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Watershed Management – Estimation of Surface Runoff and analysis of Geomorphological Properties in composite watershed, using Remote Sensing and Geographical Information System for Godavari Basin in Ahmednagar District of Maharastra

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ABSTRACT

An accurate understanding of the hydrological behaviour of a watershed is important for effective management. Runoff is the most basic and important data needed when planning water control strategies/ practices, such as, waterways, storage facilities or erosion control structures. Kinhiwatershed cover an area of near 1485 ha. And is consist of two revenue villages Kinhi and Bhairobawadi. The study was carried out in the hot and dry climatic condition; area lies between Longitude19° 04′27″ to 19°08′00″ N and Latitude 74°24′51″ to 74° 27′32″E. The most popular method used for runoff estimation is NRCS-CN method. The Runoff curve number is a key factor in determining Runoff in the NRCS based hydrological modelling method. Now a days GIS and RS is being used with NRCS-CN method highly, most of the researchers found that use of NRCS-CN with help of GIS very accurate results in determination of Runoff. Remote sensing provided a powerful tool for estimating curve number values in Kinhi watershed and eventually values of runoff. Also RS and GIS technologies used in Geomorphological investigations give incredible advantages. The SRTM DEM data collected base on spectral reflectance properties of land and Harmonised soil data, Global land cover data base used in the morphometric analysis and also Watershed Modelling System software were used.

Keywords: Toposheet, Weather station, Basin Map, Curve Number ,Remote Sensing, Geographical Information System, Natural Resources ConservationServices, Shuttle Radar Topography Mission (SRTM), Digital Elevation Model, Watershed Modelling System, SOI.

1. INTRODUCTION

Remote sensing Techniques are more reliable, up-to-date, and faster than conventional techniques. It plays a vital role in acquisition of data in the different aspects of land use and soil cover, which are essential parameters in the field of watershed runoff estimation. GIS is capable of handling spatial and a spatial data when compared to conventional information system. The use of GIS technology as a spatial data management and an analysis tool provides an effective mechanism for hydrologic studies. Thus the remote sensing along with GIS application aid to collect, analyse and interpret the data rapidly is very much helpful for watershed planning and management.

A watershed is the hydrological unit which drains the Runoff to a common outlet point by the stream system. It is topographical delineated area, which composed of interrelated parts and functions. However, quickening of the watershed management programme for conservation and development of natural resources management has necessitated the Runoff information. 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 a GIS and using RS has led to significant increase in its use in hydrological applications. The NRCS-CN method also known as the hydrologic soil cover complex method is a versatile and widely used procedure for runoff estimation. This method includes several Important Geomorphological properties and the various physical, hydraulic properties of soil, of the watershed. In the present study, the runoff from NRCS-CN model modified for Indian conditions has been used by using conventional database and GIS for Estimation of runoff for Kinhi watershed.

2. LITERATURE SURVEY

Dr.SeemaJagtap April 2014 studied and published paper entitled "Rainfall Runoff Modelling Using Model Tree Techniques " The study was conducted for the predicting one day ahead runoff at Nigoje ,Velhloli and Paud village in river basin namely Krishna in Maharastra state.

Arun W. Dhawale Jan 2013 Studied and published paper entitled "Runoff Estimation for Darewadi Watershed using RS and GIS" The study was conducted for the Darewadi Watershed having area of 3569 hector in ahmednagar district.

Surindar G Wawale July –Aug. 2012 Carried out research work and published paper entitled as "Geomorphologic Analysis of Pravara River using Topographical and Remote Sensing Database: A Case Study of Pravara River in Ahemadnagar District of Maharashtra"

3. METHODOLOGY AND MATERIALS

3.1 Site Features/Study Area

The Project area "Kinhi watershed" is subwatershed of *GV-115* which is of Kalu River, sub tributary of Mula River. It is located in Parnertahasil in the district of Ahmednagar district of Maharashtra State about 50 Km. from district headquarters. This area lies in the South-West of Ahmednagar district.

