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# Hydroclimate of Wadi Diwana Basin in Sulaymaniyah Governorate using Gis & Rs

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## ABSTRACT

The study relied on the relationship of climatic characteristics to the surface runoff of the Wadi Diwanah Basin, by studying the nature and type of rainfall for the study area and creating a climatic water balance,the study was used Climate mathematical equations (Penman-Monteith equation) Prepared by the Food and Agriculture Organization of the United Nations through the (Gropwat 8.0) model to extract the climate water balance for the Darbandikhan station, and for the purpose of applying the equation and obtaining the amount of evapotranspiration, the main climate elements represented by wind m/s, maximum and minimum temperature, relative humidity, and solar brightness were entered into the model. The user, for the purpose of making a climate water balance to know the size of the water surplus and water deficit, and then detecting the size of surface runoff based on the application of the Soil Conservation Service (scs-cn) model, which was designed by the Department of Agriculture in the United States of America in 1970 , as the highest volume of surface runoff reached (5.96) $m^3$ at a rain intensity of (71.24) mm, and how to invest these water resources for the purposes of economic development as many human activities are concentrated near river basins.

**Keywords:** hydroclimatology, Diwanah Valley Basin,SCS-CN model, Gis&Rs.



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The impact of climate hydrology appears from two aspects: rain and the resulting floods and torrents, and drought and the resulting scarcity of rainwater, drying up of lakes, and a decrease in the level of groundwater. Hence the need to study the relationship between climate and the hydrological characteristics of water, as water is one of the elements that must be available and achieved. Its continuous development, as water resources represent the key to sustainable development that contributes to achieving food security for the region.

**Research problem**

1. Do natural characteristics and climate variables have an impact on estimating the volume of surface runoff in the basin?

2. Do the nature of rainfall and rain intensity have an impact on the volume of surface runoff in the basin?

**The study is a hypothesis**

1- The study area is characterized by natural characteristics and climatic variables that affected the volume of surface runoff and the depth of surface runoff of the Diwanah Basin.

2- The rainfall regime and rain intensity affected the volume of water flow.

**Purpose of the study:**

To know the natural characteristics of the study region, as well as knowing the prevailing climate system in the region and its relationship to the surface runoff of the Wadi Diwanah basin, through creating a climate water budget, studying the hydrological situation, determining the impact of the climate, and revealing the water deficit and water surplus in the region during the specified time period.

**Study area location:**

The study area is located astronomically between latitudes (5.35°-23.35°) north and longitudes (10.45°-45.45°) east, with an area of (0.608) km². Geographically, the study area (Wadi Diwanah Basin) is located in North-eastern Iraq is within the borders of Sulaymaniyah Governorate, and the valley ends in the Diyala River in the southwest of Sulaymaniyah Governorate. The region includes two districts: Qarah Dagh and Darbandikhan districts, to the north is Bazian district, to the south and


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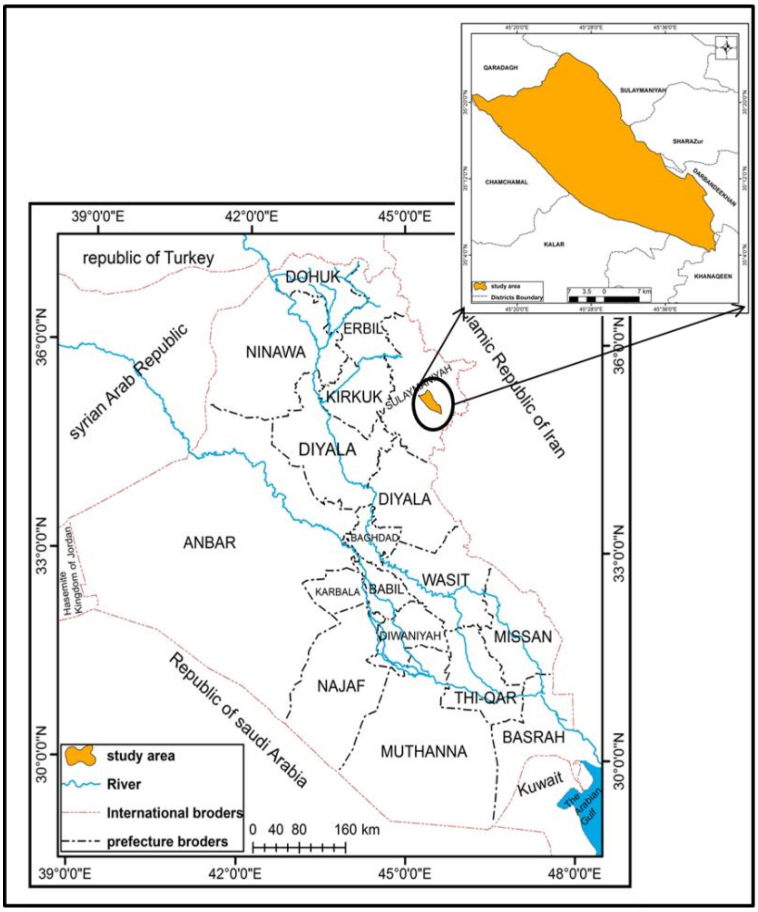
southeast is Baukhushin district, to the west is Chamchamal district, and to the southwest is Beybaz district, affiliated with Kalar district. Map (1)

**Map (1) The study area**




**Refrence: Based on: the Ministry of Water Resources, the General Authority for Survey, the administrative map of Iraq, scale 1/1000000, year 2021, and the outputs of the Arc map 10.8 program.**

## First: The natural characteristics of the study area:

### 1- Geology of the study area:

Tectonically, the study area is located within the range of high layers within the unstable shelf according to the classification of **(Buday 1984).** The Wadi Diwana basin consists of a group of geological formations. Map (2) is the formations of the Miocene era: The formation of this era dates back to 22 million years and consists of two formations: The Fatha Formation and the Inganah Formation, which were deposited during the early stage of the Miocene era, which is from the oldest to the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newest. The Inganah Formation (Upper Miocene) consists of marl, silt, and sandstone rocks with some calcareous deposits that constitute a small percentage,The thickness of the formation is (200) $^{m}$**( Farouk Sanallah1977),** This formation is found on Along the western edge of the study area, the area of this formation is (56.8) km$^{2,}$ the environment of deposition is a riverine environment, the Fatha Formation (middle Miocene), and the exposures of this formation are in the upper part of it, consisting of limestone, gypsum stone, and mudstone. The thickness of the formation is (65) $^{m}$ and the width is (10-20) km(**Paula Ezad2007p21),** Its area within the study area is (134, 7) km$^2$ distributed within the eastern, northwestern and central parts of the basin.

**The Formation of Muqdadiya** (Pliocene) is found on the western side of the study area, with an area of (21.2) km$^2$. The rocks of this formation are associated with limestone or clayey material that is easily removed by erosion factors**(Hatem Khudair2006p16)**.

**The formation of Bay Hassan** (Pliocene) consists of successive concretions and gravel. With layers of silt, clay, and sand, these sediments represent the products of erosion of the mountain ranges that surround the basin. This formation is found in a range northwest of the study area, with a thickness ranging between (300-1900) km **(Hala-Al-Musawi2007p51)**

The environment of deposition is continental fluvial. The Pila Spi Formation (middle Eocene) includes the western and northern parts of the region, with an area of (107.5) km$^2$. The environment of deposition is marine, deposits of multiple origins (Pleistocene - Holocene), which are deposits formed within scattered ranges surrounding the slopes of synthetic convexities and covering flat areas. Between the highlands and consisting of a mixture of sand, silt and clay**(Yousef Muhammad Ali and Iman2022)**, the thickness of these deposits varies between (1-10) $^{m}$ in the outskirts and central areas. Its area within the study area is (29.6) km$^2$.


