Evaluating SCS-CN Method in Estimating the Amount of Runoff in Soofi Chay basin Using GIS

Ali panahi

Department of Geography, Tabriz Branch, Islamic Azad University, Tabriz, Iran
panahin@yahoo.com

Abstract: Every year, due to the penetration of cyclone and different air masses and also local conditions, the resulting flood phenomena cause extreme damage to the natural and economical resources. Sometimes, due to the flood waves or high density of residual materials, hydrometric stations are damaged and consequently the recorded data do not match to real data. Considering the lack of hydrometrical stations in most of the small watersheds, determination of runoff and maximum flood discharge requires a suitable method to estimate runoff and peak flow which to be used in flood and erosion control management plans. In this study empirical CN method is used. In this study, a principle of work method is applying of statistical data (60-90 statistics year of climatology stations Maragheh, Hargalan, Yengejeh, Kordadeh, Alaviyan Dam, Eshan,Moghanjigh and station hydrometric Tazehkand). Spatial data analysis and also using of satellite images for gaining CN map in SCS model with GIS, in the next stage recognized applying the SCS equation, CN map and precipitation layer which zones have the potential for creating of similar runoff. In this study, also due to assessment curve number CN choice several flood danger that the results shows the high correlation between curve number calculated and curve number observed and also resulted that use of weight model in curve number calculate provided to consider all of effective factors in runoff existing and at the result attain reliable estimate of runoff resulting the rainfall.
[Ali panahi. **Evaluating SCS-CN Method in Estimating the Amount of Runoff in Soofi Chay basin Using GIS.** *Life Sci J* 2013;10(5s):271-277] (ISSN:1097-8135). http://www.lifesciencesite.com. 49

Key word: rain fall- runoff- curve number-geographical information system- Sofi Chai basin

1. Introduction

Since the question of predicting and estimating the runoff resulting from precipitation and a quantitative understanding of the different processes involved in its production is considered a fundamental and essential issue in hydrology, obtaining its quantitative and qualitative amount with a systemic approach is important in that it constitutes the research basis for construction plans in the various fields of development and utilization in water resources and water constructs or other environmental fields in water fields.

In order to estimate surface runoff there have been developed different methods, including estimating surface runoff using soil penetrability, estimating runoff using argumentative method, estimating surface runoff using experimental methods like field level-based method, Krieger method, Dacon relation, Buch curve, Fowler experimental relation, Kuck method and estimating runoff using the number of CN curve. Due to the factor that among the above methods number of CN curve is more reliable and more precise and is used in different countries throughout the world, we have decided to use it in this research (Van Dijk, 2010).

The SCS-CN method was soon adopted for various regions, land uses and climate conditions (Elhakeem and Papanicolaou, 2009; King and Balogh, 2008; Mishra and20 Singh, 1999; Romero et al., 2007). It was also evolved well beyond its original scope and it became an integral part of continuous simulation models (e.g. Adornado and Yoshida, 2010; Holman et al., 2003; Mishra and Singh, 2004; Moretti and Montanari, 2008; Soulis and Dercas, 2007). Many studies aiming at finding a theoretical basis for the method, facilitating its use in regions and for climate conditions not previously evaluated, and supporting its further improvement, were carried out as well (Hjelmfelt, 1991; Tramblay et al., 2010; Yu, 1998).

Soofi Chay field, being a field which has always been vulnerable and destructive torrents in recent years have occurred in there, requires more attention. Environmental factors have been enumerated as the cause of this occurrence, among which we can mention human interference in the natural cycle of water by destroying plants in water fields, inexpert using of soil and ground and developing impenetrable levels and so on. The general objectives of the present research are: a scientific analyzing and evaluating in order to quantitatively study and predict the runoff resulting from precipitation, and proposing a model for estimating runoff and determining potential sites of the runoff production of Soofi Chay River field by using experimental methods.