- Site Location: Kinhi, Bhairobawadi-ParnerTahsil, Dist- Ahemadnagar.
- Latitude: 74°24′51″ to 74° 27′32″E
- Longitude: 19° 04′27″ to 19°08′00″ N
- Average Rainfall: 533.80 mm for last 5 years (2009-2014)
- Altitude: 851.75m.
- Area: 1485 ha.
- Name of River and tributaries : Godavari- Pravara- Mula- Kalu River.
- Code of Watershed: GV115 (Milli-Watershed).
- Shape of Watershed: fern.
- Average slope: 0.0506 m/m.
- Maximum length of stream: 9864.27 m
- Co-ordinates of outlet point: 19007'46.1"N 74026"17.4"E
- Nearby weather station: TakaliDhokeshwar(Parner).

3.2 Climatic features of AhemednagarDistrict (ParnerTaluka)

The climate of the district is characterized by a hot summer and general dryness throughout the year except during the southwest monsoon season.The mean minimum temp. are 7°C and mean maximum temperature is 42°C.The normal rainfall over the district varies from 533.80mm.It is the minimum in the south west parts of the district and it gradually increases towards Akole and Sangamner.The district being situated in "Rain Shadow" zone of 'Western Ghats', it often suffers the drought conditions.Almost all district covering Ahmadnagar, Rahuri, Nevasa, Shevgaon, Jamkhed, Karjat, Srigonda, Pathardi and Parnertalukas comes under "Drought Area".

3.3 Geomorphology and Geology

This area falls under Deccan plateau, hot semi-arid Eco-region at western plateau and hilly agro-climatic region in scarcity agro-climatic zone of Maharashtra State.

3.4 Soil Characteristics

The soil types of the project area are broadly divided into three categories namely coarse shallow soil; medium black soil; and greyish soil. The existing farming systems being adopted by majority of farmers in rain fed area of district.

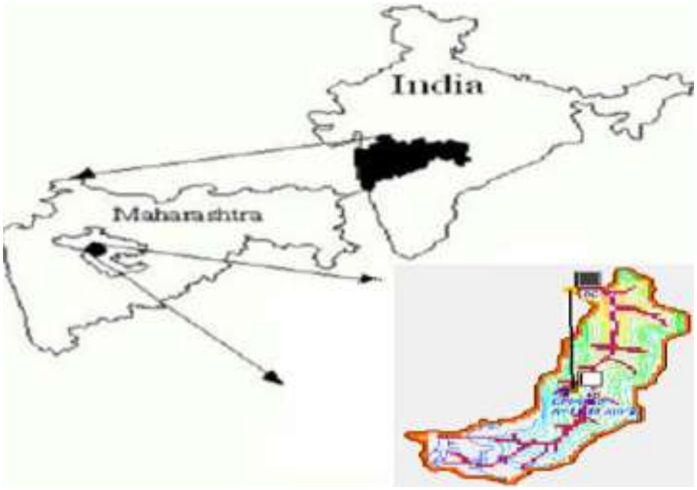

Fig .1- Watershed Location map(Ahmednagar)

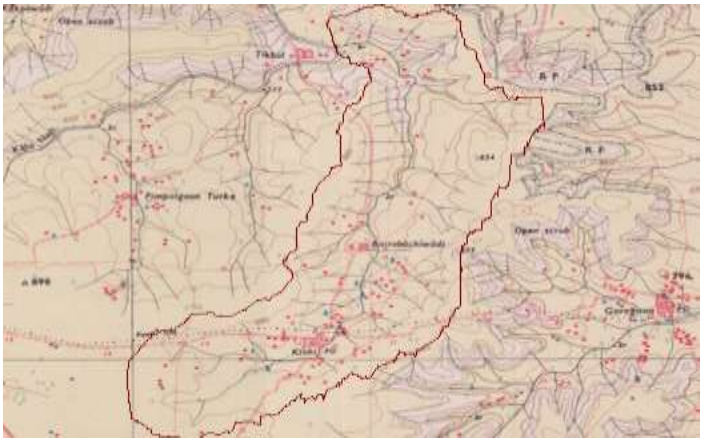

Fig.2-Physically Delineated Watershed on Toposheet.

