SURFACE RUNOFF EVALUATION FOR AGRANI RIVER BASIN USING GEOSPATIAL TECHNIQUES

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SANDHYA S. KORE
T.S.S.M`s BSCOER Narhe, Pune, India
Email: sandykore1@gmail.com

ABHIJIT M. ZENDE
ADCET Ashta, Sangli, India
Email: zenabhi31@gmail.com

ATUL P. KHATRI
T.S.S.M`s BSCOER Narhe, Pune, India
Email:atul.khatri@rediffmail.com

ABSTRACT:

Nowadays in water resources engineering watershed management plays a vital role. Water harvesting structure based on management of water resources is essential to plan and protect the existing resources. Geographic Information System (GIS) and Remote Sensing (RS) techniques are mostly useful to achieve spatial and non-spatial database that signify the hydrologic features of the watershed use as accurately as possible. In this study area of Agrani river basin, Upper Krishna basin, Western Maharashtra, India. The yearly rain fall data of 7rain gauge stations (1998 – 2015) together used to calculate the yearly runoff from the watershed using Soil Conservation Service – Curve Number (SCS – CN) method and Arc GIS tool. From the collected annually rainfall data for the years of 1998 to 2015 in the study area annual run off has been calculated. The average rainfall is 466.63 mm respectively and typical runoff for the year of 1998 to 2015 is 20.75 mm^3 respectively. The developed rainfall–runoff model is used to understand the watershed and its runoff flow characteristics.

INTRODUCTION:

Water is the most important requirements for fiscal and social development. In India Human population is always increasing thereby water demand for domestic, agricultural and industrial use also increasing. However, the significant of rain and ground water availability has resulting in over-utilization of surface water, decreasing water table levels and water quality deterioration. To improve watershed at micro level it is required to reduce the runoff, increase the groundwater level and quality. Making variations in land management or constructing suitable structures can be achieving decrease of surface runoff. Detailed understanding and investigation of several rainfall-runoff model such as hydraulic properties of the soil, land use, rainfall intensity,slope soil moisture, and litho logy is required to study micro-watershed development approach (Cosh*et al* 2004, D Ramakrishnan 2009).Every single watershed has certain features such as shape, size, drainage, slope, geology, vegetation, geomorphology, soil, land use and climate. Water shed management indicates proper utilization of water for natural resources and land in a watershed forvaluation of runoff helps for developing, planning and managing the irrigation scheduling and water resources. In the management planning and water resources applications runoff is very important hydrologic variables used. Valuation of runoff requires much time and effort on land surface and rivers for gauged watershed accuracy. In this study to produce rainfall runoff model by integrating spatial difference of the various physiographic features like as geology, geomorphology, land use/ land cover, structures, soil and drainage pattern using SCS-CN technique with the help of RS data and GIS techniques (Abhijit Zende et. al, 2012, R. Amutha 2009).

OBJECTIVE:

To generate a Rainfall-Runoff-Model (RR Model) by incorporating spatial variation of various physiographic characteristics of the study area such as slope, land use/land cover, soil and drainage pattern integrated with the help of Geospatial techniques.

MATERIALS AND METHODS:

STUDY AREA:

This study was carried out in Agrani Riverwhich is a tributary of Krishna Riverin Sangli and Belgavi district of Maharashtra (Fig. 1). The basin length is about 97 km and perimeter is 249 km^2. It originates from the rain shadow region near to Western Ghats at an altitude 885 m and confluence point is Hulga Bali at Altitude 549 m. Agrani river basin lies between 16° 39' 24" N to 17°19' 25"N Latitude and 74° 40' 16" E to 75° 13' 20" E longitude. The watershedexperiences humid monsoon climate with normaltemperature, evaporation and humidity throughout the year. The monsoon season in this study area is from June to September. The rainfall occurrence during July and August is comparatively more than rest of the year and significant amount of runoff occurs in the river basin. The rainfall stationsare Kavthe Mahankal, Vita, Miraj, Tasgaon, Jat, Madabhavi, and Atpadi. The annual rainfall is about 466.63 mm for a period 1998-2015.TheAgrani basin has 7th order drainage basin (Fig. 2).

