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Runoff Estimation by Using GIS Based Technique and Its Comparison with Different Methods- A Case Study on Sangli Micro Watershed

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Abstract—

In current study, an attempt has been made of estimating runoff by one of the well-known methods i.e. soil conservation services method of America. It is compared with empirical methods. In the present study, satellite data for geographic information is used for computing runoff in soil conservation service method with GIS software's. The micro watershed is located in Sangli region, Maharashtra. Area covered in this study is 51.91 sq.km. The land use, land cover and soil details are extracted from satellite images. The rainfall data of in & around micro watershed is collected and analysed . Curve number can be expressed by a numerical number .The CN number lies between 0 to 100. Different soils produce different volume of Runoff according to their soil types. So it is the most dependable, accurate method for un-gauged catchments because CN number depends on land use land cover, permeability & infiltration capacity of soil. For given study area that is Sangli micro watershed's CN number is calculated. This is used for daily runoff calculations. From the runoff calculations, it is found that SCN Curve number method results are closure to strange table method, khoslas method and Englis desouza method. Laceys method shows very low runoff and Irrigation department method shows very high runoff as compared to all other methods . Study of runoff estimation is useful for calculating volume of runoff from land surface meets in the river or streams. The proposed construction of weir or barrage can be thought of in the given study area. This study is also useful for the watershed development and planning of water resources effectively.

Keywords— runoff depth, gis based method, scs-cn method, empirical formulae.

I. INTRODUCTION

water is a most precious natural resource that has to be utilized , managed & planned effectively . As population is increasing day by day so demand of water is increasing and due to industrialization , urban development further load on available water is increased. So its serious issue or need of estimating available water for optimum use of water for various purposes like domestic , agriculture & industrialization . Many empirical formulae are developed based on the study of different catchments. They became popular because their utilization is simple, easy and reliable.

Still there are many watersheds or catchments which are un-gauged so there we can use these empirical formulae for estimating runoff volume and watershed planning and managements . Various hydraulic or water related projects' design and analysis is done on the basis of rainfall and runoff . So it is needed to develop relations between rainfall and runoff. These relations are used for interpolation or extrapolation.

In the present study runoff depth of study area is calculated by SCS-CN method and finally compared with different empirical relations.

II. NEED OF RUNOFF ESTIMATION

The study area i.e. SMW (Sangli micro watershed) is located in the semi arid region of Maharashtra. The average rainfall in Sangli district is as follows. Shirala tahsils and areas is round about 1016 mm (40"), in Tasgaon and Khanapur tahsils 508 mm (20") and in Sangli and Miraj areas it about 457.2 mm (18"). The rainfall in Kavathemahankal, Jath and Atpadi areas on the other hand is very short and near about 254 to 381 mm (10" to 15").

The water-supply from the rivers is also not sufficient as most of the rivers dry up in late summer. Krishna and Yerala are the only two important rivers which supply water for irrigation.

So the usage of available water should be made efficiently to meet the people's need and demand. In order to have accurate idea of available water runoff is to be computed.

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III. DIFFERENT EMPIRICAL RELATIONS FOR ESTIMATION OF ANNUAL RUNOFF DEPTH-

Many empirical formulae are developed based on the study of different catchments. They became popular because their utilization is simple ,easy and reliable . Still there are many watersheds or catchments which are un-gauged so there we can use these empirical formulas for estimating runoff volume and watershed planning and managements . Following empirical formulas used for calculation purpose.

1) Inglis formulae .
2) Khosala method

3) Lecys method
4) Stranges table
5) Barlow's tables
6) Irrigation Department method.
7) SCS curve number method.

3.1 SCS CURVE NUMBER METHOD

The soil conservation services method is also known as hydrologic soil cover complex method is a versatile and widely used method for runoff estimation . This method developed in 1969 at USA. In this method several important characteristics of the watershed are used. Like land use land cover , permeability & infiltration capacity of soil are taken . Different soils produces different volume of Runoff according to there soil type. It can be expressed by a numerical number i.e. is called CN number & it is lies between 0 to 100 .

The thematic maps developed by using satellite data with the help of GIS software's . Land use land cover calculated with percentage . soil map in the study area is also prepared according to there type as shown in fig .

