Rainfall-Runoff Modeling Using NRCS-CN method and GIS approach

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Abstract

Rainfall-Runoff modeling is a hydrological modeling which is extremely important for water resources planning, development, and management. In this paper, Natural Resource Conservation Service-Curve Number (NRCS-CN) method along with Geographical Information System (GIS) approach was used to evaluate the runoff resulting from the rainfall of four stations, namely, Bilodra, Kathlal, Navavas and Rellawada of Sabarmati River basin. The rainfall data were taken for 10 years (2005-2014). The curve number which is the function of land use, soil and antecedent moisture condition (AMC) was generated in GIS platform. The CN value generated for AMC- I, II and III were 57.29, 75.39 and 87.77 respectively. Using NRCS-CN method, runoff depth was calculated for all the four stations. The runoff depth calculated with respect to the rainfall for Bilodra, Kathlal, Navavas and Rellawada shows a good correlation of 0.96. The computed runoff was compared with the observed runoff which depicted a good correlation of 0.73, 0.70, 0.76 and 0.65 for the four stations. This method results in speedy and precise estimation of runoff from a watershed.

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Figure 1. Location Map of Study Area

Figure 2 Flowchart of Proposed Model

Figure 3: Reclassified LULC Map of Watershed

Figure 4: HSG Soil Map of Watershed

Figure 5: CN Grid Map of Watershed

Figure 6: Rainfall and Estimated Runoff (a) Bilodra station (b) Kathlal station (c) Navavas station (d) Rellawada station

Figure 7: Scatter plot between Rainfall and Estimated Runoff (a) Bilodra station (b) Kathlal station (c) Navavas station (d) Rellawada station

Figure 8: Scatter plot between Estimated and Observed Runoff (a) Bilodra station (b) Kathlal station (c) Navavas station (d) Rellawada station

Table I Data required for modelling and their Sources

Data	Source
DEM	SRTM 90m (CGIAR – CSI) http://srtm.csi.cgiar.org/
Soil Map	FAO http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/
Land Use	Decadal Land Use and Land Cover Classification across India https://daac.ornl.gov/VEGETATION/guides/Decadal_LULC_India.html
Meteorological Data	State Water Data Centre (SWDC), Gandhinagar Indian Meteorological Department, Pune India - Water Resources Information System

Table II SCS Hydrologic Soil Group (USDA)

Group	Properties	Soil Textures	Runoff Potential	Water Transmission	Minimum Rate of Infiltration (mm/hr)
A	Deep well drained soils	Sand, sandy loam, loamy sand	Low	High rate (0.3 in/hr)	> 7.62
B	Moderately deep, well drained with moderately fine to coarse texture	Loam or silt loam	Moderate	Moderate rate (0.15-0.3in/hr)	3.81-7.62
C	Soils with moderately fine to fine texture	Sandy clay loam	Moderate	Low rate (0.05-0.15in/hr)	1.27-3.81
D	Soil which swell significantly when wet, heavy plastic and soil with a permanent high-water table	Clay, clay loam, sandy clay, silty clay, silty clay loam	High	Very low rate (0-0.05in/hr)	0-1.27

Table III Classification of Antecedent Soil Moisture Condition

AMC	Properties of Soils	Total 5-day antecedent rainfall (mm)	
		Dormant Season	Growing season
I	Soils are dry (soil moisture content is at wilting point)	< 13 mm	< 36 mm
II	Average Condition	13-28mm	36-53mm
III	Soils are saturated from antecedent rainfalls (soil moisture content is at field capacity)	> 28 mm	>53 mm

Table- IV Curve Number of Sabarmati river basin under AMC-II, AMC-I & AMC-III

Curve Number							
Land Use	HSG	Area (km ²)	CN	CN*Area	CNw(II)	CN(I)	CN(III)
Water Bodies	-	1371.13487	100	137113.49	75.39	57.29	87.77
Medium Residential	A	7.893683	76	599.91991			
	B	355.694355	85	30234.02			
	C	26.930029	90	2423.7026			
	D	1.274995	92	117.29954			
Forest	A	1283.07424	37	47473.747			
	B	2884.83287	60	173089.97			
	C	128.333441	73	9368.3412			
	D	22.7169	79	1794.6351			
Agricultural	A	2654.15283	67	177828.24			
	B	14665.1308	77	1129215.1			
	C	6327.6183	83	525192.32			
	D	595.745791	87	51829.884			

Table- V Estimated annual runoff depth for annual rainfall using NRCS-CN

Year	Rellawada		Bilodra		Kathlal		Navavas	
	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)
2005	657.5	291.97	1280	847.16	1243.5	835.21	905	538.15
2006	1544.5	1011.95	1593	1114.54	1417	996.73	1518	1118
2007	912	549	1093.5	678.56	1009.5	587.46	1152	763
2008	442	137	1050	694.85	944	553.68	586	289.1
2009	590	338	501.5	286.87	326.5	151.23	457.5	197.32
2010	716.5	307.13	1081.5	712.62	832.5	487.19	848	390.35
2011	1068	655.91	561.5	308.51	368.5	156.55	1253.5	911.18
2012	1018	690.17	598	299.49	710.5	346.26	697	297.78
2013	1016	541	985	516.67	1068	571.49	872.5	405.27
2014	648	306.63	770	458.43	642	319.57	654.5	359