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(٤١٣)–(٤٣١)

# مخاطر الشدة المطرية لأحواض شرق مدينة أربيل

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المستخلص :

ينجم الجريان السطحي عن الشدة المطرية، ثم يعتمد بعد ذلك على المنحدر واستخدام الأراضي والغطاء الأرضي ونوع التربة. استخدمت طريقة رقم المنحنى خدمة الحفاظ على التربة (SCS CN) في هذه الدراسة لتقدير الجريان السطحي كطريقة نمذجة هيدرولوجية. هناك ٣ مجموعات تربة هيدرولوجية في منطقة الدراسة (A، B، C) تتراوح من إمكانات منخفضة للجريان السطحي بسبب معدلات الترشيح المرتفعة للمجموعة (A) إلى مجموعة الجريان السطحي العالية / المتوسطة بسبب بطء معدلات الترشيح للمجموعة (C). بالنسبة لتصنيف LULC (الغطاء والاستعمال الارضي) في المنطقة هناك ٦ أصناف احتلت الأراضي الجرداء المساحة الأعلى (١٣٧) كم² (٣٦٪) بينما يمثل الغطاء النباتي أدنى مساحة (٣) كم² (١٪). المنطقة تميزت بان لها قيم عالية من CN، هناك (١٣) فئة ذات قيم عالية تراوحت بين (٥٥-٩٤) بينما (٢) فئة فقط تراوحت بين (٢٥-٣٠)، مما يدل على ارتفاع الأسطح المنيعة مما أدى إلى زيادة توليد الجريان السطحي في المنطقة. وكانت نتيجة معلمات طريقة SCS-CN في المنطقة على النحو التالي تتراوح قيم Q بين (٥٠-٦٤٦.٨) ملم، وكانت قيم Ia بين (٥-١٥٤.٢) ملم. قيم S قيم S بين (٢٥-٧٧١) ملم، وقيم Qv ممتدة بين (٤٥-٥٨٢.١٢) م³، والشدة المطرية المختارة للمنطقة كان إجمالي الهطول المطري ب (٤٤) ملم.

الكلمات المفتاحية : مخاطر، شدة مطرية ، مدينة أربيل .

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# Risks of Rainfall Intensity in Erbil's Eastern Basins

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Abstract:

Runoff is triggered by the rainfall intensity, then it depends upon the slope, land use land cover, and soil type. Soil Conservation Service Curve Number (SCS CN) method is used in this study to estimate runoff as a hydrologic modeling method. There are 3 hydrologic soil groups in the study area (A, B, C) Ranging from Low runoff potential due to high infiltration rates (A) group to High/moderate runoff potential due to slow infiltration rates (C) group. for LULC (land use land cover) classification in the area, there are 6 types: Barren lands occupied the higher area (137) $km^2$ (36%), while vegetation represented the lowest area (3) $km^2$ (1%). The area has high values of CN, A (13) class with high values ranging between (55-94) while (2) class only (25-30), indicating high Impervious surfaces resulting in an increased runoff generation in the area. The result of SCS-CN method parameters was as follows; Q values were between (646.8-50) mm, and values of la were between (154.2-5) mm. S values for the area between (771- 25) mm, Qv values between (582.12-45) $m^3$, for chosen rainfall intensity for area total rainfall with (44) mm.

Keywords: Risk , Rainfall , Kurdistan geomorphology .

## 1. Introduction

Predicting runoff for ungauged watersheds has vital importance in hydrologic modeling and for many applications, among them hazards administration. There are many models to estimate surface run off one of them the Soil Conservation Service Curve Number (SCS-CN) method was originally developed by the SCS (US Department of Agriculture). It is a

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simple method, based on many factors that affect runoff generation, which integrate into a single CN parameter. The SCS-CN method (SCS 1985) is one of the most popular methods for computing the volume of surface runoff in catchments for a given rainfall event. This approach involves the use of a simple empirical formula and readily available tables and curves. A high curve number means high runoff and low infiltration (urban areas), whereas a low curve number means low runoff and high infiltration (dry soil). The curve number is a function of land use and hydrologic soil group (HSG). It is a method that can incorporate land use for the computation of runoff from rainfall. The SCS-CN method provides a rapid way to estimate runoff change due to land use change (Shrestha, M. N. 2003. p2.); (Zhan, X. Y., and Huang, M. L. 2004, p875-879.). the curve number is based on soil type and land use. So, in this study use of GIS as an accurate spatial information tool is required to apply this method for its easily retrieve and processing of the soil type and land use. The increase and spread of impervious surfaces within urbanizing catchment areas of the study area have a dramatic risk to the quality of physical and urban environments.

## 2. Materials and Methodology

### 2.1. Study Area

Located in the northeastern part of Iraq, the city grew with their impermeable surface and basins most of them with impermeable formation, this will initiate a surface flow after an effective rain intensity, the study area bordered between 44°00´97"- 44°25´50"N and 36°17´75"- 36°22´42" (Fig.1), with the total area (386 $km^2$) and altitude 411m, where it lies between east of Erbil city and the Pirash mounts so its selection has not been arbitrary.

