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Article

Estimation of Surface Runoff in Erbil Basin Using WMS

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Abstract:

Estimating runoff using the Natural Resources Conservation Service (NRCS)-Curve Number (CN) is one of the most common methods used worldwide. The WMS Software facilitates accurate estimating of surface runoff from the Erbil basin. The present paper evaluates the applicability of the NRCS-CN method using the Watershed Modeling System (WMS) application in the Erbil basin, KRG, Iraq. The software required a digital elevation model (DEM), hydrologic soil groups (HSG), and Land use Land cover (LULC) shapefile as input data. Then, the WMS processed and calculated the weighted CN for each sub-catchment area within the study area, giving the total weighted CN for the basin. The results estimated that the high Runoff amount was obtained in (2018-2019) because the annual depth of the daily rainfall data was recorded as (1008, 769.7, and 1002.60) mm, and depth of runoff for (2018-2019) were calculated as (181.79, 127.48, and 266.73) mm, respectively, for the stations in Erbil, Khabat, and Qushtepa. As a result, the average volumes of the sub-basins of Central, North, and South, part of Erbil, were calculated as (101,083,979.17; 27,793,570.64; and 30,741,656.15) m^3, respectively. Also, the average weighted curve number for 12 sub-catchment results estimated by WMS was (76.1), involving 12 sub-catchment areas. Whereas the results of CNI and CIII were (57.2 to 88) for dry and wet conditions. The kappa method was used to determine the overall accuracy of the LULC map in (2022). The result showed that the overall accuracy was 91.94%, and the Kappa coefficient (Ka) was 0.89, which is acceptable and perfect and verified the results' accuracy.

Keywords:

Curve number; Erbil basin; NRCS-CN; Rainfall; Runoff; WMS.

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Highlights:

- Estimating surface runoff for Erbil basin.
- Estimating curve number for Erbil basin.
- Applying WMS software for CN estimation.
- Runoff management for Erbil basin.
- Using WMS software for calculating CN.

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1.INTRODUCTION

A watershed is an area covered with all the surface that contributes runoff water to a specific point. However, each watershed has several characteristics: slope, size, shape, drainage, geology, geomorphology, vegetation, soil, climate, and land use. In addition, runoff is one of the main hydrologic elements in water resources management. It depends on the occurrence and characteristics of rainfall events, such as intensity, duration, and distribution. The common methods for calculating runoff are mostly the Rational method, Green-Ampt method, and NRCS-CN method. The Rational method is mainly used for small drainage areas of up to 200 acres (80 ha) to estimate the maximum discharge of catchment. In contrast, NRCS-CN and Green-Ampt methods are used for relatively large areas to estimate runoff. It estimates weighted CN by Arc GIS based on the different land cover and soil types as weighting factor. As well as, the study concluded that the SCS-CN method coupled with RS and GIS is capable of estimating runoff successfully for the Rupen-Khan watershed [1]. In addition, Tirkey et al. [2] applied high-resolution satellite data and GIS techniques to compute CN by NRCS-CN method for estimating Runoff for small watersheds of Palamu district, Jharkhand, India. The study concluded a strong correlation between Rainfall-Runoff and between observed Runoff and estimated Runoff, indicating the high accuracy of Runoff estimation by the NRCS-CN technique. Then, Viji et al. [3] studied the Kundapallam ungauged watershed in India, 14.37 km². The study estimated runoff using a modified Soil Conservation Curve Number (SCS-CN) and Green-Ampt loss method. The study computed the runoff characteristics using ArcGIS and IDRISI image processing software. The catchment delineation was generated using the HEC-GeoHMS extension in ArcGIS. CN was estimated depending on the Soil Wetness Index (SWI). The authors concluded that the modified SCS-CN provided lower runoff estimation than the Green-Ampt loss method. Balvanshi and Tiwari [4] studied the runoff depth using (SCS-CN) method, using RS and GIS in India. The SCS-CN quantitatively describes a watershed's LULC and soil complex characteristics. The study concluded that the RS and GIS-based SCS-CN can effectively estimate the runoff from the river basins. Rajbanshi [5] determined the runoff depth and volume using (NRCS-CN) method for the Konar catchment in Jharkhand, India. The soil types map was prepared in GIS techniques using the LULC map. The author revealed that the NRCS-CN method, integrating GIS and remote sensing technology, can effectively estimate the runoff in an ungauged river catchment with similar hydrological characteristics. Kimeli [6] estimated the floodwaters by (SCS-CN) method using GIS. However, Gajbhiye [7] determined the direct runoff using RS and GIS. The total area of the watershed was 19.53 km². ArcView GIS 9.3 with ArcInfo, Arc Hydro Tool, and Geospatial Hydrologic Modeling Extension (Hec-GeoHMS) were used to calculate Salt Creek watershed (SC) in USA watershed (19210 ha) CN [8]. According to Al-Juaidi [9], the SCS-CN method takes time when calculating in hydrologic modeling. Therefore, GIS was coupled with HEC-GeoHMS, which includes land topography, to produce more accurate CN and runoff volumes for the Gaza Strip catchments in Egypt. The importance of this paper is that it developed an approach to determine the accurate CN. The study also concluded that land-use changes play an important role in CN number and runoff volumes over time. Moreover, using GIS with HEC-GeoHMS and SCS-CN methods provides a quick and accurate method to calculate CN and runoff volumes compared to the rational method. Zhang [10] determined the relationship between typhoon events and natural hazards using the NRCS-CN method in the Chenyoulan watershed in Taiwan. Falih [11] determined CN for the Barada Ali basin, 73.9 km², using the SCS-CN method by the HEC-HMS model. This model worked within the environment of GIS and RS techniques. The study concluded the weighted CN of (78) for the total basin area (26.5) km². The present study was conducted in the Erbil Basin due to the area's importance. This catchment is selected to compute CN because the area requires water resources management, and the existing studies only determined CN for different areas. Most previous studies described a lack of water resources management in the Erbil basin [12-17]. Therefore, the present study used Watershed Modeling System (WMS) Software to estimate the CN for multiple sub-catchment areas regarding the Erbil basin. Whenever CN is estimated, estimating the runoff depth for the proposed location would be easy. The main objective of the present study is to present the reliability and simplicity of WMS software to calculate CN for the large catchment area. There are numerous studies and works available on estimating curve number (CN) by Soil conservation Service (SCS), which is the same as the NRCS method; most of the common methods applied by Geographical Information System software (GIS) and a few of them used Watershed Modeling System (WMS). The present study shows the applicability of this software and the possibility of the method using WMS for the Erbil catchment area. The summarized previous studied results are listed in Table 1. The present study was conducted in the Erbil Basin due to the area's importance. This catchment was selected to compute CN because no other study computes all Erbil catchments; the existing studies only determined CN for a small area. Therefore, the present study used Watershed Modeling System (WMS) Software to estimate CN for multiple sub-catchment areas regarding the Erbil basin. Whenever CN is estimated, it would be easy to estimate Runoff depth for the proposed location. The main objective of the present study is to present the reliability and simplicity of WMS software to calculate CN for large catchment areas.

2.MATERIALS AND METHODS

2.1.Location of the Study Area

The Erbil Basin is located between latitudes 35° 46' N and 36° 34' N and longitudes 43° 34' and 44° 19' E. The Greater Zab River is the main tributary of the Tigris River. On the other hand, the Lower Zab River extends from northeast Iran to Iraq. The reason behind selecting the Erbil basin as a study area is the importance of the Erbil basin in the Middle East. The area depends on surface water resources, involving river water and precipitation, with groundwater resources through wells mentioned as north, central, and South parts sub-basins [12, 13]. Moreover, the total area of the Erbil catchment, Fig. 1, calculated by Arc Map, is about (3,100 km²).

