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Application of NRCS-curve number method for runoff estimation in a mountainous watershed

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ABSTRACT

The major problem in the assessment of relationships between rainfall and runoff occurs when a study is carried out in ungauged watersheds in the absence of hydro-climatic data. This study aims to evaluate the applicability of Natural Resources Conservation Service-Curve Number (NRCS-CN) method together with GIS in estimating runoff depth in a mountainous watershed. The study was carried out in the semi-arid Kardeh watershed which lies between 36º 37′ 17″ to 36º 58′ 25″ N latitude and 59º 26′ 3″ to 59º 37′ 17″ E longitude, about 42 km north of Mashhad, Khorasan Razavi Province, Iran. The hydrologic soil groups, land use and slope maps were generated with GIS tools. The curve number values from NRCS Standard Tables were assigned to the intersected hydrologic soil groups and land use maps to generate CN values map. The curve number method was followed to estimate runoff depth for selected storm events in the watershed. Nash-Sutcliffe efficiency, pair-wise comparison by the *t*-test, Pearson correlation and percent error were used to assess the accuracy of estimated data and relationship between estimated and observed runoff depth. The results showed relatively low Nash-Sutcliffe efficiency ($E = -0.835$). There was no significant difference between estimated and observed runoff depths ($P > 0.05$). Fair correlation was detected between estimated and observed runoff depth ($r = 0.56$; $P < 0.01$). About 9% of the estimated runoff values were within ±10% of the recorded values and 43% had error percent greater than ±50%. The results indicated that the combined GIS and CN method can be used in semi-arid mountainous watersheds with about 55% accuracy only for management and conservation purposes.

Keywords: *Geographic Information System, Watershed, Rainfall-runoff modelling.*

INTRODUCTION

Due to serious soil erosion and water deficiency in most areas of Iran, natural resources conservation is a vital issue. Conventional methods of runoff measurement are costly, time consuming, error-prone and difficult because of inaccessible terrain in many of the watersheds. Thus, the use of new tools, for instance GIS, to generate supporting land-based data for conserving soil and water resources in watershed planning is very much needed. In addition, most basins in Iran do not have sufficient numbers of gauges to record rainfall and runoff (Nassaji and Mahdavi, 2005). Scarcity of reliable recorded data, therefore, is another serious problem which planners and researchers face for the analysis of the hydrology of watersheds.

There are several approaches to estimate runoff in ungauged watersheds. Examples are the University of British Columbia Watershed Model (UBCWM), Artificial Neural Network (ANN), SCS Curve Number (SCS-CN) method and Geomorphological Instantaneous Unit Hydrograph (GIUH) (Beckers*et al.*, 2009). Among these methods, the SCS-CN method (now called Natural Resources Conservation Service Curve Number method (NRCS-CN)) is widely used because of its flexibility and simplicity (Zhan and Huang, 2004). The method combines the watershed parameters and climatic factors in one entity called the Curve Number (CN). However, slope is not considered as an effective parameter on runoff rate in the NRCS-CN method. The reason is that, in the United States cultivated land in general has slopes of less than 5%, and this range does not influence the Curve Number value to a great extent. However, under conditions in Iran for example, slopes vary much more in many watersheds. Therefore, the applicability of the CN method in mountainous watersheds should be evaluated prior to being used for management and planning purposes.

Many researchers (Pandey and Sahu, 2002; Nayak and Jaiswal, 2003; Zhan and Huang, 2004; Gandini and Usunoff, 2004) have utilized the Geographic Information System (GIS) technique to estimate runoff curve number value throughout the world. In India, Pandy and Sahu (2002) pointed out that land use is an important input parameter of the SCS-CN method. Nayak and Jaiswal (2003) found that there was a good correlation between the measured and estimated runoff depth using GIS and NRCS-CN method. They concluded that GIS is an efficient tool for the preparation of most of the input data required by the SCS-CN method. In Iran, Sadeghi *et al*. (2008) found a correlation coefficient of 57% between estimated runoff by CN method and measured runoff in humid Amameh watershed. In China, Xianzhao and Jiazhu (2008) observed that the simulated runoff with CN method was in good agreement with measured runoff, and the simulated accuracy was over 75%. The study concluded that the integration of remote sensing, GIS and SCS-CN model provides a powerful tool for runoff simulation of small watersheds. Akhondi (2001) and Sadeghi (2008) pointed out that correlation between estimated and observed discharge using CN method is decreased by increasing watershed area. While having runoff data is essential in all watershed development and management plans, very little work has been previously done in the mountainous areas of Iran in estimating runoff in ungauged watersheds. This study emphasizes the use of GIS technique to develop a database containing all the information of the study watershed in a mountainous region for direct runoff depth estimation using the NRCS-CN method. The objective of this study was to evaluate the use of NRCS Curve Number method with GIS for estimating runoff depth in a well-equipped gauged mountainous watershed. If the estimated runoff values are accurate compared to observed runoff, the NRCS-CN method can be recommended for estimating runoff in other ungauged mountainous watersheds of the region.

