ICAR

SOIL LOSS PREDICTION RESEARCH IN INDIA

Bulletin No. T-12/D-9

$A = RKLSCP$

GURMEL SINGH
RAM BABU
SUBHASH CHANDRA

Central Soil & Water Conservation Research & Training Institute
DEHRA DUN-248195 INDIA

1981

CONTENTS

Page

1.0 INTRODUCTION ... 1

2.0 RAINFALL EROSIVITY FACTOR (R) ... 3

2.1 Rainfall erosion index ... 4
2.11 Computation of erosion index values ... 4
2.2 Research work done on R factor ... 5
2.21 Distribution of monthly and seasonal erosion index values ... 6
2.22 Iso-erodent map of India ... 6
2.23 Probability values of erosion index ... 12

3.0 SOIL ERODIBILITY FACTOR (K) ... 15
3.1 Determination of K factor ... 15
3.11 Determination of K from runoff plots ... 15
3.12 Determination of K based on soil properties ... 21
3.13 Determination of K with soil erodibility nomograph ... 22
3.2 Research work done on K factor ... 23

4.0 SLOPE-LENGTH FACTOR (L) ... 30
4.1 Research work done on L factor ... 31

5.0 SLOPE GRADIENT FACTOR (S) ... 33
5.1 Research work done on S factor ... 34
5.2 Topographic factor (LS) ... 36

6.0 CROPPING MANAGEMENT FACTOR (C) ... 37
6.1 Research work done on C factor ... 43

7.0 SUPPORTING CONSERVATION PRACTICE FACTOR (P) ... 52
7.1 Contour cultivation and research work done on P factor .. 52
7.2 Bunding and terracing and research work done on P factor ... 54

8.0 APPLICATION OF THE SOIL LOSS EQUATION ... 55
8.1 Working example ... 56
8.2 Soil loss tolerance ... 57
8.3 Management of erosion on agricultural lands ... 59

9.0 SUMMARY ... 59

10.0 ACKNOWLEDGEMENTS .. 60

11.0 REFERENCES ... 61

APPENDICES ... 65

1.0 INTRODUCTION

Erosion is the greatest destroyer of land resources. In addition to losses of soil, many other problems are created by soil erosion like siltation of reservoirs, canals and rivers, deposition of unfertile material on cultivated lands, harmful effects on water-supply, fishing, power generation and most important the destruction of fertile agricultural land.

Land management is the science of selecting most appropriate agricultural use for land. There are many different ways in which each tract of land may be used. The soil losses vary considerably from different land uses and also the manner in which the land is treated. For sound soil and water conservation planning, the soil conservation planner needs some means to evaluate the various alternative treatments as related to the amount of expected soil loss. There is a great need to have reliable information to provide a guide to discuss with land owners and land users the rates of soil loss which are expected from the land treated under different possible ways. Such information, if available, will assist the land users in deciding on the different land uses.

Reliable soil loss estimation is a valuable design, extension and planning tool. Its most immediate advantage is that a well-defined conservation objective can be formulated, namely, to reduce soil losses to specified acceptable levels and thereby ensure the maximum safe economic use of each piece of land.

Attempts have been made for many years to quantify the erosion effect of cropping practices in numerical form which would allow erosion to be predicted for given circumstances (Hudson, 1971).

Beginning in 1941, emperical equations were developed for estimating average annual field soil loss for different combinations of soil, slope, cropping management and conservation practices. Although the rainfall erosion research began with the work of Wollny in Germany in the later half of the 19th century but the systematic study on the soil loss prediction from agricultural fields was conducted in the United States beginning around in 1930's. Data for derivation and field use of equations were obtained from the field runoff plots Zingg (1940) proposed a relationship of soil loss to slope length raised to a power. Later in 1947, a committee chaired by Musgrave proposed a soil loss equation having some similarity to the present day Universal Soil Loss Equation (USLE . The equation of Musgrave was adopted for use in

---

Authorised for publication by the Director as Bulletion No. T-12/D—9 from Central Soil & Water Conservation Research & Training Institute, Dehra Dun.

farm planning in the North-Eastern States of the United States and for computation of gross erosion from watersheds in flood abatement programmes. In 1953, a laboratory was established at Lafayette, Indiana (USA) to collect, summarise and combine runoff, soil loss data from more than 35 field stations. Based on nearly 10000 plot year runoff plot data, Wischmeier and Smith (1965) developed the universal soil loss equation (USLE). This equation was later refined with more recent data from runoff plots, rainfall simulations, and field experience (Wischmeier and Smith, 1978). USLE is so far the best equation available for estimating soil loss and it is the most widely used. The essence of the universal soil loss equation is to isolate each variable responsible for erosion and reduce its affects to a number so that when the number of different variables are multiplied together, the answer is the amount of soil loss.

The USLE is an erosion model design to predict the longtime average soil losses from a specified land in a specified cropping and management system. The equation predicts only the losses from sheet and rill erosion under specified conditions. With appropriate selection of numerical values for various soil erosion variables, the equation will compute the average soil loss for a cropping system, for a particular crop year in a rotation, or a particular cropstage period within a crop year. It computes the soil loss for a given site as a product of six major factors whose most likely values at a particular location can be expressed numerically (Wischmeier and Smith, 1978).

The soil loss equation is :

$$A = RKLSCP \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where

A is the computed soil loss per unit area, expressed in the units selected for K and for the period selected for R. In practice, these are usually so selected that they compute A in metre tonnes per ha per year, but other units can be selected.

R, the rainfall erosivity factor, is the number of rainfall erosion index units for a particular location.

K, the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as 21 13 m (72.6 ft) length of uniform 9 percent slope continuously in clean-tilled fallow.

L, the slope length factor, is the ratio of soil loss from the field slope length to that from a 21.13 m (72.6 ft) length under identical conditions,

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9 percent slope under otherwise identical conditions.

C, the cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P, the support practice factor, is the ratio of soil loss with a support practice like contouring, strip-cropping, or terracing to that with straight-row farming up and down the slope.

The USLE enables planners to predict the average rate of soil erosion for each feasible alternative combination of crop system and management practices in association with a specified soil type, rainfall pattern and topography. When these predicted losses are compared with given soil loss tolerances, they provide a specific guidelines for effecting erosion control within specified limits. The equation groups the numerous inter-related physical and management parameters that influence erosion rate under six major factors whose site specific values can be expressed numerically.

This bulletin discuss the six parameters of the USLE in details and also give specific values of various parameters for the Indian conditions.

2.0 RAINFALL EROSIVITY FACTOR (R)

The rainfall factor (R) in the universal soil loss equation is the number of rainfall erosion index units (EI_{30}) for a particular location.

Rills and sediment deposits observed after an unusually intense storm have sometimes led to the conclusion that the significant erosion is associated with only a few storms, or that it is solely a function of peak intensities. However, more than 30 years of measurements in many States in USA have shown that this is not the case (Wischmeier, 1962). The data showed that a rainfall factor used to estimate average annual soil loss must include the cumulative effects of the many moderate sized storms, as well as the effects of the occasional severe ones.

