



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2024; SP-7(8): 322-331

Received: 15-05-2024

Accepted: 18-06-2024

More Ram M

Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Bhuibhar BW

Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Khodke UM

Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Pendke MS

Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Ingle VK

Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Jadhav MG

Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Corresponding Author:

More Ram M

Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Estimation of surface runoff using SCS–CN and GIS approach in the Karpara watershed, Maharashtra, India

More Ram M, Bhuibhar BW, Khodke UM, Pendke MS, Ingle VK and Jadhav MG

DOI: <https://doi.org/10.33545/2618060X.2024.v7.i8Se.1265>

Abstract

Water and land are the most crucial natural resources on Earth and require scientific management for sustainable development, particularly in the agricultural sector. In arid and semi-arid regions, the competition for shared land and water resources among sectors such as agriculture, industry, and domestic use underscores their importance. Water scarcity is already a pressing issue, and climate change projections indicate that it will become even more critical in the future. Therefore, there is an urgent need for sustainable water management, and the application of emerging tools and technologies is crucial for achieving this in watersheds everywhere. Maharashtra is one of the major states in the country in terms of natural resources like rainfall, soil but it may soon become state facing increasing water crisis with perennial water shortage. The Karpara watershed was divided in to 19 sub watersheds. The SRTM DEM and satellite imagery downloaded from USGS Earth Explorer was the basic input used to delineate the watershed, slope map and drainage map of the study area in Q GIS environment. The runoff of the Karpara area was determined by using SCS-Curve number method along with GIS. The curve number obtained by overlaying the land use/ land cover and soil map of the study area from which runoff was calculated. The runoff was found as maximum in 2005 which was 24% and minimum in 2015 about 15% of the average rainfall. The calculated sub watershed wise runoff was found highest in sub watershed 19.

Keywords: GIS, SCS-CN, runoff, land use land cover, DEM

Introduction

The watershed is an ideal unit for analysing the development and management of natural resources, where different entities such as soil, water, geomorphology, and land use interact harmoniously, allowing for a holistic approach to problem-solving. The three basic resources of soil, vegetation, and water must be managed collectively and interestedly for sustainable watershed management. The productive interaction between these natural resources is determined by various factors such as the physiography of the land, slope and nature of soil cover, land use, land cover, hydrology, geomorphology, climate, socio-economic and legal aspects, and the hydrological characteristics of the land area. (Suhas P Wani and Kaushal K Garg, 2009) ^[26].

India receives an average annual rainfall of 119.4 cm and is home to about 4% of the world's fresh water. Despite occupying only 3.29 million km² of land, which is 2.4% of the world's land area, India supports over 15% of the world's population. With 1/6th of the world's population, 1/50th of the world's land, and 1/25th of the world's water resources, India has a significant impact globally. Additionally, India has a livestock population of 500 million, accounting for approximately 2% of the world's total livestock. Cattle, in particular, play a crucial role in Indian agriculture. The country's total utilizable water resources are estimated at 1086 km³ (Hutti, B., & Nijagunappa, R. 2011) ^[12].

Maharashtra is one of the major states in the country in terms of natural resources like rainfall, soil but it may soon become state facing increasing water crisis with perennial water shortage.

The agricultural land under irrigation is divided into two main categories: groundwater irrigated and flow/canal irrigated. Groundwater irrigation covers 28.75 lakh hectares (71%) of the total area, while flow or canal irrigation covers 11.83 lakh hectares (29%). A large portion of the groundwater, 85%, is utilized for irrigation, with 10% being used by industries and only 5% allocated for domestic consumption. Additionally, approximately 80% of the rural population relies on groundwater for their drinking water needs (CGWB, 2013) [6].

In Marathwada region, Parbhani is one of the district where groundwater occurrence and movement in the area is influenced by its rock formation. Parbhani district is underlain by basaltic lava flows and alluvium only. The average annual rainfall is about 900 mm which is unevenly distributed all over district. About 84% of the annual rainfall in the district is received during the South-West monsoon season for the month of June to September (Rawat, A., Kumar, P., & Deoli, V. 2019) [19].

Runoff is the most important hydrologic variables used in most of the resource applications. Reliable prediction of quantity and rate of runoff from land surface into stream and river is difficult and time consuming to obtain for ungauged watershed. However, this information is needed in dealing with many watershed development and management problems. Conventional methods for prediction of river discharge require considerable hydrological and meteorological data. Collection of these data is expensive time consuming and difficult process (Ramana, G. V. 2014) [18].

In our country, the availability of accurate information on runoff is scarcely available and that too in a few selected sites where recording and automatic hydrological gauging stations are installed. Thus, there is an urgent need to generate information on basin runoff and sediment yield for acceleration of the watershed development and management programs. In India most of the agricultural watersheds are ungauged having no past record what so ever of rainfall-runoff processes. Non availability of continuous rainfall and runoff record in majority of Indian watershed has led to the development of techniques for estimation of surface runoff from ungauged basins (Patil, J. P., Sarangi, A., Singh, A. K., & Ahmad, T. 2008) [16].

Quickening of the watershed management programme for conservation and development of natural resources management has necessitated the runoff information runoff estimation from

Remote Sensing data so as to provide quick result for decision makers, before any experimentation of quantification is taken up (Sandhya Rani, B. H. (2004) [24]. This is a less time-consuming method and also gives a reliable result. Advances in computational power and the growing availability of spatial data have made it possible to accurately predict the runoff. The possibility of rapidly combining data of different types in geographical information system (GIS) has lead to significant increase in its use in hydrological applications (Gupta, P. K., Panigrahy, S., & Parihar, J. S. 2011) [10]. Out of several methods for runoff estimation from ungauged watershed, the curve number (CN) is an index developed by the Natural Resource Conservation Service (NRCS) to represent the potential for storm water runoff within a drainage area. The curve number method (SCS 1972) [24] also known as hydrologic soil cover Complex method is a versatile and widely used procedure for runoff estimation. The CN for drainage basin is estimated using a combination of land use, soil permeability and the antecedent soil moisture condition (AMC). In the present study the runoff from SCS (soil conservation services) curve number method modified for Indian conditions is used to determine runoff volume with aid of remote sensing and GIS techniques (Ayushi Trivedi and Manoj Kumar Awasthi, 2021) [3].

Materials and Methods

The methodology adopted in achieving the set of objectives, the location, its characteristics, features and other relevant components of the study. The adopted methodology of the present study is shown in Figure 2.

