

Estimation of Flow Volume in Wadi Harran Basin in Eastern Iraq Using the SCS-CN Method

Shatha Abbas Jassim

Department of Geography, College of Education for Women, University of Baghdad, Iraq

Email: shatha.a@coeduw.uobaghdad.edu.iq

ABSTRACT

Surface runoff is considered one of the most significant water resources in arid and semi-arid environments. Estimating the volume of surface runoff through the application of Geographic Information Systems (GIS), along with maps detailing the geomorphological and geological characteristics of the Wadi Haran basin, is an essential process. This estimation is supported by mathematical equations based on the Soil Conservation Service Curve Number method (SCS-CN), which is among the most widely used approaches for calculating runoff volume.

The study area, Wadi Haran basin, covers approximately 1,895 km². The Curve Number (CN) was found to be 92, with runoff volume (QV) values ranging between 582.71 m³ and 12.85 m³. The total surface runoff was calculated to be 198.2 m³. These results confirm the presence of significant surface runoff in the northern and northeastern parts of the basin. This is primarily attributed to the wide basin area and the presence of hard, low-permeability geomorphological soil characteristics that contribute to water accumulation and surface flow, rather than infiltration into the soil. Conversely, the southwestern part of the basin, characterised by higher-permeability geomorphological features, exhibits lower surface runoff.

Overall, the basin is characterised by increased surface runoff rates, particularly in the northern and northeastern sections, due to the broader basin area and low soil permeability compared to the southern and southwestern areas.

Keywords: Surface Runoff, Runoff Volume, Hydrological Soil Types, Wadi Harran, GIS.

Introduction

Estimating surface runoff volume is a fundamental process in assessing water availability in the Wadi Haran basin. This estimation is carried out using the SCS-CN method, which involves analysing its input parameters and producing results based on the surface runoff characteristics as influenced by the geological formations of the basin. Most of the basin is composed of the Injana and Fatha formations, consisting primarily of marlstone, limestone, and gypsum.

The predominant soil type in the basin is classified as Type C, covering 80.4% of the area. This soil type is moderately permeable and relatively steep, which contributes to water accumulation and surface flow rather than infiltration. This results in accelerated surface runoff, particularly in the northern and northeastern parts of the basin, compared to the southern and southwestern parts.

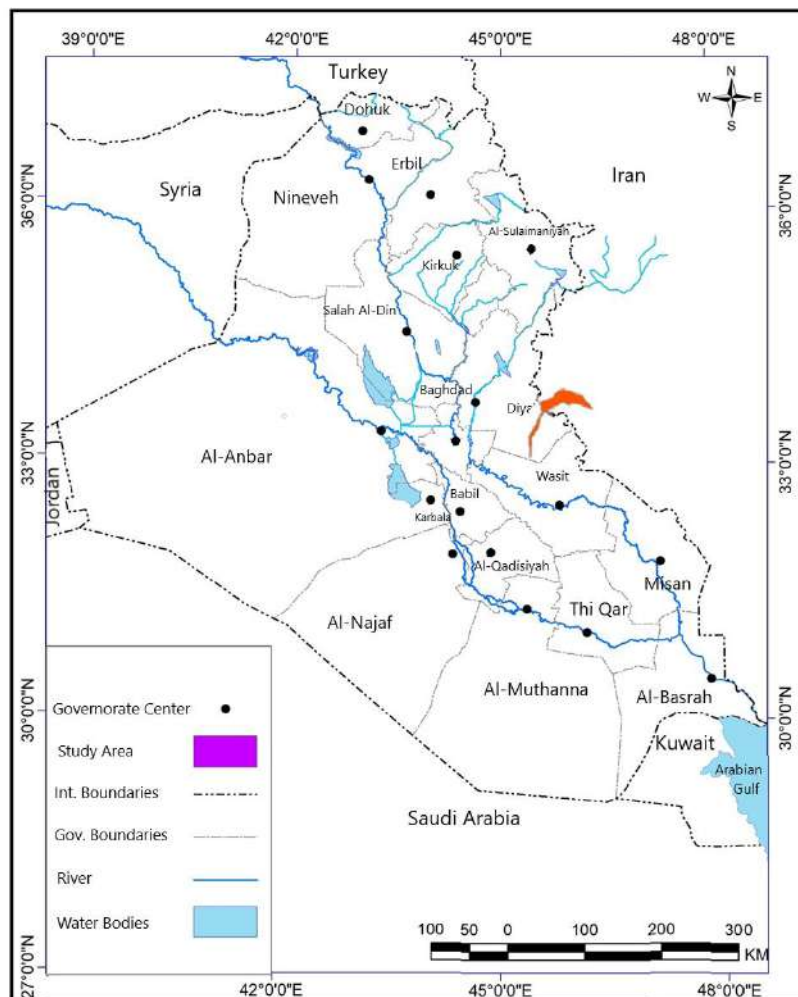
The results of the CN method ranged between 68 and 92 m³, with the total surface runoff in the basin amounting to 198.2 m³. Consequently, the basin demonstrates high surface runoff rates, especially in the northeastern part, due to the expansive basin area and limited permeability of its soil compared to the southwestern section.

Geographical Location of the Wadi Haran Basin in Iraq

The Wadi Haran basin is geographically located in eastern Iraq, within Diyala Governorate, specifically in its eastern part. It is bordered to the north by Kalar District, to the east by the international border of the Republic of Iran, to the west by Baladruz District, and to the south by Wasit Governorate.

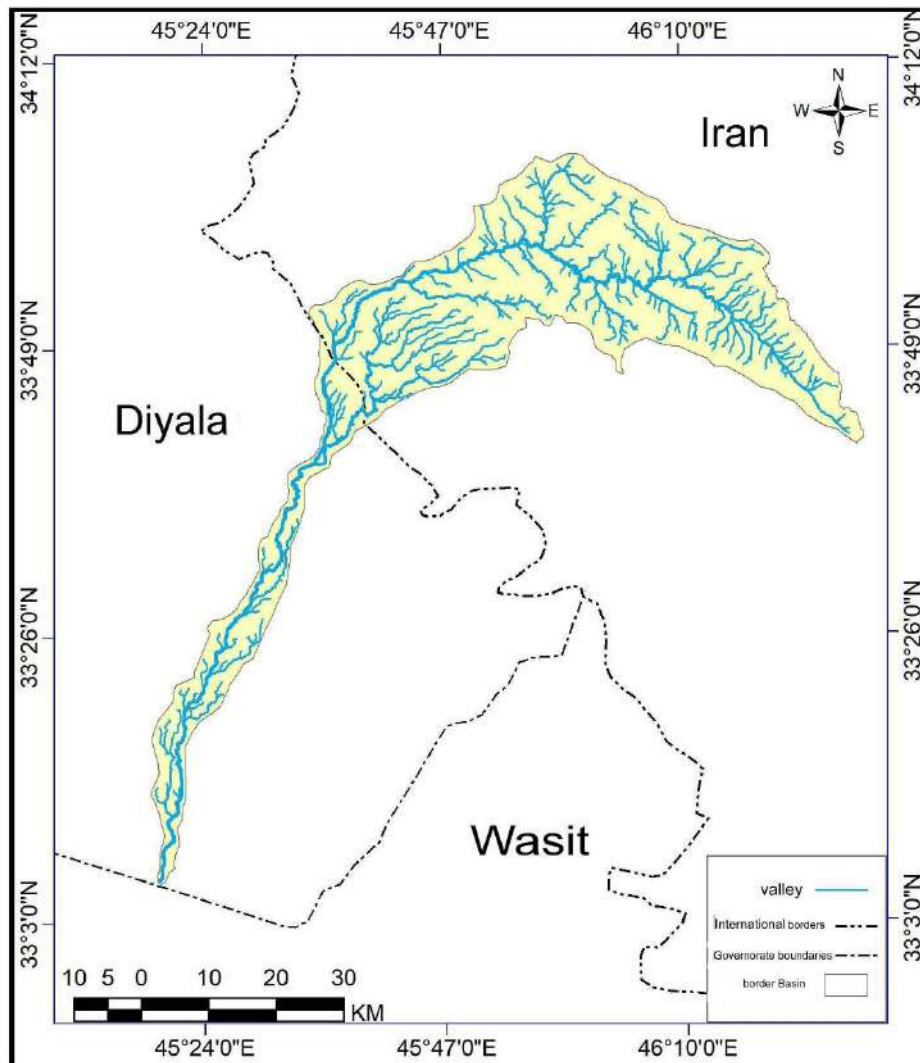
Astronomically, the basin lies between latitudes 33°20' and 34°26' North, and longitudes 44°59' and 46°00' East (Al-Saeed, Hala Mohammed, Lina Ali Abdullah, 2021, p. 91). It covers an area of 1,895 km², as shown in Map (1). The Wadi Haran basin consists of a group of valleys, as illustrated in the Digital Elevation Model (DEM) in Map (2).

