

GIS and remote sensing techniques for the assessment of the impact of land use change on runoff

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Abstract Soil Conservation Service (SCS) curve number (CN) is used to calculate the potential runoff value in ungauged catchment basins. The CN method was applied to calculate the runoff in the catchment basin of the Yamula Dam which is located on the Kızılırmak River in the semi-arid climate of the Central Anatolia Region of Turkey. The analysis of the relation between the land use change and the change of the curve number (change of the runoff values) in the catchment basin can be calculated through geographic information system (GIS) techniques by using the data obtained from satellite images. Using GIS analysis with Python language, SCS-CN technique was applied to study area efficiently. The estimated CN values indicate an uptrend in proportion to the increase in the water level and agricultural lands in the catchment basin. This change is relevant to the land use/land cover (LULC) and the land inclination and in connection with the morphological structure of the soil.

Keywords Curve number · Remote sensing · Geographic information system · Runoff · Python language

Introduction

The relation between rainfall and runoff and the measurement of this relation in the water cycle, which are a critical part of our lives, are important. Due to its importance, the precipitation on fields and its runoff path have usually been a subject of

interest for research and analyses. The conversion of precipitation to runoff, you have to be known some events and terminology. Rainwater accumulate from hallows, intercept on vegetation, and infiltrate into soil. Infiltration is the vertical penetration of rain into the soil through the soil surface, that is, absorption of water by the soil. While rain continues, soil infiltrates water as much as infiltration capacity of the soil. When soil exceeded this capacity, runoff occurred. Precipitation, runoff, and infiltration measurements have been made using different methods depending on the soil type, and hydrologic soil groups have been created. Infiltration and runoff are important data for hydrology (Te Chow et al. 1988). In order to obtain such data, it is necessary to have precipitation and runoff measurement stations. Therefore, to determine these values which cannot be measured in basins that do not include such measurement stations, the curve number (CN) method is used. Infiltration is important in hydrology, because the amount of infiltration indicates the feeding of groundwater sources. Therefore, data relating to the infiltration level of the soil are important. In order to determine the hydrologic soil groups, it is necessary to know the characteristics of the soil and the flora living in the soil. The structure, texture, organic matter content, and moisture of the soil affect the amount of infiltration (NRCS 2004b).

In Soil Conservation Service (SCS) CN calculation, different CN values are calculated for different antecedent moisture conditions (AMCs). While the AMC I condition corresponds to the dry time of year, the AMC III condition corresponds to the humid time and the AMC II condition to the normal time. The CN values in these conditions are called CNI, CNIII, and CNII, respectively. The CNI and CNIII values are calculated by utilizing the CNII value (Mishra et al. 2008; Mishra and Singh 2013). For CN calculation, the values which the soil will have depending on its geological structure, land use/land cover (LULC) characteristic, and inclination value have been

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tabulated by the SCS. In remote sensing, such data are obtained by utilizing satellite images and geographic information system (GIS) techniques. Then, the obtained maps are superimposed on each other, the curve number determined as per these characteristics is assigned, and thus, the curve numbers of the basins are acquired. With the CN obtained, the runoff of the catchment basin is calculated retrospectively.

The literature includes numerous works based on the SCS-CN method (Deshmukh et al. 2013; El-Hames 2012; Guzmán et al. 2011; Huang et al. 2008; Mishra and Singh 1999; Mishra et al. 2006; Moretti and Montanari 2007; Shi et al. 2007; Singh et al. 2008; Young and Carleton 2006; Zhan and Huang 2004). El-Hames used the SCS-CN method to calculate the peak discharge in basins located in arid and semi-arid regions but made no measurements (El-Hames 2012). In another application, the SCS-CN technique was used to determine the change in sediment amount (Tyagi et al. 2008). Kottogoda et al. (2000) prepared statistical models of the daily runoff values in three different river basins in Italy by using the CN technique. Lin et al. integrated the curve number method to determine the impact of land use change on environmental runoff (Lin et al. 2014). Isik et al., on the other hand, applied the curve number technique by combining it with artificial neural networks to determine the impact of land use change on runoff (Isik et al. 2013).

This study reveals through remote operate in the year 2005. Therefore, the Landsat Thematic Mapper (Landsat TM) images from the years 2000, 2006, 2010, and 2011 were used to produce the land use change maps. In order to cope with the detailed steps of the process and routine calculations in the weighted curve number calculation, it was ensured, by developing a user interface with the Python software language, that the process steps can be completed easily and quickly. The obtained results can be used as methodological references for studies to be conducted on other catchment areas (potable water and non-potable water).

Methodology

As outlined in Fig. 1, we use remote sensing and GIS to analyze the effects of land use change on the hydrologic structure of the Yamula Basin in Kayseri metropolitan area.

Study area

Within the scope of the application, our aim was to determine the runoff values in the catchment area of the Yamula Dam located on the provincial border of Kayseri (Turkey) with help of the curve number calculation to be made with integration of the remote sensing and GIS. The study area has a total surface area of 5773 ha and lies between the latitudes of 38°52'–39°05' N and the longitudes of 35°12'–35°2' E. The Yamula Dam is a

hydroelectric power plant located on the Kızılırmak River. It started to retain water in the year 2003 and to generate power in the year 2005. The catchment area map of the study area is shown in Fig. 2.

Data

In this study, the data of the land use/land cover, land use capability, hydrologic soil groups' maps, and precipitation values were used to calculate the SCS-CN and the runoff associated therewith.

The precipitation values of the region were obtained from the rainfall observation stations of the Turkish State Meteorological Service, which are near the basin.

Land use/land cover map

The satellite images that were acquired in 2000, 2006, 2010, and 2011 (NASA 2016) were processed by the following three processes: pre-processing, classification, and post-classification, as shown in Fig. 1. In classification, a supervised image classification maximum likelihood method was used. First, Landsat satellite images were converted to the Universal Transverse Mercator (UTM) coordinate system. Next, Erdas Imagine 9.1 and ArcGIS 10.3 were selected for various analyses and image classification (Erdas 2014; ESRI 2014). The classified images were further smoothed with a majority filter with a 3×3 kernel to reduce the number of misclassified pixels (Erdas 1999). The classification categories in the study area are water, cropland, settlement, dryland, and grassland.

