

Article

Assessment of hydro-environmental loss as surface runoff using CN method of Pahuj River Basin Datia, India

Ajay Kumar, Pushpendra Singh Rajpoot

Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna, M.P., India

E-mail: prajpoot179@gmail.com

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Abstract

Datia is a district of Madhya Pradesh, facing problem of water scarcity during maximum part of the year for sustainability of natural ecosystem (biotic and abiotic components and other purposes). Pahuj River is a tributary of Sind River and flows from west to east direction in Datia district. Pahuj river basin covers 911.96 sq km area in central and southern part of district and has 31.25 inches (793 mm) average annual rainfall. Present study aims to assess the surface hydro-environmental loss as surface runoff of water which is received in the basin and passes out within a short time period. Whole basin is inclined towards north east with hilly area in SW and NE area is plain. Curve number (CN) is used for calculation of loss of basin water as runoff of Pahuj river basin. Estimated runoff is 62012.59×10^6 CM which is a huge quantity of hydro-environmental loss. Pahuj River basin has a good surface hydro-environment potential to reduce the water scarcity problem of district. Current situation demands to prepare a proper plan for reducing the losses of surface water of the basin.

Keywords hydro-environment; runoff; CN method; Pahuj River and Datia.

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1 Introduction

The relationship between amount of rainfall and the resulting amount of runoff is mainly dependent on soil infiltration. The type of land use and cover, agricultural management, hydrologic conditions, soil type distribution and soil moisture status, all affect the proportion of water runoff as hydro-environmental loss in a given watershed area. Surface water runoff leads to huge quantity of fresh water loss along with major soil nutrient which is a big environmental loss (Pakrou and Dillon, 2004; Eckard et al., 2004). Method used to estimate rainfall runoff is USDA – SCS (Lamb, 1999), as runoff Curve Number (CN) method (USDA, 1972). The SCS method has been used by many researchers to determine the rainfall runoff relationship (Stuebe and Johnston, 1990; Sharma et al., 2001; Sharma and Kumar, 2002; Mishra et al. 2004; Pandey and Dabral, 2004; Pandey and Sahu, 2004; Pandey et al. 2005; Mishra et al. 2005; Jain et al. 2006). Curve number method depends on land use, management type, hydrologic conditions and hydrologic soil group.

Arnold et al. (1993) prepared a model named SWAT (Soil and Water Assessment Tool) with the help of CN method and Geographic Information System. Using SWAT he simulated runoff of Mississippi large catchment area. By using this method, Bingner (1996) found that mean annual runoff was adequately estimated which is 76% for their watershed. A number of investigators have attempted to develop rainfall runoff relationships that could apply to any region or watershed under any set of conditions (Wasley, 1991). The SCS (SCS 1964, 1975, 1986) (USDA, 1986) represent a useful set of rainfall runoff curves that also include land cover, soil type and initial losses (abstraction) in determining direct runoff.

Pahuj River is a tributary of Sind River and covers 911.97 sq km area of Datia District. Pahuj River flows from south west to north east direction in central & southern part of Datia district (Fig. 1). Datia is the district of M.P. and lies in Sindh -Paluj Doab. Annual average rainfall of Datia district is 31.25 inches (793 mm). Maximum temperature rises up to 47⁰ C in the month of May and minimum temperature goes up to 2⁰ C in the month of January. Natural vegetation is scanty. District faces the problem of water scarcity during most of the part of year for all needs.

The District can be divided in two physiographic divisions, viz. the Lower Extension of Bundelkhand hilly Plateau in SW and the alluvial Plain in NE. The whole district is sloping towards the north-east.

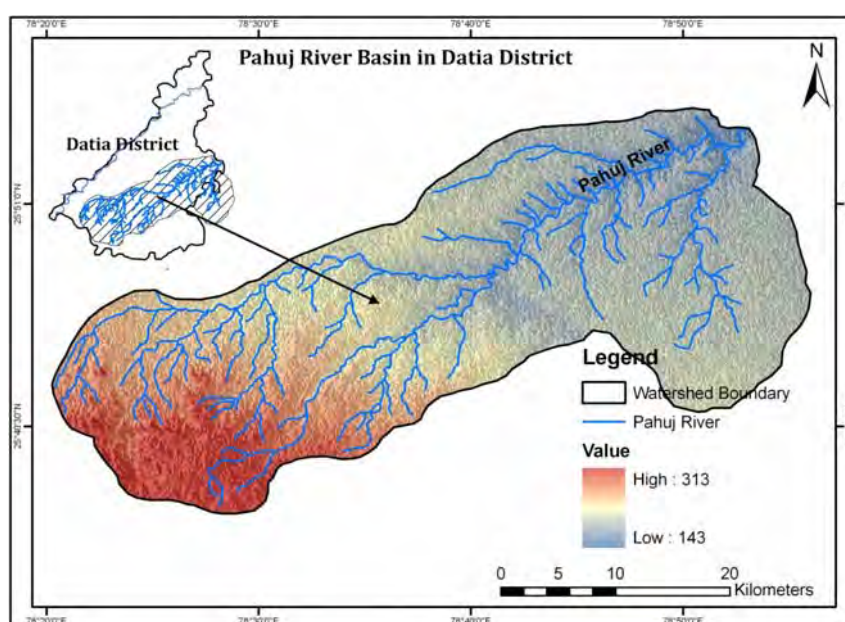


Fig. 1 Location map of study area.

