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Building a runoff model of Wadi Al-Rahimawi basin by SCS-CN method

By

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Abstract

The importance of studying the Al-Rahimawi Basin comes from the fact, it provides an important water resource for all human uses, especially since a lot of human activities were centered on it. Administratively, the Wadi Al-Rahimawi basin is located in the Najaf Governorate, it is bounded on the northwest and north by the Khar Valley basin, from the east, the eyes of the lions, from the south and southwest, the basin of Wadi Abu Khamisat, from the west, the Al-Hajara region. It has an area of 111 km². The research problem was that the Al-Rahimawi basin suffers from a lack of water resources, it is one of the areas that fall within the dry and fluctuating rain region, led to be the environments that repel any human use, despite the appropriate geomorphic and hydrological capabilities. While the research hypothesis (At the Al-Rahimawi basin there were large quantities of water, it goes to waste without being used in various fields, as a result of the availability of suitable geomorphic and hydrological capabilities). The aim of the research is to estimate the quantities of water, which were found in the aquarium and benefit from it in all respects. The study found the possibility of developing the basin in all aspects, by water harvesting, about ways to create a small-sized earthen dam, or follow the process of industrial injection, in addition, the development of agricultural activity and natural vegetation, development of human settlements and recreational and tourism aspects, development of transportation routes and exploitation of natural resources in the basin. It also found the presence of five types of ground covers and two types of hydrological soils in the Al-Rahimawi Valley Basin. It also found that the highest surface run-off depth was 20,120.5 mm in the downstream area, this indicates the possibility of generating surface runoff, the results also showed that the highest volume of surface runoff reached 511,059.81 m^3.

Keywords: Building a runoff model, Wadi Al-Rahimawi basin, SCS-CN method.

Introduction

The SCS-CN method was used to estimate the water harvest, developed by the US Department of Agriculture's Soil Conservation Service in 1970. The water harvest was estimated according to this method in a GIS environment, adopting Environment (ARG GIS 10.4), and remote sensing technologies, for accurate determination of areas with runoff, to choose the optimal site for water harvesting. This study works with cell units (pixels), dimensions (30 x 30) meters, this allows to obtain accurate results covering the pelvis.

Research problem:

Is there a surface runoff in the Wadi al-Rihimawi basin that can be used in the development of the area?

Research hypothesis:

In the basin there are quantities of water that can be used to develop the basin.

Research goal:

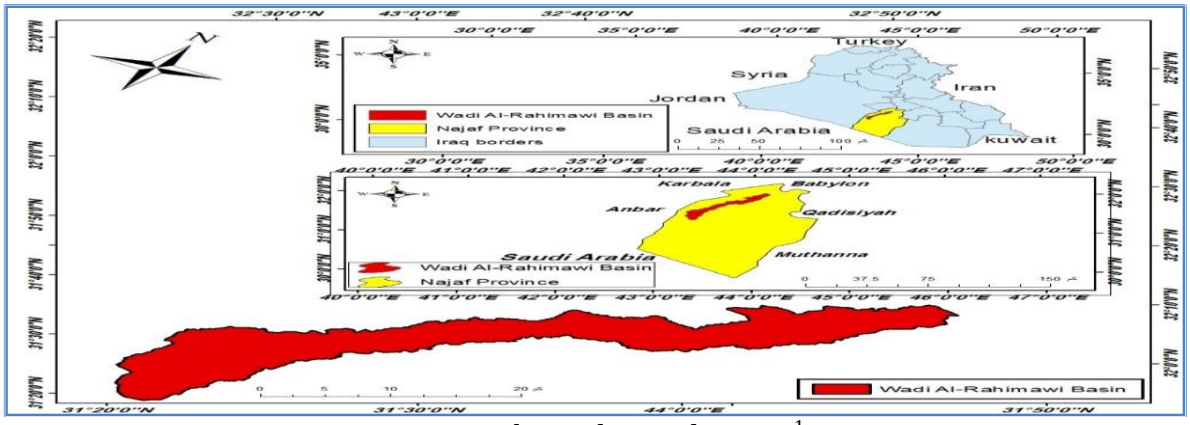
The research aims to estimate the volume of runoff in the Wadi Al-Rahimawi basin and work on its development.

Research structure:

The research included an introduction and calculation of the volume of runoff, by extract method (cn), by describing the vegetation cover and hydrological soils in the basin, calculation of the maximum water retention capacity after the start of the runoff (s), calculation of the initial extraction coefficient for the Wadi Al-Rahimawi basin (Ia), then the estimation of the depth of the runoff and the estimation of the volume of the runoff. The research also included conclusions, recommendations and a list of sources.