The Kappa statistic and overall accuracy were used to measure the agreement between two sets of categorizations of a dataset while correcting for chance agreements between the categories. Jenness's kappa analysis in the ArcView 3.x extension was used to estimate the sample size required to achieve a confidence level and precision for statistical analysis (Jenness and Wynne 2005). The error matrix was produced after calculating the minimum sample size. Table 1 shows the overall classification accuracy and kappa results for the Yamula Basin. Our results show that the kappa coefficient and overall accuracy statistic are greater than 80 %. The high overall accuracy and high kappa coefficient suggest a good relationship between the classified image and the reference data (Congalton and Green 2008; Landis and Koch 1977).

Then, the classified raster images were converted to vector maps, and thematic land use maps were obtained (Fig. 3). The GIS database was created by eliminating topological errors in the land use data obtained. The geological and agricultural land use capability maps were overlaid with the created land use maps. Finally, the resulting GIS database was used as the input parameter for the SCS method which was developed by the Soil Conservation Service for the calculation of curve numbers.

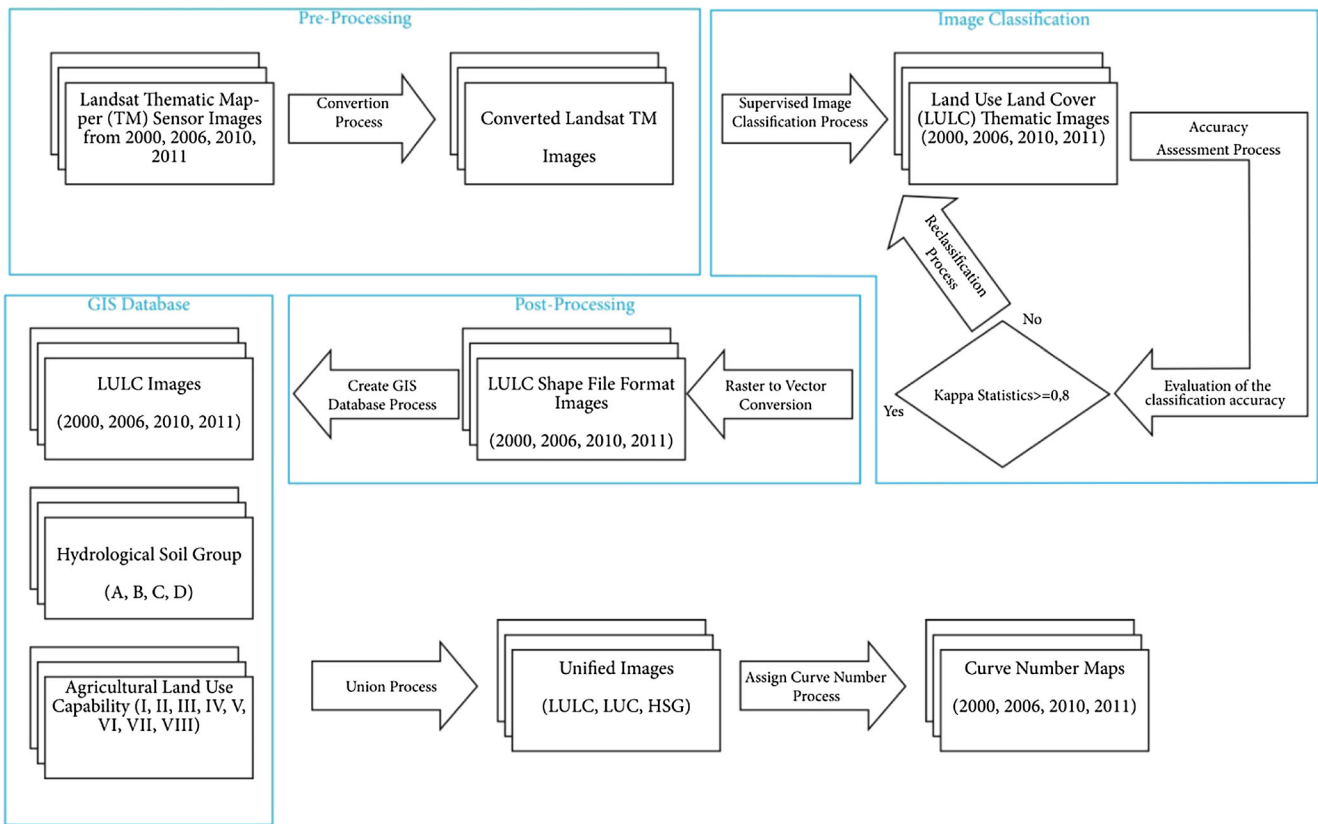


Fig. 1 The methodology of this study

Fig. 2 The location maps of the geographic basin area (Yamula Dam) used in this study

