HYDROLOGICAL EVALUATION OF AGRICULTURAL WATERSHED IN UTTAR PRADESH

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Abstract

In the present study Universal Soil Loss Equation (USLE) were tested on the event basis for estimating the soil loss and surface runoff and then applied to evaluate the performance of soil conservation structures of Chandaus watershed in U.P State. The topographical and drainage maps of the watershed were used to determine the input parameters of the USLE.

The value of all USLE factors which include rainfall erosivity factor, soil erodibility factor, slope length factor, crop management and conservation practice factors were determined and used for validation of the USLE for estimating the soil loss for the Chandaus watershed. The curve number (CN) for watershed was also determined. Adequately validated USLE was applied for estimating the soil loss. The performance evaluation of soil conservation structures was carried out on the basis of soil loss from watershed and different hydrological parameters based upon standard USLE factor were quantified for Chanduas village.

Keywords: USLE, Hydrological modeling, Watershed modeling, Topographical modeling

Nomenclature

Ω	Highest stream order
θ	Volumetric soil moisture content
A_Ω	Area of watershed
cm	Centimeter
cm/hr	Centimeter per hour
cumec	Cubic meter per second
ha	Hectare
hr	Hour
km	Kilometer
mm	Millimeter
Ni	No. of streams of order i
$Q_B(t)$	Discharge from basin at time t
t	Tonnes

1. INTRODUCTION

'Water' is one of the most important resources for mankind and Soil is other most import resource to grow food crop for human life. One big challenge with soil degradation is top-soil erosion which is a widespread in many parts of the world. The adverse effect of widespread soil erosion is soil nutrient degradation, lower agricultural production, water quality problem, eco-hydrological system problem. Water and soil losses are also the main reasons for sediment entering the reservoirs and these processes potentially reduce water quality. Soil erosion in this area strongly influences the ecological health of the city. Thus, accurate estimation of soil loses and sediment yield from watershed areas is extremely important for determining suitable land use and designing appropriate resource management or soil/water conservation measures.

The watershed receives an average annual rainfall of 1100 mm out of which the monsoon season contributes more than 65% rainfall. About 60-70% of total rainfall occurs between June to September, most of which goes out as runoff resulting continuous depletion and poor recharge of ground water due to high infiltration rate, poor moisture retention capacity and low irrigation potentials as majority cultivated area is rain fed. The daily mean temperature ranges from a maximum of 39^0C to a minimum of 7^0C. The monthly mean relative humidity varies from a minimum of 32% in the month of April to a maximum of 87% in the month of August.

The Universal Soil Loss Equation (USLE) is one of the most significant developments in soil and water conservation. It is an empirical technology applied around the world to estimate soil erosion by rain and surface runoff.

Estimation of soil erosion and sedimentation are needed to select the best management practices for reducing erosion hazard for maintaining the soil productivity and to control sediment yield for erective excessive degradation. This equation is based on large data sets over, 10,000 plots year of data from natural runoff plots and equivalent of 1000 plot year of data from field plots under rainfall simulators. Some limitations of USLE restrict its application in many modeling analysis. First, it is not intended for estimating soil loss from single storm event. Second, it is an erosion equation and consequently it does not estimate deposition [1]. Third, it does not estimate gully or channel erosion. Although USLE has its own limitation, it has considerable use for estimating the long-term average soil erosion from the cultivated field for use in conservation planning. It has also been used to estimate sediment yield to small reservoirs. The aim of their study was to evaluate some other parameter of USLE like Rainfall erosivity, Soil Erodibility, Length slope factor, Crop management factor and conservation practice factor.

1.1 Study area and Description

Chandaus watershed located in the Aligarh district of Uttar Pradesh state has been selected for investigation. *Chandaus* watershed located at about 34 Km away from Aligarh city towards Bulandshahr district. The watershed boundary covering various villages namely Resra, Banjaran ka Nagla, Chamar ka Nagla, *Chandaus*, Gulabgarhi, Nagla Khuba(Kalyanpur), Daigwan, Nagla Bhup Singh, Maihgaura, Marhi, Nagla Badam, Jaraila Nagla, Nagla Ramnagar etc. The watershed lies between $77^0$46' to $77^0$0'E longitude and $28^0$1' to $28^0$64'N latitude. Topographic maps No. 53 H/16 of 1:50000 scale cover the entire watershed. The total area of the watershed comes about to be 5.70 km^2.