Research limits:

The basin area is 111 km² .Administrative within the Najaf Governorate, it was bounded on the northwest and north by the Khar Valley basin, from the east were Ayoon Asaweed, from the south and southwest, the Abu Khamsat valley basin, from the west, Al-Hijjara area. An astronomer is located between latitude 5100 1840-29 32 N, between longitudes 42 48 42-45 34 44 East, (Map 1).



Map 1: The study area location[1]

The (SCS-CN) method requires many stages, equations, and procedures, to obtain accurate runoff estimates, to complete the water harvesting selection processes. The approved equation for measuring the flow curve according to (USDA) is as follows (USDA-SCS, 1986):

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

Where Q = depth of runoff (inches).
P = Rainfall (inches).
Ia = primary extracts before surface runoff, such as soil, reception by plants, and evaporation (inches).
S = maximum runoff after onset of runoff (inches).
It was found that Ia was equal to one-fifth of the value of S, and Ia is calculated as follows:
Ia= 0.2 S .....(2)

S was calculated by the following mathematical formula:

$$S = \frac{1000}{CN} - 10 \quad \text{.....(3)}$$

[1] The researchers' work based on the administrative map of Iraq and Najaf Governorate and the satellite video of LANSAT, using the Arc Gis 10.4 program.

Note that the data input was in inches, so it was necessary to reformulate the equation, for compatibility with metric scales, the numbers in the previous equation are multiplied by 4.25, to convert to millimeters, it became in the following form: -

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

To prepare layers (Q, Ia , S), the equations have been entered into the program (ArcGis10. 4), by using the Raster Calculator, within the functions of the Spatial Analyst. Finally, the volume of surface runoff was calculated using the following equation:

$$= (Q * A/1000) \quad \text{.....(5)}$$

First: Extraction (CN):

(CN) can be extracted in the following stages:

It was used to characterize the rain characteristics of a specific type of soil, land cover and land use (Hameed, 2013), its value ranges between (1-100), it expresses the water response of the components of the basin between high and low permeability, as the values go towards 100, the surfaces of the basin are less permeable, if the values go to zero, the surfaces of the basin are highly permeable to water.

To get (CN) values, conducting the merging process of the two layers of soil hydrological groups, between the earth's cover layer (land uses), after encoding (Gode) for each layer, values that are different from the values in the other layer, so that the program does not merge categories that will have the same value, two layers (the land uses layer and the hydrological soil layer) have been combined, by the (combine) function in the (ARG GIS 10.4) program, thus, the (CN) values of Wadi Al-Rahimawi basin appear.

The following was an explanation of the requirements that have been studied and analyzed to obtain (CN) values:

A. Description of the vegetation cover:

This process was concerned with clarifying the types of vegetation cover spread in the Al-Rihimawi Valley Basin, as it was relied on the satellite visual for LANSAT (7), on (30/6/2018) with an accuracy of (30) AD for the basin, by relying on wave rating, which was based on previous information from the natural spectral group, or the existing gatherings in the video, what we have found in the repeated field study of the pelvis, then the satellite data was subjected to several stages of processing, via software environment (ARG GIS 10.4), after merging the seven bands, the bands (GBR) were used, were pandas (7, 5 and 3), then the emergence of the ground cover method (Raster) through:

Tool Box ➡ Datamanugment tools ➡ Raster processing ➡ composite Bands land sat

After applying and using these tools on the Land Sat data, it was possible to determine the uses or uses of the land in the Wadi Al-Rahimawi basin, the areas of each use and their percentage of the basins area were used, as indicated in Table (1) and Map (2), as follows:

1. The lands of Botton valleys:

This type of land covers an area of 145.51 km^2 with a percentage of (13.08)% of the basin area, it consists of sediments that are moved to it by erosion processes, it has some permanent trees, which grows throughout the year and its soil is suitable for agricultural and human uses.

2. Barren lands:

It consists of rocky lands and open lands, be unsuitable for cultivation, due to the presence of a number of rock discoveries, to be free from vegetation, these lands occupied the first place in the region in terms of area, it reached (447.97) km^2, or (40.27%) percent.