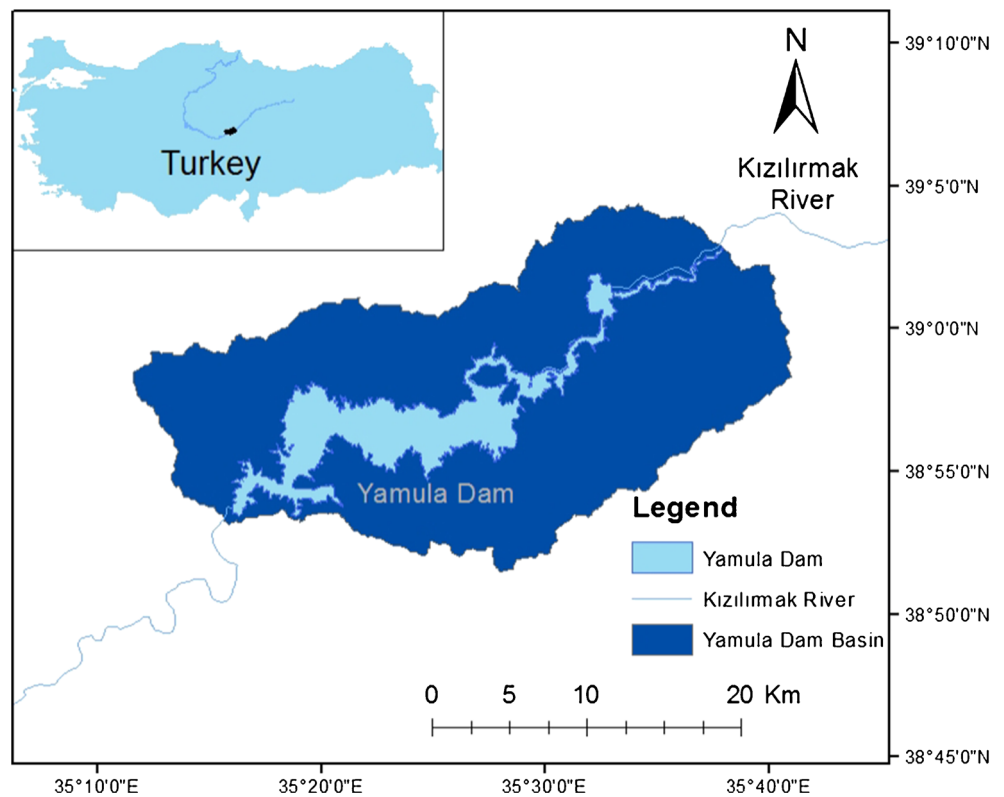


Table 1 Results of the classification accuracies for Yamula Basin

Images	Overall classification (%)	Kappa statistics
2000 Landsat	95	0.9288
2006 Landsat TM	90	0.8647
2010 Landsat	95	0.9249
2011 Landsat TM	93	0.8978

Hydrologic soil groups

The HSG data is one of the types of data used in the SCS-CN method. The soil structure was divided into hydrologic groups by Musgrave in 1955 (Musgrave 1955). This classification is prepared by measuring the precipitation, runoff, and infiltration values. These four groups are named by letters from A to D. Among these groups, group A has low runoff potential, while group D has high runoff potential (Table 2).

For this classification, these groups were created by first performing the precipitation and runoff measurements on the soils with specific characteristics by using an instrument called an infiltrometer and then calculating the infiltration

Table 2 The definitions of the hydrologic soil groups (Musgrave 1955)

Group	Soil type
A	Lowest runoff efficiency: deep sand, loess, aggregate, and silts
B	Medium-low runoff efficiency: shallow loess, sandy, and floral soil
C	Medium-high runoff efficiency: clay loams, shallow sandy loams, soils with low organic ingredients, and soils generally rich in clay
D	Highest runoff efficiency: soils which inflate/swell considerably when wet, heavy plastic clays, and certain saline soils

amount by using the difference between such measurements (NRCS 2004b; SCS 1993).

Land use capability classes

The map of the land use capability (LUC) classes was prepared by using the land inclinations. It has the values ranging between LUC I and LUC VII depending on

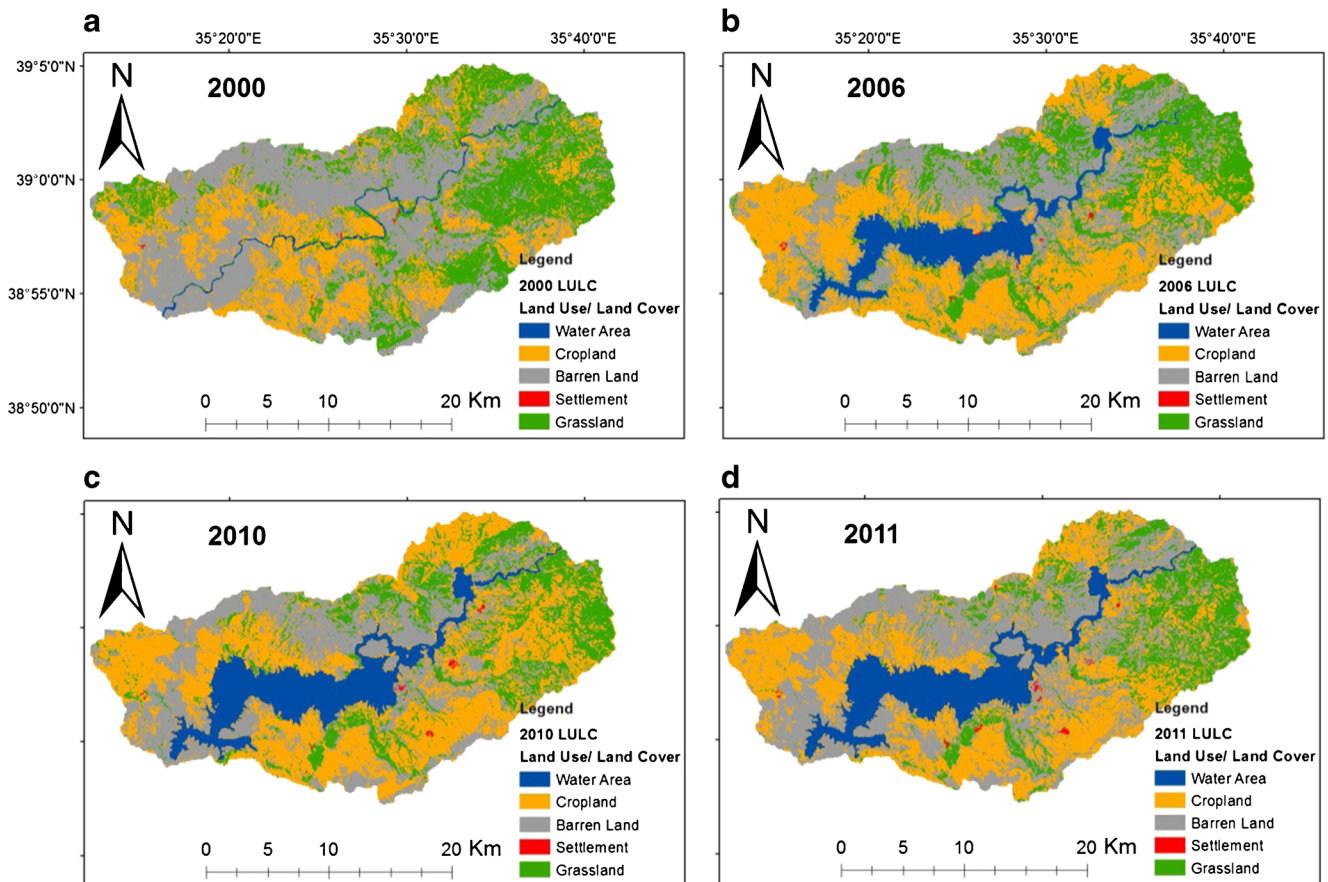


Fig. 3 Thematic land use maps: **a** year 2000, **b** year 2006, **c** year 2010, and **d** year 2011

Table 3 The values of slopes for different land use capability classes (Şen et al. 2010)

Land use capability class	Slope range (%)	Description
I	0–2	Flat
II	2–6	Undulating
III	6–11	Gently rolling
IV	12–15	Rolling
V	16–20	Moderately steep
VI	21–25	Steep
VII	26–30	Very steep
VIII	>30	Extremely steep

whether the land is flat or steep. The value “I” indicates lands with a flat inclination, while the value “VII” refers to steep lands, with the inclination values increasing gradually between them (Table 3). The land use capability classes of the region were obtained from the Geographic Information Systems Department of the General Directorate of Agricultural Reform, Republic of Turkey Ministry of Food, Agriculture and Livestock.

