

Comparison of the SCS-CN and Hydrograph Separation Method for Runoff Estimation in an Ungauged Basin: The Izmit Basin, Turkey

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Abstract: The separation of surface runoff and base flow is a very specific problem in water balance calculations, particularly if there is not enough measured flow data. In this study, the SCS-CN method is used to estimate the surface runoff in the ungauged Izmit Basin. The CNs are estimated using the Hydrologic Soil Groups map, based on soil data of the General Directorate of Rural Services of Turkey and land use obtained from the CORINE-2006 database for different AMCs. The surface runoff was computed using the SCS-CN method for the ungauged Izmit Basin that corresponds to 17% and 21% of the rainfall, i.e. 134 mm (for Kocaeli Meteorological Station; rainfall=804 mm) and 171 mm (for Sakarya Meteorological Station; rainfall=820 mm). According to SCS-CN method estimates, approximately 41-42% of the annual rainfall in the Izmit Basin directly contributes to the total streamflow, and 21-25% of it contributes to base flow and unmeasured infiltration. To compare the results of the SCS-CN method along with hydrograph separation method, the gauged Yuvacık Dam Sub-Basin, which is hydro-meteorologically similar to the Izmit Basin, was selected. The results showed that 16% of the rainfall in the Yuvacık Dam Sub-Basin became surface runoff. Also, it was found that about 42% of the annual rainfall in the Yuvacık Dam Sub-Basin directly contributes to the total streamflow and 23% of it contributes to the base flow and unmeasured infiltration. These results confirm that the ratio of surface runoff obtained by the hydrograph separation method in the Yuvacık Dam Sub-Basin matches with the ratio of surface runoff calculated using the SCS-CN method for the entire Izmit Basin.

Keywords: Ungauged basins, SCS-CN Method, hydrograph separation, base flow, surface runoff, land use/land cover.

Introduction

Modelling of the rainfall-runoff process is essential for the quantification of surface runoff for watersheds (Gupta et al., 2020). It plays an important role in the design of hydraulic structures, soil and water conservation structures, the mitigation of floods and droughts, streamflow prediction, assessing the water yield potential of watersheds for planning and the development of integrated water resource management plans in the basin (Singh et al., 2010). The need for modelling the rainfall-runoff process has led to the development of various concepts, methodologies and models ranging from empirical models to fully process-based models. However, the field applicability of the various complex models in data-scarce basins may have an impact on their potential performance in applications, due to large input data requirements and uncertainty in specifying the parameter values. The Soil Conservation Service Curve Number (SCS-CN) method developed by the United States Department of Agriculture (USDA) (SCS, 1956) is one of the widely used methods for the estimation of surface runoff from the total of rainfall events (Singh et al., 2010). The method is extremely useful for the estimation of runoff from ungauged watersheds (Mishra and Singh, 1999; Singh et al., 2010; Durán-Barroso et al., 2016; Walega

et al., 2017; Walega et al., 2015; Wang, 2018; Baiamonte, 2019; and Zhang et al., 2019, Shi and Wang, 2020; Kang and Yoo, 2020; Soulis, 2021; Munna et al., 2021) because it has a lower data requirement. The method uses the descriptive inputs (catchment properties) of soil type, land use/treatment, surface condition (soil-vegetation-land use (SVL) complex) and antecedent moisture condition. Then it converts them into a single numeric parameter called “Curve Number (CN)”, which also represents the runoff potential of the watershed. A high value of CN indicates high runoff, while a low CN indicates low runoff.

The SCS-CN method is also widely used as a runoff component in most standard hydrologic modelling software packages: Storm Water Management Model (SWMM) (Metcalf and Eddy, 1971), Hydrologic Engineering Center-1 (HEC-1) (HEC, 1981), Agricultural Non-point Source Model (AGNPS) (Young et al., 1989), Soil and Water Assessment Tool (SWAT) (Neitsch et al., 2002) and several modified versions of the SWAT Model (Singh and Goyal, 2017; Zhang et al., 2019&2020). This shows that the SCS-CN Method has enormous capabilities to harness the advances in remote sensing and GIS techniques for modelling the rainfall-runoff process from ungauged basins. Notably, the SCS-CN method gives satisfactory

results in the absence of runoff measurements (ungauged basin) (USDA, 1972; Shadeed et al., 2010; Sahu et al., 2010; Mishra et al., 2018, Ling et al. 2020). Topno et al. (2015) estimated annual runoff depth using the SCS-CN Method and found that the method can be successfully utilized for regions where no observations are available. Further, the advances in remote sensing and geographic information systems (GIS) technology have been coupled with the SCS-CN Method for runoff estimation, particularly for regions where there is data scarcity in terms of river discharge, land use/land cover, soil maps, digital elevation models (DEMs), and other watershed parameters (Merzi and Aktas, 2000; Poongothai and Thayumanavan, 2006).