Map (1): Location of Wadi Haran Basin in Iraq



Source: Ministry of Water Resources, General Directorate of Survey, Administrative Map of Iraq, scale 1:1,000,000, 2015.

Map (2): Wadi Haran Basin Drainage Network



Source: Digital Elevation Model (DEM) with 30-meter resolution, 2015, processed using Arc Map 10.8 (GIS).

Geological Formations of Wadi Haran

The geological structure and natural properties of the rocks—comprising Quaternary deposits—have played a significant role in shaping the hydrological network of Wadi Haran (Al-Saeed, Hala Mohammed; Lina Ali Abdullah, 2021, p. 95). These consist of alluvial fan deposits characterized by geomorphological features made up of rock materials of varied grain sizes, deposited irregularly by watercourses (Al-Jubouri, Sahar Laith Hameed; Mohammed Najm Khalaf, 2024, p. 173). This formation

occupies a small area of the study region, estimated at 17 km², representing 0.9% of the total.

In addition, there are colluvial deposits covering 183 km² or 9.7%, which develop over gently sloping surfaces with minimal water flow and weak erosional processes, resulting in shallow stream channels (Desouky, Islam Saber Amin, 2019, p. 103). Depressional deposits occupy 72 km² or 3.8%, and floodplain deposits cover 49 km² or 2.6%. These areas consist mainly of gravel, silt, and calcareous rocks, predominantly characterized by low slopes that slow water runoff and promote sediment accumulation (Al-Qaisi, Hader Thahir Mohammed, 2019, p. 125).

Injana Formation: Composed of limestone, gypsum, sandstone, and red clay layers. It is fragile due to the presence of organic materials and plant remains (Al-Jawadi, Azaddin Saleh; Salem Qasim Al-Naqeeb; Thanon Abdulrahman Thanon, 2021, pp. 44–45). It includes formations from the Tertiary period (Miocene–Pliocene) and Quaternary period (Pleistocene–Holocene), featuring slope deposits, river terraces, and floodplain sediments (Al-Saleh, Qasim Jumaa, 2022, p. 306), covering an area of 253 km², or 13.4%.

Fatha Formation: The largest geological formation in Wadi Haran, composed of marl, limestone, gypsum, and interbedded layers of sandstone and siltstone (Al-Naqeeb, Salem Qasim; Thabit Dawood Muhdhar Yashi, 2003, p. 101). This formation spans an area of 1321 km², representing 69.7% of the basin.

The total area of all geological formations amounts to 1895 km², as shown in Table (1) and Figure (1).

Table (1): Area of Geological Formations in Wadi Haran Basin

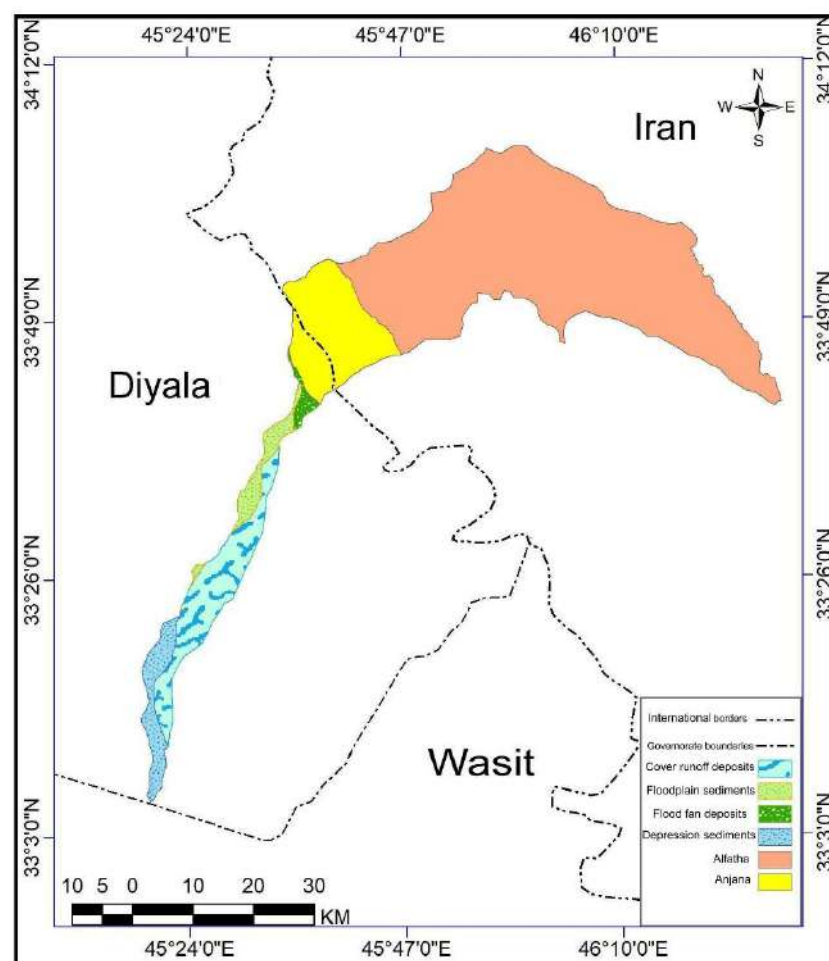
Formation	Area (km ²)	Percentage (%)
Alluvial Fan Deposits	17	0.9
Colluvial Deposits	183	9.7
Floodplain Deposits	49	2.6
Depressional Deposits	72	3.8
Injana Formation	253	13.4
Fatha Formation	1321	69.7
Total	1895	100.0

Source: Areas calculated using Arc Map 10.8 (GIS)

An analysis of the location and geological formations of Wadi Haran reveals that the formations with the smallest area and lowest percentage—namely the alluvial fan deposits, colluvial deposits, depressional deposits, and floodplain deposits—are predominantly located in the southern and southwestern parts of the basin. These regions are characterized by low geological slopes, which result in slower surface runoff compared to the Injana and Fatha formations situated in the northern and northwestern parts of the basin. These latter areas constitute the largest proportion of the basin and exhibit steeper geological characteristics, which lead to faster surface runoff.

This differentiation is determined using software based on Geographic Information Systems (GIS) (Govindaraju, T. Y.; Vinutha, C. J.; Rakesh, S.; Lokanath, A.; Kishor Kumar, 2024, p. 853), and by applying the SCS-CN method, which relies on the Curve Number (CN) for runoff estimation (Govindaraju et al., 2024, p. 853), as illustrated in Map (3).

Map (3): Geological Formations of Wadi Haran



Source: Ministry of Industry and Minerals, General Commission for Geological Survey and Mineral Investigation, Geological Map of Iraq, Scale 1:250,000, 2000.

Soil Types of Wadi Haran

1. **River Basin Soils:** These soils are part of the alluvial plain and are characterized by low elevation levels (Al-Saadi, Abbas Fadel, 2009, p. 90). They are composed of fine-grained clay and sandy particles and cover an area of 174 km², constituting 9.2% of the total soil types in Wadi Haran.
2. **Alluvial Fan Soil:** It is the result of geomorphological processes involving erosion and sedimentation. The more level and expansive the terrain, the more

- capable it is of collecting and storing greater amounts of surface and groundwater (Al-Hasnawi, Jawad Kazem & Zaman Sahib Jawad, 2018, p. 307). These soils cover an area of 53 km², representing 2.8% of the study area.
3. Marsh Soils or Mesopotamian Marsh Soi: These soils are part of the alluvial plain and are typically found in low-lying areas covered by water (Abd Al-Rahman, Hala Mohammed, 2016, p. 152). They occupy an area of 120 km², or 6.3%, and are located in the southern and southwestern regions of Wadi Haran.
 4. Cracked Degraded Soils: These soils exhibit poor physical properties and are marked by limited vegetation due to aridity, physical degradation, and high alkalinity (Nafeh, Faisal Abd Al-Fattah, 2019, p. 208). They cover an area of 518 km², which constitutes 27.3% of the study area, as shown in Table and Figure (2).
 5. Rugged Mountain Soils: This category occupies the largest area within the study region, estimated at 1030 km², or 54.4%. These soils are found in mountainous zones, are shallow and rocky, and mainly composed of limestone, making them unsuitable for agriculture. These two dominant soil types are located in the northeastern part of Wadi Haran, as illustrated in Map (4).