Method

Curve number method

In practice, the SCS-CN method (NRCS 2004a; USDA/NRCS 1986) has been used to estimate the runoff. The Natural Resources Conservation Service (previously SCS) developed the curve number method in 1964 with the intention of detecting the non-measurable runoffs in basins where no runoff measurement can be performed. The curve number method allows the calculation of non-measurable runoff values. The CN that gives the relation between the rainfall and the runoff empirically takes a value from 0 to 100. The CN method was developed initially for the USA. Then, it started to be applied globally. Although the basic concepts are the same for the

Table 4 Antecedent rainfall limits for different AMCs (US Department of Agriculture Soil Conservation Service)

Antecedent moisture condition class	5-Day antecedent rainfall (mm)		
	Dormant season	Growing season	Average
I	<13	<36	<23
II	13–28	36–53	23–40
III	>28	>53	>40

entire world, additional criteria are introduced for different regions.

The mathematical relation between the rainfall and the runoff is expressed with the following equation:

$$\frac{F}{S} = \frac{Q}{P-I_a} \tag{1}$$

where *F* refers to the actual retention, *S* to the potential maximum retention (mm), *Q* to the direct runoff (mm), *P* to the rainfall depth (mm), and *I_a* to the initial abstraction (mm), that is, the amount of water absorbed by the soil at the first stage.

In fact, the actual amount retained in the soil is obtained by subtracting the runoff and the initial abstraction from the rainfall.

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

When the two equations are combined, the following equation is obtained:

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

The calculations made for the *I_a/S* ratio by using the measurement values obtained from the sample basins revealed that it had values lower than 0.2 which is the default value (Baltas et al. 2007). This ratio had different values because the geological structures are different in different basins. In numerous studies, however, the 0.2 value is used for the *I_a/S* ratio. If this value is included in Eq. 3, Eq. 4 will be obtained.

$$Q = \frac{(P-0.2S)^2}{P + 0.8S}, P > 0.2S \tag{4}$$

This rainfall-runoff relation equation is used in the CN method. The potential maximum retention value (*S*) is converted into the CN value. The relation is as shown in Eq. 5.

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

Theoretically, the potential maximum amount of water retained by the soil (*S*) varies between 0 and infinity, while the CN value varies between 0 and 100. When the amount of water retained by the soil is 0, the curve number is 100, and the entire rainfall turns into runoff. When the amount of retained water is infinite, on the other hand, the CN value is 0, which indicates that the entire rainfall has infiltrated the soil, and no runoff at all is observed.

At the implementation stage of the CN method expressed mathematically in the equations above, the CN values are obtained by using the remote sensing and GIS methods in a combined manner. For this, the land use/land cover map, the hydrologic soil groups’ map, and the

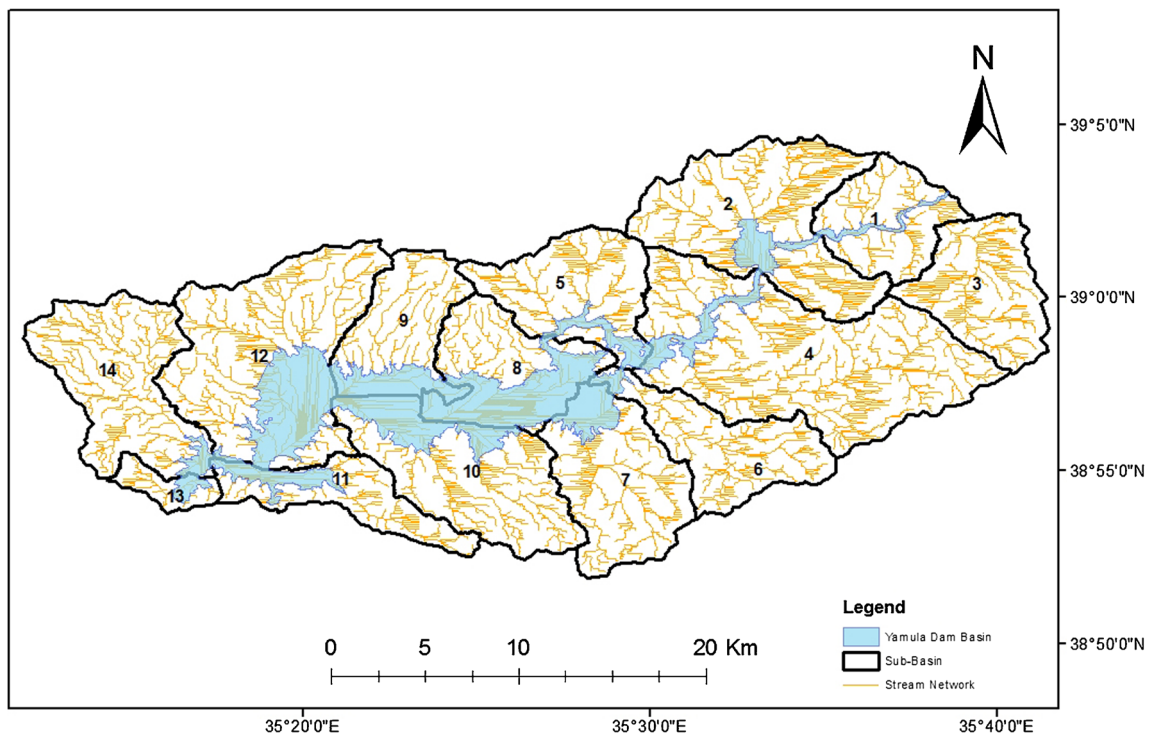


Fig. 4 Sub-basin and stream network in study area

antecedent rainfall values of the study area must be available. The SCS has tabulated the curve number values in line with such data. The CN tables were created for the