Description of Study Area

Location

The Karpura watershed is part of Godawari-Purna sub basin, located between 76° 44' to 76° 64' E and 19° 48' to 19° 73' N as shown in fig 1. The Karpura reservoir is constructed on river Karpura in the year 1974 by Government of Maharashtra. The height of the dam above lowest foundation is 16.66 m while the length is 1,046 m. The gross storage capacity of Karpura reservoir is 1.08 TMC. Reservoir is located at village Niwali. Average annual rainfall of study area is about 780 mm and the catchment area is about 26932.59 ha (Parbhani NIC).

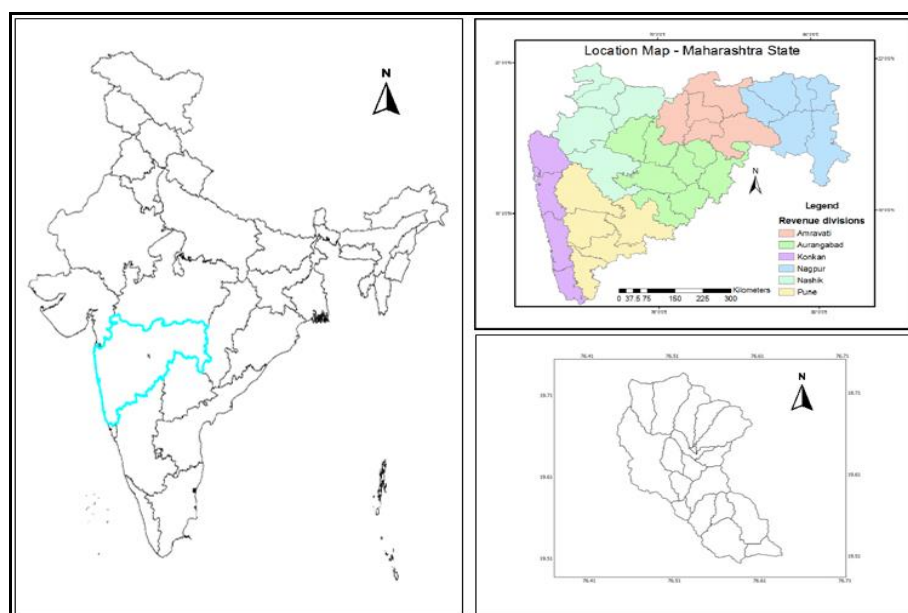


Fig 1: Location map of Karpura watershed

Data Collection

The distinct information and data required for the present study were procured from different sources and then imported into the GIS environment. The ensuing section gives a brief review of data collection and GIS software.

- SRTM Digital Elevation Model was obtained from USGS Earth Explorer.
- The Landsat-8 satellite imagery was procured from USGS Earth Explorer for the study area dated 19 December 2020.
- Rainfall data was obtained from Indian Meteorological Data as a grid data from 1991 to 2020.
- Soil texture map obtained from FAO world soil map of scale 1:50000.

Software used: Q GIS and Arc GIS

Delineation of Watershed

In GIS based digital delineation of watershed, one grid data matrices are required. These are elevation, flow direction, flow accumulation and stream link grids, of which the elevation grid is the primary input-data matrix, which leads to the generation of the remaining three secondary and data matrices. The elevation grid represents the topography while other represents the drainage of an area. The elevation grid is represented by means

of a Digital Elevation Model (DEM), which is a representation of the surface terrain consisting of a rectangular mesh of elevation points laid out over the landscape (Arbind K. Verma 2017). A 30 m resolution Digital elevation Model was obtained from USGS earth explorer and then Q GIS 3.32 software used for further demarcation of drainage line network and generation of various thematic layers.

Surface Runoff Estimation

The integration of GIS and Soil Conservation Service- Curve Number Method is used to estimate the surface runoff. The Soil Conservation Service Curve Number (SCS-CN) method is widely used in determination of direct surface run-off in long-term (continuous) hydrologic simulation models (Mishra SK, 2011). In this approach, GIS is used to create a spatial database that represents hydrologic characteristics of the watershed. Base map, land use and soil coverage's of the study area are created using GIS. The appropriate area-weighted curve number for the study area is computed using overlaying tool of GIS. Then the daily rainfall database is incorporated in the analysis to estimate the direct runoff. The result obtained is useful for watershed management and irrigation scheduling of the study area. The details flow chart for estimation surface runoff as shown in fig 2.

