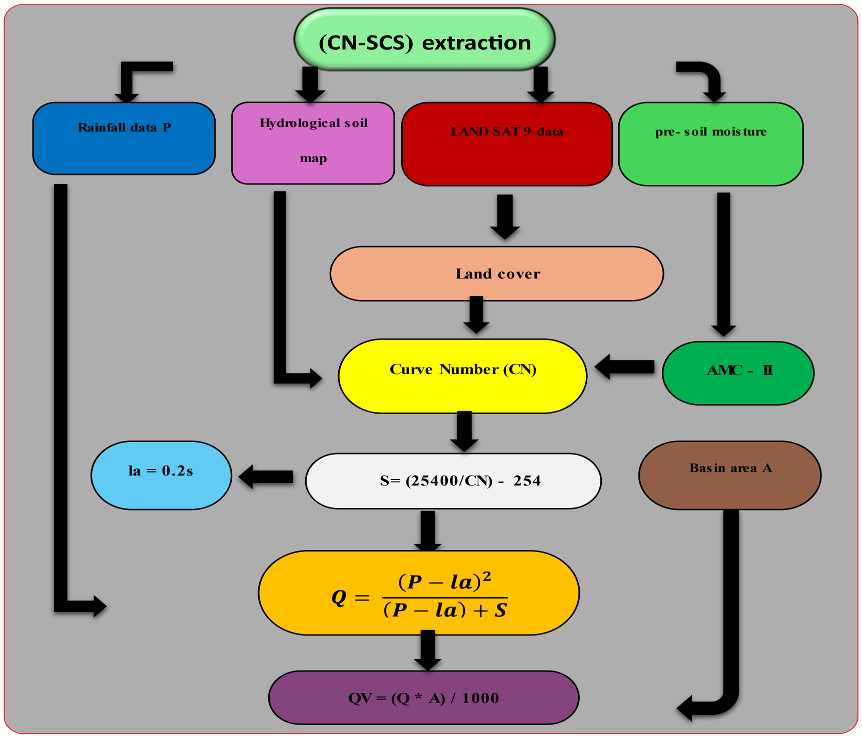
The study area suffers from low water discharge in the dry season, unlike the wet season

3. Study objectives

:The study aims to

- .Estimating the volume of surface runoff of water basins in the study area
- .Building hydrological models to identify locations and areas exposed to flooding

Figure (1) : An illustrative diagram of the stages of estimating the volume of surface runoff according to the method (CN-SCS)



. **Source** : Prepared and designed by researcher An

1.1: Concept of Curve Number (CN):-

The curve number (SCS-CN) is one of the methods used to estimate surface runoff, and was developed by the Soil Conservation Service in the United States. The curve number (CN-SCS) ranges from 0 to 100. The higher the value or the closer it is to 100, the greater the surface runoff. This is due to impermeability caused by soil saturation with water. Conversely, a lower value or a value closer to 0 indicates less surface runoff due to high permeability and dry soil.[1]

1.1.1: Stages of surface runoff extraction (SCS-CN)

The stages of surface runoff extraction according to the CN method depend on two variables:

a. Hydrological soils. b. Land use.

a. Hydrological soils: The US Soil Conservation Service has classified hydrological soils into four categories, as shown in Table 1, where each category has characteristics that distinguish it from the other categories in terms of porosity, permeability, and mineral materials that play an important role in surface runoff.

1 Shayma Thamer Jawad, "Estimating Surface Runoff in the Pasture Basin Using the CN-SCS Method," Journal of Basic Sciences, 2023, Issue 15, pp. 80–81.

Table (1): Hydrological soil types

The category	flow depth	**Soil type**
A	a little	A deep sandy layer with a very small amount of clay .and silt
B	middle	A shallower sand layer than ClassA with a medium .infiltration rate
C	above average	A rock layer covered by a layer of soil with a below-.average infiltration rate
D	High	A layer of mud covered by a shallow layer of fine silt or exposed rock layer

Source : Hawra Hamid Latif, Hydrogeomorphology of the Shishin Valley Basin, South of Tikrit Master's Thesis (unpublished), Department of Geography, College of Education, Samarra , .University, 2024, p. 159

Accordingly, the study area included two types of hydrological soil types (A and B), as shown in Table 2 and Map 1, where type A covered an area of 76.56 km2, accounting for 5.73% of the total area of the study area. This type is characterized by a deep sandy layer containing a small percentage of clay and silt, meaning it has high permeability. The second area included area (B), which covered an area of 1258.44 km2 and accounted for 94.27% of the total area. It is similar to area (A) but is shallower and has low permeability.

