ESTABLISHMENT OF RAINFALL - RUNOFF RELATIONSHIP FOR THE ESTIMATION RUNOFF IN SEMI-ARID CATCHMENT

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ABSTRACT

The rainfall-runoff relationship is helpful in forecasting runoff rate and runoff depth. The forecasted runoff can be used for hydrologic and hydraulic engineering design, water availability, water supply, flood control, drainage, power generation and planning and management of water resources. The study was undertaken to establish the rainfall-runoff relationship using the Soil Conservation Service Curve Number (SCS-CN) technique and Remote Sensing and GIS for semi-arid catchments of Ozat River located in Junagadh district, Gujarat, India. The weighted curve number (73.03) of the study area was estimated using the Remote Sensing and GIS derived land use/ land cover maps. The relationships between the daily rainfall with daily observed and estimated runoff were established with the correlation coefficients of 0.6568 and 0.8591, respectively.

KEY WORDS: Rainfall-runoff relationship, remote sensing, runoff, Soil Conservation Service Curve Number (SCS-CN)

INTRODUCTION

The requirements for water resources management is analysis of water availability and demand in the area, which vary with time and area. The rainfall-runoff relationship help to predict the runoff, which is useful planning for water supply, flood control, irrigation, drainage, power generation, water quality, recreation, fish and wildlife, etc. However, there is a need to take up such studies for estimate the available surface runoff for the region under the changing climatic scenarios.

Out of several methods for runoff estimation from ungauged watershed, the Natural Resources Conservation Services Curve Number (NRCS-CN) (U. S. Soil Conservation Service, 1969) method along with its modifications have been widely applied to ungauged watershed systems and proved to be a quicker and accurate estimator of surface runoff than other empirical and lumped parameter models (Thiam and Singh,

2002). Yuan *et al.* (2001) compared predicted subsurface flows using the modified SCS-CN method with observed subsurface flows in the Little Vermilion River watershed in East-Central Illinois. Qiuning *et al.* (2002) applied the SCS model (Curve number method) to calculate runoff amounts of different typical small watersheds in Shaanxi province, China. Hong and Adler (2008) estimated global SCS curve numbers using satellite remote sensing and geospatial data. Satasiya and Vavdiya (2008) found out the average SCS curve number for the Meghal basin was found 77. ZhiHua *et al.* (2009) used the Soil Conservation Service Curve Number (SCS-CN) for predicting direct runoff from rainfall. The ratio of initial abstraction (Ia) to maximum potential retention (S) was assumed in its original development to be equal to 0.2 in SCS-CN method in the Three Gorges Area of China. Melesse and Shih (2002) used of geographic information systems (GISs) and remote sensing to estimation of runoff from watershed and agricultural fields in Kissimmee River basin in south Florida. Zade *et al.* (2006) estimated curve number (CN = 68 to 82) for major basins of India using remote sensing. Thiam and Singh (2002) used long-term data on rainfall and annual runoff, an investigation was made of the spatial and temporal variability of rainfall and runoff in West Africa. Ishioka *et al.* (2004) established rainfall-runoff characteristics in wetland, using tank model for different land use in East-Hokkaido. The study was undertaken to establish the rainfall-runoff relationship for the Ozat river of Junagadh district of Gujarat.

MATERIALS AND METHODS

Study area

The study area lies between latitude 21°32’ 35.31”N to 21°12’20.22”N and longitude 70° 39’15.71” E to 70°46’35.38” and 37 m altitude of outlet point of the catchment. The study area is falls in the catchment of Ozat river of Junagadh District of Gujarat state. Total catchment study area of Ozat river catchment is 1409.16 km^2. The location of the study area is showed in Figure 1.

Climate of study area

The climate of study area is subtropical and semi-arid type which receives rainfall South-West monsoon with an average of 929.81 mm. It is received from the mid of the June to the mid of the October month. January is the coldest month with mean monthly temperature varying from 7°C to 15 °C and maximum monthly temperature is recorded in the month of May varying between 29.50 °C to 39.40 °C.

Remote sensing and data used

The satellite data were collected from Bhaskaracharya institute for space Application and Geo-informatics (BISAG), Gandhinagar and the data were utilized for the remote sensing and GIS application for the study. Geometica V 10.0 was used for different remote sensing and GIS operations. The daily runoff data (year: 2006-2012) were collected from the Irrigation Department, Junagadh.