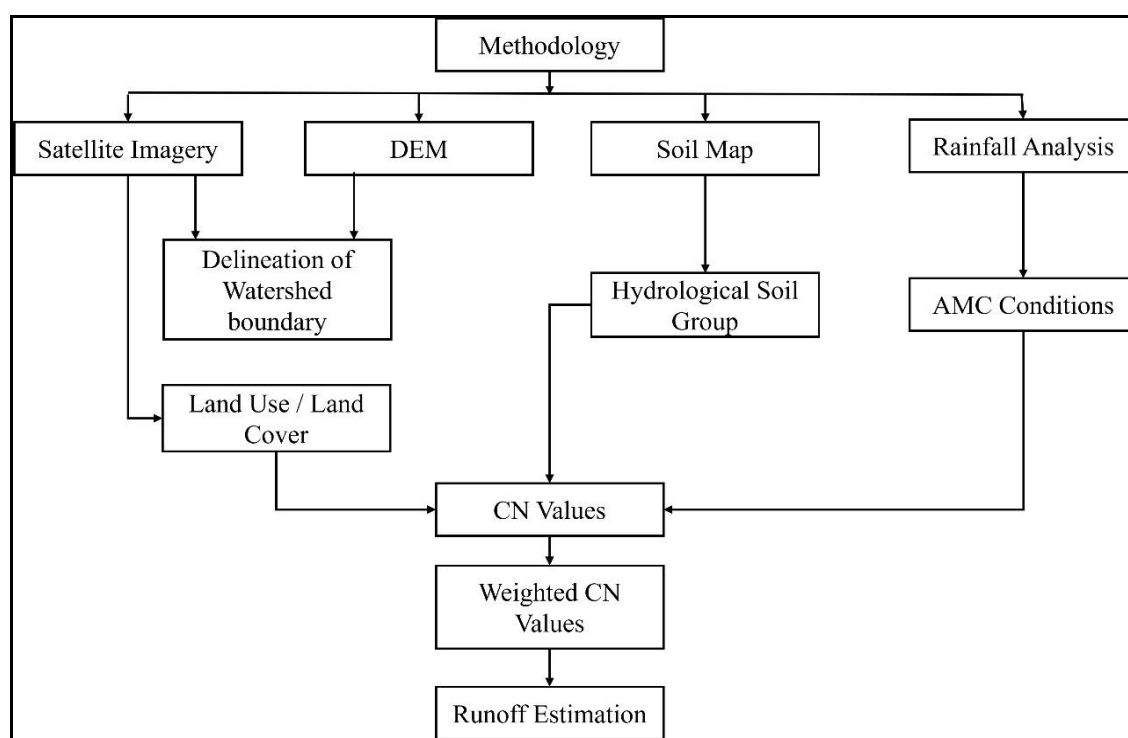


Fig 2: Methodology for estimation of runoff

Thematic maps

In order to study runoff and site suitability different thematic maps such as Elevation map, Slope map, Soil map, Geomorphology and Land use/ Land cover map were prepared in Q GIS 3.32.

Drainage map

The potential availability of water for harvesting depends on drainage network of the study area. Drainage network was derived by using Arc GIS and the watershed delineation has been done. The DEM had undergone different operations fill sinks, flow direction, flow accumulation.

Slope map

Slope influences recharge and infiltration, hence the amount of runoff that is expected from the terrain. Suitability of different water harvesting options highly depends on the slope of a given area. Input DEM used for deriving slope map after the delineation of watershed.

Land use/ Land cover map

Land use/ Land cover is the main representative factor in identifying runoff potential zones. The land use land cover map was prepared in Q-GIS environment for the analysis. supervised classification of the map was done to obtain different land cover

classes for each sub watershed which includes agriculture land, fallow land, scrub land, water body etc.

Soil map

Soil texture was an important factor in determining infiltration rate of soil that which decides the runoff potential of soil and the suitability of structures. Soil map obtained from FAO world soil map of scale 1:50000 were used in Q-GIS to get the soil map of

the study area.

Hydrological soil group

Hydrologic soil group for Indian conditions are divided into four classes i.e. HSG-I (A), HSG-II (B), HSG-III (C) and HSG-IV (D). Different HGS classes were demarcated by assigning number to each class and thematic map was prepared using Q GIS (USDA, SCS 1972)^[24].

Table 1: Hydrologic soil group and corresponding soil texture

Hydrologic soil group	Runoff Description	Soil Texture
A	Low runoff potential because of high infiltration rates	Sand, loamy sand and sandy loam
B	Moderately infiltration rates leading to moderately runoff potential	Silty loam and loam
C	High/moderate runoff potential because of slow infiltration rates	Sandy clay loam
D	High runoff potential with very low infiltration rates	Clay loam, silty clay loam, sandy clay, silty clay and clay

Source: (USDA, SCS 1972)^[24].

SCS-CN method

SCS-CN method developed by Soil Conservation Services (SCS) of USA in 1969 is a simple, predictable and stable conceptual method for estimation of direct runoff depth based on storm rainfall depth. It is a versatile and widely used procedure for runoff estimation. The SCS approach involves the use of simple empirical formulas and readily available tables and curves, developed by the Soil Conservation Service (SCS, 1985). The SCS runoff expressed in unit depth spread over the watershed for Indian conditions is given by

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \dots\dots 1$$

$$CN = \frac{25400}{(254 + S)} \dots\dots 2$$

Where,

Q direct flow volume expressed as a depth,

P total rainfall

S potential maximum soil retention,

CN curve number value used to estimate potential maximum soil retention (S)

The potential maximum soil retention estimation, the initial abstractions (IA) was calculated. Initial abstractions are water losses, e.g. plant interception ns, infiltration and surface storage which occur prior to runoff and are then subtracted from the total runoff (USDA-SCS 1985). The standard assumption is that IA = 0.2S

Antecedent moisture condition (AMC)

The antecedent moisture condition refers to the water content present in the soil at a given time. It is determined by total rainfall in 5-day period preceding a rainfall event (SCS, 1986)^[25]. There are three antecedent soil-moisture conditions (I, II & III) according to different soil conditions and rainfall limits for dormant and growing seasons

AMC-I: Indicates the lowest runoff potential because the soils are dry enough

AMC-II: Indicates the average soil moisture condition

AMC-III: Indicates highest runoff potential of the soil, which practically happens when areas of watershed are saturated from antecedent rains.

Table 2: Classification of antecedent moisture conditions (SCS, 1986)^[25]

Antecedent moisture condition	Dormant season	Growing season	Runoff Potential
AMC – I	< 12.7 mm	< 35.6 mm	Lowest runoff potential
AMC – II	12.7 – 27.9 mm	35.6-53.3 mm	Moderate runoff potential
AMC – III	> 27.9 mm	> 53.3 mm	Highest runoff potential

These values are applied only to AMC-II and in order to derive curve number values for AMC-I and III. If the antecedent moisture condition is I (dry), the curve number Adjustment based on Hawkins *et al.*, 1981^[11] as follows

For AMC I

$$CN_i = \frac{CN_{ii}}{2.281 - 0.01281 \times CN_{ii}} \dots\dots 3$$

If the antecedent moisture condition is III (wet), the curve number adjusted using Hawkins *et al.*, 1981^[11]

For AMC III

$$CN_{iii} = \frac{CN_{ii}}{0.42 + 0.0573 \times CN_{ii}} \dots\dots 4$$

Results and Discussion

SCS-CN method were used for surface runoff potential for of the Karpara watershed of the Godawari-Purna basin. The results of the study of sub-watersheds have been described in this chapter.

Delineation of Karpara Watershed and Sub-watersheds

The extraction of drainage networks and demarcation of the all sub-watersheds boundary were completed with Q GIS 3.32 coupled with tools using ASTER (DEM). The following DEM processing methods (fill sinks, flow accumulation, flow direction, stream definition, stream segmentation, and catchment grid delineation) were carried out to extract the drainage network and demarcate the sub-watershed's boundary as shown in fig. 1. The Karpara river basin is divided into nineteen sub-watersheds. The Karpara River catchment's drainage network and sub-watershed boundaries are shown in fig. 4 & 5.

