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SPATIAL VARIATION OF RUNOFF VOLUMES AND ITS HAZARD IN THE ESTBLAN

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Abstract

The Estblan basin is located within the administrative boundaries of Dohuk Governorate, northern Iraq, between longitudes (- 42°42°58 '30" 44 ' 00) E, and latitudes (37° 21' 00 - 37° 13' 00) N, its area (188) km2 and it runs within a steep slope area. The problem of the study lies in the lack of detailed studies on the surface runoff volume and its flow risks in the study area and the ways to treat it. Moreover, the study aims to calculate the surface runoff volume using the Soil Conservation Service-Curve number (SCS-CN) method. The results of the spatial variance analysis showed that there is a variation in the surface runoff volume in the study area, as the quality of the rocks that pass through it, the uses of the land, and the hydrological condition of the soil are all factors that largely control the volume of runoff. Furthermore, it was found that there is a variation between the secondary basins in the surface runoff volume, where the highest volume of runoff was 202 m3 / s in the main basin, while the lowest values were recorded in the Karin basin, reached 18 m3 / s. It was found that the region varied in the severity of the flood from one basin to another, where Estblan valley basin was classified as a high-risk secondary basin, while the Merses Basin was a medium risk, and the (Hauraki and Karin) basin was low risk.

Keywords: Geographic information system, Hydrology, Surface runoff, Risks.

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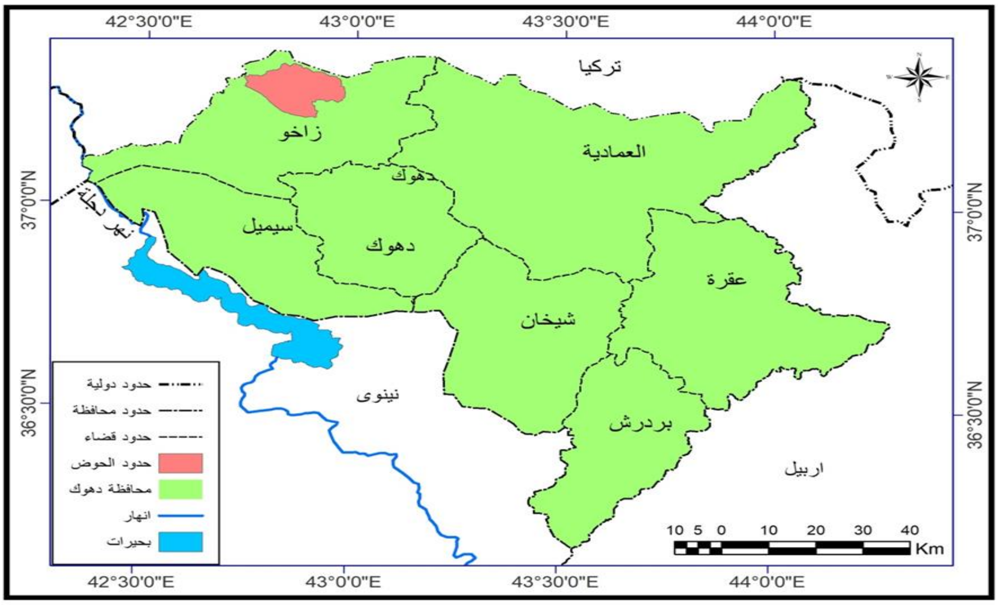
Introduction

The study of surface water is of great importance in hydrological studies because water is the main pillar for the sustainability of life on the planet and the emergence, growth, and prosperity of population colonies. A technical understanding of the relationship between rainfall and runoff helps researchers to plan the effective distribution of water and improve development activities, this effective management can be done by measuring the amount of runoff caused by rainfall through spatial modeling of watersheds. The usual procedures that involve predicting surface runoff are time-consuming and reach erroneous results. Therefore, modern techniques using remote sensing and geographic information systems can calculate the surface runoff volume and determine the resulting risks. However, water basins in humid and semi-humid environments receive large amounts of rain, which leads to the occurrence of very rapid water flows in the form of devastating floods. The amount of torrents flow depends on the characteristics of the area, the nature of basins, the topography of the area. Most studies rely on estimation to evalute the surface runoff volume due to the absence of hydrological stations and among the many methods for estimating the surface runoff volume is the conservation Soil Service method, which is called (SCS) of the United States Agriculture Administration. The CN-SCS method has been widely accepted in the United States of America and is one of the most accurate and common methods of calculating the surface runoff volume, which depends on the natural and human components of the drainage basin. This method is also known as the land cover and its uses such as the type of soil and the interaction with the amount of rainfall, land use. In addition to the hydrological condition of the soil, which has a direct impact on the surface runoff, the research aims to study the spatial variation of the runoff in the Estblan Valley Basin and determine its levels and risks.

