

Estimation of Surface Runoff In Northeastern Missan Governorate by Using (Nrcs-Cn) Technique And Gis



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Received: 16 Aug. 2014, Revised: 27 Sep. 2014, Accepted: 16 October 2014

Published online: 30 November 2014

Key words: Surface runoff, NRCS-CN technique, GIS, Missan Governorate, Iraq

Abstract

In this study, an attempted was made to estimate average of annual total surface runoff in the northeastern Missan Governorate, south of Iraq by using Natural Resources Conservation Services Curve Number (NRCS – CN) empirical technique in GIS platform. Thematic layers of soil hydrological groups and LULC were created using ArcGIS 9.3 software. Intersection of these two thematic layers generated a map with new polygons representing the merged hydrological soil group and LULC. The appropriated CN values adapted from different sources and technical release of United State of Department of Agriculture (USDA) were assigned manually for each new merged polygon. The curve numbers for different antecedent moisture content (AMC) were calculated as 38, 59, 77 for dry, normal, and wet soil conditions. The associated maximum potential retention for each AMC were calculated as 75, 87, 176.51, and 414.42 for dry, normal, and wet soil moisture conditions. Application of the method showed that the average annual runoff depth is 0.36 mm. This figure was multiplied by the area of the study area (1856) km² to get the total average of runoff volume 7424000 m³ which represents 0.0003 from the total annual average of rainfall. The applied method is robust and easy to implement and could be used to roughly estimate the surface runoff with minimal data.

1. Introduction

Surface runoff or overland flow is the discharge of precipitation from a catchment, which flows out through its natural drainage system (Anderson and McDonnell, 2005). It is one of the most important hydrologic variables used in most of the water resources application. In semi-(arid) region like Iraq, accurate information on runoff is scarce and only available in a few selected sites. Thus, using runoff estimation techniques suitable for ungauged watersheds are relevant where hydrologic gauging stations are not widely

available. Also, most of the areas in Iraq are ungauged, having no past records of the rainfall – runoff process. Of the several methods for runoff estimation from ungauged basins, the Soil Conservation Service Curve Number (SCS – CN) (renamed as Natural Resources Conservation Services Curve Number (NRCS – CN)) (USDA-SCS, 1993) method along with its derivatives has been widely applied to ungauged watershed systems and has been proved to be a rapid and accurate estimator of surface runoff. The (NRCS – CN) model developed by United States Department of

Agricultural (USDA) computes direct runoff through an empirical equation that requires the rainfall and a watershed coefficient as inputs. The watershed coefficient is called the curve number (CN). The CN is a dimensionless runoff index determined based on hydrologic soil group, land use, land treatment, hydrologic conditions and antecedent moisture conditions (AMC). The CN values range between 1 and 100. Higher values of CN implies higher runoff and vice versa. The NRCS runoff equation is widely used in estimation direct runoff because its simplicity, flexibility, and versatility (Melesse and Shih, 2002). In this context, many authors (for example Dutta et al. 2006; Patil et al. 2008; Patil et al. 2008; Mahboubeh et al. 2009; Manoharan and Murugappan, 2012;; Zahraa and Hachum, 2013) attempt to use this technique for estimating surface runoff.

The aim of this study is to use (NRSC – CN) technique for estimating surface runoff from rainfall in northeast Missan governorate. Surface runoff estimation is necessary for put plans for manage excess water and protect engineering structure.

2. The study area

The study area is located in the northeastern of Missan governorate, south of Iraq between (32°03'25.52"-32°30'30") latitude and (47°05'21.16"-47°40'53.52") longitude, Fig. 1. It encompasses an area of (1856 km²). The topography elevation ranges from (7 – 230) m. The area is crossed by two ephemeral streams

namely, Teeb and Dewereg. The source of both is the Iranian territory. The average discharges of both streams are variable depending on falling rainfall, Table 1. Both streams attained maximum flows during winter months (January through March), while the minimum flows occur during summer months. From the geomorphological point of view, the study area is flat and featureless surface bounded by the foothill zone in the northeast along the Iraqi-Iranian border. The most common landforms within the interested area are valleys network, alluvial fans, flood plain, sebkahs, Ahwar (marshes), and sand dunes. Tectonically, the largest part of the study area lies in the Mesopotamian structure zone. The small part along the Iranian boundary belong the folded zone. Geologically, most part of the study area covers with fluvial, lacustrine, aeolian sediments of recent age. The Quaternary deposits encompass about 72% from the study area whereas Tertiary sediments occupy 28%. The stratigraphic column consists of the following Formations (from oldest to newest): Euphrates, Fatha, Injana, Mukdadiyah and Bai Hassan, and Quaternary deposits. The climate of the study area is characterized with hot, dry summer, cold winter and a pleasant spring and fall. Approximately 90% of the annual rainfall occurs between November and April, most of it in the winter months from December to March. The remaining six months are dry and hot

