Analysis Of The Hydrological Characteristics Of The Basins Of Sharbazir District, East Of Sulaymaniyah Province, Using CN-SCS Method

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Abstract:
The research relied on the method (CN-SCS), which is one of the important methods used to estimate water harvesting, which was developed by the Soil Conservation Department of the United States Department of Agriculture (Soil Conservation Service (Service) in 1970 AD, Its famous formula was developed in 1986 AD. The (SCS) method is a set of mathematical equations that depend on its inputs to provide information on land covers and patterns of their use, soil hydrology, type of vegetation cover, and amounts of rainfall to know the characteristics of runoff and the possibility of water harvesting in the Sharbazir district, By knowing and analyzing the description of the land cover and knowing the types of hydrological soils in the region and determining the prior condition of soil moisture, and after completing these three elements, the values of CN were obtained, which expresses the extent of soil permeability, and the coefficient that expresses the maximum ability of the soil to retain water, and the coefficient (LA) which shows the amount of rainwater lost before the start of surface runoff and the coefficients (Q) and (QV) Which expresses the depth and quantity of surface runoff volume in the district.

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Introduction:

The relationship between rain and surface runoff is the nucleus or hydrology of surface water because surface water runoff is the final stage of rainwater and reveals the volume of hydrological work on the surface and the associated possibility of exploiting it as it is a natural water resource. Therefore, the hydrological studies of water valleys are a large part of them, including the study The current aims to obtain special information about the nature of surface water runoff, represented by the depth and volume of runoff. Many modeling techniques and methods used in estimating surface runoff vary through the variables that are used in the analysis. One of the most important methods used is the method of the Soil Conservation Authority. Many modeling techniques and methods vary. used in estimating surface runoff by the variables that are used in the analysis. The research included a study of the volume of surface runoff in the district of Sharbazir, and the district consists of eight seasonal basins that depend on rainfall, as its water increases during the winter season, They will be studied to reveal the most contributors to the occurrence of surface runoff.

boundaries of the search area

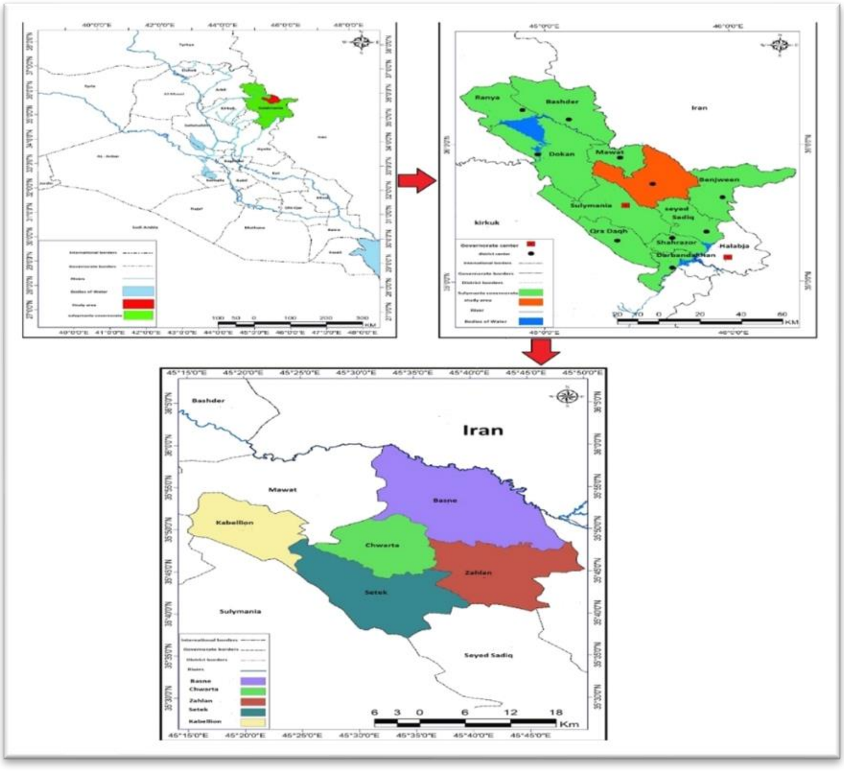
The study area (Sharpazir district) is located between longitudes (45°.00.16 - 45°.00. 51) east and between two latitudes (35°.00.21 - 36°.00.01). As for its administrative location, it is located within Sulaymaniyah Governorate, as it occupies the eastern part of it, and in the northeastern part of Iraq Map (1). and its area is as a district (1056.6) km^2.