The Boundaries of the Study Area

The Estblan Valley Basin is located within the Dohuk Governorate, northern Iraq, between longitudes (- 42°42°58 '30" 44 ' 00) E, and latitudes (37° 21' 00 - 37° 13' 00) N. This Basin occupies an area of (188) km^2, and it runs within a steep slope area, with elevations ranging from 500 to more than 2000.

Map (1) location of the study area in Dohuk Governorate



Reference: Ministry of Water Resources, General Survey Authority, administrative map of the governorate of Dohuk, scale 1: 1500000 for the year 2010

Data and method of work

The surface runoff volume in the study area was calculated by relying on the mathematical equations for hydrological studies and Geographic Information System (GIS) programs as follows:

- Time of Concentration

It is the time period for water to move from the farthest point of the drainage basin to the gathering point (the basin downstream), as whenever the time of concentration was higher, the surface runoff was greater, which leads to erosion operations and transport sediments in the valleys. The time of concentration is calculated according to the following equation (Manjunath, 2006):

$$T_c = 0.057 \frac{L^{0.8}\left(\frac{25400}{CN} - 228.6\right)^{0.7}}{\sqrt{S}} \ldots .(1)$$

Where:

T_C = concentration-time in hours.

L = stream length (km).

S = average basin slope percentage.

CN = curve numbers.

- ***Lag Time***

It is the time of the basins' response to precipitation (in hours) to reach the highest degree of drainage (the peak), which is the interval between the peak of rain and flow, and it is called the first response time (Imran and Abdul Rahman, 2018) and is calculated according to the following equation:

$$\mathrm{LT(hr)} = \mathrm{CT(Lb\ \ Lca)}^{0.3}$$

Where**:**

Lb = main stream length (km)

Lca = distance between the downstream of the basin and its center of gravity (km)

CT = the peak flow coefficient, which is specific to the nature of the basin and the degree of slope, and its value ranges between (1.8 - 2.2)

- ***Timebase for torrents (Tb)***

It is the period of time for a flow of a drainage basin from its source to its downstream, and this period is similar in its variance to the variance in the lag time. The time base of the torrents (days) is calculated according to the following equation: (Muhammad, 200):

$$\mathrm{Tb(days)} = \frac{3 + \mathrm{tb(hr)}}{8}$$

Where:

Tb (days) = time base for torrent (day)

Tp = basin response period to rainfall / hours (lag time)

- ***Time of gradual rise of torrents flow Tb (hr)***

It is the time period required for the gradual rise of rainwater at the bottom of the valleys' streams after the occurrence of surveying surface sediments and soil by infiltration, and it is calculated according to the following equation:

$$\mathrm{Tm(hr)} = \frac{1}{3}\mathrm{Tb(r)}$$

Where:

Tm = time of the gradual rise of torrents flow (hours), it represents on hydrograph, the period extending from the start of the torrent runoff to the duration of its peak on a curve.

Tb (hr)= time base of torrent calculated in (hours).

- ***Time of gradual reduction in the torrents flow Td***

It is the time period required for the basin in which the water is completely drained from source to downstream according to the following equation:

$$\mathrm{Td(hr)} = \frac{2}{3}\mathrm{Tb(hr)}$$

Where:

Td (hr) = gradual reduction time in hours

Tb (hr) = time base for torrent calculated in hours

- Estimation of the surface runoff time

It is the time period that water takes through the basin streams and its tributaries to reach the downstream. This range is measured by measuring the hydrograph width (the peak hydrograph), by applying the following mathematical relationship (Imran and Abdul Rahman, 2018):

$$\mathrm{T} = \mathrm{N} \times \mathrm{hr}$$

Where:

T = Time taken to complete the runoff to the end (hour)

N = constant value of (5) and Hr = lag time (hours)

- ***The velocity of surface runoff***

Measuring the velocity of runoff is an indicator to know the risk of drainage basin during the surface runoff. There are several ways to measure the velocity of surface runoff, such as calculating the velocity of water movement from one place to another. As well as, calculating the distance it travels through dividing the distance over time, and it is one of the most expensive methods for that, it can be measured according to the following equation (Imran and Abdul Rahman, 2018):

$$\mathrm{V} = \frac{\mathrm{L}}{\mathrm{Tc}}$$

Where:

V = velocity of surface runoff

L = length of the drainage basin (km)

Tc = time of concentration (hours)

- ***The ideal duration of rainfall on drainage basins (Tr)***

It is the water volume through the river section during a unit of time. The flow velocity in valley streams is one of the most important morphometric parameters of drainage basins because it determines the degree of the risk of valleys. In addition to its ability to erosion and transport sediments, the flow velocity in rivers and waterways is measured by various methods by using different devices, and it can be calculated and estimated by applying the following equation (Al-Zubaidi, 2018):

$$\mathrm{Tr(hr)} = \frac{\mathrm{tp(hr)}}{5.5}$$

Where:

Tr (hr) = ideal duration of rainfall calculated in hours

Tp (hr) = duration of water basin response to rainfall calculated in hours

- ***Surface runoff volume***

It is the increase in the amount of rain over the amount of water loss by infiltration, and it refers to all the water that flows in the drainage network of the dry basin. Likewise, it occurs when the intensity of the rain exceeds the basin capacity to assimilation, and it is calculated according to the following equation (Al-Saadi, 2014):

$$Qt\left(\frac{m^3}{s}\right) = \sum(\text{km})0.85$$

Where:

Qt (m^3 / sec) = runoff volume (thousand m^3)

$\sum$L (km) = lengths sum of the basin runways (km)

0.85 = constant expressing the basin conditions

- **Peak runoff value of torrents (Qp)**

This value is used to know the peak runoff of torrents water that can reach the valleys in the case of strong torrent activity, the values of peak runoff for torrents in fan basins can be calculated by the following equation (Al-Zubaidi, 2018):

$$Qp\left(\frac{m^3}{s}\right) = \frac{CpA}{tp\ (hr)}$$

Qp (m^3 / s) = the peak runoff value of torrents in the drainage basin (m^3 / s)

A = basin area (km^2)

Tp (hr) = drainage basin response time to rainfall (hour)

Cp = a coefficient related to the ability of the drainage basin to store water, and its value ranges between (2.0-6.5)

- Fixed infiltration value

This value represents the maximum rate at which water can penetrate into the soil, and the rate of infiltration in wet soils is initially lower during all times of the storm. Then, it decreases in all soils during the duration of the storm, meaning that the infiltration velocity varies for a particular rainstorm with the passage of time, and it is calculated according to the following equation (Carson et al., 1979):

$$Fp = A \times Td \times 0.0158$$

Where:

Fp = fixed infiltration value

A = area

Td = drainage time

Results

The analysis results of the surface runoff characteristics of the Estblan Valley Basin showed that there is a clear variation in the surface runoff values according to the secondary basins and as shown in Table (2) and the spatial distribution maps of the surface runoff characteristics were as follows:

1- Concentration time

The results showed the variation of (Tc) values at the level of basins, as it is noticed that (the main basin) is of low risk. Estblan and Merses are within the degree of low risk, which their concentration-time values reached (1.4, 1.4), respectively. On the other hand, the values of concentration-time were (0.7 and 0.2) respectively in two basins (Hauraki and Karin) respectively, they are within the high-risk basins. The variation in the values of the concentration, time reflects the time difference between the velocity of water arrival between the Hauraki Valley and Karin. It is evident through the classification of the degrees of risk of the drainage basins of Alluvial fans in the study area according to the concentration-time factor. Moreover, there is a group of factors affecting the strength and flow velocity of torrents from the source to the downstream, which causes a variation in their concentration time. Among these factors are the morphometric characteristics of the basins, the degree of slope, the geological structure, the vegetation, and the narrow width of the valley, as the flow velocity increases in the narrow valleys, because of not assimilation the volume of running water in them.