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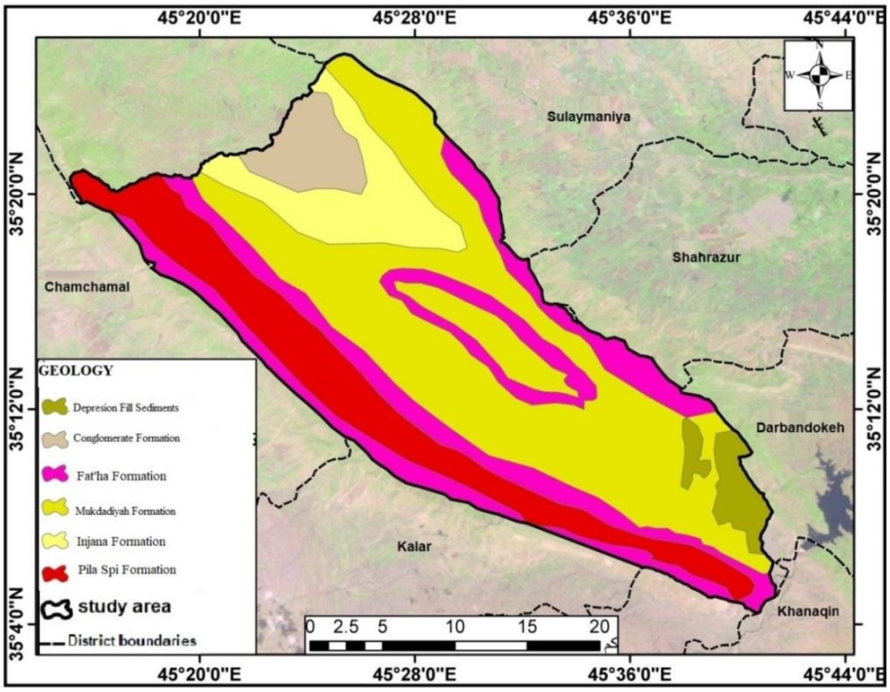
**Map (2) The study area Geology**




**Reference**: The two researchers relied on digital maps issued by the General Authority for Geological Survey and Mineral Investigation and the outputs of the Arc Gis 10.8 program.

**Depression deposits**: These deposits are the latest within the Quaternary deposits, which originate from erosional materials transported from high areas during rainfall and deposited at the bottom of valleys. They are a mixture of gravel, sand, silt, and clay, with varying thicknesses, and are concentrated in the south of the study area with an area of (19.6) km2.

**2- Topography of the study area**: The study area is located within areas of high convolution, and the shapes and surface appearances are distributed within the high mountainous lands in the far north and northeast, and semi-mountainous plateau lands between the highest elevation of 1847 (m) at the extreme northwest of the basin and the lowest elevation (367) m from Sea level map (3) .Altitudes in the middle of the basin vary between (872-1068 m) above sea level.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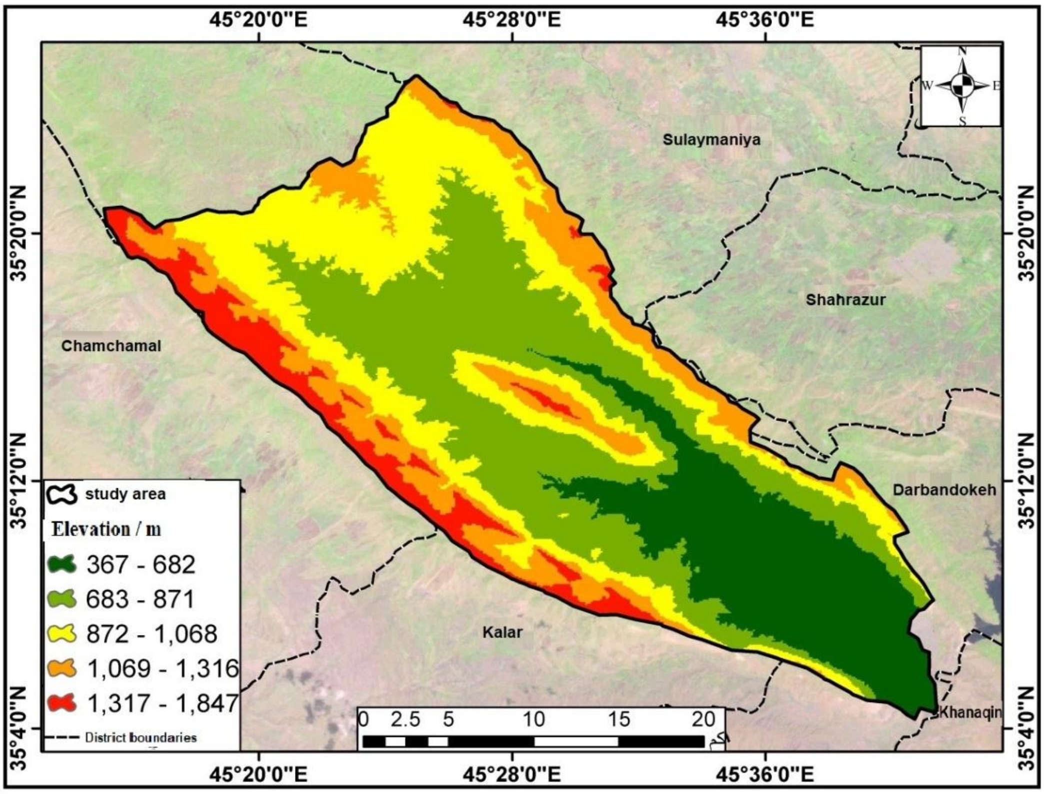
**Map (3) The of Topography of the study area**




**Reference: Based on the DEM digital elevation model, with a resolution of (15*15) m for the year 2023 and the outputs of the Arc map 10.8 program**

**3- Slope characteristics**: Studying the slopes of any area is significant in knowing the flow system and the characteristics of the water network of the river basin. The slopes of the study area were studied, which were derived from the digital elevation model of the study area (DRM) by relying on the geomorphological classification prepared by (ZinggA.W)( Digital elevation model of (30) m US Geological Survey (USGS).

The study area was divided into five regression categories map (4)
**The first category**: Its slope is between (0-1.9) and includes flat plain lands extending in the central and central parts and valley bottoms to the southern parts of the basin, with an area of (21) km².
**The second category**: includes lands with mild undulation and moderate slope, with a degree ranging between (2-7.9) degrees and an area of (267.0) km².
**The third category**: includes hilly areas in the middle of the region affected by water erosion, with a slope of (8-15.9) degrees and an area of (185.8) km².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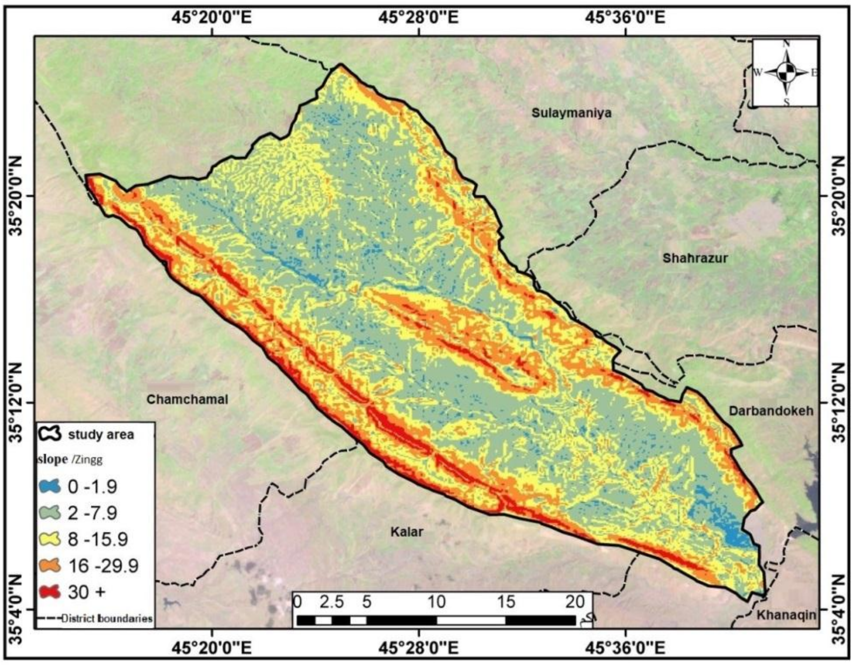
**The fourth category**: includes highland areas whose slope ranges between (16-29.9) degrees and is concentrated in the northeastern regions of the region with an area of (106) km².