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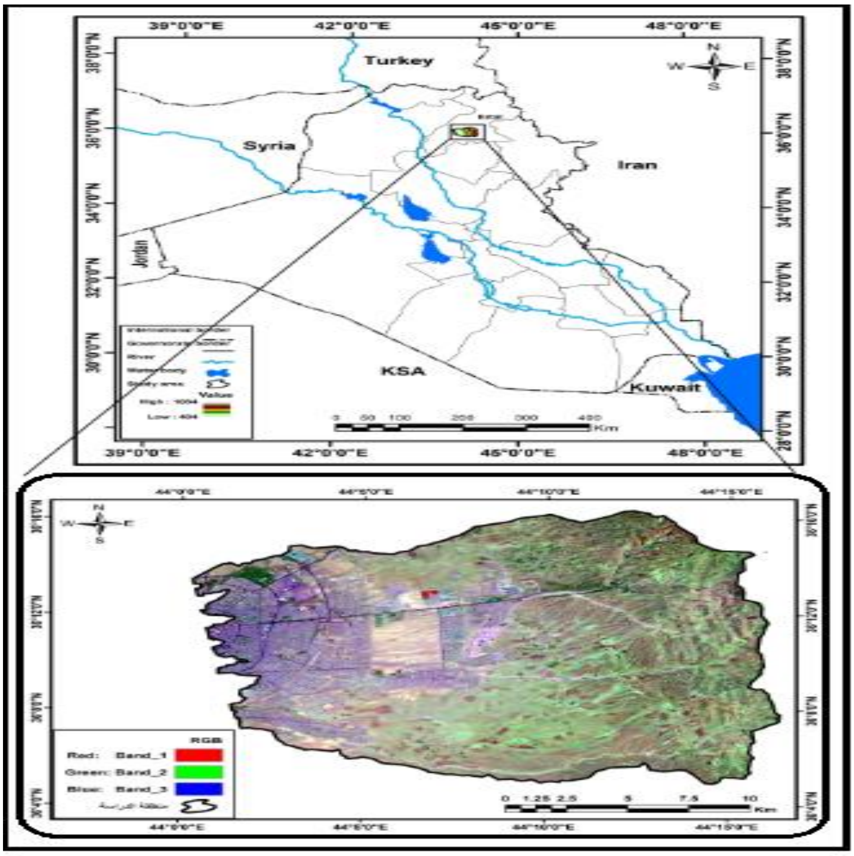


Fig.1 Location of study area

The area lies within high folded zone and low folded zone for the tectonic divisions of Iraq (Fouad, S. F. 2015. p1-7). The geology of the area consists of 1- Tertiary formation represented by Bai Hassan formation (Pliocene) dominated by thick conglomerate units alternating with claytons, siltstones, and sandstones (Buday, T. C., 1980. p445) 2-Quaternary Deposits includes; A- Slope Deposits (Pleistocene–Holocene). It consists of mainly of limestone and dolostone with some silicate, igneous and metamorphic pebbles, which are derived from the exposed formations. There deposits are poorly to moderately cemented by calcareous, sandy, and silty materials. Locally, it is well cemented and very hard the thickness of the slope deposits is also widely variable. It ranges from less than one meter up to 20

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m, but usually it is about 2-5 m. B-_Residual Soil and Polygenetic Deposits (Holocene) Its form either flat plains or rounded hilly lands. These deposits are of sandy and/or loamy type, locally gypsiferous. In the mountainous parts is mainly calcareous. The dominant colours are reddish brown, light brown, and greyish brown. The thickness varies from less than one meter up 3 m. C- valley fill deposits are well developed within the area, the composition and thickness are widely variable, and they are almost similar to slope deposits but without cementation and predominance of gravels, sand, silt and very rarely clay size (Sissakian, V. K. 1998. p30-42.).

Landform of area contains three main geomorphic units: 1- high lands unit 2- pediment unit 3- accumlation surface unit which Erbil city extend on it (fig.2). Longitudinal profile for basins show the higher points between (1000-440m) while lowest ranged between (500-410) (fig.3).Topography of district gradation from mounts in East north with highest elevation (1084m) while the lowest elevation is (440m) represented the plain zone. Slope degree vaired between (0°-18.4°) . Aspect in district parts its varies but the dominate its for South , Southeast, West. There are Three types of soil according to Buringh:1- Brown soils charactirise with deep profile containing sand,clay and silt its represented high lands soil. 2- Brown soil with medium to shallow profile over Bakhtiary gravel,sand,silt and partly clay cover hilly and pediment zone. 3- Lithosolic soil in limestone,sandstone,claystone ,fine clastic gypsum and anhydrite semi impermable rock this type covers the accumlative plain.the district contain eight sub basins (fig.4).

The climate is mild, and generally warm and temperate. There is more rainfall in the winter than in the summer in Erbil. The Köppen-Geiger climate classification is Csa. The temperature here averages 20.3°C. In a year, the rainfall is 560 mm . Precipitation is the lowest in July, with an average of 0 mm. With an average of 104 mm , the most precipitation falls in January. At an average temperature of 35.0 °C , July is the hottest month

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of the year. January has the lowest average temperature of the year. It is 6.3 °C . Between the driest and wettest months, the difference in precipitation is 104 mm. During the year, the average temperatures vary by 28.6 °C The month with the highest relative humidity is January (68.23 %). while the lowest is July (16.51 %). month with the highest number of rainy days is January (10.13 days). month with the lowest number of rainy days is August (0.10 days) (climate-data.org) (Fig.5&Table1 ) .