So far, numerous researches have been carried out on curve number method, but in this regard, Sherman (1949) was the first person ever to suggest the relation between precipitation and runoff experimentally and in hydrograph format. Following these studies the US Soil Conservation Society in 1954 offered a method for calculating surplus precipitation, which became known as curve number (CN) method. According to this

method, always in one shower surplus precipitation 2 or direct runoff 3 is smaller than, or equal to, total precipitation (Chaw, et. al 1988). Moreover, a great number of researchers carried our researches using GIS technique in order to determine curve number and torrent quantity in different regions in the world.

Drogton, et, al (1992) studied the use of geographical information systems and satellite pictures in estimating runoff through curve number method in a extended manner in a watershed region no. 5 of Wales, Britain. Runoff was calculated through satellite pictures in each cell. Then, topographic qualities of the region were calculated using GIS method and were later combined with the runoff of each cell. Finally, a model was proposed for combining topographic qualities, GIS, RS and hydrological processes (Drogton, 1992). Inci Tekeli ,et ,al (2006) determined the digits of curve number for Guvence field in India using the instruments of GIS and RS. They used the maps of Landsat satellite for determining land usability, and NDVI index for determining the flora. The measured precipitation and runoff amounts of 1978-2005 of watershed field have been used for calculating discharge of spate for various return periods. They also compared the digits of curve number, which has been determined using GIS and RS techniques, with the curve number which has been obtained using alternating method (S frequency) and determined the effect of the changes between these curve numbers on the Discharge of the torrent of watershed field.

Akhondi (2002) used curve number method in estimating flood utilizing geographical information system in north Karoon River field. After merging and incorporating maps and map information, the curve number of the field was calculated and, by having the information concerning showers (discharge and precipitation altitude) and by considering the curve number of each shower, the height of runoff and the maximum discharge of spate were calculated.

The obtained results demonstrated that with the increase in calculating the field, the correlation coefficient between observational and estimative discharges decreases. Taheri and

Yaghoobzadeh (2006) provided curve number map of the runoff of Mansorabad (Birjand) watershed field using Landsat pictures plus ETM and IRS of years 2002 and 2006. He provided the land usability map using satellite pictures, and flora map using NDVI and VI indices.

The map of soil hydraulic group was determined in field manner and based on geology, geomorphology, land usability, soil texture and slope maps. By merging these maps in GIS and by the help of SCS table, curve number map for the years 2002 and 2006 was provided and in the results it showed 80 percent precision.

Analyzing Curve Number (CN) of Soil Conversation Society (SCS) of the USA

The SCS method estimates runoff in unmeasured watershed areas in regard to precipitation and the characteristics of watershed areas. Basically this method is valid until the runoff results from raining and if it is a result of slush this method will not be applicable. In this section this method is going to be examined (khojini, 1999).

The relation between precipitation and runoff in SCS method

Soil Conversation Society (SCS) of the USA in 1975, based on multiple and numerous observations in famous fields and in different lands, has offered methods for estimating the height of runoff resultant from precipitation.

The quantity of runoff (Q) is dependent on the precipitation (P) and the real holding (F). Real holding (F) is the difference between precipitation and runoff quantities. Moreover, a certain quantity of precipitation, at the start of shower, does not participate in runoff flow and is set aside for surface absorption, potholes, and penetrability capacity before the start of runoff, which is known as initial absorption (IA).

$$(1)\quad \frac{F}{S} = \frac{Q}{P - I_a}$$

In which S is the maximum agent in water holding on the surface of the ground.

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

If the equation (2) is contained in equation (1), the result will be like this:

$$(3)\quad \frac{(P - I_a)}{S} = \frac{Q}{(P - I_a)}$$

Equation (3) has been adjusted as following in order to solve Q variable.

$$(4)\quad Q = \frac{(p - I_a)^2}{(p - I_a) + s}$$

Equation (2-6) needs the two parameters Ia and S. the quantity of (Ia) has been mentioned as following:

$$(5)\quad I_a = 0.2S$$

Equation (5), when it is contained in Equation (4), is adjusted as the main equation of estimation.