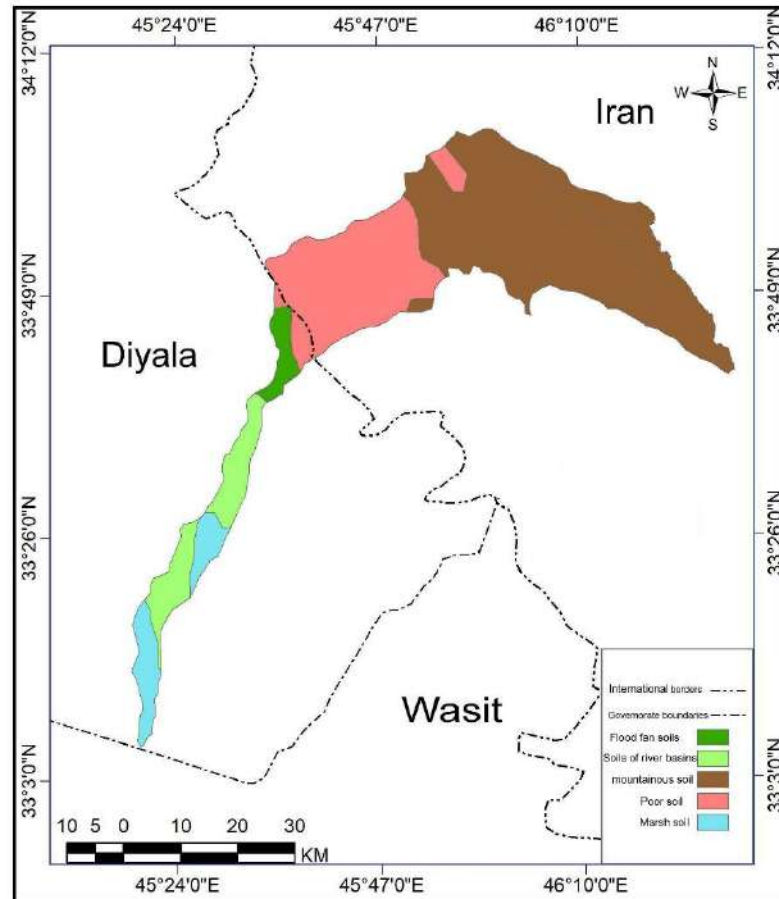
From the analysis of area, proportion, and type of soils in Wadi Haran, it is observed that river basin soils, marsh soils, and fan soils occupy the smallest areas and exhibit characteristics favourable for storing large volumes of water, resulting in lower surface runoff. In contrast, cracked degraded soils and rugged mountain soils dominate in area and percentage. Due to their limited vegetation, steep slopes, and hard geological features, they result in higher surface runoff.

Table (2): Soil Types of Wadi Haran

Soil Type	Area (km ²)	Percentage (%)
River Basin Soils	174	9.2
Fan Soils	53	2.8
Marsh Soils	120	6.3
Cracked Degraded Soils	518	27.3
Rugged Mountain Soils	1030	54.4
Total	1895	100.0

Source: Area calculations extracted using Arc Map 10.8 (GIS).

Map (4): Soil Types of Wadi Haran



Source: Table (3)

Area of Land Cover Types in Haran Valley

Land cover is defined as the physical state of the Earth's surface, consisting of soil and vegetation materials, characterized by the prominent surface features of the land cover in the study area. It is represented by sandy cover (Soomro, Abdul Ghani, Muhammad Munir Babar, Anila Hameem Memon, Arjumand Zehra Zaidi, Arshad Ashraf, Jewell Lund, 2019, p. 2738), which consists of recent fluvial sandy deposits composed of calcium carbonate and fragments (Al-Jari, Talal Maryoush, Nadia Hatem Ta'mah, 2018, p. 571). This cover constitutes the largest portion with an area of 911 km², accounting for 48.1%. Light vegetation cover occupies 439 km² (23.2%), barren lands cover 143 km² (7.5%), degraded lands cover 351 km² (18.5%), rocky outcrops cover 8 km² (0.4%), and dense vegetation cover covers 43 km² (2.3%).

Analysing the proportions and areas of land cover reveals that sandy cover forms the largest and most dominant part of the study area, indicating the prevalence of sandy deposits compared to light vegetation, which ranks second, followed by degraded and

barren lands. This suggests the presence of an arid or semi-arid environment. The third rank includes dense vegetation and rocky outcrops, which occupy very small areas, indicating the rarity of these land cover types. This reflects the predominantly arid nature of the region with limited vegetation or agriculture, resulting in increased soil permeability and reduced surface runoff, especially in the southern and southwestern parts. In contrast, the northern and northeastern parts, characterized by degraded lands and rocky outcrops, exhibit increased surface runoff due to lower soil permeability. Since the catchment area in the northeastern parts constitutes a larger area and percentage compared to the southern and southwestern parts, the prevailing feature in the basin is an increased volume of surface runoff.

As illustrated in Map (7) and Table (4).

Map (7): Land Cover Types of Haran Valley

Source: Satellite imagery (Landsat 8) with a spatial resolution of 30 meters for the year 2023, processed using ArcMap 10.8 (GIS).

Table (4): Area of Land Cover Types in Haran Valley

Land Cover Type	Area (km ²)	Percentage (%)
Sandy Land	911	48.1
Light Vegetation	439	23.2
Barren Land	143	7.5
Degraded Land	351	18.5
Rocky Outcrops	8	0.4
Dense Vegetation	43	2.3
Total	1895	100

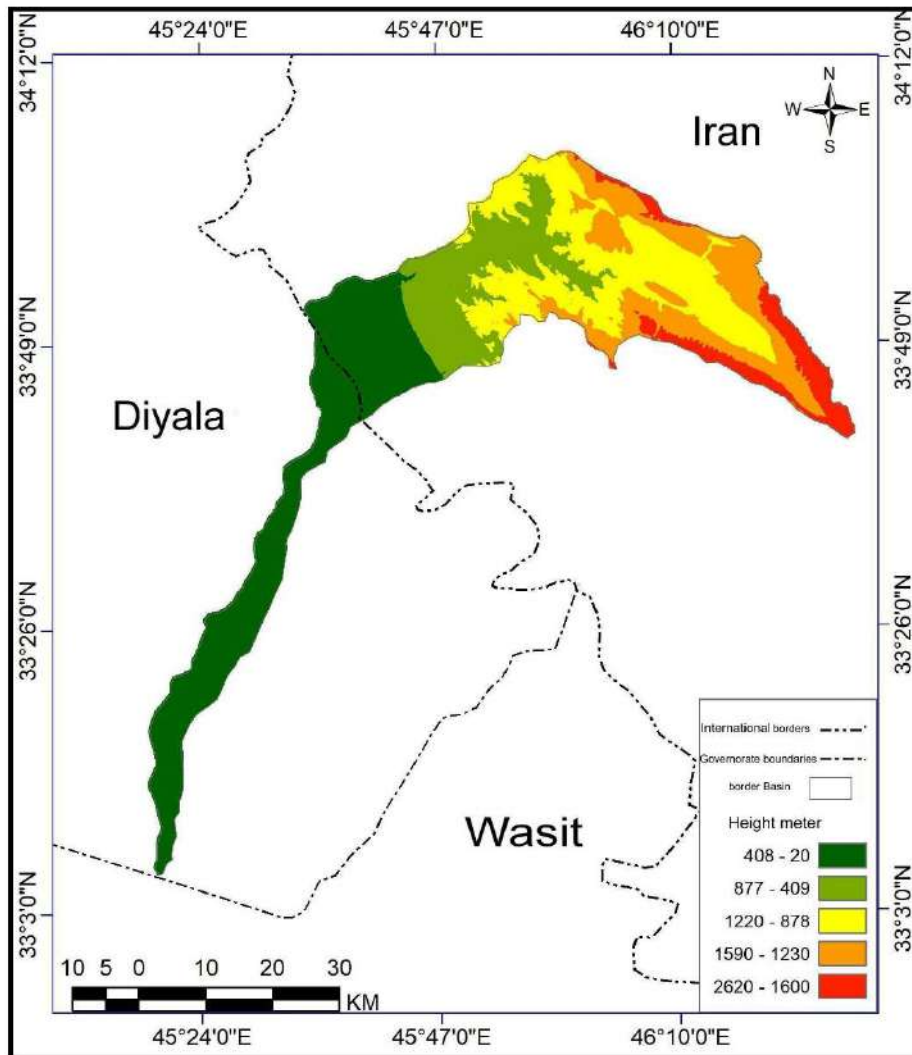
Source: Areas extracted using ArcMap 10.8 (GIS).