3. Swampy lands:

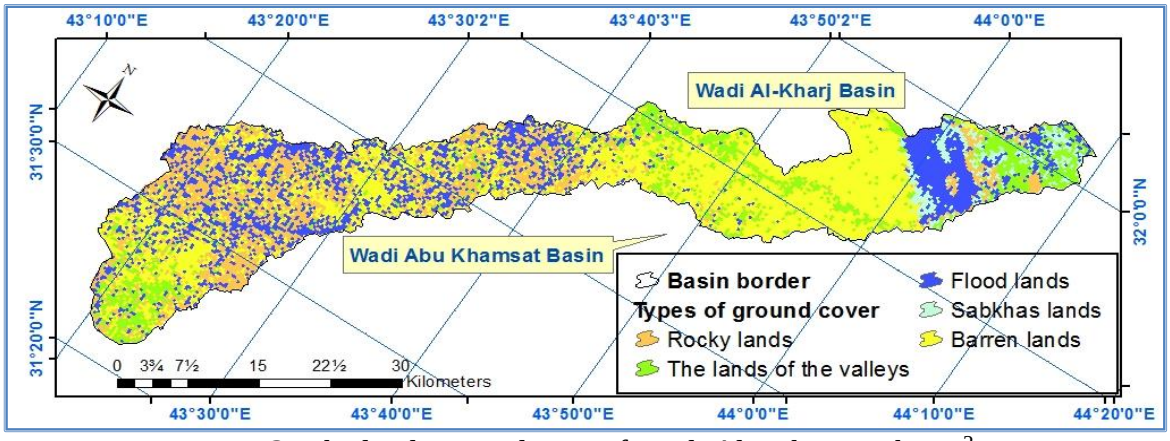
These lands are located in some flood areas, and areas of the stomachs of the valleys, where the groundwater was close to the surface, these lands are formed as a result of the high capillary property and the rise of groundwater from the ground to the surface, thus, it evaporates, leaving the salts on the surface, these lands are not suitable for cultivation, because the percentage of salt does not help the plant to grow and is not suitable for human use, and the area of these lands is 37.84 km^2 at a rate of (3.42)% of the area of the basin.

4. Rocky lands:

These were bare areas of soil with exposed rocks, the infiltration rate of this type of ground cover is related to both its porosity and the degree of permeability, which differ according to the rocks, joints and fissures, it constitutes an area of (236.55) km^2, or (21.27%) of the area of the basin. In general, bare rocks were solid and have little porosity, this allows the emergence of high surface runoff.

5. flooded lands:

It was covered with water in the winter, especially after rain, it has low permeability and porosity, thus, it was covered with water for as long as possible compared to the surrounding lands, it occupies an area of (244.34) km^2, or (21.96%) of the area of the basin, as these lands were low, thus, it collects water coming from the surrounding lands.



Map 2: The land cover classes of Wadi Al-Rahimawi basin[2]

Table 1: The land cover classes of the Wadi Al-Rahimawi basin[3]

Cover types	Area (km^2)	Percentage
Flood lands	244.34	21.96
Rocky lands	236.55	21. 27
The lands of the valleys	145.51	13.08
Sabkhas lands	37.84	3.42
Barren lands	447.97	40. 27
Total	1112. 21	100.00

[2] From researchers based on satellite visuals for Lancet and using the Arc Gis 10.4. program
[3] The researchers work based on map (2).

B. Hydrological soils:

According to the rate of water transfer or water infiltration into the soil, or distinguish between levels of water infiltration into the soil. Soils were classified by the US Soil Service (SCS) into four hydrological groups (A, B, C, and D). Soil hydrological groups are named, and each type has its own characteristics. (A and D) represent two extreme cases. (A) Very low runoff. (D) Very high runoff. The values (C, B) are two average cases for the flow, according to Table (2), it was observed that there are two types of hydrological soils in the Wadi al-Rihimawi basin, its area and percentages were calculated as in Table (3) and Map (3).