2.2.Hydrological Data and Climate Conditions

For the present study, the climate data of the Erbil meteorological station was collected from (1995-2020). The sum and average amount of each parameter are shown in Fig. 2. The three meteorological stations' locations are shown in Fig. 3. The coordinates of each meteorological station are listed in Table 2.

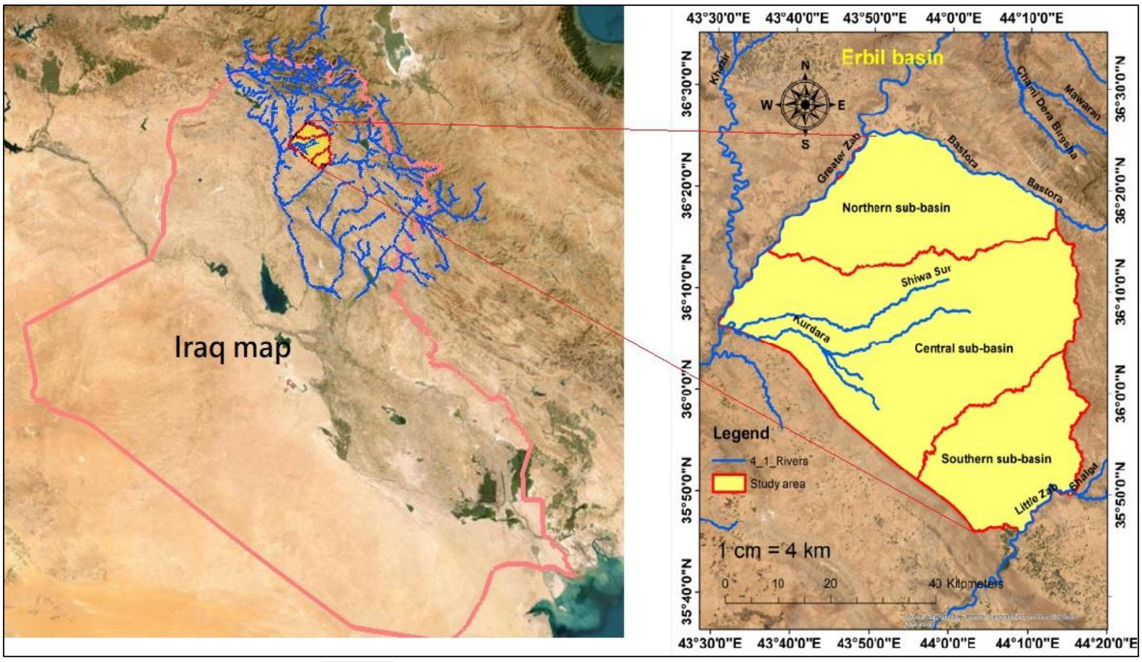
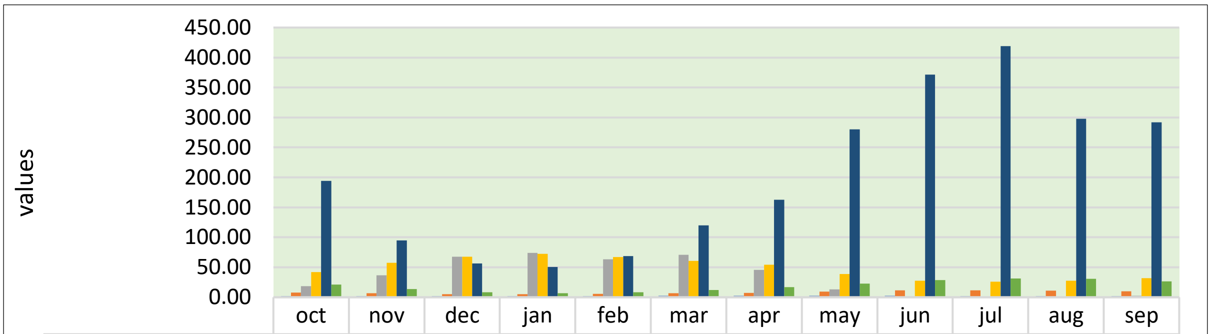


Fig. 1 Description of Study Area Location.

Table 1 Summary of the Previous Studies on CN Determination.

Author Name	Year	Software	Study Area	Area (Km²)	NRCS-CN
Zhan and Huang [18]	2004	Arc CN-Runoff tool, GIS	USA	100	1-94
Patil et al. [19]	2008	GIS	India	1,751	…….
Ebrahimian [20]	2012	GIS	Kardegh, Iran	448.15	35-93
Hameed [21]	2013	GIS	Erbil, Iraq	15,074	65-100
Garg et al. [22]	2013	GIS	India	530	…..
Zakaria et al [23]	2013	WMS	Suleimani, Iraq	176.79	58.3-92
Tirkey et al. [2]	2014	GIS	Jharkhand India	38.67	77
Nasiri and Alipur [24]	2014	GIS , RS, HEC-HMS	Iran	30	30-85
Ahmad et al. [25]	2015	GIS	Doundi, India	726.19	68.01
Gajbhiye [7]	2015	GIS and RS	Kanhaiya nala	19.53	54.5
Tailor and Shrimali [26]	2016	GIS	Rupen-Khan watershed, India	1620.8	76
Rajbanshi [5]	2016	GIS and ERDAS	Konar, India	934.18	59
Kumar et al. [27]	2016	RS and GIS	India	1252.9	0-98
Chavda et al. [1]	2016	RS and GIS	India	1409.1	73
Vannasy and Nakagoshi [28]	2016	GIS	Mark-Hiao River, Vientiane City	11.7	30-98
Mawlood and Hussein [29]	2016	GIS	Mala Omer, Iraq	9.326	67-98
Kimeli et al. [6]	2017	GIS and ERDAS, HEC-GeoHMS	Kenya	208.3	84
Shukur [8]	2017	GIS, HEC-GeoHMS	Osage County	1.921	58-100
Rao et al. [30]	2017	GIS, RSand HEC-GeoHMS	India	3,13,81	30-85
Rawat and Singh [31]	2017	GIS	India	150.06	79.35

Hameed [32]	2017	GIS	Erbil sub-basin, Iraq	177 km2	69-98
Mustafa [33]	2017	GIS	Gomaspan Dam chatchment area	132.5	68.8-92.4
Ezz [34]	2018	GIS, HEC-RAS	Assiut plateau, Egypt	20.52	85
Al-Juaidi [9]	2018	GIS, HEC-GeoHMS	Gaza Strip	365	52-66
Ara and Zakwan [35]	2018	GIS, RS	India	70,196	72.53
Shanmukha et al. [36]	2018	RS, GIS	India	75.37	83
Zhang [10]	2019	GIS	Taiwan	448	38-94
Pathan and Joshi [37]	2019	GIS	India	1358.8	88.95
Rajkumar and Viji [38]	2019	RS, GIS	India	4,509	26-100
Farran and Elfeki [39]	2020	....	Saudi Arabia	106.7 -4,944	84
Kumar et al. [40]	2020	GIS	India	1138	84.79
Aziz et al [41]	2020	WMS	Nazanin watershed, Iraq	73.14	61.5-90.9
Mustafa and Szydłowski [42]	2020	HEC-Geo HMS *GIS	Erbil, Iraq	508.074	82.44-87.84
Falih [11]	2021	GIS, HEC-HMS	Diyala, Iraq	73.9	78
Daide et al. [43]	2021	GIS, HEC-GeoHMS	Beht, Morocco	4,560	78
Fathy et al. [17]	2021	GIS, WMS	Egypt	351,11	78 -87
Dawood et al. [44]	2021	WMS	Koya, Iraq	324.27	71
Khzr et al. [45]	2021	GIS	Suleimani, Iraq	295.39	60-98
Mohanan [46]	2022	GIS	India	....	78
Neelam and Hooda [47]	2022	GIS	Haryana	65.51	59.78
Ahmed and Suleimany [48]	2022	GIS	Rawanduz, Iraq	2956	58-92
Salman and Hamdan [49]	2023	GIS	Lesser Zab River (LZR) watershed, Iraq	19780	56-100
Kadhim [50]	2023	GIS	Bastoura Basin, Iraq	533.6	60-98
Khidir [51]	2023	WMS	Goizha-Dabashan, Iraq	2.02	69.1
Dawood and Mawlood [52]	2023	HEC-HMS	Zerin City, Iraq	24.54	79
Majeed [53]	2023	GIS	Erbil's Eastern Basins, Iraq	137	55-94
Khidir [54]	2023	WMS	Goiza, Dabshan, Khoshanan, Yousifka, Solag, Iraq	111.68	59.83-81.50