Runoff is mostly depends upon amount of rainfall , initial abstraction & moisture content in the soil . The curve number method is based on the water balance equation & two basic hypotheses which are as follows , ratio of Actual runoff to the potential runoff is equal to the actual infiltration to the potential infiltration , and the volume of initial abstraction is some fraction of the potential infiltration .

$$Q/(P-Ia) = F/S \quad \text{----------A)}$$

$$F = (P-Ia) - Q \quad \text{----------B)}$$

Substituting eq.(B) in eq. (A) & by solving;

$$Q = (P - Ia)^2 / (P-Ia) + S \quad \text{----------C)}$$

Where ,
Q – Runoff depth in mm,
Ia = Initial Abstraction ,
P = Rain fall in mm
S = Maximum Retention .

Training Institute (ICAR) Dehradun has suggested some of relations for indian conditions .

All other regions Ia= 0.3S
Black soils regions AMC -2 & AMC -3 Ia= 0.1S.
Black soils regions AMC -1 Ia= 0.3S.

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FOR INDIAN CONDITIONS CURVE NUMBERS- (AMC-2)

Table no-1

Sl No.	Land use	Hydrologic Soil Group			
		A	B	C	D
1	Agricultural land without conservation (Kharif)	72	81	88	91
2	Double crop	62	71	88	91
3	Agriculture Plantation	45	53	67	72
4	Land with scrub	36	60	73	79
5	Land without scrub (Stony waste/ rock out crops)	45	66	77	83
6	Forest (degraded)	45	66	77	83
7	Forest Plantation	25	55	70	77
8	Grass land/pasture	39	61	74	80
9	Settlement	57	72	81	86
10	Road / railway line	98	98	98	98
11	River / stream	97	97	97	97
12	Tanks without water	96	96	96	96
13	Tank with water	100	100	100	100

CN for AMC 3= (23 x CN -2)/(10+0.13 x CN -2) ----------1)
CN for AMC 1= (4.2 x CN -2)/(10-0.058 x CN -2) ----------2)
S = (25400/CN)-254 ----------3)
$Q = (P - 0.3S)^2 / (P - 0.3S)$ ----------4)
Where
P= rain fall in mm,
Q= runoff depth in mm,
Ia= 0.3s initial abstraction.

Table no-2

Hydrologic Soil Group	Type of Soil	Runoff potential	Final infiltration rate mm/hr	Distribution (%)	Remarks
Group A	Deep, well drained sands and gravels	Low	>7.5	4.73	High rate of water transmission
Group B	Moderately deep, well drained with moderately fine to coarse textures	Moderate	3.8-7.5	25.54	Moderate rate of water transmission
Group C	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Moderate	1.3 – 3.8	52.04	Moderate rate of water transmission
Group D	Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high water table	High	< 1.3	18.69	Moderate rate of water transmission

Antecedent moisture content – Antecedent moisture content (AMC) means water content present in the soil . It is computed by total rainfall in 5 days before the storm . It is given in table no.5 according to Dormant season and Growing season.

Table no-3

AMC Class	Description of soil condition	Total five day antecedent rainfall (mm)	
		Dormant season	Growing season
I	Soils are dry but not to the wilting point; satisfactory cultivation has taken place.	< 12.7 mm	< 35.56 mm
II	Average conditions.	12.7 - 27.94 mm	35.56 - 53.34 mm
III	Heavy rainfall or light rainfall and low temperatures have occurred within last 5 days; Saturated soils.	> 27.94 mm	53.34 mm

Procedure

1) Define or finalize the boundary of the basin or catchment area, for which we need to find out curve number .
2) Find out the area of basin or catchment.
3) After studying satellite mage determine the land use and land cover area of each type of land .
4) Determine the soil types and convert them in to hydrological soil groups like A, B, C & D according to their infiltration capacity of soil.
5) Superimpose the land use map on the hydrologic group maps , obtain each land use soil group polygon and find out the area of each polygon
6) Assign a curve number to each unique polygon , based on standard SCS curve number tables .
7) Calculate the curve number for each drainage basin by area-weighting the land use-soil group polygons within the drainage basin boundaries

The detail procedural flow chart is given below .