2 Materials and Methodology

To assess the hydro-environmental loss of rainfall water as surface runoff, needful thematic layer of soil type of study area is prepared using geological survey of India and LANDSAT-7 ETM+ (2006) image is used for preparation of land use/land cover classes of study area. Curve number method is used for estimation of runoff.

The Curve Number Equation is actually a relationship between runoff volume and rain volume and ubiquitously used, especially for rural areas. The basic equation is:

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

where Q is the runoff depth (to get volume, multiply by the watershed area), P is the rainfall depth, I_a is the initial abstraction, and S is the watershed storage.

All units are depth in inches. The initial abstraction is conceptualized as the amount of rain that falls before runoff is initiated; this is usually grossly assumed to be $0.2S$. Eq. is usually written as:

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

The S term is determined indirectly from tables relating qualitative land use information to a runoff index called the Curve Number (CN). The CN is related to S with:

$$S = \frac{1000}{CN} - 10$$

or

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

Land Use / Land Cover of study area has been classified in six classes viz., pastures, crop land, forest, water bodies, built-up area and unused land with wild vegetation. Area under each class has been calculated from the attribute table and given in Table 2. The Land Use/ Land Cover thematic map and soil map are interpreted. Weighted CN for each sub area is worked out using the following equation.

$$\text{Weighted Curve Number} = \frac{\sum(CN_i * A_i)}{A}$$

where CN_i = Curve number from 1 to 100, A_i = Area with curve number CN_i , and A = Area of each sub area.

3 Results and Discussion

Pahuj river basin covers southern and central part of Datia district. It flows in north east from south west and cover about around 911 sq km. Highest elevation is 313 meters in south west and lowest elevation is 143 meters is in north east. Stream length is 70 km (Table 1). This shows that average gradient is 24 km/km but digital elevation map prepared (Fig. 2) using contour with the help of GIS technique, shows that maximum slope gradient is in south west part of study area while the north east part has low gradient.

Table 1 Basin parameters of Pahuj River.

Name of the area	Highest Elevation in m	Lowest Elevation in m	Area in Sq. Km.	Perimeter in Km	Stream Length in Km
Pahuj River Basin	313	143	911.97	164.02	70

To calculate the surface runoff various land use types are analyzed and spatially covered area is calculated as shown in Table 2 & Fig. 2. Percent area is representing in Fig. 3.

Table 2 Land use/land cover of Pahuj river basin Datia district.

S No	Land use types	Area sq km	Percent Area	Soil Group
1	Pastures	144.59	15.85	B (Loamy with sandy)
2	Crop land	559.80	61.38	C (Alkaline loamy)
3	Forest	39.77	4.36	B (Loamy with sandy)
4	Water bodies	1.90	0.21
5	Built up area	3.61	0.39	B (Loamy with sandy)
6	Unused land with wild vegetation	162.29	17.79	B (Alkaline loamy with sandy)

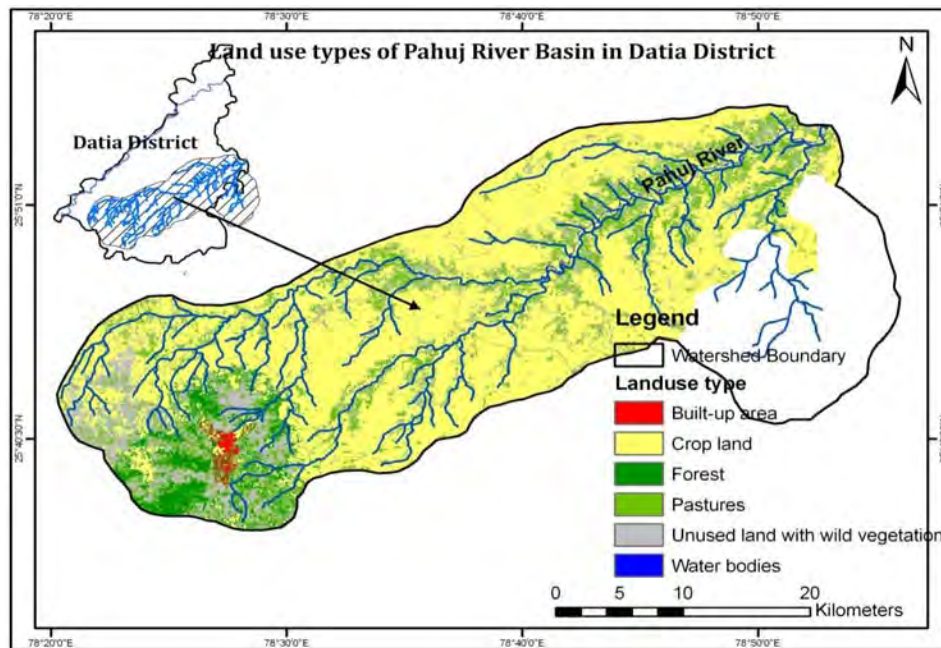


Fig. 2 Land use/land cover map of study area.