Wischmeier (1959) found that one hundredth of the products of the kinetic energy of the storm (KE) and the 30 minutes intensity (I_{30}) is the most relaible single estimate of rainfall erosion potential and was termed as EI_{30}. Annual total of storm EI_{30} value is referred to as the rainfall erosion-index. The location value of this index is the rainfall factor, R in the universal soil loss equation. However, the index does not include the erosive forces of runoff from thaw, snowmelt or irrigation.

2.1 Rainfall Erosion Index

Soil loss measurements made in 23 States of the United States showed that when factors other than rainfall were held constant, storm soil losses from cultivated field were directly proportional to the product value of total kinetic energy of the storm times its maximum 30 minutes intensity (EI_{30}). This product variate is an interaction term which measures the effect of the particular manner in which splash erosion and turbulance are combined with runoff to transport dislodged soil particles from the field. However, there have been few exceptions in tropical countries in Africa and India. Hudson (1971) found that the kinetic energy of individual storms falling at intensities of 25mm/hr or greater were closely related to soil loss and appears to be more appropriate than EI_{30} for tropical and subtropical rainfall. Experiments conducted in Western Nigeria indicated a lower correlation coefficient between EI_{30} and soil loss (Lal, 1976). In India, Dehra Dun, Coimbatore and Ootacamund, attempts have been made to find out correlations between EI values and the soil loss from bare plots. The results indicated that EI_{30} values gave a better correlation ($r=0.74$) with soil loss in Dehra Dun (Ram Babu *et al*, 1970). At Coimbatore, highly significant correlation coefficients ($r=089$ to $r=096$ for varying slopes) were noticed between the product of kinetic energy and maximum 30 minutes intensity (EI_{30}) with soil loss (Balasubramanian and Sivanappan, 1981). However, it did not give a good correlation at Ootacamund, where EI_5 value proved better. EI_5 was found to explain 25 percent variation as compared to EI_{30} explaining 17 percent variation (Das *et al*, 1967). Till sufficient soil loss data from field plot for large number of storms from various countries become available to disprove the reliability of EI_{30} value in estimating soil loss, EI_{30} continues to be the most reliable estimate of rainfall erosion potential.

The annual EI value is important to find out geographical difference in the ability of the average annual rainfall to cause erosion. Monthly and seasonal EI values are required to find out the local differences in the distribution of erosive rainstorms within the year.

2.11 Computation of Erosion Index Value

The method suggested by Wischmeier (1959) may be used for estimating the erosion index value of each storm. Storms greater than 12.5 mm should be considered for computation of EI value. The storm separated by more than 6 hours may be considered as different storm. The EI_{30} can be expressed as :

$$EI_{30} = \frac{KE \times I_{30}}{100} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where, EI_{30} = erosion index

KE = kinetic energy of the storm; and

I_{30} = maximum 30 minutes rainfall intensity of the storm.

For computing the kinetic energy for the storm, the equation proposed by Wischmeier and Smith (1958) is :

$$KE = 916 + 331 \log I \quad \ldots \quad \ldots \quad (3)$$

where, KE = kinetic energy in foot-tons per acre inch; and

I = rainfall intensity in inches per hour.

A table was prepared to compute the KE for intensities upto 10 inches per hour. Recent studies showed that the median drop size of rain does not continue to increase for intensities greater than about 2.5 to 3.0 inches per hour (Carter *et al*, 1974 and Hudson, 1971). Therefore, energy per unit of rainfall also does not continue to increase, as was assumed in the derivation of energy intensity table published in 1958 by Wischmeier and Smith. Hence the value given in the energy intensity table published in 1958 for the intensities, 3 inches per hour should be used for all intensities greater than 3 in/hr (Wischmeier and Smith, 1973).

The equation (3) was converted into metric units by Wischmeier and Mannering (1969) and the equation in metric unit is :

$$KE = 210.3 + 89 \log I \quad \ldots \quad \ldots \quad (4)$$

where, KE = kinetic energy in metre tonnes per ha-cm; and

I = rainfall intensity in cm/hr.

Based on equation (4), rainfall energy table has been prepared (Table 39) for intensity upto 7.5 cm/hr and is given in Appendix-I. The use of the table can be very helpful in easy computation of the kinetic energy in metric system (Wischmeier and Smith, 1978).

Detailed procedure for computing the erosion index from recording raingauge charts is given in Appendix-I.

In order to obtain monthly and yearly EI values, the storm EI for that length of period are added. 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

2.2 Research work done in India

The importance of rainfall erosion index is well-recognised in soil conservation programmes Data from 45 stations situated in different zones have been utilised for computing EI_{30} values for these stations. This information has been further developed in monthly, seasonal and annual EI values and subsequently the first approximation of the Iso-Erodent-Map of India was made, based on this information.

2 21 Distribution of Monthly and Seasonal Erosion Index Values

The monthly, seasonal and annual EI values of 9 stations of northern zone, 10 stations of central zone, 7 stations of western zone, 10 stations of eastern zone and 9 stations of southern zone of India are given in Tables-1 to 5 (Ram Babu *et al,* 1978a). It is observed from these tables, that except in southern zone of india, nearly 75 to 98 percent of total EI values are concentrated during the period of June to September (rainy months). However, the pattern is different in southern zone. In Vishakhapatnam, Mangalore, Bangalore, Tiruchchirappalli and Hyderabad, 53 to 81 percent of total EI values are contributed through south-west monsoon (June-September). In the remaining three stations of southern zone, i.e. Trivandrum, Madras and Kodaikanal, 30 to 38 percent of total annual EI values are contributed through south-west monsoon (June-September) and 21 to 60 percent through north-east monsoon (October-December).

2.22 Iso-Erodent Map of India

Iso-erodents are lines joining areas with equally-erosive rainfall (Wischmeier, 1962). The average annual EI value of 45 stations distributed in different rainfall zones (Tables-1 to 5) were plotted on a map of India but they were found to be insufficient to establish a clear path of iso-erodents. To obtain additional computed values of erosion index, regression analysis was made between rainfall amount and EI_{30}.

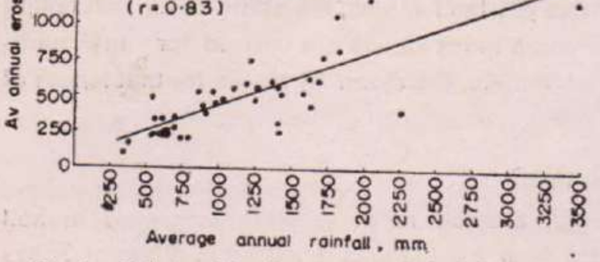


Fig. 1. Relationship of average annual rainfall to average annual erosion index.

Linear relationships were found when average annual and seasonal (June-September) erosion index values were plotted against their average annual and seasonal (June-September) rainfall respectively for all the 45 stations in different zones of India except Mahabaleshwar where exceptionally high rainfall (>6000mm) ooccurs. The coefficient of correlation were found to be 0.83 with annual and 0.88 with seasonal (June - September) values (Figs. 1 & 2).