Research problem:

The study area suffers from many problems worthy of scientific research, and among these problems:

1. The acute shortage of surface water resources during the dry season of the year.
2. The study area suffers from high infiltration rates due to the coarse sandy soil nature.

Map (1) The geographical location of the study area in relation to Iraq



Source: From the researcher's work, based on: the Kurdistan Regional Government of Iraq, the Ministry of Interior, Sulaymaniyah Governorate, Survey Department, the administrative map of Sulaymaniyah Governorate, scale 1:100000, 2018.

Research hypothesis:
The surface runoff depth in the Abu Ghar basin is affected by the type of land cover and soil permeability. . The depth of surface runoff varies with the amount of rainfall in the basin.

Research objective The research aims to:
1- Studying the types of ground cover in the basin.
2- Determining the hydrological characteristics of the soil and determining the extent of its moisture after rainfall.
3- Determination of surface runoff depth In the basin, based on the hypothesis of the American Soil Conservation Service (SCS), which depends on the quality of the soil and the degree of its permeability. The ground cover of the basin was classified, and then the expected depth and volume of runoff were estimated after rainfall.

Surface runoff according to the (SCS-CN) method:
The US Soil Conservation Service (SCS-CN) was relied upon to calculate the volume of surface runoff for water basins in the study area, It is a series of mathematical equations that depend in their main inputs on (hydrological soil class, land cover, land uses, initial soil moisture, and the amount of rainfall), using the program (Watershed Management system 10.1), While its outputs are represented by the digital curve CN in addition to the quantities of water resulting from a rainstorm that reaches the mouth of the valleys, one of the most important mathematical equations for calculating the volume of surface runoff is according to what was stated in (USDA, 1986)[1] , and according to the following:

Since:

$$Q = \frac{(P-Ia)^2}{P-Ia+s} \qquad \text{............... (1)}$$

Q: runoff depth/mm
P: the amount of rain falling/mm
La: losses before runoff begins (evaporation, infiltration, vegetation)
S: surface agglomeration after the onset of runoff.

Since La is one-fifth of the value of S, La is calculated as follows:

$$Ia = 0.2S \qquad \text{...........(2)}$$

Accordingly, the equation will be:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8\,S} \qquad \text{................. (3)}$$

The calculation of the value of (S) is based on the following mathematical formula[2]

$$S = \frac{1000}{CN} - 10 \qquad \text{.................. (4)}$$

To convert the units of equation No. (4) into mm to comply with metric measurements, it takes the following form:

$$S = \frac{25400}{CN} - 254 \qquad \text{.............. (5)}$$

To calculate the surface runoff, the values of the digital curve (CN) must be determined, and its extraction requires relying on three elements represented by (the hydrological group of soil, soil moisture, land cover, and land uses)[3], as (CN) values range between (0-100)[4].

Which represents the lowest and highest surface runoff, respectively, and also reflects the water response to the components of the basin, as low values indicate high permeability and water leakage through surfaces into the soil, which leads to a decrease in its ability to generate surface runoff, while high values indicate surfaces The low permeability and its ability to generate high surface runoff, while the average values (50) reflect surfaces with medium permeability and surface runoff.

These values are extracted by classifying the basin on the basis of the prevailing soil type, as the US Soil Conservation Service (SCS) prepared a special table for hydrological soil groups that includes dividing them into four categories divided according to the rate of water movement through them, which are (A, B, C, D), each category has a numerical meaning that expresses a specific hydrological condition, based on several characteristics represented in the percentages of sand, clay and silt and the extent of its impact on the levels of water infiltration into the soil and the emergence of surface runoff, and each category of these soils has its own characteristics, As represents (A, D) represent two extreme cases, the case (A) represents a very low surface runoff, while the case (D) represents a very high surface runoff, and the values (B, C) represent two average cases for the runoff [5]. According to Table (1).