	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Winspeed m/s	1.92	1.71	1.83	1.97	2.20	2.37	2.36	2.36	2.23	2.08	1.84	1.71
Sunshine hr/day	7.86	6.50	5.19	4.91	5.81	6.57	7.49	9.31	11.52	11.66	11.21	10.12
Rainfall mm	18.61	36.92	67.63	74.27	63.13	70.88	45.68	13.27	1.62	0.20	0.04	2.41
Relative Humidity%	42.18	57.72	67.70	72.39	67.23	60.69	54.30	38.90	27.59	25.71	27.62	31.75
Evaporation (mm)	194.18	94.73	56.22	50.70	68.45	120.09	162.71	280.16	371.26	419.11	297.82	292.10
Avg Temp Ċ	21.09	13.50	8.47	6.95	8.20	11.97	16.78	22.76	28.53	31.57	31.02	26.40

Fig. 2 The Climate Data Record in Erbil Station for (1995-2020).

Table 2 The Coordinates of Three Meteorological Stations by UTM.

Stations	Easting (m)	Northing (m)	Elevation (m)
Erbil	418123.2	4002223.03	479
Khabat	370579	3999165.63	223
Qushtepa	412750.5	3984814.35	399

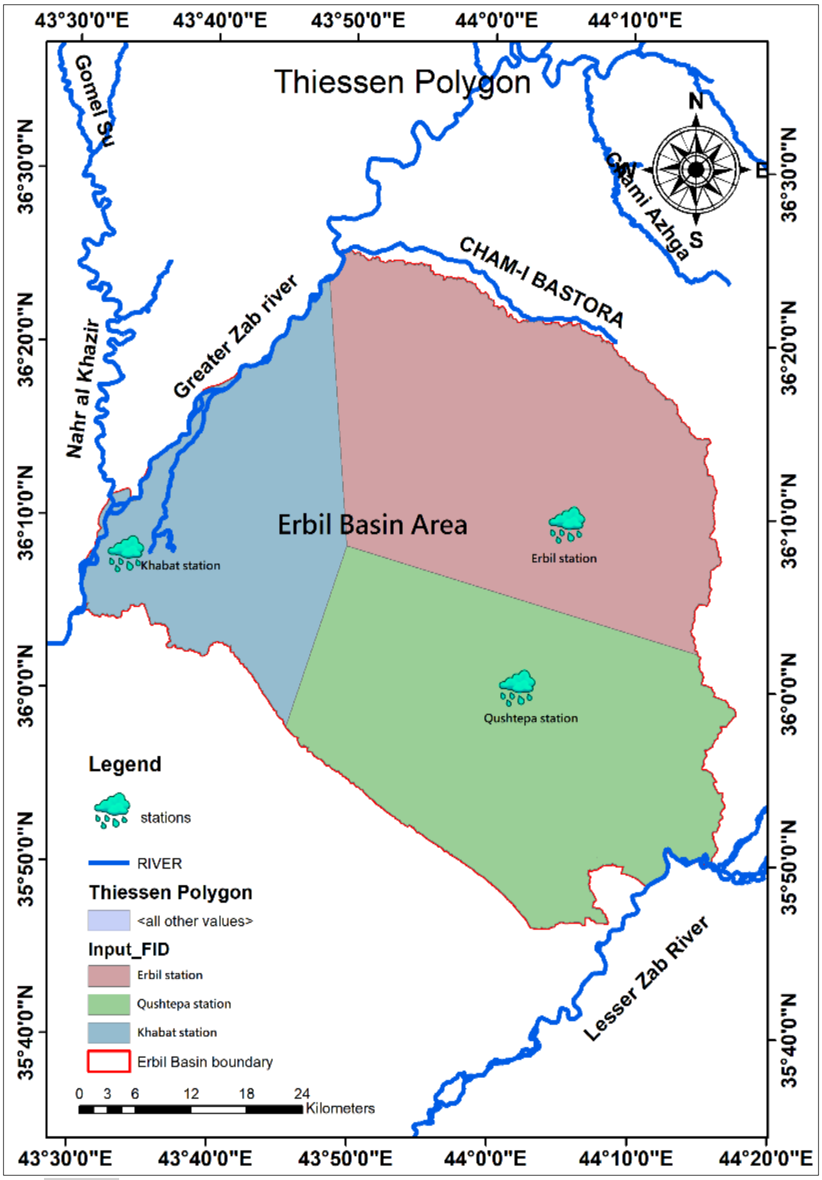


Fig. 3 Three Meteorological Stations Locations in Erbil Basin.

3.METHODOLOGY AND DATA ANALYSIS

3.1.Method Description

Runoff estimation is vital for planning and managing most water resource projects. There are a lot of methods available for estimation of surface runoff. The USDA Soil Conservation Service curve number (SCS-CN) method, now called (NRCS-CN), is the most popular and widely used method. Moreover, the advantages of this method are its simplicity, predictability, and reliance on only one value, namely the Curve Number (CN). The land Use/ Land Cover (LULC) classes can be integrated with the hydrologic soil groups (HSG) of the sub-basin in WMS, and the weighted CN can be estimated. The estimated weighted (CN) for the entire watershed area can be used to compute runoff. The computed runoff values can be checked with the observed data. The main inputs required for the (NRCS-CN) method are the delineation of the watershed boundary by digital elevation model (DEM), downloading of global soil types and land cover, then by WMS preparation of soil map, preparation of LULC map and antecedent moisture condition (AMC) to estimate daily runoff for the years (2018-2019). The main objective of the present paper is to calculate the daily runoff for the Erbil watershed by WMS software. The main process used in WMS software is explained in Fig. 4.

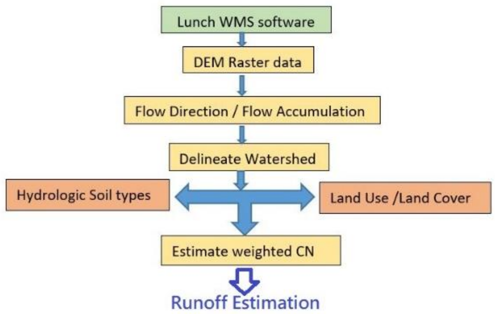


Fig. 4 The Flow Chart of the Study Works.

3.2.Soil Types (Hydrologic Soil Groups (HSG))

Soil types of the study area are classified into four group types, i.e., A, B, C, and D, according to Chow Ven (1988) [56], who stated that CN depends on Soil types and land use, such as described in (SCS-CN) method. The soil groups are described as Group A: Deep sand, deep loess, and aggregated silts; Group B: Shallow loess and sandy loam; Group C: Clay loams, soils low in organic content, shallow sandy loam, and soils usually high in clay; and Group D: Soils that swell significantly when heavy plastic clays and curtain saline soils). On this basis, the Erbil Construction Laboratory collected nine Borehole samples in different locations and analyzed them to determine the soil groups in the study area. According to the soil samples, it has been determined that the samples are all in Group D. Therefore, to satisfy the reliability of the soil samples with field data, a map is created by WMS software, which coincides with global soil types downloaded in the software itself, see Fig. 5. Several samples collected within the study area determined the soil types of the Erbil basin, located within the clay and loam part of HSG. The information about locations and types is shown in Table 3.