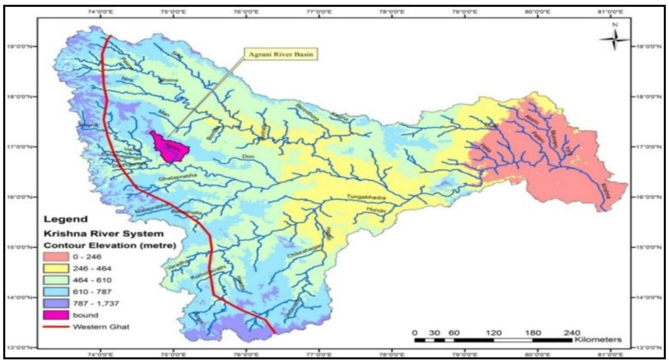

Fig. No.1: Location map of Agrani River basin

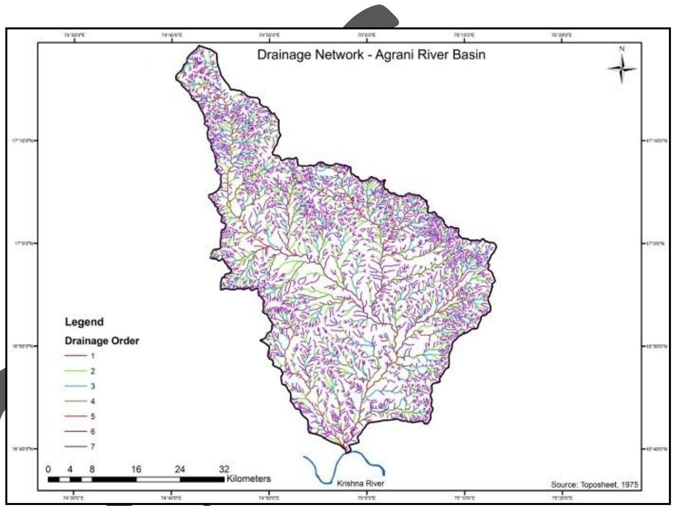

Fig.2 Drainage network of Agrani River Basin

METHODOLOGY:

In this study, Survey of India topographical sheet no. E43U10, E43V1, E43U9, E43O16, E43U14, E43U13, E43P4, 47P/2 on the scale 1:50,000 were used to delineate the watershed boundary, drainage and contour. Remote sensing data of IRS P6 - LISS 3sensor, on a scale of 1:50,000 for outlining land use/land cover map (Fig. 3) and hydrological soil map (Fig. 4). Hydrologic soil group was prepared according to soil characteristics and type of land use/land cover for the assessment of runoff by river basin. Yearly rainfall data from 7 rain gauge stations for the year of 1998 to 2015 (18 years) data were used to calculate the runoff using SCS-CN method.

SCS CURVE NUMBER METHOD:

Soil Conservation Service Curve Number (SCS-CN) is the greatest method to evaluate the direct runoff from a watershed (USDA, 1972). The SCS-CN method explaining the water balance equation can be expressed as below (Mishra and Singh 2003).