Nagarajan and Poongothai (2012) developed spatial maps of runoff depth using the SCS-CN method coupled with remote sensing and GIS. Kadam et al. (2012) and Kumar & Jhariya (2017) used the GIS-coupled SCS-CN method to identify potential water harvesting sites. Turkey et al. (2013) used high-resolution satellite data, GIS and NRCS-CN technique for the estimation of rainfall-induced run-off in the small catchment of Jharkhand, India. Nigam et al. (2017) used the SCS-method for the field assessment of surface runoff and erosion in a GIS environment. Rajasekhar et al. (2020) used the geospatial, Analytical Hierarchical Process (AHP), and SCS-CN methods for the identification of groundwater recharge-based potential rainwater harvesting sites for the sustainable development of a semiarid region of southern India. Furthermore, the SCS-CN method coupled with remote sensing and GIS has been successfully applied by other researchers such as De Roo et al. (2001), Burns et al. (2005), Siriwardena et al. (2006), Podwojewski et al. (2008) and Wehmeyer and Weirich (2010) to investigate the impact of land-use change on runoff. Zhan and Huang (2004) investigated an extension of ESRI ArcGIS software (Arc CN Runoff tool) to determine CNs and runoff for a storm event within a watershed. These applications show that GIS and remote sensing coupled with hydrologic models improve the accuracy of the traditional hydrological models and considerably reduce the cost and time in applications.

Keeping the above in view, within the scope of hydrogeological investigations in the Izmit Basin, the objective of this study was to assess the quantity of surface runoff from the study area using the SCS-CN method. This will be helpful to decision making processes for the future development of water resource projects in the Izmit basin, which does not have flow measurements.

Materials and Methods

Study Area (Morphological, Geological, Hydrologic and Hydrogeological)

The Izmit Basin has approximately 1,370 km² of drainage area and the elevation varies between 0 and 1606 m (Kartepe) (Fig. 1). The basin is located in the Marmara Region between longitude 29° 22' and 30° 21' East and latitude 40° 31' and 41° 13' North. It is bordered by Sakarya to its east and southeast, by Bursa to its south, by Izmit Bay, the Sea of Marmara, and Istanbul to its west, and by the Black Sea to its north, as shown in Figure 1.

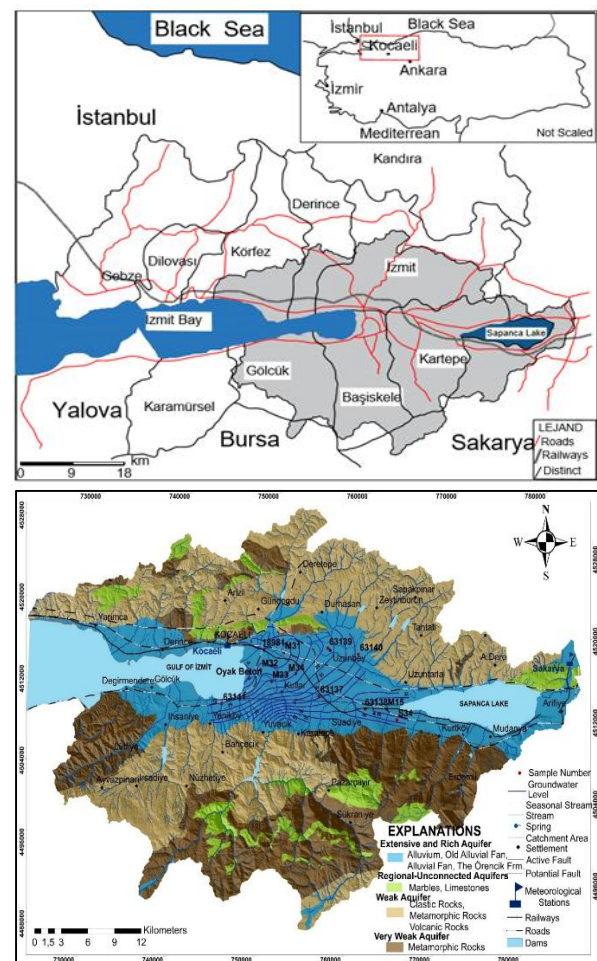


Fig. 1. Location map and Geological/Hydrogeological map of the study area (simplified from MTA-General Directorate of Mineral Research and Exploration, 2005).