2- Lag time

It is evident that the highest value of the lag time was (6.1) hours in the main basin, and the reason for this is due to the lack of the basin slope, and that the geological formations over which the basin runs are modern formations with fine sediments that allow water to penetrate through. These factors lead to increased losses by infiltration and evaporation due to the accumulation of water above the ground for a period of time that allows water to infiltrate through the soil. Whereas, the lowest value was (2.7) hours in the basin of Karin valley. The variation in the lag time explains the variation in area, slope and drainage intensity in the basins of the study area.

3- The time base for torrents

The results showed the variation of the time base values (Tb), as the highest value was (77.3), days recorded in the main valley basin, while the lowest values were (3.34) recorded in the Karin valley basin. The variance in the time base of the torrent is observed in the basins of the study area, but with a very slight variance, and this is due to the similarity of the geological and climatic conditions and the rates of rainfall.

4- Time of gradual rise of torrents flow

It is evident that the duration of the gradual rise of torrential flow (Tm) varies in the basins of the study area, as the highest value reached (1.26) hours in the main valley basin, while the lowest values were (1.11) hours recorded in the Karin valley basin. There are many factors that affect the determination of the time of the gradual rise of torrents flow in the basins, and the nature of rocks in the upper and middle sources of the basins, which are characterized by porosity and low permeability, which results in a rapid runoff despite the lack of rainfall.

5- Time of gradual reduction in the torrents flow

It is clear that the time of gradual reduction varies in the basins of the study area, as it reached (2.50) hours in the basins of both Estblan and the main basin, while it reached (2.30, 2.40, 2.20) hours in the basins of (Hauraki and Karin and Merses) respectively.

6- Estimation of the surface runoff time

It was evident that the duration of the surface runoff of drainage basins in the study area reached the highest value of (30.5, 28.0) in the main basin and Estblan respectively, while the lowest value was (13.5) hours in the Karin basin.

7- The velocity of surface runoff

The results of surface runoff velocity in the basins of the study area showed that the lowest velocity of torrential flow was in the Hauraki basin of (5.44 km/hour), while the highest velocity was in the Merses basin, which reached (20.50 / hour).

8- The ideal duration of rainfall on drainage basins

It is clear that the ideal duration of rainfall varies in the basins of the study area, as the highest value reached (1.11), in the main basin, while the lowest value was (0.49) in the Karin Valley Basin. A variation is observed in the ideal duration of rainfall in the basins of the study area, but with a slight variance, and this is due to the similarity in the geological and climatic conditions and the rates of rainfall.

9- Surface runoff volume

The results of calculating the volume of surface runoff showed that there is a clear variation, as the highest runoff volume was (202) m^3 / s recorded in the main basin, while the lowest runoff volume was (18) m^3 / s recorded in the Karin basin, and it represented the lowest rate in drainage basins in the region.

10- Peak runoff value of torrents (Qp)

It is clear that there is a variation in the values of peak runoff of torrents in the basins of the study area, as it reached (12.22) m^3 / s for the Karin basin, while it reached (92.46) m^3 / s in the main basin.

11- Fixed infiltration value

The results of calculating the fixed infiltration value showed that there is a clear variation, as the lowest values of Fixed infiltration was (0.4) m recorded in the Karin basin, while the highest infiltration values were (7.4) m in the main basin. It is noticed that there is a great variation in the infiltration values of the study area basins, this is due to the variance in geological and climatic conditions and the rates of rainfall.

Table (1) Hydrological characteristics of the Estblan Valley Basin

Basins	*Tc(hr)*	*LT(hr)*	*Tb(days)*	*Tm(hr)*	*TD(hr)*	T(hr)	V(*k/hr*)	*Tr*	Qt(*m3/s*)	Qp(m3/s)	*Fp*
Hauraki	0.7	3.7	3.46	1.15	2.30	18.5	5.44	0.67	33	17.84	0.8
Merses	1.4	5.3	3.66	1.22	2.40	26.5	20.50	0.96	122	60.00	4.0
Karin	0.2	2.7	3.34	1.11	2.20	13.5	9.17	0.49	18	12.22	0.4
Estblan	1.4	5.6	3.70	1.23	2.50	28.0	9.89	1.02	67	26.25	1.9
Main valley	2.0	6.1	3.77	1.26	2.50	30.5	15.98	1.11	202	92.46	7.4