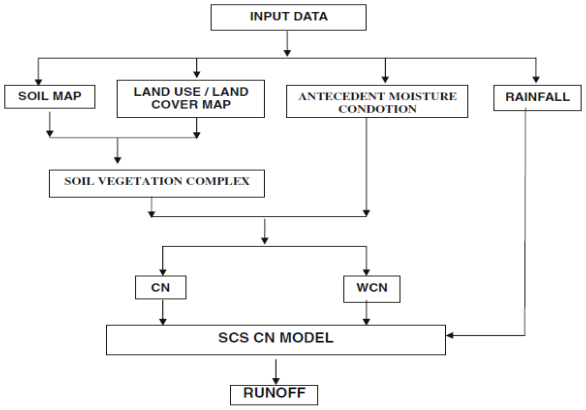
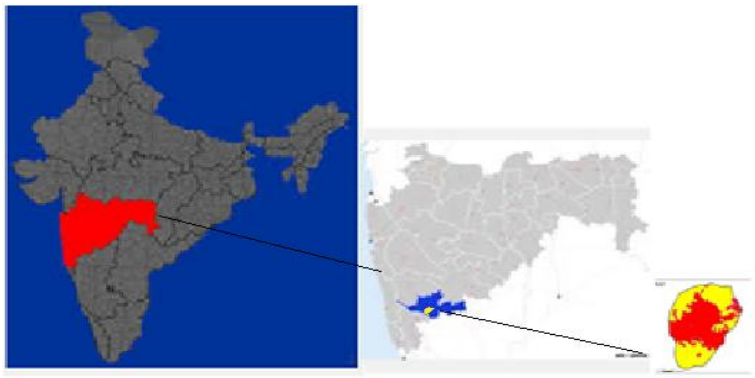


Fig no . 1 FLOW CHART of runoff estimation by using SCS CN model.

IV. CASE STUDY AREA

The micro watershed is located at sangli district in Maharashtra . Its area is 52.03 sq. km. geographically lies between 17^0 47' & 17^0 55' N latitude and 74^0 32' & 74^0 40' E longitude as per survey of india topo sheet map no. E43U9 (47L/9). The details of topographic maps are shown in table no. 1. Sangli is located in the western part of Maharashtra. Yerla ,agrani ,morna are small tributaries of Krishna river and warna is the largest tributary of the Krishna in the district. The highest level point in the micro watershed is 600m and lowest level point is 540m the overall difference is 60m.



V. DATA COLLECTION

Temperature & Daily Rainfall data of three rain gauge stations in and around micro watershed for the period of 1998 to 2012 is taken from hydrological project division Nashik .

Sangli rain gauge station annual rainfall data.

Temperature.

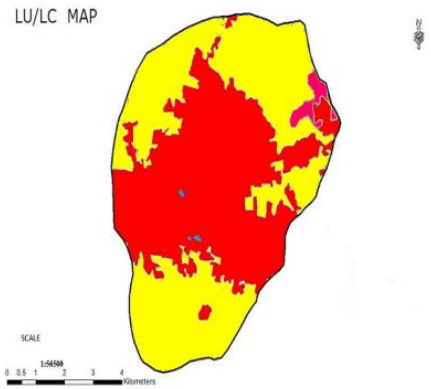
The meteorological station in the district is at Miraj. The records of this station may be taken as representative of the climatic conditions over the district in general. The cold weather starts by about the end of November and lasts till about the middle of February, December being the coldest month

Details of topographic maps are given below.

Topo sheet no	scale	year of survey	year of publications
E43U09	1:50000	1978-79	2010

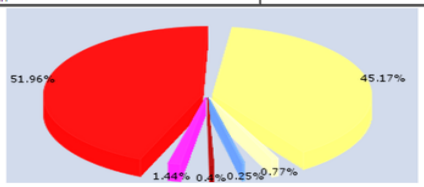
SATELLITE IMGAES DATA :-

Toposheet No.	**Bounding Box**	**Date of Pass**
E43U09	74.5E16.75N-74.75E17.0N	18-Oct-08
E43U09	74.5E16.75N-74.75E17.0N	13-Nov-11
E43U09	74.5E16.75N-74.75E17.0N	17-Feb-12



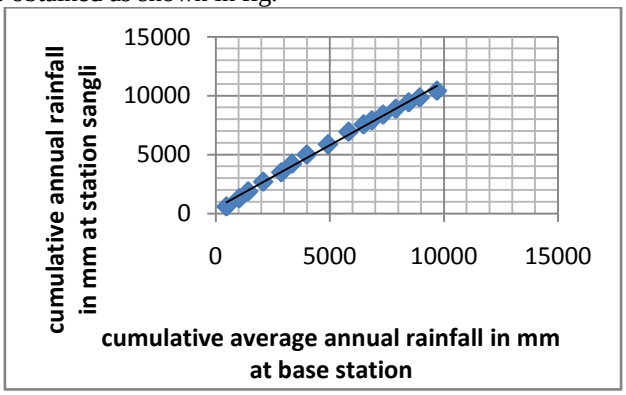
LAND USE LAND COVER MAP OF SANGLI MICROWWATERSHED.