The spatial information in the form of maps required for the preparation of land capability classification. The soil characteristics maps like soil texture, soil erosion, soil depth and slope maps were prepared by Geomatica V 10.0.L and use/land cover map from satellite image of IRS P6, LISS III merged digital data of Ozat catchment was prepared with the help of BISAG. Based on visual image interpretation of satellite imagery, the land use/land cover map was

generated. Hernandez *et al.* (2008) used remote sensing and GIS techniques with rainfall time-series data, spatial ancillary information, and the curve-number method (SCS-CN) to assess the runoff response in the sub basin. In the present study slope map was prepared using SOI in topo-sheet. Slopes were classified on the basis of the guidelines mentioned in Integrated Mission for Sustainable Development (IMSD) document.

Ground truth verification and error estimation

The ground truth verification for the different themes has been carried out. The primary and secondary data were collected and information on the thematic map was verified under the ground truth verification. The accuracy was also checked for the land use land cover map.

Estimation of the runoff using Curve Number technique

The US Soil Conservation Service developed the Curve Number method for application to large agricultural areas to predict surface runoff from one day rainfall data.

Estimation of runoff Curve Number (CN)

The CN incorporates the effects of infiltration characteristics of the soil, land use and agricultural practices.

The wetted curve number

$$CN = \frac{(A_1 \times CN_1) + (A_2 \times CN_2)}{A_1 + A_2} \quad (1)$$

Where,

A_1 and A_2 are the areas of different fields and CN_1 and CN_2 are the curve number of respected fields.

Calculation of Potential Maximum Retention (S)

The formula used for the calculation of potential maximum retention (S) is

$$CN = \frac{2540}{25.4 + S} \quad (2)$$

Where,

S = Potential maximum retention of rainwater at any time in cm

CN = Runoff Curve Number which representation the combined effect of soil, land use, hydrologic condition and antecedent soil moisture.

Calculation of Initial Abstraction (I_a)

Initial abstraction (I_a) which consists of interception losses, depression storage and infiltration before the runoff begins. The antecedent moisture conditions were accounted in the present study using the procedure of Hawkins (1983).

$I_a = 0.1\ S$ for AMC II and AMC III (3)

$I_a = 0.3\ S$ for AMC I (4)

Calculation of runoff

The values of S and I_a have been put into the below equation to get the runoff (Q) value on one day basis, which calculates the runoff in cm being given precipitation in cm.

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \quad (5)$$

Where, P = rainfall depth, cm

I_a = Initial abstraction

S = Potential maximum retention of rainwater at any time in cm.

Sharma and Kumar (2002) modified Soil Conservation Service (SCS) model for the estimation of runoff from an arid watershed.

Rainfall and runoff relationship

Relationship was developed by plotting the rainfall (P) and corresponding calculated or observed runoff (R) data and drawing best fit curve. More authentic method is drawing the best fit "linear regression line" between runoff and rainfall, which gives accurate estimate when correlation coefficient between them is 1.0. The form of linear regression equation between R and P is given as,

$R = a P + b$ (6)

Where, a and b are the regression coefficients.

The value of correlation coefficient (r) lying between $0.6 < r < 1.0$ indicates a good correlation between the variables.

RESULTS AND DISCUSSION

Land use / land cover

Land use/land cover map was prepared using the satellite image of IRS P6, LISS III of Ozat catchment. The land use / land cover map (Figure 2) generated from satellite data clearly brings out spatial information on settlements, agricultural land like single crop, double crop, village, cities/towns, industrial, current fallow, deciduous forest (Moist/Dry), scrub forest, plantations, prosophis, land with scrub, land without scrub, lakes/ponds, *etc*. The row crop with good hydrological condition occupies an area of 1004.79km^2. Orchard with an average hydrological condition fall under 84.23 km^2 area, Deciduous forest (Moist/Dry) with average hydrological condition occupy 141.06 km^2 area, Fellow waste land under 65.83km^2 with poor hydrological condition, built-up, farmstead, *etc* were under 63.82 km^2 area and remaining 49.43 km^2 area was under Pasture with fair hydrological condition. The total area of Ozat river catchment is 1409.16 km^2.

Soil of study area

The soil units on the soil map are the association of sub-groups. In study area, there were Fine, Montmorillonitic, Hyperthermic, Calcareous, Vertic, Loamy, Mixed, Hyperthermic, Calcareous, Lithic and Fine, Hyperthermic, Calcareous, Vertic Ustochrepts. The maximum 74% area having the fine texture soil followed by loamy texture (12%) as shown in Figure 3.

Drainage and topographic condition

The ground slope of the area classified into 7 group viz. 0 to 1%, 1 to 3%, 3 to 5% and 5 to 10%, 10 to 15%, 15 to 35% and 35 to 50%. These data show that the major part of the catchment is having slop less than 1% (Table 1.).

