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STUDY OF SOIL EROSION FOR DIFFERENT LAND USE AND VEGETAL COVERS USING UNIVERSAL SOIL LOSS EQUATION

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A B S T R A C T

The fundamental importance of maintaining soils to meet the food and fiber needs of a burgeoning world population merits the attention and concern of all people. Erosion of soil by water poses an increasing threat as needs for food, fiber production and space for social and economic necessities of a growing population add, pressures to our nation's land resources. The soil loss prediction techniques have developed over many years as understanding of the erosion process expanded and increasingly more erosion research was conducted. Early estimates were primarily qualitative in nature and illustrated that some cultural practices differed in their ability to control soil erosion. Initially, equations were developed to describe soil loss using a single independent variable. These single facator equations were for local situations were developed as more data became available and researchers were better able to describe contributing factors. These analyses culminated in the eqution most widely used today for soil loss prediction the Universal Soil Loss Equation (USLE). The USLE is a highly useful tool for predicting sheet and rill erosion under various conditions of land use and management. Recent investigations have focused on defining the parameters of the USLE for a greater range of conditions. Considerable work continues to define the soil erosion process and, hence, eventually predict soil loss, from a physical basis in contrast with the predominantly empirical soil loss predictions of the past and present.

The Universal Soil Loss Equation was applied to the Chaukhutia catchment of Ramganga River. The Chaukhutia watershed is located between 29°46'15" to 30°6' N latitude and 79°12'15" to 79°31' E longitude in Almora and Chamoli districts of Uttar Pradesh under Ranikhet sub-division of Ramganga reservoir catchment. The area of the watershed is 452.25

sq km with mean length of 30 km and width of 15 km. The maximum elevation of the watershed is 3114.14 m above M.S.L. and the minimum elevation at Chaukhutia is 929.00 m. The average annual total precipitation in the area is 1466 mm which varies from 1205 mm to 1773 mm at different locations. The methods of determination of different parameters and results of universal soil loss equation for predicating soil loss from the above basin are presented in the report.

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1.0 INTRODUCTION

The soil as one of the main resources of the biosphere has been defined by the International Soil Science Society as follow: 'The soil is a limited and irreplaceable resource and the growing degradation and loss of soil means that the expanding population in many parts of the world is pressing this resource to its limits. In its absence the biospheric environments of man will collapse with devasting results for humanity'. One of the first scientists to assess the dimension of world soil erosion was geologist Sheldon Judson, who estimated in 1965 that the amount of river-born soil carried into the oceans had increaed from 9.9 billion tons a year before the introduction of agriculture, grazing, and related activities to 26.5 billion tons a year. Hydrologists estimate that one fourth of the soil lost through erosion in a river's watershed actually makes it to the ocean as sediment. The other three-fourths is deposited on footslopes in reservoirs, in river flood plains and other low-lying areas, or in the river bed itself, which often causes channel shifts.

Soil and land use have become extremely competitive not merely in India but all over the world because of the tremendous pressure of growing population in recent years. The problems of soil erosion in India, their extent, severity and nature vary greatly in different parts of the country depending upon climate, topography, soil, land use and also in the pattern of agricultural economy and increasing human and livestock population. In 1975, Indian agricultural scientist estimated that 6.6 billion tons of soil are eroded from India's cropland each year and about 60% of the cropland is eroding excessively. An estimated area of about 175 million hectares constituting 53.3 percent of Indian's geographical area of 328 million hectares is subject to various kinds of degradation problems. Active soil erosion, by water and wind, alone accounts for over 140 million hectares with amounts to about 6,000 million tonnes of fertile soil causing a nutrient loss of about 5.53 million tonnes of NPK casting around Rs. 700 crores. About 1572 million tonnes are washed into the sea while 480 million tonnes are getting deposited in various reservoirs of India. At present days, soil erosion is taking place at the rate of 16.35 ton/ha./annum which is more than the permissible limit of 4.5 - 11.2 ton/ha/annum.

The rainfall erosion research began with the work of a German scientist, Wollny (1988) in the last quarter of the 19th century but the systematic study on the soil loss prediction from agricultural fields was conducted in United States beginning around in 1930's. Cook (1936) gave mathematical relationship between the factors which cause soil erosion and listed three factors: (1) the susceptibility of soil to erosion (soil erodibility), inclulding need for tests to evaluate an erodibility index, (2) the potential erosivity of rainfall and runoff, including the influence of degree of slope and slope length, and (3) the degree of protection afforded by vegtal cover. Later the concepts of empirical soil loss equations and specified soil loss limits began around 1940 with the work of Smith and Zingg in Missouri (U.S.A.). In the year 1947, a committee chaired by Musgrave proposed a soil equation having some similarity to the present day Universal Soil Loss Equation (USLE). The USLE concept of a generally applicable equation, with its basic soil loss rate and all its factors freed of geographically oriented reference points and regional boundaries, was developed in the 1950's from analysis at the ARS Data centre at Purdue. Wischmeier and Smith (1965) developed a methodical procedure from statistical analyses of more than 10,000 plots years data from about 50 locations in 24 states and this equation is known as USLE. This equation was later modified with more recent data from runoff plots, rainfall simulations, and field experience (Wischmeier and Smith, 1978). The USLE was developed to provide a means of estimating longtime average soil losses in runoff from specified field areas under specified cropping and management practices. This equation predicts only the losses from rill and sheet erosions under a specified conditions. The USLE is one of the most convenient working tool for conservationists. It enables land management plnners to estimate average annual erosion rates for a range of rainfall, soil, slope, crop, and management conditions and to select alternative land use and practice combinations that will limit erosion rates to acceptable levels. This equation involves six major factors that affect upland soil erosion by water, rainfall erosiveness, soil erodibility, slope length, slope steepness, cropping and management techniques, and suporting conservation practices. The six variables involved in the erosion process are inter related in the fig.1.

A is the predicted soil loss per unit of area, computed by multiplying values for the other six factors. As usually used, it is an estimate of the average annual sheet plus rill erosion from rainstorms for field size upland areas. It generally excluded gully or stream bank erosion, snowmelt erosion, or wind erosion, but it includes eroded soil that is deposited before it reaches downslope streams or reservoirs.

R is the rainfall and runoff factor for a specific location.

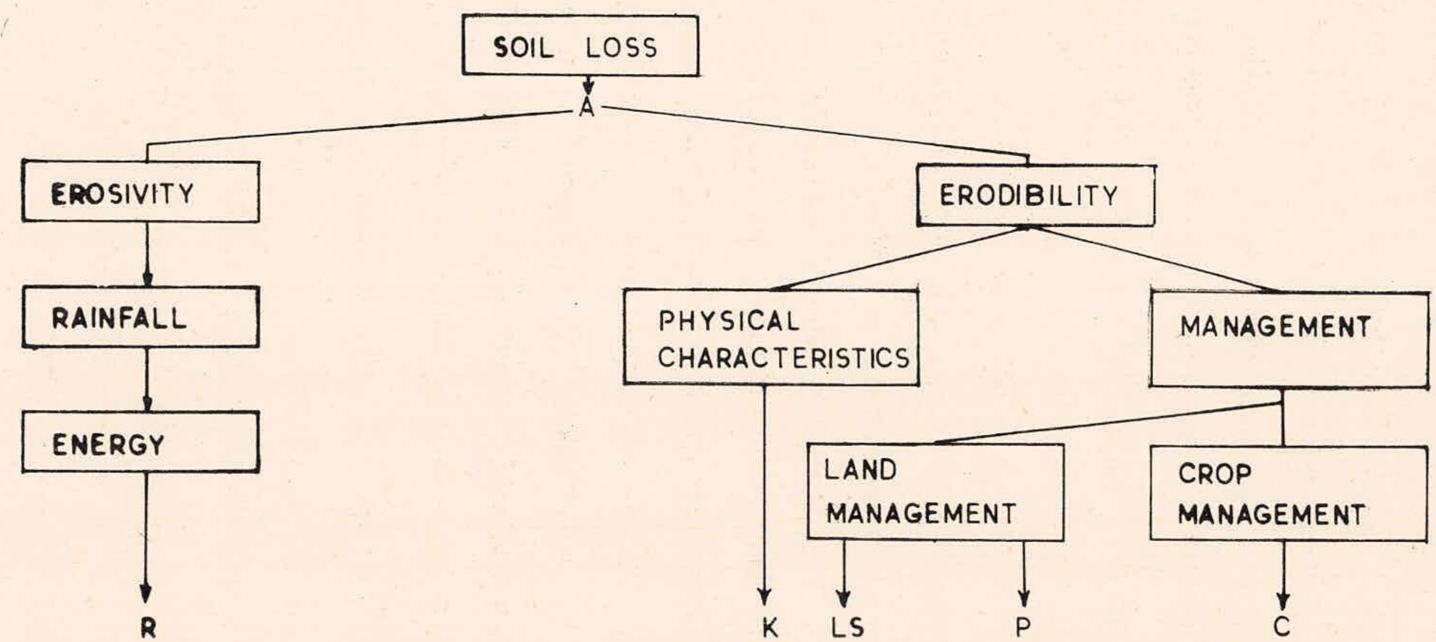


FIG.1 INTER RELATION BETWEEN VARIABLES INVOLVED IN WATER EROSION PROCESS

Usually, R is expressed as average annual erosion index units.