Table (1) Hydrological groups for soils

Soilclass	depth of runoff	soil type
A	**Little**	**deep sandy layer with very little amount of clay and silt**
B	**Medium**	**sandy layer, less deep than class A, with a medium infiltration rate**
C	**Above average**	**a shallow clay layer with a below average infiltration rate or a rocky layer covered by a layer of soil.**
D	**High**	**A thick clay layer covered with a shallow layer of fine silt or bare rocky layer**

Source: USDA-SCS, Urban hydrology for small watershed, department of agriculture, USA, 1986, p.3.

Method for calculating the total surface runoff volume :

Qv = (Q * A/1000) …….…... (6)

Since:

Qv = volume of runoff
Q = runoff depth/mm
A = drainage basin area / km2
1000 = conversion factor

First: the method of extracting the digital curve of the basins :

The method of extracting the digital curve CN depends on the hydrological characteristics of the soil, land cover, and land uses, in addition to the pre-condition of soil moisture AMC and its effect on the generation of surface runoff [6]. And as follows:

1: Hydrologic Soil groups[7] :

Accordingly, the soils of the study area were divided into two hydrological groups, in accordance with the standard soil groups and their structural categories, and based on the soil texture map prepared by the Organization (FAO), which ranges from soil category B to soil category C, And according to the following:

1.1: Soil Class B:

It mainly consists of deep to medium depth soils with a fine to medium coarse sandy clay texture[8]. Its area is (951) km 2 i.e. (90.2%) of the basin area. This category of soils is widely spread in parts of the study area except for the northern and northeastern parts. For the region, and when the soil is completely wet in this category, the possibility of surface runoff and infiltration rates are fairly average, Table (2) and Map (2).

Table (2) Hydrological Soil Group (HSG) and its texture

No	HCG hydrological soil class	Soil hydrological texture
1	B	LOAM
2	B	SILT LOAM
3	B	SILT
4	C	SANDY CLAY LOAM

Source: 1- Hong, Yang, et al. A first approach to global runoff simulation using satellite rainfall estimation. Water Resources Research, 2007, 43.8.
2- Hong, Y.; Adler, R. F. Estimation of global SCS curve numbers using satellite remote sensing and geospatial data. International Journal of Remote Sensing, 2008, 29.2: 471-477.
3- Abraham, Shiny; HUYNH, Chau; VU, Huy. Classification of soils into hydrologic groups using machine learning. Data, 2020, 5.1:

1.2: Soil Class C:

They represent mixed soils that have a texture of silty clay and sandy clay, which have a level of permeability from medium to good, so when they are completely wet, the rate of water infiltration in them is low. These soils were formed by the seasonal flooding of rivers. Their color is dark, and their color tends from pale brown to dark brown. It occupies the upper northern and northeastern parts of the study area. The area of this category is (103) square kilometers, i.e. (9.8%) of the total area of the study area, Table (3), Map (2).

Table (3): Hydrological soil classes in the study area

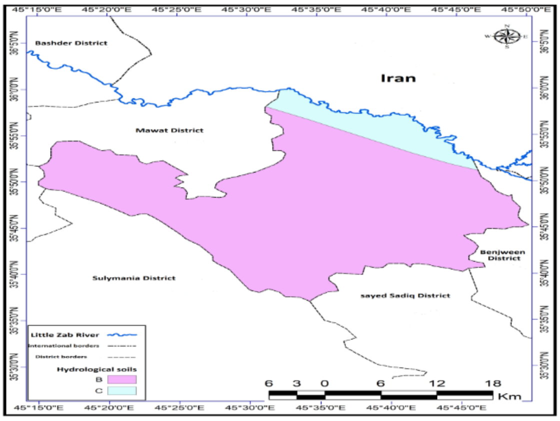
no	Soil hydrological class	Area (km²)	Area %
1	**B**	**951**	**90.2**
2	**C**	**103**	**9.8**
	Total	**1054**	**100.0**

Source: Map (2) using (ArcGIS 10.8).