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

The quantity S in this equation is related to the type of flora and land usability and the condition of soil surface from penetrability viewpoint and the inside of soil from transmission viewpoint is 1. Consecutive precipitations reduce S and do not give the soil the opportunity to have air, drain, evaporate and perspire. As a result, for S there

is a minimum and maximum quantity, which is also dependent on the previous moisture of soil.

Quantity S is connected through a relation with an aspectless agent called CN. The quantity of CN is variable between 0 and 100 and in the CN of zero no runoff has followed and in the CN of 100 all precipitation has flowed on the surface of ground and the height of runoff is equal to the height of precipitation (Hawkins, 1993).

$$(7)\quad S = \frac{2540}{CN} - 25.4$$

1.3. The characteristics of Soofi Chay watershed area

Soofi Chay watershed field, covering an area of 253.63 square kilometers, is located in the northwest of Iran in East Azerbaijan province, 27 kilometers north of Maraghah city, and its geographical range is located between the coordinates 46 10 to 26 29 eastern abscissa and 37 26 to 37 45 northern breadth.

Soofi Chay River originates from the southwestern slopes of mount Sahand and after passing by some villages reaches Maraghah and, finally, pours into Urmiyah Lake.

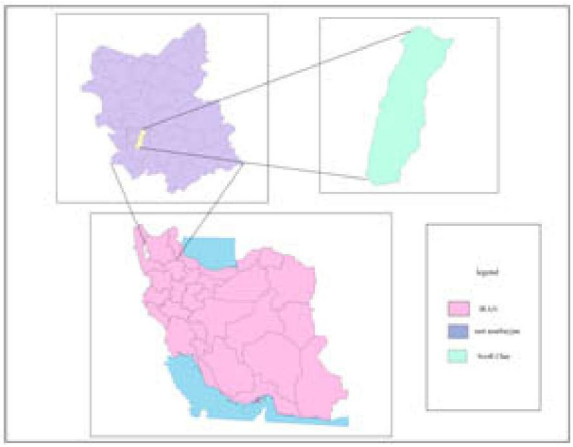

Figure 1: location of the Soofi Chay watershed

2. Materials and methods

The materials used in this research include satellite pictures 2002, aerial pictures and land usability maps, desert information collected by GPS, and flood and precipitation information of the region. Research method includes two stages of analyzing and providing land usability maps and the hydraulic regime of the field during the study period.

As regards the research objectives we have used ETM pictures of Landsat satellite (2002) for providing land usability maps. In order to boost the precision of job, land usability maps, the present topography and aerial pictures have also been used. In order to examine usability change, using aerial pictures and thematic maps, land examination was carried out.

In the next step, the terrestrial map of the region which had been prepared by the Agricultural Jihad Organization of East Azerbaijan province in 1:50000 scales, was used and based n soil texture, penetrability, soil depth, the existence of penetrable layer, the map of hydrologic groups of soil was prepared using the method of SCS – Soil Conservation Society.

After merging land usability maps with the map of hydrologic groups of soil, the CN map was prepared. Based on this map and the hydrologic condition of various types of farming and flora, the amount of CN for each equal unit was determined. Then, the amount of CN for the field was obtained in weight form based on the area, which after determining the type and area of each land usability, the quantities of curve number of penetration in average moist circumstances for the field was obtained as equal to 78.

Also in this research by using meteorology stations and hydrometry in the statistical region related to meteorological information, the average precipitation, the passing Discharge of spate, and the daily similar Discharge were collected, and by choosing a 10-year statistical period (2003-2012) in order to estimate the runoff of 24-hour showers, from among rainy months, 9 showers which had been damaging and destructive in 10 recent years were selected. After collecting the statistics of daily precipitations in the stations of the field, and obtaining the average precipitation with regard to curve number method, and also with regard to the soil's previous moisture condition and taking into account the precipitation of 5 days prior to the spate, the quantity of runoff for each of the showers were estimated and correlation coefficient between observed runoff and calculated runoff was obtained. The different steps of this research are as follows.