American continent. The resource (Şen et al. 2010) was used as a reference to prepare the CN tables in the study area. In the CN method used, the land use capability

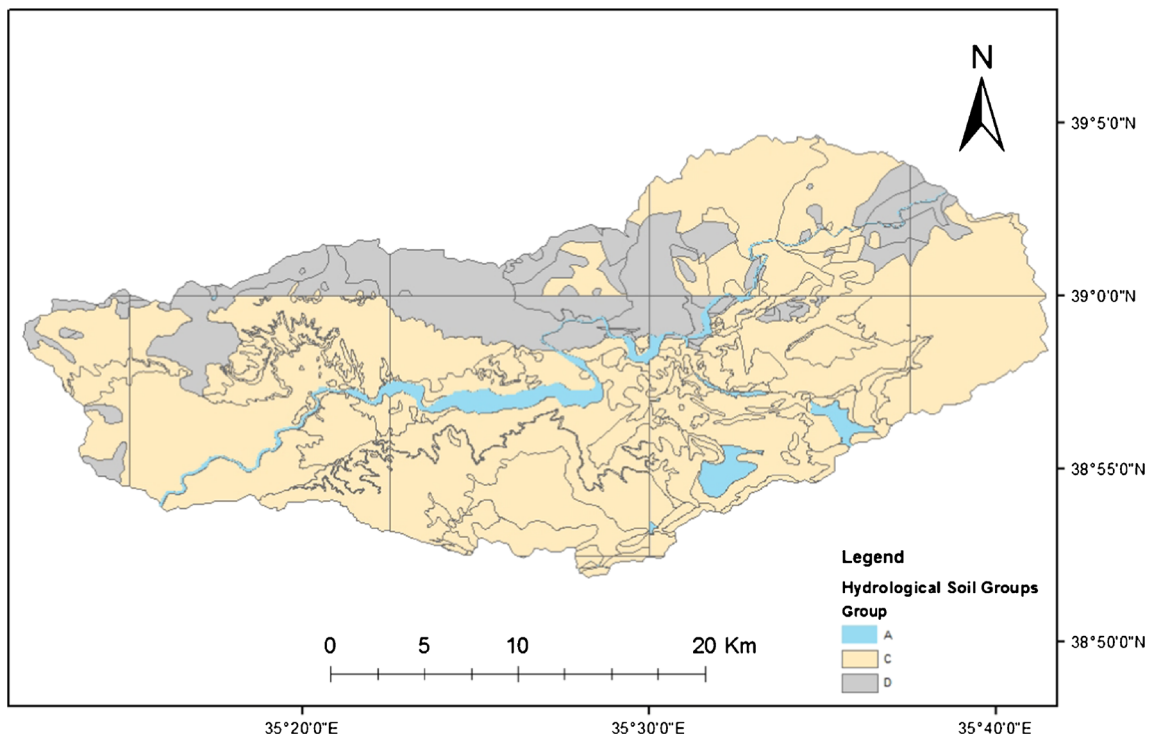


Fig. 5 Hydrological soil groups' map of Yamula Dam basin area

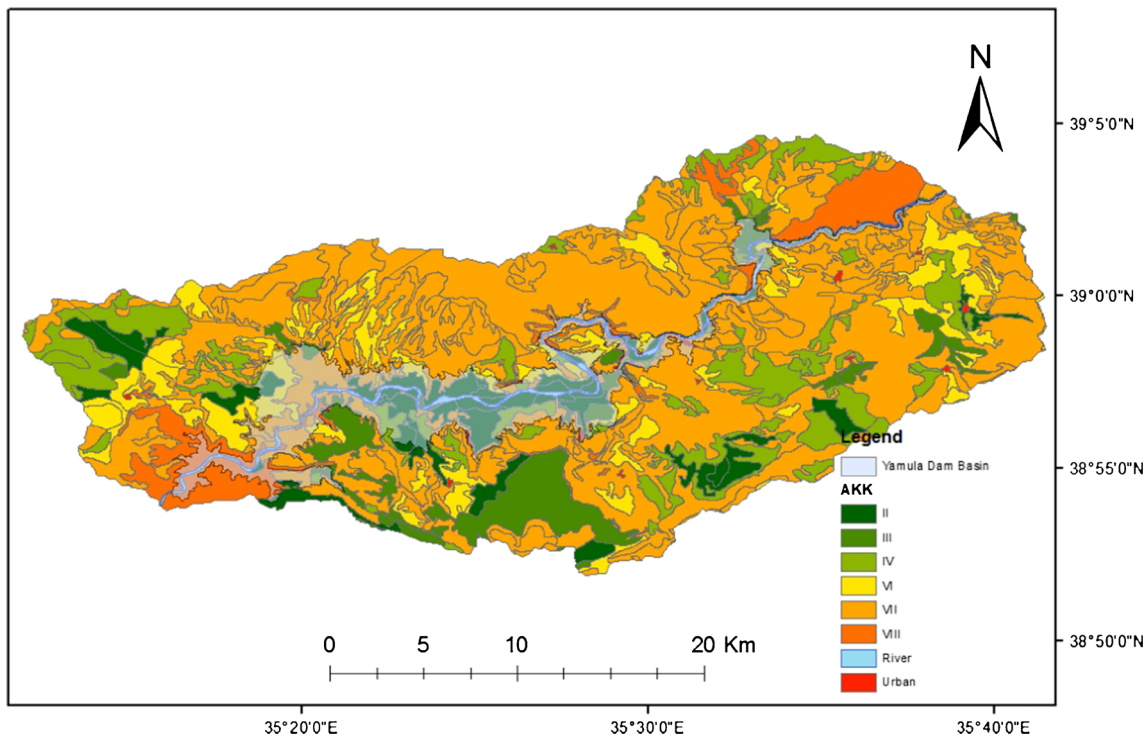


Fig. 6 Land use capability classes map of study area

classes’ map created by considering the inclination classes was used practically, in addition to the land use/land cover map, the hydrologic soil groups’ map, and the antecedent rainfall values. The curve numbers of the catchment area were calculated by utilizing these maps.