2: Classification of land cover and land uses for the study area:

This study relied on the space data of the Landsat-8 satellite to classify land covers and land uses (LU/LC) in the study area, with a discriminatory accuracy of 30 meters, according to the Supervised classification method, using the ENVI 5.3 program, and according to the Anderson classification, which is approved by The US Geological and Survey Authority (USGS), and after conducting several manipulations of the satellite data by using the ArcGIS 10.8 program, and in accordance with the (SCS) classification, four types of land cover and land uses were distinguished for the studied basins, as shown in Table (4) Map (3), **as follows:**

Map (2): Classes of hydrological soils for the basins of the study area



Source: The researcher's work based on Table (2) and using (ArcGIS10.8) software.

1.2: Agricultural lands:

These lands are spread in separate areas of the study area, especially in the western and northwestern parts of the study area, with an area of (59) km^2, or (5.6%) of the total area of the region. It is represented by the lands of the valley basins and the alluvial flood soils formed from the deposits of the valleys' streams[(9)].

2.2: Residential lands:

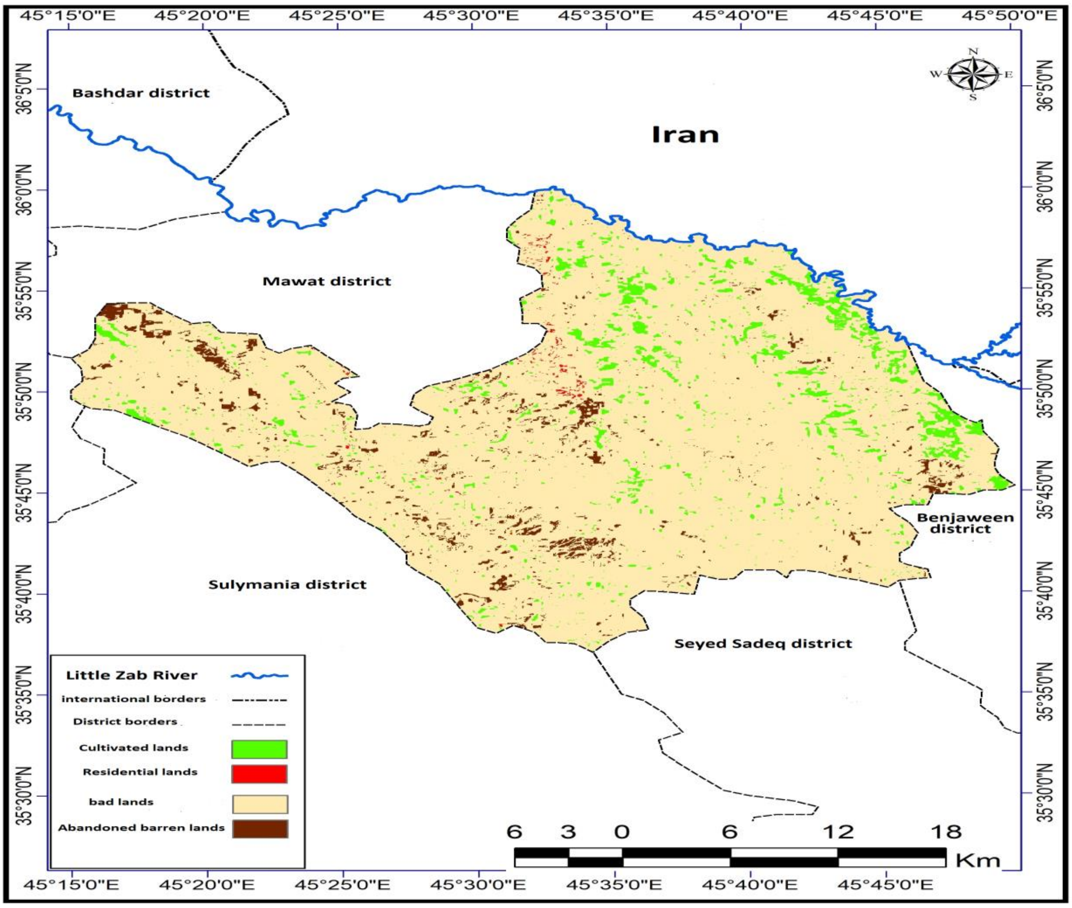
This category includes residential uses represented by villages, health and educational institutions, small industrial places, and others. This category occupies separate parts represented in villages scattered in the valleys[(10)]. The area of this classification is (3) km^2, and by (0.3%) of the area of the basin, and thus it represents the smallest area. among other categories.