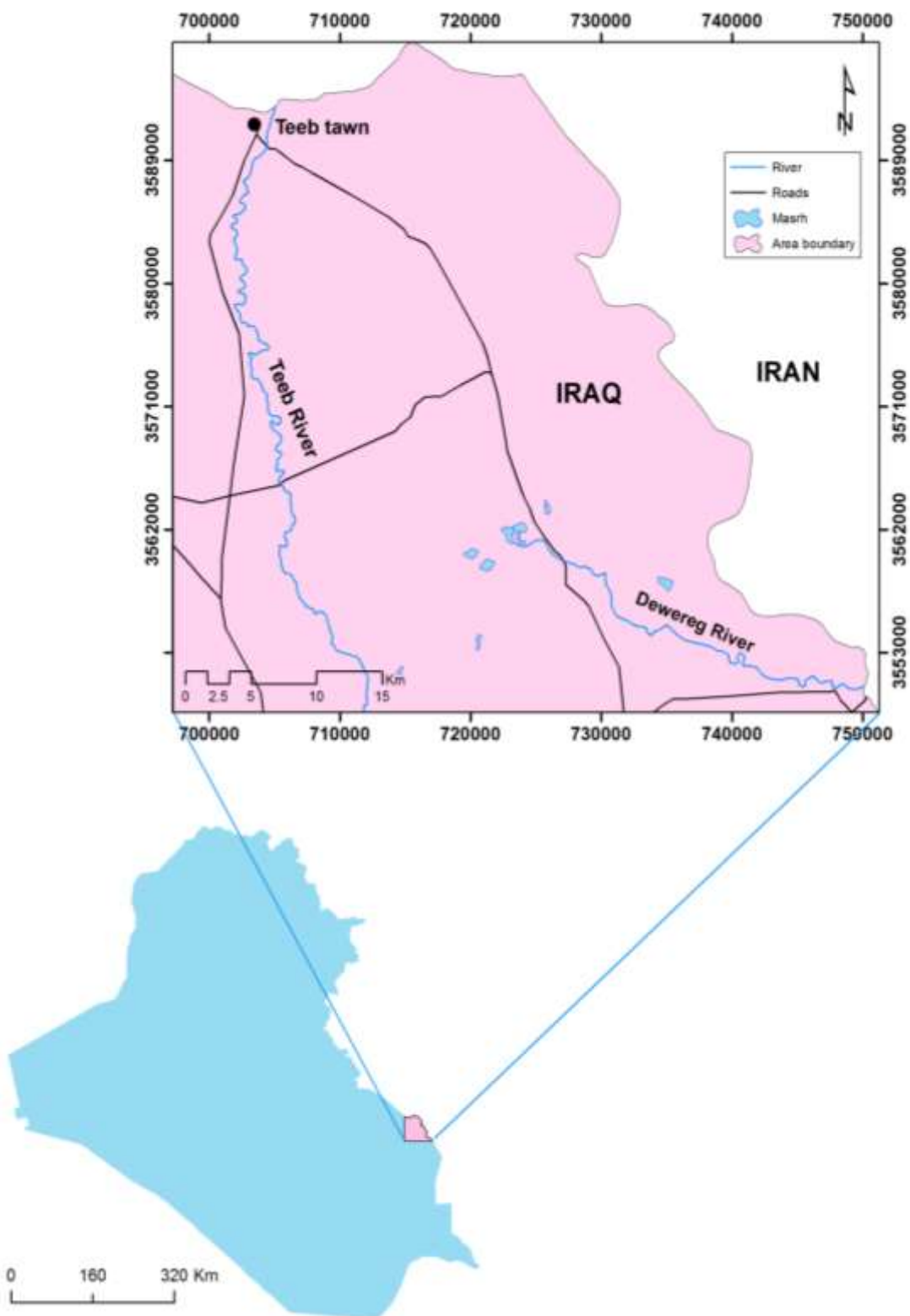


Fig. 1: Location map of the study area

Table 1: Discharge of Teeb and Dewereg streams (Iraqi Ministry of Water Resources, Unpublished data)

	Discharge (m ³ /s)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep
Teeb	15	18	75	400	1000	700	125	50	12	10	10	10
Dewereg	5	12	30	250	500	450	65	25	7	0	0	0

3. Methodology

The (NRCS – CN) method is based on the water balance equation and two fundamental hypothesis (SCS, 1956). The water balance equation is written as:

$$P = I + F + Q \quad (1)$$

where P : total rainfall (mm)

I : initial abstraction (mm)

F: is the amount of potential maximum retention (mm)

Q : actual direct runoff (mm)

The first hypothesis states that the ratio of amount of rainfall infiltrated after runoff begins (F) to watershed storage (S) was assumed to be equal to the ratio of actual direct runoff (Q) to total rainfall (P) minus initial abstraction. In mathematical form this hypothesis is written as (USDA, 1986):

$$\frac{F}{S} = \frac{Q}{P - I} \quad (2)$$

where S: watershed storage (mm)