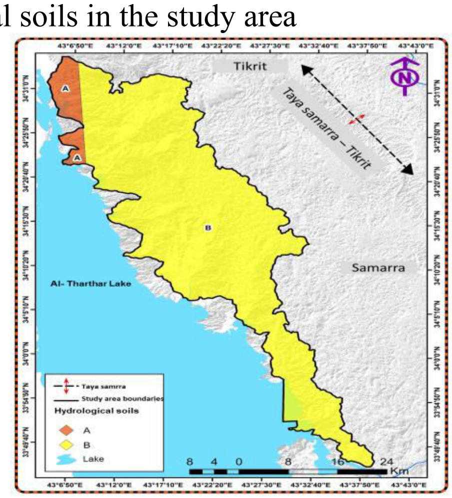
The importance of hydrological soils is highlighted by the fact that they play an important role in surface runoff, which is largely related to soil type. The more permeable the soil, the greater the effect on surface runoff, as it helps filtration into the soil, and vice versa.

Table (2): Hydrological soils in the study area

%	**Area**	**Scope**
5.73	76.5 6	A
94 .27	1258.44	B
% 100	1335	the total

.**Source** : Based on Map (1)

Map (1): Types of hydrological soils in the study area



Source: Based on US Soil Conservation data andArc GIS Map 10.8 output .

B. Land use in the study area.

Table 3 and Map 2 show that the study relied on remote sensing data, particularly data from the American Landsat 9 satellite (Landsat 9) with OLI sensor, which has a spatial resolution of 30 x 30 m, and used it in a geographic information system environment to perform targeted classification of satellite imagery to derive and diagnose land uses. The data entered was classified into three categories, namely:

A. Residential areas: This category occupies an area of 6.34 km2 of the total area of the region, representing 0.47% of the total percentage.

B. Agricultural areas: Cultivated areas and pastures covered approximately 117.29 km2 of the total area, accounting for 8.79% of the total percentage.

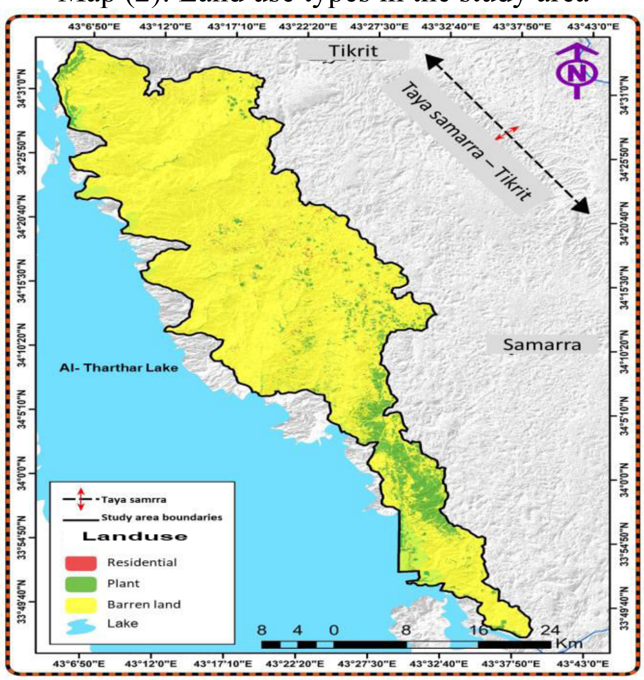
C. Barren land: These areas occupied approximately 1,211.37 km2 of the total area of the study area and were the most extensive type, accounting for approximately 90.74% of the total percentage. It should be noted that land use plays a vital and fundamental role in relation to surface water runoff in the study area. The wetter the land and the more vegetation it contains, the less surface water runoff there is in these areas, unlike barren areas, which are more responsive and adaptable to surface water runoff.

Table (3): Land use types

Usage category	%	Area
residential	0.47	6.34
plants	8.7 9	117.29
barren land	90.7 4	1211. 37
the total	100%	133 5

.**Source** : Based on Map (2)

Map (2): Land use types in the study area



the US Landsat 9 satellite withOLI sensor m spatial resolution for the year 2025 , and 30*30 ,Arc GIS Map 10.8 output .