The Northern Anatolian Fault runs through the middle of the Izmit Basin. Regarding its morphological properties, the Izmit Basin consists of three parts: Kocaeli Peninsula in the north, Armutlu Peninsula in the south, and Izmit Bay in the centre. The southern part of the Izmit Basin consists of mountain ranges running in an east-west direction and ranging from 700 m to 1600 m in altitude. The Kocaeli Peninsula, which consists of Istanbul's Paleozoic and Kocaeli's Triassic strata, is located in the north of the Izmit Basin. The Armutlu

Peninsula is located in the southern part of the Sakarya Region. Flysch, volcanic and metamorphic strata dominate the study area, ranging from the Paleozoic to the Quaternary periods. Also, quaternary alluvium is widespread in the middle of the basin, as shown in Figure 1. The clastic rocks (flysch) and volcanic rocks in the basin are described as "Poor Aquifer". The metamorphic rocks are classified as "Very Poor Aquifer", the marble, which occurs in limited areas, and limestone are classified as "Local Aquifer,". The alluvium sediments are classified as "Rich and Extensive Aquifer" (Figure 1).

Infiltration is relatively high and surface runoff is low in aquifer characteristic environments. The streams, which come from the north and south part of the basin and flow toward Izmit Bay, combine in alluvium (Figure 1). There are three flow observation stations in the southern part of the basin, which are operated by İSAŞ (Izmit Water Corporation). The hydrological observations carried out to date in the basin are not sufficient and are infrequent and irregular. Therefore, the SCS-CN method coupled with GIS and remote sensing will be applied to estimate surface runoff.

The Soil Conservation Service Curve Number (SCS-CN) Method

The method is well suited to estimating surface runoff from small agricultural watersheds (gauged/ungauged), and establishes CN values (descriptive of the runoff potential of a watershed) under various hydrologic soil groups, land use/land cover, and antecedent moisture conditions (AMCs) with acceptable accuracy (Berthet al., 2009; Chung et al., 2010; Walega and Rutkowska, 2015; Bartlett et al., 2016; Walega and Salata, 2019, Al-Ghobari, 2020; Gabriels, 2021). The SCS-CN method is based on the water balance equation along with two fundamental hypotheses. The first hypothesis equates the ratio of the actual amount of direct surface runoff (Q) to the total rainfall (P) (or maximum potential surface runoff) to the ratio of actual infiltration (F) to the amount of the potential maximum retention (S). The second hypothesis relates the initial abstraction (I_a) to S:

(a) Water balance equation

$$P = I_a + F + Q \tag{1}$$

(b) Proportional equality (first hypothesis)

$$\frac{Q}{P-I_a} = \frac{F}{S} \tag{2}$$

(c) I_a-S relationship (second hypothesis)

$$I_a = \lambda S \tag{3}$$

where P = total rainfall; I_a = initial abstraction; F = cumulative infiltration excluding I_a; Q = direct runoff,

and S = potential maximum retention or infiltration. The values of P, Q, and S are in-depth or volumetric dimensions, while the initial abstraction coefficient (λ) is dimensionless. In a typical case, a certain amount of rainfall is initially abstracted as interception, evaporation, infiltration, and surface storage before runoff begins. The sum of these four elements at the initiation of surface runoff is usually termed 'initial abstraction' (Singh et al., 2010; Singh et al., 2015).