LULC Class	Area (Sq. Km.)
Cropland	23.45
Fallow land	0.4
Reservoirs/ Lakes/ Ponds	0.13
Rural	0.21
Scrub land	0.75
Urban	26.98

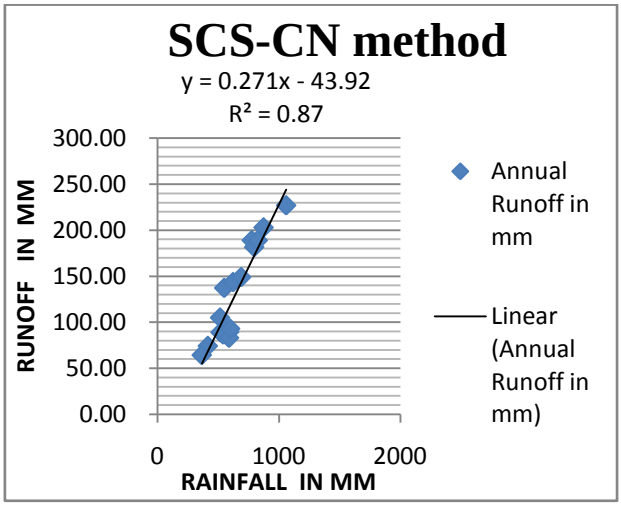


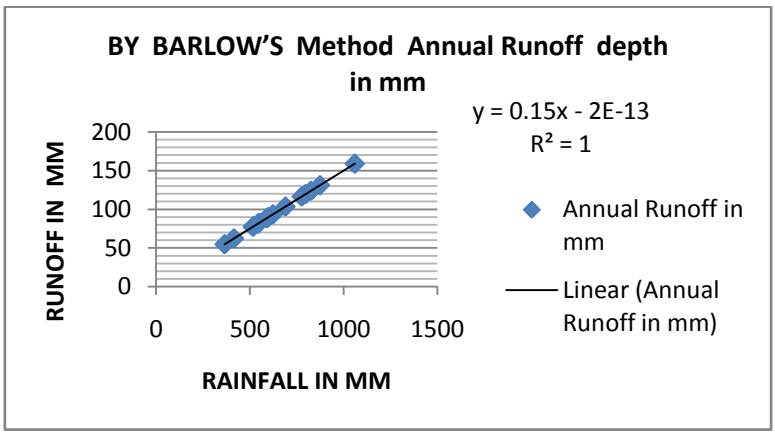
VI. CHECK FOR CONSISTANCY OF RAINFALL DATA:-

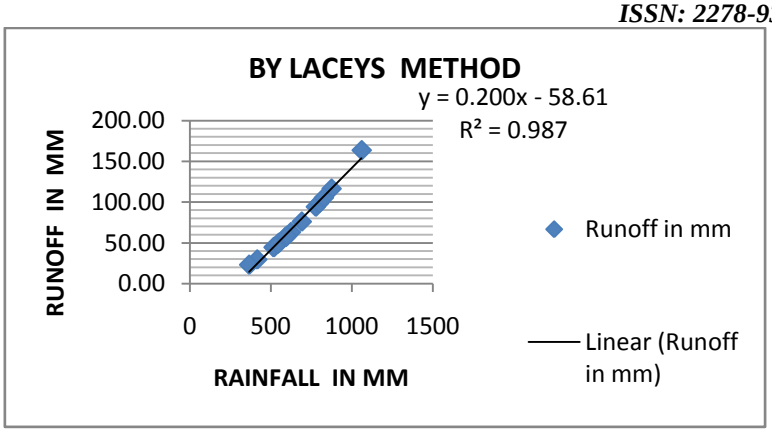
Before start the calculation of runoff it is required to check the consistency of rainfall data . Because many times inconsistency in the rainfall data due to various reasons .Double mass curve is one of the well known technique for to check the consistency of any rain gauge station . In Double mass curve technique graph is plotted between cumulative average rainfall of the base stations to the station whose consistency need to be checked .If the data is consistent then straight line is obtained as shown in fig.