MATERIALS and METHODS

Study area:

This study was conducted in the Kardeh watershed about 42 km north of Mashhad, Khorasan Razavi province in the northeast of Iran (Fig. 1). The watershed lies between 36° 37′ 17″ to 36° 58′ 25″ N latitude and 59° 26′ 3″ to 59° 37′ 17″ E longitude. Kardeh watershed is 448.2 km^2 in size. The elevation of the watershed ranges from 1320 to 2960 m above mean sea level. The climate of the watershed is semi-arid with mean annual precipitation and temperature of 296.4 mm and11.6 °C, respectively. The mean relative humidity is about 52.6%, but varies from 32.1% in August to 82.3% in February.

In most parts of the study area, topsoil is loamy and the subsoil is sandy clay loamy except in alluvial deposits that have relatively heavy texture of clay. In barren areas where soil is shallow, fine platy structure surface soil and compressed blocky structure subsurface soil are sound. Rangeland with coverage of 74% is major land use in the watershed (Fig. 2 and Table 1). The watershed is instrumented with three recording rain gauges, two storage rain gauges, two hydrometric stations and two evaporation stations.

Data sources:

Topographic maps at the scale of 1:25000 (National Cartographic Centre, 1990), land use map (Watershed Management Department, 1996) and soil map (General Office of Natural Resources, 1995) were used for demarcation of study watershed border, identification of types and areas of land use, and extracting soil information, respectively. Rainfall, evaporation, temperature and recorded runoff data (1990–2000) were obtained from Khorasan Razavi Regional Water Authority. Arc View version 3.3 powerful GIS software was used for creating, managing and generation of different layers and maps.

Fig 1. Location of the study area in Iran.

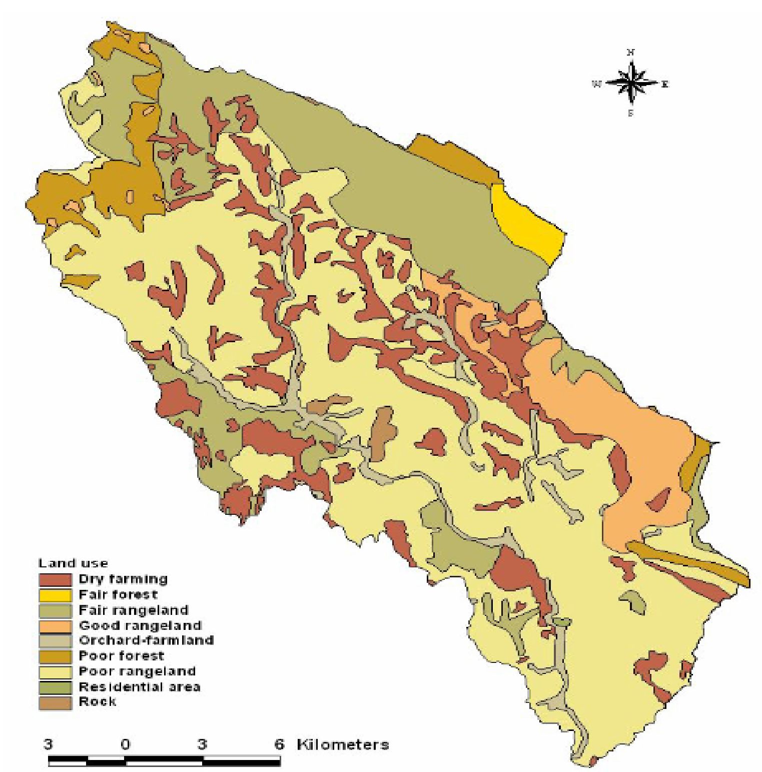

Fig 2. Land use map of the study watershed

Table 1. Land use classes present in the Kardeh watershed*

Land use		Area (km²)	% of total area
Dry farmland (rain-fed farming)		66.90	15.0
Forest	Thin	25.50	5.7
	Fair	5.20	1.2
Rangeland	Good condition	32.80	7.3
	Fair condition	92.70	20.7
	Poor condition	204.40	45.5
Orchards and irrigation farmland		17.40	3.9
Settlement		0.28	0.1
Rocks		2.90	0.6
Total area		448.20	100