K is the erodibility factor for a specific soil horizon. K is expressed as soil loss per unit of area per unit of R for a unit plot. (A unit plot is 72.6 feet long with a uniform 9% slope, maintained in continuous fallow, with tillage when necessary to break surface crusts. These dimensions were selected because most early erosion research plot in United States were 72.6 feet long with slopes that averaged about 9 percent. Continuous fallow was selected as a base because no cropping system is common to all agricultural areas. Soil loss from any other plot condition would be influenced by residual and current crop and management effects that very from one location to another).

L is a dimensionless slope-length factor, not actual slope length and expressed as the ratio of soil loss from a given slope length to that from a 72.6 feet slope length under same condition.

S is a dimensionless slope-steepness factor not actual slope steepness from a given slope steepness to that from a 9 percent slope under the same conditions.

C is a dimensionless crop and management or cropping management factor and expressed as a ratio of its soil loss from the condition of interest to that from tilled continuous fallow.

P is a dimensionless supporting erosion control practice factor and expressed as a ratio of the soil loss with practices, such as contouring, strip cropping, or terracing to that with farming up-and-down slope.

In the present report, an attempt has been made, to show the

the applicability of the 'Universal Soil Loss Equation' to hilly catchment of Ramganga river to predict stormwise sediment yield for Chaukhutia watershed.

2.0 REVIEW OF LITERATURE

Erosion is caused by rainfall and by surface runoff and is affected by a number of natural and anthropogenic agents. It may be expressed as the relation between the erosivity of rainfall, i.e., the potential ability of rain to cause erosion, and soil erodibility, i.e., the potential ability of rain to cause erosion, and soil erodibility, i.e., the susceptibility of the soil to erosion. Rain as the principal erosion agent was usually characterised by intensity, size of raindrop and raindrop velocity, soil properties were expressed by coefficients showing the effects of soil texture and structure on the soils and by other factors affecting the origination and course of erosion processes, namely, slope gradient, slope length, the vegetative cover etc. This chapter covers a brief review of the work carried out by a number of scientists to interrelate these factors with the aim of obtaining erosion intensity expressed by soil loss from a soil unit over a unit of time.

2.1 Development of USLE

The basis for the mathematical relationships describing soil erosion probably bagan with efforts such as those by Cook (1936) to identified the major variables involved. Cook listed three factors: (1) Soil erodibility, i.e, the susceptibility of soil to erosion including the need for test to evaluate an erodibility index, (2) the potential erosivity of rainfall and runoff including the influence of degree of slope and slope length, and (3) the degree of protection afforded by vegetal cover. Cook also described in detail the subfactors affecting each factor. Use of equations to calculate field soil loss began when Zingg (1940) published the results of his comprehensive study on the effect of degree of slope (S) and slope length (L) on soil loss (X). Zingg recommended the following relationship:

$$X = C\,S^{1.4}\,L^{1.6} \quad \ldots (1)$$

in which C is a constant of variation and X is the total soil loss or

$$A = C\,S^{1.4}\,L^{0.6} \quad \ldots (2)$$

where A is the average soil loss per unit of area.

The following year, Smith (1941) added crop (C) and supporting practice (P) factors to the equation and proposed a following form of equation:

$$A = C\,S^{7/5}\,L^{3/5}\,P \quad \ldots (3)$$

Smith used this equation to develop a graphic method for selecting the necessary conservation practice on Shelby and associated soil in the Midwest. The C-factor included effects of weather and soil as well as cropping system. Smith also introduced the concept of a specific annual soil loss limit for midwestem soils. Browning et.al. (1947) added soil erodibility and management factors and prepared more extensive tables of relative factor values for different soils, rotations, and slope lengths. This approach emphasized the evaluation of slope-length limits for different cropping systems on specific soils and slope steepness with and without contouring, terracing, or strip-cropping. The National Committee of U.S.A. (1946) presented and adopted the cornbelt equation. They added a rainfall factor in the land slope practice method and suggested the following equation which is also known as the Musgrave equation:

$$A = F.C. \frac{S_g^{1.35}}{10} \; \frac{L^{0.35}}{72.6} \; \frac{P_{30}^{\,1.75}}{1.375} \quad \ldots (4)$$

where A is the sheet erosion in tons/acre,F is the soil factor ;basic erosion rate in tons/acre/year, C is the cover factor, and P_{30} is the maximum 30 minutes duration 2year frequency rainfall in inches. The so called Musgrave equation that resulted included factors for rainfall, flow characteristics of surface runoff as affected by slope steepness and slope length, soil characteristics, and vegetal cover effects. The 1.75 power of the 2 years, 30 minute rainfall was adopted on the rainfall factor. Slope length and steepness exponents were lowered from Zingg's 0.6 and 1.4 (1940) to 0.35 and 1.35 respectively. Annual cover factors were estimated relative to a value of 100 for either continuous fallow or continuous rowcrop. A soil factor was desired by adjusting measured annual soil losses at the experimental locations for differences in rainfall, slope, and cover. Quantitative values for the factors in the equation were limited, particularly for different cropping covers. This earlier equation was further modified by Musgrave (1947) for estimating gross erosion from large, heterogeneous watersheds and for flood abatement programs as

$$A = KCR \frac{S_g^{1.35}}{10} \frac{L^{0.35}}{76.6} \qquad \ldots (5)$$

in which R is the rainfall factor (rainfall erosion index), and K is the soil factor in tons/acre/year/unit rainfall index.

Smith et.al. (1947) presented a method for estimating soil losses from fields of caly-pan soils. They described the effect of slope percentage (S) as

$$A \ \alpha \ a + bS^{314} \qquad \ldots (6)$$

when a and b were constants. The effects of slope length (L) was described as A α $L^{1.6}$. Soil loss ratios at different slopes were given for contour farming, strip cropping, terracing. Recommended slope length limits were presented for contour farming. Relative erosion rates for a vide range of crop rotations were also given.

The following year, Smith et.al. (1942) presented the following rational erosion estimating equation for the principal soils of Missouri:

$$A = C\ S\ L\ K\ P \qquad \text{... (7)}$$

where C factor was the average annual soil loss from claypan soils for a specific rotation on a 3 percent slope, 90 feet long, farmed up-and-down slope. The other factors for slope (S), length (L), Soil group (K), and supporting practice (P) were dimensionless multipliers to adjust the value of C to other conditions. P-factor values were discussed in detail. The work also acknowledged the need for a rainfall factor to make this equation applicable over several states.

Musgrave (1942) discussed the importance of designing agronomic practices to meet specific erosion hazards, and showed how the rainfall erosion hazard changes through the year at different locations in United States, and also stressed the need to use cropping practices that provide soil cover during periods of serious erosion hazards. Graphs to solve the Musgrave equation for use 'on the spot for a specific set of conditions' were prepared by Lloyd and Eley (1952). They tabulated values for many major conditions in the northeastern states.

Van Doren and Bartelli (1950) proposed following erosion equation:

$$A = f\ (T,S,L,P,K,I,E,R,M) \qquad \text{... (8)}$$

where A was annual estimated soil loss, T was measured soil loss, S was steepness of slope, L was the length of slope, P was practice effectiveness, K was soil erodibility, I was intensity and frequency of 30-minute rainfall, E was previous erosion, R was rotation effectiveness, and M was management level. The key value for T was 3.5 tons per acre for Flanagan silt loam on a 2 percent slope, 180 feet long, cropped continuously to corn. Estimates of other conditions were made using $S^{1.5}$ and $L^{0.38}$ ($L < 200$ feet) or $L^{0.6}$ ($L > 200$ feet). Other factor values were given in tables and graphs for application on soils and cropping conditions throughout Illinois.

In 1955, SCS state conservationists in nine midwestern states requested the latest available information on the slope-practice approach, Powered this end, joint conferences of personnel from SCS, the Soil and Water Conservation Research Branch of the Agricultural Research Service, and Cooperating State Agencies were held at Purdue University in Feburary 1956 and July 1956. This group concentrated its efforts on reconciling differences among existing soil-loss equation and extending this technique to regions where no measurements of erosion by rainstorm had been made. The equation considered at these workshope was

$$A = C \times M \times S \times L \times P \times K \times E \qquad \ldots (9)$$

in which A was estimated soil loss, C was a crop rotation factor (C=100 for continuous corn), M was a management factor (values from 0.5 to 0.8 for different residuse and methods of tillage), S was degree or percent of slope factor ($S \propto$ steepness $^{1.4}$ with continued study of a proposed quadratic relationship), L was the length-of-slope factor ($L \propto$ length $^{0.5+0.1}$), P was a conservation practice factor (specific values for slope groups from 1.1 to 24%), K was the soil erodibility factor (each soil given a value of 0.75, 1.0, 1.25, 1.5 or 1.75) and E was a previous erosion factor (not evaluated, but considered when establishing the permissible soil loss limit for each soil).

Subsequent efforts by (Wischmeier and Smith, 1960) led to combination of the crop rotation and management facators and to a rainfall factor for the states east of the Rocky mountains. The resulting universal soil loss equation was introduced at a series of regional soil loss prediction workshops from 1959 through 1962. Which was revised in the year 1978.