Table 1. *Average monthly, seasonal and annual erosion index value (metric units) of northern zone*

Month	Amritsar	Chandigarh	Dehradun	New Delhi	Jaipur	Agra	Jochpur	Lucknow	Allahabad
January	1.1	7.8	10.0	4.5	1.0	0.1	0.4	1.1	—
February	—	6.2	9.0	1.2	3.7	0.3	—	—	1.7
March	—	8.7	15.0	2.9	0.7	2.9	0.6	1.4	1.3
April	—	0.7	6.0	2.3	0.3	0.1	—	1.2	1.5
May	0.7	16.7	17.0	0.8	4.6	3.3	2.1	16.6	2.1
June	8.7	76.7	98.0	16.2	21.6	12.4	10.3	38.6	47.8
July	129.6	178.6	321.0	105.9	116.1	63.5	37.7	175.2	136.2
August	128.7	177.0	449.0	117.3	136.5	121.3	42.1	142.5	180.8
September	73.1	72.4	133.0	78.8	41.2	72.1	28.4	78.7	77.7
October	12.2	10.3	3.0	14.1	18.3	—	4.9	28.5	8.5
November	0.7	1.3	4.0	—	—	1.1	—	—	—
December	0.4	12.9	1.0	0.4	—	0.3	—	—	—
Annual	355.2	569.3	1066.0	346.4	344.0	277.4	126.5	483.1	457.6
June-September values	340.1	504.7	1001.0	320.2	315.4	269.3	118.5	435.0	442.5
June-September values as % of annual values	95.7	83.7	93.9	92.4	91.7	97.1	93.7	89.9	96.7

Table 2. *Average monthly, seasonal and annual erosion index values (metric units) of central zone*

Month	Kota	Indore	Bhopal	Jabalpur	Punasa	Thikri	Bagra Tawa	Nagpur	Raipur	Jagdalpur
January	—	0.3	1.6	2.5	—	—	1.3	—	1.7	1.1
February	0.5	1.3	0.2	2.7	—	—	—	—	0.5	8.6
March	0.6	0.7	3.4	4.3	1.2	—	2.1	7.9	8.4	4.3
April	—	—	0.1	0.5	—	—	—	3.2	1.9	32.2
May	1.9	2.6	16.4	11.7	0.5	5.1	9.6	10.0	3.8	32.2
June	40.1	69.2	69.6	87.5	79.8	60.2	25.7	108.9	193.9	116.9
July	139.6	139.0	175.4	119.9	101.8	90.3	132.2	161.6	171.8	77.3
August	111.9	99.8	186.7	182.8	87.1	52.6	190.3	88.5	123.1	143.2
September	55.1	81.8	103.9	88.0	97.7	106.8	139.4	82.0	87.5	74.8
October	3.4	14.4	4.6	7.6	9.7	14.6	12.9	14.4	10.4	38.4
November	0.5	3.3	1.6	0.8	0.7	2.0	0.2	0.6	1.3	1.3
December	0.4	0.9	—	3.0	1.1	2.2	—	5.9	1.4	4.1
Annual	354.0	413.3	563.5	511.3	379.6	333.8	513.7	483.0	605.7	534.4
June-September values	346.7	389.6	535.6	478.2	366.4	309.9	487.6	441.0	576.3	412.2
June-September values as % of annual values	97.8	94.3	95.0	93.5	96.5	92.8	94.9	91.3	95.1	77.1

Table 3. *Average monthly, seasonal and annnal erosion index values (metric units) of western zone*

Month	Vasad	Bhuj	Veraval	Nandurbar	Aurangabad	Mahabale-shwar	Vengurla
January	—	—	—	—	1.8	—	—
February	—	—	—	—	5.7	—	—
March	—	1.0	—	—	0.4	1.3	—
April	—	—	—	3.3	—	13.8	—
May	0.6	—	—	2.4	9.7	8.2	90.3
June	121.4	12.0	86.3	31.4	76.3	132.6	411.3
July	150.4	77.4	224.1	102.5	45.1	799.5	390.6
August	97.1	27.7	107.0	34.3	42.2	245.9	198.9
September	149.8	1.6	92.4	44.4	18.6	70.4	99.4
October	—	—	23.6	25.0	14.3	42.2	28.4
November	—	—	—	1.8	7.5	4.1	23.6
December	—	—	—	—	3.9	1.9	16.4
Annual	519.3	119.7	533.4	245.1	225.5	1319.9	1258.9
June-September values	518.7	118.7	509.8	212.6	182.2	1248.4	1100.2
June-September values as % of annual values	99.8	99.2	95.6	86.7	80.8	94.6	87.4

Table-4 : *Average monthly, seasonal and annual erosion index values (metric units) of eastern zone.*

Month	North Lakhimpur	Gauhati	Shillong	Imphal	Agartala	Gaya	Jamshed-pur	Dum-Dum	Sagar Island	Jharsu-guda
January	0.5	—	—	—	2.8	2.9	—	0.7	0.6	4.3
February	1.8	—	—	1.0	18.7	—	0.4	1.1	12.7	5.8
March	6.2	5.9	4.8	1.3	39.8	4.2	2.9	5.6	5.0	6.7
April	18.9	40.6	17.8	7.9	104.8	1.5	13.7	32.9	22.4	9.4
May	102.5	74.2	55.4	42.7	282.1	18.2	19.9	75.6	54.4	14.3
June	242.9	146.9	122.4	51.1	283.0	82.9	108.2	154.2	122.2	109.6
July	288.3	149.5	56.7	38.2	203.2	119.4	167.3	151.0	197.6	164.6
August	268.6	139.3	50.0	53.2	141.8	214.8	148.6	154.3	207.3	214.1
September	200.5	65.7	84.7	20.0	122.9	136.4	93.3	154.7	325.1	76.8
October	43.9	9.6	15.7	12.1	79.5	14.6	27.8	44.1	100.8	22.9
November	5.1	3.7	—	1.2	2.0	—	3.9	—	16.9	—
December	1.8	—	—	—	—	—	—	—	—	—
Annual	1181.0	635.4	407.5	228.7	1280.6	594.9	586.0	774.2	1065.2	628.9
June-September values	1000.3	501.4	313.8	162.5	750.9	553.5	517.4	614.2	852.2	565.1
June-September values as % of annual values	84.7	78.9	77.0	71.1	58.6	93.1	88.3	79.3	80.0	89.9

Table-5 : *Average monthly, seasonal and annual erosion index values (metric unit) of southern zone.*