Table 3 The Collected Soil Samples and Group Types by UTM Coordinates.

ID	Easting	Northing	Soil type	Depth(m)
1	407992.16	4008687.0	D	26
2	416601.94	4003536.9	D	2.5
3	407080.14	4007827.1	D	14
4	407707.35	4005394.5	D	21
5	415280.59	4010590.5	D	2
6	411523.31	4016039.4	D	23.5
7	410393.75	4008491.5	D	2
8	408105.65	4013090.8	D	3
9	406165.10	4003099.1	D	1.5

The above data was tested by the Erbil Construction Laboratory for different locations within the study region. The soil samples from different depths and locations were found to be Type D, coinciding with the global soil map.

3.3.Land Use/Land Cover (LULC)

Spatial data is downloaded inside WMS software as shapefiles and then converted to land use coverage to prepare Land Use/Land Cover (LULC) maps for the Erbil basin. Sentinel-2 with a 10 m resolution image was used [61]. This method of LULC classification is suitable for the study area. Figures 6–8 represent the Erbil watershed LULC, slope aspects, and slope of the Erbil basin. The main concepts and differences between slope and aspect are that aspect determines the fall line direction according to the north, while slope determines the gradient directly down the fall line.

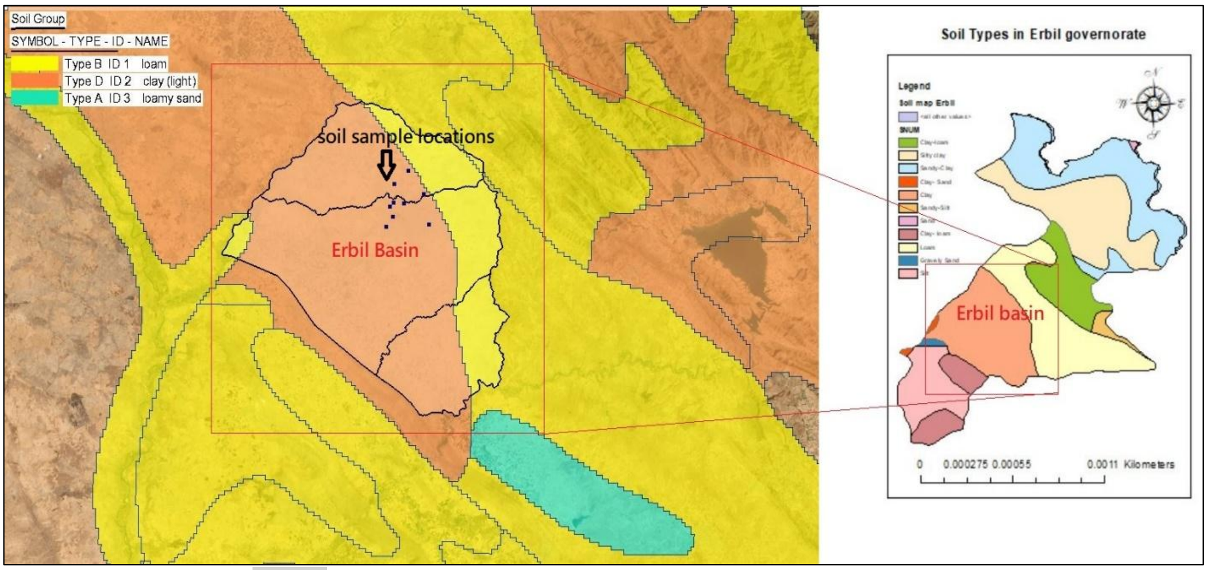


Fig. 5 Soil Types and Samples Locations in WMS Software.

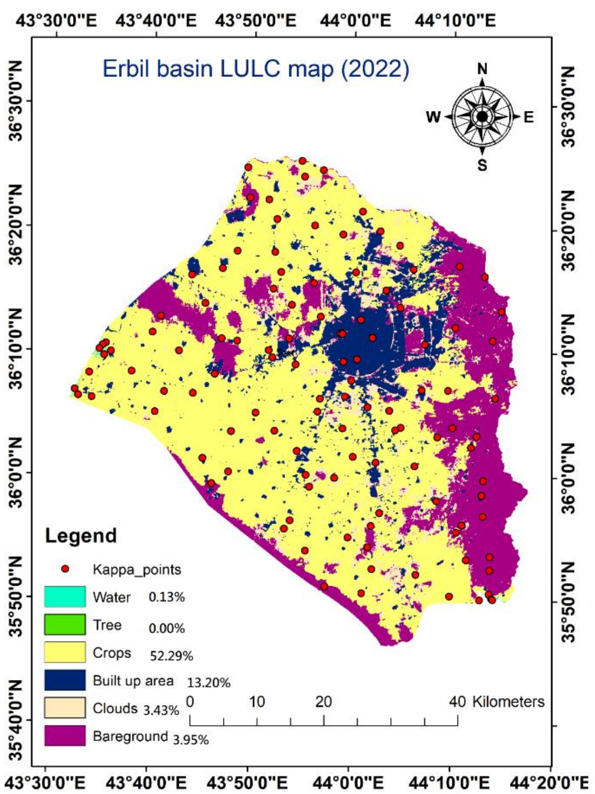


Fig. 6 Erbil Watershed Land Use / Land Cover (LULC) Map.

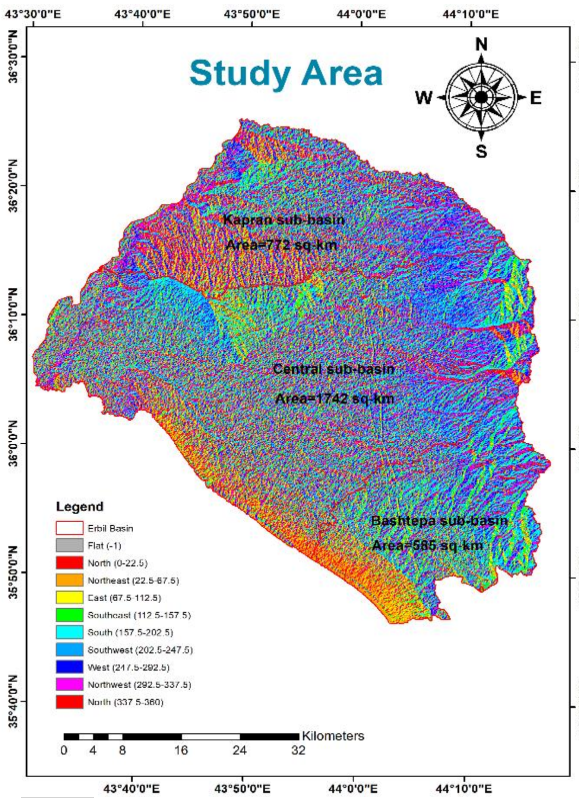


Fig. 7 Slope Aspect Map of the Study Area Arc Map (10.8).