3.2: Bad lands:

and this type of uses occupies the upper parts of the mountain slopes, as the degree of land slope does not allow the accumulation of fragments on it. basin and thus occupies the first place in terms of area, This region occupies large parts of the study area, as its area (958) km^2 constitutes (90.9%) of the total area of the pelvis, and thus occupies the first rank in terms of area.

4.2: Mixed Barren Land:
and is spread particularly in the central parts and the eastern and northeastern sections of the study area, and it ranks third in the region in terms of area as it reached (34) km^2, i.e. (3.2%) of the total area.

Map (3) Land Cover and Land Use, Sharbazir District



Source: The researcher's work, based on (ArcGIS 10.8)

Table (4) Classification of land cover and land uses in the study area

no	Land cover type and land uses	Area/km2	Area %
1	Cultivated lands	59	5.6
2	Residential lands	3	0.3
3	bad lands	958	90.9
4	Rocky barren lands	34	3.2
	the total	1054	100.0

Source: The researcher's work based on satellite visualization and the program (ArcGIS 10.8).

3: Antecedent Moisture Conditions (AMC):
It is an indication of the content of the soil surface moisture consisting of three levels of soil moisture for each of the three cases of humidity of its own CN values[11]. notice table (5), This study corresponds to the first case (AMC-I) of soil moisture, which is dry conditions and promised the basis for the humidity of all valleys in the study area and in various models.
AMC equations were the following [12]:

$$\text{CNI} = \frac{4.2 \times \text{CNII}}{10 - 0.058 \times \text{CNII}} \ldots\ldots 1 \quad \text{dry conditions}$$

CNII =CN ....2 normal conditions

$$CNIII = \frac{23 \times CNII}{10 + 0.13 \times CNII} \dots\dots 3 \quad \text{damp conditions}$$

Table (5) Soil Moisture Prior Condition Classification (AMC)

No	the condition	AMC mm	فئةAMC
1	dry	< 35	AMC I
2	Moderate	35-52.5	AMC II
3	Heavy rain	> 52.5	AMC III

Source: Al-Ghobari, H.; Dewidar, A.; Alataway, A. Estimation of Surface Water Runoff for a Semi-Arid Area Using RS and GIS-Based SCS-CN Method. Water 2020

4: How to extract (CN) values for the basins of the valleys of the study area:

CN values express the state of the ground cover and the quality of the soil in terms of the amount of permeability of the surface and water response, and thus shows the ability of the basin to create a surface flow(13). CN values were obtained through the tables prepared by the soil maintenance department American (SCS). Showed in Table (6), through this Table was determined by the values of the (CN) of the study area, as shown in Table (7) we find that the values of the (CN) range between (58-94) with a variation in the areas that each category occupies each of these categories, The average value of the CN was (75.9) This indicates that the permeability is few in general In the study area, Most parts of the study area can obtain a water -watery generation, with the possibility of determining the appropriate place to reside a water harvesting project in it. notes Table (6, 7) and Map (4).

Table (6) corresponding CN values for land cover, land use and hydrological soil class.

<table>
<tr><th rowspan="2">Anderson classification code</th><th rowspan="2">Land cover and land uses</th><th colspan="4">The value of the digital curve according to the hydrological soil class</th></tr>
<tr><th>D</th><th>C</th><th>B</th><th>A</th></tr>
<tr><td rowspan="6">21</td><td colspan="5">agricultural lands</td></tr>
<tr><td>Without soil protection treatment</td><td>91</td><td>81</td><td>79</td><td>72</td></tr>
<tr><td>With soil protection treatment</td><td>81</td><td>78</td><td>71</td><td>62</td></tr>
<tr><td>Light wing, light cover, no diseases</td><td>83</td><td>77</td><td>66</td><td>45</td></tr>
<tr><td>poor conditions</td><td>94</td><td>86</td><td>79</td><td>68</td></tr>
<tr><td>Good conditions</td><td>80</td><td>69</td><td>58</td><td>30</td></tr>
<tr><td rowspan="2">16</td><td>Residential lands</td><td colspan="2">widget size rate</td><td colspan="2">non-access rate</td></tr>
<tr><td colspan="5">92 | 90 | 85 | 77 | 65 units | 1-8 and over</td></tr>
<tr><td rowspan="2">74</td><td colspan="5">poor lands</td></tr>
<tr><td>rocky outcrops</td><td>93</td><td>92</td><td>89</td><td>83</td></tr>
<tr><td rowspan="3">77</td><td colspan="5">Barren lands, grasslands, golf courses, cemeteries</td></tr>
<tr><td>Commercial and professional areas 85% are not enforceable</td><td>95</td><td>94</td><td>92</td><td>89</td></tr>
<tr><td>Grassland (orchard or herb farm) medium conditions herbs 50-75%</td><td>82</td><td>76</td><td>65</td><td>43</td></tr>
</table>