3.5 Procedure to Delineate watershed on Toposheet

To trace the boundary, - start at the outlet & then draw a line away on the left bank, maintaining it always at right angles to the contour lines. (The line should not cross the drainage paths), Continue the line until it is above the headwaters of the stream network. Return to the outlet and repeat the procedure with a line away from the right bank. Two lines should join to produce the full watershed boundary.

3.6 Watershed Delineation Steps:

There are two basic steps to follow in watershed delineation.

Step 1: Choose the point of the watershed outlet. This is generally our point of interest for designing a structure or monitoring location.

Step 2: Delineate the watershed boundary by drawing perpendicular lines across the elevation contour lines for land that drains to the point of interest.

3.7 Physical Procedure adopted for Measurement of Area/Length/Perimeter by Digital Planimeter

The digital planimeter is widely used, nowadays, as it helps in providing the most accurate results. These devices are based on advanced technology. These work on the computer algorithms that help in calculating the area of the two-dimensional figures. These devices contain microprocessor chips, display screen and other components.

The working principle of the algorithm used in the digital planimeter is based on the green theorem. This theorem helps in calculating the area. The basic fundamental involved in this is the integral calculus. In this, the whole figure is sub-divided into different segments. The area of these segments is calculated and then added up in order to measure the whole area of the figure.

Table 1: Various data sets

SN	Type of Data	Details of Data	Source of Data
1	Toposheet	47(I/8) at 1:50,000 scale	Survey of India Dept. (SOI)
2	Land Cover Data	Local type	Pirence Database
3	Soil Texture Data	1:60,000 scale	District Soil Laboratory
4	Rainfall Data	Daily (2011-12)	Takali Dhokeshwar weather station

3.8 Toposheet/Topographical Map

It is map which shows all topographical features present on the earth surface such as hill ,contour river streams,roadsetc.we used the toposheet no 47 I/8 of ParnerTahsil for our study area as showen in fig.2
The CN depends on the basin characteristics and soil moisture conditions at the time of occurrence of rainfall. It can be evaluated from tables as a function of hydrologic soil group, antecedent rainfall, land use pattern, density of plant cover and conservation practices followed in the areas.

Table 2: Hydrologic soil group (USSCS)

S.N.	Soil Group	Description
1	A	**Lowest rainfall potential**- It includes sand with very little clay and silt, deep, rapidly permeable loess.
2	B	**Moderately low runoff potential**- It includes sandy soil less deep than A, and loess less deep than A, the group has average infiltration.
3	C	**Moderately high runoff potential**- It includes Shallow soil with Clay and colloids, though less those of group D.
4	D	**Highest runoff potential**- It includes clay of high swelling percentage and some shallow soil with impermeable horizon near the surface.

Table 3: Seasonal Rainfall limits for Antecedent Moisture Condition classes.

Antecedent moisture condition	Description	Total 5-days antecedent rainfall (mm)	
		Dormant season	Growing season
AMC I	Dry soils, prior to or after plowing or cultivation, or after periods with no precipitation.	<12.5	<35
AMC II	Typical or average conditions	12.5 to 27.5	35 to 52.5
AMC III	Saturated soil due to heavy rainfall	>27.5	>52.5

3.9 Curve Number Method

Single event Hydrograph methods such as the NRCS Curve Number Method used to develop Hydrographs to estimate the peak flow rate and volumes for specific design storms. These methods can also be used with flow routing techniques to size detention facilities. This theory presents a general description of the NRCS Curve Number Method. For additional information refer to the NRCS National Engineering Handbook. Modelling with these methods is generally conducted using commercially available computer software packages.

4. NRCS CURVE NUMBER METHOD THEORY

Empirical methodology developed by the National Resources Conservation Service (previously the Soil Conservation Service) to separate rainfall into abstractions and overland flow supply. In general, the rainfall-runoff equation of the NRSC Curve Number Method relates a land area's runoff depth (precipitation excess) to the precipitation it receives and to its natural storage capacity.