*Watershed Management Department,Jihad-e-Agriculture Organization, Khorasan Razavi, 1996

Generating hydrologic soil group (HSGs) and CN maps:

The hydrologic soil group is an attribute of the soil mapping unit (each soil mapping unit is assigned a particular hydrologic soil group: A, B, C, or D). In the preparation of the hydrologic soil group (HSG) map, a digital text file of soil data was prepared to assign the soil data layers based on soil mapping unit. Spatial Analyst and XTools extensions of Arc View 3.3 were applied for map preparation. The Soil Surveys from NRCS which provides a list of soil types and corresponding hydrologic soil groups were used. The generated map contains individual polygons of the characterized hydrologic soil group.

To create the CN map, the hydrologic soil group and land use maps were uploaded to the Arc View platform. The Xtools extension of Arc View was used to generate the CN map. The hydrologic soil group field from the soil theme and the land use field from the land use map were selected for intersection. After intersection, a map with new polygons representing the merged soil hydrologic group and land use (soil-land map) was generated. The appropriate CN value for each polygon of the soil-land map was assigned. The CN values for different land uses and hydrologic soil groups were adopted from Technical Release 55, USDA-NRCS, 1986.

Antecedent moisture condition (AMC):

The calculated CN value for each polygon is for average conditions (i.e. antecedent moisture condition class II). The CN values for AMC II can be converted into CN values for AMC I and AMC III by using the SCS (Soil Conservation Service) Standard Tables (USDA-SCS, 1993). To determine which AMC Class is the most appropriate in relation to the study area, the use of rainfall data is necessary. The 5-day rainfall prior to the event date was determined to be used for converting the calculated CN value to AMC classes II and III based on the NRCS Standard Tables.

Calculating runoff depth:

After generating the CN map, the next step was to calculate maximum potential retention (S). The S values indicate the initial abstraction of rainfall by soil and vegetation and were computed for each polygon using eq. '(1)'. Runoff depth was ascertained for each rainfall event by using eq. '(2)'. Arithmetic mean rainfall of available rain gauge stations in the watershed was used for estimation of runoff depth in the watershed for selected events.

$$S = \frac{25400}{CN} - 254 \quad (1)$$

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

where S is potential maximum retention (mm); CN is Curve Number; Q is runoff depth (mm); P is rainfall (mm) and S is initial abstraction of rainfall by soil and vegetation (mm).

In the next step, weighted runoff depth was estimated for the watershed by multiplying the area of each polygon in runoff depth value and divided by total area of watershed (eq. 3). A total of 35 daily rainfall events were employed in the NRCS-CN model to estimate runoff depth.

$$\overline{Q} = \frac{\sum QiA_i}{A} \quad (3)$$

where $\overline{Q}$ is weighted runoff depth, Q_i is runoff depth for each polygon (mm); A_i is polygon area (ha) and A is watershed area (ha).

Determining runoff depth for observed data:

Direct runoff volume was calculated by subtracting base flow and total runoff volume in WHAT (Web-based Hydrograph Analysis Tool) software (Engel *et al*., 2004). Runoff depth was calculated by eq. (4) as follows:

$$H = \frac{\sum_{i-1}^{24}(Q - bf) \times t}{A} \quad (4)$$

where H is runoff depth (m); Q is runoff volume (m^3/s); bf is base flow (m^3/s); t is hourly time interval (3600) and A is watershed area (m^2).

Data analysis:

Nash-Sutcliffe efficiency: The Nash-Sutcliffe efficiency (NSE) was used to assess the NRCS-CN model performance. NSE is a normalized statistic that determines the relative magnitude of the residual variance ("noise") compared to the measured data variance ("information") (Nash and Sutcliffe, 1970). NSE indicates how well the plot of observed versus estimated data fits the 1:1 line. NSE is computed using eq. (5).

$$E = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \quad (5)$$

where O_i is the *i*th observation for the dataset being evaluated, P_i is the *i*th estimated data, $\bar{O}$ is the mean of observed data for the dataset, and n is the total number of observations.