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

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

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

Where,

P denoted as total precipitation (mm);

Q is the direct runoff (mm),

F indicates the cumulative infiltration (mm),

$I_a$denoted as initialabstraction (mm);

S is the potential maximum retention (mm) and

λthe initial abstraction coefficient (0.3) and consist of surface storage,infiltration and interceptionprior to runoff in thewatershed and empirical relation was developed forthe term I_a and it is given by,

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \tag{4}$$

Which is valid for P ≥ Ia. Otherwise, Q = 0. For a constant value of Ia (0.3S), P-Q datacan be useful to determine S.In practice mapping equation is used to derive Sand expresses in terms of the curve number (CN)

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

The CN (dimensionless number ranging from (0 to 100) is determined from a table, based on land-cover, HSG and AMC. HSG is expressed in terms of four groups (A, B, C and D), according to the soil after prolonged wetting. AMC is expressed in three levels (1, 2 and 3), according to rainfall limits dormant and growing seasons.

$$CN_w = \frac{\sum(CN_i i * A_i)}{A} \qquad (6)$$

Where, CN_w is the weighted curve number;
CN_i is the curve number from 1 to any number N;
A_i is the area with curve number CN_i; and
A the total area of the micro-watershed.

The SCS curve number is a function of the abilityof soils to permit infiltration of water with respecttoantecedent soilmoisture condition (AMC) and land use/land cover. According to U.S.SCS soils are separated into fourhydrologic soil categories such as group A, B, C & Dwith respect to rate of runoff potential and finalinfiltration rate.

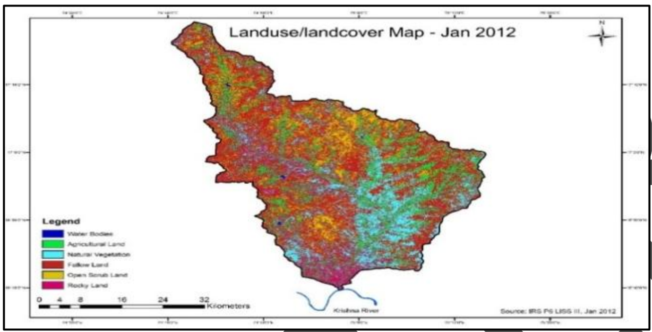

Fig. 3 LU /LC Map-Jan 2012 of Agrani River Basin

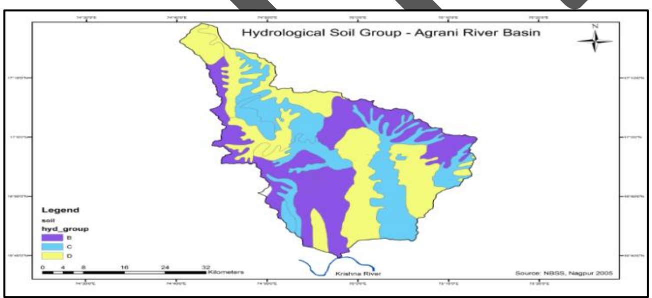

Fig. 4Hydrological Soil Group Map

Fig. 5 Slope Map of Agrani River Basin

HSG AND ANTECEDENT SOIL MOISTURE CONDITION (AMC):

According lowest infiltration rate of the soil, after continued wetting which is gained fora bare soil (Table 1) HSG is stated as four groups. Soil conservation service (SCS) had established three antecedent soil moisture conditions such as AMC 1, AMC 2 & AMC 3 and significant effect on rainfall runoff. Prior to estimate rainfall runoff for event, depend on the spell and antecedent precipitation the curve numbers are adjusted. At three levels AMC is stated, according to rainfall restrictions for inert and growing seasons. Even if originally intended for use on river basin of 1930 km^2, it has-been amended by various operators for significance to greater watersheds, predominantly bland-cover created area-weighting of curve numbers (Jackson *et al.*, 1976; Rawls *et al.*, 1981; Still and Shih, 1984, 1985, 1991).

2.2.3 AREA WEIGHTED CURVE NUMBER:

One by one the different layers ofHSG, soil and land use/landcover were superimposed using Arc GIS 9.3 and the original PAT(polygon attribute table) was found. PAT was used tocalculate the entire area weighted curve number of thestudy area to calculate the AMC 2 andthe result obtained refer (Table 2).