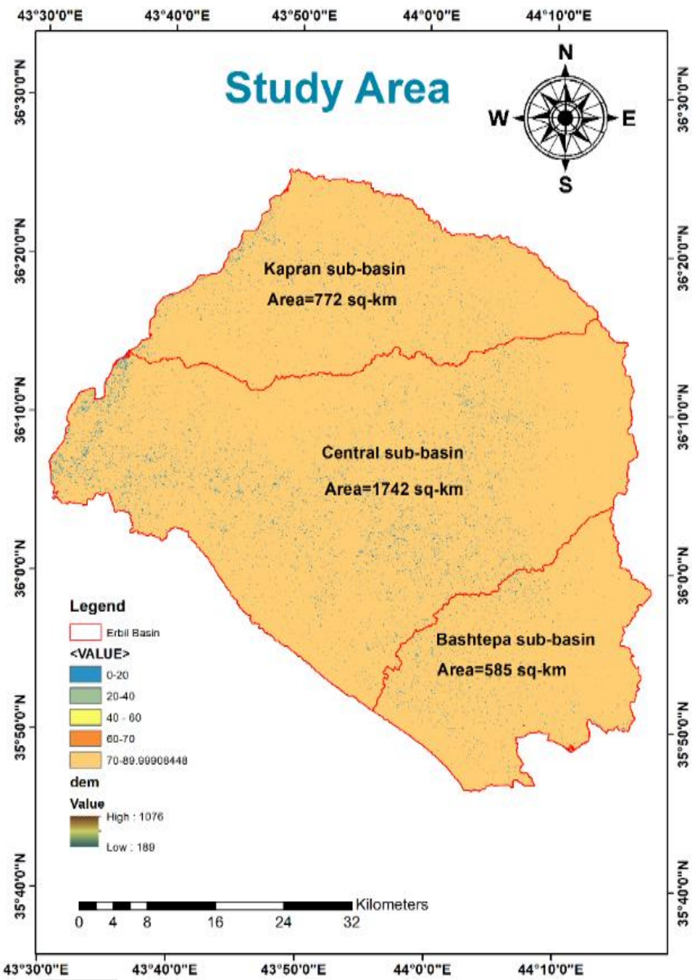


Fig. 8 Slope Map of the Study Area Arc Map (10.8).

3.4. Natural Resources Conservation Service (NRCS-CN) Method

The present study used the (NRCS-CN) method for estimating runoff from rainfall data. This method computes the Curve number for the catchment area [1]. The SCS curve number method is based on the water balance equation and the following two fundamental hypotheses:

- The ratio of the actual direct runoff to the potential runoff is equal to the ratio of the actual infiltration to the potential infiltration.
- The amount of initial abstraction is some fraction.

The details and derivation of the NRCS method are as follows:

$$\frac{F}{S} = \frac{Q}{(p-Ia)} \quad (1)$$

$$F = (P - Ia) - Q \quad (2)$$

Substituting Eq. (2) in Eq. (1) yields Eq. (3):

$$Q = \frac{(P-Ia)^2}{(P-Ia)+S} \quad (3)$$

Where:
Q: Runoff depth (mm)
P: Daily Rainfall data (mm)
I_a: Initial abstraction, which includes all losses before runoff begins in (mm).

$$Ia = 0.2\,S \quad (4)$$

Substitute Eq. (4) in Eq. (3):

$$Q = \frac{(P-0.2S)^2}{(P-0.2S)+S} \quad (5)$$

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \quad , For\ (P > 0.2\,S) \quad (6)$$

Where:
S: The potential infiltration after Runoff begins given by:

$$S = \frac{25400}{CN} - 254 \quad (7)$$

Where:
CN is a curve number between (0-100) and unitless. The high CN value means a higher Runoff amount, and the low number of CNs means a low Runoff value. Based on the Technical Release [55], CN was adapted, and it stated that the SCS method was originally designed for a watershed of (15 km²); however, it is modified for a larger watershed by computing weighted curve number as follows:

$$CN_w = \frac{\int (CNi\ x\ Ai)}{A} \quad (8)$$

Where:
CN_w: Weighted Curve Number (Unitless)
CN_i: Curve number for each sub-catchment (Unitless)
A_i: Area of the sub-catchments (km²)
A: The total area of the watershed (km²)
CN_w represents the existing water content in the soil at a given time. It is vital for determining the actual CN values. The NRCS method developed three AMC types, numbered I, II, and III, according to soil characteristics and rainfall limits for dormant and growing seasons [51, 54]. For computing AMC types, selected Dormant seasons are based on Table 4. The classification of AMC used for determining the CN values for Erbil catchment areas is shown in Table 5.

Table 4 Calculated 5 Days AMC According to [14].

AMC Type	Total rain in previous 5 days	
	Dormant season	Growing season
I	Less than 13mm	Less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

Table 5 Calculated Curve Number Based on AMC I, II, III.

AMC types	Values
CN I for Dry conditions	57.2
CN II for Normal conditions	76.1
CN III for Wet conditions	88

According to [56], the estimated CN for normal antecedent moisture conditions (AMC II), i.e., equals (76.1), for dry conditions (AMC I) and for wet condition (AMC III).

$$CN\ I = \frac{4.2\ CNII}{10-0.058\ CNII} = \frac{4.2\ (76.1)}{10-0.058\ (76.1)} = 57.2 \quad (9)$$

$$CN\ III = \frac{23\ CNII}{10+0.13\ CNII} = \frac{23\ (76.1)}{10+0.13\ (76.1)} = 88 \quad (10)$$

A sample of calculation for Erbil meteorological stations is shown in Table 6.

4. RESULTS AND DISCUSSION

The present study used the Natural Resources Conservation Service (NRCS) method for calculating direct runoff volume for a given rainfall event during (2010 – 2020), which is the maximum rainfall depth recorded in Erbil meteorological station. As well as, the weighted CN values were estimated using the Watershed Modeling System (WMS) based on global shape files of soil types and LULC in the software itself. Then, the land use and soil maps were processed using WMS software to estimate the Curve number for normal conditions, denoted by (CNII). The results of the daily Rainfall-Runoff data for the years (2010-2020) and the average runoff estimated from the SCS-CN method for different sub-areas are summarized in Table 7. The relation between Rainfall-Runoff data are plotted in Figs. 9–11. In addition, to estimate the volume of Runoff for each Erbil sub-basin, Runoff depth was multiplied by the sub-basin area, i.e., 1742, 772, and 585 km² for Central, North, and South sub-basins parts, respectively. The values are tabulated in Table 8. The Erbil basin consists of several sub-basins with different areas and weighted CNs. Figure 12 shows a map of all created sub-basins by WMS software version (11.04) in the study area, divided into 12 sub-basins. The results of the calculated weighted CN by WMS software are shown in Table 9. The present study results coincide with previous studies conducted in Iraq [51, 54], indicating the present study results and the obtained values. Thus, using WMS software for calculating CN and then applying it in NRCS-CN can give good values of Runoff methods. The results of the present and previous studies are compared in Table 10.

Table 6 Sample of Calculation for Estimating Runoff for Jan 2018.