The first hypothesis (Eq. 2) is primarily a proportionality concept and the second hypothesis (Eq. 3) is a linear relationship between initial abstraction I_a and potential maximum retention S. On coupling Eqs. (1-3), the expression for Q can be written as:

$$Q = \frac{(P-\lambda S)^2}{(P+S(1-\lambda))} \quad ; \text{ for } P \geq \lambda S; \tag{4}$$

$$Q = 0 \quad ; P \leq \lambda S;$$

Eq. (4) is the general form of the popular SCS-CN method. The parameter S is limited by either the rate of infiltration at the soil surface or the amount of water storage available in the soil profile, whichever gives it a smaller value. Since S can vary in the range of 0 ≤ S ≤ ∞, it is mapped on to a dimensionless curve number CN, varying in a more appealing range 0 ≤ CN ≤ 100, as:

$$S = \frac{25400}{CN} - 254 \tag{5}$$

where S is in mm. The difference between S and CN is that the former is a dimensional quantity (L) whereas the latter is non-dimensional. The highest possible numerical value of CN (i.e. 100) symbolizes a condition of zero potential maximum retention (S = 0), which is a real physical situation represents an impermeable watershed. The curve number (CN) ranges from 0 to 100 and is determined according to the basin's soil type, topography, and land use/land cover. In this study, the λ value in Eq. 4 is taken as 0.10 because the calculated CN value of the Izmit basin was found to be in the range of 70 < CN < 80. Aron et al. (1977) suggested λ ≤ 0.1, and Hawkins et al. (2001) and Singh et al. (2008) suggested that λ = 0.05 may also result in improved performance. Some other studies, e.g. SCS (1972); Springer et al. (1980); Cazier and Hawkins (1984); Ramasastry and Seth (1985) and Boszany (1989) reported that λ varied in the range of 0 to 0.3.

Antecedent Moisture Condition

The antecedent moisture conditions (AMCs) play a dominating role while applying the SCS-CN technique in a variety of situations. The SCS defines AMC as an index of the watershed wetness (Hjelmfelt, 1991). The NEH-4 Table uses the antecedent five-day rainfall as the

antecedent precipitation index (API) for three AMCs as AMC I through AMC III. Finally, the computed CNs are adjusted to CN_I to CN_{III} based on AMC conditions.

Izmit Basin Database

Various thematic maps required for runoff estimation using the SCS-CN method were prepared using ArcGIS 10.3.1 in this study. A brief discussion on these maps is given in the following sections.

Hydrologic Soil Groups (HSG)

The hydrologic features of soil groups are the main factors in the analysis of a drainage basin. HSG describes the infiltration capacity of the soil types. The Hydrologic Soil Groups map was created in an ArcGIS environment using the Turkish Soil Mapping Surveys (Özer, 1990), which were developed by the Soil-Water General Directorate in the period 1966 -1970.

Land Use/Land Cover Map

Land cover refers to the vegetation covering the surface, whereas, land use refers to human activities on the land surface (Halley et al., 2000). Land use/land cover map of the Izmit Basin prepared using the CORINE-(2006) database. Table 1 shows the distribution of land use/land cover for the Izmit Basin. The land use/land cover map of the Izmit Basin shows that there is a total of ten types of land use/land cover classes. However, the basin contains forest (56.10%), pastures, heterogeneous agricultural areas (27%), arable land (6.66%), discontinuous urban fabric (4.06%), scrub and/or herbaceous vegetation associations (2.99%), industrial, commercial and transport units (2.03%), mineral

extraction sites, construction sites (0.51%), inland wetlands (0.38%), continuous urban fabric (0.15%), and others. The major area of the Izmit Basin falls under forests followed by pastures, heterogeneous agricultural areas, arable lands and discontinuous urban fabric.

CN Map

The CN map was generated for application of the SCS-CN method in this study using HSG and land use/land cover maps obtained using ArcGIS 10.3.1 as shown in Figure 2. The computed CNs as per the land use/ land cover and HSGs are also given in Table 1. Also, Eq. 5 was used to compute the values of S based on the estimated CN values for the estimation of surface runoff using Eq. (4). The lower values of CNs represent low run-off potential and high infiltration, and a high value of CN (100) represents the highest run-off and lowest infiltration.

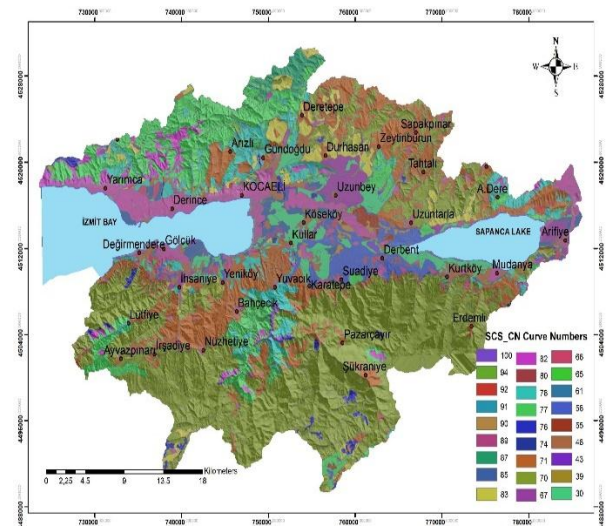


Fig. 2. Curve Number (CN) map of Izmit Basin.