Statistical analysis: Estimated (dependent variable) and observed (independent variable) runoff data were checked for normality with Kolomogorov-Smirnov test. Percentage of error was calculated to compare the difference between the estimated and observed runoff depth. Pair-wise comparison was done with the independent *t*-test to compare observed and estimated runoff depth data. The Pearson correlation analysis was used to investigate the relationship between estimated and observed runoff depths. All the tests were run using statistical software (SPSS Inc., 2007). The differences were considered statistically significant ($P<0.05$).

RESULTS AND DISCUSSION

Hydrologic soil groups:

A hydrologic soil group map generated with GIS tool is shown in Fig 3. All hydrologic groups including A, B, C, and D were found in the Kardeh watershed. Group A soils having a low runoff potential due to high infiltration rates (7.62–11.43 cm/h). Group B soils having a moderately low runoff potential due to moderate infiltration rates (3.81–7.62 cm/h). Group C soils having a moderately high runoff potential due to slow infiltration rates (1.27–3.83 cm/h) and finally group D is soils with a high runoff potential due to very slow infiltration rates (< 1.27 cm/h)(USDA-SCS, 1993). Only 2% of soil was placed in group A and about 40.6 and 31.7% of soil were placed in group C and D, respectively (Table 2).

CN values:

The CN value for each hydrologic soil group and corresponding land use class are presented in Table 2. Hydrologic soil groups A and B lead to low CN value while the hydrologic group D lead to the high CN value in the Kardeh watershed. Gandini and Usunoff (2004) observed that hydrologic soil group B lead to lower CN values in a humid temperate watershed of Argentina. In terms of land use and hydrologic soil group combination, the lowest CN value was found to be 35 and 36 in forests and rangelands with good condition and the highest CN value was found to be 93 in settlement areas. Gandini and Usunoff (2004) found the CN value of 92 for urban areas and 45 for forests in good condition in Argentina. Table 2 indicates that rangelands with poor condition, settlements and mountainous areas without developed soil layer (rocks) are major contributors in runoff generation in the Kardeh watershed. Nassaji and Mahdavi (2005) found that rangelands with poor and very poor conditions had CN values greater than 85 in three rangeland watersheds in semi-arid areas of northern Iran. High CN values in poor rangelands can be explained by low vegetation density, high soil compaction due to treading by grazing animals and low infiltration rate.