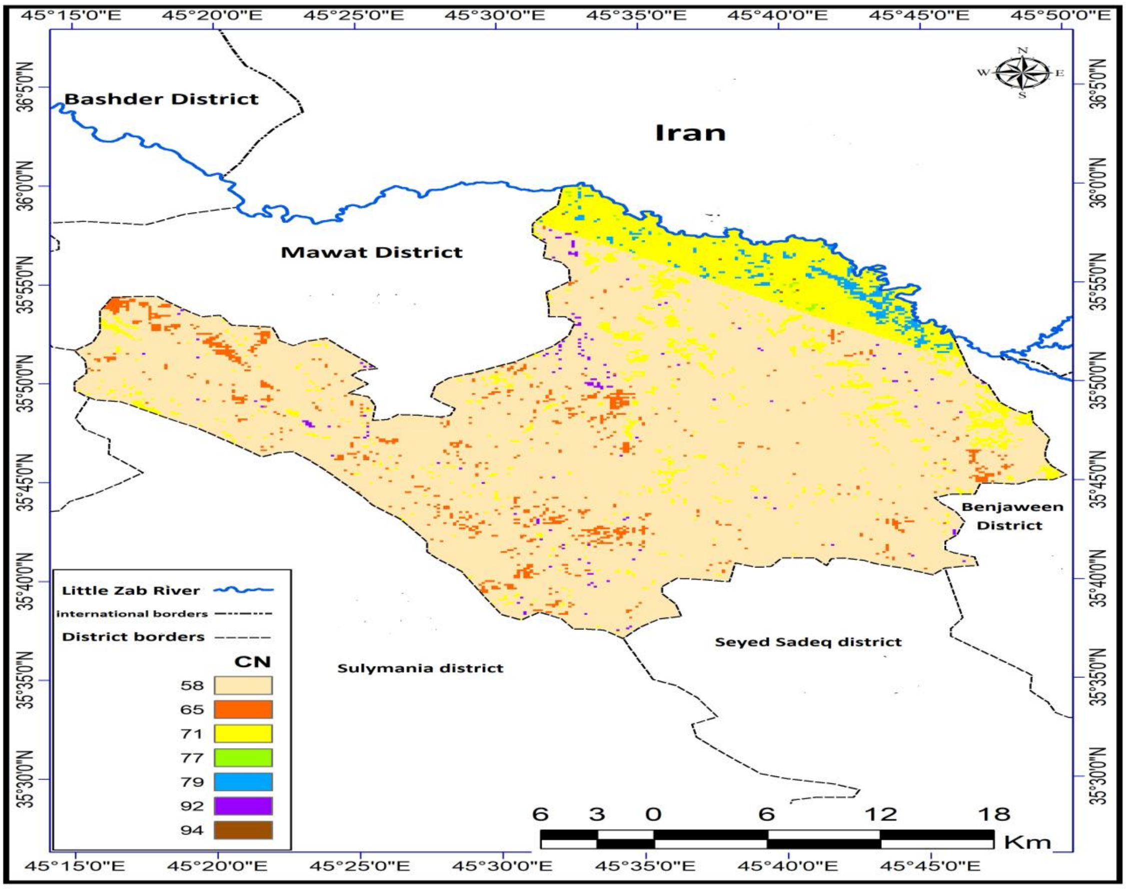
Source: 1-Depending on the classification (Anderson, 1976) and the program (ArcGIS 10.8)
2-USDA-SCS, Urban hydrology for small watershed, department of agriculture, USA,1986, P.3.