Month	Ootacamund	Vishakhapatnam	Hyderabad	Bangalore	Mangalore	Madras	Tiruchchirappalli	Kodaikanal	Trivandrum
January	0.1	5.5	—	0.1	—	5.4	7.4	1.6	13.8
February	1.5	1.1	0.5	3.7	—	1.0	—	6.3	25.5
March	8.0	6.2	5.0	0.5	—	3.8	2.4	21.5	17.8
April	19.7	10.8	11.0	29.7	10.6	16.6	45.0	104.4	93.7
May	74.7	18.0	14.5	67.2	135.8	7.1	42.7	40.8	113.5
June	28.4	65.2	22.5	31.9	352.8	36.3	33.4	23.5	121.4
July	45.9	57.7	31.3	29.7	513.9	42.9	40.4	36.5	44.2
August	18.1	73.9	39.1	72.6	202.5	106.1	90.4	52.5	18.3
September	25.7	120.5	61.4	92.3	105.0	82.6	123.3	52.8	58.5
October	57.1	147.8	25.0	65.8	82.2	168.7	125.6	56.0	190.2
November	28.4	22.4	1.2	19.8	32.4	232.2	24.9	26.8	77.9
December	7.0	4.4	3.3	15.6	21.4	50.2	9.4	9.8	45.3
Annual	314.6	533.5	214.8	428.9	1456.6	752.9	544.9	432.5	820.1
I. *South-West Monsoon showers (June September)*									
Seasonal total	118.1	317.3	154.3	226.5	1174.2	267.9	287.5	165.3	242.4
% of year	37.5	59.5	71.8	52.8	80.6	35.6	52.8	38.2	29.6
II. *North-East Monsoon showers (October to December)*									
Seasonal total	92.5	174.6	29.5	101.2	136.0	451.1	159.9	92.6	313.4
% of year	29.4	32.7	13.7	23.6	9.3	59.9	29.3	21.4	38.2

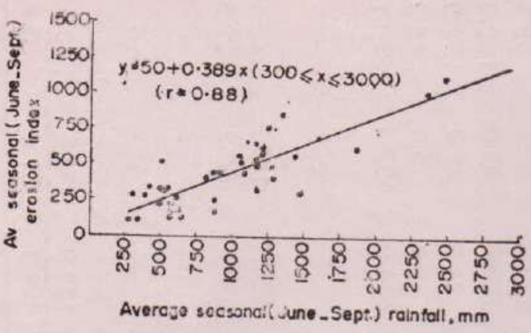


Fig. 2. Relationship of seasonal rainfall to seasonal erosion index

The relationship so derived was as follows :

$$y = 79 + 0.363\,x \; (r = 0.83) \qquad \ldots \qquad \ldots \qquad (5)$$

$$y = 50 + 0.389\,x \; (r = 0.88) \qquad \ldots \qquad \ldots \qquad (6)$$

where, y = average annual erosion index in equation (5) and average seasonal erosion index in equation (6); and

x = average annual rainfall (mm) in equation (5) and average seasonal rainfall in equation (6).

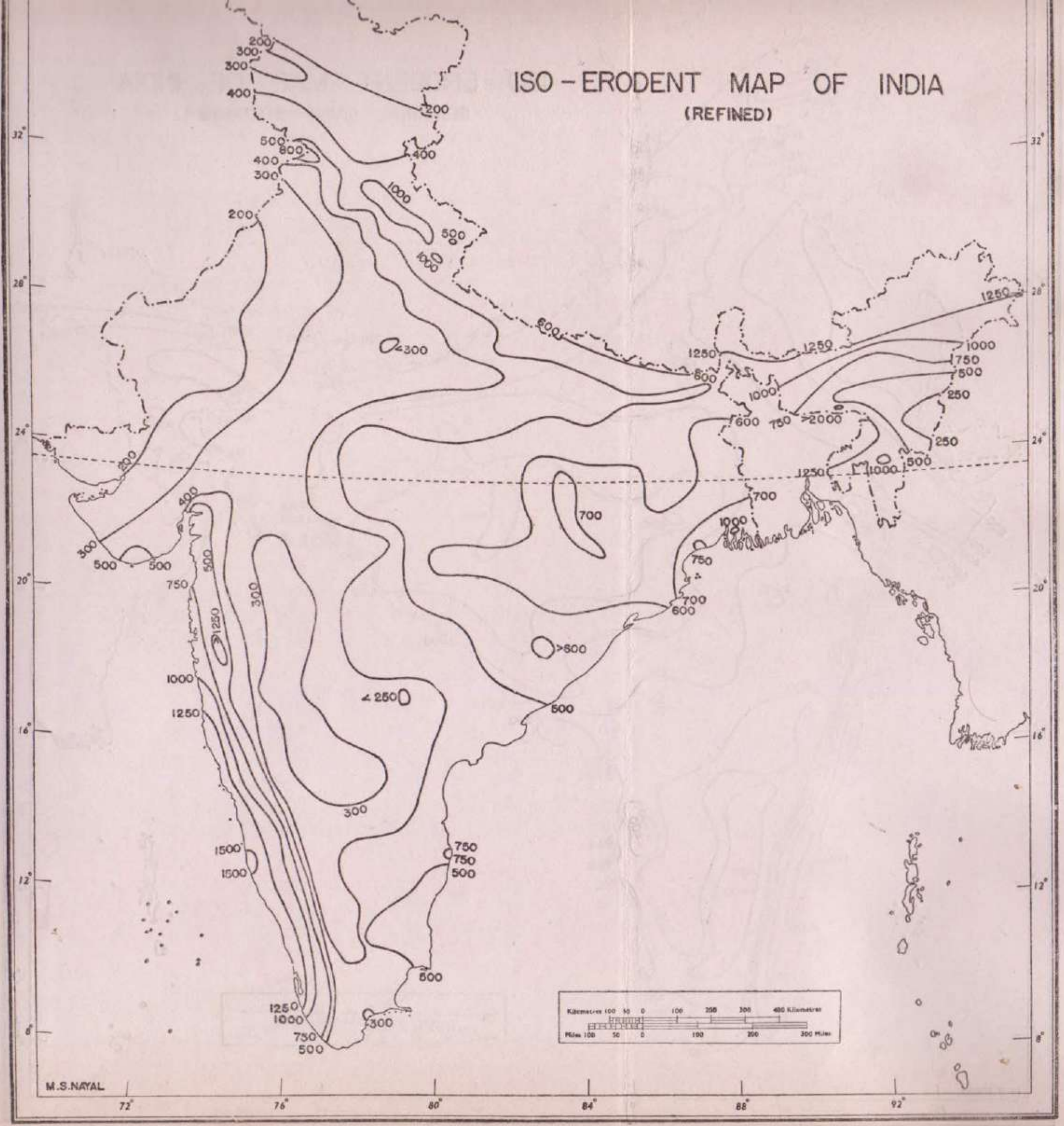
The above equations thus derived from the data for the 44 stations were used to approximate the erosion index values of 180 additional locations, fairly distributed to represent whole of the country.

These additional values were then mapped alongwith those obtained from 45 stations. The 225 data points made the paths of iso-erodents quite clear. Iso-erodent maps for mean annual and mean seasonal (June September) erosion index values were drawn and are given in Figs. 3 and 4 (Ram Babu *et al*, 1978 b). These maps can be improved upon further when data from large number of recording raingauge stations become available.

The number identifying each iso-erodent is the numerical value of erosion index along that line. Points lying between the indicated iso-erodents may be approximated by linear interpolation. The annual EI values ranged from 120 at Bhuj in western zone to 1457 at Mangalore on western coast of southern zone. The seasonal (June-September) EI values ranged from 119 at Bhuj to 1248 at Mahabaleshwar in western zone. Large variations in erosion index values reflect the diversity of rainfall erosion potential in different parts of the country.