**The fifth category**: includes parts whose slope exceeds (30) meters and is distributed within the parts represented by the high mountains in the north of the basin and the western outskirts, with an area of (26.8) km².

**Map (4) the Slope categories**




Reference: The two researchers, based on the outputs of the digital elevation DEM and the outputs of the (ArcGis10.8) program.

**Soils in the study area are classified into the types**:

**Shallow rocky soil**: This soil is distributed on the slopes of the highlands within the region and was formed by the disintegration of limestone and gypsum rocks through the process of weathering, both chemical and physical**( Sayeh Salam Saberp216**).

**Alluvial fan soils**: They are formed in slope areas between mountainous and plain lands and are characterized by a mixture of rock debris deposits, small gravels, and sand. These soils are characterized by high permeability and good drainage, They are exploited by village residents and are found in the western part of the study area.

**Floodplain soil:** consists of sediments from valleys sloping from the mountain slopes towards the mainstream during the flood season.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**Valley bottom soil**: This type of soil occupies the valley bottoms of the study area and consists of a mixture of sand, silt, clay sediments, lime deposits, and a mixture of gravel. It has good drainage and it is rich in organic materials.

**5- Climate of the study area:**

To determine the climate in the region, the Dumbarton equation (drought assumption) was applied to determine the type of climate prevailing within the study area based on data for the climatic elements of the Darbandikhan station for the period from (2010-2020), which is a shorter climatic period(* See: Ali Hassan Musa2002p27-28).

$$\text{Dumbarton equation (drought assumption} = \frac{\text{Total annual rainfall amount/mm}}{\text{Average annual temperature/C} + 10}$$

After applying the equation, it was found that the study area is located between a humid and semi-humid region, Table (1)

**Table (1) Classification of the climate of the study area according to the Demarton classification for the Darbandikhan station for the period (2010-2020)**

| Station | Annual average temperature/C | Total annual rainfall/m | Demarton equation | Climate type |
|---|---|---|---|---|
| **Darbandikhan** | 24,35 | 834,9 | 24,30 | wet |

**Reference: The researcher's work based on climatic data for the Darbandikhan station for the period (2010-2020) issued by the Meteorological Authority - Sulaymaniyah - Climate Department - Climatic Data (unpublished).**

**Thermal characteristics**: Solar radiation and heat: The amount of solar radiation arriving in a particular area depends on the length of the radiation period and the angle of incidence of the radiation. It appears from Table (2) that the actual sunshine rates during the winter reached (12) hours/day in July and decreased in December. The second reaches (4.2) hours/day, and the actual hours of brightness begin to gradually increase during the summer after March 21 and gradually increase in subsequent months to (11.8) hours/day in the study area. As for temperature, it has a role in influencing the hydrological characteristics and flow. Surface runoff, as a thermal characteristic, affects the increase and decrease in evaporation thus reducing the amount of surface runoff during precipitation, which is considered a source of nourishment for the river valleys. It is noted from Table (2) that temperatures rise during the summer months, especially June, July, and August, at the Darbandikhan station. For the period from (2010-2020), it ranges between (33.7 to 41.0) C, while during the winter the average monthly temperature ranges between (11.4 to 15.6) C for December, January, February, and March, respectively.


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**Wind**: It is one of the elements that contribute to the activity of evaporation and transpiration and has an effective role in rainfall from the hydrological aspect. The prevailing winds in the study area are westerly. As for the average wind speed, from observation in Table (2), the annual average wind speed at the Darbandikhan station for the period (2010-2020) As the wind speed varies, it reached its maximum in December, January, and March at a rate of (2.11-2.1-2) m/s, and the lowest wind rate reached during July at a rate of (1.4) m/s. The cold winds work to reduce temperatures, and this leads to the saturation of the surface area of the soil with water due to precipitation during this month, which leads to a decrease in evaporation and then an increase in surface runoff.

**Rainfall**: Rainfall and heavy rainfall begin at the beginning of October and in some years in the middle of September, and most of this rain is of the ascending type. The total rainfall at Darbandikhan station reached (835.2) mm for the period (2010-2020), Table (2). It is noted that precipitation varies from month to month. It is absent during the summer months, during July and August, and reaches its peak during January, reaching (145.4) mm in the winter. As for the fall and spring seasons, the highest total was recorded during March (141.6) mm

**Table (2) Characteristics of climatic elements in Darbandikhan station for the period (2010-2020)**

| T | Months | Temperature Temperatures | Solar radiation hour/day | Wind m/s | Rainfall mm | Relative humidity% | Evaporation mm |
|---|---|---|---|---|---|---|---|
| **1** | January | **12.2** | 4.2 | 2.1 | 145.4 | 75.11 | **37.39** |
| **2** | February | **11.4** | 4.8 | 1.9 | 127.8 | 66.63 | **42.27** |
| **3** | March | **15.6** | 6.3 | 2 | 141.6 | 74.6 | **65.43** |
| **4** | April | **20.5** | 7.4 | 1.9 | 87.5 | 63.5 | **98.02** |
| **5** | May | **25.8** | 9.1 | 1.6 | 66.9 | 54.5 | **136.08** |
| **6** | June | **33.7** | 10.4 | 1.5 | 54.2 | 48.7 | **172.03** |
| **7** | July | **39.2** | 12 | 1.4 | 0 | 28.7 | **204.09** |
| **8** | August | **41** | 11.8 | 1.5 | 0 | 25.3 | **210.72** |
| **9** | September | **30.7** | 10.4 | 1.5 | 6.9 | 48.2 | **149.32** |
| **10** | October | **26.4** | 8.6 | 1.6 | 34.6 | 54.8 | **102.18** |
| **11** | November | **20.8** | 6.3 | 1.9 | 72.9 | 60 | **64.72** |
| **12** | December | **14.9** | 4.4 | 2.11 | 97.4 | 65.9 | **46.48** |


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| | | | | | | |
|---|---|---|---|---|---|---|
| **Total** | | | | 835,2 | | |

**Source**: The researchers worked based on data from the Ministry of Transport and Communications, the General Authority for Meteorology, and the Climate Department (unpublished data) for the period from (2010-2020)

**Humidity**: The climatic data in Darbandikhan station for the period (2010-2020) indicate that the highest rate of relative humidity is during December, February, March, and January, at an amount of (75.1-66.6-74.6-65.9)% and begins to decrease. During the summer months, it reaches (28.7-25.3)% in July and August, and this is related to the amount of rain falling in the region, which is significant in increasing the amount of water in surface sewers.

**Evaporation:** Evaporation is one of the most significant climatic phenomena affecting the rise and fall of surface water levels, as the amount of evaporation increases in the study area during August, with a total of (210.7) mm and the lowest in January (37.3) mm. Table (2), The phenomenon of evaporation is a difficult and complex process, as it occurs under the influence of other climate factors, the most important of which are temperature, relative humidity, wind speed, atmospheric pressure, soil moisture, and vegetation cover.

## Second/rainfall system:

Rainfall is the main source of surface water recharge, so there are basins that are classified according to the season of rainfall. There are temporary seasonal basins and permanent flowing river basins. Wadi Diwanah basin is one of the seasonal flowing river basins.

**1- Annual rain system**: Rainfall amounts, occurrence, intensity, and spatial and temporal changes have a role in managing water resources, especially in arid and semi-arid areas that suffer from fluctuations in rainfall amounts(Hafez Issa2012p778).

It is noted from Table (2) that the total annual rainfall for the period from (2010-2020) for Darbandikhan station reached (834.9) mm/year, with an overall average of (83.5) mm/year, as rainfall begins at the beginning of September and October, at a rate of (6.9-34.9) mm/year, it also decreases in May, June, September, October, and November at a rate lower than the general rate, and the annual rate for the period from (2010-2020) respectively reached (66.9- 54.2-6.9-34.9-72.9) mm/year.