Table (7) extracted total CN values for Sharbazir district

cn values	Area/km2	Percentage %
58	859	81.5
65	36	3.4
71	94	8.9
71	47	4.5
77	0.7	0.1
79	12	1.1
92	5	0.4
94	0.3	0.03
Total	1054	100.0

Source: From the researcher's work, based on map (4).

Map (4) extracted total CN values for the study area



Source: 1-Map (3). 2- Map (2). 3- Table (6) using WMS10.1

5: Calculation of the maximum water retention potential coefficient after runoff initiation (S):

The value of (S) denotes the extent to which the soil can retain water after precipitation falls and the onset of surface water runoff(14). To extract the value of (S), mathematical equation No. (5) was applied. Note Table (8).

Through the above table, it was noticed that there is a large discrepancy between the values of (S), as the highest value of it spread in the Sewell Basin, with a value of (183.93) mm, and thus it recorded its highest spread in the Sewell Basin, with an area of (244) km, The total prevalence in all basins of the studied area amounted to (721.3) km2, while the lowest value of (S) amounted to (16.21) mm, and the highest prevalence was in the Little Zab River basin with an area of about (0.2) km2, Based on the foregoing, there are large parts that have the ability to generate surface runoff, especially since the basins of the study area are located within the hydrological (B, C) soil groups, which are characterized by moderate water infiltration because they are medium.

Table (8) S values for the valley basins in the study area

S values	Area/km2	Percentage %
183.93	859	81.5
136.77	36	3.4
103.75	94	8.9
103.75	47	4.5
75.87	0.7	0.1
67.52	12	1.1
22.09	5	0.4
16.21	0.3	0.03
Total	1054	100.0

Source: From the researcher's work, based on map (5) and the application of equation (5).

6: Calculation of the primary extraction coefficient of Sharbazir basins (la):

The primary extraction coefficient (la) shows the amount of rainwater lost before the start of the runoff process, through evaporation, leakage, or through plants intercepting the water, as well as the water collected in depressions[15], The value of (La) represents five value (s), The value that approaches (zero) indicates a decrease in the amount of missing water before the start of the surface water flow, which in turn leads to an increase in the speed of generation of flow[16], and by noticing the table (9) we find that the values (La) is low.

Table (9) values (la) for the valley basins in the study area

la values	Area/km2	Percentage %
36.79	859	81.5
27.35	36	3.4
20.75	94	8.9
20.75	47	4.5
15.17	0.7	0.1
13.50	12	1.1
4.42	5	0.4
3.24	0.3	0.03
Total	1054	100.0

Source: From the researcher's work, based on the values of S and the application of equation (2).

6: Estimating the annual surface runoff depth (Q) using the (SCS-CN) equation:

The depth of the surface runoff for the basins of the study area was calculated based on the annual rainfall data, as the highest rainfall was recorded for the year (2022) on (04/29) for the climate station (Chwarta). Which amounted to (73) mm, and through the application of equation (1) on the basins Study area It is clear that the value of (Q) total amounted to (992.8) mm for all basins of the study area, By observing Table (10), we find that the value of the depth of runoff in a rainstorm varies from one basin to another, just as the same values vary within one basin. (5.96) mm is the lowest value for the depth of runoff, and it extends over a large area of the studied basins, It reached (721.3) km, or (72.65%) of the total area of the basins, The highest value is considered to be the runoff depth, which is (56.60) mm, as it occupied about (0.3) km of the ponds' area, (0.03%) of the studied ponds' area. The rest ranged between (11.52-52.88) mm of the runoff depth.

This discrepancy in the surface runoff depth values of the basins of the study area is due to the variation in leakage rates, and according to the Horton model, the leakage capacity of any area during rain is It is not stable, as it starts with high initial values and then decreases rapidly, that is, after about half an hour to two hours, to reach a stable peak after that, Therefore, a large amount of the beginnings of precipitation is lost through leakage, As the leakage rates increase with an increase in the amount of rain and decreased by their decrease[17].