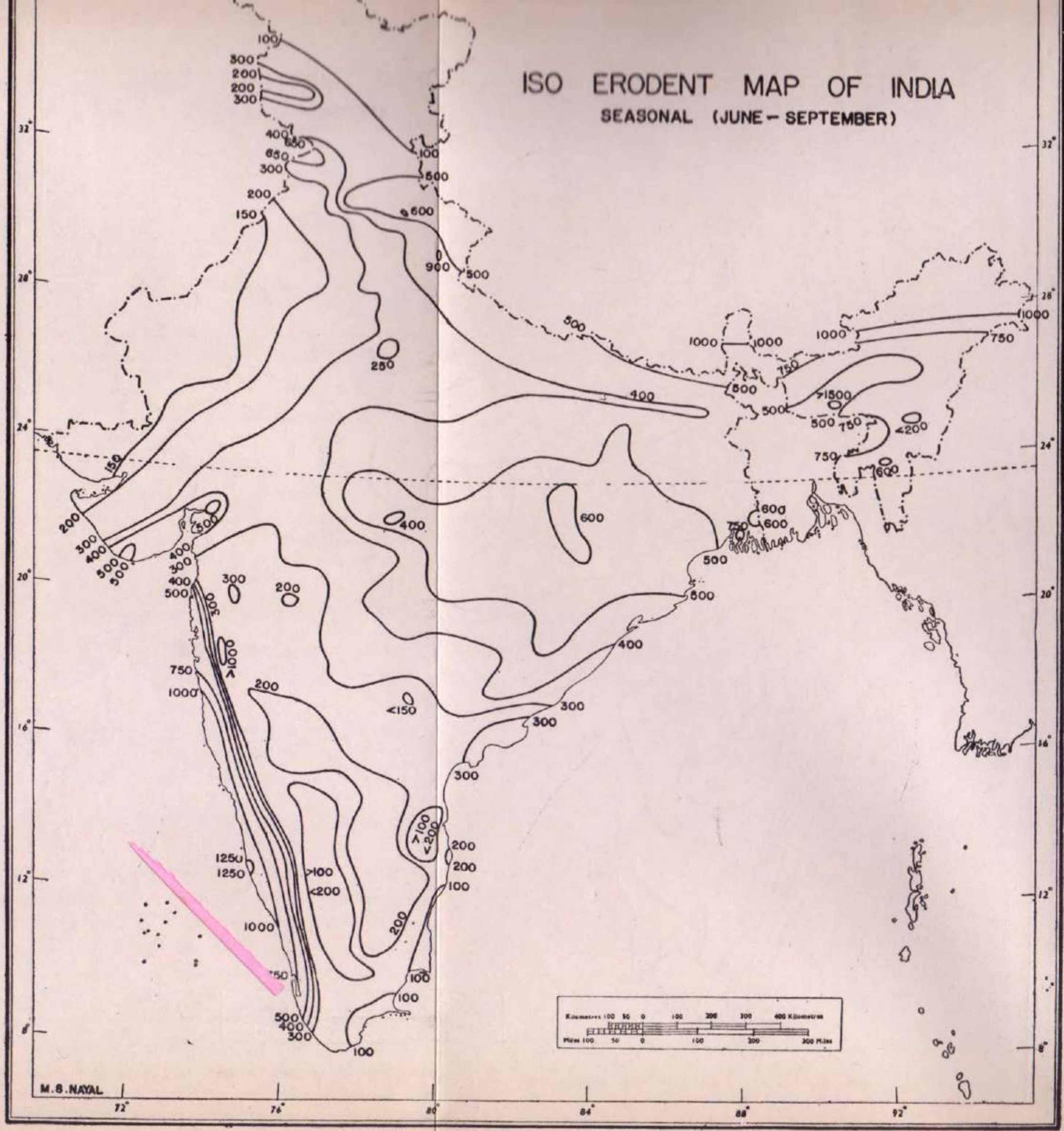
2.23 Probability Values of the Erosion Index

The annual values of EI at any given location differ substantially from year to year. The observed ranges and 50 percent (2 year return period), 20 percent



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

Fig. 3. Iso-erodent map of India on annual basis.



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line

Fig. 4. Iso-erodent map of India on seasonal (June-September) basis.

(5 year return period) and 10 percent (10 year return period) probabilities of annual EI values from 15 years precipitation records at 44 locations in different zones of India are listed in Table-6 (Ram Babu *et al*, 1978b). Other probabilities can be derived by plotting the 50 percent and 10 percent values on log-probability paper and joining the two points by a straight line.

Table 6. *Observed range and 2, 5 and 10 year return period values of erosion index at each of 44 Stations in India*

Location	Average annual EI	Values of erosion Index (EI)			
		Observed 15 year range	2 year return period*	5 year return period	10 year return period
1	2	3	4	5	6
Northern zone					
Amritsar	355	105–912	270	540	760
Chandigarh	569	309–974	530	710	825
Dehradun	1066	404–2206	966	1410	1750
New Delhi	346	124–853	300	475	600
Jaipur	344	86–765	280	580	820
Agra	277	120–433	308	412	500
Jodhpur	127	53–250	100	175	225
Lucknow	484	163–866	385	605	795
Allahabad	458	174–860	415	600	725
Central zone					
Kota	354	10–1063	233	625	1000
Indore	413	193–751	375	550	680
Bhopal	464	183–1209	480	745	920
Jabalpur	511	198–967	468	690	830
Punasa	380	173–800	340	525	645
Thikri	334	89–870	280	500	660
Bagra Tawa	514	201–998	450	700	840
Nagpur	483	266–861	465	620	715
Raipur	606	330–1322	555	790	950
Jagdalpur	534	438–682	527	600	650
Eastern zone					
North Lakhimpur	1181	332–1854	938	1450	1800
Gauhati	635	407–902	617	760	840

(Contd.)

1	2	3	4	5	6
Shillong	408	156–934	360	550	690
Imphal	229	122–411	213	300	360
Agartala	1281	613–1902	1200	1650	1850
Gaya	595	172–1182	520	840	1125
Jamshedpur	586	218–1091	540	760	940
Dum Dum	774	361–1229	722	970	1200
Sagar Island	1065	533–1860	1000	1400	1600
Jharsuguda	629	286–1018	590	820	950
Western zone					
Vasad	519	178–1103	469	710	870
Bhuj	120	14–176	140	165	175
Veraval	533	150–1125	395	720	1000
Nandurbar	245	108–416	200	320	400
Aurangabad	226	112–349	210	305	350
Mahabaleshwar	1320	262–1960	1120	1620	2050
Vengurla	1259	873–1686	1150	1550	1850
Southern zone					
Vishakhapatnam	534	268–1113	490	690	800
Hyderabad	215	92–362	195	275	335
Bangalore	429	156–668	405	560	670
Mangalore	1457	825–2074	1400	1780	2000
Madras	753	504–1163	725	900	1005
Tiruchchirappalli	545	138–1059	490	750	925
Kodaikanal	433	230–796	425	575	670
Trivandrum	820	285–1606	755	1010	1025

$$^{*}\text{Return period} = \frac{100}{\text{Percent chance}}$$

In order to estimate average annual soil loss, the value of the factor, R must be equal to the average annual value of the erosion index at that location. If desired, however, some specific return period value of the erosion index other than the annual average, may be substituted for R in the equation. For example, the quantity of soil loss that will be exceeded, 1 year in 5 on the average, may be estimated by assigning 5 years return period value of erosion index in the universal soil loss equation.