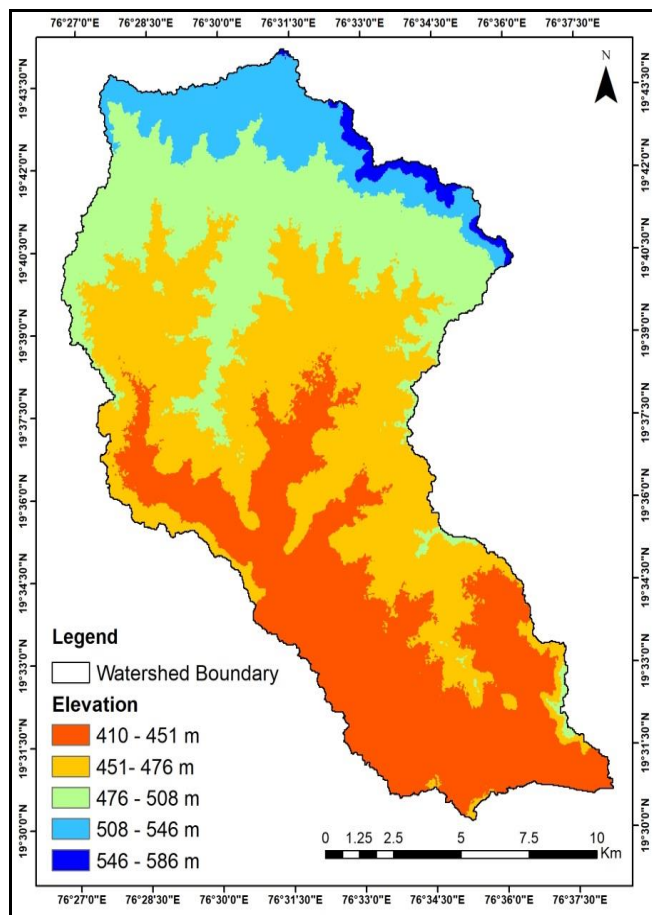


Fig 3: Digital Elevation Model

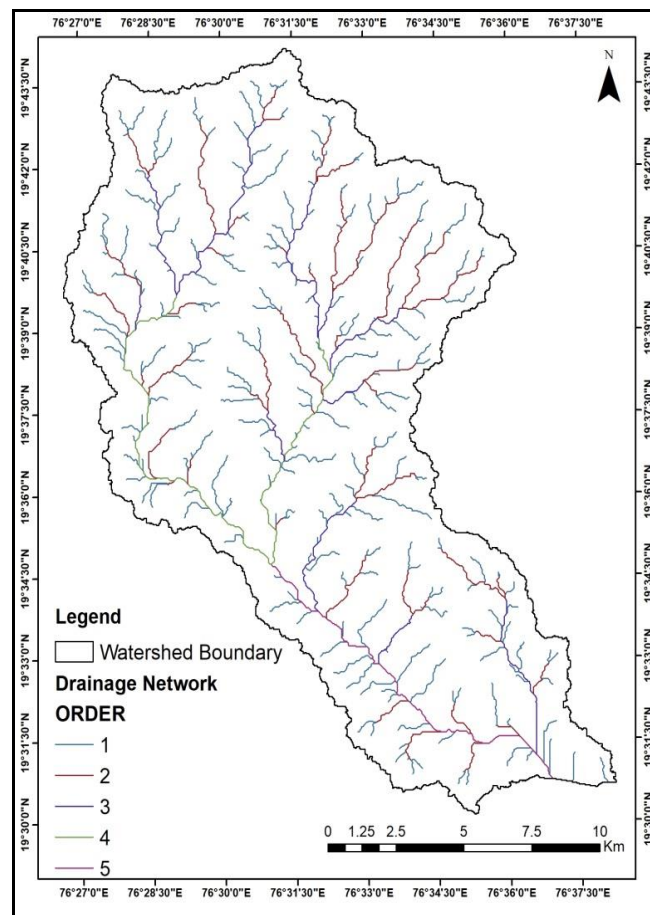


Fig 5: Drainage Network Map of Karpara watershed

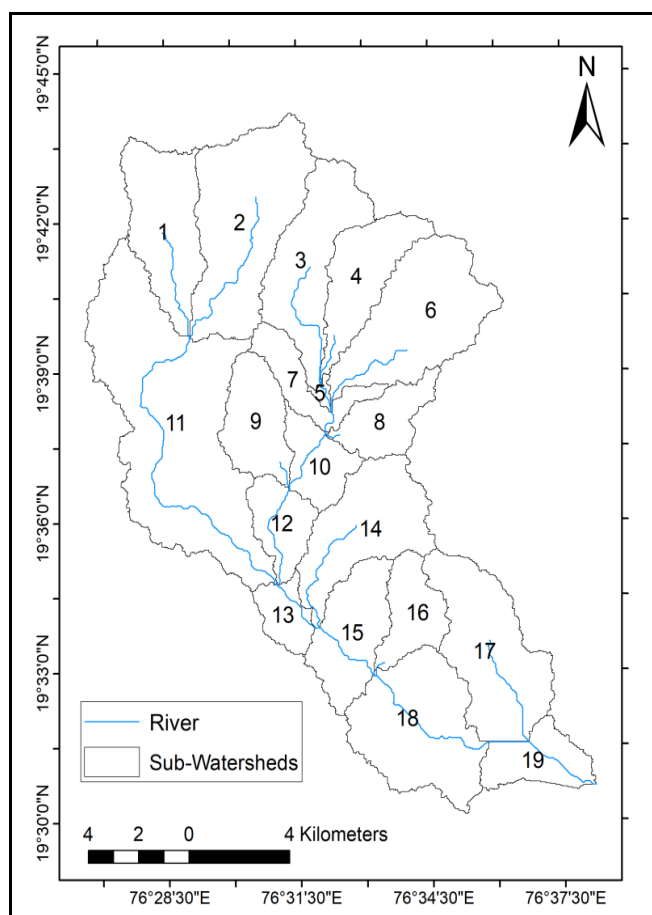


Fig 4: Delineation of Karpara Watershed and Sub-watersheds

Table 3: Area of sub watersheds of Karpara basin

Sr. No.	Sub Watershed	Area (ha)
1	SW - 1	1568.97
2	SW - 2	2634.12
3	SW - 3	1701.27
4	SW - 4	1163.88
5	SW - 5	58.5
6	SW - 6	2190.06
7	SW - 7	647.37
8	SW - 8	747.27
9	SW - 9	986.49
10	SW - 10	678.42
11	SW - 11	4734.36
12	SW - 12	682.83
13	SW - 13	451.62
14	SW - 14	1706.85
15	SW - 15	1220.13
16	SW - 16	762.57
17	SW - 17	2061.54
18	SW - 18	2185.29
19	SW - 19	751.05
Total Area of Karpara Watershed		26932.59

The Karpara watershed was sub divided into 19 sub watersheds based on the drainage pattern and shown in fig. 5. The area of each sub watershed is shown in Table 3. Among the sub watershed the lowest area (58.5 ha) in Karpara watershed was found to be for sub-watershed no 5 and the largest area (2634.12 ha) was found to be of sub-watershed No 2. The total geographical area of Karpara watershed was measured as 26932.59 ha.