1. Hydrological group (B):

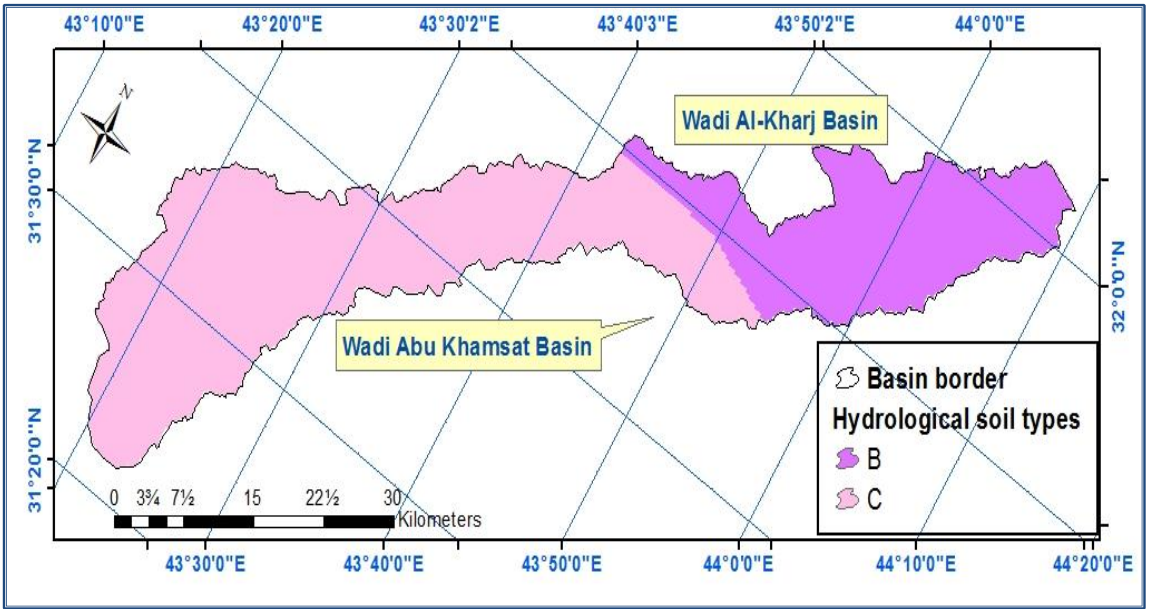
This group consists of coarse to medium texture soils, with depths and permeability ranging from medium to good, often shallow in depth, it was a mixture of boulders, pebbles and rock fragments, what binds them is a material consisting of silt and containing gypsum materials, this group covers most areas of the basin, it was located in the upper reaches of the Wadi Al-Rahimawi basin, in the central regions of the basin in the sloping regions, this group occupied an area of (377.20) km^2 of the basin area, with a percentage of (33.92)%.

2. Hydrological group (C):

It consists of pebbles, boulders and stones covered with a sandy layer of coarse texture, its color ranges from pale brown to dark brown, because it contains oxides of iron and clay, it occupies the upper sewers of the basin, its texture is coarse, as well as the middle parts in areas with sloping sediments, in which the tissue is less coarse than the upper ducts, it covers an area of (735.01) km^2 and represents (66.08)% of the basin.

Table 2: Types of Hydrological Soils According to (SCS) (USDA-SCS, 1986)

Types	Flow depth	Soil types
A	Little	Deep sandy layer with a small amount of clay and silt.
B	Middle	Sand layer shallower than A with middle infiltration rate after wetting.
C	Above middle	A clay layer with a specific depth, with a sub-median infiltration rate before the soil is saturated, or a rocky layer covered with a layer of soil.
D	High	A clay layer with a high rate of swelling with a shallow layer of soft soils close to the surface or a bare rocky layer.



Map3: The hydrological soil classes of the Wadi Al-Rahimawi basin (USDA-SCS, 1986)

Table3: The hydrological soil classes of the Wadi Al-Rahimawi basin[4]

Percentage	Area (km^2)	Soil types
33.92	377. 20	**B**
66. 08	735. 01	**C**
100	1112. 21	**Total**

C. Antecedent Soil Moisture Condition:

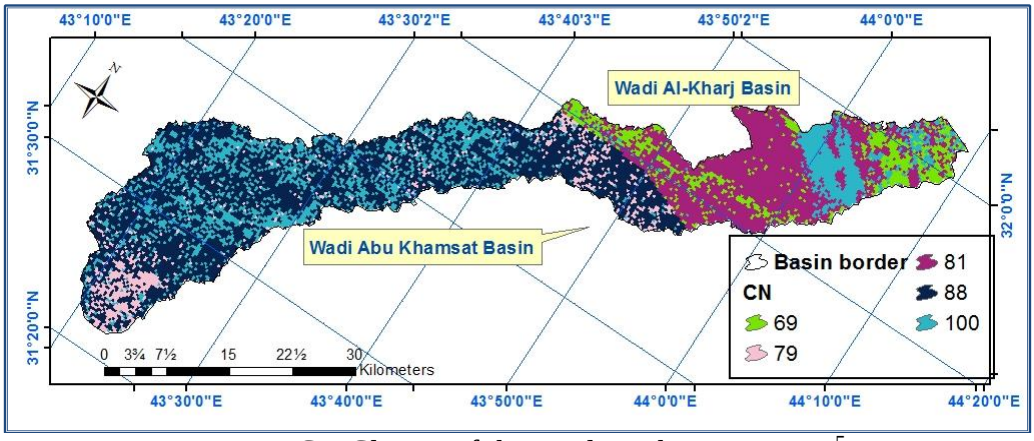
Its role was important in the volume of surface runoff, it was also an indicator of the moisture content of the soil before the rainstorm, as a result of the above, the SCS method, to develop work on this aspect of estimating (CN), three levels of humidity were used:

- **The first level (ACI)** represents the cut-off point for dry soil.
- **The second level (ACII)** represents the soil in the normal state
- **The third level (ACIII)** requires light to heavy rain and a decrease in temperatures during the previous five days to calculate the surface runoff, as the soil is saturated with water.

Table 4: Appendix prepared according to (SCS) method to derive curve numbers (CN) (Singh & Frevert, 2010)

Land Use Description		Hydrological soil groups			
		A	**B**	**E**	**D**
Cultivated land					
Without soil protection treatment		72	81	88	91
With soil protection treatment		62	71	78	81
Artificial pastureland and natural pasture					
Poor conditions		68	79	86	89
Very rich conditions		39	61	74	80
Grassland					
Good conditions		30	58	71	78
Forest lands					
Light wing - little cover - no diseases		45	66	77	83
Thick and rich cover		25	55	70	77
Open grounds - grasslands - golf courses - cemeteries					
Good conditions: grass cover 75% or more		39	61	74	80
Medium conditions: grass cover between 50-75%		49	69	79	84
Commercial and professional areas are 85% impermeable		89	92	94	95
Industrial provinces 72% are not permeable		81	88	91	93
Residential lands					
Ineffective rate	**Widget size rate**				
1-8 or more	**65**	77	85	90	92
1-4 or more	**38**	61	75	83	87
1-3 or more	**30**	57	72	81	86
1-2 or more	**25**	54	70	80	85
1 or more	**20**	51	68	79	84
Paved parking lots - rooftops, driveways...etc.		98	98	98	98
Streets and roads					
Paved with sidewalks and storm drains		98	98	98	98
Unpaved gravel roads		76	85	89	91
Abandoned roads		72	82	87	89

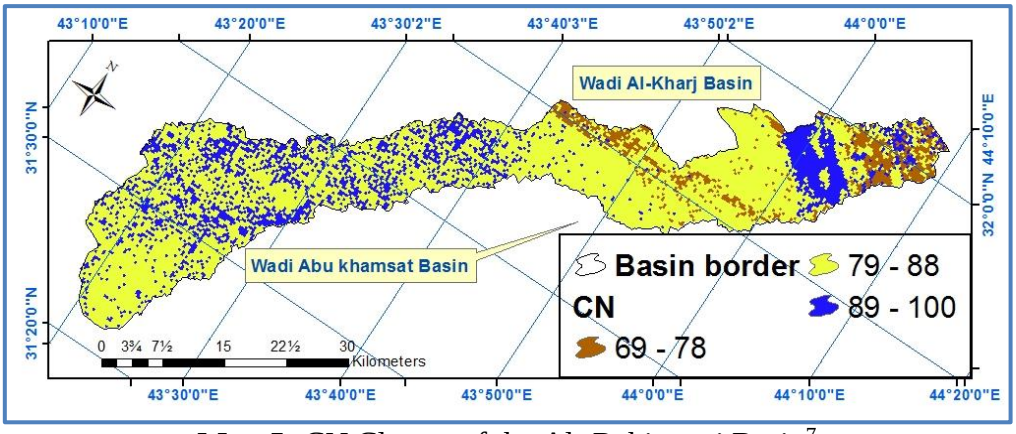
[4] The researchers' work based on a map (3).



Map 4: CN Classes of the Wadi- Rahimawi Basin[5]

Table 5: CN values for Wadi Al- Rahimawi Basin[6]

Percentage	Area (km^2)	CN
6.87	76.43	69
6.24	69.37	79
20.92	232.76	81
44.78	497.95	88
21.19	235.70	100
100	1112. 21	**Total**



Map 5: CN Classes of the Al- Rahimawi Basin[7]

These levels have their own CN values, in this study, the second level of soil moisture was determined, represented by the normal natural condition for calculating the characteristics of the surface runoff of the Al-Rahimawi basin.