3.0 SOIL ERODIBILITY FACTOR (K)

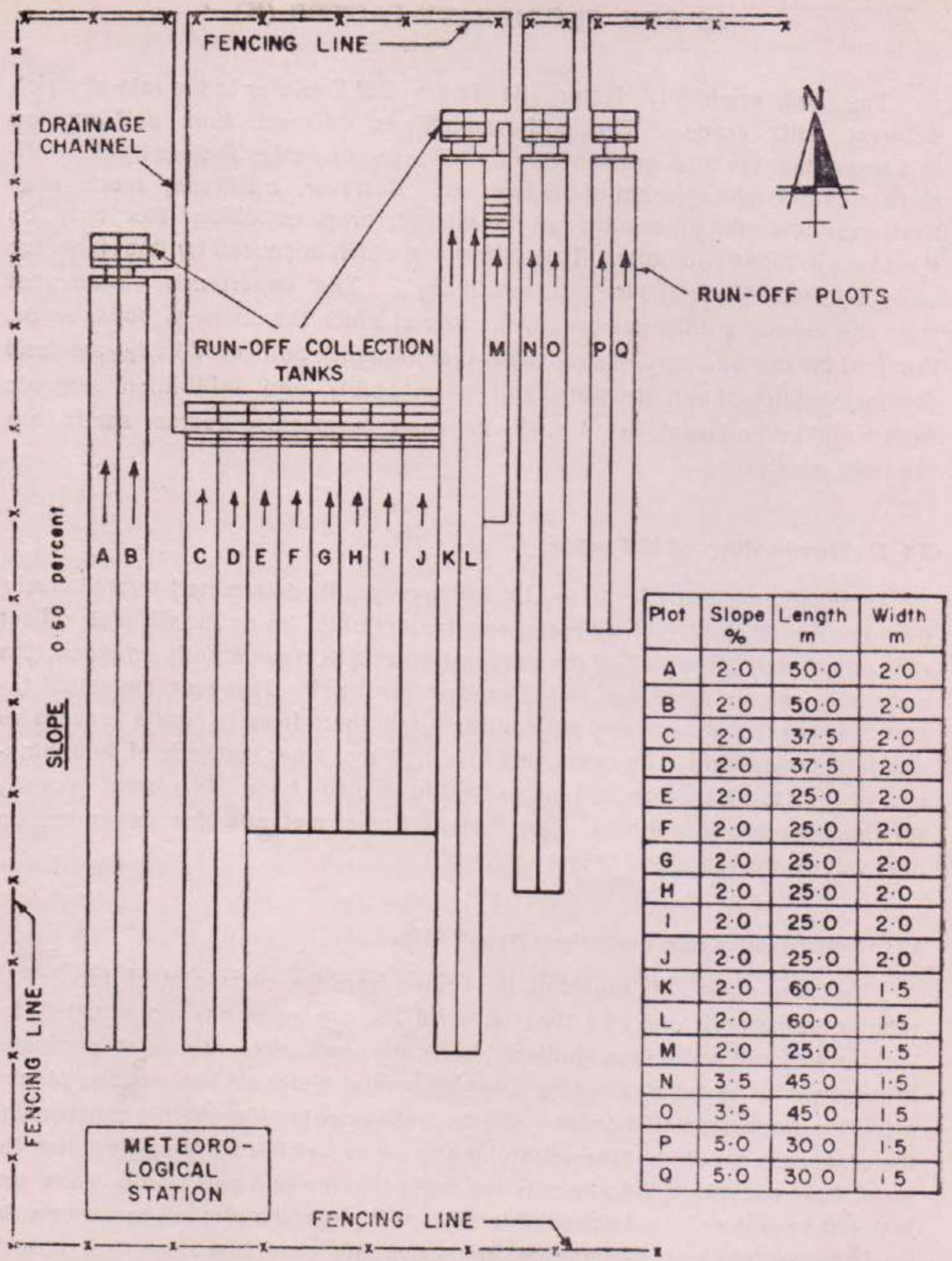
The soil erodibility factor (K) in the USLE relates to the rate at which different soils erode. The soil erodibility is different from soil erosion in a sense that the total erosion may be influenced by other factors like rainfall-climate, crops, management of the land etc. However, a soil may erode relatively more than the other although the rainfall, crop condition etc. may be the same in these two soils. This difference which is caused by the inherent soil properties is referred to 'soil erodibility'. The experience shows that the soil properties influence greatly the rate at which the different soils erode. Some of the more important properties that influence soil erodibility are soil texture, stability of soil structure, soil permeability and infiltration, organic matter and soil mineralogy. Usually the deep, permeable, coarse sands are the least erosive.

3 1 Determination of K Factor

The soil erodibility factor in USLE was originally determined quantitatively from the runoff plots. The direct measurement of K from runoff plot reflect the combined effects of all the soil properties that significantly infuence the ease with which a particular soil is eroded by rainfall. However, the establishment of runoff plots and and collection of data there from is quite expensive and time consuming. To over come this problem, other methods of determination of K factor, based on soil properties, have also been developed recently (Wischmeier and Mannering, 1969). The different methods for determination of K values are described below :

3.11 Determination of K Factor from Runoff Plots

Various sizes of runoff plots ranging from the micro-plot of 1 to 2m^2 to regular size runoff plot of 1/1000 ha to 1/5 ha are generally constructed for various soil and water loss studies. In small runoff plots, the plot perimeter boundary may be constructed by either of several materials like wooden planks, asbestos sheets, metallic strips or bricks and cement mortar. While constructing the plot, care should be taken that the plot perimeter border is so fixed that the water from outside of the plot may not enter into the plot and also it does not leak out from the plot. In case of large runoff plots, the plot perimeter can be made by earthen embankment and again the care should be taken that outside water does not come into the plot or the plot runoff does not go out of the plot unaccounted. A typical layout of runoff plots is given in Figs. 5 and 6.



Plot	Slope %	Length m	Width m
A	2·0	50·0	2·0
B	2·0	50·0	2·0
C	2·0	37·5	2·0
D	2·0	37·5	2·0
E	2·0	25·0	2·0
F	2·0	25·0	2·0
G	2·0	25·0	2·0
H	2·0	25·0	2·0
I	2·0	25·0	2·0
J	2·0	25·0	2·0
K	2·0	60·0	1·5
L	2·0	60·0	1·5
M	2·0	25·0	1·5
N	3·5	45·0	1·5
O	3·5	45·0	1·5
P	5·0	30·0	1·5
Q	5·0	30·0	1·5

Fig. 5. Layout of experimental runoff plots.