Table 1. Land use/land cover table for the Izmit Basin (Source: Halley et al. 2000) and Computed CNs as per land use/land cover and HSG.

S.No.	Land Use/Land Cover	Area (km ²)	Map Code	Area (%)	Land Use/Land Cover	CN values for HSG			
						A	B	C	D
1	Continuous urban fabric	2.13	111	0.15	Continuous urban settlement	57	72	81	86
2	Discontinuous urban fabric	57.72	112	4.06	Discontinuous urban settlement	48	66	78	83
3	Industrial, commercial and transport units	28.90	121,122,124	2.03	Industrial, commercial and transport units	85	90	92	94
4	Mineral extraction sites, construction sites	7.23	131,133	0.51	Mineral extraction sites, construction sites	76	85	89	91
5	Arable land	94.76	211,212,222	6.66	Arable land	67	77	83	87
6	Artificial, non-agricultural vegetated areas	1.74	141,142	0.12	Artificial, non-agricultural vegetated areas	39	61	74	80
7	Pastures, heterogeneous agricultural areas	384.36	231,242,243	27.00	Pastures, heterogeneous agricultural areas	30	58	71	78
8	Forests	798.53	311,312,313	56.10	Forests	30	55	70	77
9	Scrub and/or herbaceous vegetation associations	42.56	321,324	2.99	Scrub and/or herbaceous vegetation associations	43	65	76	82
10	Inland wetlands	5.44	411,512,521	0.38	Water/inland wetlands	100	100	100	100

As discussed above, the SCS-CN method was used to estimate surface runoff from the daily rainfall. Land use/land cover, hydrological soil cover and AMCs were considered in the analysis. The annual values of the computed runoff for the observed annual rainfall are given in Table 2 for Kocaeli and Sakarya Meteorological Stations for the period 2006-2016. Based on the average annual rainfall values of Kocaeli and Sakarya Meteorological Stations of 804 mm and 820 mm, the average annual runoff for Izmit Basin was computed using the SCS-CN method was found to be 134 mm and 171 mm respectively for the period 2006-2016. It comes out to be 0.166 and 0.210 of the the ratio of the runoff to rainfall (Q/P) in the Izmit Basin (Table 2).

Table 2. Rainfall-runoff statistics for Kocaeli and Sakarya Meteorological Stations of the Izmit Basin.

Year	Kocaeli Meteorological Station P (mm)	Kocaeli Meteorological Station Q (mm)	Sakarya Meteorological Station P (mm)	Sakarya Meteorological Station Q (mm)
2016	1046	172	1038	241
2015	846	182	---	---
2014	935	147	942	206
2013	695	84	704	133
2012	817	91	818	155
2010	884	218	843	199
2009	872	179	928	217
2008	688	65	690	120
2007	653	135	---	---
2006	601	71	600	100
Avg.	804	134	820	171
Runoff coefficient C = 0.166			Runoff coefficient C = 0.210	

Results and Discussion

As discussed above, the Izmit basin does not have flow records. Therefore, the Yuvacık Dam Sub-Basin was selected as the 'validation' basin to check the validity of the runoff computations using the SCS-CN method. It largely represents the basin investigated, i.e. the Izmit Basin, in terms of slope condition and hydrological and geological features. The Yuvacık Dam Sub-Basin also contains marble (Local Aquifer), volcanoclastic rocks (Poor Aquifer), and metamorphic rocks (Very Poor Aquifer) as does the Izmit Basin. The Yuvacık Dam Sub-Basin has an average rainfall of 1198 mm and covers a drainage area of 258 km². This reservoir is used to provide water during drought periods and works as a flood protection measure. The Yuvacık Dam sub-basin has three streamflow observation stations located in Kirazdere (M1), Kazandere (M2) and Serindere (M3) as shown in Figure 3.