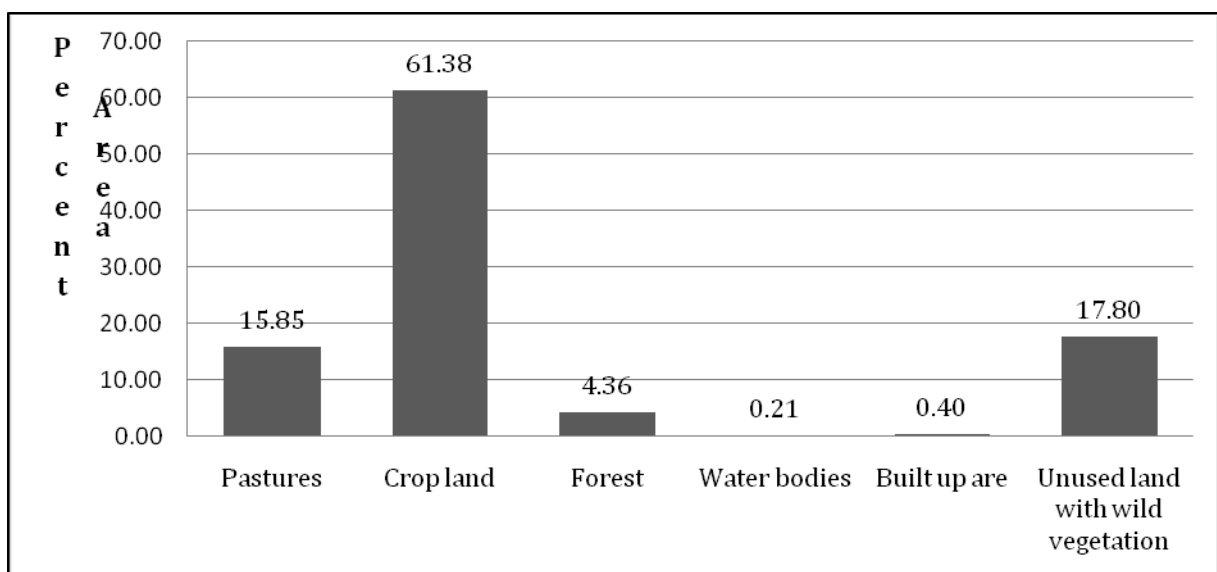


Fig. 3 Land use/land cover in percent of Pahuj river basin.

Loss of basin water as surface runoff of Pahuj river in Datia district is calculated using various parameters and is given in Table 3. Total runoff is 26.83 inches, amounting to total quantity is 62012.59×10^6 CM of Pahuj river basin area. This amount shows that Pahuj river basin, with normal average rainfall is having a good hydro-environmental.

For basin area of 911 sq km within Datia district, amount of water loss as surface runoff 62012.59×10^6 CM is a huge amount and demand proper management to reduce the hydro-environmental loss of the area as surface runoff. DEM of Datia district and basin area of Pahuj River can be divided in to two parts, high slope area and low slope to almost plain area. High slope area is about 40 % from where maximum runoff takes place due to high slope and rocky surface with thin soil cover and plain area is about 60 % with thick soil cover agricultural field. For management of the basin area, surface runoff to be checked by accumulation of water by minor check dam/ ponds in SW (high slope area) while the in NE part of the basin (plain area), surface runoff of the water to be reduced by agriculture field bunding and small pond system.

Table 3 Runoff calculation of Pahuj river basin.

S No	Land use types	Curve Number (C _{Ni})	Area sq km (A _i)	C _{Ni} *A _i	Weighted CN $\frac{\sum(CN_i \cdot A_i)}{A}$	Runoff (Inch) $\frac{(P-0.25)^2}{P+0.85}$	Runoff (CM)
1	Pastures	77	144.59	1113373.8	71	26.83	62012.59×10^6
2	Crop land	67	559.80	3750681.105			
3	Forest	77	39.77	306274.815			
4	Water bodies						
5	Built up area	77	3.61	27778.905			
6	Unused land with wild vegetation	77	162.29	1249674.773			
	Total		A= 91007.62	$\sum(CN_i \cdot A_i) =$ 6447783.398			

*Rainfall (P) = 31 inches

4 Conclusion

Pahuj River is a tributary of Sind River and covers a major part of Datia district. Average slope gradient of this basin is 24 m/km. Southwestern part is hilly and north eastern part is almost plan with thick soil cover. Maximum hydro-environmental loss as surface runoff occurs in SW region. Annual loss of rain water as surface runoff of study area is calculated by CN method and total runoff is 62012.59×10^6 CM. Pahuj river basin has a good hydro-environmental potential to reduce the water scarcity problem. It is recommended to prepare proper management plan and reduce hydro-environmental loss of Pahuj river basin area.

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