4.1 Applicability

- Method can be used for any size homogeneous watershed with a known percentage of imperviousness.
- Method may not be applicable in extreme terrains (e.g. mountainous regions).
- Method does not take into account rainfall intensity in the initial abstraction.
- Method can only be used for individual storm events and not for continuous hydrologic modelling since it does not account for the recovery of infiltration capacity (and other abstractions) between storm events.
- Runoff from snowmelt or rain on frozen ground cannot be estimated using this method.
- Method is less accurate if effective rainfall is less than 0.5 inches in which case another method should be used.
- Method cannot be used if the weighted curve number is less than 40.

P = gross cumulative rainfall (inches) = Q + F+ Ia
Q = effective rainfall = cumulative overland flow supply which will eventually appear at the watershed outlet as direct runoff (inches).
Ia = initial abstractions (prior to beginning of runoff) which includes infiltration prior to ponding, depression storage and interception (inches)
ta = time when initial abstractions end and infiltration starts
F = cumulative infiltration since beginning of runoff (inches) F + Ia are the abstractions or rainfall retention (inches)
S = maximum retention or the maximum possible abstraction (F + Ia) for the storm (inches)
Pt = maximum runoff potential (Pt = Q + F = P – Ia) (inches)
Note that for there to be any runoff at all, the gross cumulative rainfall (P) must equal or exceed the initial abstraction (Ia).
Schematic curves of P, Q, F+Ia (Note: Constant rainfall intensity is assumed)
Empirically based on:

$$\frac{Q}{P} = \frac{F}{S}$$

Setting F = Pt - Q and after some derivation, you arrive at:

$$\mathrm{Q} = \frac{(\mathrm{P} - \mathrm{Ia})^2}{\mathrm{P} + \mathrm{S} - \mathrm{Ia}}$$

Generic equation, applies when initial abstractions are known. If initial abstraction, Ia, cannot be determined, the NRCS recommends using Ia = 0.2S, in which case:

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

Use only if initial abstraction cannot be determined the maximum retention, S, can be obtained from an index called the Curve Number (CN), which ranges from 0 to 100 with higher values indicating higher runoff potential.

$$\mathrm{S} = \frac{1000}{\mathrm{CN}} - 10 \quad , \quad \mathrm{CN} = \frac{1000}{10 + \mathrm{S}}$$

The curve number is a function of the watershed antecedent moisture conditions, hydrologic soil group and land use/land cover. Tables give the runoff curve number for urban and agricultural areas for an antecedent moisture condition of II (AMC II, average condition).

Formulas for converting from AMC II (average condition) to AMC I (dry condition) and from AMC II to AMC III (saturated condition) are given below:

$$\text{CN for AMC I}=\frac{(4.2\mathrm{CNII})}{(10-0.058\mathrm{CNII})}$$

$$\text{CN for AMC III}=\frac{23\text{CNII}}{(10+0.13\text{CNII})}$$

When the watershed varies in soil type, antecedent moisture condition, or land cover a composite curve number is used, which is computed as the weighted areal average of the curve number for each region of the watershed. Alternatively, the runoff can be computed for each region individually and then added.

$$\text{Weighted CN} = \frac{\text{Sum (Ai} * \text{CNi)}}{\text{Sum (Ai)}}$$

N = number of regions, i = region index, Ai = area for region i, CNi = curve number for region i, CN = composite curve number for the watershed.

Table 4: Various Types of Land use and land cover with CN.

Sr.No	Type of land use land cover	Area (ha.)	% Area	CN	Area*CN
1	Agriculture	1260.22	84.86	91	114680
2	Wasteland	145.82	9.81	94	13707.08
3	Habitation	6.97	0.47	80	557.6
4	Water body	12.17	0.82	100	1217
5	Transportation	9.94	0.67	93	924.42
6	Pasture	9.65	0.64	89	858.85
7	Orchards, Nurseries	21.08	1.33	83	1749.64
8	Herbaceous range land	8.76	0.6	84	735.84
9	Shrub and Brush range land	5.94	0.5	77	457.38
10	Streams and canals	4.45	0.3	100	445
	Total	1485	100		135332.8
			Weighted CN	91.1	