Land use / Land cover map

The land use and land cover of a particular area have a substantial impact on the drainage patterns of a watershed. The differences in land coverage can significantly influence the susceptibility of erosion in micro watersheds. Additionally, variations in vegetal cover can strongly affect soil moisture, infiltration, evapotranspiration, and the interception process of watersheds (Choudhary *et al.*, 1996; Rashid and Romshoo 2012) [7, 20]. Impervious land, whether naturally occurring or due to human settlement, contributes to increased runoff by obstructing the infiltration process (Dams *et al.*, 2013) [8]. It also plays a vital role in shaping the drainage pattern within the watershed (Fohrer *et al.*, 2001) [9]. A higher percentage of plant cover and a large amount of root biomass are effective in slowing erosion rates (Badar *et al.*, 2013) [4]. Furthermore, tree canopies and foliage from smaller plants intercept rainwater, aiding in erosion prevention (Mustard and Sunshine 1999; Romshoo *et al.*, 2012) [14, 20]. The classification of land use and land cover (LULC) was carried out based on the understanding that identified classes in the study area strongly influence runoff and soil erosion. The resulting classes were agriculture, barren land, built up area and waterbody as shown in fig 6.

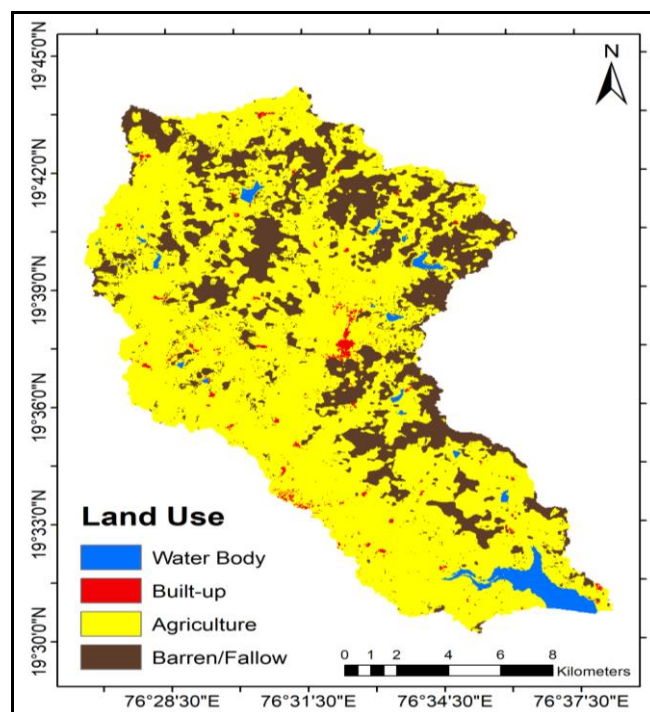


Fig 6: Land use details in Karpara watershed

Table 4: Land use land cover classification of the Karpara sub-watershed

Sr. No.	Lu / LC	Area (Ha)	Percentage Area
1	Water Bodies	634.5	2.4
2	URHD	299.88	1.2
3	Agricultural Land	19589.6	73
4	Barren Land	6408.63	24

Land use pattern indicate that majority of the area i.e. 73% is under agricultural cropped land and 24% area in under fallow land. Urban and rural housing development area in the watershed recorded as 1.2 per cent. The water submergence area in watershed is about 2.4% as presented in fig 7.

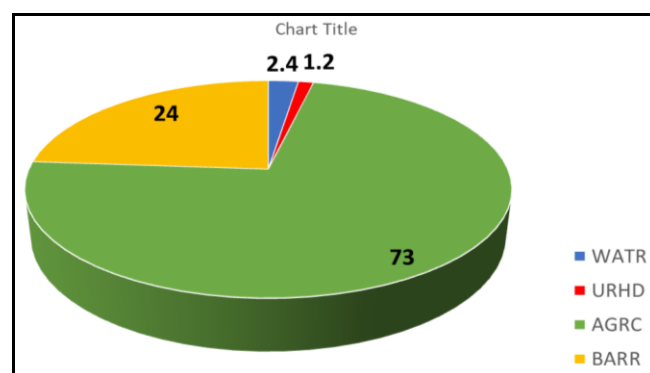


Fig 7: Pi chart of land use land cover

Table 5: Land use land cover statistics of Karpara sub watersheds

Sub watershed	Waterbody (ha)	URHD (ha)	Agriculture land (ha)	Barren land (ha)	Total Area (ha)	CN
SW - 1	0.63	7.29	1051.2	509.85	1568.97	78.67
SW - 2	39.96	18.18	1827.18	748.8	2634.12	78.64
SW - 3	0.63	5.49	1045.89	649.26	1701.27	79.27
SW - 4	11.43	6.57	637.2	508.68	1163.88	80.16
SW - 5	0.09	3.69	54.72	0	58.5	76.24
SW - 6	46.08	9.63	1186.02	948.33	2190.06	80.37
SW - 7	1.98	19.71	495.81	129.87	647.37	77.86
SW - 8	15.12	20.97	478.89	232.29	747.27	79.46
SW - 9	0.27	12.24	792	181.98	986.49	77.27
SW - 10	0	42.75	474.03	161.64	678.42	78.82
SW - 11	31.14	50.94	4071.15	581.13	4734.36	76.72
SW - 12	0	10.26	632.97	39.6	682.83	75.92
SW - 13	0	31.32	415.44	4.86	451.62	76.44
SW - 14	16.65	8.01	1013.76	668.43	1706.85	79.64
SW - 15	0	13.5	959.85	246.78	1220.13	77.44
SW - 16	0	4.77	608.04	149.76	762.57	77.28
SW - 17	125.64	9.09	1441.08	485.73	2061.54	79.20
SW - 18	61.11	18	1983.06	123.12	2185.29	76.48
SW - 19	283.77	7.47	421.29	38.52	751.05	85.20

Surface runoff estimation

Surface runoff is one of the most important hydrologic variables used in most water resource applications. Its occurrence and quantity depend on the rainfall event's characteristics, i.e., the intensity, duration and distribution. Apart from these rainfall characteristics, there are several catchment-specific factors that directly affect the occurrence and volume of runoff. This includes soil type, vegetation cover, slope and catchment type. The direct runoff over the basins has been calculated (Eq. no 1, 2). The resulted values of surface runoff are depicted in Table 6, 7, 8 and 9.