The amount of rainfall infiltrated after runoff begins can be expressed as:

$$F = (P - I) - Q \quad (3)$$

By substituting Eq. (3) into Eq. (2) and solving for Q in terms of P, I, and S, equation (2) becomes:

$$Q = \frac{(P - I)^2}{(P - I + S)} \quad (4)$$

The second hypothesis relates the initial abstraction I to the potential maximum retention. The initial abstraction defined by (NRCS – CN) mainly consists of interception, depression storage, and infiltration occurring prior to runoff. The relation between I and S was estimated by analyzing rainfall – runoff data from many small watersheds (USDA-SCS, 1975). The empirical relationship is:

$$I = 0.25S \quad (5)$$

Substituting Eq. (5) into Eq. (4) yields

$$Q = \frac{(P - 0.25S)^2}{P + 0.8S} \quad (6)$$

which is the rainfall – runoff equation used by the (NRCS – CN) for estimating depth of direct runoff from a storm rainfall on the daily basis.

The potential maximum retention storage S of watershed is related to a CN, which is a function of land use, land treatment, soil types and antecedent moisture conditions of watershed. The S is related to curve number by the following equation:

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

The basic requirements for application of (NRCS – CN) model are:

1. Type of land use/ land cover (LULC) such as bare soil, vegetation, impervious surface, agricultural lands etc. and hydrologic conditions of such land use.

2. Hydrologic soil group; Soil properties influence the relationship between rainfall and runoff by affecting the rate of infiltration. NRCS divides soils into four hydrologic soil groups based on infiltration rates (Groups A-D).
3. Antecedent moisture conditions (AMC): It is an indicator of watershed wetness and availability of soil moisture storage prior to a storm and can have a significant effect on runoff volume (Al-Jabari, 2007). The AMC is based on the season and 5-day antecedent precipitation (SCS, 1956). Three levels of AMC are used in the (NRCS – CN) method: AMC-I for dry, AMC-II for normal, and AMC-III for wet conditions. In the (NRCS – CN) method, the values of CN are estimated for AMC-II. The following equations are used to adjust the CN for other two AMC (Chow et al., 2002):

$$CN_I = \frac{4.2 \times CN_{II}}{10 - (0.058 \times CN_{II})} \quad (8)$$

$$CN_{III} = \frac{23 \times CN_{II}}{10 + (0.13 \times CN_{II})} \quad (9)$$

To determine the appropriate CN value, various tables can be used. Firstly, there are tables relating the value of CN to LULC, to treatment or practice, to hydrology conditions, and to hydrological soil group. Together, these four categories are called the **hydrological soil – cover complex**. The relationship between the CN values and the various hydrological soil – cover complexes is usually given for average conditions, i.e, for AMC-II. With the aid of these tables and some experience, the curve number of various combinations of LULC, soil group, treatment and practice within a study area could be estimated.

In practical situation, the procedure to estimate surface runoff using this technique is:

- The hydrological soil group to each of the soil unit found in the drainage basin is assigned and consequently, the hydrological soil group thematic map would be prepared.
- Prepare the LULC thematic map either from the satellite images or from conventional data.
- By superimposing the LULC and hydrological soil group maps the main soil – cover complex should be delineated.
- Calculate the weighted average CN value according to the areas they represent. This could be done through what is called the weighted curve number and obtained by the following equation:

$$CN = \frac{\sum A_i \times CN_i}{\sum A_i} \quad (10)$$

where CN : weighted curve number, A_i : area for each curve number, and CN_i : curve number for each area A_i

4. Generating of soil and LULC thematic layers

The Land use/land cover (LULC) map of Iraq was downloaded from (www.unosat-maps.web.cern.ch/unosat-maps/IQ/land_cover.pdf) as a portable document format (.pdf). This file was then converting to file with jpg extension, georeferenced, rectified, digitizing, and clipping for the study area using clipping command in spatial analyst extension to create LULC thematic map of the study area, Fig. 2. Four LULC classes were recognized in the study area: Shrub land, Barren land, grass and pasture, and cropland. These classes occupy 82%, 13%, 3%, and 2% from the study area, respectively. The dominance of shrub (> 75%) demonstrates that most of the water within soil profile takes by plants because of rooting

depths (1-2) m of such plants. A total of 20 samples of soil were collected at a depth of about 25 cm below the surface after removing the top soil cover. The soil samples were collected in clean polyethylene containers and transported to soil laboratory of civil engineering/ Engineering College/University of Basra to carry out grain size analysis. Locations of these samples were selected after many criteria such as easy to access, even distribution over the study area, and easy to dig through the soil surface. The collected soil samples of the study area were assigned texture name based on the web-based USDA soil texture calculator (<http://soils.usda.gov/technical/aids/investigations/texture/>), Table 2. The soil types in the study

area then converted to soil permeability values based on soil taxonomy. According to this classification each soil hydrological group is assigned a range of values of infiltration rates in mm/hr. The average value of infiltration rates is then interpolated using kriging techniques in Geostatistical analyst extension of ArcGIS 9.3 to produce the soil hydrological group layer of the study area, Fig. 3. Areas covered by each of these groups are summarized in Fig. 4. The high percentage extension of moderately infiltration group (B and C) linked with high water holding capacity (= 18.2 cm) supports the fact that most of the infiltrated water goes to the plant demands and evapotranspiration.