Day	Date	p(mm)	5 days	AMC	CN	S	0.2S	Runoff (mm)
1	2018-01-01	6.4						
2	2018-01-02	6						
3	2018-01-03	0						
4	2018-01-04	0						
5	2018-01-05	0						
6	2018-01-06	0	12.4	I	57.20	190.1	38.0	0.00
7	2018-01-07	0	6	I	57.20	190.1	38.0	0.00
8	2018-01-08	0	0	I	57.20	190.1	38.0	0.00
9	2018-01-09	0	0	I	57.20	190.1	38.0	0.00
10	2018-01-10	0	0	I	57.20	190.1	38.0	0.00
11	2018-01-11	0	0	I	57.20	190.1	38.0	0.00
12	2018-01-12	0	0	I	57.20	190.1	38.0	0.00
13	2018-01-13	0	0	I	57.20	190.1	38.0	0.00
14	2018-01-14	0	0	I	57.20	190.1	38.0	0.00
15	2018-01-15	0	0	I	57.20	190.1	38.0	0.00
16	2018-01-16	0	0	I	57.20	190.1	38.0	0.00
17	2018-01-17	1.6	0	I	57.20	190.1	38.0	0.00
18	2018-01-18	0.6	1.6	I	57.20	190.1	38.0	0.00
19	2018-01-19	5.2	2.2	I	57.20	190.1	38.0	0.00
20	2018-01-20	0	7.4	I	57.20	190.1	38.0	0.00
21	2018-01-21	0	7.4	I	57.20	190.1	38.0	0.00
22	2018-01-22	0	7.4	I	57.20	190.1	38.0	0.00
23	2018-01-23	0	5.8	I	57.20	190.1	38.0	0.00
24	2018-01-24	2.3	5.2	I	57.20	190.1	38.0	0.00
25	2018-01-25	17.1	2.3	I	57.20	190.1	38.0	0.00
26	2018-01-26	4.5	19.4	II	76.20	79.3	15.9	0.02
27	2018-01-27	0.3	23.9	II	76.20	79.3	15.9	0.00
28	2018-01-28	0	24.2	II	76.20	79.3	15.9	0.00
29	2018-01-29	0	24.2	II	76.20	79.3	15.9	0.00
30	2018-01-30	0	21.9	II	76.20	79.3	15.9	0.00
31	2018-01-31	0	4.8	I	57.20	190.1	38.0	0.00

Table 7 The Sample of Calculation Runoff Depth by NRCS-CN Method.

Station names	Erbil station		Khabat station		Qushtepa station	
Year	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)
2010-2011	349.8	51.10	256.7	35.43	185.20	1.48
2011-2012	242.6	3.63	126.8	0.00	133.00	6.70
2012-2013	491.1	80.87	422.5	47.57	378.60	50.91
2013-2014	299.6	39.58	274.8	25.45	176.30	12.01
2014-2015	355.1	33.78	212.5	33.18	199.80	12.00
2015-2016	491.5	66.07	393.9	28.43	424.30	72.08
2016-2017	337.7	39.06	242.1	15.78	282.00	18.19
2017-2018	435.9	58.37	239.4	8.22	268.60	18.83
2018-2019	1008	181.79	769.7	127.48	1002.60	266.73
2019-2020	401.1	26.05	443.3	38.49	463.80	66.57
Sum	4412.4	580.28	3381.7	360.02	3514.20	525.50
Average	441.24	58.03	338.17	36.00	351.42	52.55

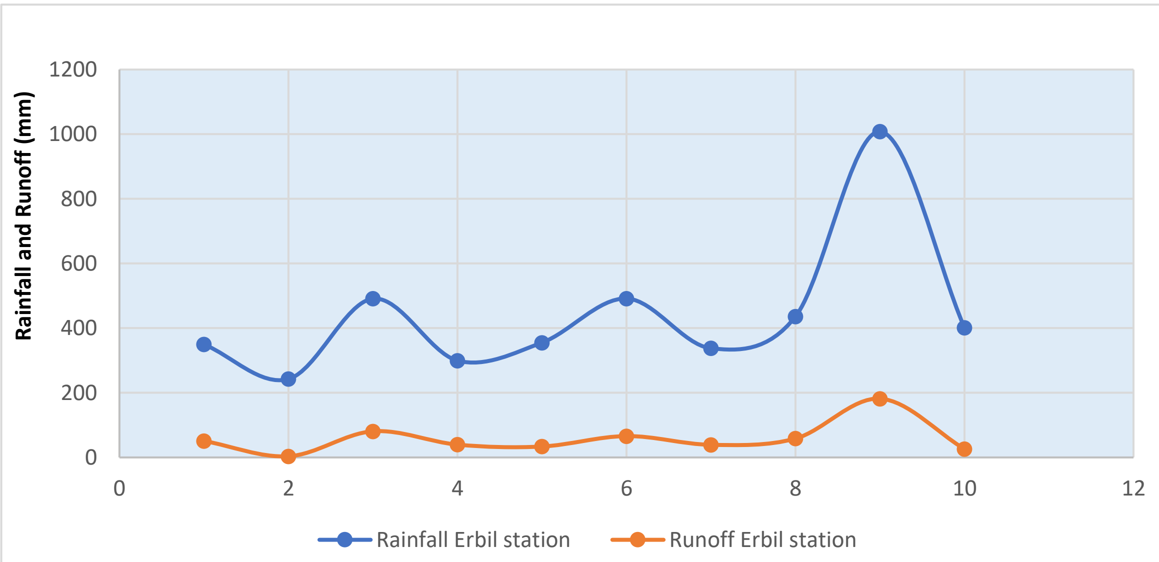


Fig. 9 Rainfall-Runoff Depth in Erbil Meteorological Station (2010-2020).

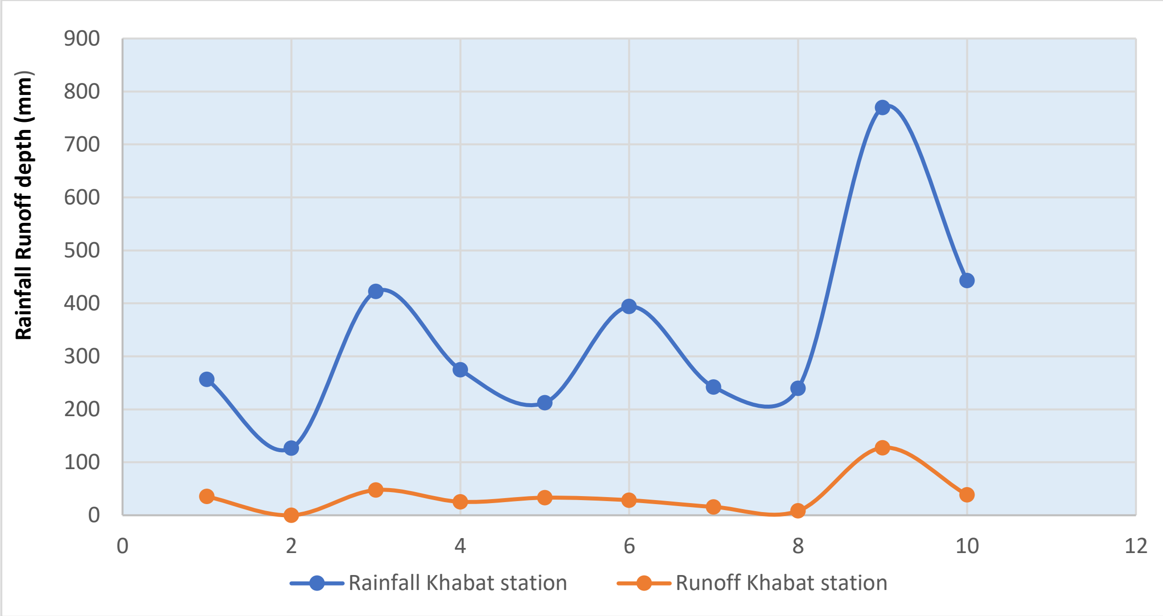


Fig. 10 Rainfall-Runoff Depth in Khabat Meteorological Station (2010-2020).