Sediment yield is sometimes estimated by estimating gross erosion with the USLE and then multiplying by a delivery ratio to obtain sediment yield (ASCE, 1975). For small watersheds, especially fields, this method is often inadequate and can be lead to totally false conclusions. Thus, it should be used only as a first approximation. A typical delivery ratio for terraces is 0.2 (Wischmeier and Smith, 1978) meaning that 80 percent of the sediment produced on the interterrace interval is trapped in the terrace channel. In many watersheds, especially those large than fields, some deposition usually occurs, the overall sediment yeild response is influenced by a variety of deposition features rather than by a single major feature. When deposition does occur, sediment yield is highly correlated with runoff characteristics, since flow controls sediment transport capacity which is closely related to sediment load when deposition occurs. Williams (1975) modified the universal soil loss equation to estimate sediment yield for individual runoff events from a given watershed by replacing the USLE rainfall erosivity factor with:

$$R = 9.05 \, (VQ_p)^{0.56} \qquad \ldots (10)$$

where V = volume of runoff (m^3) and Q_p = peak discharge rate (m^3/sec.). The USLE with this R factor is referred to as the Modified universal Soil Loss Equation or MUSLE.

2.2 Work on USLE in India

Nema et.al. (1978) determined some parameters of the Universal Soil Loss Equation from runoff plot study conducted at Soil Conservation Research Demonstration and Training Centre (ICAR), Vasad. Singh et.al. (1981) evaluated the universal soil loss equation parameters for different regions of the country and presented a report on soil loss prediction research in India. The work showed the applicability of this equation for different land use pattern, soil condition, rainfall conditions, erosion control-practices and topographic conditions. Pratap Narain et al. (1982) presented a method for determination of different parameters of USLE from runoff plot at Soil Conservation Research Centre, Kota. Das (1982) based on the Williams equation proposed the following equation for estimation of sediment yield from Naula watershed of Ramganga reservoir catchment. He also proposed the equation:

$$S_y = 11.8\ (Q.q_p)^{0.257}\bar{K}.L.S.C.P \qquad \ldots(11)$$

where S_y = the sediment yield from watershed in m. tons per storm, Q = the runoff amount in cu.m, q_p = the peak rate in cu-m per second and the other factors remain same. Chinnamani et.al (1982) showed the applicability of the universal soil loss equation in mountain watersheds in semiarid and humid regions. They applied universal soil equation to sixteen subwatersheds (13 from the hills and 3 from the plains) of the Bhivani basin. The soil loss in the basin has been broadly subdivided into eight catagories namely extremely low, very low, low, moderately low to medium, moderately to high, high, very high and extremely high. They also determined the sediment delivery ratio. The values of the permeters of the USLE for the Himalayan sub watersheds of Ramganga river have been determined by Mehta (1986), and Tiwari (1986). They applied USLE equation as determined by Das (1982) and showed the applicability of the equation for the montainuous watersheds of Ramganga river.

3.0 DESCRIPTION OF WATERSHED, INSTRUMENTATION AND COLLECTION OF DATA

The Ramganga is a springfed river and has its origin in the middle Himalayas near Gairsain in Chamoli district of Uttar Pradesh. It traverses a course of 125 km. through parts of Almora and Pauri Garhwal districts before it debouches into the plains at Kalagarh in the Himalaya foot hills. The total area of catchment is 3076.44 sq.km., which is located in Almora, Chamoli, Garhwal and Nainital districts of Uttar Pradesh. The Chaukhutia catchment in one of the 12 sub-watersheds of Ramganga reservoir catchment was considered for sediment yield analysis

3.1 Description of Chaukhutia Watershed

3.1.1 Location and Climate

The Chaukhutia watershed is located between $29^{o}46'15''$ to $30^{o}6'$ N latitude and $79^{o}12'15''$ to $79^{o}31'$ E longitude as shown in figure 2. the climate of the watershed is Himalayan sub-tropical to sub-temperate having the mean annual temperature of about $21^{o}C$. The mean air temperature is highest in the months of May and June and lowest in December and January. The Monthly mean daily maximum temperature is highest ($39^{o}C$) in the month of April while it is lowest ($22^{o}C$) in December. The monthly mean daily minimum temperature is lowest ($1.9^{o}C$) in January and highest ($20^{o}C$) in August. The daily mean temperature remains low during the period of December to February. Lower elevations in the watershed are characterised by hot summer and severe winters, while higher elevations have pleasant summers and very severe winters. Frosts are very common in winters. The area has three distinct seasons, i.e., long winter (October to March), summer (April to mid June) and monsoon (mid June to September).

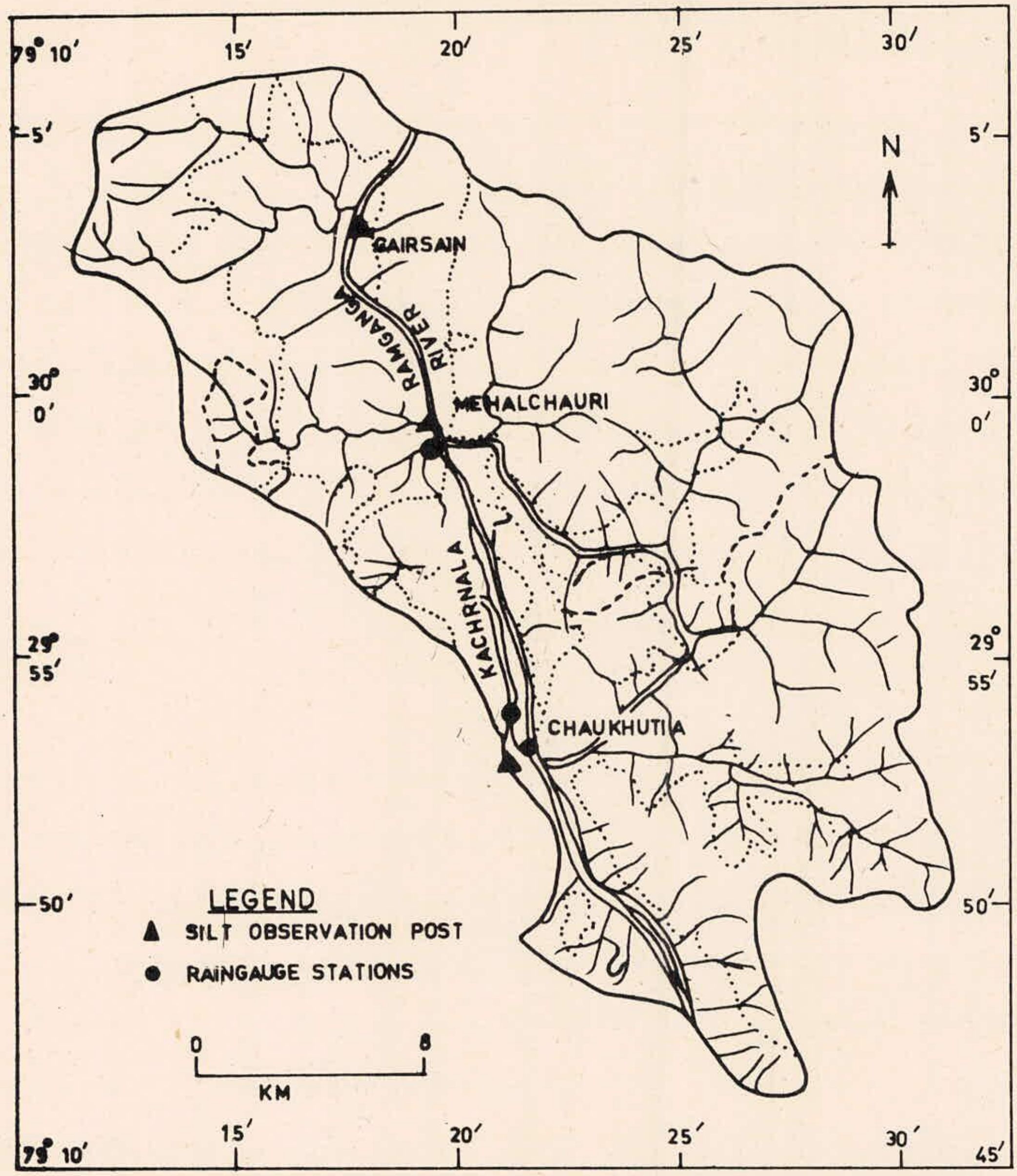


FIG. 2 - LOCATION AND GAUGING STATIONS OF CHAUKHUTIA BASIN

Table 1 Monthly total rainfall (mm) at different rainfall gauging stations

Months	Raingauge stations						Meam total rainfall
	Gairsain	Mahalchauri	Chaukhutia	Bungidhar	Binta	Bhirapani	
January	71 (4.3)	68 (3.8)	50 (3.8)	55 (4.3)	50 (4.3)	57 (4.4)	58.5
February	66 (4.0)	49 (2.8)	47 (3.5)	55 (3.2)	47 (4.0)	47 (3.7)	51.83
March	52 (3.1)	32 (1.8)	37 (2.8)	57 (3.3)	40 (3.1)	42 (3.5)	43.26
April	41 (2.5)	78 (4.4)	33 (2.5)	29 (1.7)	36 (3.1)	35 (2.6)	42.00
May	21 (5.5)	170 (9.6)	57 (4.3)	68 (4)	54 (4.7)	76 (5.9)	74.33
June	209 (12.6)	229 (12.9)	171 (12.9)	181 (10.5)	159 (12.1)	215 (16.8)	194.00
July	411 (24.6)	530 (29.9)	384 (30.6)	488 (26.1)	262 (22.9)	297 (23.3)	395.33
August	445 (26.7)	424 (23.9)	339 (27)	504 (29.3)	310 (27.1)	303 (23.7)	387.50
September	209 (12.6)	135 (7.6)	165 (12.5)	227 (11.2)	160 (14)	153 (12)	174.83
October	30 (1.8)	11 (0.6)	19 (1.4)	24 (1.4)	21 (1.8)	24 (1.9)	21.50
November	13 (0.8)	10 (0.6)	4 (0.3)	3 (0.2)	7 (0.7)	6 (0.5)	7.16
December	21 (1.3)	40 (2.3)	13 (1)	13 (0.8)	12 (1.0)	16 (1.2)	19.16

Note : Figures in the parenthesis are percent of the average annual total rainfall.