Estimation of runoff using Curve Number technique

The Soil Conservation Service (SCS) Curve Number method is used for estimating the runoff from the recorded rainfall data of the area. The values of curve number were determined from the standard table for AMC-II as 78 for straight raw crop, 54 for average orchard, and 44 for open forest area, 86 for fellow waste land, 74 for built-up, farmstead and 69 for fair pasture range. By using these curve numbers, weighted curve number was calculated as 73, which is in the range of 68 to 82 (Zade *et al.* 2006). Using the value of curve number (CN), the maximum potential retention (S) was calculated. By considering antecedent moisture condition of previous five days rainfall, maximum potential retention and rainfall data, the one day runoff was calculated using one day rainfall data.

Rainfall - runoff relationship

The runoff was calculated using SCS-CN method. The daily runoff data were collected from the Irrigation Department, Junagadh for different catchments of the Ozat river. The calculated and observed runoff data were used to derive different rainfall-runoff relationships for different catchments of Ozat river. The relationship between daily rainfall and daily observed and estimated runoff (year: 2006-12) for Ozat river catchment is shown in Figure 4. The relationship between daily rainfall and daily observed runoff was having the correlation coefficient as 0.6568. The estimate daily runoff was correlated with the daily rainfall and the correlation coefficient was found as

0.8591.

CONCLUSION

Reliable prediction of quantity of runoff from land surface into streams and rivers is difficult and time consuming to obtain for ungauged watersheds. Soil Conservation Service Curve Number (SCS-CN) method was used for predicting direct runoff volume for a given rainfall event. The area weighted curve number for the study area was estimated as 73.03 using the remote sensing and GIS approach. The relationship was established between daily rainfall and daily observed and estimated runoff (Year: 2006-12) for Ozat river catchment. The correlation coefficient between the daily rainfall and measured runoff was observed as 0.6568 where as for the correlation coefficient between the daily rainfall and estimated runoff was found as 0.8591. The higher value of correlation coefficient shows good relationship between rainfall and runoff.

ACKNOWLEDGMENT

The acknowledgement to the BISAG-Gandhinagar and Irrigation Department- Junagadh for providing the necessary data for the research work.

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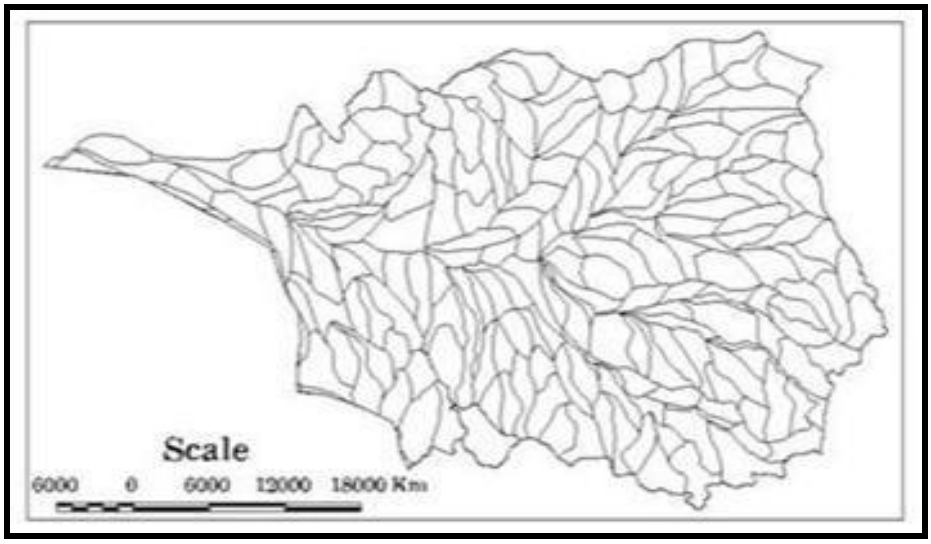

Fig. 1: Ozat River Catchment.