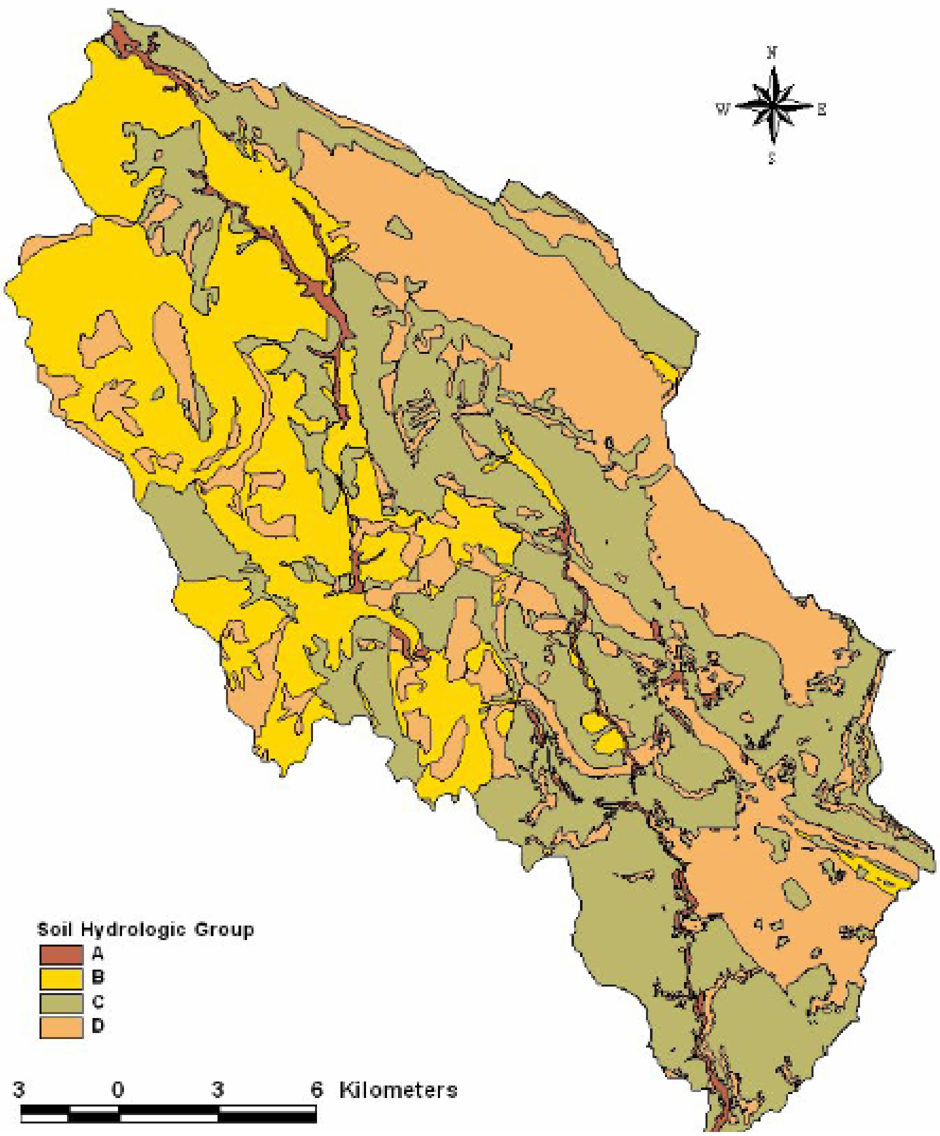

Fig 3. Hydrologic soil groups of Kardeh catchment.

The CN map can be viewed as a mosaic of CN values due to differences in land use (Fig 4). About 70% of the Kardeh watershed has CN values between 60 and 80, 4% less than 50 and 0.7% greater than 90. These values show that Kardeh watershed generates more runoff for a given rainfall in areas having greater CN values. Because by increasing the value of CN in a specific area, the amount of runoff will be increased. Mellesse and Shih (2002) indicated that any changes in land use can alter CN values of the watershed and accordingly the runoff response of the watershed by increasing runoff volume. The study also reported that by decreasing the area of croplands and rangelands within two decades the CN values greater than 90 increased by 2.2% and the area of the watershed having runoff depth greater than 180 mm increased by 2%.

Table 2. Curve number of various land use and HSG in Kardeh watershed

Land use	Hydrologic soil group	Area (ha)	CN
Dry farmland (rainfed farming)	A	102.30	62
	B	2204.90	71
	C	4378.10	78
Forest [1]Thin forest	A	83.98	36
	B	1262.60	60
	C	809.60	73
	D	398.70	79
Forest [2]Fair forest	B	24.40	55
	C	447.70	70
	D	44.16	77
Rangeland [3]Good condition	A	4.70	35
	B	72.60	35
	C	1208.54	47
	D	1996.19	55
Rangeland [4]Fair condition	A	26.97	51
	B	1809.90	51
	C	2628.26	63
	D	4808.70	70
Rangeland [5]Poor condition	A	215.36	67
	B	5649.30	67
	C	7930.9	80
	D	6649.90	85
Orchards and irrigated farmland	A	428.99	43
	B	510.30	65
	C	803.00	76
Settlement	D	28.40	93
Rocks	D	286.50	91
Total area		44814.95	-

1. *Thin forest*: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning. 2. *Fair forest:* Woods are grazed but not burned, and some forest litter covers the soil. *Good forest:* Woods are protected from grazing, and litter and brush adequately cover the soil.
3. *Rangeland with Good condition*: > 70% ground cover.
4. *Fair condition*: 30 to 70% ground cover.
5. *Poor condition*: <30% ground cover (litter, grass, and brush over-story). (USDA/NRC,1986).