3. Results

3.1. Estimating the quantities of Curve Number (CN)

The quantity and amount of runoffs depends on the characteristics of the field and meteorological conditions and estimating runoffs requires an index to demonstrate these two elements. In addition to the quantity of precipitation, which is one of the most important hydrological characteristics of estimating runoff quantity, the type of soil, land usability and flora, the hydrological condition of the area and, also, the former moisture of the soil are important factors that have an important influence on determining the amount of runoff.

Calculating the CN of the field is done according to the physiography of the field, the hydrological groups of soil, land usability, the hydrological condition of the area and former moisture of the soil. In this research, by taking into consideration the abovementioned factors, weight model and observational data were used for measuring CN. Therefore, based on satellite pictures pertinent layers were inserted into the software environment of Arc GIS and were analyzed.

Soil characteristics influence the generation and transformation of runoff and are a very important factor in the calculations of curve number. For preparing the map of the hydrological groups of soil in the studied area, the maps of area soil were used, which have been field studied in order to boost precision. In the next step, the present map was inserted into Geomatical environment and by taking into consideration the coordinates of the map the base was coordinated and its coordinates were turned into UTM. Later, the intended layer was inserted into Arc GIS environment and was made numeral. and with regard to soil information, the map of hydrological groups of soil were provided (map no. 2) in which the soils of the area were put into two groups of B, C and D. characteristics of these three hydrological groups are brought in table 1.

As it is to be seen from table 1, 63.5 percent of the whole region has soil type C , which results from very little layers of soil and stone emergence, and 35.5 percent of it belongs to group D, and 0.88 percent of the soil of the region belongs to group B.

Table (1): hydrological soil groups of the Soofi Chay field

hydrological soil groups	Area (km^2)	Area (%)
B	2.19	0.88
C	157.83	63.5
D	88.17	35.5

After implementing the above methods, we prepared the map of land usability of the area in Arc GIS environment (map no. 3) which reveals that taking into consideration this map and table 2 and due to the soil of the area, and the quantity of rainfall and snowfall, the highest usability belongs to average pasture.

3.2. Calculating curve number (CN) using SCS method

After determining the hydrological groups of soil and land usability, in which maps were merged using the capabilities of Arc GIS method by Overlay and Crossing, and by taking into consideration SCS table, the quantities of curve number for regions which had similar hydrological groups of soil, flora and land usability were determined. As it is to be seen in table 3, by combining usability layers and hydrological groups of soil and merging common CNs, 10 regions were formed that have been demonstrated in map 6. The average CN of the region has been obtained by weight method in which the area of each region is multiplied by the related CN and from the product of region area s in CN related to each polygon, which has been divided into the total area of the region, the weight CN of region 78 is obtained.

Table 2: Land use of the Soofi Chay field

Curve number	Area (km^2)	CN×Area	Area (%)
91	0.85	77.07	0.40
88	4.14	364.31	1.88
85	0.01	1.01	0.01
84	35.40	2973.35	15.31
80	61.34	4907	25.26
79	57.68	4556.59	23.45
76	1.76	133.57	0.69
74	86.26	6383.39	32.86
69	0.1	7.01	0.04
60	0.4	23.86	0.12

Table 3: curve number in average former moisture condition for Soofi Chay field

Land use	Area (km^2)	Area (%)
Good Range	138.9	56
Medium Range	73.65	29.7
arid	0.95	0.38
Residential	0.41	0.16
Dry Land	22.21	8.95
Gardens and watery farms	11.9	4.8