Then (CN) values were obtained, through a process of integrating the ground cover layer and the hydrological groups of the soil, considering that the pre-condition of soil moisture is the second level, it was possible to obtain (CN) (SCS) values to derive these values, as it can be noted that the (CN) values range between (66-100). The researchers classified these values into three categories, (Map 5). As these categories showed a discrepancy in terms of the space they occupy. We note from the above that the entire area of the Al-Rahimawi basin falls within the high (CN) values, this indicates to us that a large

[5] The researchers' work based on the map (3,4) and table (4), and using the Arc Gis 10.4 . program.
[6] The researchers' work based on Map (4) and using the Arc Gis 10.4 . program
[7] The researchers' work based on a map (4).

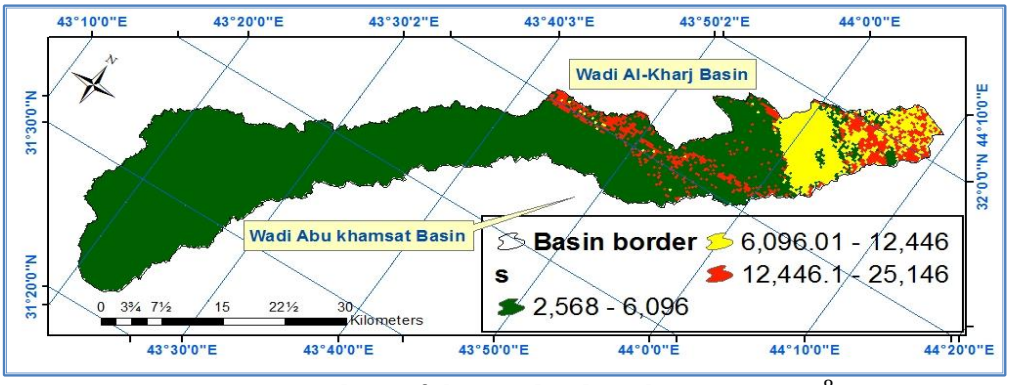
proportion of the basin area. It can generate a large surface runoff, as we note that all values exceed (50), this was in support of the possibility of the Al-Rahimawi Basin to create strong surface runoff, with the lack of infiltration, which makes the basin suitable areas for the establishment of dams and projects for water harvesting.

Second: Calculating the maximum water retention capacity after the start of the surface runoff (s):

Factor (S) Potential Maximum Retention After Runoff, an indicator of the maximum water retention potential in the soil, or water retention in the soil after surface run-off, the parameter describes the condition of the soil completely saturated with water after run-off, meaning, after the leak, there was variation in the thickness of the soil layer saturated with water, depending on the type of soil and its ability to absorb the largest amount of water during a rain wave, from that, it can be emphasized that this parameter is directly related to the type of soil and land use (Al-Nafi'i, 2010).

The high values of the coefficient (S) indicate the high water holding capacity of the soil, thus, the amount of runoff decreases, whereas, values close to zero indicate a low water retention capacity of the soil, which was reflected in the provision of a large amount of running water on the surface (runoff water).

The values were calculated according to equation No. (4) Table (6), extracting results in a program environment (Arc Gis10.4), using (raster calculator), obtaining values and results from which a map was extracted to determine these values, their areas and proportions. The values of the parameter (S) ranged between (2,600) mm. It was the least able to hold water on its surface, between (25,000) mm for the most water-retaining parts, that do not assist in the completion of the process of surface runoff, from observing the maps, it becomes clear that most parts of the basin and their regions fall within the low categories (2,600 - 6,100) of the (S) parameter, this indicates a high surface run-off, this proves the validity of the results of (CN) as in Map (6) and Table (6).



Map 6: S-values of the Wadi Al- Rahimawi Basin[8]

Table 6: S-value distribution clsses for the Wadi Al- Rahimawi Basin[9]

Values S	Area (km^2)	Percentage
6,096 - 2,568	912.88.	82. 07
12,446 - 6,096.01	122. 06	10.98
25,146 - 12,446.1	77. 27	6.95
Total	1112.21	100

[8] The researchers' work based on (S) equation and using the Arc Gis 10.4 . program
[9] The researchers' work based on Map (6) and using the Arc Gis 10.4 . program