Source : The Research Report on Integrated Natural and Human Resource Planning and Management in the Hills of U.P., G.B. Pant University of Agriculture and Technology, Pantnagar (Nainital), Part I, September, 1982.

Table 2 Annual total rainfall (mm) at different rainfall gauging stations

Raingauge stations	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Mean total rainfall
Gairsain	1346	1683	1653	2436	1501	1935	1259	1325	1371	1761	2249	1490	1667.41
Mahalchauri	-	-	-	-	-	-	-	-	1917	1898	1775	1505	1773.75
Chaukhutia	1332	1497	1592	1320	1360	1429	955	1331	1204	1587	1346	882	1208.58
Bungidhar	1283	2102	1450	1681	2114	1955	1418	2133	1478	1856	2082	1087	1719.91
Binta	-	1569	1267	1242	896	1004	761	1280	1415	1432	1319	467	1150.18
Bhirapani	1216	1643	1187	1680	1140	1416	872	1209	1161	1404	1461	980	1280.75
								Average annual total rainfall					1466.76

Source : The Research Report on Integrated Natural and Human Resource Planning and Management in the Hills of U.P., G.B. Pant University of Agriculture and Technology, Pantnagar (Nainital), Part I, september, 1982

Snow-fall occurs at its ridge line and at elevations of more than 1500m above mean sea level, but the snow does not stay for long periods. Severe forsts occur during nights from middle of December to middle of February when winter rains are deficient, and damage fruit crops and vegetables. Most of the precipitation occurs in the form of rainfall from the South-West monsoon occurring from mid June to end of September. Tables 1 and 2 give monthly and annual total precipitation at different raingauge stations located at Bhirapani, Mahalchauri, Gairsain, Chaukhutia, Binta and Bungidhar. July and August are the wettest months of the year as is evident from monthly distribution of rainfall at different locations as given in Table 1.

The average annual total precipitation in the area is 1466 mm which varies from 1208 mm to 1773 mm at different locations, of which 78 percent is received during the four rainy months (June to September). The rest 22 percent is contributed over remaining eight months, of which January and May contribute the larger portion.

3.1.2 Topography

The Chaukhutia watershed is located in the middle and outer ranges of Himalayas and has a total area of 452.25 sqkm (45225 ha) with mean length as 30 km and width 15 km. The shape of the watershed is more or less rectangular. The maximum elevation of the watershed is 3114.14 m above M.S.L. and the minimum elevation at Chaukhutia is 929.00 m. The watershed has extremely undulating and irregular slopes varying from moderate to steep. On the basis of the slopes the land may be classified under three categories, i.e., valley, moderate and steep hills. The valley areas consist of narrow belt located on either side of the river Ramganga. In these areas the cultivation is performed under rainfed and irrigated conditions. The slopes in the valley range from 8 to 10 percent. In moderate hills slope usually very from 10 to 50 percent. The steep hills are generally near the hill tops. The slopes in this particular zone vary from 50 percent to almost vertical hills. Which are covered mostly under permanent cover of grasses, herbs, shurbs and forests. The steep slopes of the land-scape appear to have been formed under the past and present erosion cycles. The bank erosion and bed erosion take place due to steep bed slopes of the drains and torrential rainfall. Denudation seems to be the major process for the development of landscape.

3.1.3 Geological Characteristics

Geological formations found in the Chaukhutia watershed consist mica schists, granitie gneiss and quartzitic sand stone as reported by Satyanarayana et al. (1968). At some places patches of calcarious formation of dolomite stones are also found. Low elevation areas are composed of colluvial material brought from upper reaches. Thin layer of alluvium is observed along the Ramganga river course. As per the report of Singh et al. (1969) the major geological formations within these hills in the increasing order of altitude are: lower Shivalik-characaterised by red and purple sand stone and red shale, upper and middle krol-consisting of dolomite and lime stone, and the lower and infra-krol comprising mainly of quartzite, quartizite-phyllite, garneti ferous mica schist, gnesis granite and graneti-ferous mica and sericite schists. The soil mostly seem to have been derived from coarse textured quartzites. Shales and silty phyllites at some places also seem to have contributed toward soil formation.

3.1.4 Soil Characteristics and Drainage Pattern

The soils of the area have mostly developed from micamuscovite, sand stone and biolite parent material. The soil are primarily coarse textured with mixed stones and gravels. The soil texture varies from charty gravelly loamy sand to silt loam. The soils are dominaced with chert/gravel and soil depth varies from 22.5 cm to 135 cm. The soil is generally immature due to washing away of top soil and continuous biotic interference over most of the area. Soils under the reserved forests are good, and are medium to deep and rich in organic matter. Soils under pastures, waste lands and poorly managed civil and Panchayat forests are severely over-grazed and eroded. Organic matter is medium to high depending on land use. Available nitrogen is generally low. Available phasphorous is mostly medium while the level of availale potassium is mostly high. The soils are slightly acidic to neutral (pH 5.5 to 6.7).

The drainage in the area is pretty dense and has dentritic pattern. The area is mainly drained by rivers Ramganga and Khachar. These rivers have several tributaries spread over the entire area. There are a number of small torrents which go on expanding and creating problems of land sliding and erosion of cultivated lands. The soil have rapid to excessively rapid drainage and thus have low nutrient and water holding capacity. The sheet and rill erosion are common in almost all types of land uses namely pasture lands, waste lands, poorly managed civil and panchayat forests.

3.1.5 Land Use Pattern

The area can be grouped under three categories on the basis of land use pattern viz, forests, cultivated lands and land under grazing, waste and barren lands. The forests in the catchment are mainly of two types viz,civil or panchayat forests and reserved forests. The parts of civil or van panchayat forests managed by Gaon-sabhas are well managed

Table 3. Land use pattern of Chaukhutia watershed

Land use pattern	Area (ha)	Percent of total area
Crop land	12337.38	27.28
Hay land and grazing land	19338.21	42.76
Reserved forest and Wood land	8986.20	19.87
Miscellaneous land	4563.20	10.09

Source : Divisional Office of Forest Department, Ranikhet, U.P.

but most of these forests are open for cattle grazing and have poor vegetable cover. The reserved forests managed by Forest Department of U.P. Government are well managed. The forest has been divided into three categories based on the crown density is the shadow coverage area of the trees when the sun is making a zero zenith angle with the trees, divided by the total area of plots under tree plantation. The open forest has been defined as the area with less than 50 percent crown density, and the dense forest has been defined having more than 75 percent crown density. Cultivated lands are mostly poorly terraced and face severe erosion problem. The grazing and waste lands are severly eroded and have very poor vegetation cover. Land use pattern of Chaukhutia watershed is given in Table 3.

The vegetation of the area may be grouped under two categories viz, cultivated and natural. Cultivated vegetation includes various field and horticultural crops grown on the terraced or unterraced lands. The irrigated terraces are well managed with proper soil conservation practices like shoulder bunds and stone pitched risers. Unirrigated terraces are not so well maintained. According to all India Soil and Land Use Survey Organisation (1980), the area is mostly rained and important field and horticultural crops are paddy, madua, maize, jhingora, wheat, barley, mustard, onion, tobacco, chillies, garlic, potato, mango, citrus, bean, cabbage, plum and cauliflower. Karle et al. (1978) reported that the common forest species in Ramganga catchment are: Sal (Shorea robusta), Khair (Acacia catechu). Chirpine (Pinus longifolia), deodar (Cedrus deodara) and Oak (Quercus incana). At high elevations the most common vegetations are Karondh, Naghphani, Khumuha, Kilmora, Crataegus cerenulata and Barberis asiatica while at lower and mid elevations among grasses Saccharum actoponum, Chrysopogon and Heteropogon are most commonly found. The under growth community includes Dhamphne bholua, Skimnia laureola, Targaria versea, Arundinorea falcate , Indegefera gerardiana, Berberiscycium etc.