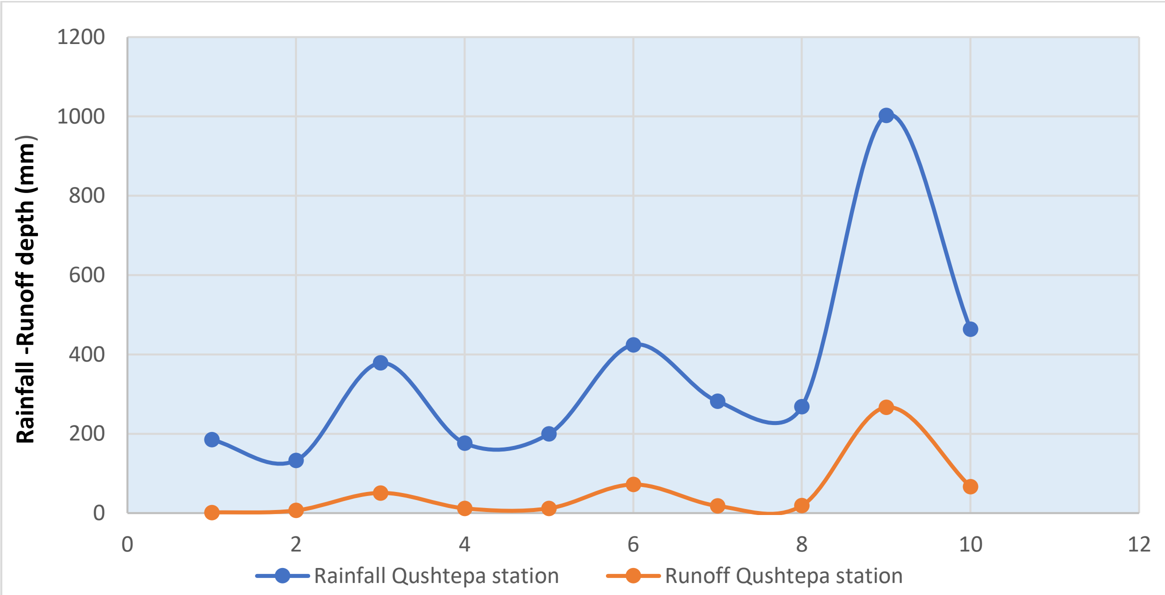


Fig. 11 Rainfall-Runoff Depth in Qushtepa Meteorological Station (2010-2020).

Table 8 The Calculated Runoff Volumes for Each Sub-Basin Area.

Stations	Erbil station		Khabat station		Qushtepa station	
Year	Runoff (m)/106	Volume of Runoff (m3) × Area (1742) Km2	Runoff (m)/106	Volume of Runoff (m3) × Area (772) Km2	Runoff (m)/106	Volume of Runoff (m3) × Area (585) Km2
2010-2011	51.10	89012420.83	35.43	27348121.38	1.48	863258.53
2011-2012	3.63	6320897.39	0.00	0.00	6.70	3918433.05
2012-2013	80.87	140870554.57	47.57	36725925.05	50.91	29781482.43
2013-2014	39.58	68944328.20	25.45	19645079.08	12.01	7025974.71
2014-2015	33.78	58842875.81	33.18	25614247.95	12.00	7020519.72
2015-2016	66.07	115092435.02	28.43	21946989.30	72.08	42169149.91
2016-2017	39.06	68035612.56	15.78	12184958.94	18.19	10641401.45
2017-2018	58.37	101672923.55	8.22	6344122.12	18.83	11016835.07
2018-2019	181.79	316673330.91	127.48	98414030.90	266.73	156034373.35
2019-2020	26.05	45374412.86	38.49	29712231.70	66.57	38945133.23
Sum	580.28	1010839791.71	360.02	277935706.43	525.50	307416561.46
Average	58.03	101083979.17	36.00	27793570.64	52.55	30741656.15

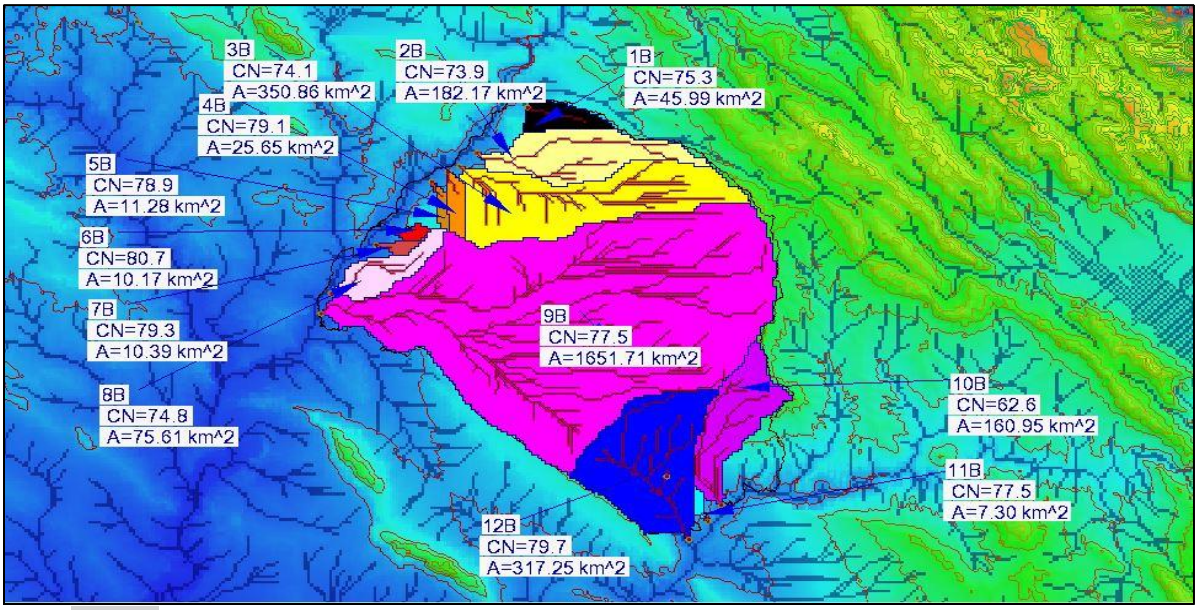


Fig. 12 The Calculated CN Values for Each Sub-Basin in the Erbil Area by WMS Software.

Table 9 The Summarized Results of Weighted CN for Each Sub-Basin Area.

Basin ID	Weighted CN	Sub-catchment area (km²)	Erbil Basin part
1B	75.3	46.0	North
2B	73.9	182.2	North
3B	74.1	350.9	North
4B	79.1	25.7	North
5B	78.9	11.3	North
6B	80.7	10.2	Central
7B	79.3	10.4	Central
8B	74.8	75.6	Central
9B	77.5	1651.7	Central
10B	62.6	161.0	South
11B	77.5	7.3	South
12B	79.7	317.3	South
Weighted CN	76.1		

Table 10 Computed CN by NRCS Method and Compared with Previous Studies.

Author name	Year	Software	Study Area	Area (Km2)	CN
Hameed [21]	2013	GIS	Erbil, Iraq	15,074	65-100
Zakaria et al. [23]	2013	WMS	Suleimani, Iraq	176.79	58.3-92
Mawlood and Hussein [29]	2016	GIS	Mala Omer	9.326	67-98
Hameed [30]	2017	GIS	Erbil sub-basin	177 km2	69-98
Mustafa [31]	2017	GIS	Gomaspan Dam catchment area	132.5	68.8-92.4
Aziz et al. [41]	2020	WMS	Nazanin watershed, Iraq	73.14	61.5-90.9
Mustafa and Szydłowski [42]	2020	HEC-Geo HMS *GIS	Erbil	508.074	82.44-87.84
Falih [11]	2021	GIS and HEC-HMS	Diyala, Iraq	73.9	78
Dawood et al. [44]	2021	WMS	Koya, Iraq	324.27	71
Khzr et al. [45]	2021	GIS	Suleimani, Iraq	295.39	60-98
Ahmed and Suleimany [48]	2022	GIS	Rawanduz, Iraq	2956	58-92
Salman and Hamdan [49]	2023	GIS	Lesser Zab River (LZR) watershed, Iraq	19780	56-100
Kadhim [50]	2023	GIS	Bastoura Basin, Iraq	533.6	60-98
Khidir [51]	2023	WMS	Goizha-Dabashan, Iraq	2.02	69.1-94.66
Dawood and Mawlood [52]	2023	HEC-HMS	Zerin City	24.54	79
Majeed [53]	2023	GIS	Erbil's Eastern Basins	137	55-94
Khidir [54]	2023	WMS	Goiza, Dabshan, Khoshanan, Yousifka, and Solag	111.68	59.83-81.50
Present study results	2023	WMS	Erbil basin	3100	57.2-88