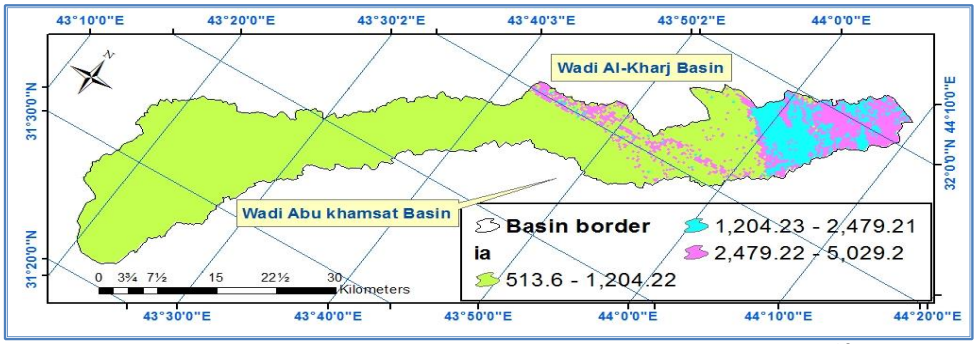
We also note that the category (2,568 - 6,096) occupies most of the area, with an area of (912.88) km^2 and a rate of (82.07)%, it represents the lowest values of the parameter (S). If these lands are characterized by being rocky with little permeability and porosity, it reduces water retention, which do not contain within their components what would allow the preservation of water on the surface, thus, the maximum potential of the surface to hold water becomes low, this allows the surface run-off process to take place, while we note that the category (12,446.001 - 25,146). The values of the parameter (S) are high in those regions they represent, as these areas have a large capacity to conserve water, and consequently, the surface run-off is slow, as this can be observed in the areas covered by the estuary region, which was characterized by soil with porosity and high permeability.

It can be seen from the map (6). We note that the high values (CN) were the same regions for the low parameter values.

Third: Calculating the initial extraction coefficient for a basin according to (Ia):

Initial extraction factor (Ia), one of the important elements in equation (1), from which all values are extracted estimating the amount of runoff, as it was known that this factor has a close relationship with soil and land cover and its relationship to the parameter (S), as shown in Equation (Ia), it represents one-fifth of a value (S), it was inferred from the initial extraction values that are close to (zero) that the amount of rain water lost before the start of the surface run will decrease and decrease, which helps speed runoff, while the initial extraction rate becomes equal to the rate of running water on the surface, if the median value of the parameter (Ia) is (50.8) mm, whereas if the value of (Ia) was higher than the median value, this indicates the loss of higher amounts of rain, thus, the amount of running water on the surface decreases.

It was possible to calculate the parameter values for the Al-Rihimawi Basin using the (Arc Gis) program, by the tool (Raster Calculator) under the Spatial Analyst menu. The equation was calculated to produce a Raster map in which pixels with similar values are shown in a certain color, from that, we find that the pan of the Al-Rahimawi basin, it cannot generate runoff in large quantities, provided that all the values that appeared above the median values mentioned above (50.8) mm, as shown by the map (7), this was due to the high temperatures throughout the region, this leads to an increase in evaporation. The total water turbidity throughout the year was (2448.8) in the study area, in addition, we note that there is discrepancy in the values of (Ia), as we notice high values at the mouth of the basin, it reached (5,029.2) mm, and this is due to the manifestations of rock weakness in that region, this allows water filtration, as well as being the most permeable and least able to generate surface runoff in the basin.



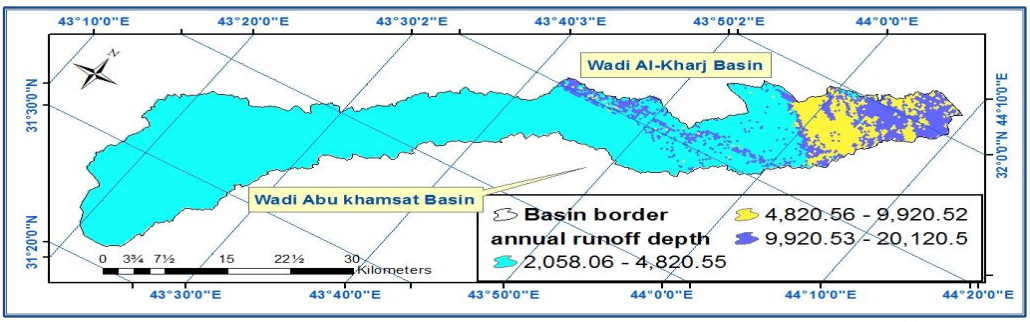
Map 7: The Ia values of the Wadi Al- Rahimawi Basin[10]

[10] The researchers' work based on (Ia) equation and using the Arc Gis 10.4 . program

Fourth: Estimation of the depth of flow (Q):