3.2 Instrumentation, Measurement and Collection of Data

3.2.1 Instrumentation

The gauging work of Ramganga river flow and collection of silt load data wer initiated in the year 1967 for hydrological studies to assess the effects of soil conservation measures on surface runoff and sedimentation under a centrally sponsored scheme of soil conservation in the Ramganga River valley projecat area. Figure 2 shows the location of automatic raingauges installed both inside and outside of the watershed are at Chaukhutia, Gairsain and Naula, while the non-recording raingauge stations are at Bhirapani, Mehalchauri, Binta and Bungidhar. Silt observation stations alongwith automatic water-stage recorders are installed at Mahalchauri and Chaukhutia in Chaukhutia sub-watershed. The details of the silt observation post installed at Chaukhutia are shown in Figure 3.

3.2.2 Measurements of Rainfall, Runoff and Silt Load

3.2.2 (a) Measurements of Rainfall

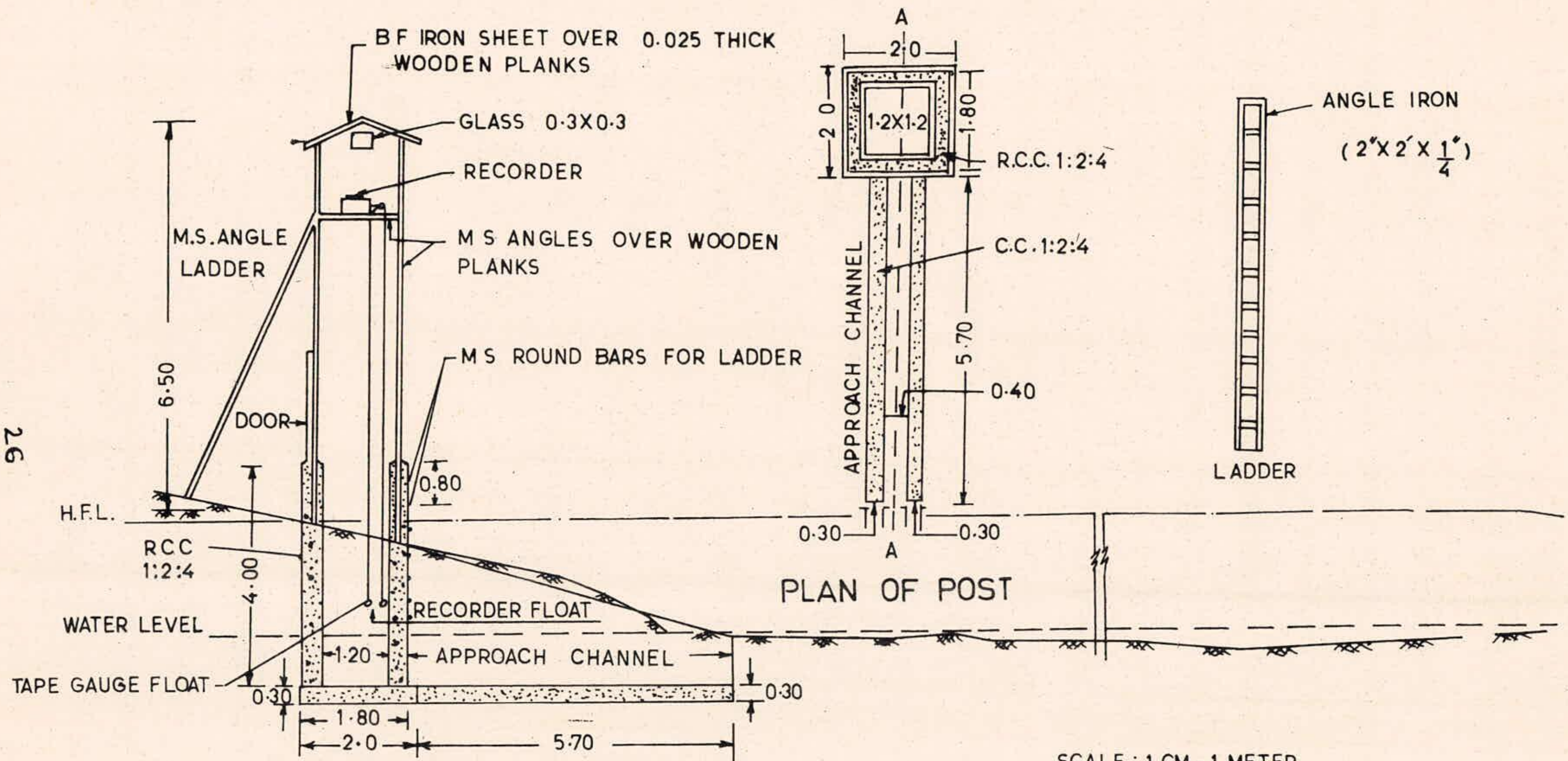
At the raingauge stations rainfall is measured with recording type and non-recording type raingauges. The rainfall is measured in terms of depth as well as its distribution with respect to time using automatic raingauges. In recording type raingauges, raingauge charts are changed at 8.00 A.M. and at the same time total depth of rainfall is also recorded from non-recording raingauges. At the end of each month, the daily precipitation data and rainfall charts are sent to the divisional Forest Office (Soil Conservation) at Ranikhet for permanent record.

3.2.2 (b) Measurements of Runoff

Automatic float type water-stage level recorders are installed at the Mahalchauri and Chaukhutia which give the stage hydrographs. The runoff volume for every 24 hours is calculated from the stage hydrograph on the basis of the gauge discharge rating curves. These curves are developed by the Forest Department (Soil Conservation) using the area-velocity method. The velocity of flood water is generally measured with the help of a float. Runoff measurements are computed in cubic meter per second.

3.2.2 (c) Measurements of Silt Load

Suspended sediment measurements are taken at Chaukhutia and Mahalchauri silt observation posts. Suspended sediment samples of wash load are collected by one liter bottle sampler. During the lean flow season when the suspended sediment is negligible, the sediment sample is collected at 8.00 A.M. only once in a day. During the



VERTICAL SECTION AT 'A-A'

FIG.3 VIEW OF WATER STAGE RECORDER

rainy season, the samples are collected daily at every four or eight hours intervals from as far as it is possible to move in the stream from the river bank. Due to non-availability of boat or craddle device, sample collection in the mid stream and at different depths are not possible during torrential flow.

The sediment samples collected at the silt observation posts are analysed in the laboratory established by Forest Department (Soil Conservation) in order to determine the quantity of suspended sediment. The analysis of suspended sediment samples includes determination of concentration of sediment by weight and textural distribution i.e. coarse, medium and fine according to the size of particles. The quanitative measurement of suspended sediment is reported in cu cm/lit. Based on the days discharge, the quantitative evaluation of suspended sediment is also reported in the volumetric units, i.e. ha-m, for the corresponding period, taking the average density of suspended sediment to be 1.4 gm/cc. These analysed data are sent monthly to the Divisional Forest Office (Soil Conservation), Ranikhet for compilation and record.

3.3 Collection of Data

The required data related to Chaukhutia watershed for the hydrological study were obtained from the Divisional Forest Office (Soil Conservation), Ranikhet. The data related to characteristics of watershed such as topographic features, land use pattern, rainfall and sediment were also collected.

4.0 ANALYSIS OF DATA

In the North West Himalayan region of Uttar Pradesh, land and water are the two most important natural resources. In the absence of any integrated policy for their management, both these resources have been deteriorating over time. The indiscriminate use of land in the these regions is causing devasting erosion of the land surface, silting of reservoirs, and flood in plains. A need therefore, exists in any comprehensive regional planning programme, to examine not only how land and soils are presently used, but managed. In order to quantify the rate of soil erosion from Chankhutia catchment the USLE was applied to the catchment.

4.1 Rainfall and Runoff Factor, R

The rainfall and runoff factor in the USLE is the rainfall erosion index as presented by Wischmeier (1959). The term rainfall erosion index implies a numerical evaluation of a rainstorm or of a rainfall pattern which describes its capacity to erode soil from an unprotected field. Differences in rainfall erosion potential are not necessarily associated with comparable differences in rainfall amount. The various intensities involved in a specific rain, antecedent climatic and surface conditions, interaction effects, and extraneous variable all influence the erosion potential of a storm. Rarely, if ever, is a natural rainstorm exactly duplicated. Values of the respective characteristics may occur in any one of numerous possible combinations. The most useful rainfall erosion index is, therefore, one whose magnitude represents a composite measurement of the various rainstorm characteristics which influence the rate of erosion.

Wischmeier et. al. (1958) concluded from the results of regression analyses that, with soil and slope constant, the most valuable combination of indicators of erosion loses from fallow soil is the following:

i) Rainfall energy

ii) A product term which measures the interaction effect of storm energy and maximum prolonged intensity

iii) Antecedent moisture index

iv) Total antecedent rainfall energy since the last tillage operation

The most accurate single composite erosion index found in the studies is the second of the four variable listed above. The magnitude of the variable for a given storm is the product of the storm energy in foot-tons per acre and its maximum 30-minutes intensity in inches per hour. This product, designated by EI, provides a measure of the specific manner in which energy and prolonged intensity are combined in the storm. Commonly occuring values of the EI term for individual erosion-producing storms range from about 100 to slightly more than 10,000. By dividing the EI values by 100, a rainfall erosion index is defined whose magnitude for a single storm usually lies within the very convenient range 1 to 100.