Fig (2) Landform units: 1 hilly unit its ends with black line. 2 pediment unit ends with red line 3 accumulation surface unit show Erbil city extend on it

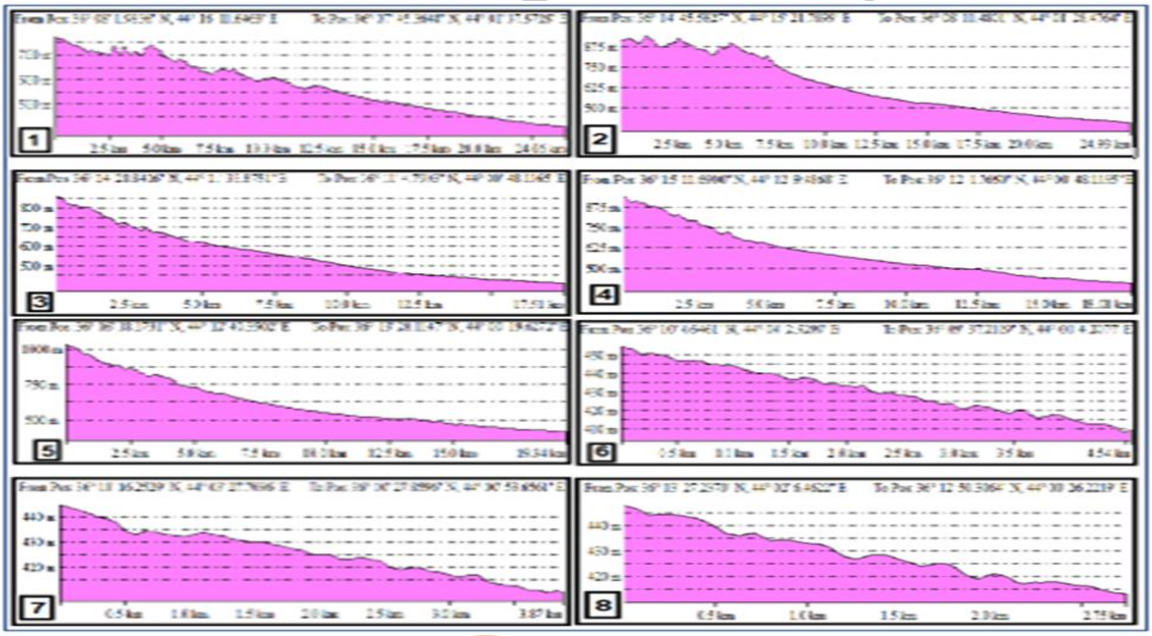

Fig.3. Longitudinal profiles for area basin

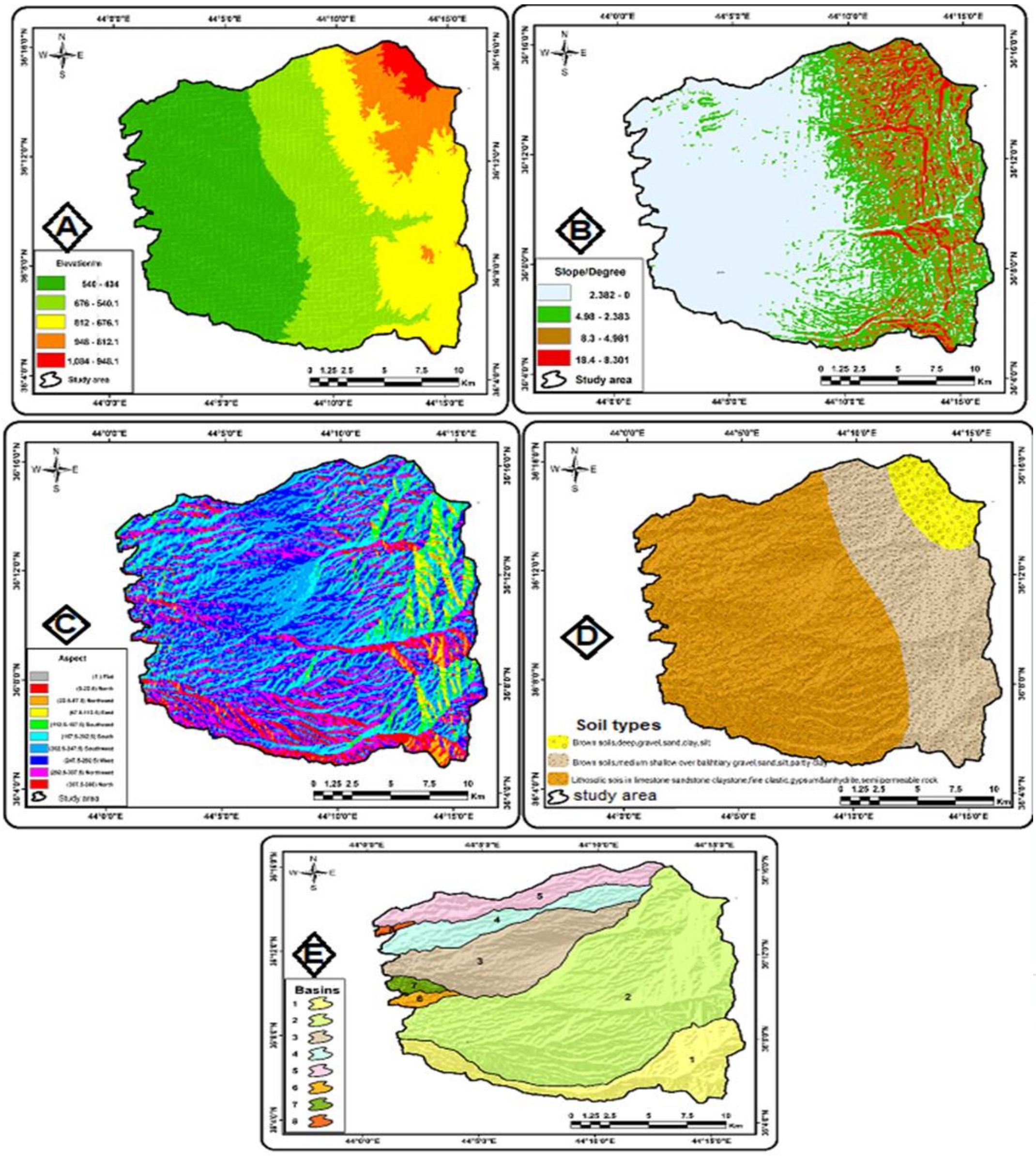


Fig.4. Physical features of study area: A- Elevation B- Slope C-Aspect D-Soil types E-Basins

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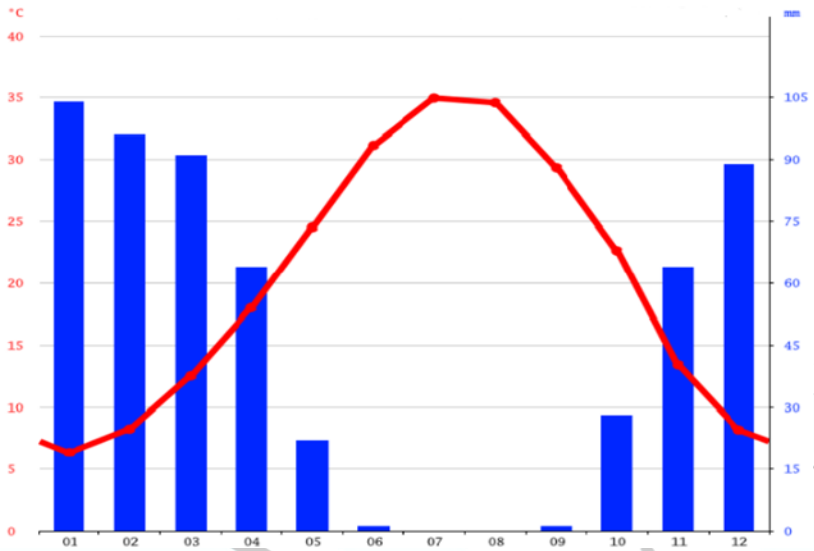


Figure 5. Climate graph Weather by Month Erbil (climate-data.org)

| | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. Temperature °C | 6.3 °C | 8.3 °C | 12.5 °C | 18 °C | 24.6 °C | 31.2 °C | 35 °C | 34.6 °C | 29.4 °C | 22.7 °C | 13.4 °C | 8.2 °C |
| Min. Temperature °C | 1.4 °C | 2.6 °C | 6.1 °C | 11 °C | 16.6 °C | 22.4 °C | 26.2 °C | 25.9 °C | 21.1 °C | 16.1 °C | 7.8 °C | 3.3 °C |
| Max. Temperature °C | 12 °C | 14 °C | 18.5 °C | 24.3 °C | 31.2 °C | 38.1 °C | 41.9 °C | 41.7 °C | 36.7 °C | 29.5 °C | 19.8 °C | 14 °C |
| Precipitation / Rainfall mm | 104 | 96 | 91 | 64 | 22 | 1 | 0 | 0 | 1 | 28 | 64 | 89 |
| Humidity(%) | 68% | 67% | 59% | 49% | 32% | 19% | 17% | 17% | 21% | 31% | 51% | 64% |
| Rainy days (d) | 8 | 7 | 7 | 6 | 3 | 0 | 0 | 0 | 0 | 2 | 5 | 6 |
| avg. Sun hours (hours) | 7.0 | 7.9 | 9.6 | 11.3 | 12.6 | 13.1 | 12.9 | 12.2 | 11.2 | 10.0 | 8.5 | 7.1 |

Table 1. Weather by month, Weather Averages Erbil (climate-data.org)