Table (4) : Derivation of the curve number CN) according to the (SCS method

Land use description		Hydrological soil groups			
)LAND USE DESCRIPTION (		A	B	C	D
cultivated land					
Without soil protection treatment		72	79	81	91
With soil protection treatment		62	71	78	81
Artificial pasture lands and natural pastures					
poor conditions		68	79	86	94
very rich circumstances		39	61	74	80
Herbal lands					
good conditions		30	58	69	80
forest lands					
Light wing - little cover - no diseases		45	66	77	83
thick, rich cover		25	55	70	77
Open land - lands - grassy land - golf courses - cemeteries					
Good conditions: grass cover 75% or more		39	61	74	80
Average conditions: grass cover between 50-75%		49	69	79	87
Commercial and professional areas 85% impermeable		89	92	94	95
.Industrial zones are 72% inaccessible		81	88	91	93
residential lands					
Non-penetration rate	Average piece size				
8-1	65	77	85	90	92
4-1	38	61	75	83	87
3-1	30	57	72	81	86
2-1	25	54	70	80	85
or more 1	20	51	68	75	84
.Paved parking lots - surfaces, driveways...etc		98	98	98	98
Streets and roads					
Paved with sidewalks and storm drains		98	98	98	100
unpaved gravel roads		76	85	89	91
abandoned roads		72	82	87	89

Source : Vijay P. Singh, Donald K. Frevert , Watershed Models CRC Press is an imprint of Taylor & Francis Group, 2006, P 364 .

2.1.1: Runoff extraction according to the (CN- S CS) method

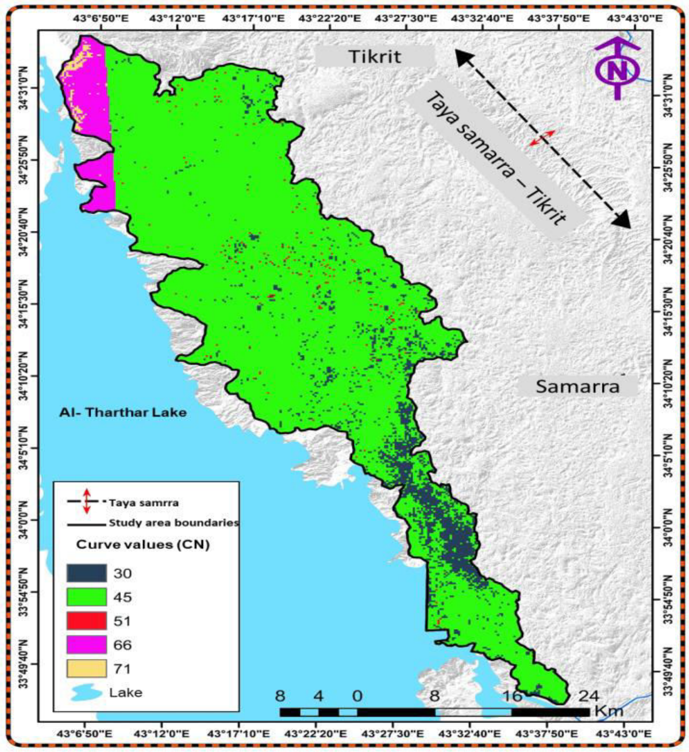
This method relied on the hydrological soil map and the land use map, which were then entered into the geographic information system environment in order to combine them using the Combine tool in the Toolbox. This resulted in obtaining the CN value in the study area basins. The results showed that most values exceeded 55, ranging between 30 and 71. These high values indicate that soil permeability is low, represented by a value of 71 and an area of 7.50 km2, which contributes to the formation of high surface runoff that allows water to carry out extensive erosion processes within the basin. The low values indicate high soil permeability, which reached a value of 30 and an area of 107.90 km2 of the total area of the study area.We can therefore conclude that these high values indicate low porosity and permeability of the impermeable rock layer, which significantly enhances surface runoff and increases the amount of sediment transported by this runoff.

Table (5): Shows the values of the CN .curve in the study area

%	Area (km2)	CN curve values	T
8.08	107.90	30	1
85.90	1146.87	45	2
0.43	5.76	51	3
5.01	66.97	66	4
0.56	7.50	71	5
100%	1335	the total	

.**Source** : Based on Map (3)

Map (3): Shows the values of theCN in the study area curve



Source: Based on hydrological soil map, land use map, andArc GIS Map 10.8 outputs .