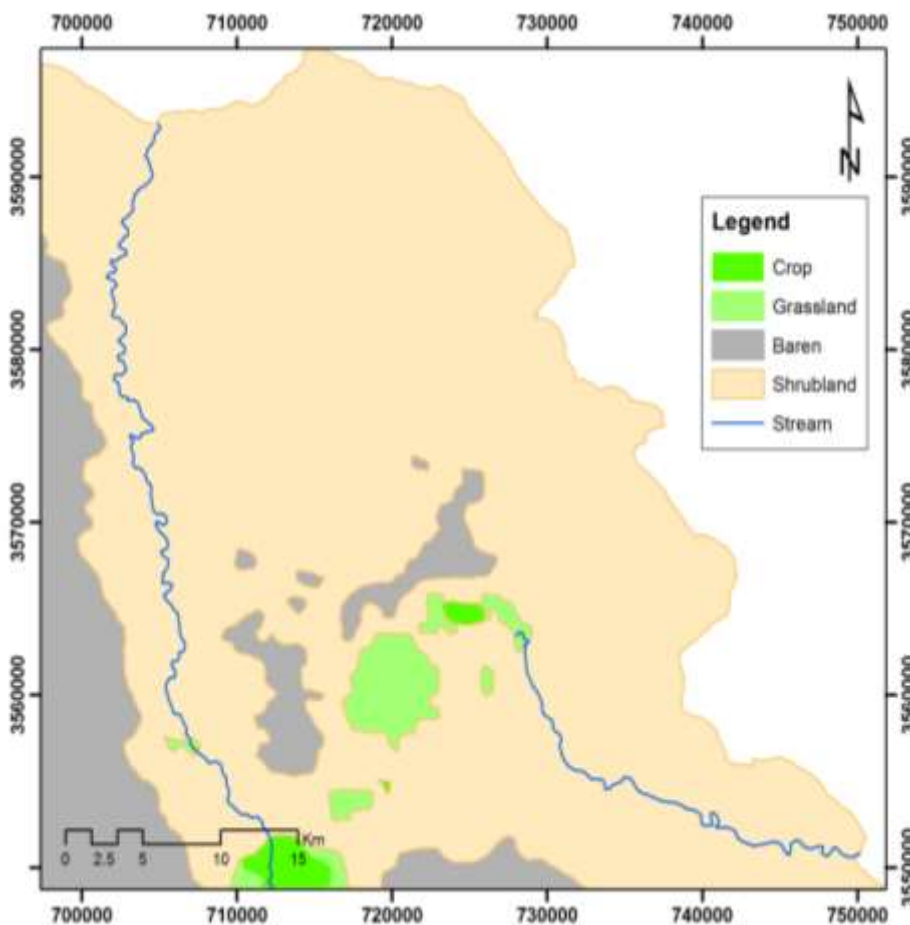


Fig. 2: LULC map of the study area

Table 2: Grain analysis of soil samples

Sample No.	Easting	Northing	Clay	Silt	Sand	Gravel	soil texture	SCS hydrologic soil grouping
			%					
S1	731753.42	3548745.65	2	83.7	14.3	0	Silt	C
S2	736244.86	3555958.87	36	61.5	2.5	0	silt clay loam	D
S3	739262.9	3552324.88	30	57.9	12.1	0	silt clay loam	D
S4	728337.79	3566166.87	8.5	82.8	8.7	0	Silt	C
S5	724552.62	3572969.93	24	66.7	9.3	0	silt loam	C
S6	724552.62	3572969.93	23	10.1	37.06	26.84	Loam	B
S7	717339.53	3582075.51	22	74.6	3.4	0	silt loam	C
S8	713035.62	3585339.34	32	54.7	13.3	0	silt clay loam	D
S9	704701.21	3592333.58	17	26.3	56.7	0	sandy loam	B
S10	718316.56	3585027.32	0	0	89	11	Sand	A
S11	714536.54	3579938.42	3	63.4	33.6	0	silt loam	C
S12	709185.65	3583252.5	9.5	61.6	28.9	0	silt loam	C
S13	705495.71	3565372.51	0	30	70	0	sandy loam	B
S14	712287.5	3570063.91	0	14	86	0	Sand	A
S15	711560.42	3573521.48	0	5	75	20	Loamy sand	B
S16	726160.26	3560891.34	0	77	23	0	silt loam	C
S17	730610.13	3571768.85	2	1	97	0	Sand	A
S18	724508.46	3586226.84	1	1	98	0	Sand	A
S19	702115.51	3587354.1	8	1	91	0	Sand	A
S20	701629.07	3578226.77	5	5	90	0	sand	A