Also in the years (2011-2013-2018-2020), there was an increase in rainfall rates, as the annual rainfall rate for each year reached (67.5-80.4-76.1-80.1) mm/year, respectively, as noted. A decrease from the general average, as the years (2011-2012-2014-2017-2019) represent a decrease from the general average and their number is


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(5), and the years (2010-2013-2015-2016-2018-2020) represent an increase from the general average and their number is (6) years table (3).

**Table (3) Annual total rainfall, annual average, and rate mm/year for Darbandikhan station for the period (2010-2020)**

| year | Total annual rain | Annual rate |
|---|---|---|
| **2010** | 752,4 | 62,7 |
| **2011** | 810,6 | 67,5 |
| **2012** | 715,3 | 59,6 |
| **2013** | 965,1 | 80,4 |
| **2014** | 666,2 | 55,5 |
| **2015** | 760.3 | 63,3 |
| **2016** | 801,9 | 66,8 |
| **2017** | 625,9 | 52,1 |
| **2018** | 913,8 | 76,1 |
| **2019** | 760,7 | 63,3 |
| **2020** | 961.4 | 80,1 |
| **General rate** | 793,9 | 66,1 |

Reference: The two researchers worked based on data from the Ministry of Transport and Communications, the General Authority for Meteorology, and the Climate Department (unpublished data) for the period from (2010-2020)

**2- Seasonal rain system**: The increasing or decreasing annual rainfall affects the annual and seasonal surface runoff, as seasonal changes in rainfall affect the provision of water, as it is considered one of the most significant elements of the natural hydrological cycle**(Sekela Twisa2009p2**).

It was shown through Table (4) that the rain in the study area increases in winter and does not exist during summer, and if it does fall during the summer, it occurs at separate times. It is noted from Table (4) that the climatic period from (2010-2020) in Darbandikhan station: Autumn and winter rains were the largest in quantity, as rain rates during the fall season reached (6.9-34.7-72.9) mm/season, and spring rains were no less average between seasons, as they ranged between (141.6-87.5-66.9) mm/season, which represents the second peak. As well as rainfall rate in winter was the highest, as it is considered the first rain peak. In addition, the water supply reaches the basin during the winter and spring with a decrease in the amount of evaporation, reaching (97.5-145.5-127.9) mm/mm. Chapter during the years (2010-2020) table(4)

**Table (4) Total and rate of seasonal rainfall (winter - spring - fall) for the period (2010-202-) at Darbandikhan station**

| Winter | Rate | Spring | Rate | Autumn | Rate |
|---|---|---|---|---|---|
| **December** | **97,5** | **March** | **141,6** | **September** | **6,9** |
| **January** | **145,5** | April | **87,5** | October | **34,7** |
| **February** | **127,9** | **May** | **66,9** | November | **72,9** |


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| Total | 370.9 | | 296 | | 114,5 |
|---|---|---|---|---|---|

Source: The researchers worked based on data from the Ministry of Transport and Communications, the General Authority for Meteorology, and the Climate Department (unpublished data) for the period from (2010-2020)

**3- Monthly rainfall system**: A month is considered rainy if its rainfall is more than (10)% of the annual total. It is considered transitional if it ranges between (5-10)% of the annual total. A month is considered dry if the rainfall is less than 5% of the Annual total

**(Mahdi Amin Al-Toum1974p64).**

From Table (5), it is noted that the highest rainfall rate at Darbandikhan station for the period (2010-2020) is in the months (December, January, February, March), as it reached (97.5 - 145.5 - 127.9 - 141.6 - 87.5). ) mm, at a rate of (11, 17, 15, 16, 10)%, and the lowest months (September, October) were at a rate of (6.9-34.7) and at a rate of (0.8-4)%, in addition to the months of July and August, their rate was (Zero) Thus, the number of wet months (4 months) is one month, the dry months (4) months, and the transitional months (4 months) are (November, April, May, and June), and the difference in rain rates is due to the difference in the number of recurrence of weather depressions .

**Table (5) Rainfall rate mm/month, percentage, and type of month: wet, dry, transitional at Darbandikhan station for the period (2010-2020)**

| Month | Rate | Ratio | Type of Month |
|---|---|---|---|
| **January** | 145,5 | 17% | wet |
| **February** | 127,9 | 15% | wet |
| **March** | 141,1 | 16% | wet |
| **April** | 87,5 | 10% | Transitional |
| **May** | 66,9 | 8% | Transitional |
| **June** | 53,5 | 6% | Transitional |
| **July** | 0 | 0 | dry |
| **August** | 0 | 0 | dry |
| **September** | 6,9 | 0,8% | dry |
| **October** | 34,7 | 4% | dry |
| **November** | 72,9 | 8% | Transitional |
| **December** | 97,5 | 11% | wet |

Reference: The two researchers based on climate data from the Darbandikhan station for the period from (2010-2020) and the (Gropwat8.0) program.

However, A clear change in rainfall rates can be observed especially in the years (2013, and 2020), which represent the highest annual rainfall rate, and between the


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years (2014, and 2017), which represent the lowest annual rainfall rate. On the other hand winter and spring are the rainiest. Rainfall varies from one period to another during December, January, February, March, and November, depending on the period from 2010 to 2020. This variation in rainfall has affected surface runoff in the Wadi Diwanah basin.

**Third: Water-climatic balance:**

The climatic water budget for the study area was calculated that based on data from Darbandikhan station and based on monthly rates of rain, evaporation, solar brightness, humidity, and wind for the period (2010-2020) according to the following steps:

1- **Calculating evaporation/transpiration**: Latent evaporation/transpiration was extracted by adopting mathematical equations through which evaporation/transpiration can be calculated, which relied on a group of climatic elements, namely the Panman-Monteith equation, which was developed by the FAO (FAO Panman-monteith). Evapotranspiration (ETO) only requires specific data from climatic components using the Penman-Monteith method, which was developed by the FAO after it addressed the problem of missing data. Solar radiation data were obtained.

In addition to the wind speed and humidity data, the equation was developed and written in the following form(**Azhar Salman Hadi2015p5**):

$$\textbf{ETo}=\frac{\left[o.408\times\Delta(Rn-G)+r\left[\frac{900}{T273}U2(es-ea)\right]\right]}{\Delta+r(1+0.34U2)}$$

ETO = evapotranspiration mm/day

Rn = net solar radiation at the surface of the Earth covered by vegetation (MJ/m2/day)

G = soil heat flux (MJ/m2/day)

ea-en=decrease in water vapor pressure

Δ= Slope of water vapor pressure curve (kPa/m)

R=humidity constant

900=Conversion factor

Which benefited from the development by preparing a special computer program, which is GROPWATE8.0, as this program requires providing data on climate


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elements (temperature, humidity, wind, altitude, 2 hours of solar brightness), in addition to determining the location of the climate station and its height above sea level. The Penman-Monteith equation is considered one of the best empirical equations for calculating potential evaporation/transpiration. By applying the previous equation through the (Gropwat8.0) program, results related to the potential evapotranspiration of the Darbandikhan station were obtained(**Salam Hatif Ahmed2014p337).**

Then the following step was applied: the climate water balance was extracted. Table (6) Figure (1).

P-ETO

Where P = rain ETO = evaporation transpiration

**Table (6): The climatic water budget for Darbandikhan station according to the Panman-Monteith formula and the Groupwat 8.0 program.**

| Month | Rain | Effective rain coefficient | Effective rain | Evaporation/transpiration | balance |
|---|---|---|---|---|---|
| January | 145.5 | 0.55 | 80 | 37.39 | 42.6 |
| February | 127.9 | 0.6 | 76.7 | 42.27 | 34.4 |
| March | 141.6 | 0.6 | 85 | 65.43 | 19.5 |
| April | 87.5 | 0.65 | 56.9 | 98.02 | -41.1 |
| Mace | 66.9 | 0.75 | 50.2 | 136.08 | -85.9 |
| June | 54.2 | 0.62 | 33.6 | 172.03 | -138.4 |
| July | 0 | 0 | 0 | 204.09 | -204.1 |
| August | 0 | 0 | 0 | 210.72 | -210.7 |
| September | 6.9 | 0 | 0 | 149.32 | -149.3 |
| October | 34.7 | 0.7 | 24.3 | 102.18 | -77.9 |
| November | 72.9 | 0.65 | 47.4 | 64.72 | -17.3 |
| December | 97.5 | 0.6 | 58.5 | 46.48 | 12 |

Source: The two researcher, based on the outputs of the Arc Gis 10.8 program.