3.1.1: Preconditioned moisture status

This refers to the moisture content in the soil, which plays an important role in determining the amount of surface runoff. This indicator is a key factor in extracting and improving SCS-CN curve values. The preconditioned moisture status of the soil is divided into three categories: Category I (AMC I): This condition refers to areas in the dry season, while the second condition (AMC II) represents areas in the temperate or normal season, and the third condition (AMC III) represents wet areas ( ).

After applying the CN curve values according to the moisture precondition for the three conditions, the following three conditions appeared in the study area:

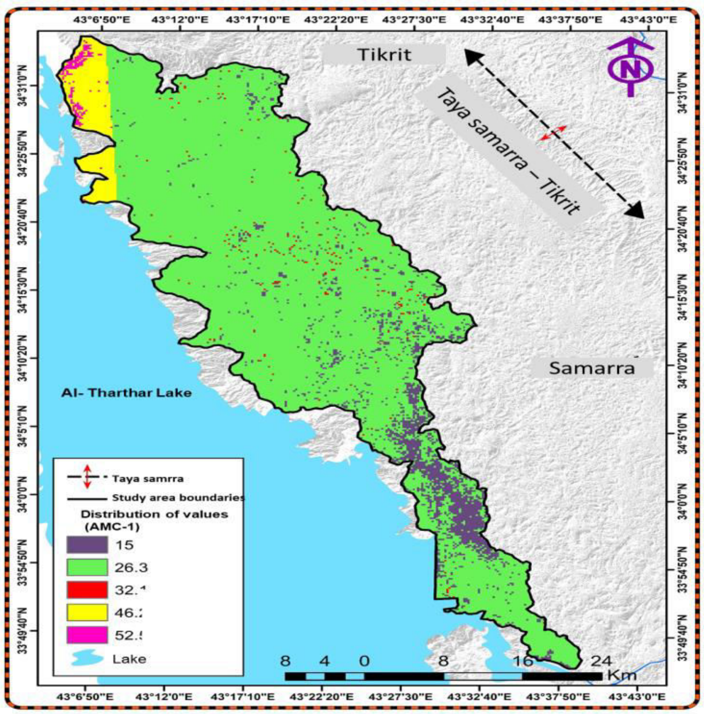
1. The first condition (AMC I): It appears that the study area suffers from low surface runoff in the hot, dry summer season, as evidenced by the highest value recorded at (52.5) and a percentage of (30.51%) and the lowest value at (15) and a percentage of (8.72%) of the total, as shown in Table (6) and Map (4).

Table (6): Shows the distribution values ofAMC-I .for the study area

%	AMC-I distribution values	T
8.7 1	15	1
15.28	26.3	2
18.65	32.1	3
26.84	46.2	4
30.5 0	52.5	5
100%	172.1	the total

.Source: Based on Map (4)

Map (4): Shows the distribution values of AMC-I .for the study area



Source: Based on a map (CN) and the output of ArcGIS Map 10.8 software.

1.) second caseAMC I This type of pre-wet condition represents the wet season's moisture :(condition, as the surface runoff in the winter is characterized by high rates compared to the summer, as the study area is exposed to flooding due to rain . Where the highest value was recorded at about (85.2) and at a rate of (24.12%), while the lowest value was recorded at about (50.1) and at a rate of (14.18%) of the total general percentage. It can be invested by constructing dams and water reservoirs to benefit from it in many uses, the most important of .which is the agricultural aspect. See Table (7) and Map (5)