Slope Grades of Wadi Haran Basin and Their Relation to Runoff Volume

The study and analysis of the geological formations, soil classifications, and natural environmental factors such as slope and terrain relief are critical in estimating the runoff volume in the Wadi Haran basin. Analysing the slope degrees and their characteristics in the study area helps determine the impact and significance of estimating runoff volume using the SCS-CN method (Abbas, Saadia Mahdi Saleh, 2020, p. 19). The Curve Number (CN) is based on soil type, condition, land use, and land cover (LULC) in the region (Haj Bazal, Youssef Sami, 2022, p. 191).

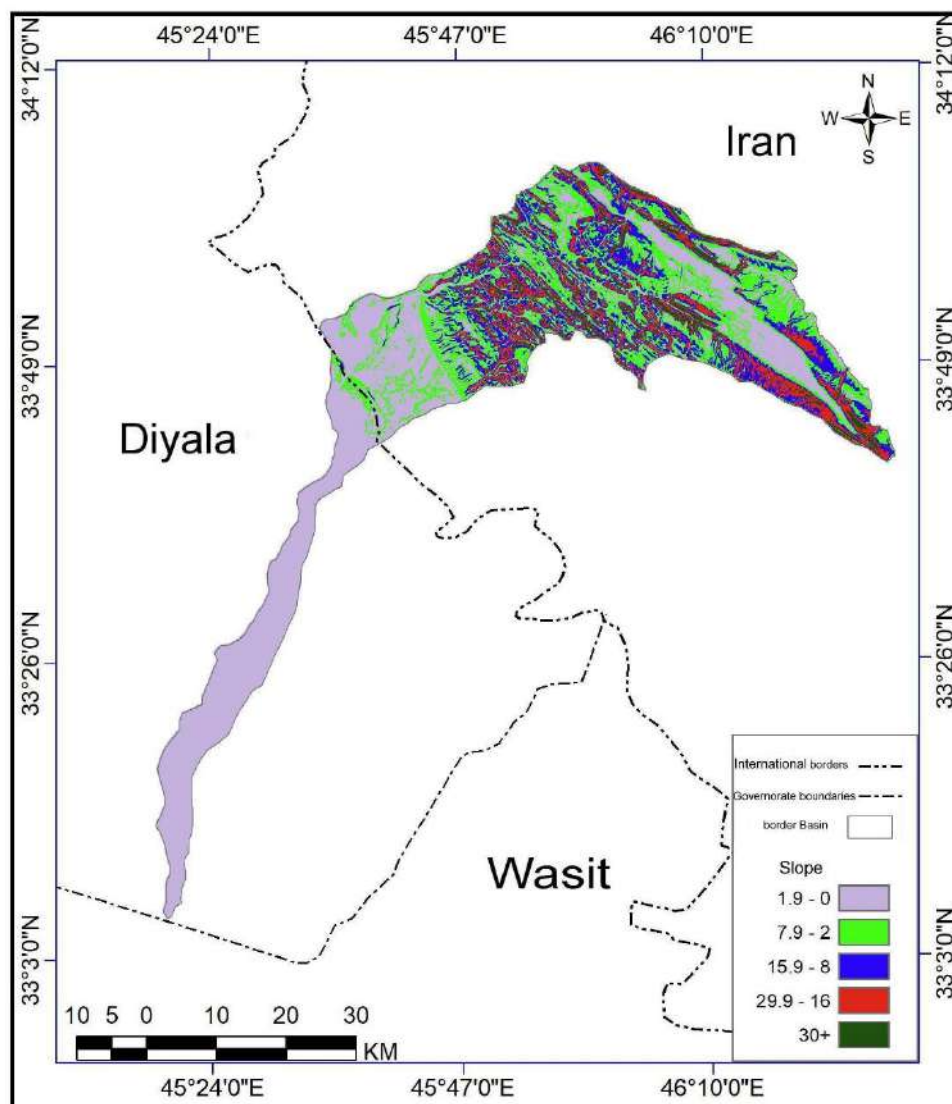
Digital analysis of slope degrees reveals that the lowest slopes are found in flat surfaces, while the highest slopes occur in highly dissected terrain. The dominant slope category is flat land, where areas with low elevations prevail, as shown in Maps (5) and (6) and Table (3). This reflects an increase in surface runoff in these areas due to the water's ability to accumulate in low-lying zones, leading to higher water levels compared to steep areas. In contrast, steep slopes facilitate water flow over larger areas, increasing erosion and sedimentation processes. As a result, water moves rapidly without settling, which increases water loss and reduces surface runoff volume (Hassan, Iman Mohammed, Suhaib Hassan Khudhur, 2022, pp. 1–957).

Map (5): Contour Elevations of Wadi Haran



Source: Digital Elevation Model (DEM) with a spatial resolution of 30 meters for the year 2015, processed using ArcMap 10.8 (GIS).

Map (6): Slope degrees in the study area.



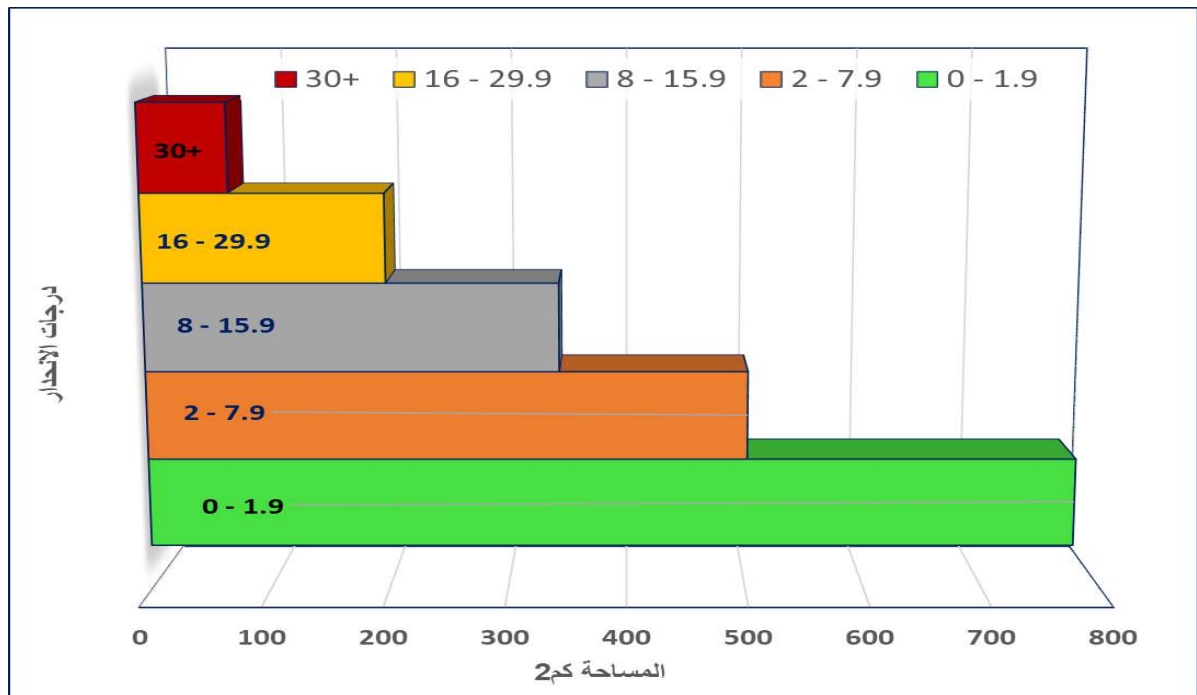
Source: Digital Elevation Model (DEM) with a spatial resolution of 30 meters for the year 2015, processed using ArcMap 10.8 (GIS).

Table (3): Slope degrees of Haran Valley.

Slope Degree (°)	Area (km ²)	Percentage (%)	Surface Type
0 – 1.9	776	40.9	Flat surface
2 – 7.9	501	26.4	Slight undulating
8 – 15.9	344	18.2	Undulating
16 – 29.9	201	10.6	Fragmented
30+	73	3.9	Highly fragmented
Total	1895	100.0	

Source: Areas extracted using ArcMap 10.8 (GIS).

Figure (1): Slope degrees of Haran Valley.