The hydrograph separation technique was used to separate surface runoff and baseflow using the streamflow records of 2007-2016 obtained at the three gauging stations (M1-M2-M3) in the Yuvacık Dam Sub-Basin, and the results are given in Table 4. It can be observed from Table 4 that the average annual

streamflow at station M1 is 37.04x10⁶ m³/year; the average annual base flow is 21.66 x 10⁶ m³/year, and the average annual surface runoff is 15.38 x 10⁶ m³/year. The average annual streamflow at station M2 is 18.74x10⁶ m³/year, the average annual base flow is 11.33 x 10⁶ m³/year, and the average annual surface runoff is 7.41 x 10⁶ m³/year. Similarly, for station M3, the average annual streamflow is 65.49x10⁶ m³/year, the average annual base flow is 38.99 x 10⁶ m³/year, and the average annual surface runoff is 26.50 x 10⁶ m³/year (Table 3). Overall, the average annual values of streamflow, base flow and surface runoff in the Yuvacık dam sub-basin were found to be 121.27 x 10⁶ m³/year, 71.98 x 10⁶ m³/year, and 49.29 x 10⁶ m³/year respectively.

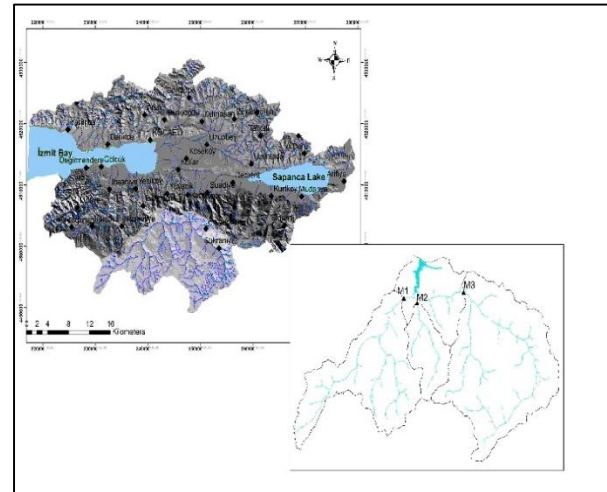


Fig. 3 Yuvacık Dam Sub-Basin of the Izmit Basin and observation station locations (M1-M2-M3).

Table 2 shows the comparison between the surface runoff computed using the SCS-CN method and the hydrograph separation technique on an annual basis for the Izmit Basin and the Yuvacık Dam Sub-Basin.

The annual values of rainfall are given in Table 3 for Kocaeli and Sakarya Meteorological Stations for the period 2006-2016. In addition, average evaporation values were obtained from DMI (Turkish State Meteorological Service, 2016) as 467 mm for Kocaeli Meteorological Station and 480 mm

for Sakarya Meteorological Station in the period 2006-2016. (Table 4).

Average precipitation was calculated as 1101×10^6 m³/year (804 mm) (Table 3) and average evaporation as 640×10^6 m³/year at Kocaeli Meteorological Station

The remaining 461×10^6 m³/year of water passes into a surface flow and ground flow. The average runoff value was calculated as 184×10^6 m³/year with the SCS-CN Method. The difference of 277×10^6 m³/year was also accepted as recharge.

method. The difference of 230×10^6 m³/year was also accepted as recharge.

Using the SCS-CN method, it was calculated that 41-42% of the precipitation in the Izmit Basin contributed to the streamflow. It can be seen that 42% of the precipitation in the Yuvacık Dam Sub-Basin contributed to the streamflow. It is also seen that 16% of the rainfall flows over the soil surface as surface runoff in the Yuvacık Dam Sub-Basin, whereas it was calculated using the SCS-CN method that 17% and 21%

Table 3. Streamflow, base flow, surface runoff values ($\times 10^6$ m³/year) at stations M1-M2-M3 and Precipitation values in the Yuvacık Dam Sub-Basin