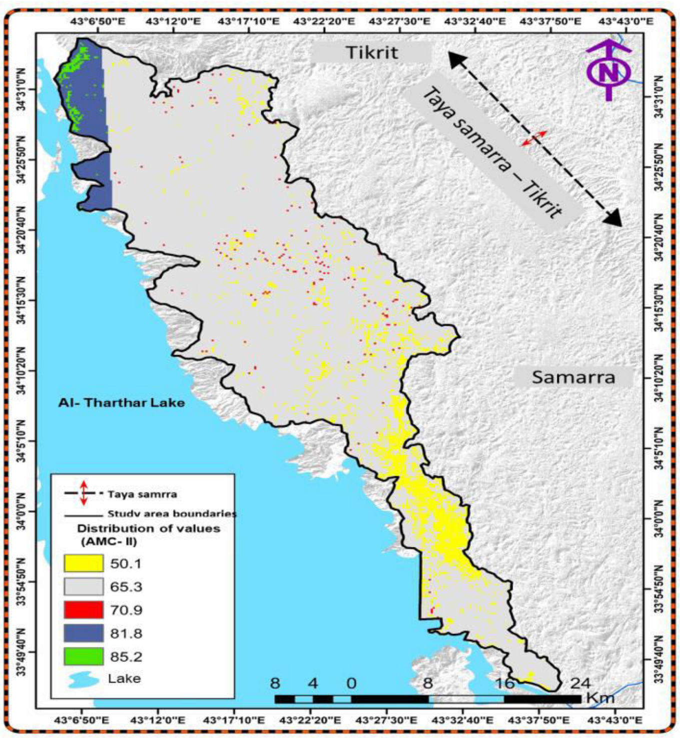
Table (7): Shows the distribution values ofAMC-III .for the study area

%	**AMC-III distribution values**	**T**
14.18%	50.1	1
18.48%	65.3	2
20.07%	70.9	3

23.15%	81.8	4
24.12%	85.2	5
100%	353.3	the total

.**Source** : Based on Map (5)

Map (5): Shows the distribution values ofAMC-III .for the study area



Source: Based on a map (CN) and the output of ArcGIS Map 10.8 software.

4.1.1: Deriving the maximum water retention coefficient (S)

This coefficient expresses the maximum amount of water that soil can retain or store at the onset of surface runoff, reflecting the state of soil saturation with water, which depends on soil type and its physical and chemical properties. In addition, vegetation cover is related to this factor in both negative and positive ways. The value of this coefficient (S) ranges between 0 and 100. The closer the value is to 100, the greater the soil's ability to retain water, and thus the less surface runoff. If the value is low, it indicates surface runoff due to the soil's inability to retain water because it is

saturated with water. The values of the coefficient (S) can be calculated using the following equation[1]
:Whereas
S Water retention coefficient :

$$S = \frac{1000}{CN} - 10$$

Note: Since the data entered is measured in inches, the equation has been rewritten to correspond to metric measurements. The constants in the previous equation have been multiplied by (4.25) to convert them from inches to millimeters, and the equation takes the following form:

$$S = \frac{25400}{CN} - 245$$

Table (8) and Map (6) show that the coefficient (S) varies spatially in the study area depending on soil type, vegetation cover, and rainfall, with the highest value recorded at (601.67) and a percentage of (42.17%). while the lowest value was recorded at around (112.75) with a percentage of (7.90%) of the total for the year. Accordingly, the map indicates that there is variation in the geographical distribution of this coefficient (S), as most of the area is characterized by sparse vegetation cover, which makes surface runoff more likely during the winter season than during the dry season. Another reason is that the topography of the region is similar to that of a plain, which contributes to this phenomenon. This is represented by the low values concentrated throughout the study area, while the high percentage indicates a low incidence of surface runoff. This is a result of topography and soil type, and is concentrated in the southeastern part of the study area.
We conclude that there is an inverse relationship between the coefficient (S) and the curve (CN). The greater the value of the first coefficient compared to the second, the more likely it is that these areas suffer from or are free of surface runoff. whereas if the first coefficient is smaller than the second, this indicates that the area experiences surface water runoff or flooding during the rainy season, and therefore these areas can be exploited for agriculture, grazing, and sustainable environmental development.

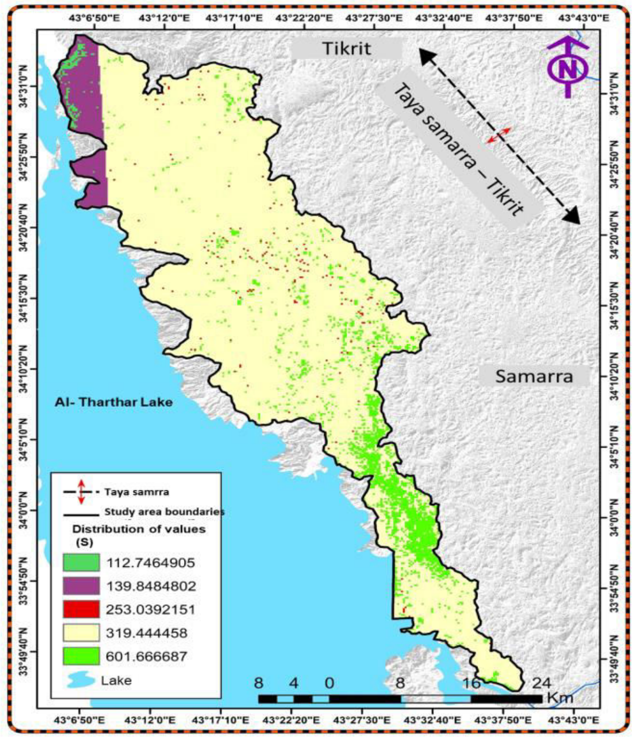
Table (8): Shows the distribution of S .values for the study area