Source: Table (3)

Area of Land Cover Types in Haran Valley

Land cover is defined as the physical state of the Earth's surface, composed of a combination of soil and vegetation materials. According to the prominent surface features of the land cover in the study area, it is primarily characterized by sandy cover (Soomro, Abdul Ghani, Muhammad Munir Babar, Anila Hameem Memon, Arjumand Zehra Zaidi, Arshad Ashraf, Jewell Lund, 2019, p. 2738), which consists of recent fluvial sandy deposits made up of limestone and fragments (Al-Jari, Talal Maryoush, Nadia Hatim Tu'mah, 2018, p. 571). This sandy cover forms the largest component of the area, covering 911 km², or 48.1% of the total. Light vegetation covers an area of 439 km² (23.2%), barren land occupies 143 km² (7.5%), degraded

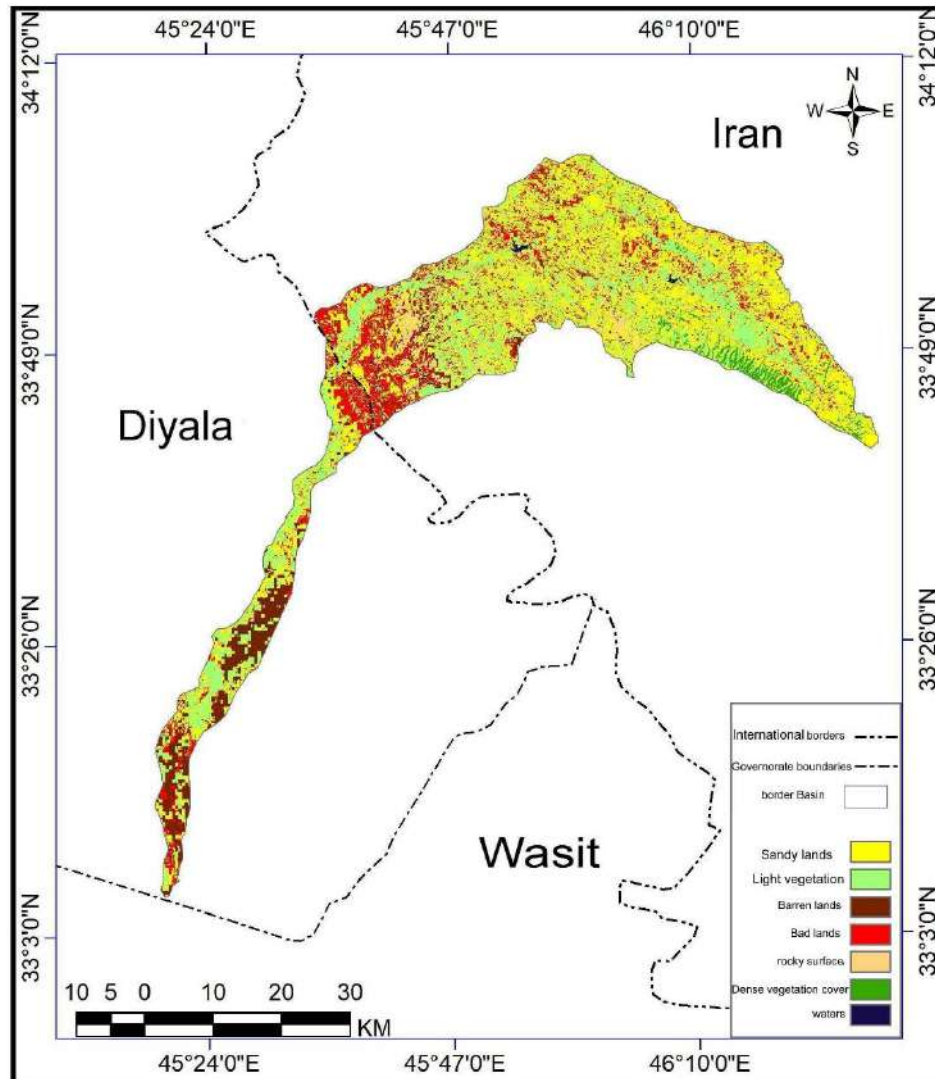
land covers 351 km² (18.5%), rocky outcrops account for 8 km² (0.4%), and dense vegetation covers 43 km² (2.3%).

An analysis of the proportions and areas of land cover reveals that sandy cover dominates the study area, indicating the prevalence of sandy deposits. Light vegetation comes in second, followed by degraded and barren lands, which reflect the presence of an arid or semi-arid environment. Dense vegetation and rocky outcrops occupy very limited areas, highlighting the scarcity of these types of land cover. This pattern suggests that the region is predominantly arid, with limited vegetation or agricultural activity. It also reflects higher soil permeability and lower surface runoff, particularly in the southern and southwestern parts. In contrast, the northern and northeastern areas, characterized by degraded lands and rocky outcrops, experience more intense surface runoff due to low water permeability.

Since the northeastern parts of the basin constitute the largest area and percentage compared to the southern and southwestern regions, the dominant hydrological feature of the basin is the increased volume of surface runoff.

As illustrated in Map (7) and Table (4).

Map (7): Land Cover Types in Haran Valley



Source: Satellite imagery (Landsat 8) with a spatial resolution of 30 meters for the year 2023, processed using ArcMap 10.8 (GIS).

Table (4): Area of Land Cover Types in Haran Valley

Land Cover Type	Area (km ²)	Percentage (%)
Sandy Land	911	48.1
Light Vegetation	439	23.2
Barren Land	143	7.5
Degraded Land	351	18.5
Rocky Outcrops	8	0.4
Dense Vegetation	43	2.3
Total	1895	100

Source: Area measurements extracted using ArcMap 10.8 (GIS)

Hydrologic Soil Groups in Haran Valley

Table (5) presents the areas of the hydrologic soil groups in Haran Valley. It is observed that Group A covers an area of 307 km², accounting for 16.2% of the total. This group represents a moderately sized area and indicates the presence of soils with relatively good hydrologic properties and high permeability, allowing for efficient infiltration of water into the soil.

Group B, on the other hand, has a very limited area of only 65 km² (3.4%), reflecting the presence of soils with lower permeability and a limited capacity for water infiltration.

Group C is the dominant class, covering an area of 1,523 km² and comprising 80.4% of the total valley area. This suggests that the majority of the soils in Haran Valley exhibit poor to moderate permeability, which leads to water accumulation or surface runoff rather than infiltration into the soil. As a result, surface runoff predominates, indicating that the region suffers from hydrologic characteristics that limit groundwater recharge (Ali, Mustafa Halo; Tareq Juma Ali Al-Mulla, 2018, p. 519).

Runoff Estimation Equation:

The volume of surface runoff was estimated using the Soil Conservation Service Curve Number method (SCS-CN), developed by the U.S. Soil Conservation Service. This method provides a widely accepted empirical approach for estimating surface runoff based on land use, soil type, and antecedent moisture conditions.

The SCS-CN curve number ranges from 0 to 100, where higher values indicate lower soil permeability and greater runoff potential, while lower values indicate higher permeability and reduced runoff (Al-Shammari, Iyad Abdul Ali Salman; Ali Majeed Yassin Al-Bu Ali, 2024, p. 741).

According to the equation results:

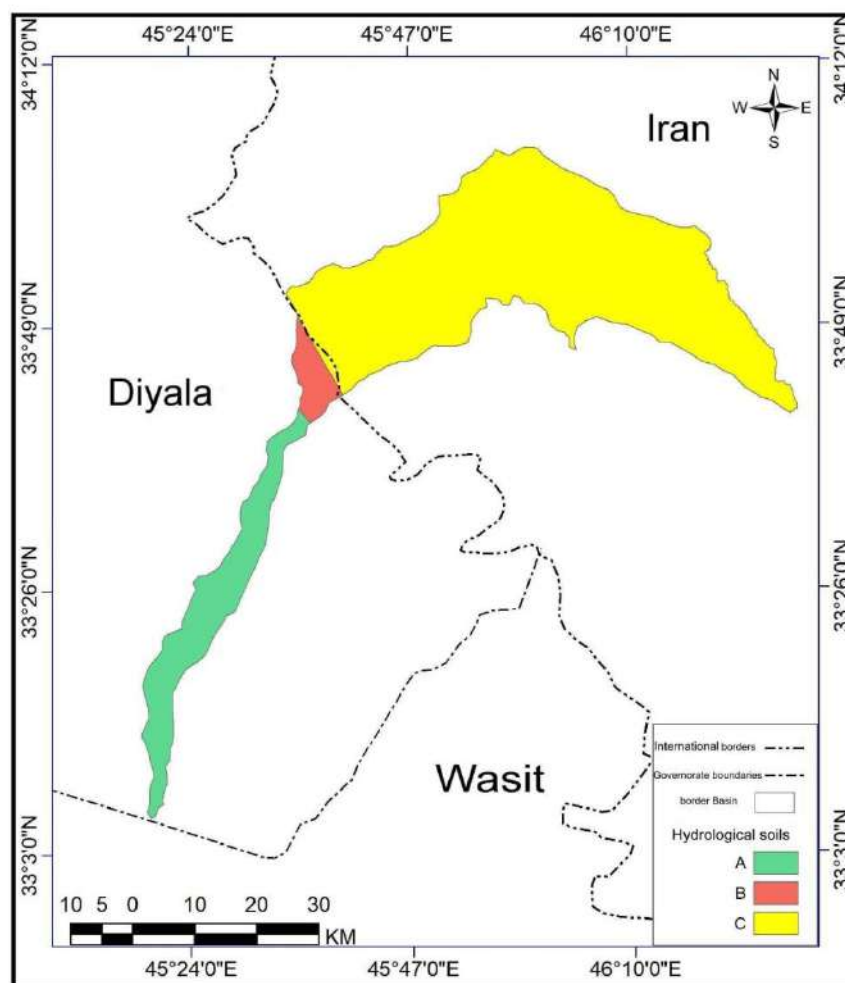
- Runoff coefficient (Q) ranged between 183.6 and 265.1
- Watershed area (LA) ranged between 4.42 and 23.91
- Potential maximum retention (S) ranged between 22.09 and 119.53
- Curve Number (CN) ranged between 68 and 92

The average runoff volume was calculated to be 198.2, derived by summing the QV values and dividing by their count.