1.2 Climate of Study Area

The watershed receives an average annual rainfall of 1100 mm out of which the monsoon season contributes more than 65% rainfall. About 60-70% of total rainfall occurs between June to September, most of which goes out as runoff resulting continuous depletion and poor recharge of ground water due to high infiltration rate, poor moisture retention capacity and low irrigation potentials as majority cultivated area is rainfed. The daily mean temperature ranges from a maximum of 39^0C to a minimum of 7^0C. The monthly mean relative humidity varies from a minimum of 32% in the month of April to a maximum of 87% in the month of August.

Fig. 1 : Chandaus watershed location in Aligarh, Uttar pradesh

1.3 Meteorological data

Observed daily rainfall data recorded at *Chandaus* watershed were collected from Department of Meteorology Bulandshahr, Uttar Pradesh for the monsoon season (July to October) and were used for determination of annual rainfall erosivity index EI_{30}. Other meteorological data including temperature, relative humidity, wind velocity and solar radiation, hydrological data were also collected for the study. Rainfall data were recorded by automatic rain gauge at *Chandaus* watershed and used for estimation of surface runoff and soil loss in the watershed.

1.4 Hydrological data

Hydrological data – daily surface runoff and soil loss data of the study watershed area were used in this investigation. Daily surface runoff and soil loss data for few selected events were recorded at study area Chandaus, with the help of automatic stage level recorder. The data were later used for determination of universal soil loss equation USLE for estimation of surface runoff and soil loss, respectively from the study area.

1.5 Soil resources and topographic data

Soil resources data of *Chandaus* watershed were collected from the Department of Soil Resource and Meteorology, Uttar Pradesh. Soil data such as per cent sand, silt clay and organic matter were used for determining the ‘Soil Erodibility’ factor of USLE. The *Chandaus* watershed is covered in the topographic maps No. 53 H/16 on 1:50,000 scale, which was collected for use from the Department of Soil and Water Engineering, Faculty of Agricultural Engineering, Uttar Pradesh.

2 LAND USE/COVER CLASSIFICATION

Land use refers to man's activities and the various uses, which are carried on land. Land cover refers to natural vegetation, water bodies, rock/soil artificial cover and others resulting due to transformations. Most common land use classification method, the supervised classification, was used in this study.

2.1 Determination of Average Slope

The average slope of the watershed was computed using the standard relation.

$$S = (M*N)/100*A \qquad (1)$$

M = Total length of all contours within the watershed

N = Contour interval

A = Area of watershed

2.2 Estimation of USLE parameters

The USLE factors to a specific location can be given by equation 2 and is most reliable method to estimate soil loss. The equation is given as:

$$\mathbf{A = R * K * LS * C * P} \qquad (2)$$

Where,

A = average annual soil loss (ton $ha^{-1}hr^{-1}$)

R = rainfall erosivity factor in MJ.mm. $(ha.h.y)^{-1}$

K = soil erodibility factor in ton ha^{-1}

LS = slope length gradient factor

C = crop/vegetation and management factor

P = conservation practices factor

2.3 Calculation of Soil Erosivity Index (EI_{30})

The R factor rainfall erosivity index, EI_{30} is the main agent of soil erosion and transportation are raindrop and the surface flow of water. The R factor was determined by both rainfall and energy imparted to the land surface by the rain drop impact. Wischmeier found that one hundredth of the product of the kinetic energy of the storm KE and the 30 min. intensity I_{30} is the most reliable single estimate of rainfall erosion potential and termed it as EI_{30}. Annual total of storm EI_{30} value is referred to as the rainfall erosion index.

$$KE = 210.23 + 89*\log(I) \qquad (3)$$

Where

KE = Kinetic energy in Jm^{-2} cm^{-2} of rain

I = Rainfall intensity in cm hr^{-1}

$$EI_{30} = \text{Total KE} * I_{30(max.)}/100 \qquad (4)$$

Where,

EI_{30} = Erosion index

Total KE = Sum of kinetic energy in Jm^{-2}

$I_{30(max.)}$ = Maximum rainfall intensity for 30 minute duration.