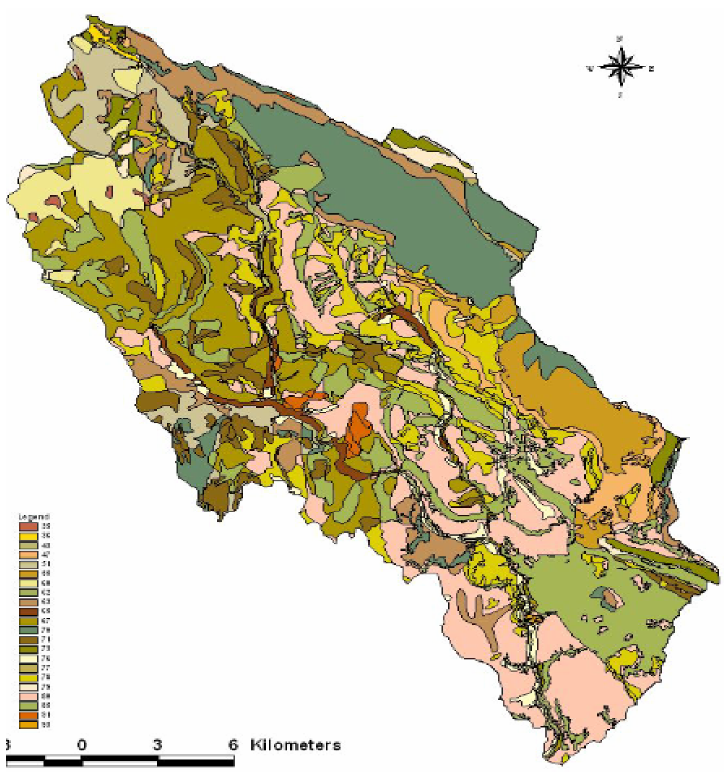

Fig 4. Map of curve number values for Kardeh watershed

Comparison of estimated and observed runoff depth:

Estimated and observed runoff depths for selected rainfall events are presented in Table 3. The study found that the NRCS models can produce unreliable estimates of runoff in mountainous watershed according to relatively low Nash-Sutcliffe model efficiency (E = – 0.835). NSE ranges between −∞ and 1, with NSE = 1 being the optimal value. Values between 0 and 1 are generally viewed as acceptable levels of performance, whereas values < 0 indicate that the mean observed value is a better predictor than the estimated value, which indicates unacceptable performance (Krause *et al*. 2005). Consequently, NRCS-CN model showed unacceptable performance in estimation of runoff in the Kardeh watershed according to NSE output.

Table 3. Estimated runoff depths for rainfall events using NRCS-CN method

Storm date	Rainfall (mm)	Sum of prior 5-day rainfall (mm)	Estimated runoff depth (mm)	Observed runoff depth (mm)
14/5/1991	18.0	18.3	5.44	3.5
1/6/1992	17.0	0.2	5.71	8.2
11/7/1992	20.0	14.9	4.94	3.8
6/1/1993	26.1	29.7	6.56	5.6
8/3/1993	8.6	11.2	8.56	6.6
13/4/1993	22.9	4.4	4.30	11.0
7/5/1993	6.3	4.0	9.54	5.5
12/3/1994	11.0	22.2	0.92	4.6
14/6/1994	13.5	00	6.77	5.2
3/10/1994	5.9	2.8	9.72	5.6
1/5/1995	9.0	3.0	8.40	6.8
3/7/1995	19.0	9.6	5.18	2.4
4/2/1996	14.9	27.7	1.26	3.9
8/3/1996	17.7	44.9	2.77	5.0
14/3/1996	9.4	32.8	0.69	3.4
23/5/1996	6.6	9.8	9.41	7.2
27/5/1996	6.2	10.3	9.59	6.1
17/7/1996	23.5	00	4.18	3.3
6/5/1997	15.6	12.0	6.11	7.8
19/6/1997	24.1	7.9	4.07	7.3
1/8/1997	17.5	0.8	5.57	3.0
6/11/1997	8.0	14.3	2.34	1.5
9/2/1998	26.1	4.3	3.27	4.0
14/3/1998	6.1	1.2	7.73	5.9
26/3/1998	14.0	0.8	5.15	4.7
6/4/1998	25.1	2.6	3.34	5.3
27/4/1998	13.1	2.2	5.39	2.6
30/5/1998	7.8	4.5	7.07	4.3
22/7/1998	6.9	00	7.41	4.7
3/8/1998	5.3	0.5	8.07	7.5
14/8/1998	4.3	00	8.51	5.1
21/2/1999	27.1	3.8	3.20	4.4
28/4/2000	19.0	10.5	4.11	3.2
9/8/2000	8.1	1.1	6.96	5.2
18/8/2001	15.5	0.3	4.80	5.3