Table (5): Area of Hydrologic Soil Groups in Haran Valley

Soil Group			Area (km ²)	Percentage (%)
A			307	16.2
B	65	3.4		
C	1523	80.4		
Total	1895	100.0		

Map (8): Hydrologic Soil Groups



Source: Area measurements extracted using ArcMap 10.8 (GIS)

Analysis of Surface Runoff Volume in the Haran Valley Basin, Eastern Iraq, Using the SCS-CN Method

Source: Soil Conservation Service. Urban Hydrology for Small Watersheds, Technical Release 55, 2nd ed., U.S. Department of Agriculture, Washington D.C., 1986.

An analysis of the surface runoff volume using the SCS-CN (Soil Conservation Service–Curve Number) method, based on Table (6) and Map (9), indicates that curve number (CN) values and potential soil storage capacity are predominantly high. These high values reflect a reduced capacity for water infiltration and increased surface runoff, particularly in the northern and northeastern sections of the basin, where rugged mountain soils and fractured poor-quality soils dominate.

In contrast, the southern and southwestern parts of the basin are characterized by alluvial soils from riverbeds and marshes, as well as fan soils, which exhibit higher permeability and absorption capacity, resulting in lower surface runoff.

As shown in Map (10), the maximum potential retention (S) values are highest in the southern and southwestern parts of the basin, indicating areas with greater infiltration and water retention, thereby reducing surface runoff. Conversely, the lowest values are concentrated in the northern and northeastern areas, pointing to limited infiltration and increased surface runoff.

Map (11) shows the initial abstraction (La) values before the onset of surface runoff. These values are higher in the southern and southwestern parts of the basin, indicating greater initial water loss from rainfall and less runoff. In contrast, lower La values in the north and northeast suggest minimal water loss before runoff, resulting in quicker and higher runoff volumes.

Map (12) highlights the depth of surface runoff (Q), which is higher in the northern and northeastern parts of the basin. This is due to low permeability, limited vegetation cover, and dominant rocky surfaces—conditions conducive to greater runoff generation. The southern and southwestern regions, with higher permeability and more vegetation, experience reduced runoff volumes.

Similarly, Map (13) illustrates the total surface runoff volume (Qv), which is significantly higher in the northern and northeastern sections of the basin due to the aforementioned factors and lower in the southern and southwestern parts.

Overall, the basin demonstrates high surface runoff potential, particularly in the expansive northeastern part compared to the southwest, primarily due to hydrological soil characteristics and land cover patterns.

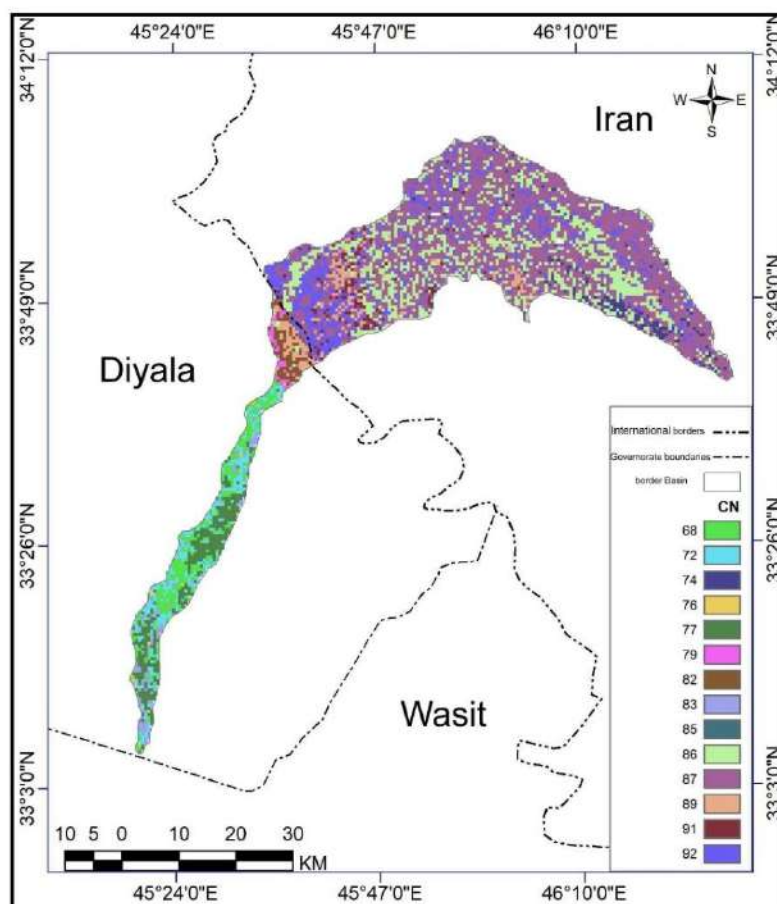
Table (6): Area Distribution of Surface Runoff Variables

No.	CN	S	La	Q	Qv	Area (km ²)	%
1	68	119.53	23.91	183.6	323.74	94	4.9
2	72	98.78	19.76	197.9	358.08	83	4.4
3	74	89.24	17.85	204.9	12.85	44	2.3
4	76	80.21	16.04	211.9	76.60	4	0.2
5	77	75.87	15.17	215.4	582.71	101	5.3

6	79	67.52	13.50	222.2	103.67	12	0.6
7	82	55.76	11.15	232.4	162.80	29	1.6
8	83	52.02	10.40	235.7	228.11	30	1.6
9	85	44.82	8.96	242.4	13.03	1	0.0
10	86	41.35	8.27	245.7	193.36	356	18.8
11	86	41.35	8.27	245.7	64.73	2	0.1
12	87	37.95	7.59	249.0	523.50	790	41.7
13	89	31.39	6.28	255.5	92.99	54	2.8
14	89	31.39	6.28	255.5	153.00	24	1.3
15	91	25.12	5.02	261.9	54.70	39	2.1
16	92	22.09	4.42	265.1	228.09	234	12.4
Average	82.2	57.1	11.4	232.8	198.2	1895	100.0

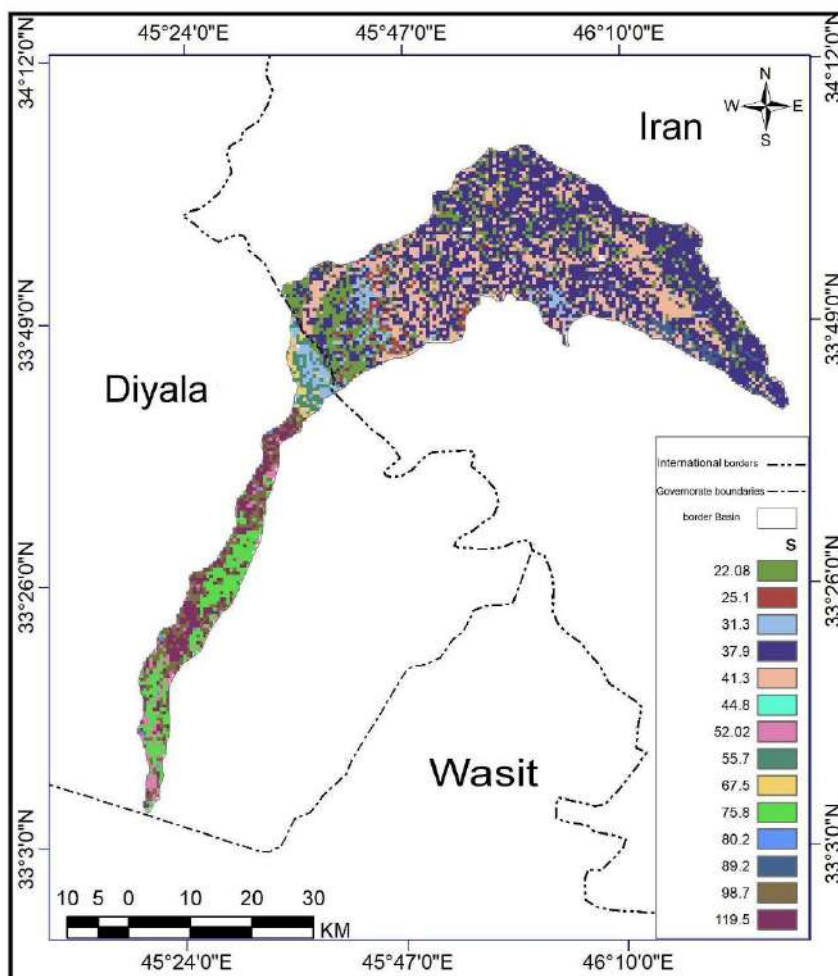
Source: Areas calculated using Arc Map 10.8 (GIS).