12- Classification of degrees of risk of the study area basins

In order to determine the degrees of risk of torrents in the study area basins, the group of hydrological parameters of the basins was combined, represented by the runoff volume (m^3) Qt, concentration-time (Tc), and lag time (Tp). Besides, surface runoff velocity (V), the time base of torrent (Tb), time of the gradual rise of torrents flow (Tm) hr, time of gradual reduction in the torrents flow (Id) hr, peak runoff value of torrents (Qp) for the purpose of extracting the degree of risk of floods on basins. Thus, a final classification of the risk degree of basins was made after the previous (11) variables were collected, where each basin gave (3) degrees of risk, so the number of variables became (33) variable. The results showed a variation in the degree of risk between the basins of the study area. The risk was high in the (Estblan) basin and (the main basin). As for the (Merses) basin, the risk was moderate, while the (Hauraki and Karin) basins were low risk as shown in Table (2) and Map (13).

Table (2) results of the final classification of the degrees of risk of the study area basins

Basins	Tc	tp	tb	tm	td	t	V	tr	Qt	Qp	Fp	Sum	Degree of risk
Hauraki	3	2	1	1	1	1	1	1	1	1	3	16	Low
Merses	2	3	2	2	2	2	3	2	2	2	1	32	Medium
Karin	3	1	1	1	1	1	1	1	1	1	3	15	Low

Estblan	2	3	3	2	3	3	1	3	1	1	3	25	High
Main valley	1	3	3	3	3	3	2	3	3	3	1	28	High

Reference: based on the tables of previous equations results.

Figure 2. concentration-time in an hour

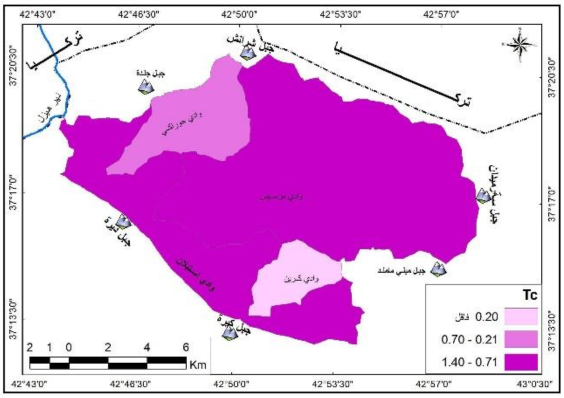


Figure 3.lag time in an hour

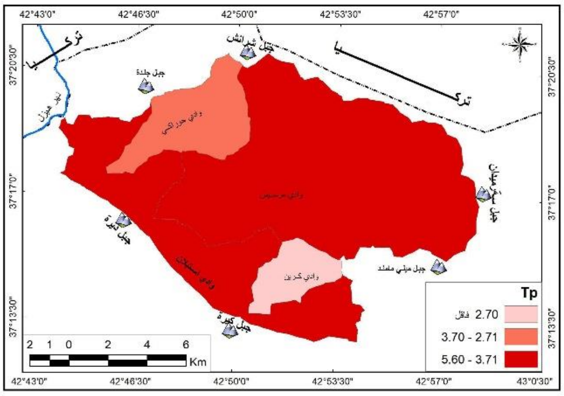


Figure 4. time base of torrent (Tb)