2.4 Determination of Soil Erodibility factor (K)

Soil erodibility factor (K) is the function of physical characteristics of soil and its management including both land and crop management. Direct measurement of erodibility factor from run-off plot is costly and time consuming. In India, there is a wide variation in the soil of different agro-climatic regions and it would not be possible to evaluate the soil erodibility factor K of this soil from runoff plot studies. The soil erodibility factor for the watershed was determined by weighting its value Ki for each soil in the watershed according to the area encompassed by the soil as

$$K = \frac{1}{A_D} \sum K_i A_{D_i} \qquad (5)$$

Where A_D is the watershed area, N is the number of different soil area in the watershed.

2.5 Slope-length factor (L)

Slope length may be defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition being or the runoff water enters a well-defined channel.

The plot data showed that average soil loss per unit area is proportional to the power of slope length. Because L is the ratio of field soil loss to the corresponding loss from 22.13m slope length, its value mass may be expressed as

$$L = (\lambda/22.13)^m \qquad (6)$$

Where, λ is field slope length in m and m assumes the value of 0.2 to 0.5 and in very rare case up to 0.9 depending on the gradient of slope.

2.6 Slope gradient factor (S)

S is the slope steepness factor and is the ratio of soil loss from the slope gradient to that from 9 per cent slope under otherwise identical condition. Wischmeier and Smith [1] gave an equation to calculate slope gradient as,

$$S = 65.41\mathrm{Sin}^2\theta + 4.56\mathrm{Sin}\theta + 0.065 \qquad (7)$$

2.7 Topographic factor (LS)

Although L and S can be calculated separately, combining the land cover factor together and considering the two as a single topographic factor have further simplified the procedure. The new equation combining the effect of L and S factor is as follows

$$LS = (\lambda/22.13)^m (65.41\mathrm{Sin}^2\theta + 4.56\mathrm{Sin}\theta + 0.065) \quad (8)$$

Where, λ is the slope length in m, θ is the angle of slope and m is exponent factor varying from 0.2 to 0.5

2.8 Determination of Crop/vegetation and management factor (C)

The cropping management factor C is the expected ratio of soil loss from land cropped under specific condition to soil loss from clean, tilled fallow on identical soil and slope and under the same rainfall.

The value of C factor was taken from Table 3.5 prescribed by [1]. The land use/land cover map of *Chandaus* watershed was used for this purpose. Wischmeier and Smith [1] sub-divided the crop season in to 6-growth period. The cover factor for various types of crop and the 6 cultivated stages have been given in a series of table in [1].

2.9 Determination of vegetation practice factor P

The vegetation practice factor P is the ratio of soil loss with a specific supporting practice to the corresponding with up-and-down cultivation. This factor of each micro-watershed under *Chandaus* watershed was estimated based on mechanical Soil Conservation measure as suggested by [1].

3 RESULTS AND DISCUSSION

The results related to evaluation of soil conservation structures are given in this chapter. The factor affecting runoff and soil loss that is rainfall erosivity factor EI_{30}, slope length factor LS, cropping management factor C and support practice factor P also given in this chapter. Analysis of rainfall data, determination of kinetic energy is also given in this chapter.

3.1 Rainfall Erosion Index (R)

Season wise kinetic energy for the *Chandaus* watershed is given in Table 4.1 for two years (2010-2011). The kinetic energy generally occurred during monsoon season (June to September). In this study it was found that kinetic energy was high during the months, July to October and negligible during the months November and December.

Season wise erosion index value EI_{30} of *Chandaus* watershed is given in Table 1. The table shows that the maximum seasonal value of R factor was found 34.9 in month of August 2003 followed by 20.3 in July, and the minimum seasonal value 14.1 in the month of October followed by 20.3 in October. It is also clear from the table that the maximum seasonal value of R factor was 26.3 in year 2004 in the month of June and the minimum seasonal value was 9.6 in October. The average seasonal (July to December) R factor value was calculated and found to be 86.25 for the *Chandaus* watershed.