In statistical analysis, percent error was used to compare the difference between the estimated and observed runoff depth (Table 4). The mean, maximum and minimum error between observed and estimated runoff depth were 42.6, 115 and 7%, respectively (Table 4). In India, Pandey *et al*. (2003) reported that the maximum and minimum error between observed and estimated runoff depths were 68.33 and 3.27%, respectively. Malekian *et al*. (2005) also reported an average percent error of 68.3 between observed and estimated runoff by the CN method for 25 storm events in semi-arid areas of northwestern Iran. In this study, about 9 and 34% of the estimated values were within ±10 and ±30% of the recorded values, respectively. In addition, about 43% of the estimated values were in error by more than ±50% (Table 4).

A percent error of less than 50% was considered acceptable (Boughton and Chiew, 2007; Pandey *et al*., 2003). One of the potential sources of error in runoff depth estimation is believed to be due to the recorded rainfall and runoff data input. The quality of the input data is the main determinant of the quality of the results in runoff estimation (Boughton and Chiew, 2007; Jacobs and Srinivasan, 2005). The presence of various land use classes, mountainous topography and large areas of the watershed may have played a part in the lack of acceptable runoff estimation results for selected storm events in this study. Field workers errors in recording rainfall and associated runoff data provide data with error to users which probably are another source of error. In mountainous watersheds, estimated runoff must be adjusted for slope; since the estimations are more affected by slope factor in these watersheds.

Table 4. Details of percent error between estimated and observed runoff depth

Study storm date	Percent error between estimated and observed runoff	% of observed runoff	% of total number of storm events	Acceptability
14/5/1991	7	0-10	8.58	Very high
1/6/1992	9			
11/7/1992	9			
6/1/1993	17	10-30	34.30	high
8/3/1993	18			
13/4/1993	21			
7/5/1993	23			
12/3/1994	26			
14/6/1994	27			
3/10/1994	28			
1/5/1995	29			
3/7/1995	30			
4/2/1996	30			
8/3/1996	30			
14/3/1996	30			
23/5/1996	31	30-50	14.30	fair
27/5/1996	33			
17/7/1996	36			
6/5/1997	44			
19/6/1997	45			
1/8/1997	55	> 50	43	unacceptable
6/11/1997	56			
9/2/1998	57			
14/3/1998	57			
26/3/1998	60			
6/4/1998	64			
27/4/1998	66			
30/5/1998	68			
22/7/1998	73			
3/8/1998	73			
14/8/1998	80			
21/2/1999	80			
28/4/2000	85			
9/8/2000	107			
18/8/2001	115			
	Minimum = 7	Maximum = 115	Mean = 46.23	

Pair-wise comparison between the variables (estimated vs. observed runoff) showed that there was no significant difference between the means of estimated and observed data (P>0.05). No significant difference between the mean of estimated and observed data indicates that the CN method was able to calculate runoff depth accurately. Therefore, the mean value of estimated runoff depth (5.63) by CN method was close to corresponding observed runoff depth (5.11) (Table 5). This result indicates that there is no provision to apply the NRCS-CN model for runoff estimation in the Kardeh watershed. Pandey *et al*. (2003) found that estimated direct runoff depth by the NRCS-CN method was significantly (P>0.05) close to corresponding observed runoff depth in the Karso watershed, India. Similar results were reported by Pandey and Sahu (2002), Pandey *et al*. (2003) in India and Akhondi *et al*. (2001) in Iran.

Fair correlation was found between observed and estimated data (r = 0.55; P<0.01). In India, Nayak and Jaiswal (2003) found a good correlation (90%) between estimated and observed data in all eight sub-basins with various areas (less than 100 km²) of the Bebas watershed, although correlation decreased by increasing the area of the sub-basins. Akhondi (2001) pointed out that the correlation coefficient (r) between observed and estimated runoff using the CN method decreased from 98% to 17% with increasing watershed area and decreasing rainfall (from semi-humid to semi-arid) in four watersheds with various areas and climate in semi-arid and semi-humid areas of southwestern Iran. Furthermore, Malekian *et al*. (2005) reported a correlation coefficient of 73% between observed and estimated runoff by the CN method in a semi-arid watershed of northwestern Iran. In the present study, correlation coefficient of 55% between estimated and observed runoff depths could be attributable to the large area of the watershed. As discussed above, correlation is higher in small watersheds compared to larger ones. In addition, low correlation may be due to the use of a non-localized and uncalibrated CN method in this study. The CN method parameters still have not been calibrated and modified based on Iranian conditions. It is recommended to calibrate some input parameters of CN model for local conditions to improve the accuracy of estimated runoff data (Khojini, 2001; Malekian *et al*., 2005).