The CN calculations were made with the AMC of the soil. The AMC values range from 1 to 3. The classes were determined by considering the 5-day antecedent rainfall.

The rainfall limits for the seasonal AMC classes are as shown in Table 4 in SCS-1972.

The weighted curve numbers based on the sub-basin were calculated from the curve numbers calculated as described above by using Eq. 6.

$$CN(II) = \frac{\sum_{i=1}^n (CN_i * A_i)}{\sum_{i=1}^n A_i} \tag{6}$$

The CNII value was used to calculate the curve number values of the arid and wet seasons. The calculation was made using Eqs. 7 and 8 (Özdemir 2007; Te Chow et al. 1988).

$$CN(I) = \frac{4.2 * CN(II)}{10 - 0.058 * CN(II)}, \sum_{i=1}^5 P_i < 13 \tag{7}$$

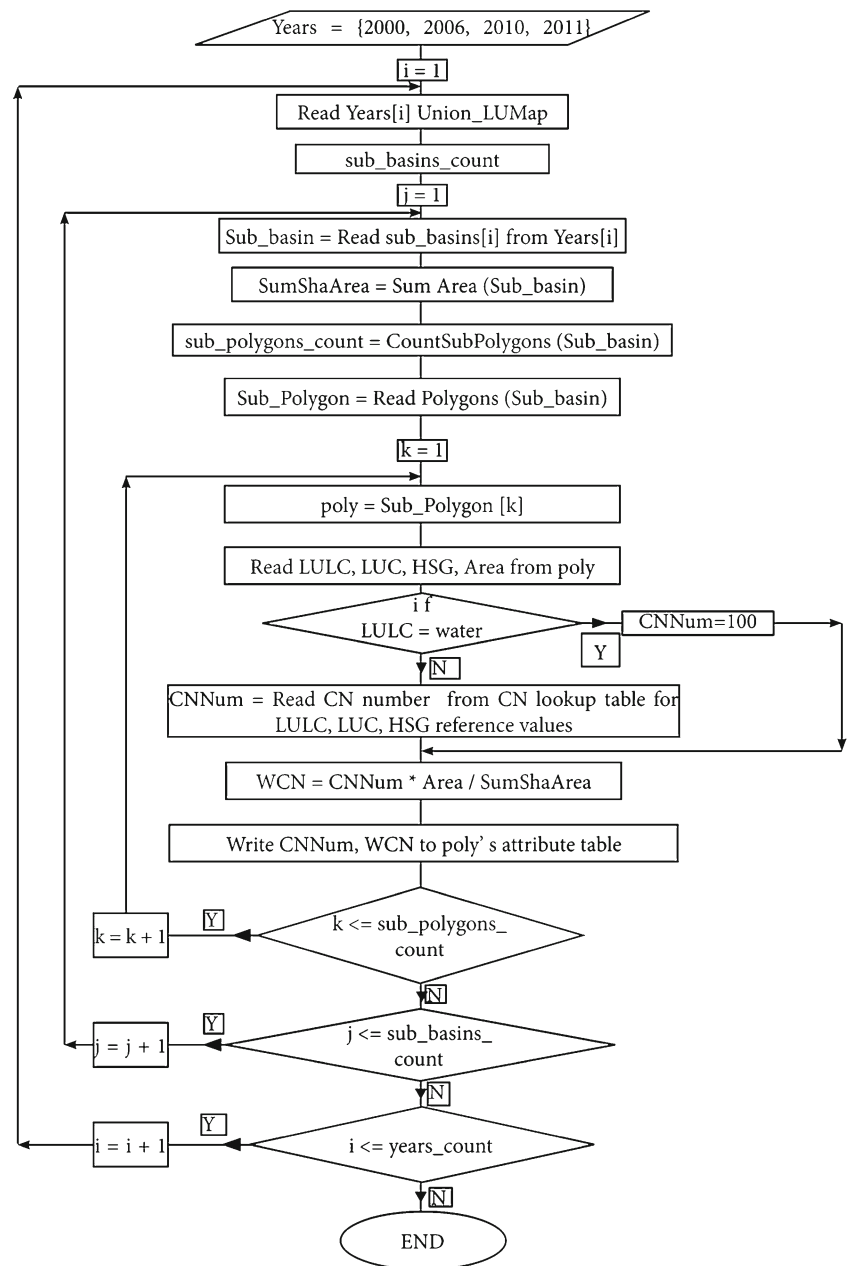
$$CN(III) = \frac{23 * CN(II)}{(10 + 0.13 * CN(II))}, \sum_{i=1}^5 P_i > 23 \tag{8}$$

Results

For the curve number method, the classification images obtained from satellite images were used as the land use/land cover map after having been converted into vector format. The study area was divided into 14 sub-basins (Fig. 4). In order to divide the basin into sub-basins, the river network map was prepared using the digital elevation map of the region. In the river network, every stream channel forms sub-basin area. Considering this river network, the Yamula Dam catchment basin was divided into sub-basins. The curve number values for these sub-basins were calculated separately for each year. The area distribution of the sub-basins is shown in Table 7. For different AMC values, the CNI, CNII, and CNIII values were calculated. According to the daily precipitation data obtained from the Turkish State Meteorological Service for Kayseri province, the months of March–April–May indicate the AMC III (rainy time), July–August–September indicate the AMC I (arid time), and October–November–December indicate the AMC II.

For the curve number calculation, the land use/land cover map (Fig. 3) for the years 2000, 2006, 2010, and 2011, the hydrologic soil groups’ map (Fig. 5), and the land use capability map (Fig. 6) were used. These maps were vector-formatted and had the same coordinate system. They were superimposed on each other in the ArcGIS program. These unified vector-formatted images

Fig. 7 Unified image (land use/land cover in year 2010, land use capability, and hydrological soil groups' maps) of basin area



were subjected to unify analysis (Fig. 7). In this way, four different images were obtained by making the same unify analysis for the years 2000, 2006, 2010, and 2011. The obtained images were clipped in compliance with the boundaries of each sub-basin area and saved in different files, thus determining 14 sub-basins for each year, and by applying the curve number method of these sub-basins, a curve number was assigned for each area. Then, considering the areas of the curve numbers, a weighted curve number was calculated for each sub-basin. Fifty-six different images were obtained, and 56 different weighted curve numbers were calculated for 14 sub-basins and four different years. In order to cope with the emerging heavy

workload, a user interface developed in the Python language in the ArcGIS program was used. The results were obtained by operating the user interface programs developed by using the Python language in the ArcGIS software.