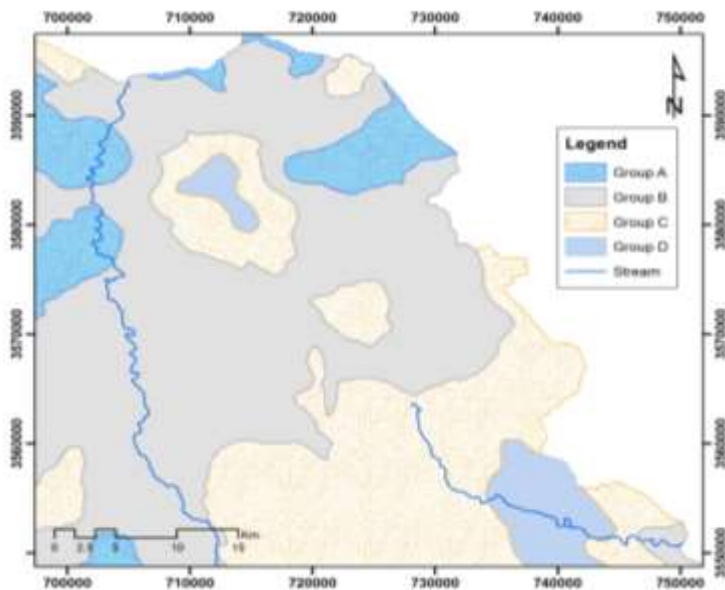


Fig. 3. Hydrological soil group map

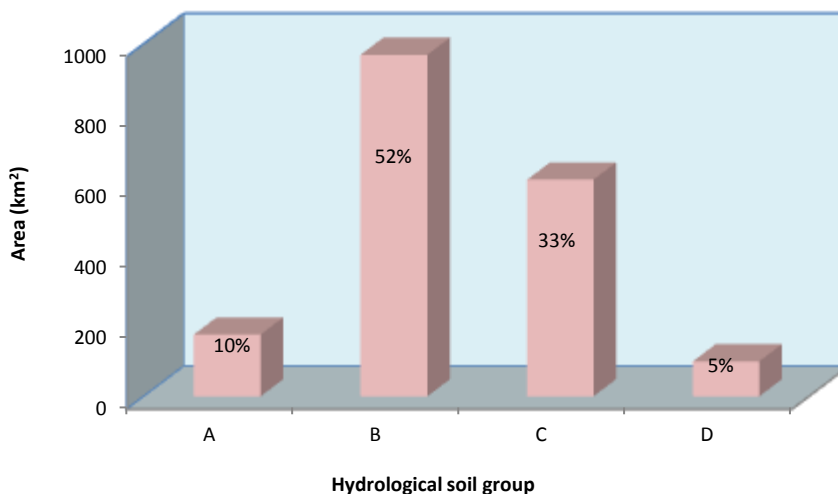


Fig. 4: Percentages of area covered by each of the hydrologic soil group

5. Results and Discussion

To create the CN map for the study area, the hydrologic soil group map (Fig. 3) and LULC map (Fig. 2) was used. The hydrologic soil group field from soil theme and the Land use field from the land use theme were selected for intersection using intersect command in ArcToolbox of ArcGIS 9.3. After intersection, a map with new polygons representing the merged hydrologic soil group and LULC was generated. The appropriate CN values for each polygon of the intersected maps were assigned manually, Table 3 for each merged polygon. The CN values for different hydrologic soil – cover were adopted from different sources such as technical release 55, USDA – NRCS, 1986 and preciously published works. The weighted curve number for the study area was then found based on eq. (10):

$$CN = \frac{109797.4}{1856.23} = 59.2$$

This calculated weighted curve number is for the normal condition (AMC-II). CN for other two antecedent conditions were calculated from eq. (8) and (9) as follows:

$$CN_I = \frac{4.2 \times 59.2}{10 - (0.058 \times 59.2)} = 38$$

$$CN_{III} = \frac{23 \times 59.2}{10 + (0.13 \times 59.2)} = 77$$

After calculate CN numbers, the next step was to calculate maximum potential retention (S) for each antecedent moisture condition (AMC). The maximum potential retention for each antecedent was calculated using eq. (7) with corresponding CN for each case, Table 4. Runoff occurs only when $P > 0.2 S$.