Table (10) Q values for the valley basins in the study area

Q values	Area/km2	Percentage %
5.96	859	81.5
11.42	36	3.4
17.50	94	8.9
17.50	47	4.5
25.01	0.7	0.1
27.87	12	1.1
51.88	5	0.4
56.60	0.3	0.03
Total	1054	100.0

Source: From the researcher's work, based on the results of equation No. (1).

7: Estimate Annual Runoff Volume (QV) Using the (SCS-CN) Equation:

The volume of runoff is expressed in the total water runoff to the area of the basin, and the volume of runoff is one of the important hydrological studies for many hydrological studies [18]. Estimating the volume of surface water runoff helps to know the places most vulnerable to torrential waters within the water basins, which helps in knowing the size of groundwater recharge. And locating dams and reservoirs [19].

To reach the calculation of the volume of surface runoff for the basins of the study area, Equation No. (6) was applied, and by using the results of the depth of surface runoff for the studied basins, it was concluded that the annual surface runoff volume values for the studied basins in the Sharbazir district ranged between (332515.7 - 1911086) m^3, The total volume of surface water runoff in all the studied basins of the district was (7963362) m^3, Table (11).

Table (11) The volume of surface water runoff for the basins of the study area

No	Basin Name	Surface Runoff Volume (m^3)	Percentage %
1	Sewell Basin	1911086	24.00
2	Galatsholan Basin	1179222	14.81
3	Surrey Basin	1012063	12.71
4	Zab River Little	2045468	25.69
5	Kumasi Basin	744238.2	9.35
6	Koah Basin	381272.5	4.79
7	Boalak Basin	357496.7	4.49
8	Goochy basin	332515.7	4.18
Total		م³7963362	%100

Source: From the researcher's work based on Tables (1, 12) and Equation No. (6).

Conclusions:

1- The (CN-SCS) method is one of the important methods in studying the hydrological characteristics of water basins, with reliance on geographic information systems technology represented by the program (0.71 - ArcMap) to obtain accurate estimates of the studied hydrological variables.

2- The values of (CN) range between (58-94) with a variation in the areas occupied by each of these categories, and that all values of (CN) exceed the median (50), which explains that the study area is characterized by surface runoff rates that fall between between medium to high flow, as the average value of (CN) was (75.9), and this indicates that the percentage of permeability is generally low in the study area

3- The values of the coefficient (S) in the basins of the study area ranged between low values and medium values, and this indicates the varying speed of soil response to surface water runoff during a rainstorm, and This fully agrees with the data for the values of (CN), This indicates the speed of response to surface runoff in the area during rain.

4- We can notice the values of the initial extraction coefficient (LA), which shows the amount of rainwater lost before the start of the surface runoff process in the basin, ranging between (9) mm for the lowest initial loss of rainwater, and (7905) mm for the highest loss of rainwater, which indicates To the possibility of generating surface runoff, because most of the study area is below the aforementioned median (5008) mm.

5- The annual surface runoff values for the studied basins in the district of Sharbazir ranged between (332515.7 - 1911086) m^3, the total volume of surface water runoff in all studied basins of the district is (7963362) m^3.

Recommendations :

For the purpose of preserving running water and reducing the risk of floods in the basins of the study area, the researcher suggests the following:

1- The necessity of activating water harvesting projects in the region's basin, especially since that basin possesses natural and human elements that help activate these projects, especially in lands with fertile soil that increase the elements of development in its various fields.

2- The need to install hydrological stations in the basin to know the amount of water revenues and discharges, especially since the basin receives large amounts of water that goes to the Little Zab River in vain without being properly exploited.

3- The need to pay attention to the construction of dams in the basins of the region and to manage them well to benefit from their waters.

4- Benefiting from the results of the current study by the concerned authorities in resource management water, and studying the possibility of harvesting water in the region in light of the shortage in irrigation projects to preserve the elements of agriculture and land productivity.

5- The study recommends supporting and encouraging researchers to apply the water harvesting technique in the adjacent basins and benefit from the amounts of water that are wasted every year without benefiting from it.

6- The necessity of supporting the farmer financially by government agencies and providing all requirements necessary that helps to develop the land and increase its productivity.

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