It is easy to run the ArcGIS commands with the Python language. In this way, the ArcGIS commands used in cycles facilitate the processes. The ArcGIS library is imported with the help of the “import arcpy” command.

The script file draws, with the help of the Structured Query Language (SQL) query, the curve numbers in possible conditions from the reference table in the database. It assigns values to the maps we created. Immediately after this value

Fig. 8 Graphic illustrations of estimated curve number for sub-basin areas

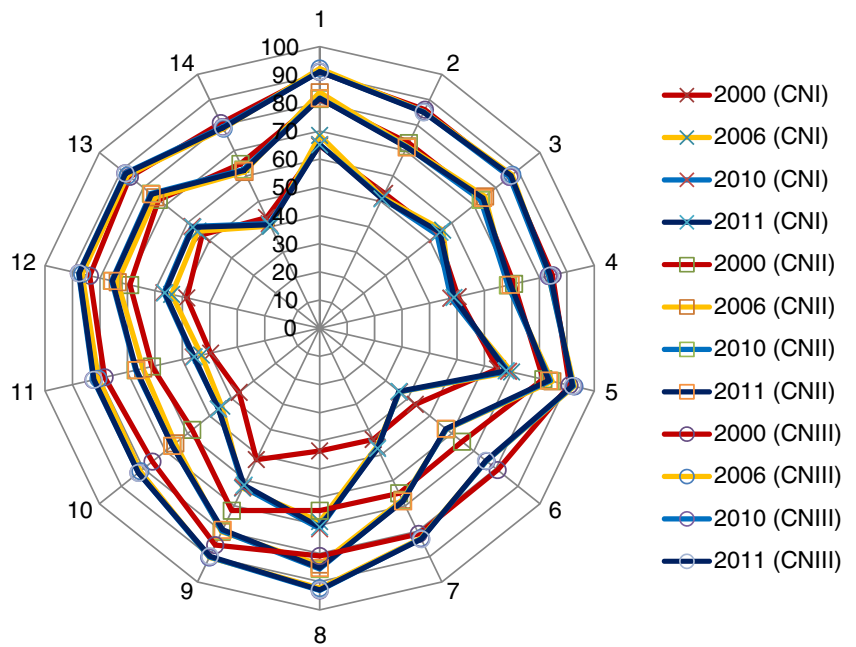


Table 5 Pseudo code of weighted curve number calculation in Python language

```

Procedure SubBasin Division:
  For Read Year
    Repeat Number of SubBasin
      Select Each SubBasin Area
      Clip selected watershed polygon area and save with SubBasin_number
      Calculate Curve Number and weighted Curve Number for SubBasin Area
      (procedure AssignCurveNumber)
    End for
Procedure AssignCurveNumber
  Read Feature class (FC)
  Open the layers in the geodatabase feature class involved in Arcpy library
  Read layer's attribute table and convert Python array (PyArray)
  Calculate sum PyArray's ShapeArea
  Open FC with update cursor in Arcpy library
  For Each sub_polygon
    Read Land Use Land Cover (LULC), Land Use Capability(LUC),
    Hydrological Soil Group (HSG) values
    CalcSCS-CN (LULC, LUC, HSG)
    Assign SCS-CN (subPolygon) with Update cursor
    WSCS-CN = SCS-CN*ShapeArea(subPolygon)/SumArea
    Assign WSCS-CN with Update cursor
  End for
  Add CSV format (year, SubBasin, Polygon Number, LULC, LUC, HSG, Area, CN, WSCS-
  CN)
Procedure CalcSCS_CN (LULC, LUC, HSG)
  If LULC=Water CNum=100
  Else CN=lookup CNVal(LULC, LUC, HSG)
  Return CN
    
```

Table 6 Estimated curve numbers of sub-basin areas

Sub-basin number	2000			2006			2010			2011		
	CNI	CNII	CNIII	CNI	CNII	CNIII	CNI	CNII	CNIII	CNI	CNII	CNIII
1	64.77	81.4	90.97	68.47	83.79	92.24	65.24	81.71	91.13	65.14	81.65	91.1
2	53.13	72.97	86.13	51.51	71.67	85.33	51.24	71.45	85.2	50.99	71.24	85.07
3	53.54	73.29	86.32	55.87	75.09	87.4	53.31	73.1	86.21	54.68	74.18	86.85
4	50.42	70.77	84.78	47.82	68.57	83.39	47.78	68.54	83.37	48.92	69.51	83.99
5	64.78	81.41	90.97	69.92	84.69	92.72	68.78	83.99	92.35	67.95	83.47	92.07
6	43.4	64.61	80.77	36.27	57.54	75.71	36.22	57.49	75.67	35.98	57.23	75.47
7	43.85	65.03	81.05	46.74	67.63	82.78	47.15	67.99	83.01	47.43	68.24	83.17
8	43.57	64.77	80.87	68.66	83.91	92.31	71.21	85.48	93.12	70.61	85.12	92.94
9	51.79	71.89	85.47	63.06	80.25	90.34	62.61	79.95	90.17	61.85	79.42	89.88
10	36.56	57.84	75.94	44.44	65.57	81.41	45.92	66.9	82.3	45.98	66.96	82.34
11	39.71	61.06	78.29	43.07	64.3	80.55	46.07	67.04	82.39	45.71	66.72	82.18
12	48.38	69.06	83.69	53.9	73.57	86.49	56.7	75.71	87.76	56.37	75.46	87.61
13	53.28	73.08	86.2	55.26	74.63	87.12	57.94	76.64	88.3	57.53	76.33	88.12
14	43.56	64.76	80.87	40.23	61.58	78.66	41.21	62.53	79.33	40.77	62.1	79.03

CNI CN for AMC I (dry season), CNII CN for AMC II, CNIII CN for AMC III (wet season)