## ٣.٢. Data Sources

Many data were used in this research, including a Landsat-8 OLI_TIRS satellite image, SRTM 30m Digital Elevation Models, meteorological, land use, and administrative division data. All the data sources are shown in Table (2) below.

| Data | Time | Format | Source | Resolution |
|---|---|---|---|---|
| Landsat-8 | 202 | Raster | https://earthexplorer.usgs.gov | 30 m _ |

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| | | | | |
|---|---|---|---|---|
| OLI_TIRS | 1 | | | 30 m |
| DEM (SRTM GL1) | 2000 | Raster | https://portal.opentopography.org | 30 m _ 30 m |
| Rain intensity | 2022 | text | https://chrsdata.eng.uci.edu | - |
| Meteorological data | 2021 | text | climate-data.org | - |
| Land use | 2021 | Raster | https://earthexplorer.usgs.gov | 30 m _ 30 m |
| Administrative division | 2020 | Shape file | Administrative Iraq map | - |

Table 2. Data Sources for the study area

3.3 Runoff Depth Estimation

To apply the SCS-CN method estimates total watershed runoff depth *Q* (mm) for a storm by the SCS runoff equation for the study area by the following steps (R.G. Cronshey, R. T. Roberts, N. Miller, 1986.p2-1):

$Q=(P-Ia)^2/(P-Ia)+S$ ………. (1)

Q: Runoff (mm)

P r: Rainfall (mm)

S: potential maximum retention after runoff begins (mm)

Ia = initial abstraction (mm)

For S is more changeable, so it can be extracted from equation 2 after identifying the CN.