Map (9): Curve Number (CN) Values



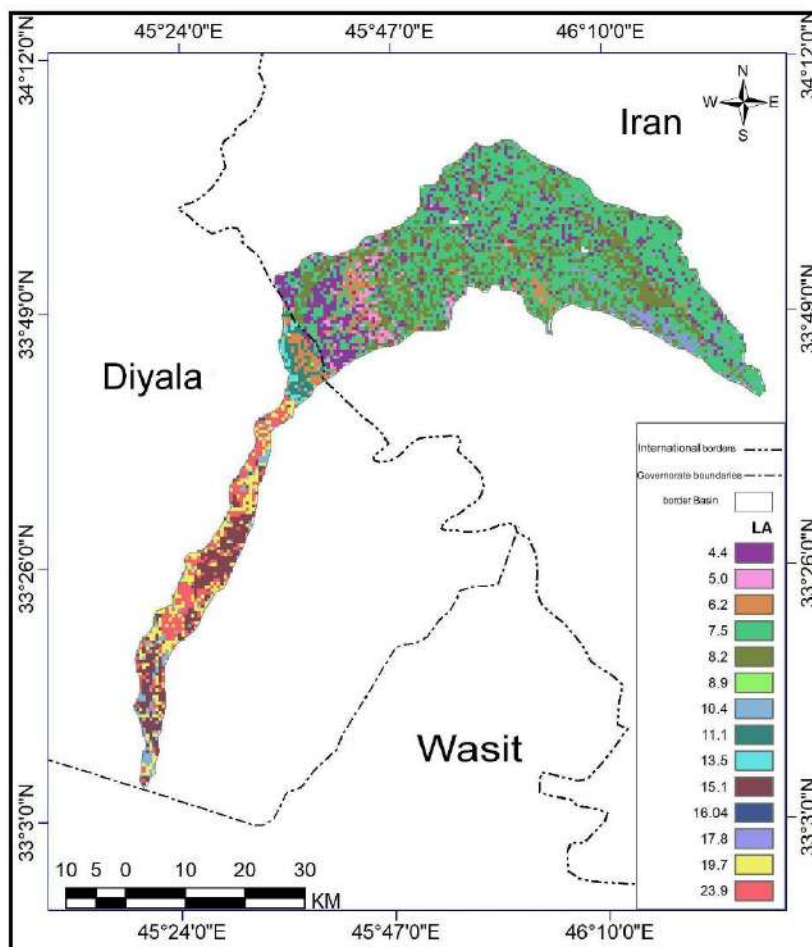
Source: Output from Arc Map 10.8 (GIS).

Map (10): Maximum Retention Potential (S)



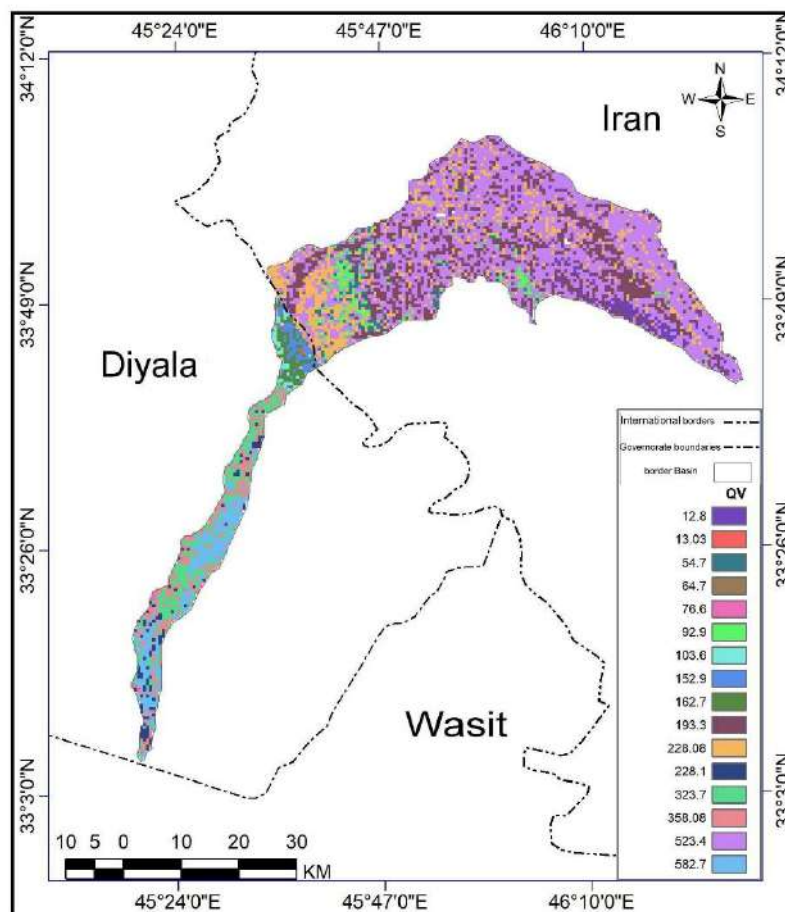
Source: Output from Arc Map 10.8 (GIS).

Map (11): Initial Abstraction Coefficient (La)



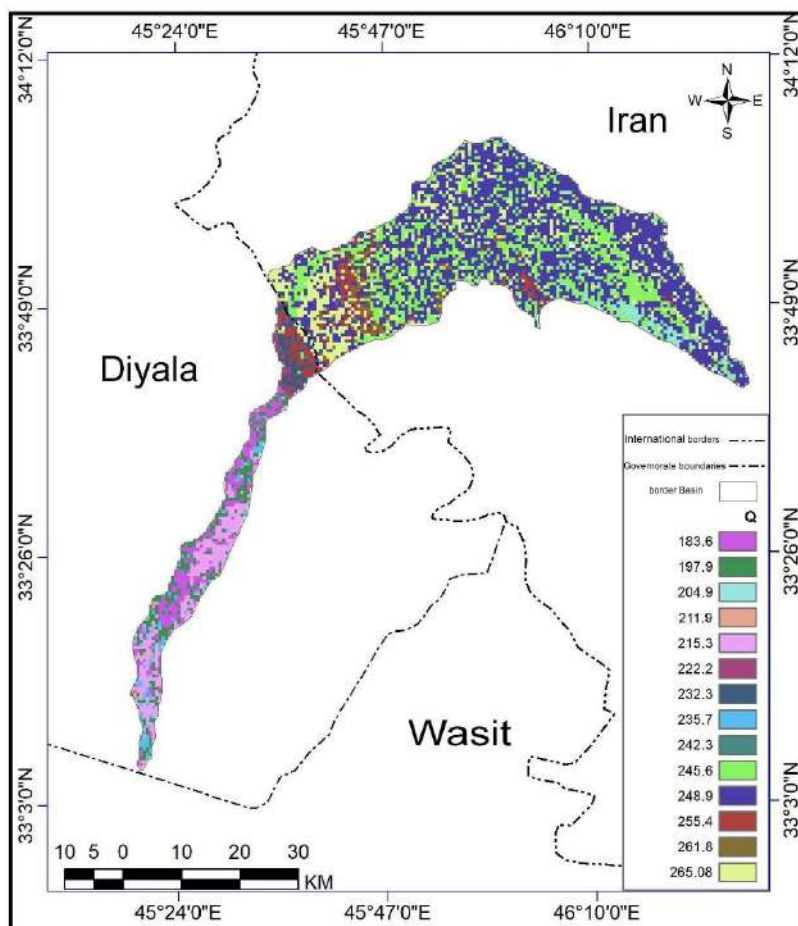
Source: Output from Arc Map 10.8 (GIS).