For SW1, SW2, SW3, SW4, and SW5, the maximum yearly runoff depth was observed in 2006, ranging from 385 to 415 mm, followed by 2002 and 2005. The lowest runoff depth was observed in 2019, ranging from 18 mm to 22 mm, followed by 2015 and 1994 were presented in Table 6.

For SW6, SW7, SW8, SW9, and SW10, the maximum yearly runoff depth was observed in 2006, ranging from 401 to 460 mm, followed by 2002 and 2005. The lowest runoff depth was observed in 2019, ranging from 20 mm to 23 mm, followed by

2015 and 1994, as presented in Table 7.

For SW11, SW12, SW13, SW14, and SW15, the maximum yearly runoff depth was observed in 2005, ranging from 411 to 462 mm, followed by 2006 and 1998. The lowest runoff depth was observed in 2015, ranging from 18 mm to 25 mm, followed by 2019 and 2004, presented in Table 8.

For SW16, SW17, SW18, and SW19, the maximum yearly runoff depth was observed in 2005, ranging from 418 to 558 mm, followed by 2006 and 1998. The lowest runoff depth was observed in 2015, ranging from 19 mm to 41 mm, followed by 2019 and 2004, presented in Table 9.

The table 10 represent, sub watershed wise rainfall – runoff and percentage runoff of Karpura watershed for the year 1991-2020. The average runoff depth of SW19 was found to be 198 mm and percentage of runoff change corresponding to rainfall was 24%. The lowest average runoff depth was found to be 124 mm for SW5 and percentage of runoff change corresponding to rainfall was 15%. The average rainfall for Karpura sub watersheds were observed in between 796 to 829 mm and average runoff depth ranges from 124 to 198 mm.

Table 6: Yearly runoff depth (mm) for Karpura sub watersheds (1991-2020)

Year	SW-1		SW-2		SW-3		SW-4		SW-5	
	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff
1991	552	151	552	150	552	153	552	158	563	154
1992	759	175	759	175	759	178	759	184	800	178
1993	727	38	727	38	727	41	727	46	715	26
1994	715	32	715	32	715	35	715	38	742	39
1995	750	45	750	45	750	48	750	51	747	46
1996	926	142	926	141	926	147	926	155	968	133
1997	691	59	691	59	691	61	691	64	750	60
1998	1332	329	1332	329	1332	339	1332	353	1274	301
1999	883	91	883	91	883	96	883	104	893	80
2000	681	94	681	94	681	98	681	105	877	159
2001	1156	289	1156	289	1156	297	1156	310	954	239
2002	1034	375	1034	375	1034	382	1034	393	938	243
2003	676	90	676	90	676	93	676	99	737	138
2004	581	33	581	33	581	35	581	38	575	26
2005	1145	364	1145	363	1145	371	1145	383	1262	415
2006	982	385	982	385	982	390	982	399	940	326
2007	748	60	748	60	748	63	748	68	775	59
2008	611	75	611	75	611	78	611	82	621	65
2009	861	139	861	139	861	145	861	153	847	144
2010	1064	192	1064	192	1064	199	1064	209	1055	177
2011	697	80	697	80	697	83	697	88	705	71
2012	605	58	605	58	605	61	605	65	609	80
2013	956	164	956	164	956	169	956	176	953	115
2014	518	61	518	61	518	63	518	66	464	54
2015	496	29	496	29	496	31	496	34	446	19
2016	704	51	704	51	704	54	704	59	694	38
2017	615	45	615	45	615	47	615	51	616	64
2018	538	54	538	54	538	56	538	59	588	69
2019	614	18	614	18	614	20	614	22	642	25
2020	760	39	760	39	760	42	760	46	818	60
Total	23377	3757	23377	3754	23377	3875	23377	4058	23568	3603
Avg	779.2	125.2	779.2	125.1	779.2	129.2	779.2	135.3	785.6	120.1
Max	1332	385	1332	385	1332	390	1332	399	1274	415
Min	496	18	496	18	496	20	496	22	446	19

Table 7: Yearly runoff depth (mm) for Karpara sub watersheds (1991-2020)

Year	SW-6		SW-7		SW-8		SW-9		SW-10	
	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff
1991	552	159	563	161	563	168	563	159	563	165
1992	759	185	800	187	800	197	800	184	800	193
1993	727	48	715	32	715	40	715	30	715	37
1994	715	39	742	45	742	52	742	43	742	49
1995	750	52	747	51	747	57	747	49	747	55
1996	926	157	968	148	968	165	968	143	968	158
1997	691	65	750	67	750	74	750	64	750	71
1998	1332	357	1274	324	1274	349	1274	315	1274	339
1999	883	106	893	92	893	104	893	87	893	99
2000	681	106	877	173	877	188	877	168	877	182
2001	1156	313	954	255	954	270	954	249	954	264
2002	1034	396	938	260	938	278	938	254	938	270
2003	676	100	737	150	737	163	737	146	737	157
2004	581	39	575	31	575	36	575	29	575	34
2005	1145	386	1262	437	1262	460	1262	429	1262	450
2006	982	401	940	339	940	353	940	334	940	348
2007	748	69	775	68	775	78	775	64	775	74
2008	611	83	621	72	621	80	621	70	621	76
2009	861	155	847	157	847	171	847	153	847	166
2010	1064	211	1055	193	1055	210	1055	187	1055	203
2011	697	90	705	79	705	88	705	76	705	85
2012	605	66	609	87	609	95	609	84	609	92
2013	956	178	953	127	953	140	953	122	953	135
2014	518	67	464	59	464	64	464	57	464	62
2015	496	35	446	21	446	24	446	20	446	23
2016	704	61	694	46	694	55	694	43	694	51
2017	615	52	616	71	616	79	616	68	616	76
2018	538	60	588	76	588	84	588	74	588	80
2019	614	23	642	29	642	34	642	28	642	32
2020	760	46	818	68	818	77	818	65	818	73
Total	23377	4105	23568	3905	23568	4233	23568	3794	23568	4099
Avg	779.23	136.83	785.60	130.17	785.60	141.10	785.60	126.47	785.60	136.63
Max	1332	401	1274	437	1274	460	1274	429	1274	450
Min	496	23	446	21	446	24	446	20	446	23