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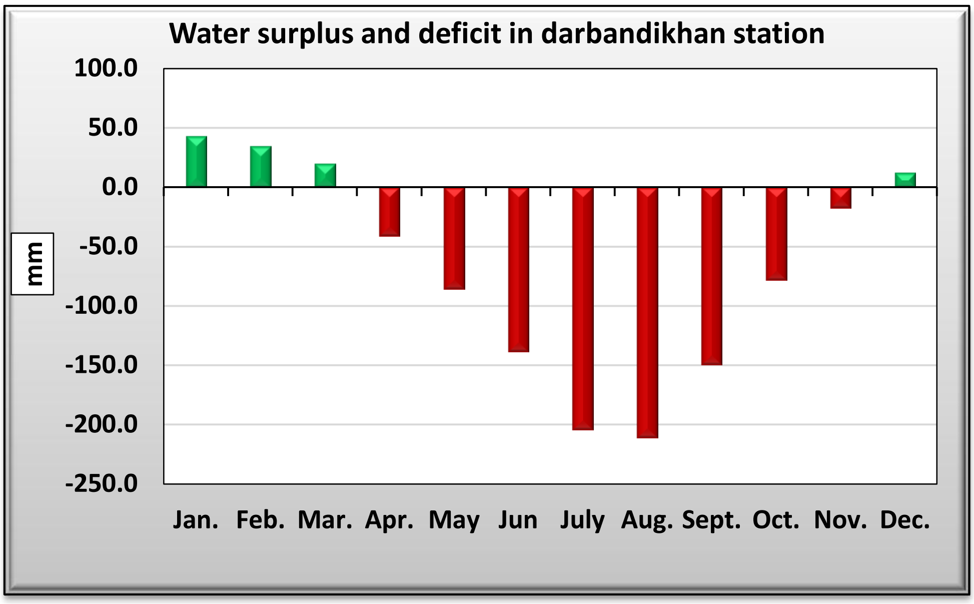
**Figure (1) Water-climatic balance in Darbandikhan station for the period (2010-2020)**




**Source: Researcher based on Table (6) data.**

It is clear from Table (6) and Figure (1) that there is a water surplus for the period from
(2010 to 2020) during the winter season of December, January, February and March at a rate of (12.0-42.6-34). ,4-19,5), for the study, the water surplus is concentrated during the period in which temperatures decrease and reach their peak during winter months, while the rest of the year months showed the presence of a water deficit in the region during these months to increase the amount of evapotranspiration over the amount of rain, as evapotranspiration reached to(136.08-210.7) mm

This water increase represented by the water surplus, which reached a total of (108.5) mm, is the source of surface runoff for the Wadi Diwana basin in the region, which has a fundamental role in the rise and fall of the drainage level during the winter. The reason for this is attributed to the water surplus that was achieved in the winter months. In spring, the evapotranspiration is less than the actual values of rainfall, in addition to soil moisture due to the high rainfall values in winter, the low rate of evapotranspiration, and the difference in soil permeability from one region to another, and thus a water increase is achieved that allows the generation of surface runoff in the climate of the study area.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**Fourth: Estimating the volume of surface runoff:**

Surface runoff is the final result of all hydrological and metrological processes in the river basin, including the drainage density, which represents the product of rainfall.
It directly affects the speed of movement of water collected in the valley stream and depends on the length of the stream and the area of the basin**(Mufida Abu Ajila2021p291).**

The volume of surface runoff was measured based on the amount of rainfall falling and some geomorphological characteristics related to the area of the basin, the length of the basin, and the slope ratio of the area. The volume of runoff is measured in several ways, including measuring water flow using soil permeability and the American soil conservation service method, which is known as the (SCS) method. -cn) is the most widely used method for estimating the depth of runoff, which deals with many variables, including land use, soil quality, vegetation, and the amount of rainfall. Studying surface runoff is not limited to providing drinking water, irrigation, or groundwater recharge, but rather extends to preserving the environment and controlling floods and the effects they cause. Dredging and construction of engineering projects, including building earthen dams and protecting areas at risk of flooding**( Iman Shihab Hassoun2016,p195).**

**1-Land cover classification**:

To classify the land cover of the region, we relied on satellite visualization, field study, and the creation of an information base using remote sensing techniques, which is one of the modern means of surveying natural and human resources and identifying their characteristics and spatial distribution, and through directed classification that relies on previous information about the natural spectral group or clusters**(Ahed Thanoun,2014,p63).**

The list in the visualWe relied on the satellite visual (Landsat 8) dated (4/21/2022) with a resolution of 15 m, to derive the land cover types for the region and through the classification directed in the (ArcMap 10.8) program, as the land cover was classified Within the area occupied by the basinshown in Table( 7) and map (5)

**Table (7): Land cover classification**

| Ground cover category | Area/km2 |
|---|---|
| **Water** | 1.4 |
| **medium vegetation** | 109.7 |
| **weak vegetation** | 271.9 |
| **Barren soil** | 127.1 |
| **Rock detectors** | 90.7 |


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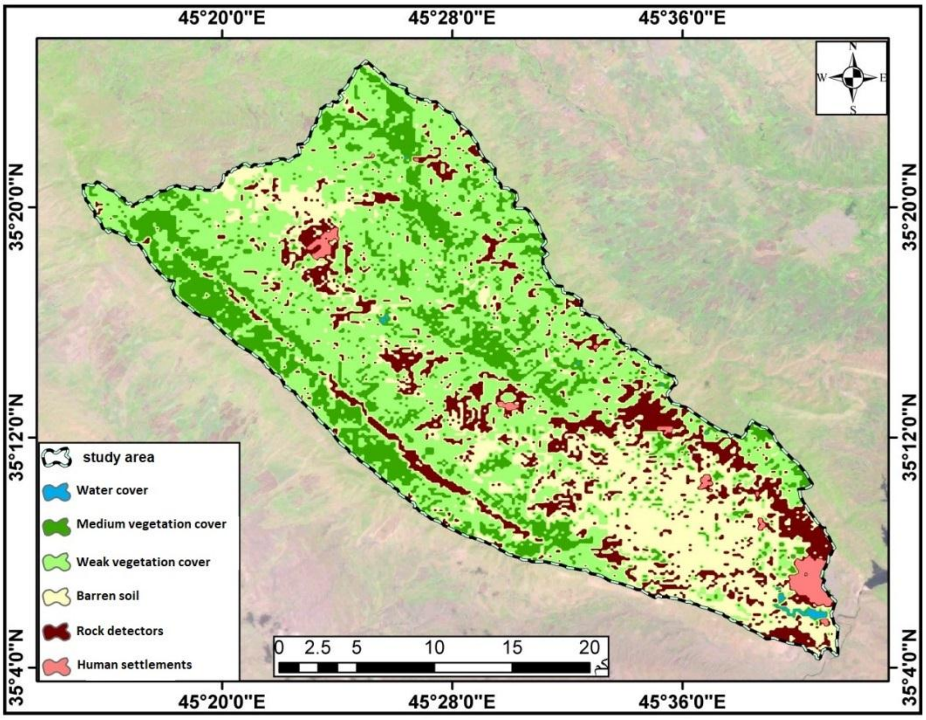
| | |
|---|---|
| **Human settlements** | 7.1 |
| **Total** | 608.0 |

Reference: Soil Conservation Service. Urban Hydrology for Small Watershed. Technical releases 55,2nd, U.S. Department of Agriculture, Washington D.C.(1986**).**

**Map (5) Ground cover varieties in the Diwanah Valley Basin**




Reference: The two researchers, based on the outputs of the digital elevation DEM and the outputs of the (ArcGis10.8) program.