Table 1. Values of Hydrological parameters in *Chandaus* watershed

Month	KE		EI_{30}		Rainfall (mm)	
	2010	2011	2010	2011	2010	2011
June	0	2299.9	0	26.3	63.9	321.7
July	1138	3004.1	20.3	25	365.1	408.9
August	3050	1342.3	34.9	13	752.2	120.5
September	1909	451.8	20.3	9.6	399.5	12.1
October	1309	430.1	14.1	9	33.1	0
November	-	0	-	0	0	0
December	-	0	-	0	0	0

3.2 Soil Erodibility Factor (K)

The value of K factor for *Chandaus* watershed is 0.21 ton.ha.hr. The value of K depends on organic matter and soil texture. Organic matter of *Chandaus* watershed varied from 0.23 to 0.26 percent. The sand, silt and clay particles varied from 40 to 54, 33 to 35 and 13 to 24 percent.

3.3 Slope Length factor (LS)

The Slope length factor for *Chandaus* watershed was calculated using slope length and average slope gradient. The average slope value of watershed was 1.5 percent. The length slope factor was calculated using standard procedure; the value was 1.23.

3.4 Cropping Management Factor (C)

The cropping management factor C in respect of different land use classes Table 2. Showed that Barren land and Fallow land was most erosive crop with 0.40 value of C factor while Shrubs are much appreciable with minimum C factor value of 0.014. The C factor was determined using prescribed procedures and referring standard tables for the Indian condition given by [1]. The C factor were calculated for the *Chandaus* watershed and found to be 0.441.

3.5 Support Practice factor (P)

The value of P factor for *Chandaus* watershed was calculated and found to be 0.67. The value of P factor depends upon support practice, land use type and slope. The value of P factor determine using prescribe procedure and referring standard table for the Indian condition

Table 2. Values of USLE parameters in *Chandaus* watershed

USLE parameters	Value
Average Annual Soil loss (A)	0.077(Ton/ha/hr)
Rainfall Runoff erosivity (R)	86.25 MJ/(ha.hr.y)
Soil erodibility(K)	0.212 (Ton.ha.hr/ha.mj.mm)
Slope Length factor (LS)	1.23
Cropping Management Factor (C)	0.441
Support Practice factor (P)	0.67

4 SUMMARY AND CONCLUSIONS

Soil and water are very important for sustainable agriculture. It is, therefore, necessary to take up measures for their conservation and management for utilizing the best technologies available otherwise; these resources might get depleted threatening the very survival mankind.

Estimation of runoff and soil loss is necessary for soil and water conservation structures, and it serves as basic inputs for evaluation of soil conservation structures. Hydrological research of the watershed is a capital-intensive and time-consuming exercise, which could be minimized by the use of existing models. Several hydrological models ranging from empirical to physically based distributed parameters model have been developed to predict surface runoff, soil erosion and nutrient transport from agricultural watershed under various management regimes.

Among several methods, the Universal Soil Loss Equation (USLE) is the most widely used for estimating the soil loss from the various types of watersheds. The current study deal with the use of USLE, and effectiveness of soil conservation structures, various factor affected for runoff and soil loss, respectively from the *Chandaus* watershed which is comes under the Aligarh city towards Bulandshahr district. The study was undertaken with the major objective to analysis of rainfall data, determination of USLE factor for estimating the surface runoff and soil loss from *Chandaus* watershed.

The *Chandaus* watershed was chosen for the study area it is located between $77^0 46'$ to $77^0 0'$E longitude and $28^0 1'$ to $28^0 64'$N latitude and covers an area of 5.70 km^2. Rainfall data were analyzed for the past three years (2010-2011) for the study watershed. Runoff sample for the selected events were collected from the outlet of the *Chandaus* watershed. The topography maps (1:50,000) and the soil resource data were collected from survey of India and metrological development of Uttar Pradesh.

The value of the several parameters *viz.* runoff curve number, mechanical conservation practices, agricultural conservation practices, surface slope, average slope length, soil erodibility factor and rainfall erosivity factor were considered for watershed.

Overall performance of the USLE was found to be satisfactory. From the data of sediment yield collected at the different soil conservation structures use to evaluate the effectiveness of the structures and it was found that the structure is more effective.

5 REFERENCES

[1] Wischmeier W.H., Smith D.D., *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning,* Agriculture Handbook No. 537. USDA/Science and Education Administration, US. Govt. Printing Office, Washington, DC., 1978.