4.2 Watershed Modelling System

WMS has paralleled tools that allow you to easily download and use spatial data for hydrologic modelling. After downloading the necessary data, you can use built-in tools to compute and extract all the parameters necessary for building an hydrologic model, save the necessary model files, run, and view the output. WMS reads digital elevation Data, images, and GIS shape files and, manipulate the files, and download digital data from the internet. It provides help how to get background images, convert coordinate projections, and convert data from shape file to map feature data that can be used for watershed modelling in the WMS.WMS includes a graphical interface to HEC-1. Geometric attributes such as areas, lengths, and slopes are computed automatically from the digital watershed. Parameters such as loss rates, base flow, unit Hydrograph method, and routing data are entered through a series of interactive dialog boxes. Once the parameters needed to define an HEC-1 model have been entered, an input file with the proper format for HEC-1 can be written automatically.

Following are the various datasets used in the WMS:

Table 5: Datasets used for the modelling

Sr.No	Type of Data	Details of Data	Source of Data
1	Satellite Data	SRTM DEM Data,90m resolution	NASA Satellite Data
2	Harmonized Soil Data	Global type	NASA Satellite Data
3	Land Cover Data	Global type	NASA Satellite Data
4	Rainfall Data	Daily (2011-12)	Takali Dhokeshwar weather station

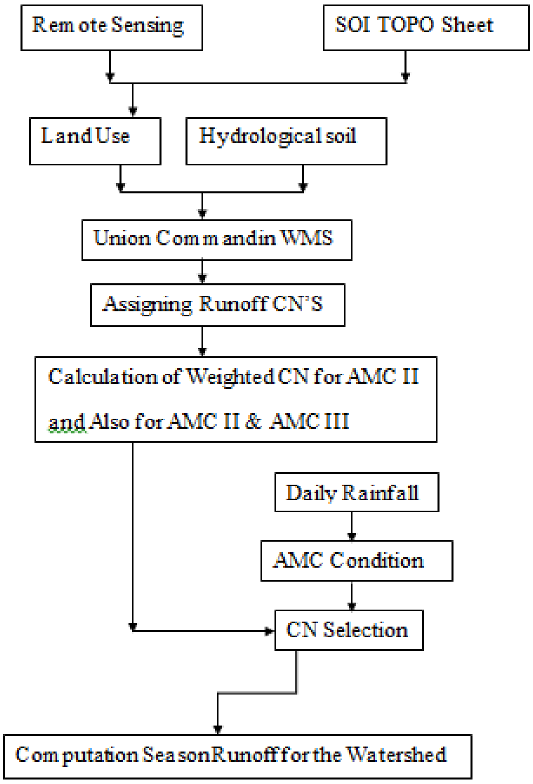

Fig 3.Flow Process Chart for the Watershed Modelling System

5. RESULT AND DISCUSSION

In India, accurate information on runoff is scarce and only available in a few selected sites. Thus, there is an urgent need to generate information on basin runoff and sediment yield for the acceleration of the watershed development and management programmes. The NRCS- CN model is a simple, empirical model with clearly stated assumptions and few data requirements.

CN is an index representing the soil cover complex that reflects the response of a specific soil under certain conditions (i.e. soil moisture, tillage practice and land cover) to a rain storm event through runoff and infiltration. CN is a non-dimensional index having theoretically a value between 0 (no runoff) and 100 (no infiltration). For a specific soil cover condition, CN can be obtained from a range of rainfall, depths and corresponding runoff depths.

The Watershed Modeling System used for the Watershed of area 1485 ha. The various parameters considered during the analysis work such as Hydrological soil group Land Use Land Cover pattern and Digital Elevation Model Spatial data, Initial losses by loss method, intensity of rainfall conservation practices. The runoff generated in the field is estimated by NRCS-CN method is found to be 124811894.8 ft3. Also runoff is estimated in Watershed Modeling System is Found to be 129808536.8 ft3. Comparing all these observations it is evident that results wear comparable and acceptable in both NRCS-CN method and WMS. And these methods are suitable for estimating the runoff for our Watershed.