4.1.1 Computation of rainfall energy on per storm basis

The energy of a rainstorm is a function of the amount of rain and of all the storm's component intensities. Median raindrop size increases with the rain intensity (Wischmeir and Smith, 1950), and terminal velocities of free falling waterdrops increase with increased drop size (Gunn and Kinzer, 1949). Since the energy of a given mass in motion is proportional to velocity-squared, rainfall energy is directly related to rain intensity. The relationship in metric units is expressed by Wischmeier and Mannering (1969) by the equation,

$$KE = 210.3 + 89 \log I \qquad \ldots (12)$$

where KE is the kinetic energy in meter tonnes per ha-cm, and i is the rainfall intensity in cm per hr.

In order to compute the kinetic energy of a rainstorm, the storm rainfall charts were divided into 0.5 hour of intensity increments. Equation 12 was utilized in computation of kinetic energy for each intensity increment of 0.5 hour. The total kinetic energy (KE) of the storm was obtained by summing up all the kinetic energy values for each 0.5 hour intensity increment. The kinetic energy for each intensity increment of 0.5 hour is given in Table 4 to 7. The energy of successive increments is in tonnes-meter per hactare per centrimeter the kinetic energy is in tonnes meter perhectare and the sum of the kinetic energy in tonnes meter per hectares gives the total energy of rainstorm.

4.1.2 Determination of erosion index (EI_{30}) values on storm basis

Wischmeier and Smith (1958) stated that the rainfall energy itself is not a good indicator of erosive potential. The total energy of storm indicates the volume of rainfall and runoff, but a long slow rain may have the same value of E as a short term rain at a much higher intensity. The erosion of the soil increases with the increase in the rainfall intensity. The prolonged peak rates of detachment and runoff are indicated by the I_{30} component. The statistical product term EI_{30} measures the interaction that reflects how total energy and peak intensity are combined in each particular storm. The detachment of soil particles and its combiation with the transport capacity is technically indicated by the product term EI_{30}.

The erosion index (EI_{30}) values for each storm was determined as the method suggested by Wischmeier and Smith (1958). The product term EI was expressed as:

$$EI_{30} = \frac{KE \times I_{30}}{100} \qquad \ldots (13)$$

where EI_{30} is the erosion index, KE is the total storm kinetic energy in tonnes meter per hectare and I_{30} is the maximum 30 minute intensity of rain storm. the successive increments of 0.5 hours of the rainfall amount, the rainfall intensity of 0.5 hour rainfall in cm per hour and

Table: 4 Estimation of erosion index (EI_{30}) for the storm event of July 17, 1983

Time hr.	Amount of rainfall in 0.5 hour cm	Rainfall intensity in 0.5 hour I cm/hr	Kinetic energy t-m/ha/cm	Kinetic energy of rainfall in 0.5 hour, KE t-m/ha	Max^m 30 min. intensity, I_{30} cm/hr	$EI_{30} = \frac{KE.I_{30}}{100}$ t-m-cm/ha-hr
12.30	0.038	0.076	110.69	4.206		
1.00	0.068	0.136	133.18	9.056		
1.30	0.343	0.686	195.73	67.135		1.820
2.00	0.463	0.926	207.32	95.989	0.926	
2.30	0.067	0.134	132.61	8.884		
3.00	0.081	0.162	139.94	11.335		

Table 5 Estimation of erosion index EI_{30} for the storm event of August 22-23, 1983

Time	Amount of rainfall in 0.5 hour	Rainfall intensity in 0.5 hour I	Kinetic energy,	Kinetic energy of rainfall in 0.5 hour K.E.	Max^m 30 min intensity I_{30}	$EI_{30} = \frac{KEI_{30}}{100}$
hr	cm	cm/hr	t-m/ha/cm	t-m/ha	cm/hr	t-m-cm /ha-hr
23.0	0.075	0.150	136.97	10.272		
23.30	0.120	0.240	155.13	18.616		
24.0	0.355	0.710	197.06	69.957		
0.30	0.360	0.720	197.60	71.136		
1.00	0.765	1.530	226.73	173.45	1.530	7.512
1.30	0.362	0.724	197.81	71.609		
2.00	0.083	0.166	140.88	11.693		
2.30	0.069	0.138	133.74	9.228		
3.00	0.086	0.1[illegible]	142.26	12.234		
3.30	0.100	0.200	148.09	14.809		
4.00	0.085	0.170	141.80	12.053		
4.30	0.106	0.212	150.34	15.936		

Table : 6 Estimation of erosion index (EI_{30}) for the storm event of July 20, 1984

Time	Amount of rainfall in 0.5 hour	Rainfall intensity in 0.5 hour I	Kinetic energy,	Kinetic energy of rainfall in 0.5 hour K.E.	Max^{m} 30 min. intensity I_{30}	$EI_{30} = \frac{KE.I_{30}}{100}$
hr	cm	cm/ha	t-m/ha/cm	t-m/ha	cm/hr	t-m -cm /ha-hr
10.30	0.011	o.o22	62.77	0.690		
11.00	0.017	0.034	79.60	1.353		
11.30	0.398	0.796	201.48	80.189	0.796	2.786
12.00	0.351	0.702	196.62	69.015		
12.30	0.273	0.546	186.91	51.026		
13.00	0.245	0.490	182.72	46.412		
13.30	0.282	0.564	188.16	53.062		
14.00	0.231	0.462	153.66	35.495		
14.30	0.043	0.086	115.47	4.965		
15.00	0.046	0.092	118.07	5.431		
15.30	0.017	0.034	79.60	1.353		
16.00	0.014	0.028	72.09	1.009		

Table 7 Estimation of erosion index (EI_{30}) for the storm event of August 18-19, 1984

Time hr	Amount of rainfall in 0.5 hour cm	Rainfall intensity in 0.5 hour, I cm/hr	Kinetic energy, t-m/ha/cm	Kinetic energy of rainfall in o.5 hour, KE t-m/ha	Max^m 30 min. intensity I_{30} cm/hr	$EI_{30} = \frac{KE.I_{30}}{100}$ t-m-cm /ha-hr
19.00	0.149	0.298	163.50	24.362		
19.30	0.343	0.686	195.73	67.136	0.686	
20.00	0.156	0.312	165.27	25.783		2.244
20.30	0.139	0.278	160.81	22.353		
21.00	0.115	0.230	153.49	17.651		
21.30	0.148	0.296	163.24	24.160		
22.00	0.105	0.210	149.97	15.747		
22.30	0.092	0.184	144.86	13.327		
23.00	0.053	0.106	123.55	6.548		
23.30	0.177	0.354	170.16	30.118		
24.00	0.098	0.196	147.31	14.436		
0.30	0.132	0.264	158.82	20.964		
1.00	0.090	0.180	144.01	12.961		
1.30	0.047	0.094	118.90	5.588		
2.00	0.079	0.158	138.98	10.979		
2.30	0.085	0.170	141.80	12.053		
3.00	0.023	0.046	91.28	2.099		
3.30	0.013	0.026	69.23	0.900		

the maximum 30 minutes intensity of the storm events of July 17, 1983, August 22-23, 1983, July 20, 1984, and August 18-19, 1984 are given in Tables 4 to 7 respectively. The computation procedure of erosion index (EI_{30}) values for these storm events one also given in Table 4 to 7.

The monthly, seasonal and yearly EI values will be determined by adding the storm EI values for that length of period. In case erosion index values are desired for any particular week, season or growing period etc. the storm EI values for that length of time may be summed up.

4.2 Determination of Soil Erodibility Factor, K

The Soil erodibility, K, in the Universal Soil Loss Equation is a quantitative description of the inherent erodibility of a particular soils. The meaning of the term soil erodibility is distinctly different from that of the term 'soil erosion'. The rate of soil erosion in the USLE may be influenced more by land slope, rainstorm characteristics, cover and management than by inherent properties of the soil. However, some soils erode more readily than others even when all other factors are the same. The difference caused by properties of the soil itself, is referred to as the soil erodibility.

The soil erodibility factor, as described by Wischmeier and Smith (1965) is a function of complex interacation of a substantial number of its physical and chemical properties. Even a soil with a relatively low erodibility factor may slow signs of serious erosion when it occurs on longer or steep slopes or in localities with numerous high intensity rain storm. A soil with a high natural erodibility factor, on the other hand, may show little evidence of actual erosion under gentle rainfall, or when the best possible management is practiced. For a particular soil the erodibility factor, K, is the rate of erosion per unit of erosion index from a standard plot.