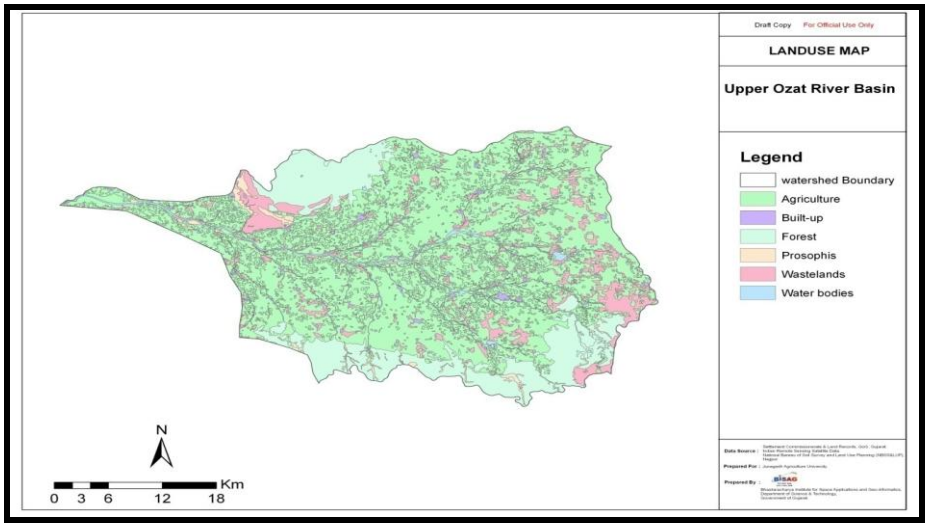

Fig. 2: Land use / land cover map

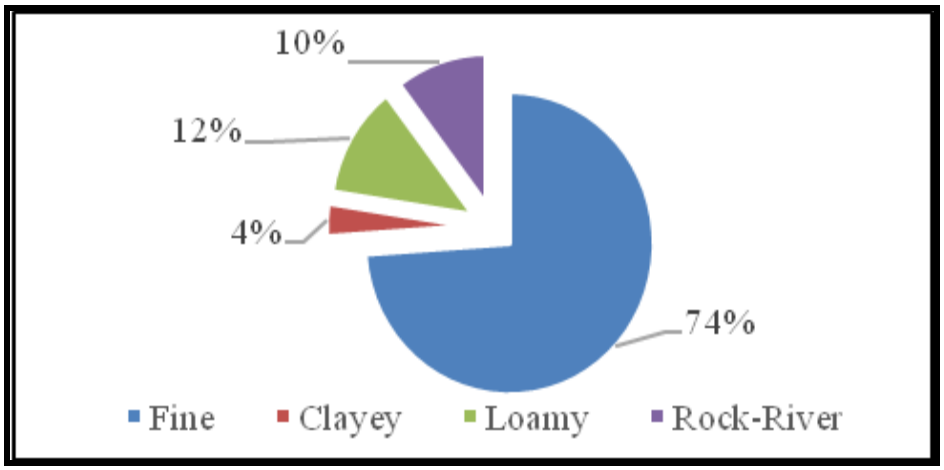

Fig. 3: Area under different soil texture

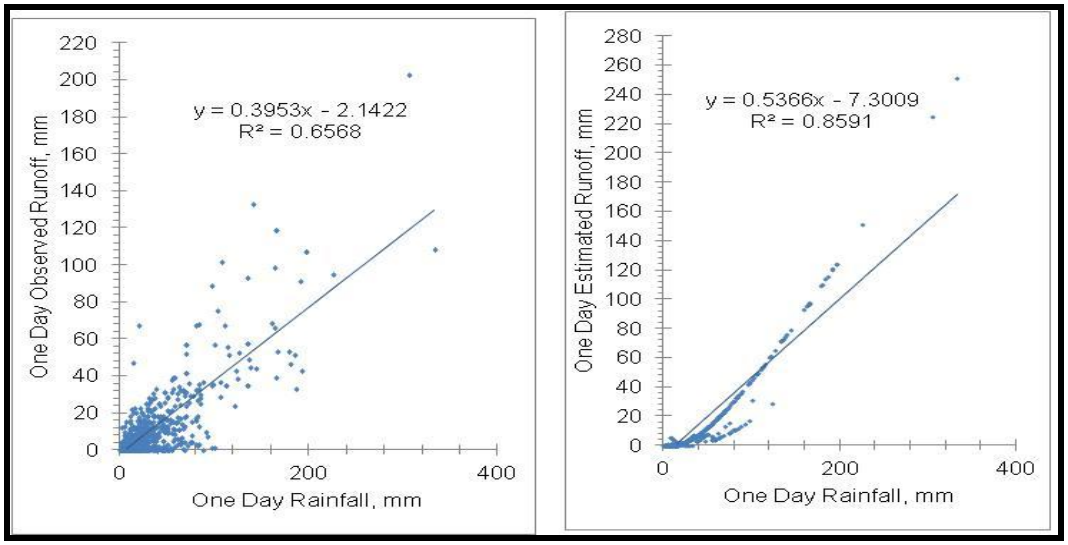

Fig. 4: Daily rainfall vs. observed and estimated runoff for Ozat river catchment

Table 1: Area under different slope groups of Ozat river catchment.

Sr. No.	Slope (%)	Area, km^2
1	Very gently sloping (1-3%)	1017.05
2	Gently sloping (3-8%)	164.80
3	Moderately sloping (8-15%)	77.73
4	River	9.24
5	Rock	140.34
	Total	**1409.16**

[MS received: February 04, 2016] *[MS accepted: March 07, 2016]*