%	S distribution values -	T
42.17%	601.67	1
22.39%	319.44	2
17.74%	253.04	3
9.80%	139.85	4
7.90%	112.75	5
100%	1426.75	the total

.Source: Based on Map (6)

1 Du'aa Mashari Muhammad al-Kanani, "Estimating the Surface Runoff of the Wadi al-Manziliya Basin in the Northeast of Maysan Province Using Remote Sensing and Geographic Information Systems (RS-GIS)," Journal of the Faculty of Education, Vol. 52, No. 2, 2024, p. 211.

Map (6): Distribution of S values for the study area



Source : Based on equation S and outputs of ,(Arc GIS Map 10.8 .

5.1.1: Calculation of the initial abstraction coefficient (IA)

This coefficient expresses the amount of rainfall lost before the onset of surface runoff through evaporation from the soil and vegetation cover, as well as seepage into the soil. High values of this coefficient (IA) indicate a high amount of rainfall lost due to the above factors, while low values indicate little rainfall loss and, consequently, surface runoff [1]. This coefficient can be calculated using the following equation:

0.2 S = La

La = Initial rainfall extraction coefficient

S = Maximum water retention potential coefficient

Table (9) and Map (7) show that the highest value recorded for this coefficient (IA) is (120.33), accounting for (42.17%) of the total for the study area, while the lowest value recorded for this coefficient (IA) is (22.55) and 7.9% of the total. Thus, the high values indicate a low incidence of surface runoff in the study area due to several factors, including the presence of vegetation cover and soil quality in these areas, which are concentrated in the southeastern parts. while the low values are characterized by surface runoff due to factors that contributed to this, such as the lack of vegetation cover and the nature of the land, which is distributed throughout the study area.

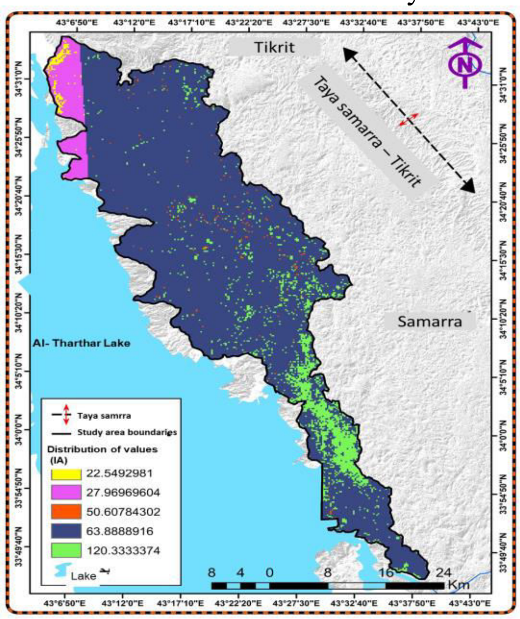
1 Suhad Shlash Khalaf, "Estimating Surface Runoff Volume and Flood Risks in the Wadi al-Marj Basin Using the CN-SCS Model," Journal of Tikrit University for Humanities, vol. 31, no. 4, 2024, p. 227.

Table (9): Shows the distribution ofIA .values for the study area

%	) Distribution valuesIA (	T
42.17%	120.33	1
22.39%	63.89	2
17.74%	50.61	3
9.80%	27.97	4
7.90%	22.55	5
100%	285.35	the total

.Source: Based on Map (7)

Map (7): Shows the distribution ofIA .values for the study area



Source : Based onthe IA equation and the outputs ofArc GIS Map 10.8 .