Years	Precipitation (mm)	M1 (10^6 m ³ /year)			M2 (10^6 m ³ /year)			M3 (10^6 m ³ /year)		
		Streamflow	Baseflow	Surface runoff	Streamflow	Baseflow	Surface runoff	Streamflow	Baseflow	Surface runoff
2007	1097	24.92	16.34	11.72	12.38	7.99	5.43	40.89	20.88	18.86
2008	972	34.21	22.87	14.10	18.58	14.51	8.51	51.09	39.71	18.53
2009	1373	33.98	21.53	11.75	20.62	12.68	9.47	51.86	29.20	25.15
2010	1301	44.25	27.26	15.04	21.49	14.17	10.18	78.26	53.65	34.42
2011	1020	46.84	31.50	17.49	18.44	10.29	8.51	66.28	47.29	20.91
2012	1226	36.03	20.20	17.68	18.05	12.24	9.27	83.41	46.21	37.34
2013	1061	24.86	15.09	8.62	9.79	7.57	3.91	43.96	30.68	14.55
2014	1413	16.65	7.25	9.39	9.10	6.71	2.85	29.67	14.40	15.27
2015	1361	69.72	41.05	28.86	30.12	20.29	10.39	125.64	77.53	48.10
2016	1155	34.96	13.47	19.16	14.18	6.85	5.62	77.11	30.34	31.88
Ave.	1198	37.04	21.66	15.38	18.74	11.33	7.41	65.49	38.99	26.50
Total Stream flow (10^6 m³/year)								121.27		
Total Surface Runoff (10^6 m³/year)								49.29		
Total Base flow (10^6 m³/year)								71.98		

Table 4. Streamflow, surface runoff and baseflow values for Izmit Basin and Yuvacık Dam Sub-Basin.

	Izmit Basin		Yuvacık Dam Sub-Basin
	Kocaeli Station	Sakarya Station	
	SCS-CN Method		Hydrograph Separation Method
Area (km ²)	1370		258
Precipitation (mm)	804	820	1198
Precipitation ($\times 10^6$ m ³ /year)	1101	1123	309
Evaporation (mm)	467	480	728
Evaporation($\times 10^6$ m ³ /year)	640	658	188
% Evaporation ($\times 10^6$ m ³ /year)	58%	59%	58%
Stream flow ($\times 10^6$ m ³ /year)	461	465	121
% Stream flow	42%	41%	42%
• Surface Runoff ($\times 10^6$ m ³ /year)	184	235	50
• % Surface Runoff (% of precipitation)	17%	21%	16%
• Recharge (Base Flow+Unmeasured Infiltration) ($\times 10^6$ m ³ /year)	277	230	71
• % Recharge (Base Flow+Unmeasured Infiltration) ($\times 10^6$ m ³ /year) (% of precipitation)	25%	21%	23%

Average precipitation was calculated as 1123×10^6 m³/year (820 mm) (Table 3) and average evaporation as 658×10^6 m³/year at Sakarya Meteorological Station. The remaining 465×10^6 m³/year of water passes into a surface flow and ground flow. The average runoff value was calculated as 235×10^6 m³/year with the SCS-CN

of the rainfall in the Izmit Basin contributed to surface runoff. It can be seen that the % of the streamflow values and surface runoff values calculated using the SCS-CN method are in good agreement with the % of the streamflow values and surface runoff values obtained using the hydrograph separation method and data

received from the flow observation stations (Table 4). These results show that the surface runoff in the ungauged Izmit Basin can be accurately determined by using the SCS-CN method.

Conclusion

In this study, the SCS-CN method was used to estimate the surface runoff in the ungauged Izmit Basin. The study presents an approach for calculating surface runoff and groundwater recharge for the Izmit Basin using the SCS-CN method. Finally, to check the validity of the SCS-CN method for runoff estimation, the hydrograph separation method was applied to the gauged Yuvacık Dam Sub-Basin, which is hydro-meteorologically similar to the Izmit Basin. The surface runoff computed using the SCS-CN method for the ungauged Izmit Basin corresponds to 17% and 21% of the rainfall, i.e. 134 mm for Kocaeli Meteorological Station where rainfall = 804 mm, and 171 mm for Sakarya Meteorological Station, where rainfall = 820 mm. The hydrograph separation technique also shows a surface runoff of about 16% of the total rainfall in the hydro-meteorologically similar Yuvacık Dam validation Sub-Basin. These results show that the surface runoff in the ungauged Izmit Basin can be accurately estimated using the SCS-CN method coupled with the GIS and remote sensing data. Groundwater recharge is a fundamental component in the water balance in a basin. In this study, base flow with unmeasured infiltration has been taken as the groundwater recharge. It can be estimated using the SCS-CN method. It was found to be 25% and 21% of the total rainfall respectively for Kocaeli and Sakarya Meteorological Stations in the Izmit Basin. Also it was found to be 23% of the total rainfall respectively for Yuvacık Dam Sub-Basin. This is an important contribution to groundwater balance calculations in situations where the data are either scarce or absent (ungauged conditions).

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