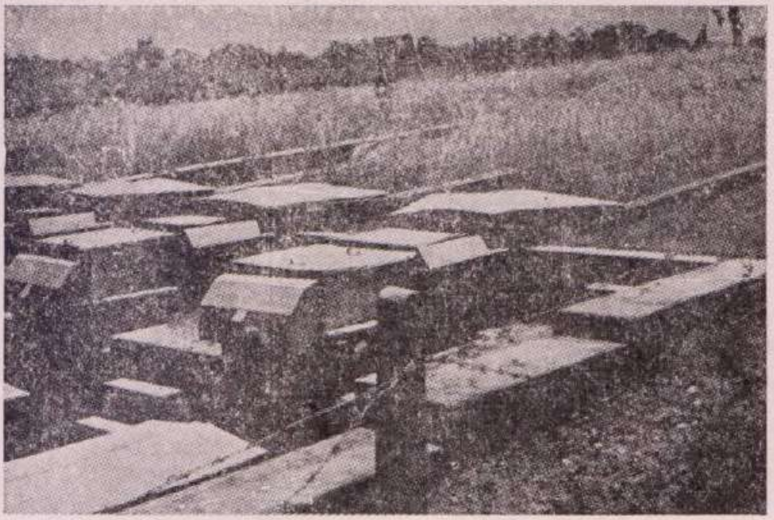


Fig. 6. Standard size runoff plots.

The measurement of runoff from the runoff plots can be accomplished either by collection of entire runoff or an aliquot of the total runoff volume. In case of very small runoff plot under medium to low rainfall areas, it may be possible to collect entire runoff in a tank and measure volumetrically. This method is very accurate but can not be adopted in large plots where runoff amount is generally quite large. This large quantity of runoff may require huge collection tanks and may be uneconomical and unmanagable. The size of the collecting tank and the cost can be substantially reduced by collecting aliquot and measuring it. The accurate sampling and measurement of aliquot is absolutely necessary for reliable results. This is accomplished by the use of devices like multi-slot divisors. The divisor consists of a number of slots of equal dimensions, out of which only one slot is measured.

This device has been used extensively in USA as well as in India. The details of one-stage multi-slot divisor and runoff collection tank (Fig. 7) and typical plan of runoff plot equipment (Fig. 8) are given for a general understanding of the runoff plot design and its working.

The multi-slot divisor divides the flow of runoff in 3. 5, 7, 9, 11, 13 or 15 aliquotes depending on the number of slots in the divisor. Smaller division of the samples, if required, can be obtained by installing two in series, e.g. when 13 slots and 9 slots divisors are used in series, it will result in 1/117 ratio. For calculating total runoff volume from the plot, the volume in the tank

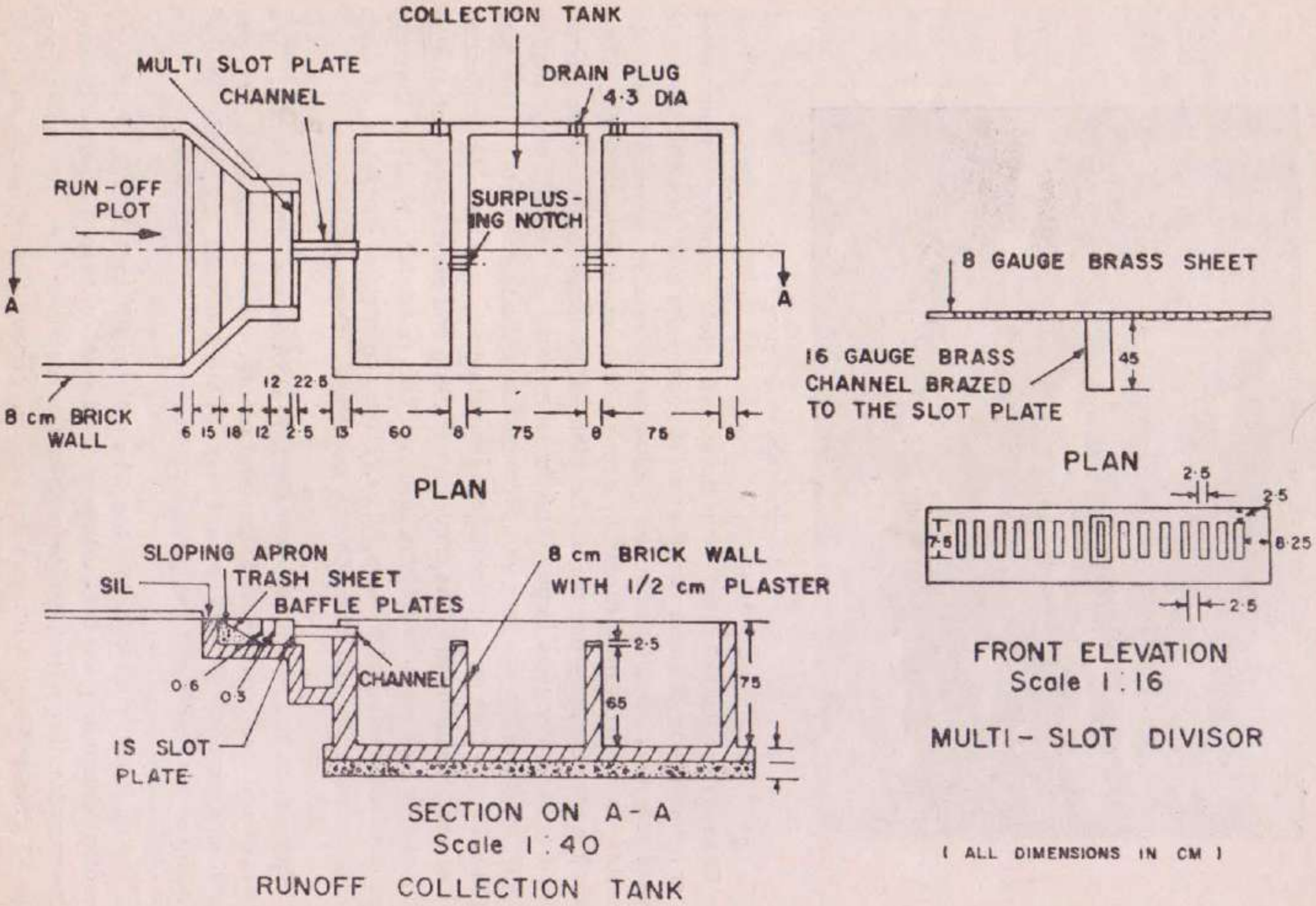


Fig. 7. Details of one-stage multi slot divisor and runoff collection tank (after Rao 1981).