The United States Department of Agriculture (1978) suggested a nomograph as shown in fig. 4 and the following equation for determination of soil erodibility for soils containing less than 70 percent silt and very fine sand:

$$100\ K = 2.1M^{1.14}(10^{-4})\ (12-a) + 3.25\ (b-2) + 2.5(c-3) \quad ..(14)$$

Here K is the soil erodibility factor, M is the particle size parameter which is equal to (percent silt + very fine sand) (100 - percent clay), a is the percentage of organic matter content, b is the soil structure code used in soil classification and c is the profile permeability class. The soil erodibility factor for different land use

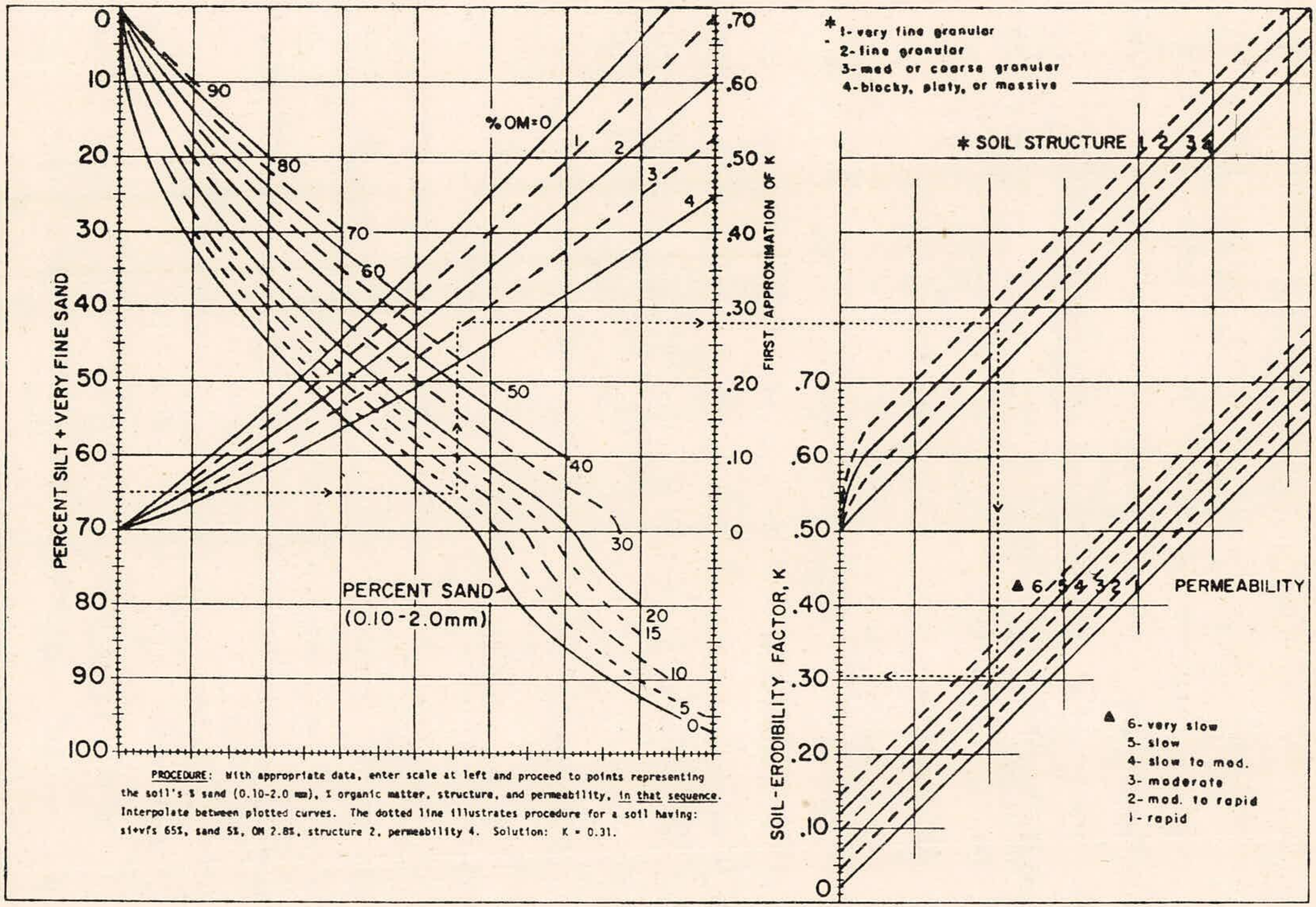


FIGURE 4.—The soil-erodibility nomograph. Where the silt fraction does not exceed 70 percent, the equation is $100\ K = 2.1\ M^{1.14}\ (10^{-4})\ (12 - a) + 3.25\ (b - 2) + 2.5\ (c - 3)$ where M = (percent si + vfs) (100 — percent c), a = percent organic matter, b = structure code, and c = profile permeability class.

pattern of Bino sub-watershed of Ramganga river was computed by using equation 14 and nomograph, Ashokan (1981). The vegetation pattern and soil factors of Chaukhutia catchment are very similar to that of the Bino catchment and therefore, his findings were adopted for also this study. The values of soil erodibility factor for different land was as reperted by Ashokan (1981) are as below:

i)	Forest and wood land	0.59
ii)	Grass and waste land	0.43
iii)	River bed and paths	0.56
iv)	Crop land	0.58

The soil-erodibility factor for Chaukhutia watershed was determined by weighting the K values of each soil in the watershed according to the area covered by the soil. The soil-erodibility factor is computed by

$$K = \frac{\sum_{i=1}^{n} K_i \cdot X \cdot A_i}{A} \qquad \ldots (15)$$

where K is the soil erodibility factor for the watershed, K_i, is the soil-erodibility factor for an individual soil, i, A_i is the area of watershed covered by an individual soil, i, A is the area of the watershed, and n is the number of different soils in the watershed. The weighted soil-erodibility factor for Chaukhutia catchment was determined to be 0.57.

4.3 Computation of Topographic Factor, LS

The topographic factor, LS, is the expected ratio of soil loss per unit area from a field slope to that from a 22.13 m length of

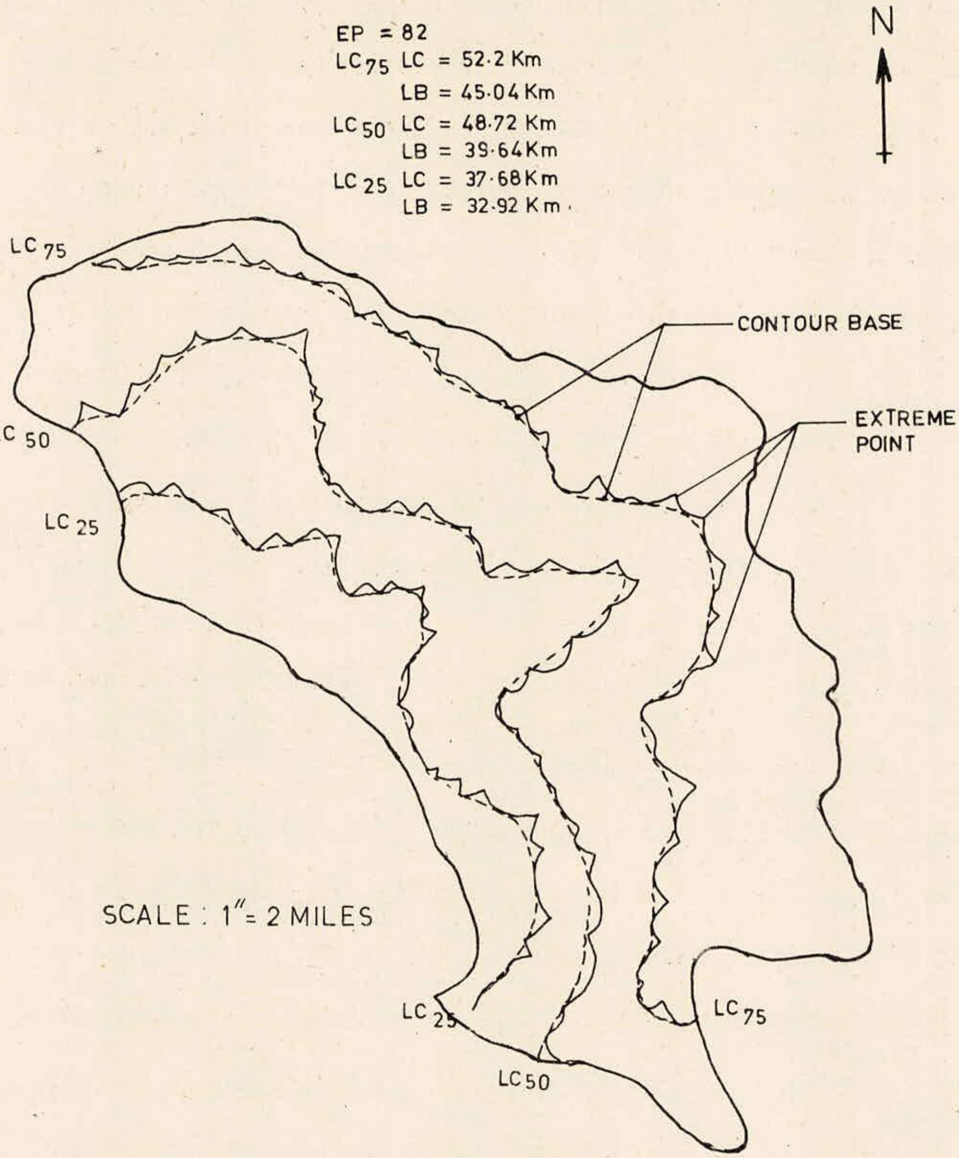


FIG. 5 - CONTOUR BASE AND EXTREME POINT OF CHAUKHUTIA BASIN

uniform 9 percent slope under other wise identical condition. The effects of slope length and gradient are represented in the universal soil loss equation as L and S respectively, however, they are after evaluated on a single topographic factor, LS. The slope length is defined as the distance from the point of origin of overland flow to the point where the slope decreases sufficiently for deposition to occur or to the point where runoff enters a defined channel. The channel may be part of a drainage network or a constructed channel. Slope gradient is the field or segment slope, usually expressed as a percentage. The topographic component, LS, was evaluated by using the contour length method suggested by Williams (1976) for large watersheds as shown in figure 5. Williams (1976) proposed a method for determiation of average watershed slope was used.

$$S = \frac{0.25Z(LC_{25} + LC_{50} + LC_{75})}{A} \qquad \ldots (16)$$

in which S is the average watershed slope, Z is the watershed relief in km, LC_{25} , LC_{50} and LC_{75} are contour lengths at 25, 50 and 75 percent of Z, and A is the watershed area in sq. km. The value of average slope of Chaukhutia watershed was determined to be 16.741 percent.