The (NRCS – CN) method needs daily rainfall for estimating runoff volume. The only data concerning daily rainfall for Al-Amarah station is that available for the period (2000 – 2009) with missing data for the water year (2002 – 2003). The rainfall data and the result of surface runoff for the water years (2000-2009) in the study area are tabulated in the Table 5 and Table 6. As a result of the calculation, it is found that the average annual surface runoff depth is equal to 0.36 mm multiplied by the area of the study (1856 km²) giving the total average volume of runoff as 7424000 m³ which represents 0.0003 of the

total average rainfall. The average total runoff calculated is too small indicating that most part of the rainfall goes to satisfy soil water demand and evapotranspiration

Table 3: Calculation of weighted CN for the normal AMC condition

Land use	hydrological soil group	CN	Area (km ²)	Area percentage (%)	CN×A
Shrub land	A	30	137.39	7.40	4121.70
	B	48	801.65	43.18	38479.20
	C	65	500.87	26.98	32556.55
	D	73	101.6	5.47	7416.80
Barren	A	80	47.03	2.53	3762.40
	B	93	155.52	8.37	14463.36
	C	90	49.68	2.67	4471.20
Grassland/Pasture	B	61	14.87	0.80	907.07
	C	74	31.94	1.72	2363.56
Agricultural	B	75	4.31	0.23	323.25
	C	82	11.37	0.61	932.34
<i>sum</i>			1856.23		109797.4

$$CN_{II} = (109797.4/1856.23) = 59.2$$

Table 4: Calculation of (S) for different (AMC)

Antecedent moisture condition	CN	Maximum potential retention (S)	P > 0.2S
AMC-I	38	414.42	82.88
AMC-II	59	176.51	35.30
AMC-III	77	75.87	15.17

6. Conclusions and recommendations

In the present study an attempt was made to estimate the amount of surface runoff from northeast Missan governorate area, southern Iraq where the records of runoff are not available. Two thematic maps namely soil classification and land use/ land cover were used to determine the hydrological soil groups and the corresponding curve number for normal, dry, and wet conditions, respectively. The soil, land use/land cover, daily rainfall, and appropriate CN values are created using field survey, previous and archival data, and CN tables (hydrological soil – cover complex

table).The available daily rainfall in the study area is for the period (2000 – 2009) with missing data for the water year (2002 – 2003).The calculated surface runoff based on (NRCS – CN) technique showed that the average annual runoff for the study area was 0.36 mm. Thus, the total volume of surface runoff was equal to (742400 m³) after multiplication average annual runoff by the area of the study area (1856 × 10⁶ m³). The applied method is robust and easy to implement and could be used for planning of various conservation measures

Table 5: Calculation of daily runoff for the study period

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)
2000-2001	10	14	0.1	0	I	38	414.42	0
		29	0.1	0	I	38	414.42	0
	11	19	17.8	0	I	38	414.42	0
		29	0.1	0	I	38	414.42	0
		30	9.8	0.1	I	38	414.42	0
	12	7	0.8	0	I	38	414.42	0
		8	0.2	0.8	I	38	414.42	0
		9	70.5	1	I	38	414.42	0
		10	0.6	71.5	III	77	75.87	0
		11	0.6	71.1	III	77	75.87	0
		13	0.7	71.7	III	77	75.87	0
		14	16.7	72.4	III	77	75.87	0.030086744
		19	7.7	0	I	38	414.42	0
		20	6.7	7.7	I	38	414.42	0
		23	7.6	14.4	I	38	414.42	0
	1	3	1.5	0	I	38	414.42	0
		4	1.6	1.5	I	38	414.42	0
		8	2	0	I	38	414.42	0
		18	0.4	0	I	38	414.42	0
		19	0.2	0.4	I	38	414.42	0
		22	0.5	0.6	I	38	414.42	0
		23	1.2	1.1	I	38	414.42	0
		25	1.4	2.3	I	38	414.42	0
		26	4	3.7	I	38	414.42	0
	2	8	0.2	0	I	38	414.42	0
		10	0.8	0.2	I	38	414.42	0
		14	4.8	0	I	38	414.42	0
		8	3.6	0	I	38	414.42	0
		9	13.7	3.6	I	38	414.42	0
		14	8.6	0	I	38	414.42	0
		24	2.6	0	I	38	414.42	0
		25	1.8	2.6	I	38	414.42	0
							SUM	0.03

Table 5 continue ...

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)	
2001-2002	10	26	0.1	0	I	38	414.42	0	
		27	0.3	0.1	I	38	414.42	0	
		28	0.8	0.4	I	38	414.42	0	
	11	30	7.2	0	I	38	414.42	0	
	12	1	15.4	7.2	I	38	414.42	0	
		3	12.1	22.6	II	59	176.51	0	
		4	7.2	34.7	III	77	75.87	0	
		7	3.2	7.2	I	38	414.42	0	
		10	0.8	3.2	I	38	414.42	0	
		11	0.4	4	I	38	414.42	0	
		12	0.001	4.4	I	38	414.42	0	
		18	3.5	0	I	38	414.42	0	
		19	8.2	3.5	I	38	414.42	0	
		30	0.6	0	I	38	414.42	0	
	1	1	14	0.6	I	38	414.42	0	
		3	6.2	14.6	II	59	176.51	0	
		6	9.4	6.2	I	38	414.42	0	
		7	0.7	15.6	II	59	176.51	0	
		10	0.5	0.7	I	38	414.42	0	
		23	1.2	0	I	38	414.42	0	
		28	1.4	0	I	38	414.42	0	
		30	0.001	1.4	I	38	414.42	0	
	2	11	0.4	0	I	38	414.42	0	
		12	0.001	0.4	I	38	414.42	0	
		13	0.7	0.401	I	38	414.42	0	
		18	0.7	0	I	38	414.42	0	
		19	2	0.7	I	38	414.42	0	
	3	14	0.1	0	I	38	414.42	0	
		16	4	0.1	I	38	414.42	0	
		17	1.9	4.1	I	38	414.42	0	
		18	0.001	6	I	38	414.42	0	
								SUM	0

Table 5 continue ...