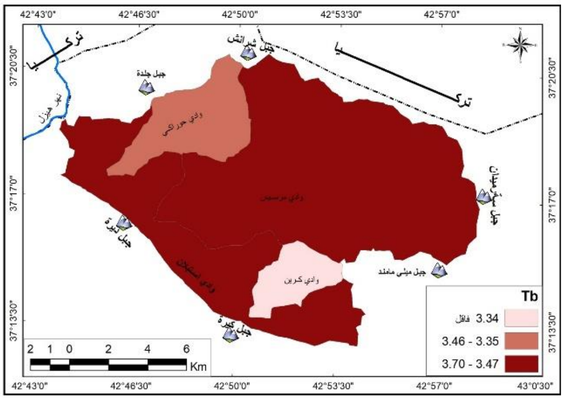


Figure 5. time of the gradual rise of torrents flow (Tm) hr

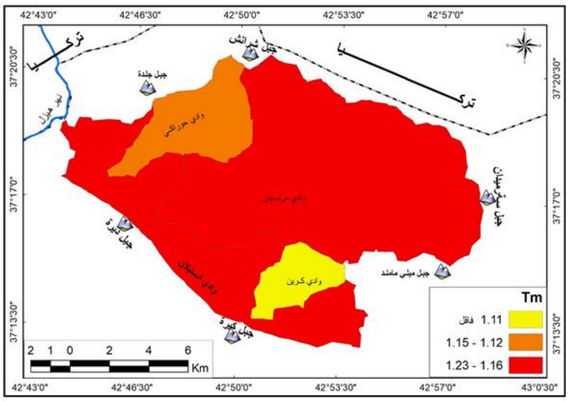


Figure 6. time of gradual reduction in the torrents flow (Id) hr

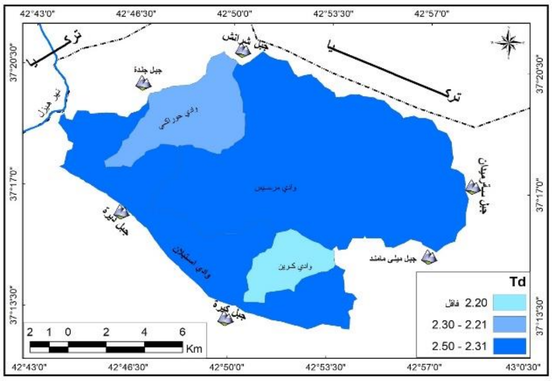
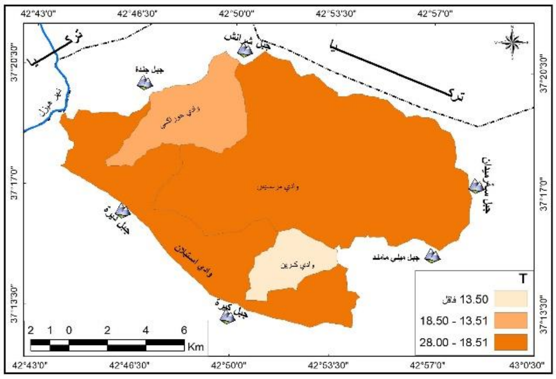


Figure 7. surface runoff time



Reference: Based on Digital Elevation Model DEM, Arc Map 10.5 program, and Table (1)

Figure 8.surface runoff velocity (V)