$Ia = 0.2\,S$ ………. (٢)

$S = 25400/CN - 254$ ………. (3)

$QV = (Q*A)/1000$ ………. (4)

QV = Surface runoff volume ($m^3$)

A= Area ($m^2$)

4.Results and discussion

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4.1 Runoff Depth Estimation for the Study Area

SCS- CN is simple method used for the determination of the approximate runoff value corresponding to a certain rainfall quantity in a certain area. it’s designed for a single storm event. This model is simple when applying it and adopted a few parameters (Pasupati M. Shrestha, Geetha K. Jayaraj, 2018, p2364), it’s based on the area's hydrologic soil group, land use, it is an empirical method that expresses how much runoff volume is generated by a certain volume of rainfall (Zare M, Zare AAN, Samani, Mohammady M,2016.1279). The SCS curve number method is as follows:

In order to obtain (CN) values for the area, The LULC was extracted from space images with a map of hydrologic soil group to match the hydrologic soil group with LULC. Fig. (6)(7) table (3)(4). There are 3 hydrologic soil groups in the study area (A, B, C) Ranging from Low runoff potential due to high infiltration rates (A) group to High/moderate runoff potential due to slow infiltration rates (C) group. for LU classification in the area, there are 6 types Barren lands occupied the higher area (137) km$^2$ (36%) while Vegetation cover represented the lowest area (3) km$^2$ (1%).

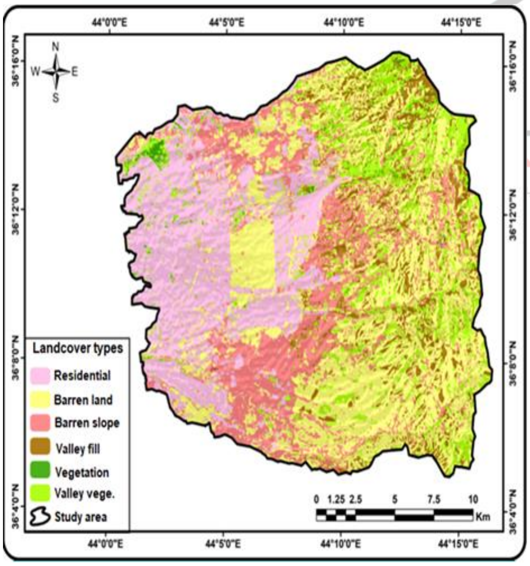


Fig.6. Land cover types

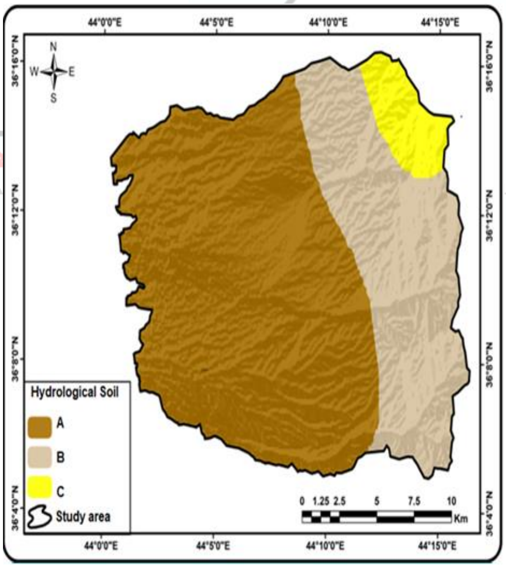


Fig.7. Hydrologic soils group

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| LC Type | Area (km²) | Percentage (%) |
|---|---|---|
| Barren lands | 137 | 36% |
| Vallie's veg. | 48 | 12% |
| Barren slopes | 72 | 19% |
| Vegetation | 3 | 1% |
| Valley fill | 34 | 9% |
| Built up | 92 | 24% |
| Total | 386 | 100% |

Table 3. LULC types

| Hydrological Soil Type | Area (km²) | Percentage (%) |
|---|---|---|
| A | 246 | 64 |
| B | 118 | 30 |
| C | 22 | 6 |
| Total | 386 | 100 |

Table 4. Hydrologic soil type

Hydrological soil map and LULC map were merged. The result is CN values was converted to raster with 30 m resolution. Fig. (8). Table (5) it appears that most of CN values in study area with high values indicating impermeable surfaces have a potential high run off meanwhile rainfall.