Table 5. Means comparison of estimated and observed runoff data

Variables	Mean	SD	P
Estimated runoff depth (mm)	5.63	2.53	
Observed runoff depth (mm)	5.11	1.90	0.16

SD: standard deviation
P: significance level

CONCLUSIONS

The incorporation of NRCS-CN model and GIS facilitates runoff estimation and improves the accuracy of estimated data. In this study, the CN model to estimate runoff data in a mountainous watershed was neither approved nor rejected completely. In other words, NSE value of –0.835 indicated unacceptable performance of NRCS-CN model to estimate runoff data in mountainous watersheds, whereas statistical analysis showed a correlation coefficient of 55% between estimated and observed runoff data. Consequently, this study concludes that the CN method can be used in ungauged mountainous watersheds with the same conditions to the Kardeh with about 55% (correlation coefficient between estimated and observed runoff data) accuracy only for management purposes, but not for computation of design floods. Although there was fair correlation between estimated and observed runoff depth (r = 0.55) in this study, one of the alternative methods which can still be considered for ungauged watersheds, without runoff records, to generate runoff data for the purpose of management is the CN method. Calibration of CN model input parameters such as maximum potential retention (S) and adjustment of CN values with slope are highly recommended.

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کاربرد روش شماره منحنی در برآورد رواناب در حوضه آبخیز کوهستانی

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چکیده

مشکل اصلی در ارزیابی رابطه بین بارش و رواناب هنگامی رخ می دهد که مطالعه در حوضه آبخیز فاقد ایستگاه و داده های اقلیمی - هیدرولوژیکی انجام می شود. هدف این مطالعه ارزیابی قابلیت کاربرد روش شماره منحنی- سرویس حفاظت منابع طبیعی (NRCS-CN) به همراه سیستم اطلاعات جغرافیایی در برآورد عمق رواناب در حوضه آبخیز کوهستانی بود. این مطالعه در حوضه آبخیز کارده با مختصات جغرافیایی "17 '37 °36 تا "25 '58 °36 عرض شمالی و "3 '26 °59 تا "17 '37 °59 طول شرقی با اقلیم نیمه خشک در استان خراسان رضوی انجام شد. نقشه گروه های هیدرولوژیک خاک، کاربری اراضی و شیب با استفاده از توانمندی سیستم اطلاعات جغرافیایی تهیه شد. برای تهیه نقشه شماره منحنی، مقادیر شماره منحنی حاصل از جداول استاندارد NRCS به نقشه ادغام شده کاربری اراضی و گروه های هیدرولوژیک خاک تخصیص داده شد. برای محاسبه عمق رواناب برای بارش های انتخاب شده، مراحل مختلف روش شماره منحنی گام به گام انجام شد. ضریب ناش-ساتکلیف، مقایسه زوجی با آزمون *t*، ضریب همبستگی پیرسون و درصد خطا برای سنجش صحت داده های برآورد شده و رابطه بین عمق رواناب برآوردی و مشاهده ای استفاده شد. نتایج نشان داد که مقدار ضریب ناش-ساتکلیف (E) برابر با 0/835– بود. تفاوت معنی داری بین عمق رواناب برآورد شده و مشاهده ای وجود نداشت (P > 0/5). بین داده های برآوردی و مشاهده ای همبستگی متوسط (r =0/55) وجود داشت. حدود 9 و 43 درصد از مقادیر رواناب برآورد شده دارای مقدار خطای ٪10 ± و ٪50 ± نسبت به داده های مشاهده ای بود. این نتایج جاکی از آن است که روش شماره منحنی همراه با سیستم اطلاعات جغرافیایی می تواند در حوزه های آبخیز کوهستانی نیمه خشک با حدود 55 درصد دقت فقط برای اهداف مدیریتی استفاده شود.