Table 8: Yearly runoff depth (mm) for Karpara sub watersheds (1991-2020)

Year	SW-11		SW-12		SW-13		SW-14		SW-15	
	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff
1991	563	156	563	153	563	155	563	169	563	159
1992	800	181	800	177	800	180	800	198	800	185
1993	715	27	715	24	715	26	715	41	715	30
1994	742	41	742	38	742	40	742	53	742	44
1995	747	47	747	45	747	46	747	58	747	50
1996	968	138	968	131	968	135	968	167	968	144
1997	750	62	750	59	750	61	750	75	750	65
1998	1274	308	1274	297	1274	304	1274	351	1274	318
1999	893	84	893	78	893	82	893	106	893	89
2000	877	163	877	156	877	160	877	190	877	169
2001	954	244	954	237	954	241	954	272	954	250
2002	938	248	938	240	938	245	938	280	938	255
2003	737	142	737	136	737	140	737	164	737	147
2004	575	27	575	25	575	26	575	37	575	29
2005	1262	421	1262	411	1262	418	1262	462	1262	431
2006	940	330	940	324	940	328	940	355	940	336
2007	775	61	775	57	775	60	775	79	775	65
2008	621	67	621	64	621	66	621	80	621	70
2009	847	148	847	142	847	146	847	173	847	154
2010	1055	181	1055	174	1055	179	1055	212	1055	188
2011	705	74	705	70	705	72	705	90	705	77
2012	609	82	609	78	609	81	609	96	609	85
2013	953	118	953	113	953	116	953	142	953	124
2014	464	55	464	53	464	54	464	65	464	57
2015	446	19	446	18	446	19	446	25	446	21
2016	694	41	694	37	694	39	694	56	694	44
2017	616	66	616	63	616	65	616	80	616	69
2018	588	71	588	68	588	70	588	84	588	74
2019	642	26	642	24	642	25	642	35	642	28
2020	818	63	818	59	818	61	818	78	818	66
Total	23568	3691	23568	3551	23568	3640	23568	4273	23568	3823
Avg	785.6	123.0	785.6	118.4	785.6	121.3	785.6	142.4	785.6	127.4
Max	1274	421	1274	411	1274	418	1274	462	1274	431
Min	446	19	446	18	446	19	446	25	446	21

Table 9: Yearly runoff depth (mm) for Karpura sub watersheds (1991-2020)

Year	SW-16		SW-17		SW-18		SW-19	
	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff
1991	563	159	563	167	563	155	629	227
1992	800	184	800	195	800	180	854	287
1993	715	30	715	39	715	27	758	121
1994	742	43	742	51	742	40	651	47
1995	747	49	747	56	747	46	841	123
1996	968	143	968	162	968	136	816	149
1997	750	64	750	73	750	61	799	179
1998	1274	316	1274	344	1274	304	1215	374
1999	893	88	893	102	893	82	1016	214
2000	877	168	877	186	877	161	860	235
2001	954	249	954	268	954	242	1043	369
2002	938	254	938	275	938	245	912	305
2003	737	146	737	160	737	140	777	205
2004	575	29	575	35	575	27	455	41
2005	1262	429	1262	456	1262	418	1288	558
2006	940	335	940	351	940	328	993	419
2007	775	64	775	76	775	60	785	129
2008	621	70	621	78	621	66	639	110
2009	847	153	847	169	847	146	816	155
2010	1055	187	1055	207	1055	179	1175	338
2011	705	76	705	87	705	72	715	121
2012	609	84	609	93	609	81	596	87
2013	953	122	953	138	953	117	1117	265
2014	464	57	464	63	464	55	475	83
2015	446	20	446	24	446	19	586	92
2016	694	43	694	53	694	39	762	123
2017	616	68	616	78	616	65	608	81
2018	588	74	588	82	588	70	587	101
2019	642	28	642	34	642	26	647	67
2020	818	65	818	76	818	61	782	72
Total	23568	3797	23568	4178	23568	3648	24197	5677
Avg	785.6	126.6	785.6	139.3	785.6	121.6	806.6	189.2
Max	1274	429	1274	456	1274	418	1288	558
Min	446	20	446	24	446	19	455	41

Table 10: Sub-watershed wise rainfall–runoff and percentage runoff of Karpura Watershed for the year 1991-2020.

Watershed Code	Rainfall 30 - Years	Runoff 30 - Years	% Runoff change
SW – 1	796	130	16
SW - 2	796	130	16
SW - 3	796	134	17
SW - 4	796	140	18
SW - 5	804	124	15
SW - 6	796	142	18
SW - 7	804	135	17
SW - 8	804	146	18
SW - 9	804	131	16
SW - 10	804	141	18
SW - 11	804	127	16
SW - 12	804	122	15
SW - 13	804	125	16
SW - 14	804	147	18
SW - 15	804	132	16
SW - 16	804	131	16
SW - 17	804	144	18
SW - 18	804	126	16
SW - 19	829	198	24

Conclusion

Soil Conservation Service and Curve Number model have been utilized in this research work by land use land cover and soil map described in QGIS 3.32, as input. For un-gauged watershed.