VII. RESULTS AND GRAPHS

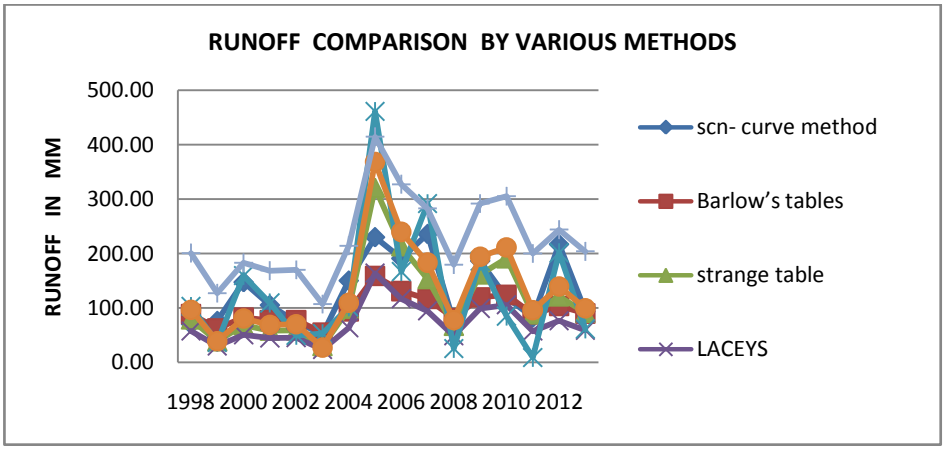






SUMMERY OF RUNOFF BY SEVEN METHODS

	RUNOFF DEPTH IN MM						
Year	Scn-curve method	Barlow's tables	Strange table	LACEYS	Khosala Method	Engli D esouza	Irrigation department method
1998	89.63	88.74	78.98	57.58	113.02	96.33	200.64
1999	74.23	62.25	38.89	29.78	41.86	38.72	126.79
2000	137.27	82.49	68.19	50.33	98.6	80.51	182.76
2001	105.00	77.39	58.30	44.72	76.14	68.63	168.37
2002	89.00	77.91	58.69	45.28	86.3	69.81	169.84
2003	64.30	54.75	30.08	23.37	36	26.87	106.92
2004	143.56	93.44	98.67	63.29	112.62	109.11	214.22
2005	227.00	159.03	320.93	163.84	396	368.25	414.53
2006	203.00	131.13	213.30	116.67	208.64	239.61	327.22
2007	189.00	116.52	153.03	94.47	199.6	183.13	282.66
2008	86.56	81.24	67.16	48.93	79.3	77.53	179.23
2009	181.67	119.54	161.54	98.91	201.16	194.20	291.80
2010	189.00	123.99	191.11	105.60	212.12	211.08	305.33
2011	83.00	88.47	88.41	57.26	97.3	95.62	199.87
2012	149.00	103.50	121.23	76.27	172.2	139.09	243.73
2013	93.00	89.81	91.13	58.87	73.48	99.18	203.73



APPLICATION OF THE STUDY (i.e. the value of yield)-:-:

1) The above study of runoff estimation is useful for volume of runoff from land surface of study area meets in the river or streams .
2) For the proposed construction of weir or barrage in the given study area.
3) Watershed development and planning of water resources effectively.

VIII. CONCLUSION

From the above seven methods of runoff estimating the SCS – curve number method is more reliable and accurate for predicting the runoff depth of vast area in minimum time and efforts . As In this method remote sensing technology is very effectively used . With the help of GIS Software satellite images are studied and extract the land use and land cover pattern accurately and that is the most important part of this method because on the basis of land use and land cover pattern we decide CN number accurately .

In SCN Curve number method Antecedent moisture condition of soil plays very important role because CN number varies according to water content present in the soil and that is considered while estimating runoff depth . For given study area that is sangli micro watershed CN number is calculated equals to 88 for AMC-2 , 76 – AMC-1 . And 94 for AMC-3 .

From the above runoff calculations it is found that SCN Curve number method results are closure to strange table method, khoslas method and Englis desouza. Laceys method shows very low runoff and Irrigation department method shows very high runoff as compare to all other methods .

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