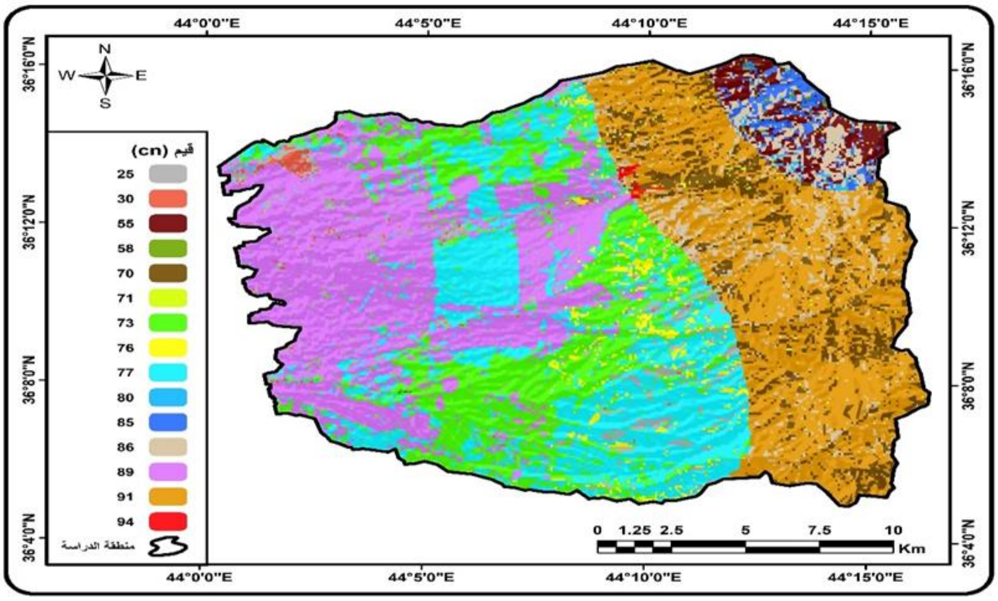


Fig.8 CN values

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| Basin 1 | | |
|---|---|---|
| Cn | Area ($km^2$) | Percentage (%) |
| 91 | 18 | 35.3% |
| 70 | 5 | 9.8% |
| 71 | 1 | 2.0% |
| 86 | 2 | 3.8% |
| 91 | 4 | 8.6% |
| 89 | 5 | 10.1% |
| 77 | 9 | 17.9% |
| 25 | 1 | 1.0% |
| 76 | 1 | 1.5% |
| 73 | 5 | 10.1% |
| Total | 51 | 100.0% |

| Basin 2 | | |
|---|---|---|
| Cn | Area ($km^2$) | Percentage (%) |
| 55 | 6.2 | 3.0% |
| 86 | 6.8 | 3.3% |
| 58 | 0.5 | 0.2% |
| 91 | 31.4 | 15.2% |
| 85 | 4.7 | 2.3% |
| 70 | 13.5 | 6.6% |
| 71 | 0.3 | 0.2% |
| 86 | 9.0 | 4.4% |
| 91 | 12.7 | 6.2% |
| 80 | 0.7 | 0.4% |
| 89 | 29.6 | 14.4% |
| 77 | 39.7 | 19.3% |
| 25 | 7.5 | 3.6% |
| 76 | 5.9 | 2.8% |
| 73 | 37.0 | 18.0% |
| 30 | 0.2 | 0.1% |
| 94 | 0.2 | 0.1% |
| Total | 206.0 | 100.0% |

| Basin 3 | | |
|---|---|---|
| Cn | Area (km2) | Percentage (%) |
| 91 | 3.1 | 5.2% |
| 70 | 1.4 | 2.3% |
| 71 | 0.0 | 0.0% |
| 86 | 0.5 | 0.8% |
| 91 | 0.5 | 0.9% |
| 89 | 32.7 | 54.5% |
| 77 | 14.0 | 23.2% |
| 25 | 2.3 | 3.8% |
| 76 | 0.2 | 0.4% |
| 73 | 4.7 | 7.9% |
| 30 | 0.3 | 0.6% |
| 94 | 0.3 | 0.5% |
| Total | 60.0 | 100.0% |

| Basin 4 | | |
|---|---|---|
| Cn | Area (km2) | Percentage (%) |
| 55 | 0.1 | 0.4% |
| 86 | 0.3 | 1.1% |
| 91 | 3.9 | 13.9% |
| 85 | 0.2 | 0.7% |
| 70 | 1.8 | 6.4% |
| 71 | 0.1 | 0.4% |
| 86 | 0.4 | 1.4% |
| 91 | 1.4 | 5.0% |
| 80 | 0 | 0.0% |
| 89 | 11.5 | 41.1% |
| 77 | 3.3 | 11.8% |
| 25 | 1.2 | 4.3% |
| 76 | 0 | 0.0% |
| 73 | 3.6 | 12.9% |
| 30 | 0.2 | 0.7% |
| Total | 28 | 100.0% |

| Basin 5 | | |
|---|---|---|
| Cn | Area (km2) | Percentage (%) |
| 55 | 2.2 | 7.0% |
| 86 | 0.4 | 1.2% |
| 58 | 0.1 | 0.4% |
| 91 | 3.9 | 12.4% |
| 85 | 0.4 | 1.1% |
| 70 | 1.2 | 3.8% |
| 71 | 0.0 | 0.1% |
| 86 | 0.5 | 1.7% |
| 91 | 1.0 | 3.2% |
| 89 | 6.0 | 19.2% |
| 77 | 5.3 | 17.0% |
| 25 | 1.9 | 6.2% |
| 76 | 0.4 | 1.2% |
| 73 | 6.9 | 22.2% |
| 30 | 1.0 | 3.2% |
| Total | 31.0 | 100.0% |

| Basin 6 | | |
|---|---|---|
| Cn | Area (km2) | Percentage (%) |
| 89 | 3.4 | 85.0% |
| 77 | 0.3 | 7.5% |
| 25 | 0.2 | 5.0% |
| 73 | 0.1 | 2.5% |
| Total | 4.0 | 100.0% |

| Basin 7 | | |
|---|---|---|
| Cn | Area (km2) | Percentage (%) |
| 89 | 3.67 | 89 |
| 77 | 0.02 | 91.8% |
| 25 | 0.22 | 0.5% |
| 73 | 0.05 | 5.5% |
| 30 | 0.04 | 1.3% |
| Total | 4.00 | 1.0% |

| Basin 8 | | |
|---|---|---|
| Cn | Area (km2) | Percentage (%) |
| 89 | 0.4 | 20.0% |
| 77 | 0.5 | 25.0% |
| 25 | 0.5 | 25.0% |
| 73 | 0.3 | 15.0% |
| 30 | 0.3 | 15.0% |
| Total | 2.0 | 100.0% |