Through what was revealed from the natural data of the Al-Rihimawi Basin, which we infer through the values of (Ia, S, Cn), calculate the annual average for each cell, which we obtained based on the annual rainfall data for the stations, through which the surface runoff was calculated in the Al-Rahimawi Basin, using the cellular calculator (Raster Calculator), within the list of Spatial Analyst in Arc Gis, where the depth of runoff was calculated for each cell in the basin, according to equation No. (1) mentioned at the beginning of the research, the depth of runoff reflects the amount of water running on the surface during rainfall, regardless of the aggregate area of the aquarium. The study showed a decrease in the values of the depth of surface runoff in the headwaters area, as in Map (8), the lowest amounted to (2,058.06) mm, while the highest amounted to (20,120.5 mm) in the downstream region, which indicates the possibility of generating surface runoff.

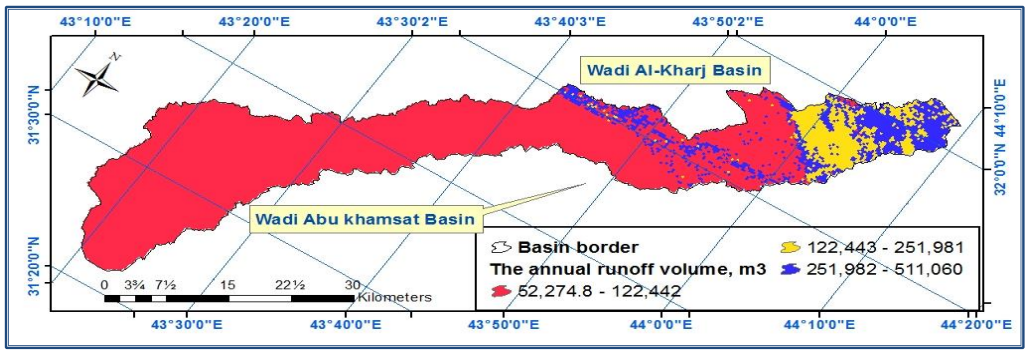
The study showed a discrepancy in the values of the depth of flow between the upstream region and the downstream region, this indicates the possibility of generating aggregate surface runoff in the upstream and central regions (collection), where 70% of the precipitation water turns into surface runoff.



Map 8: The depth of runoff of the Wadi Al- Rahimawi Basin[11]

Fifth: Estimation of the volume of surface runoff:

After the depth of flow (Q) has been obtained, the annual runoff volume has been calculated, as shown by equation No. (7), using the program (4Arc Gis 10), after we get the value of (Q) for each existing pixel and the presence of the area of each pixel, which was (30 x 30) meters, this gave a fixed area for all pixels of (900) m^2, when applying the formula for annual runoff volume (QV). The results showed that the highest flow rate was (511,059.81) m^3 represented by the third category, whereas, the lowest surface runoff in the basin in the upstream region reached (52,274.848) m^3, and this is represented in the first category.



Map 9: The annual runoff volume, m3 for the Wadi Al- Rahimawi Basin[12]

[11] The researchers work and using the Arc Gis 10.4 program, based on equation (1) and a map (7-6-4).

Conclusions

The researcher reached a number of conclusions that can be listed as by relying on the (SCS - CN) method, by which the annual runoff volume of the Wadi Al-Rahimawi basin was estimated, which varies between 511,059.81 m^3 as the highest volume of surface runoff, and 52,274.848 m^3 as the minimum surface runoff volume in order to obtain the most accurate information.

We note that the basin has a surface runoff that can be used in the process of water harvesting and basin development.

Suggestions:

1. Interest in hydrological studies through model representation, it helps in estimating the conditions of the hydrological processes taking place in the Al-Rahimawi water basin, it may enrich us in many cases in studying many of the hydrological characteristics of the water drainage basin, hydrological modeling is the link between remote sensing techniques, using the data and maps provided by satellites on the one hand, and geographic information systems on the other.
2. Working on the construction of low-cost dams for neighborhoods of the largest possible amount of land, instead of building large dams without objectively benefiting from water, by government support and encouragement to benefit from them in environmental development.
3. Make the most of the water of all the aquarium, especially since the area has a dry climate and suffers from a very large scarcity of water and work to benefit from it locally.
4. It is necessary to establish hydrological measurement stations on the course of the Al-Rahimawi Basin, to find out the volume of water drainage, in order to enable subsequent studies in order to obtain a comprehensive access to all the hydrological and natural characteristics of the study area, benefiting from it in the development of the region, whether through water harvesting or other human uses.

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[12] The researchers work and using the Arc Gis 10.4 program, based on equation (1) and map (8).