ESTIMATION OF RAIN FALL – RUNOFF:

Area weighted curve number andyearly rainfall database from 1998 to 2015 (for 18 years) of Agrani basin were filledinto the SCS formula and theresults are found from the yearly runoff results are found. Thedetailed annual rainfall and runoff values forthe 18years are given below in Table 3.

RESULTS AND DISCUSSION:

Every year due to high runoff, minimum average yearly rainfall, and evapo-transpiration in Agrani river basin like scarcity of water situation overcomes because oflack of proper management surface and sub-surface water resources. Discontinuities (fractures/joints) in the rigid rock zones play important role in groundwater restore movement and discharge in Agrani watershed. The basin creates different landuse/ land cover of about 26.67% of the area is occupiedby agricultural land, 20.37% area occupied byforest land, 27.06%area of fallow land,7.98% area covers open scrub land andremaining 17.89% of the area iscovers by othersuch as water body and rocky land. In general, the fallow land among the different landcover types acts the main role forthe direct surface runoff.

Table 1 Yearly Runoff for Agrani River Basin

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

Table 2 Weighted Curve Number for Agrani River Basin (For AMC 2)

Sr. No.	Land use	Soil Type	Area in km²	CN	% area	% area * CN	Weighted Curve Number (WCN)
1	Agricultural	B	40.14	75	2.08	155.984	AMC 1 =77.93 AMC 2 = 83.06 AMC 3=88
		C	200.72	81	10.40	842.4	
		D	257.93	86	13.36	1149.33	
2	Natural Vegetation	C	218.42	81	11.32	916.685	
		D	164.73	86	8.54	734.03	
3	Open scrub land	B	59.67	85	3.09	262.795	
		C	39.68	71	2.06	145.973	
		D	54.7	81	2.83	229.57	
4	Fallow Land	C	282.38	81	14.63	1185.12	
		D	240.02	85	12.44	1057.08	
5	Rocky Land	B	276.81	84	14.34	1204.77	
		C	17.3	81	0.90	72.6062	
		D	71.33	86	3.70	317.844	
6	Water bodies	-	6.17	100	0.32	31.9689	

Table 3Yearly runoff for Agrani river basin

Year	Rainfall (mm)	Runoff (mm)	Runoff (mm³)	Year	Rainfall (mm)	Runoff (mm)	Runoff (mm³)
1998	561.33	497.36	103.19	2007	570.00	505.95	104.97
1999	505.85	442.43	91.79	2008	420.14	357.84	74.24
2000	527.67	464.02	96.27	2009	582.59	518.43	107.56
2001	480.57	417.44	86.61	2010	618.51	554.07	114.95
2002	328.19	267.65	55.53	2011	345.64	284.7	59.07
2003	235.13	177.53	36.83	2012	351.49	290.66	60.30

2004	447.60	384.9	79.85	2013	560.99	560.98	116.39
2005	377.86	316.27	65.62	2014	601.60	537.29	111.47
2006	542.47	478.68	99.31	2015	369.67	308.23	63.95