4.1.Kappa Accuracy Assessment

This method is used to accurately assess LULC classification using Google Earth pro of Erbil basin, Iraq, in 2022. For this study, sentinel-2 10-meter resolution in 2022 was used and analyzed using Arc GIS 10.8 [56, 57]. Unsupervised classification was used to classify the image. Under LULC categories, water, trees, crops, built-up areas, bare ground, and clouds were studied. After the classification of LULC types, 124 Random Points were generated in ArcGIS, and converted points were to KML to open in Google Earth Pro. Each point's ware is used to measure how many ground truth pixels are classified correctly. For this study, Google Earth Pro was used for comparison [61], shown in Fig. 13. The study used the kappa method to determine the image classification accuracy of resample-classified imagery with an actual field sample [57-60]. The image with a 10-meter resolution can be downloaded from the Esri landcover website [61]. The LULC map accuracy results of this study using the Kappa method are tabulated in Table 11.

Table 11 Kappa Accuracy Assessment by Compute Confusion Matrix.

No.	Class Value	Water	Tree	Crop	Built Up Area	Cloud	Bare Ground	Total	User Accuracy	Kappa Coeffic.
0	water	10	0	1	0	0	0	11	91	0
1	Tree	0	10	0	0	0	0	10	100	0
2	Crops	1	0	55	0	0	3	59	93	0
3	Built up area	0	0	1	10	0	0	11	91	0
4	clouds	0	0	0	0	7	3	10	70	0
5	Bare ground	0	0	0	1	0	22	23	96	0
6	Total	11	10	57	11	7	28	124		0
7	Producer Accuracy	91	100	96	91	100	79			0
	Kappa coefficient									0.89

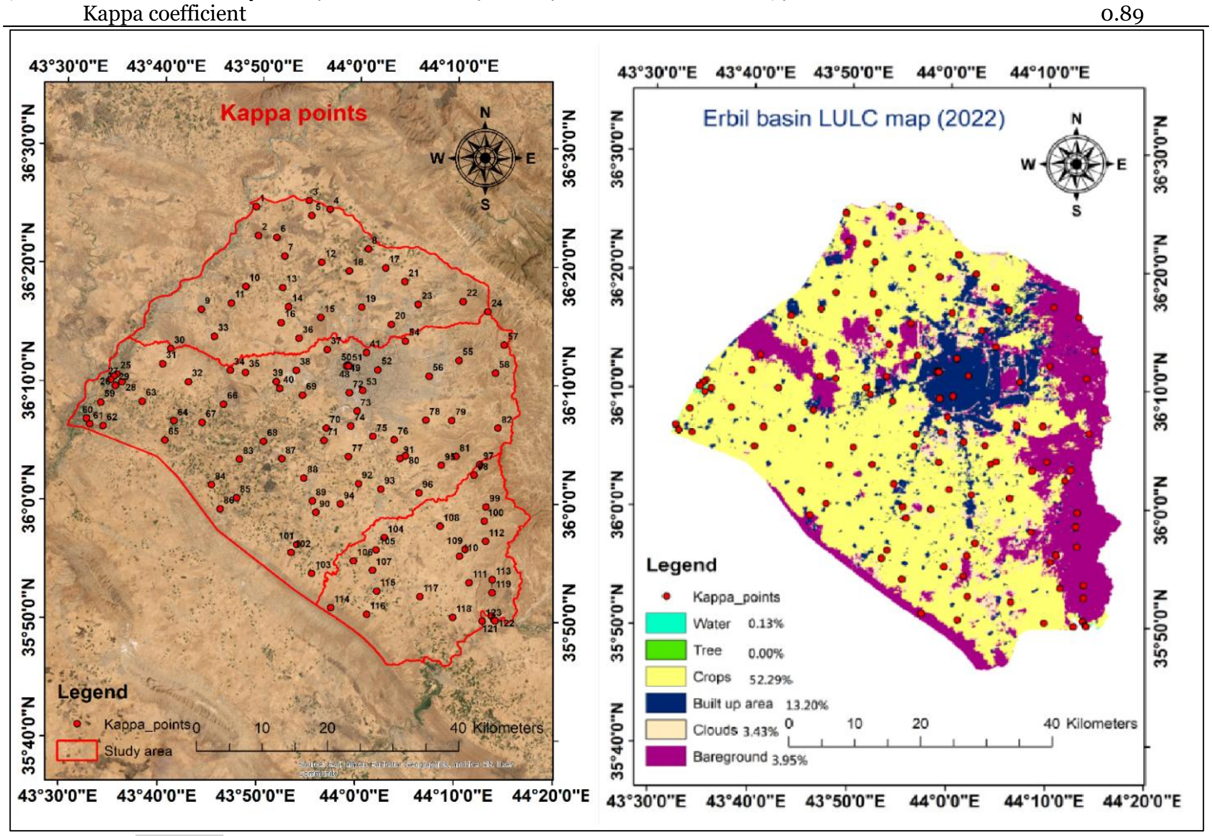


Fig. 13 The Map of LULC and Kappa Points Location on Satellite Image (2022).

Table 12 Strength of Agreement of Kappa Statistics [54].

Kappa statistics	Strength of Agreement
<0	Poor
0.00- 0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect/Perfect

The description of the method is in Eq. (11):

$$\textbf{Overall accuracy} = (\textbf{Total Number of correctly classified pixels (Diagonal)} / \textbf{Total number of Reference Pixels})\ x100 \quad \textbf{(11)}$$

$$Overall\ accuracy = \frac{114}{124} x100$$

$$Overall\ accuracy = 91.94\%$$

To calculate the Kappa Coefficient (Ka):

$$Ka = \frac{(Total\ sample - Total\ corrected\ sample - \int(Column\ total\ x\ Row\ Total)}{Total\ sample^2 - Total\ corrected\ sample - \int(Column\ total\ x\ Row\ Total)} x100 \quad (12)$$

$$Kappa\ Coefficient(Ka) = \frac{(14136 - 4419)}{124^2 - 4419} X\ 100$$

$$Kappa\ Coefficient(Ka) = 0.89$$

Based on the results of this study, the overall accuracy was 91.94%, and Ka was (0.89), which is within (0.81-1.00) according to Table 12., meaning almost perfect results.

5. CONCLUSIONS

The study concluded that the WMS software has successfully estimated surface runoff and CN in the Erbil basin. It was found that the rainfall, slope, LULC, and soil types are important factors in estimating the surface runoff. The selected basin receives relatively good rainfall over the entire area. Therefore, the results showed that the high runoff values were obtained in (2018-2019) because the annual depth of the daily rainfall data was 1008, 769.7, and 1002.60 mm, and the depth of runoff for (2018-2019) was calculated as 181.79, 127.48, and 266.73 mm for the Erbil, Khabat, and Qushtepa stations, respectively. As a result, the average volume of each sub-basin of Central, North, and South parts of Erbil was also calculated, i.e., 101,083,979.17; 27,793,570.64; and 30,741,656.15) m^3, respectively. The output of the average weighted curve number for 12 sub-catchments was estimated by WMS, i.e., (76.1), involving 12 sub-catchment areas. Whereas the results of CNI CIII were (57.2 to 88) for dry and wet conditions, respectively. Also, the kappa method was used to determine the overall accuracy of the LULC map in (2022). The result showed that the overall accuracy of land use and land cover was 91.94.00%, and the Kappa coefficient (Ka) was 0.89, which is acceptable and perfect and verified the results' accuracy.

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