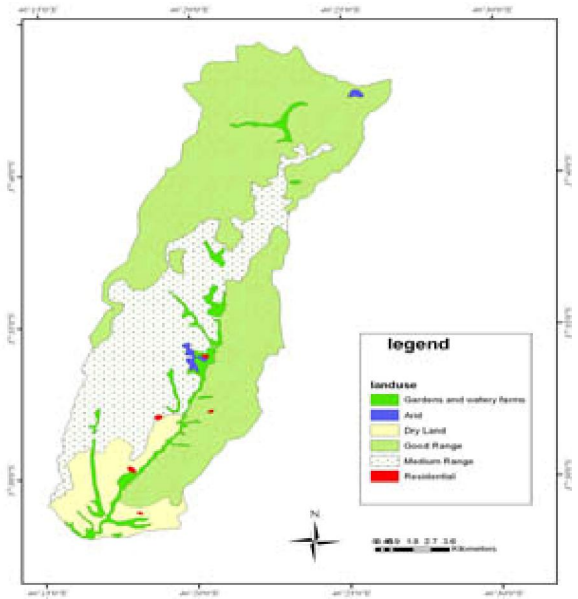

Figure 2: hydrological soil groups of the Soofi Chay

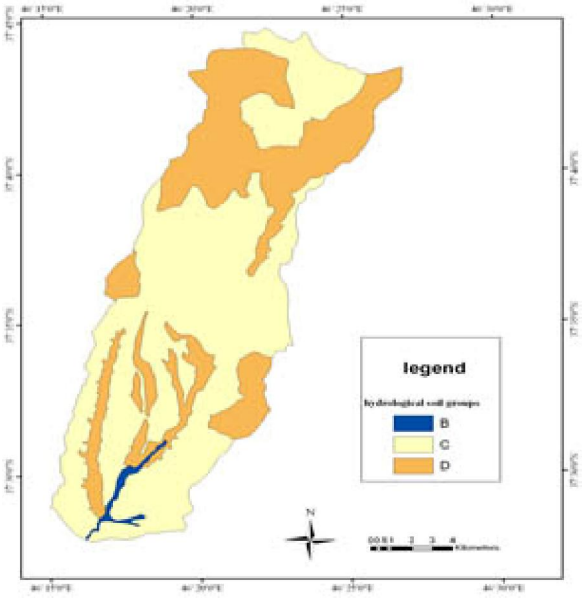

Figure 3: Land use of the Soofi Chay

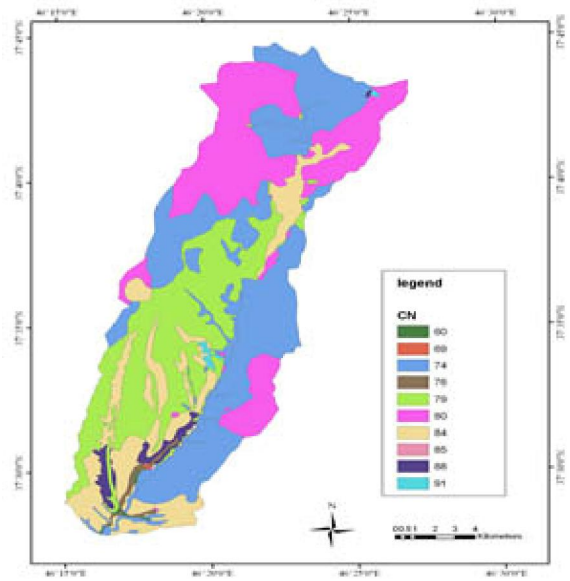

Figure 4: Curve Number of the Soofi Chay

4. Discussion

In order to test the estimation of the runoff according to curve number method, first some events in which the corresponding Discharge data had been registered were selected. In the next step, in order to calculate the hyetograph, the precipitation was extracted with a one-hour alternation from hyetograph paper and was registered in a table. For the same date the quantities of the corresponding registered Discharges in water-measurement station was analyzed with two-hour alternation.

After that, in order to draw the hydrograph of the observed flood, the common Discharge methods were used and, finally, the amount of the runoffs of the field for intended periods was calculated in a separate column. With regard to the amount of generated runoff in the specified two-hour alternation, the quantity of runoff was obtained.