Table 5. CN values for 8 watersheds basins

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To apply the SCS-CN method estimates total watershed runoff depth *Qv* ($m^3$) for a storm by the SCS runoff equation for the area by applying the equations (1,2,3,4) (Q, la, S, Qv):

- Q values range between (646.8-50) mm, the variation between run off deep values in the distract it's belonged to climatic conditions, Land cover nature, Vegetation and slopes, the high value indicating slopes, barren area, urban area and such another impermeable surfaces in the study of the area.
- la after applying the equation of la on the area, it has been found that most of the areas which lost water from rainfall and rain intensity were limited. This means high runoff causes vegetation scarcity and barren lands and slopes while loss of rainfall water quantities was sparse in mid of the study area and parts of Erbil city cause of green cover and permeable soils, values of la were between (154.2-5)mm.
- S values for area between (771- 25) mm, most of values with low numbers Indicate Low potential water retention for soil So an intensive run off That's represent urban area, slopes, Barren lands.
- Qv values between (582.12-45) $m^3$, the variation in values belonged for climatic condition, rainfall intensity, lithological outcrop, slopes and soil types fig (9).

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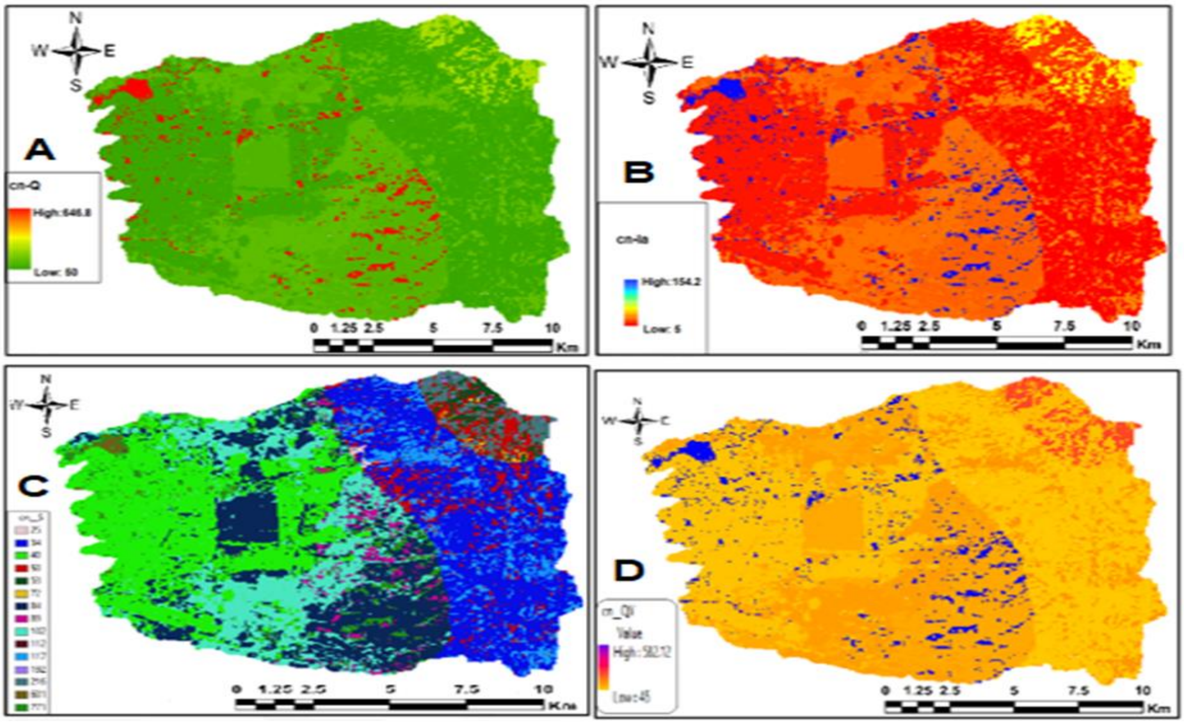

Fig 9. SCS CN: A- Q values B- la values C- S values D- Qv value

4.2 Rainfall intensity analysis

The study area was affected by many rainfalls, which were intervened by two rainfall intensities that lasted 5 days (18.19.20.21.22) starting from 1:00 A.m. on 18 /2/ 2022 to 4:00 p.m. on 25 /2/ 2022 with 16 hours of rainfall. The total rainfalls were (44) mm, with the highest rain intensity recorded at 3:00 Am on 20/2/2022 with 11mm, and then the second rainfall intensity at 1:00 Am on 25/2/2022 with (10) mm fig (10), the rain was at night, which means that there are few water losses by evaporation. This was preceded by rainfall that saturated the soil with water, which reduced filtration rates and then slope stability after deprivation of the loss sediments layer, high CN values point to higher surface runoff, while lower values refer to lower runoff. finally, the area was divided according to risk class fig 11 the southeast area showed that it’s with class 1 which mean high potential for

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flood. Main landform units are divided into subunits which have a special unique system of landforms and processes, cities when extend sure will occupy many landforms units. This will perturb its own local process reflecting problems in the city itself, and distorting landscape (Halah Mohammed S. Majeed, Raja K. Ahmed, Tanzeeh Majeed Hameed and Ruqaya Ahmed M. Amin,2020,4027), and geomorphic processes like what happened in the area when built area expanded on the stream valleys so the flood risks increase in the area photo (1).