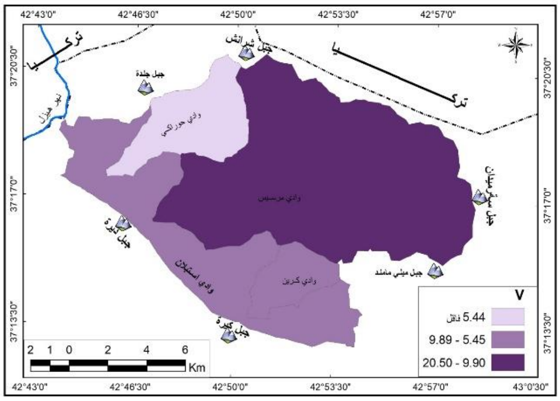


Figure 9. ideal duration of rainfall

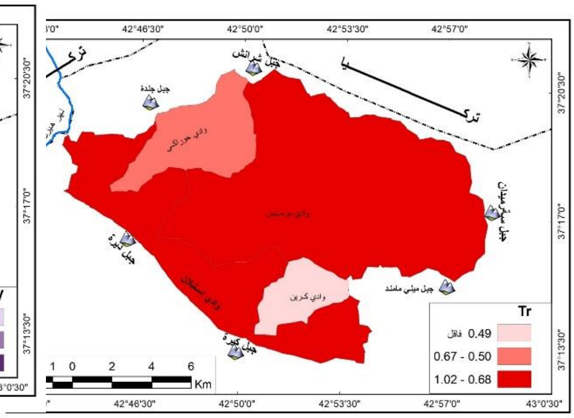


Figure 10. runoff volume (m3) Qt

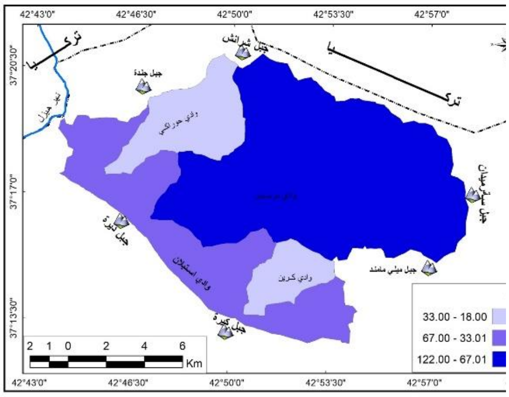


Figure 11. Peak runoff value of torrents (Qp)

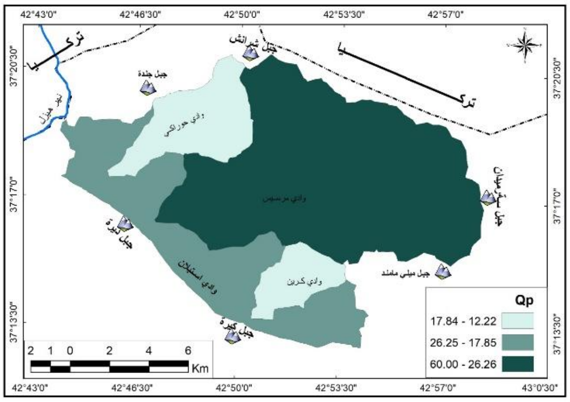


Figure 12. Fixed infiltration value

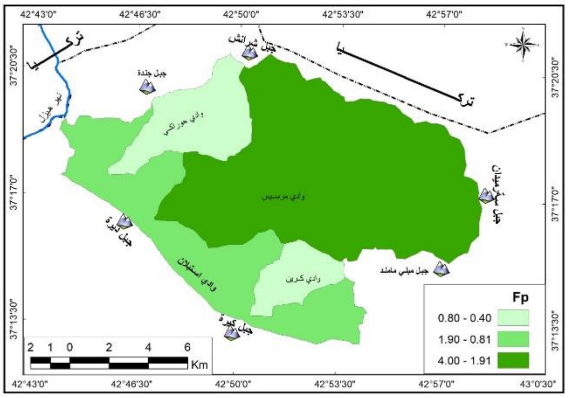
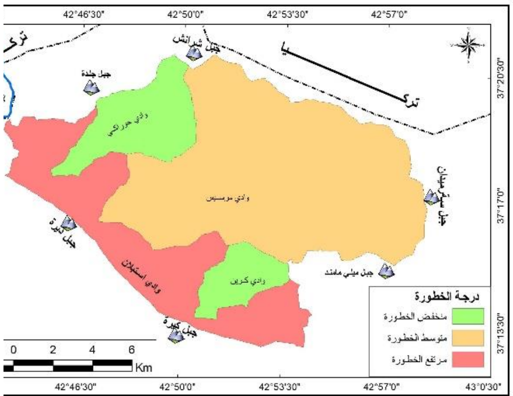


Figure13.Classification of torrents risk



Reference: Based on Digital Elevation Model DEM, Arc Map 10.5 program, and Table (1-2)

Conclusions

1- The study showed through the different models using a method according to the SCS-CN method for the Estblan Valley Basin, the efficiency of this method compared to the classical methods such as the Berkeley method.

2- It was found that there is a variance between the secondary basins in the surface runoff volume, as the highest runoff volume in the main basin reached (202) m^3 / s, while the lowest values were recorded in the Karin basin, which reached (18) m^3 / s.

3- It was found that there is a variation in the Peak runoff value of torrents in basins of the study area, as the Qp value reached (12.22) m^3 / s for the Karin basin, while it reached (92.46) m^3 / s in the main basin.

4- The study showed that the region suffers from the risks of torrential flow, and the degree of its risk varies from one basin to another, as the secondary Estblan Valley is characterized as high-risk torrents, while the Merses Basin is characterized as a medium degree of risk, while the rest of the basins are of low risk.

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