By using the data of the total quantity of runoff, the area of the field, precipitation height and runoff height were obtained. But in order to estimate the runoff of 24-hour showers , nine showers were chosen from among rainy months at random and after obtaining the daily precipitation statistics of field stations and getting the average of precipitation using curve number method, and also with regard to the former moisture of soil and the precipitation 5 days prior to the flood , the quantity of runoff was estimated and the correlation coefficient between the observed runoff and the calculated runoff was calculated as /81 , which has been shown in table 4 nad figure 5.

Table 4: the height of runoff in each flood in Soofi Chay field

The height of estimative runoff	The height of observational runoff	Prior moisture condition AMC	precipitation mm	The date of flood occurrence
1.77	1.26	I	31.7	16/4/2003
0.79	1.48	I	19.5	26/4/2003
2.79	2.03	I	43.1	23/4/2004
2.48	2.6	I	39.8	1/5/2004
2.16	1.7	I	36.1	16/4/2005
0.98	1.15	I	22	18/4/2006
0.52	1	I	15.7	9/4/2007
1.14	1.35	I	23.8	2/5/2010
2.85	3.59	II	35.9	22/4/2011

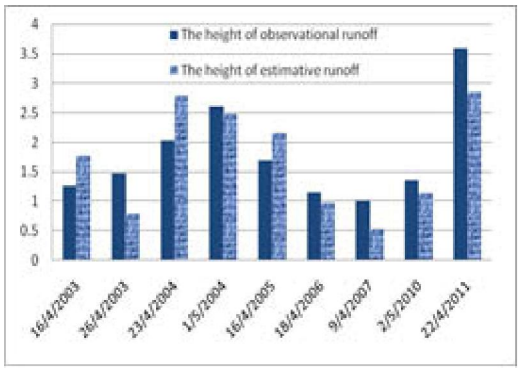

Figure 5: comparing the height of estimative and observational runoff in Soofi Chay field

5. Conclusion

Generally in carrying out research projects on the issues concerning flood , due to lack of sufficient statistics and information in watered fields , researchers have to provide experimental models or calibrations of existing experimental models with the regional conditions of their own fields. Taking into consideration

the effect of physical characteristics, geology, soil, flora, precipitation regime, geometrical conditions and the physical qualities of the main and secondary waterways of watered fields, the aforementioned experimental models are important in simulating precipitation, runoff and flood. With regard to the effective role of the quality of obtained information in the precision and correctness of estimative results through the models that have been used in this research, the capabilities of geographical information systems and remote survey were utilized. The existing traditional methods in estimating and providing the needed information in this research have different capabilities and merits in terms of speed and precision, which is due to the interference of different tastes and technical knowledge among various experts. However, by employing geographical information system and remote survey, the possibility of the interference of personal taste is reduced to a great extent. Furthermore, by using processing and categorizing satellite pictures in providing the maps of ground resources, all areas of the research are covered by informational layers. However in providing such maps by traditional methods, especially in mountainous regions, because of lack of new aerial photos and the costs and time needed for its provision, inevitably a reference is made to the same existing information in the pictures. Therefore, the ease with which to provide the satellite pictures of the research provided us with the ability to precisely analyze the situation of the research and is also considered an effective instrument in analyzing the trend of changes in phenomena. In this research SCS-CN experimental method has been utilized, due to its precision and efficiency. By preparing CN, runoff production potential of the region was determined. These amounts are drawn and presented as similar widths with same values, in which each polygon indicates a certain amount of CN and is determined with regard to the databank by having precipitation amount, runoff production amount and the flood Discharge of the field, in order to be used in managerial and conservative planning for controlling flood and erosion and designing architectural constructs such as soil dams, digression dam and using runoffs in appropriate regions. On the other hand, surplus precipitation was compared using both SCS weight models and although discrepancies were observed in the observation and measurement of runoff, the height of estimated runoff and observed runoff has a very close correlation coefficient of around 0.81, which is a sign of the reliability of this method in estimating the runoff ij the studied region. Therefore, estimating the height of runoff resulting from precipitation by this model is measurable in all periods. In similar researches, including one carried out by Ebrahimian et al (2009) for Kardeh field, they calculated the correlation coefficient between the height of observational and estimative runoffs equal to 0/56. Therefore, under these circumstances, by having the width layer of the weight model of curve number, precise calculation of the damages of rain (rain that has not turned into runoff) is possible in a very simple manner. This calculation method is realized in GIS software space very conveniently.