6.1.1: Measuring surface runoff depth (Q)

This coefficient refers to the interaction of rain waves with the components and characteristics of drainage basins, which include vegetation cover type and soil properties. Therefore, surface runoff depth varies with the stability of the rainstorm. This coefficient is calculated using the following equation [1]

$$Q = \frac{(P - LA)2}{P + 0.8 * S}$$

= Q Depth of runoff (mm) = P rainfall amount (mm)
= La primary extraction coefficient of rainwaterS Maximum water retention coefficient =

We note from Table (10) and Map (8) that the study area varies in terms of geographical distribution according to climatic conditions and the geological nature of the area. Low values of

1 Hawra Hamid Latif al-Samarrai, former source, p. 175.

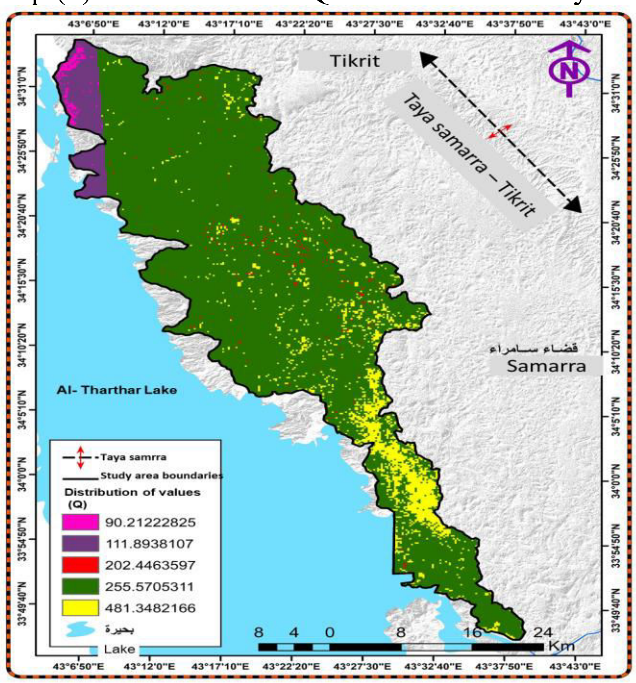
around (90.21) and 7.9% of the total, representing areas with good surface water flow, while the most valuable areas, which reached about (481.35) and 42.17% of the total area, represent a shortage of surface water flow due to soil permeability and the presence of vegetation cover.

Table (10): Distribution of Q values for the study area

%	Q distribution values	T
42.17%	481.35	1
22.39%	255.57	2
17.74%	202.45	3
9.80%	111.89	4
7.90%	90.21	5
100%	1141.47	the total

.Source: Based on Map (8)

Map (8): Distribution of Q values for the study area



Source : Based on the equation Q and the outputs of ,(the Arc GIS Map 10.8 program .

7.1.1: Calculating and estimating surface runoff (QV)

This coefficient (QV) refers to the total surface runoff relative to the basin area and can be calculated using the following equation [1]

$$QV = Q\frac{A}{1000}$$

QV runoff volume (m3) =Q Depth of runoff (mm) =

A Area (km2) 1000 = Conversion factor to convert results to cubic meters =

The study concluded through Table (11) and Map (9) that the study area was characterized by a kind of spatial variation in calculating and estimating the volume of surface water runoff according

1 Haifa Muhammad Al-Nafei, "Estimating Surface Runoff and Its Flood Risks in the Wadi Arna Basin East of Mecca Using Remote Sensing and Geographic Information Systems," Umm Al-Qura University, Faculty of Social Sciences, Saudi Arabia, 2010, p. 134.