**A- Water coverage:**

Within the study area's basin, the Diwanah Dam Lake serves as the main water body, situated in the southern part of the river basin and covering an area of 1.4 square kilometers. This lake is a crucial water resource for nearby communities, supporting the establishment of various facilities and quarries in its vicinity, enabling locals to utilize its waters effectively.

B- **Semi dense grass coverage:**

These plants are distributed in the east, north, and middle of the study area, as forests of evergreen trees grow on steep mountain slopes, especially those facing the wind. Which occupied an area of (109.7) km².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**C-Poor grass coverage**:
It is characterized by its scarcity and scattered distribution, as it prevails in low-lying areas and valley bottoms, which provide a suitable environment for the growth of herbs with an area of (271.9 km2).
**D-Barren soil**:
This type is represented by soil devoid of vegetation with an area estimated at approximately (127.1) km2, distributed in the middle and southern parts of the river basin, as it works to create surface runoff with an increase in the slope of the surface and vice versa in the case of high permeability **( Ahmed Salem,1999,135).**
**C- Rock detectors:**
It extends from the northern and southern sides of the basin, starting from the sources towards the middle, with an area estimated at (90.7) km². These rocks covered with a little sediment allow the falling water to seep into the soil because it has high porosity.
**H-Human settlements**:
Human settlements are distributed within the study area in an unorganized manner, especially in the parts close to water resources within the area represented by the Diwana Dam Lake at the mouth of the river basin with an area of (7.1) km², which was established to collect water resulting from the flood during rainfall, which is currently being exploited by the inhabitants of the region for the purposes of establishing sand quarries and mines Image (1)(2)
Image (1) Diwana Lake within the study area Image(2) Quarries near Diwanah Lake

Source: Field study on (19/12/2023)

**2-.Varieties of hydrological soils for the Wadi Diwana basin:**
The SCS-CN method identified four types of soils: namely (A-B-C-D). These soil hydrological groups are called (Hydrologic Soil Groups), and each type has its characteristics, as (A, D) represent two extreme cases: A, low surface runoff, and D,


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Very high surface runoff and values of (B, C) are two moderate cases of flow, as it is clear that the basin is dominated by three hydrological soil types that reflect the characteristics of the basin on the emergence of surface runoff according to Table (8) (9) map(6) .

**Table (8): Classifications of hydrological soils according to the (SCS) method.**

| Soil class | Flow depth | Soil type |
|---|---|---|
| A | A little | Deep sandy layer with very little clay and silt |
| B | medium | Less deep sand layer than class Awith average leaching rate |
| C | Above average | Clay layer of limited depth with a sub-average leaching rate or a rock layer covered with a layer of soil |
| D | High | A thick clay layer covered with a shallow layer of fine silt or a bare rock layer |

Reference: Soil Conservation Service.Urban Hydrology for Small Watershed. Technical releases 55,2nd, U.S. Department of Agriculture, Washington D.C.(1986)

**Table (9) Hydrological types of soils in the study area**

| Soil class | Soil description | Area/km2 |
|---|---|---|
| A | Deep sandy layer with very little clay and silt | 113.5 |
| B | Less deep sand layer than class Awith average leaching rate | 286.7 |
| C | Clay layer of limited depth with a sub-average leaching rate or a rock layer covered with a layer of soil | 207.7 |
| Total | | 608.0 |

**Reference: The researchers, based on Table (8) and the outputs of the ArcGis 10.8 program.**

**1- Class (A)**: The soil within this class is characterized by a coarse texture consisting of a layer of Deep sand with a small percentage of clay and silt. It is spread in the middle of the basin and at the mouth and includes gypsum and gravel materials, and the area of this type reached (113.5 km2).

**2: Class B:** The soil is of an alluvial loam texture, shallow in depth, and has little permeability, which has an important role in collecting falling rainwater and reducing water losses due to seepage. The area of this type was about (286.7 km2) of the basin area.

**3 - Class C**: This class consists of sediments carried by valleys from neighboring areas and deposited in low-lying areas. The soil texture is a clayey mixture and its area is (207.7) km² of the basin area. It is clear from the classification of soil classes for the study area that the basin is dominated by It has the type (B, C) that is characterized by little leakage and surface runoff.


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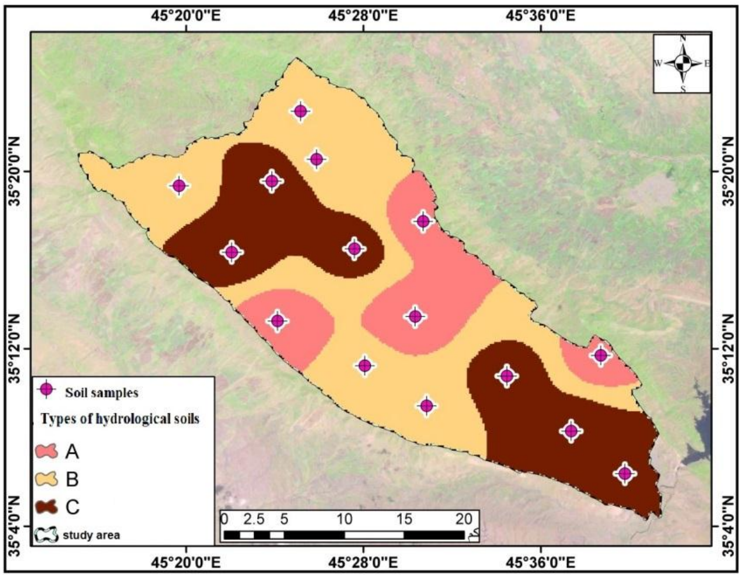
**Map (6) Hydrological Soil Varieties in the Study Area**




**Source: The authors based on the outputs of the ArcGis10.8 progra**

3- **Extracting the value of CN for the Wadi Diwanah basin**:

Estimating the volume of surface runoff using the CN model requires combining the land cover types variable with the hydrological soil types variable. This was done through the Combine command within the Spatial Analyst Tools, and through the table prepared by (SCS) to obtain (CN) values (Curve Number) for significance. On the surface permeability, its value ranges between (0-100), as high values of (cn) indicate that the surface of the basin is low permeability, while low values indicate a high percentage of permeability, as a number close to zero indicates high permeability, high leakage, and lack of water accumulation,On the surface, while numbers close to 100 indicate low permeability and the accumulation of water in large quantities and thus the emergence of surface runoff following rainfall, the results showed that the (CN) values of the soil in the normal condition of the region ranged between (49 – 98) ,Table (10) (11) map(7) .


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**Table (10): Extracted CN values and soil types for the Wadi Diwana basin**

| Hydrological soil varieties / Ground cover varieties | A | B | C |
|---|---|---|---|
| | CN **Values** | | |
| **Solid rock exposers** | 98 | 98 | 98 |
| **Barren soil** | 74 | 86 | 91 |
| **poor vegetation** | 68 | 79 | 86 |
| **medium vegetation** | 49 | 69 | 79 |
| **Human settlements** | 68 | 82 | 87 |

**Reference: Based on USDA-SCS, Urban Hgdrology for Small Watersheds Department of Agniculture, USA, 1986, TR55, p2-6..**

**Table (11): Extracted cn values for the Wadi Diwana basin**

| CN Values | Area km² | Percentage % |
|---|---|---|
| **49** | 24.6 | 4.0 |
| **68** | 63.8 | 10.5 |
| **69** | 58.3 | 9.6 |
| **74** | 6.3 | 1.0 |
| **77** | 0.9 | 0.1 |
| **79** | 178.8 | 29.4 |
| **82** | 37.0 | 6.1 |
| **86** | 59.8 | 9.8 |
| **87** | 81.1 | 13.3 |
| **91** | 5.7 | 0.9 |
| **98** | 91.7 | 15.1 |
| **Total** | 608.0 | 100% |