The soil loss per unit area generally increases substantially as slope length increases. The greater accumulation of runoff on the longer slopes increases its detachment and transport capacities. The average watershed slope length was determined by the following equation proposed by Williams (1976)

$$L = \frac{LC \times LB}{2EP\sqrt{LC^2 - LB^2}} \qquad \ldots (17)$$

where L is the watershed slope length in km, LC is the total contour length in Km which is equal to $LC_{25} + LC_{50} + LC_{75}$, and LB is the total contour base length in km. Using equation (17) the value of slope length factor for Chaukhutia watershed was determined to be 1.3549 km.

The topographic component, LS, for Chaukhutia watershed was evaluated by the following equation:

$$LS = \frac{(L)}{22.1}^{m} (0.065 + 0.0454S + 0.0065S^2) \qquad \ldots(18)$$

in which LS = Average length slope component,

L = Slope length in meter,

S = Average watershed slope in percent, and

M = Exponent.

Current recommendations (Wischmeier and Smith, 1978) for the exponent m are:

m = 0.5 if slope $\geq$ 5 percent,

m = 0.4 if slope < 5 percent and > 3 percent

m = 0.3 if slope $\leq$ 3 percent and $\geq$ 1 percent, and

m = 0.2 if slope < 1 percent

The average length slope component for Chaukhutia watershed was determined to be 0.6552 by using equation (18).

4.4 Evaluation of Cropping Management Factor, C

The cropping management factor, C, in the universal soil loss equation measures the combined effect of all the interrelated cover and management variables and is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled continuous fallow.

Jaiswal (1982) determined the croping management factor for different land use patterns in the Gagas sub-watershed, which is one of the sub-watersheds of the Upper Ramganga catchment. The values of crop management factors proposed by him are listed as below:

i.	CropLand	0.32
ii.	Hay land and grazing land	0.21
iii.	Reserve forest and wood land	0.02
iv.	Rokhar and Miscellaneous	1.00

The cropping management factor, C, for Chaukhutia watershed, is determined by weighting the C values of each crop and management level according to the size of area growing the crop with the same management level, C is computed by

$$C = \frac{\sum_{i=1}^{n} C_i \times A_i}{A} \qquad \ldots(19)$$

in which C is the cropping management factor for the watershed, C_i = is the cropping management factor for crop i, A is the drainage basin area growing crop i with a particular management level, n is the number of land use areas in the watershed, and A is the total watershed area. The value of crop management factor, C, for Chaukhutia watershed was determined to be 0.098.

4.5 Evaluation of Support Practice Factor, P

In general, whenever, sloping soil is to be cultivated and exposed to erosive rains, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will slow the runoff water and thus reduce the amount of soil it can carry. The most important of these supporting crop land practices are contour tillage, strip cropping on the contour, and terrace systems. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

The support practice factor, P, in the universal soil loss equation is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope culture.

In computing the P factor, only the cultivated area of the watershed is considered. The P facator was ascertained to be 0.6 for terraced agricultural land, and for the rest of the land 1.0, based on the method proposed by USDA (1978). The weighted P factor for the watershed was determined to be 0.95.

5.0 RESULTS AND DISCUSSION

The major purpose of the soil loss prediction procedure is to supply specific and reliable guides for selecting adequate erosion control practices for farm fields, construction area, watershed resources management etc. The procedure is also useful for computing the upland erosion phase of sediment yield as a step in predicting rates of reservoir sedimentation or stream loading, but the universal soil loss equation factors are more difficult to evaluate for large mixed watersheds. An attempt was made, to evaluate these different factors of the USLE for Chaukhutia watershed, comparising an araea of 452.25 sq km of Ramganga reservoir catchment to predict the sediment yield on storm basis.

The general description of the watershed, instrumentation and procedure for collection of hydrologic data were described in Chapter 3. Chapter 4 described the procedure of evaluating the different factors of universal soil loss equation. This Chapter will describe the results of the universal soil loss equation for predicting sediment yield on storm basis.

In order to compute the soil loss for individual storm by using USLE, the rainfall-runoff factor,R, in USLE is replaced by the erosion index value of that particular storm event. The storm events of July 17, 1983, August 22-23, 1983, July 20, 1984; and August 18-19, 1984 were selected for comparison of measured sediment yield to that of predicted by using USLE on storm basis. The percentage errors in sediment yield predicted by USLE for the storm event of July 17, 1983, August 22-23, 1983, July 20, 1984; and August 18-19, 1984 were + 6.168,-8.72, - 21.35, and -15.69 respectively as given in Table 8. The percentage

Table 8 Measured and estimated sediment yield on storm basis

Date of storm event	Measured sediment yield tons/ha	Estimated sediment yield tons/ha.	Percentage error
July 17, 1983	0.0674405	0.0632803	+ 6.168
August 22-23, 1983	0.2402211	0.2611877	- 8.72
July 20, 1984	0.0798235	0.0968675	- 21.35
August 18-19, 1984	0.0674405	0.0780225	- 15.69

$$\text{Percentage Error} = \frac{\text{Measured} - \text{Estimated}}{\text{Measured}} \times 100$$

error of estimate of sediment yield is within the permeasible limit of 30% showed the validity of the USLE for estimating sediment yield on storm basis from a large complex watershed.

The error in estimatd sediment yield due to, the USLE is designed to predict long time average soil loss. The long time average tends to average out the variation in the extreme years of climate and crop and provide a middle order estimation of soil loss from a given set of conditions on an average basis.

6.0 CONCLUSIONS

The main objective of the loss prediction procedure is to supply specific and reliable estimates and guides for selecting adequate erosion control practices for farm fields and construction areas. The USLE procedure is also useful for computing upland erosion phase of sediment yield as a step in predicting reservoir sedimentation or stream loadings. However, in case of very large watersheds USLE factors are difficult to compute. In brief, the universal soil loss equation can be used for:

1. Predictng average annual soil loss from a field slope with specific land use condition.
2. Guiding the selection of cropping and management system and conservation practices for specific soils and slopes.
3. Predicting change in soil loss that would result in change in cropping or conservation practices on a specific field.
4. Determining how conservation practices may be applied or altered to allow more intensive cultivation.
5. Estimating soil loss from land use other than agriculture, and
6. Providing soil loss estimates for conservation purposes.

Various techniques are available for determining different factors of the USLE i.e. R,K,L,S,C and P. The methods of determining these factors have been discussed in the report. However it would be worthwhile to mention attempts made on finding these factors in exceptional cases.

It is very important to find adequate rainfall erosivity index (R) for areas outside of those for which USLE was developed. In such cases one has to consider large variability in computed EI values affected primarily by high intensity, short duration orographic storms. It has also be inferred that the soil loss estimate using EI values is too large for low itensity rainfalls. It may be verified using large amount of data. As far as the K value, that is the erodibility values is concerned, it would be beneficial to have nomographs revised for all available values of K for all types of soils. Recently very detailed, complicated relationships have been developed for estimating L (slope-length factor) and S (slope-gradient factor) values. However, their reasonability and applicability should be tested before hand. The cropping management factor, C is also very important and is very sensitive factor. However its value for all regions is very desirable.

The universal soil loss equation and similar soil loss estimating techniques were developed primaily to provide a planning tool for conservation technique and therefore, case of application was a predominant consideration in their development. The general acceptance of USLE by technicians and scientists has demonstrated the extent to which this technique has been successful as a useful field tool and in providing reasonably accurate estimates of soil loss. However, these methods are empirical relations combined in equations to predict average soil loss from fields. They do not satisfy the need for a detailed model that simulates soil erosion as a dynamic process.

Soil losses computed by the USLE are best available estimates, not absolutes. They will generally be most accurate for medium textured soils slope lengths of less than 120 meters, gradients of 3 to 18% and consistent cropping and management practices. The further these limits are exceeded, the greater will be the probability of significant extrapolation error.

It would be very useful to compute the soil loss from large watersheds and also to attempt to improve the soil loss equation for such cases. This would mean going into the basic philosophy behind the hydrological behaviour of small and large watersheds. The present study may also serve as a first step to develop generalised, regionwise soil loss equation. The results achieved by taking small watershed on Ramganga river has given good soil loss indication.

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