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)	
2004-2005	11	2	98	0	I	38	414.42	0.531938286	
		19	0.6	0	I	38	414.42	0	
		20	3.2	0.6	I	38	414.42	0	
		22	11.2	3.2	I	38	414.42	0	
	12	6	0.2	0	I	38	414.42	0	
		7	7	0.2	I	38	414.42	0	
		8	6.8	7.2	I	38	414.42	0	
		9	0.9	14	I	38	414.42	0	
		11	0.2	14.9	II	59	176.51	0	
		12	1.7	15.1	II	59	176.51	0	
		16	0.6	1.7	I	38	414.42	0	
		17	1.3	2.3	I	38	414.42	0	
		19	4.6	3.6	I	38	414.42	0	
		24	27.9	0	I	38	414.42	0	
		25	1.5	27.9	II	59	176.51	0	
	1	9	10.3	0	I	38	414.42	0	
		10	1.7	10.3	I	38	414.42	0	
		17	5.1	0	I	38	414.42	0	
		21	2.4	0	I	38	414.42	0	
		22	59.8	2.4	I	38	414.42	0	
	3	3	0.1	0	I	38	414.42	0	
		4	2.3	0.1	I	38	414.42	0	
		9	0.7	0	I	38	414.42	0	
		10	10.5	0.7	I	38	414.42	0	
		11	22.9	11.2	I	38	414.42	0	
		12	1.2	34.1	III	77	75.87	0	
	4	15	1.3	1.2	I	38	414.42	0	
		26	5.4	0	I	38	414.42	0	
								SUM	0.53

Table 5 continue ...

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)	
2005-2006	11	4	0.001	0	I	38	414.42	0	
		7	0.001	0	I	38	414.42	0	
		15	2.2	0	I	38	414.42	0	
		16	0.9	0.9	I	38	414.42	0	
	12	16	4.3	0	I	38	414.42	0	
		22	0.001	0	I	38	414.42	0	
		23	5.3	0	I	38	414.42	0	
		25	19.4	5.3	I	38	414.42	0	
	1	7	9.8	0	I	38	414.42	0	
		20	0.001	0	I	38	414.42	0	
		23	0.4	0	I	38	414.42	0	
		24	8.3	0.4	I	38	414.42	0	
		25	17.1	8.7	I	38	414.42	0	
		26	1.5	25.8	II	59	176.51	0	
	2	3	44.5	0	I	38	414.42	0	
		7	0.7	44.5	III	77	75.87	0	
		8	23.6	45.2	III	77	75.87	0.842233923	
		11	0.001	68.8	III	77	75.87	0	
		15	0.001	68.801	III	77	75.87	0	
		16	0.001	68.802	III	77	75.87	0	
		21	3.1	0	I	38	414.42	0	
	3	1	0.001	0	I	38	414.42	0	
		26	3.7	0	I	38	414.42	0	
		27	0.3	3.7	I	38	414.42	0	
		28	2.3	4.0	I	38	414.42	0	
	4	1	0.001	0	I	38	414.42	0	
		2	0.2	0.2	I	38	414.42	0	
		6	4.9	5.1	I	38	414.42	0	
		16	1.2	6.3	I	38	414.42	0	
		24	4.5	0	I	38	414.42	0	
		25	0.4	4.5	I	38	414.42	0	
		26	0.6	5.1	I	38	414.42	0	
	5	2	0.001	0	I	38	414.42	0	
		3	0.5	0.5	I	38	414.42	0	
		6	0.001	0.501	I	38	414.42	0	
								SUM	0.84

Table 5 continue ...