**Reference: Based on the outputs of (ArcGis 10.8 program)**


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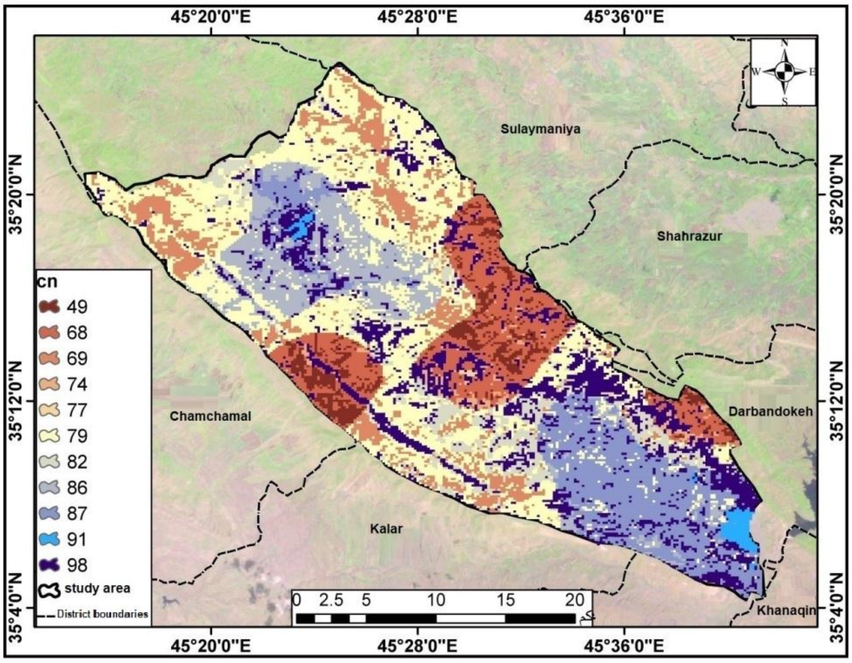
**Map (7) CN values for the Diwana Valley Basin**




Source: The authors based on the outputs of the ArcGis10.8 program

**4- Calculating the coefficient of the maximum possibility of retaining water after surface runoff ((S) and water losses (seepage and evaporation) (La):**

The equation prepared by SCS was relied upon to calculate the values of ((S) according to the following equation (USDA 1986)

$$S = \frac{25400}{CN} - 254$$

The values of the maximum potential for water retention coefficient, which is symbolized by the symbol (S), which are close to zero, represent the low ability of the soil to retain water on the surface after the start of the flow, which leads to an increase in the amounts of water running on the surface, while the high values of (S) reflect an increase in the soil's ability to retain water, which It reduces the amount of surface runoff, and the coefficient of losses before the start of rainwater runoff, which is symbolized by the symbol (Ia), is closely related to the soil and land covers through a direct connection to the coefficient (S), as the low values of the initial extraction coefficient (Ia)( Haifa Muhammad Al-Nafi'I,2010,103), which are close to (zero ) indicates a decrease in the amount of rainwater lost before the start of the surface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runoff process, which leads to an acceleration of the runoff process. This coefficient is extracted according to the following equation (USDA, 1986):
La=0.2S

From Table (12), it is clear that the values expressing the (S) factor and the (La) factor in the Diwana Basin amounted to (12) values, and their values ranged between (5 - 264) mm, for the (s) factor, and between (1 - 53) mm. , for the factor (la), and from a hydrological standpoint, it indicates that the surface of the study basin is natural with water conservation on its surface, with areas of high leakage and increased water losses from rainwater within the high values of these two factors, but the largest part of the basin is characterized by its ability to generate surface runoff. Which causes high surface runoff, and we find that the most distributed value of (S) in the basin is the value of (68), as its area reached (178.8) km2, and the value of (14) is expressed in the values of (a), which are low values indicating a decrease Water losses due to leakage and the high amount of surface runoff.

**Table (12): Values of (cn), factor (S), and factor (Ia) in the Wadi Diwana basin**

| **cn** | **s** | la | **Area/km2** |
|---|---|---|---|
| **49** | 264 | 53 | 24.6 |
| **68** | 120 | 24 | 63.8 |
| **69** | 114 | 23 | 58.3 |
| **74** | 89 | 18 | 6.3 |
| **77** | 76 | 15 | 0.9 |
| **79** | 68 | 14 | 178.8 |
| **82** | 56 | 11 | 37 |
| **86** | 41 | 8 | 59.8 |
| **87** | 38 | 8 | 81.1 |
| **91** | 25 | 5 | 5.7 |
| **98** | 5 | 1 | 91.7 |
| **Total** | | | 608.0 |

**Reference: Based on the (S) and (Ia) coefficient equation and the outputs of the (ArcGis10.8) program.**

### 5-Calculation of the volume of runoff of the Wadi Diwana basin:

In order to calculate the volume of runoff of the basin, the highest rainfall intensity was monitored for the time period (2010-2020) for Darbandikhan station, Table (13), which amounted to (71.24) mm on 17/2/2018, in order to estimate the depth of rain according to the (SCS) method, and to estimate the depth of runoff after the rainstorm through the following equation (USDA-TR55 1986):


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Q = (p-Ia)2/((p+0.8S) )

Q = depth of runoff
P = rainfall
Ia= primary extracts before runoff such as soil, plant reception and evaporation
S = maximum surfaceagglomeration after the beginning of runoff

The runoff depth (mm) represents the interaction between a given rain wave and with the elements and characteristics of the drainage basin.

**Table (13) The highest daily rainfall intensity for the period (2010-2020) for Darbandikhan station**

| Day/Month/Year | Total rainfall mm |
|---|---|
| 2/5/2010 | 27,4 |
| 30/4/2011 | 25,64 |
| 13/11/2012 | 40,93 |
| 10/11/2013 | 45,53 |
| 9/12/2014 | 47,66 |
| 28/10/2015 | 46,98 |
| 28/3/2016 | 48,3 |
| 15/2/2017 | 24,71 |
| 17/2/2018 | 71,24 |
| 28/1/2019 | 48 |
| 22/11/2020 | 14,65 |

**Reference: https://power.larc.nasa.gov/data-access-viewer/**

To estimate the volume of surface runoff, we relied on the values of the surface runoff depth and the following(USDA-TR55 1986)

$$\mathbf{QV = (Q * A/1000}$$

QV: surface runoff volume.
Q: Depth of surface runoff.
A: Area of drainage area.

The results can be observed in Table (14). The values of the runoff depth (Q) appeared between the highest value of (65) mm and the lowest value of (1) mm. This indicates that rainfall is transformed into surface runoff in the facility. It indicates that


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the comprehensive basin has a large capacity and a high possibility of creating a large surface on the surface of the community, which allows for a large pool of water in the Diwana Valley and we obtain large water revenues that we can invest in the economic development and economic vision of a large part of the residential areas and industrial facilities represented by sand quarries. As for the surface runoff values for the Wadi Diwana Basin, so far, the highest value was (5.9) m³ at the depth of the runoff, which reached (65) mm, and this moved to higher values (CN) as it reached (98), and even higher surface runoff, as These parts are classified within specific solid disclosures, which reflects the nature of the surface and the lack of variation of surface runoff water Table (14) map(8) .