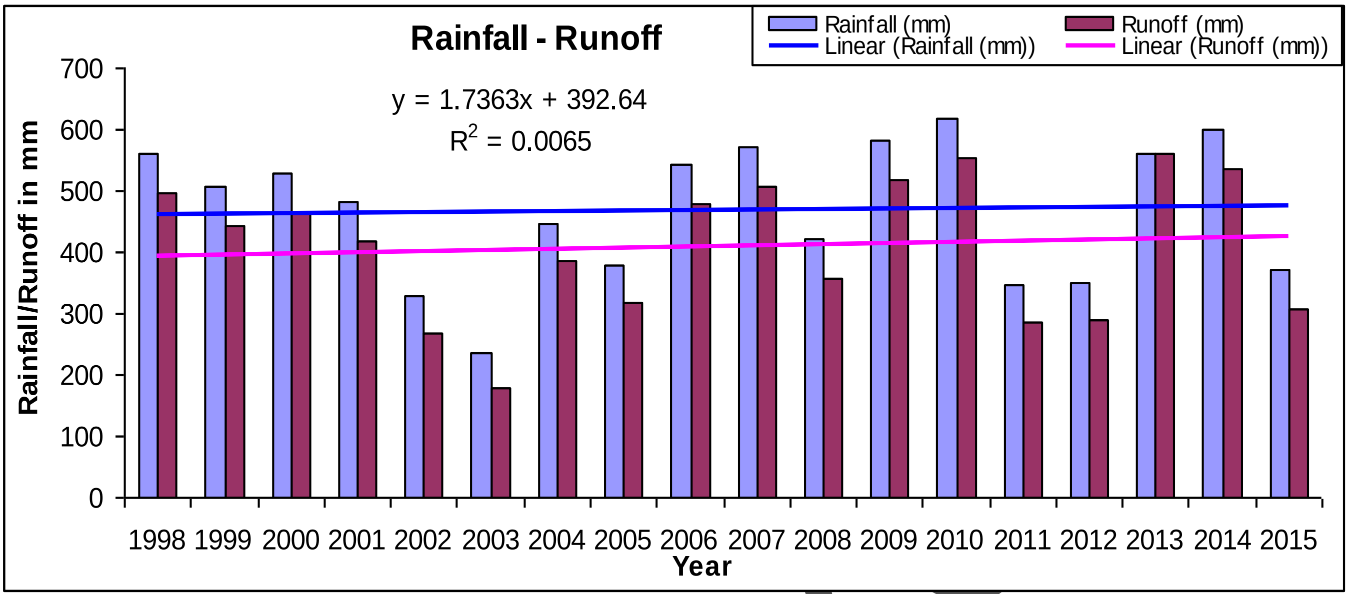

Fig. 5Average Rainfall vs Average Runoff

The hydrologic soil group which signifies the soil type, characteristics, and its infiltration capacity acts important role while measuring the runoff potential. The hydrologic soil category of 'B', 'C' and 'D' were explained with by forest land, 27.06%area of fallow land,7.98% area covers open scrub land and remaining 17.89% of the area is covers by other such as water body and rocky land. In general, the fallow land among the different land cover types acts the main role for the direct surface runoff. The hydrologic soil group which signifies the soil type, characteristics, and its infiltration capacity acts important role while measuring the runoff potential. The hydrologic soil category of 'B', 'C' and 'D' were explained with reference to remote sensing data and other secondary data in this study area. Throughout the study area gained that 'C' category of HSG mostly covered which is predominantly included of crop and agricultural land and then followed by 'B' and 'D' category. By intersecting the hydrologic soil group and land use the curve number was allotted according to Scand resulting the antecedent moisture conditions values are AMC 1, AMC 2 and AMC 3. The yearly runoff evaluated in both mm^3 and mm and has decreased from the year of 1998 to 2003 and suddenly increased between the years of 2004 to 2010 and gradually decreases and increases from the year 1998 to 2015.The trend line for the average rainfall is in the straight line for indicates that rainfall has decreased from the year 1998 to 2015. The result of the rainfall runoff trend line indicates that there is high runoff taking place comparatively. It is reasonably more runoff in this area and further it can be controlled by converting fallow land into agricultural land since it occupies 53.73% of the total land area.

CONCLUSION:

The conventional hydrological data are insufficient for determination of design and process of water resources schemes. The great use of RS data for the evaluation of important hydrological parameters, such as soils, land use/land cover, drainage, geomorphology etc.The estimation of runoff value using combination of SCS model and remote sensing gives the great accuracy within time.GISis an effective tool provides the adequate input data for the preparation of the SCS curve number model in watershed management. The analysis can be extended further to evaluate the effect of land use variations, after Progresses in the watershed, on the rainfall-runoff relationship. Water irrigation can be done to the related agricultural land and other utility purposes by evaluating the difference in annual runoff.

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