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)
2006-2007	10	15	0.001	0	I	38	414.42	0
		24	0.001	0	I	38	414.42	0
		27	0.001	0	I	38	414.42	0
		28	0.6	0	I	38	414.42	0
		29	23.7	0.6	I	38	414.42	0
		30	1.1	24.3	II	59	176.51	0
		31	0.2	25.4	II	59	176.51	0
	11	1	7.8	25.6	II	59	176.51	0
		8	0.001	7.8	I	38	414.42	0
		12	10.3	7.801	I	38	414.42	0
		13	12.2	18.101	II	59	176.51	0
		23	2.7	30.301	III	77	75.87	0
	12	6	8.2	0	I	38	414.42	0
		7	39.0	8.2	I	38	414.42	0
		10	3.4	47.2	III	77	75.87	0
		16	10.9	3.4	I	38	414.42	0
		17	3.0	14.3	II	59	176.51	0
		23	0.7	3.0	I	38	414.42	0
	1	5	0.4	0	I	38	414.42	0
		8	0.2	0.4	I	38	414.42	0
		11	0.8	0.6	I	38	414.42	0
		12	5.4	1.4	I	38	414.42	0
		16	4.5	6.8	I	38	414.42	0
		20	1.1	11.3	I	38	414.42	0
		21	1.8	12.4	I	38	414.42	0
	2	3	0.001	0	I	38	414.42	0
		10	0.1	0	I	38	414.42	0
		13	0.8	0.1	I	38	414.42	0
		18	0.3	0	I	38	414.42	0
	3	1	3.1	0	I	38	414.42	0
		24	0.001	0	I	38	414.42	0
		25	0.001	0.001	I	38	414.42	0
		26	36.4	0.002	I	38	414.42	0
		27	24.7	36.402	III	77	75.87	1.062626713
	4	1	0.001	61.102	III	77	75.87	0
		2	0.001	61.103	III	77	75.87	0
		9	0.001	0	I	38	414.42	0
		10	0.3	0	I	38	414.42	0
		13	0.3	0.3	I	38	414.42	0
		14	0.001	0.6	I	38	414.42	0
		24	1.2	0	I	38	414.42	0

Table 5 continue ...

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)
2006-2007		25	5.0	1.2	I	38	414.42	0
		29	2.3	6.2	I	38	414.42	0
		30	0.001	8.5	I	38	414.42	0
	5	15	0.001	0	I	38	414.42	0
		16	0.5	0.5	I	38	414.42	0
		27	0.001	0	I	38	414.42	0
		28	0.001	0	I	38	414.42	0
		29	0.8	0	I	38	414.42	0
		30	0.4	0.8	I	38	414.42	0
		31	0.001	1.2	I	38	414.42	0
							SUM	1.06

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)	
2007-2008	11	20	1.2	0	I	38	414.42	0	
		21	0.3	1.2	I	38	414.42	0	
	12	2	1.1	0	I	38	414.42	0	
		5	1.4	1.1	I	38	414.42	0	
		6	14.7	2.5	I	38	414.42	0	
		7	4.7	17.2	II	59	176.51	0	
		21	11.2	0.0	I	38	414.42	0	
		31	0.1	0	I	38	414.42	0	
	1	1	0.001	0	I	38	414.42	0	
		5	1.8	0	I	38	414.42	0	
		10	10.5	1.8	I	38	414.42	0	
		11	8.2	12.3	I	38	414.42	0	
		22	7.2	0.0	I	38	414.42	0	
		23	5.0	7.2	I	38	414.42	0	
		26	2.2	12.2	I	38	414.42	0	
	2	25	0.4	0	I	38	414.42	0	
		26	3.2	0.4	I	38	414.42	0	
	3	1	0.001	0	I	38	414.42	0	
		2	0.3	0	I	38	414.42	0	
	4	8	0.6	0	I	38	414.42	0	
		11	1.8	0.6	I	38	414.42	0	
								SUM	0

Table 5 continue ...

Year	Month	Day	Storm rainfall (mm)	Antecedent rainfall (mm)	AMC	CN	S	Runoff by day (mm)	
2008-2009		24	0.2	0	I	38	414.42	0	
		25	11.4	0.2	I	38	414.42	0	
		26	10.2	11.6	I	38	414.42	0	
		29	3.6	21.8	II	59	176.51	0	
	11	3	0.3	0	I	38	414.42	0	
		20	1.2	0	I	38	414.42	0	
		21	1.4	1.2	I	38	414.42	0	
	2	6	0.3	0	I	38	414.42	0	
		10	2.0	0.3	I	38	414.42	0	
		21	1.7	0	I	38	414.42	0	
	3	10	0.3	0	I	38	414.42	0	
		14	0.5	0.3	I	38	414.42	0	
		29	0.9	0	I	38	414.42	0	
		30	5.7	0.9	I	38	414.42	0	
	4	7	4.2	0	I	38	414.42	0	
		8	5.1	4.2	I	38	414.42	0	
		9	0.500	9.3	I	38	414.42	0	
		28	0.6	0	I	38	414.42	0	
	5	5	0.3	0	I	38	414.42	0	
		6	4.7	0.3	I	38	414.42	0	
		11	1.0	4.7	I	38	414.42	0	
		16	2.7	5.7	I	38	414.42	0	
	SUM								0

Table 6: Average total rainfall versus average total runoff.

Water year	Total rainfall (mm)	Total Runoff (mm)	Runoff volume (m ³)
2000-2001	189	0.03	55680
2001-2002	103	0.00	0
2004-2005	290	0.53	983680
3005-2006	160	0.84	1559040
2006-2007	214	1.10	2041600
2007-2008	76	0.00	0
2008-2009	59	0.00	0
Average	155.86	0.36	662857.1

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