References:

1. Adornado HA, Yoshida M. GIS-based watershed analysis and surface run-off estimation using curve number (CN) value. J Environ Hydrol 2010;18:1–10.
2. Akhondi E. Analyzing curve number model in estimating flood by using geographical information systems. MA dissertation. The Faculty of Natural Resources and Maritime Sciences, Tarbiat-e-Modarres University 2001; pp:135.
3. Drayton RS, Wilde BM, Haris JHk. Geographical Information System approach to distributed modeling, In: Terrian Analysis and Distributed Modeling in Hydrology. Hydrological processes 1992;17:283-307.
4. Ebrahimian M, Lai FS, Ismail MH, Ismail A. Application of Natural Resources Conservation Service-Curve Method for Runoff Estimation with GIS in the Kardeh Watershed, Iran. European Journal of Scientific Research 2009;34:575-590.
5. Elhakeem M, Papanicolaou AN. Estimation of the runoff curve number via direct rainfall simulator measurements in the state of Iowa. USA Water Resour Manag 2009;23:2455–2473.
6. Hawkins RH. Asymptotic dtremination of runoff curve number. J Irrigation Drainage Eng 1993;119:3:340-345.
7. Hjelmfelt Jr AT. Investigation of curve number procedure. J Hydraul Eng ASCE 1991;117:725–737.
8. Holman IP, Hollis JM, Bramley ME, Thompson TR. The contribution of soil structural degradation to catchment flooding: a preliminary investigation of the 2000 floods in England and Wales. Hydrol Earth Syst Sci 2003;7:755–766.
9. Inci Tekeli Y, Akgul S, Dengiz O, Akuzum T. Estimation of Flood Discharge for Small watershed Using SCS Curve Number And Geographic Information system. River Basian Flood Management Journal 2006;527-538.
10. Khojini A. Analyzing curve number of SCS method in estimating the depth of VAbde Oj runoff in Maoref watered field of Alborz mountain ranges. Construction and Research Journal 1999;38:38.
11. Mishra SK, Singh VP. Another look at SCS-CN method. J Hydrol Eng ASCE 1999;4:257–264.

12. Mishra SK, Singh VP. Long-term hydrological simulation based on the soil conservation service curve number. Hydrol Process 2004;18:1291–1313.
13. Moretti G, Montanari A. Inferring the flood frequency distribution for an ungauged basin using a spatially distributed rainfall-runoff model. Hydrol Earth Syst Sci 2008;12:1141–1152.
14. Romero P, Castro G, Go`ımez JA, Fereres E. Curve number values for olive orchards under different soil management. Soil Sci Soc Am J 2007;71:1758–1769.
15. Soulis KX. Water Resources Management: Development of a hydrological model using geographical information systems. Ph.D thesis, Agricultural University of Athens 2009; Greece.
16. Tramblay Y, Bouvier C, Martin C, Didon-Lescot JF, Todorovik D, Domergue JM. Assessment of initial soil moisture conditions for event-based rainfall-runoff modeling. J Hydrol 2010;387:176–187.
17. Van Dijk A. Selection of an appropriately Simple Storm Runoff model. Hydrol Earth Syst Sci 2010;14:447-458.
18. Yaghoob zadeh M. Determining the curve number of watered field by using GIS and RS. Case in point: watered field of Mansoorabad (birjand), MA dissertation. Kerman Shahid Bahonar University, The department of water engineering 2008;150.
19. Yu B. Theoretical justification of SCS-CN method for runoff estimation. J Irrig Drain Div ASCE 1998;124: 306–310.

3/7/2013