Table & Graph 6: Comparison between Estimated Runoff by NRCS-CN and WMS.

Sr.No	Rainfall period 2012	Runoff Volume by NRCS-CN method (cu ft)	Runoff Volume by WMS (cu ft)	Acceptability (%)
1	Jan- March	0	0	100
2	April- June	10696645.06	10910577.96	98
3	July- Sept	67962578.75	71360707.69	95
4	Oct- Dec	46152670.99	47537251.12	97.4

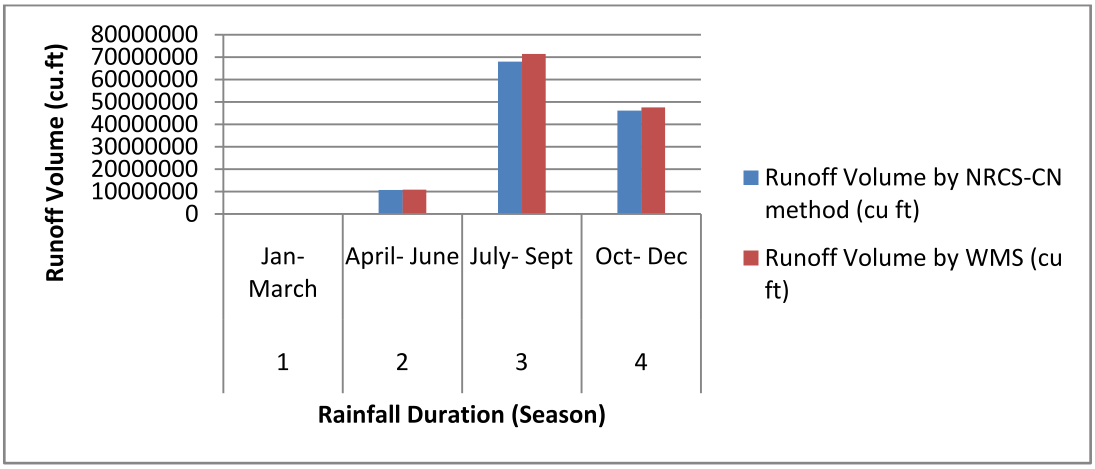

Table 7: Geomorphic Properties by WMS and Physical Analysis

Sr.no	Name of Geomorphic Properties	WMS Analysis	Physical Analysis
1	Basin ID	3	GV-115
2	Basin Name	3B	Godavari Basin
3	Basin CN	91	92
4	Basin Area	1485 ha	1484.3 ha
5	Basin Slope	0.0506 m/m	--
6	Basin Length	6600.89 m	66589.2 m
7	Perimeter	29789.8 m	29725.3 m
8	Shape Factor	2.86	2.78
9	Mean Basin Elevation	851.72 m	--
10	Maximum Flow Distance	9996.62 m	9983.2 m
11	Maximum Flow Slope	0.0124 m/m	--
12	Maximum Stream Length	9864.27 m	9874.5 m
13	Maximum Stream Slope	0.0124 m/m	--
14	Average Overflow Distance	110.78 m	--

6. CONCLUSION

For engaged watersheds accurate estimation of the surface runoff from the land in to rivers and streams requires very much time and efforts but remote sensing technology can aggument the conventional method to a great extent in rainfall runoff studies. In this study NRCS-CN for Indian condition has been used for generation of the watershed. An integrated RS and GIS based methodology has successfully demonstrated for estimation of runoff in Kinhi watershed. The manual calculation of CN’s for large areas or many drainage basins can be laborious and time consuming their fore GIS is an appropriate to use for such an application. Using NRCS-CN model for Kinhi watershed the average CN obtained for treatment is 91.This runoff potential can be used for the artificial recharge by constructing the NalaBunds and Farm ponds at suitable sites of these sub watersheds. Also, constructing the structures like check dams water can be stored it will be helpful for the dry summer days to be used as a drinking purpose as well as agricultural purpose.

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