**Table (14): Values of the coefficient (Q) mm and the volume of surface runoff (QV) for a rainstorm (71.24 mm) in the Wadi Diwanah basin**

| Value (CN) | Flux depthQ mm | Area/km2 | Flux volume QVmillion / m3 |
|---|---|---|---|
| **49** | 1 | 24.6 | 0.0216 |
| **68** | 13 | 63.8 | 0.0246 |
| **69** | 14 | 58.3 | 0.126 |
| **74** | 20 | 6.3 | 0.2736 |
| **77** | 24 | 0.9 | 0.8162 |
| **79** | 26 | 178.8 | 0.8294 |
| **82** | 31 | 37 | 1.147 |
| **86** | 38 | 59.8 | 2.2724 |
| **87** | 40 | 81.1 | 3.244 |
| **91** | 48 | 5.7 | 4.6488 |
| **98** | 65 | 91.7 | 5.9605 |
| **Total** | | 608 | 19.31 |

**Reference: The researchers, based on the outputs of the ArcGis 10.8 program.**


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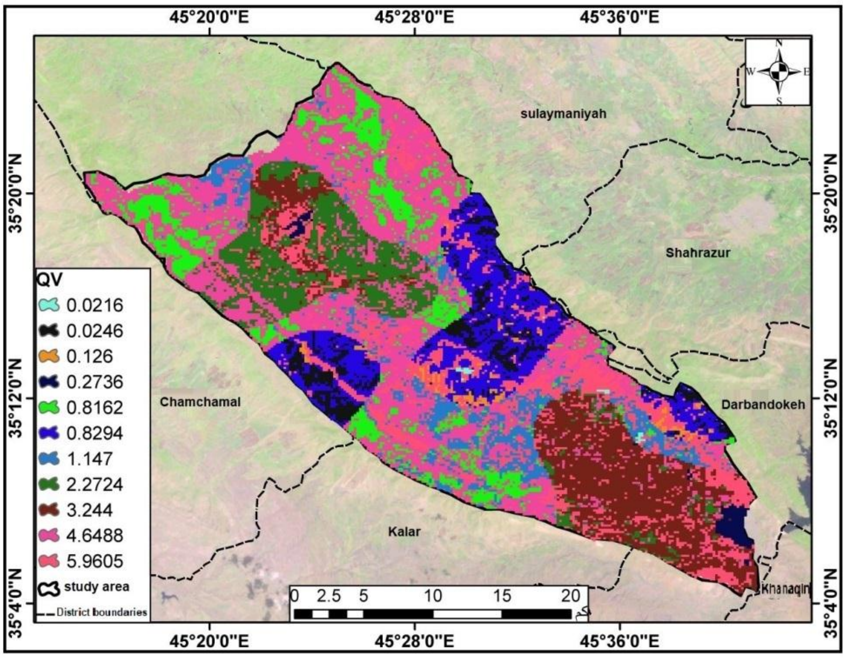
**Map (8) Distribution of QV values extracted for Diwana Basin**




Source: The authors based on the outputs of the ArcGis10.8 program

The lowest value of surface runoff.reached (0.02) m3 at a flow depth of (1) mm, which is the lowest value recorded, as this value indicates the high water losses resulting from seepage. We conclude from this that the relationship between the nature of surface characteristics and the quality of land cover contributes effectively. In determining the volume of surface runoff within the Wadi Diwanah Basin, and then clarifying the ability of the river basin to generate quantities of surface runoff resulting from rainfall, as the total seasonal rainfall for the winter reached (370.9) mm, which is considered the highest rainfall peak during the year, which can be invested for purposes Human, agricultural and animal resources through water harvesting methods or the establishment of lakes near the mouth of the basin, as is the case with the establishment of the Diwana Dam Lake to benefit from water during times of drought.

**Correlations between climate characteristics and surface runoff volume**:

To understand the impact of climate characteristics more clearly, it is necessary to find a correlation between climate characteristics and the volume of surface runoff. A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correlation coefficient was found between the climate characteristics as a basic variable to know the nature of the correlation between them and the rest of the variables, which is the volume of surface runoff. For this purpose, the Pearson correlation coefficient was adopted. Which requires two variables, the first is an independent variable and the second is called a dependent variable, Table (15 ).

**Table (15): Correlations between climate characteristics and surface runoff volume**

| Dependent variable /independent variable/ | | volume | heat | winds | Rain | evaporation |
|---|---|---|---|---|---|---|
| **proportion** | Pearson Correlation | 1 | -.889** | -.921** | .925** | -.980** |
| | Sig. (2-tailed) | .446 | .000 | .000 | .000 | .000 |
| | N | 11 | 12 | 12 | 12 | 12 |
| ****. Correlation is significant at the 0.01 level (2-tailed).** | | | | | | |

**Reference: The researchers relied on climate characteristics data, surface runoff volume data, and using the (SPSS23) statistical program for the Pearson correlation coefficient.**

It is clear from the analysis of Table (15) of the statistical relationship between the volume of flow and some climatic elements influencing it that there is a very strong direct relationship with rainfall amounting to (0.925) and with a very strong level of significance reaching (0.000). From that relationship, it is concluded that the greater the amount of rain falling, the greater the This led to a very large increase in the volume of flow because rain is one of the most important sources of nourishment for river basins. As for the other variables (temperature, wind speed, evaporation), the inverse relationship was very strong, amounting to (-0.889, -0.921, -0.980). For the three variables, respectively, there was also a very strong level of significance of (0.000) for each variable. This relationship can be explained by saying that an increase in temperature, wind speed, and evaporation will lead to a decrease in the amount of flow. This is because temperature and wind speed increase evaporation, as evaporation plays an effective role in determining the amount of flow. Surface runoff and the amount of drainage for water basins, which is responsible for determining the amount of water deficit and water supply for each basin.

**Results:**

1- The study area is located within areas of high convolution, between the highest elevation of 1847 (m) at the northwest end of the basin and the lowest elevation (367) m above sea level, and between a degree of slope ranging between (0-30) degrees, and


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this in turn affects the characteristics of the flow. 2- Climate has a major role in hydrological study, especially the elements of rain, solar radiation, humidity, and evaporation, as the variation in climate characteristics affects the surface runoff of river basins, as the climate has a positive effect during the winter due to the high rate of rainfall.

3- Rainfall is the main source of surface water recharge, as the highest rainfall rates reached in the years (2013, and 2020), which represents the highest annual rate, and between the years (2014, and 2017), which represents the lowest annual rate. As for seasonal precipitation, it is seasonal. Winter and spring are the rainiest, and the rainiest months vary from one period to another, as they were from December, second, February, March, and November, according to the period from (2010-2020). This variation in the amounts of rainfall affected the volume of surface runoff in the Wadi Diwana basin.

4- Through the work of the climatic water budget for the Darbandikhan station for the period (2010-2020), it was revealed that there is a water surplus for the period from (2010 2020) during the winter season of December, January, February and March, at a rate of (12.0-42.6- 34.4-19.5), and a total of (108.5) mm, which represents a source of supply for surface runoff.

5- The values expressing the (S) factor and the (La) factor in the Diwana Basin reached (12) values, and their values ranged between (5 - 264) mm, for the (s) factor, and between (1 - 53) mm, for the (la) factor. From a hydrological standpoint, it indicates that the surface of the study basin is natural by preserving water on its surface and generating surface runoff.

6- The flow depth values (Q) ranged between the highest value of (65) mm and the lowest value of (1) mm. This indicates that the falling rain turns into surface runoff in the basin, as it indicates that the basin has a great capacity and high potential for The emergence of surface runoff. The surface runoff volume values for the Wadi Diwana basin reached the highest value (5.9) $m^3$ at the runoff depth of (65) mm. This is due to the high values of (CN), which reached (98) and indicated a high surface runoff.

7- Through the correlations between the volume of surface runoff and some climatic elements influencing it, it was found that there is a very strong direct relationship with rainfall that reached (0.925) and with a very strong level of significance that reached (0.000). From that relationship, it is concluded that the greater the amount of rainfall that falls, this leads to The volume of runoff increased significantly because rain is one of the most important factors contributing to runoff.


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8-The study area is one of the areas that can be invested economically in implementing water projects such as lakes and water harvesting projects, especially since the area is part of the feeding areas of the Tigris River and has natural characteristics represented by the nature and quantity of annual and seasonal drainage and the amount of surface runoff.

**Recommendations:**

1- Investing in arable land, especially valley bottoms and lowlands, to improve environmental conditions and provide natural pastures.

2- Educating farmers in the region about the importance of surface water and its role in the development process of the region through the establishment of dams for water harvesting in addition to water lakes.

3- Expansion of the field of storage projects to benefit from all forms of water, harvesting and collecting it to benefit from it when needed, especially since all of these forms are fresh water.

4- Establishing a hydrological station in the study area to record measurements of water drainage, especially during wet years, which record exceptional cases that cause the occurrence of devastating floods and the resulting dangers, especially since there are population centers close to the area.

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