There was unavailability of rainfall station within watershed area. Therefore Indian Metrological Department grid rainfall data have been used for runoff estimation. The amount of runoff represents 15 to 24% of the total annual rainfall. In present study, the methodology for the tenacity of the runoff utilizing GIS & SCS-CN approach could be applied in Karpura watershed. In SCS-CN method, antecedent moisture condition of the soil plays a very consequential role because the CN number varies accordingly to the soil and that is considered while estimating runoff. For a given watershed, CN adjustments have been calculated by Hawkins (1981) ^[11] curve number formula to each sub watershed. Sub watershed no12 has lowest curve number (75.92) and sub watershed no 19 has highest curve number (85.20). The average rainfall for Karpura watershed were observed in between 786 to 829 mm and average runoff depth ranges from 124 to 298 mm. In conclusion, soil conservation service – curve number approach is efficiently proven as a better method, which consumes less time and facility to handle extensive data set as well as site selection to identify suitable location for conservation structures.

References

1. Mohamed HS. Potential sites for water harvesting in central Butana rangeland, Sudan (2006–2007) [Internet]. 2009 [cited 2024 Aug 15]. Available from: <https://core.ac.uk/download/288210136.pdf>
2. Verma AK, Jha MK. Extraction of watershed characteristics using GIS and digital elevation model. International Journal

- of Engineering Science Invention. 2017;6(7):1-6.
3. Trivedi A, Awasthi MK. Runoff estimation by integration of GIS and SCS-CN method for Kanari River watershed. *Indian Journal of Ecology*. 2021;48(6):1635-1640.
 4. Badar B, Romshoo SA, Khan MA. Integrating biophysical and socioeconomic information for prioritizing watersheds in a Kashmir Himalayan lake: A remote sensing and GIS approach. *Environmental Monitoring and Assessment*. 2013;185(8):6419-6445.
 5. Gonzalez-Hidalgo JC, Batalla RJ, Cerda A, De Luis M. A regional analysis of the effects of largest events on soil erosion. *CATENA*. 2012;95:85-90.
 6. Central Ground Water Board (CGWB). Ground water information - Parbhani district, Maharashtra. Ministry of Water Resources, Government of India. 2013;1-18.
 7. Choudhary MA, Lal R, Guo P. Tillage effects on non-point source pollution. *Proceedings of the Conference on Engineering in Agriculture and Food Processing*; 1996 Aug 24-27; Gatton College, The University of Queensland. 25(3):24-27.
 8. Dams J, Dujardin J, Reggers R, Bashir I, Canters F, Batelaan O. Mapping impervious surface change from remote sensing for hydrological modeling. *Journal of Hydrology*. 2013;485:84-95.
 9. Fohrer N, Haverkamp S, Eckhardt K, Frede HG. Hydrologic response to land use changes on the catchment scale. *Physics and Chemistry of the Earth (B)*. 2001;26(7-8):577-582.
 10. Gupta PK, Panigrahy S, Parihar JS. Impact of climate change on runoff of the major river basins of India using Global Circulation Model (HadCM3) projected data. *Journal of the Indian Society of Remote Sensing*. 2011;39(3):351-361. doi:10.1007/s12524-011-0101-7
 11. Hawkins RH. Discussion of "Empirical investigation of curve number technique". *Journal of the Hydraulics Division, ASCE*. 1981;107(7):953-955.
 12. Hutti B, Nijagunappa R. Applications of Geoinformatics in water resources management of semi-arid region, North Karnataka, India. *International Journal of Geomatics and Geosciences*. 2011;2(2):429-435. Available from: <https://www.indianjournals.com/ijor.aspx?target=ijor:ijggs&volume=2&issue=2&article=003&type=pdf>
 13. Mishra SK. Long term hydrologic simulation using SCS-CN method. *Proceedings of the Ninth National Water Convention*; 2011 Dec 15-17; Bangalore, India. Ministry of Water Resources, Government of India; 2011. p. 236-254.
 14. Mustard JF, Sunshine JM. Spectral analysis for Earth Science: Investigations using remote sensing data. In: Rencz A, editor. *Manual of Remote Sensing*. 2nd ed. New York: John Wiley & Sons; 1999. p. 251-306.
 15. National Informatics Centre (NIC). Parbhani District Services [Internet]. Available from: <https://parbhani.gov.in/service-category/nic>
 16. Patil JP, Sarangi A, Singh AK, Ahmad T. Evaluation of modified CN methods for watershed runoff estimation using a GIS-based interface. *Biosystems Engineering*. 2008;100(1):137-146. doi:10.1016/j.biosystemseng.2008.02.001
 17. Quilbé R, Rousseau AN, Duchemin M, Poulin A, Gangbazo G, Villeneuve JP. Selecting a calculation method to estimate sediment and nutrient loads in streams: Application to the Beaurivage River (Quebec, Canada). *Journal of Hydrology*. 2006;326(1-4):295-310.
 18. Ramana GV. Rainfall runoff modeling between TR-55 hydrologic watershed model and overland time of concentration model. *International Journal of Advances in Computer Science and Technology*. 2014;3(12):123-130. Available from: <https://www.warse.org/pdfs/2014/ijacst12332014.pdf>
 19. Rawat A, Kumar P, Deoli V. Daily monsoon rainfall prediction using artificial neural network (ANN) for Parbhani district of Maharashtra. *International Journal of Current Microbiology and Applied Sciences*. 2019;8(12):1964-1975. doi:10.20546/ijcmas.2019.812.233
 20. Romshoo SA, Bhat SA, Rashid I. Geoinformatics for assessing the morphometric control on hydrological response at watershed scale in the Upper Indus Basin. *Journal of Earth System Science*. 2012;121(3):659-676.
 21. Sorensen RR, Zinko U, Seibert J. On the calculation of the topographic wetness index: Evaluation of different methods based on field observations. *Hydrology and Earth System Sciences*. 2006;10(1):101-112.
 22. Rani BH. Estimation of runoff from small agricultural watershed using remote-sensing and GIS [Internet]. 2004 [cited 2024 Aug 15]. Available from: <https://core.ac.uk/download/211008692.pdf>
 23. Soil Conservation Service (SCS). Hydrology. In: *National Engineering Handbook*. Washington, D.C.: Soil Conservation Service, USDA; c1985.
 24. Soil Conservation Service (SCS). *National Engineering Handbook, Section 4, Hydrology*. Washington, D.C.: U.S. Department of Agriculture; c1972.
 25. Soil Conservation Service (SCS). *Urban Hydrology for Small Watersheds. Technical Release 55*. Washington, D.C.: United States Department of Agriculture (USDA); c1986.
 26. Wani SP, Garg KK. Watershed management: Concept and principles [Internet]; c2009 [cited 2024 Aug 15]. Available from: <https://www.researchgate.net/publication/266351616>.