Table 7 Area distributions of sub-basins

Sub-basin number	2000					2006					2010
	Water area	Cropland	Barren land	Settlement	Grassland	Water area	Cropland	Barren land	Settlement	Grassland	Water area
1	64.64	303.23	1311.22	0.00	1028.61	85.42	187.34	923.45	0.00	1511.48	149.40
2	52.75	1532.17	1687.85	0.00	2589.69	281.83	2031.20	1739.52	0.00	1809.92	413.24
3	0.00	811.93	542.70	0.00	1943.16	0.00	582.44	507.98	0.00	2207.38	0.00
4	81.71	1944.17	3592.60	8.43	3670.88	305.89	3106.92	3533.54	18.59	2332.84	465.05
5	58.37	464.19	2250.68	11.02	755.78	261.43	314.06	1833.72	4.73	1126.11	351.20
6	5.10	514.54	1464.39	5.21	1279.26	66.00	2169.78	695.55	5.41	331.77	110.21
7	18.89	1154.89	1806.63	3.17	1231.31	386.88	1978.62	910.82	17.90	920.67	510.82
8	127.95	1291.86	1670.18	8.56	359.40	1451.09	574.70	1226.61	8.08	197.46	1656.35
9	33.35	809.01	1808.22	0.00	384.18	540.78	652.69	1195.52	0.00	645.77	683.43
10	34.52	2461.33	1891.32	10.75	547.54	749.86	2455.39	855.88	10.15	874.20	1019.69
11	24.36	1104.97	1117.02	0.00	133.33	274.20	1439.89	417.73	0.00	247.86	434.23
12	60.42	2062.68	4893.55	0.00	410.56	1099.25	2823.53	2815.01	0.00	689.42	1613.58
13	40.71	41.95	625.48	0.00	1.92	95.78	223.63	341.55	0.00	49.11	127.94
14	6.78	1719.07	1928.95	7.87	966.36	119.24	3183.25	1087.20	18.32	221.02	165.43
Sum	609.55	16216.00	26590.77	55.01	15302.00	5717.63	21723.44	18084.06	83.17	13165.02	7700.59

Sub-basin number	2010				2011				Sum	
	Cropland	Barren land	Settlement	Grassland	Water area	Cropland	Barren land	Settlement		Grassland
1	693.78	727.81	0.00	1136.72	150.03	402.63	1254.08	0.00	900.95	2707.70
2	2840.84	896.34	17.59	1694.45	399.38	2217.62	1856.72	8.05	1380.70	5862.46
3	1095.43	192.19	0.00	2010.18	0.00	715.82	506.95	0.00	2075.03	3297.80
4	3858.92	2667.39	30.85	2275.56	457.06	2986.17	3404.28	16.57	2433.70	9297.78
5	562.64	1819.52	3.23	803.45	351.46	508.27	2105.06	6.26	569.00	3540.04
6	1994.42	997.34	7.09	159.44	108.94	1917.41	1142.73	6.25	93.17	3268.51
7	2015.17	921.86	37.47	729.58	494.21	1585.89	1429.14	58.62	647.04	4214.89
8	588.96	1125.67	0.00	86.96	1645.35	619.00	1143.40	0.00	50.18	3457.94
9	993.24	1057.22	0.00	300.87	683.81	905.65	1284.54	0.00	160.77	3034.76
10	2433.64	909.40	5.99	576.75	992.16	2125.31	1277.24	31.96	518.81	4945.47
11	1179.07	556.83	2.04	207.51	418.08	1011.79	825.03	0.00	124.78	2379.68
12	2559.51	2934.42	0.00	319.70	1574.00	2229.64	3501.18	0.00	122.40	7427.20
13	72.51	489.72	0.00	19.90	127.92	104.44	471.65	0.00	6.06	710.07
14	2675.29	1546.20	9.07	233.03	168.70	2585.99	1824.55	11.64	38.13	4629.02
Sum	23563.41	16841.90	113.33	10554.10	7571.09	19915.62	22026.55	139.35	9120.71	58773.33

Unit of the areas is hectare

assignment, it can also calculate the weighted curve numbers (Fig. 8 and Table 5). In such types of applications which involve detailed processes, the Python language assists users. Combined use of the Python language and SQL query accelerated the processes significantly.

The obtained results are shown in Table 6. Table 7 gives the area distribution of the sub-basins. When the change in the total weighted curve numbers between the years is examined, it is observed that the curve numbers have increased in the some sub-basins.

Conclusions

Runoff value is important data for hydrologic cycle. In this study, the remote sensing and GIS techniques and the SCS-CN technique were applied to the Yamula Dam catchment basin. By the analysis of meteorological, soil type, land inclination, and remotely sensed data, with the GIS techniques, changes of the region were examined. In the study area, data can be obtained quickly and cheaply with the integration of remote sensing satellite images and GIS techniques. By the use of Python language in GIS, data can be analyzed functionally and fast. SCS-CN method can estimate runoff outdated values belonging to ungauged stations in minimum time.

The results of this study show the important role of urban sprawl and significant change of land use regime in the increase of runoff rate within a catchment basin area. Therefore, the remotely sensed data with the aid of a GIS can provide valuable data for studies on land use changes. Also, the results of this study show that the incorporation of GIS and remote sensing data in hydrological models can effectively support decision making in the areas of risk and sustainable development.

As shown in Tables 6 and 7, when the change in the total weighted curve numbers between the years is examined, it is observed that the curve numbers have increased in the sub-basins numbered 7, 8, 9, 10, 11, 12, and 13 where the water body has increased greatly. This increase is a result of the filling of the land use/land cover areas, which are used differently with water. In terms of area, the water area in sub-basin 8 in particular rose from 128 to 1451 ha. This high rise in the water body raised the curve number from 65 to 84. This change indicates an increase in the runoff and a decrease in the amount of water retained by the soil. In other words, most of the rainfall turned into runoff.

The classification results indicated that the basin underwent vast land use changes between the years 2000 to 2011. In the sub-basins numbered 2, 4, 6, and 14, the higher increase in the agricultural fields in proportion to the rise in the total water area plus the decrease in the arid soil areas led to a decrease in the curve number between the years 2000 to 2010. The increase in cropland reduced the curve number, while the

increase in the water areas and decrease in barren soil areas in the sub-basin increased the curve number value. By increasing the water retention capacity of the soil through changes in the land use/land cover, the loss of rainfall as surface runoff will be prevented, and it will be ensured that the underground waters are fed. The SCS-CN method is a convenient method to understand and display such relations. The method will provide a better understanding of the main reasons for the effects and will support city administrators in similar projects.

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