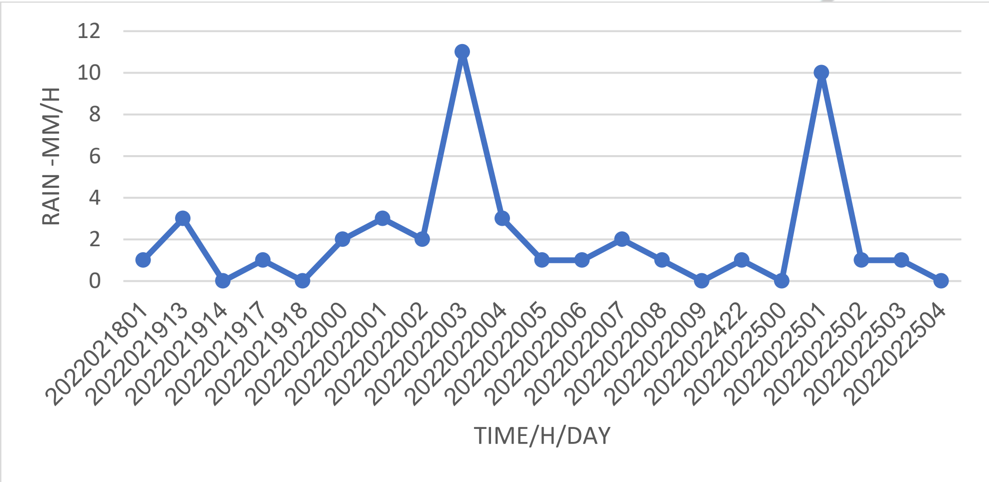


Fig 10. Rainfall intensity analysis between (18-25/2/2022)

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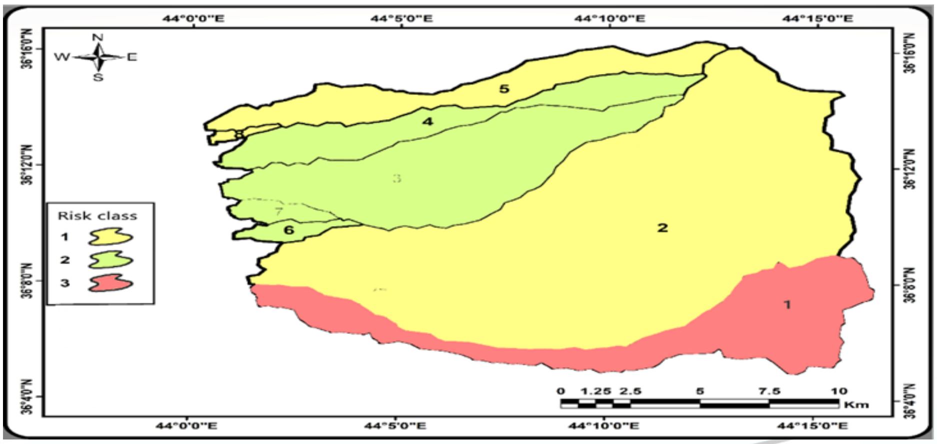


Fig.11 flood risk class

Photo (1) devastating flood in southeast Erbil city on 17/12/2021, where nearly 500 houses collapsed due to Friday's flood in Erbil and 867 cars were damaged, causing over 20 billion Iraqi dinars (IQDs) worth of destruction, Erbil Governor Omed Khoshnaw said in a press conference on Sunday (December19).source:(www.arabiaweather.com, www.nrttv.com/en/detail6/1989)

Conclusion:

Landscape which include many different factors affects and lack of study and understanding of the patterns of the physical medium and the dynamics of its processes and neglect of planning based on scientific studies, Erbil city is subjected to frequent floods caused by the city's indiscriminate expansion, which included the valleys of the watercourses and reached its eastern borders of the pediments zone, the dominated hydrologic soil class in study area it's A group (246km$^2$) (64%), there ae a 6 types of LULC in district Barren lands occupied highest class with (137km$^2$)(36%) among other LULC classes followed by second Built up class (92km$^2$) (24%) while the lowest one was the Vegetation cover with (3km$^2$) (1%) , CN values for whole basins high come corresponding with LULC mean high potential for surface runoff for example basin 1 CN values range between (91-25) higher CN value (91) with (18km$^2$) (35.3%) while the lowest and only lower value was (25) with (1km$^2$) (1%), Q values range between (646.8-50) mm , values of Ia were between (154.2-5) mm, S values for study area between (771- 25) mm, Qv values extended between (582.12-45) m$^3$, area was affected by two rainfall intensities that lasted 5 days (18.19.20.21.22) starting from 1:00 A.m. on 18 /2/ 2022 to 4:00 p.m. on 25 /2/ 2022 with 16 hours of rainfall. The total rainfall was (44) mm, with the highest rainfall intensity recorded at 3:00 Am on 20/2/2022 with 11mm and then the second rain intensity at 1:00 Am on 25/2/2022 with (10) mm.

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