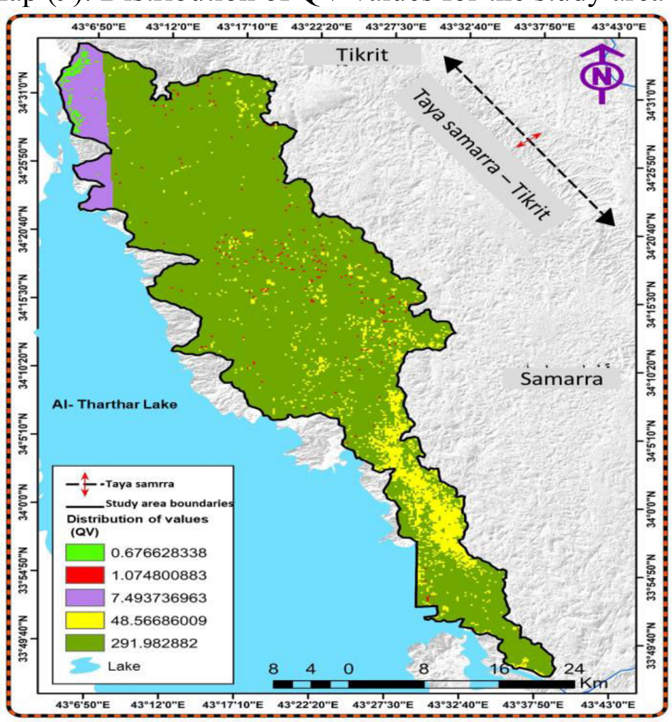
) to theQV coefficient, as the highest value of this coefficient reached about (291.98) and a (percentage of (83.47%) of the total study area, and this value represents an area with deep surface water runoff; the reason is that the soil in these areas is characterized by low permeability and ground cover, which makes the volume of water runoff large; unlike other areas that were characterized by low volume of surface water runoff, which recorded its lowest value of about and a percentage of (0.19%) of the total area in general; due to the permeability of the soil (0.68) .and the type of ground cover in the study area

Table (11): Distribution of QV values for the study area

%	QV distribution values	T
13.88%	48.57	1
83.47%	291.98	2
0.31%	1.07	3
2.14%	7.49	4
0.19%	0.68	5
100%	349.79	the total

.Source: Based on Map (9)

Map (9): Distribution of QV values for the study area



Source : Based on the QV equation andArc GIS Map 10.8 outputs .

• Conclusions

1. The results showed that most CN values exceeded 55, ranging between 30 and 71. These high values indicate that soil permeability is low, with a value of 71 and an area of 7.50 km2, which contributes to the formation of high surface runoff that allows water to erode extensively within the basin. The low values indicate high soil permeability, which reached a value of 30 and an area of 100.90 km2 of the total area of the study area.

2. The research showed that the study area suffers from low surface runoff in the hot, dry summ er season, as evidenced by the highest value recorded at 52.5 (30.51%) and the lowest value at 15 (8.72%) of the total area.
3. It was found that surface runoff in winter is characterized by high rates compared to summer, as the study area is exposed to torrents due to rainfall, with the highest value recorded at (85.2) and a percentage of (24.12%), while the lowest value was recorded at 50.1, representing 14.18% of the total percentage.
4. We conclude that there is an inverse relationship between the coefficient (S) and the curve (CN); that is, the greater the value of the first coefficient compared to the second, the more likely it is that those areas suffer from or are free of surface runoff. while if the first coefficient is smaller than the second coefficient, this indicates that the area experiences surface water flow or flooding during the rainy season, and therefore these areas can be invested in for agriculture, grazing, and sustainable environmental development.

- **Proposals**

1. Develop development plans to take advantage of the natural potential of the study area.
2. Establish hydrological stations to measure water flow, especially in areas with water catchments, to make use of it instead of wasting it.
3. Focus on modern geographic techniques to derive and extract geographic information from spatial data and make decisions quickly, with little effort and at low cost.

References:

1. Shayma Thamer Jawad, “Estimating Surface Runoff in the Pasture Basin Using the CN-SCS Method,” Journal of Basic Sciences, 2023.
2. , Hawra Hamid Latif, Hydrogeomorphology of the Shishin Valley Basin, South of Tikrit Master’s Thesis (unpublished) Department of Geography, College of Education, Samarra .University, 2024, p. 159
3. Du'aa Mashari Muhammad al-Kanani, “Estimating the Surface Runoff of the Wadi al-Manziliya Basin in the Northeast of Maysan Province Using Remote Sensing and Geographic Information Systems (RS-GIS),” Journal of the Faculty of Education, Vol. 52, No. 2, 2024.
4. Suhad Shlash Khalaf, “Estimating Surface Runoff Volume and Flood Risks in the Wadi al-Marj Basin Using the CN-SCS Model,” Journal of Tikrit University for Humanities, vol. 31, no. 4, 2024.
5. Haifa Muhammad Al-Nafei, “Estimating Surface Runoff and Its Flood Risks in the Wadi Arna Basin East of Mecca Using Remote Sensing and Geographic Information Systems,