Map (12): Surface Runoff Volume (Qv)



Source: Output from Arc Map 10.8 (GIS).

Map (13): Surface Runoff Volume (Qv).



Source: Output from Arc Map 10.8 (GIS)

Conclusions:

1. Most of the watershed area lies within the eastern international border with Iran, which shares similar geological structural characteristics with most of the watershed area in Iraq.
2. The geological formations in the southern and southwestern parts of the Haran Valley watershed are characterised by low slope gradients and slow surface runoff, resulting in lower surface runoff volumes and smaller area and proportion compared to the northern and northeastern parts, where the Injana and Al-Fathah formations dominate with steeper slopes that accelerate surface runoff volume.
3. Numerical analysis of slope gradients shows that the lowest slope areas are flat surfaces, which represent the largest area and proportion in the watershed. Conversely, high slope areas cover smaller areas and proportions but

contribute to increased surface runoff volume due to rock hardness, water stability, and limited infiltration.

4. Analysis of hydrological soil classes in the Haran Valley shows that the largest area and proportion belong to class (C), which has weak to moderate permeability, leading to water accumulation or surface runoff rather than infiltration and an increase in runoff volume. Class (A) has relatively good permeability allowing water infiltration and less runoff, while class (B) occupies the smallest area and proportion, characterized by lower permeability and infiltration capacity, which also contributes to increased runoff volume.
5. Analysis of land cover types reveals that sandy cover constitutes the largest area and proportion, characterized by an arid nature and limited vegetation cover, which enhances water infiltration and reduces surface runoff, especially in the southern and southwestern parts. The northern and northeastern parts, however, exhibit characteristics that increase surface runoff volume. Since these parts cover a larger area and proportion, the dominant watershed feature is increased surface runoff volume.
6. Analysis of surface runoff volume using the SCS-CN method shows that soil storage capacity (CN) has higher values—indicating lower water absorption and increased runoff—in the northern and northeastern parts, and lower values in the southern and southwestern parts. The maximum potential retention factor (S) reaches its lowest average in the northeastern part and highest in the southwestern part. The initial abstraction factor (LA) before runoff initiation shows higher values in the southwestern part and lower values in the northeastern part, indicating less rainfall loss and water dissipation before runoff begins, which reduces surface water quantity and velocity, thus lowering runoff volume. Surface runoff depth (Q) values are higher in the northern and northeastern parts due to low permeability, sparse vegetation, and dominant rocky cover, promoting surface runoff processes and increased runoff volume. The runoff volume (QV) generally shows higher values in the northern and northeastern parts, which represent the largest area and proportion of the watershed, and lower values in the southern and southwestern parts. Overall, the watershed is characterised by increased surface runoff rates due to the wide watershed area in the northern and northeastern regions compared to the southern and southwestern regions.

Recommendations:

1. Emphasise the role and advancements of modern technologies in estimating surface runoff volume in river basins.
2. Highlight the importance and role of contemporary human interventions and techniques in mitigating the hazards and negative impacts of surface runoff.
3. Raise awareness about harmful human practices in the environment that increase the risk of surface runoff in river basins.
4. Preserve the vegetation cover in the area, as it protects the soil from erosion and reduces the severity of surface runoff.

5. Encourage the adoption of projects involving the construction of dams and reservoirs to store water in areas continuously exposed to surface runoff risks.

References

1. Sahar Laith Hameed Al-Jubouri, & Mohammed Najm Khalaf. (2024). Development of alluvial fans on the southern slope of Northern Hamrin and their economic importance. *Tikrit University Journal for Humanities*, 31(8).
2. Hala Mohammed Saeed, & Lina Ali Abdullah. (2021). Morphometric characteristics of Wadi Haran and Eastern Tersaq Basin, Diyala Governorate. *Diyala Journal*, Diyala University, College of Education for Humanities, (87).
3. Jawad Kazem Al-Hasnawi, & Zaman Sahib Jawad. (2018). Spatial analysis of natural features in Al-Mahawil District. *University of Babylon Journal of Humanities*, 26(8).
4. Ishaq Saleh Al-Akkam, & Nawal Kamel Alwan. (2015). Estimation of surface runoff volume in Wadi Dweirij Basin using remote sensing and GIS techniques. *Journal of Geographical Research*, (21), University of Baghdad, College of Education for Women.
5. Islam Saber Amin Desouki. (2019). Application of RAP/RAC model to estimate potential water erosion in the basins of Al-Mahqen and Muhallab, Marsa Matrouh Area – Egypt, using remote sensing and GIS. *Faculty of Arts Journal*, (51).
6. Eyad Abdul Ali Salman Al-Shammari, & Ali Majid Yaseen Al-Bu Ali. (2024). Evaluation of soil classification in Iraq's exploratory maps: A case study of Western Al-Salibat area in Southern Iraqi plateau using modern technologies. *Madad Al-Adab Journal*, University of Wasit, College of Basic Education, 1.
7. Iman Mohammed Hasan, & Suhaib Hasan Khudair. (2022). Hydrological analysis of natural environmental characteristics of Erbil Basin. *Proceedings of the 4th International Teachers' Conference / Historical and Geographical Studies*, University of Mosul, College of Education for Humanities.
8. Balqis Mabhut Nasser Salah, & Mohammed Ahmed Hamoud Miyas. (2023). Estimation of surface runoff volume using the SCS-CN model in Wadi Zabid Basin – Yemen. *Sana'a University Journal for Humanities*, 4(1).
9. Haadir Dhahir Mohammed Al-Qaisi. (2019). River meanders of the Tigris River in Al-Alam Subdistrict. *Journal of Historical and Cultural Studies*, 11(40).
10. Salem Qasim Al-Naqeeb, & Thabit Dawood Mahdar Yishi. (2003). Geological and hydrological study of the area between Jabal Atshan and Wadi Qasab south of Mosul.
11. Saadiya Mahdi Saleh Abbas. (2020). Study of some soil characteristics affected by salinity and their degradation in Basra Governorate using geospatial technologies. PhD Thesis, University of Basra, College of Agriculture.
12. Talal Maryoush Jari, & Nadia Hatem Ta'mah. (2018). Flood risks in Eastern Maysan Governorate valleys. *Journal of the College of Education*, University of Wasit, (33).

13. Abbas Fadel Al-Saadi. (2009). Geography of Iraq: Its natural framework, economic activity, and human aspect. Ministry of Higher Education and Scientific Research, University of Baghdad.
14. Ezzedine Saleh Al-Jawadi, Salem Qasim Al-Naqeeb, & Dhanoon Abdulrahman Dhanoon. (2021). Assessment of the suitability of Al-Fathah and Injana Formations clays for brick and ceramic industry in Nineveh Governorate. Iraqi National Journal of Earth Sciences, 21(1).
15. Faisal Abdul Fattah Nafi'. (2019). Desertification and its impact on marshlands in Southern Iraq. Al-Mustansiriya Journal for Arab and International Studies, 16(68).
16. Qasim Juma Saleh. (2022). Sand and gravel quarries on the lower banks of the Great Zab River and their effect on land surface changes between Aski Kalk and Al-Mukhallat. Journal of Education for Humanities, 2(6).
17. Mustafa Helou Ali, & Tarek Juma Ali Al-Mawla. (2018). Land cover classification and land use in Maysan Governorate using remote sensing data and hybrid classification methods. Journal of Arts, University of Baghdad, 1(125 Suppl.).
18. Hala Mohammed Saeed, & Lina Ali Abdullah. (2021). Morphometric characteristics of Wadi Haran and Eastern Tersaq Basin, Diyala Governorate. Diyala Journal, Diyala University, College of Education for Humanities, (87). [Duplicate – consider removing]
19. Hala Mohammed Abdulrahman. (2016). Geomorphological evolution of Badra Fan. Journal of the College of Education for Women, University of Baghdad, 27(1).
20. Govindaraju, T. Y., Vinutha, C. J., Rakesh, S., Lokanath, S., & Kishor Kumar, A. (2024). Surface runoff estimation using the SCS-CN method for Kurumballi sub-watershed in Shivamogga District, Karnataka, India.
21. Youssef Sami Haj Bazal. (2022). Geomorphological risks of slopes in Erbil. AL-meed Journal, 11(42).
22. Abdul Ghani Soomro, Muhammad Munir Babar, Anila Hameem Memon, Arjumand Zehra Zaidi, Arshad Ashraf, & Jewell Lund. (2019). Sensitivity of direct runoff to curve number using the SCS-CN method. Journal Name Not Provided, 5(12), December.