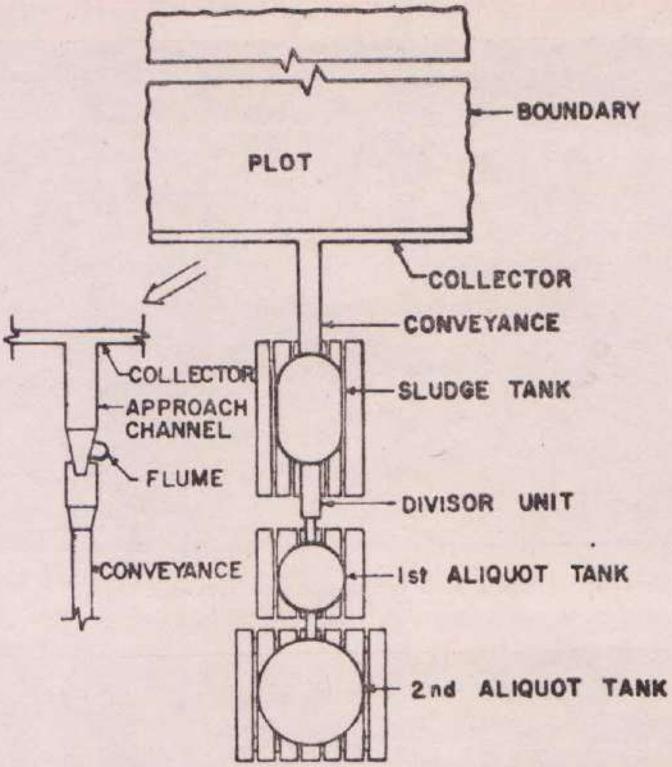


Fig. 8. Typical plan of runoff plot equipment (after Mutchler 1963).

should be multiplied by 117. For detailed design of runoff plot and installation, refer USDA Bulletin No. ARS-41-79 (Mutchler, 1963).

In larger runoff plots/watersheds, the multislot divisor may not be sufficient to handle all the runoff, In such cases, the runoff amount can be measured through the flumes with the help of stage level recorders (Fig. 9). A portion of the total runoff can then be collected with the help of devices like Coshocton Wheel (Fig. 10) and this runoff sample is then used for determination of soil loss from the plots.

For estimating the soil loss, the water in the tank is churned thoroughly and a small runoff sample of about 500 cc to 1000 cc is drawn. This sample is then evaporated in the laboratory and the amount of soil is measured gravimetrically to give soil loss in gm/litre. This quantity is further multiplied by the total runoff volume and divided by 10^6 to give total soil loss in tonnes per plot. This is further multiplied by the size of the plot to get the soil loss in tonnes/ha, for that particular storm. The soil loss from all the storms during the year are added to get the annual soil loss in tonnes/ha/year.

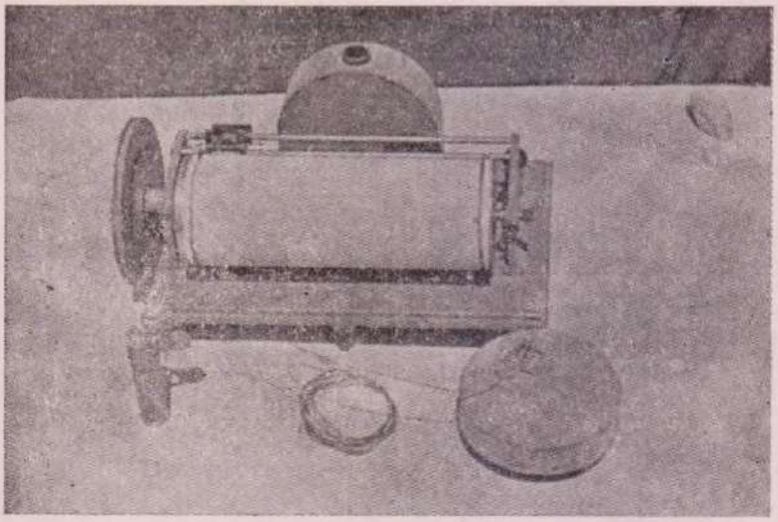


Fig. 9. F type stage level recorder.

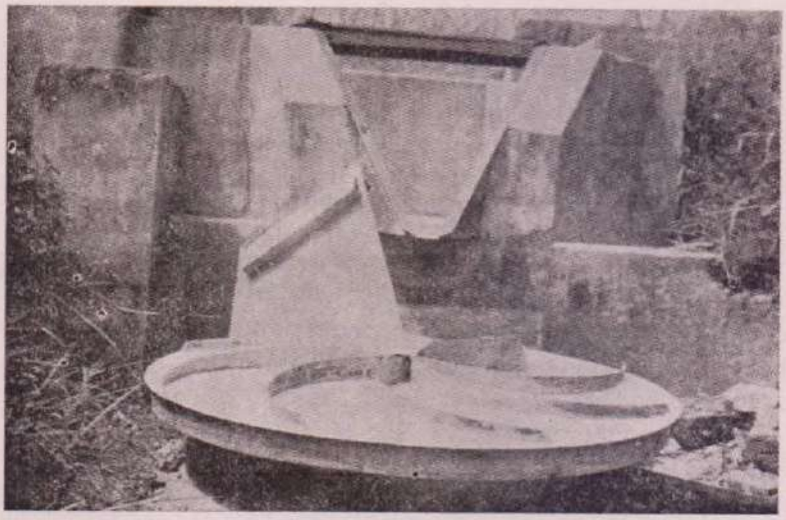


Fig. 10. Coshocton wheel silt sampler.

In order to obtain the K value, soil loss is required to be measured from a unit-plot, which has been described by Wischmeier et al (1958) as 72.6' (22.13 m) long with a uniform lengthwise slope of 9 percent, in continuous fallow, tilled up and down the slope. Instructions for establishment and maintenance of cultivated fallow plots are given in Appendix-II. The continuous fallow for this purpose is the land that has been tilled and kept free of vegetation for more than two years. During the period of soil loss measurements, the plot is ploughed and placed in the conventional maize seed bed condition and is tilled as needed to prevent vegetative growth and severe soil crusting. The soil loss obtained from above unit plot is divided by yearly EI_{30} (as described in para 2.21) to obtain soil erodibility factor, K.

In case the plot gradient and length are different than the defined unit-plot specifications, the soil loss may be adjusted by dividing it with the topographic factor (LS) as described in para 5.2.

The estimated K will then be :

$$K = \frac{\text{Total adjusted soil loss}}{\text{Total EI}} \qquad \dots \qquad \dots \qquad (7)$$

3.12 Determination of K based on Soil Properties

Direct measurement of the erodibility factor is both costly and time consuming and has been feasible only for a few major soil types. To simplify the process of determination of soil erodibility factor, many studies were carried out to correlate the soil properties with erodibility and in consequence, several emperical erodibility equations were developed and reported (Barnett and Rogers, 1966 and Wischmeier and Mannering, 1969). Factor K is a measure of the total effect of a particular combination of soil properties. Some of these properties influence the soils' capacity to infiltrate rain, and therefore, help to determine the amount and rate of runoff; some influence its capacity to resist detachment by the erosive forces of falling raindrops and flowing water and thereby determine soil content of the runoff. The inter-relation of these variables are highly complex.

Wischmeier and Mannering (1969) initiated studies to see as to what extent various properties of soil affect its erodibility. The significant variables were percent sand, percent silt, clay ratio, organic matter content, aggregation index, antecedent soil moisture, bulk density, percent slope, pH of surface and subsoil, soil structure, thickness of soil layer, land use preceding three year period, volume of pore space filled by air, slope shape, presence or absence of loessial mantle and clay skins on ped surfaces.

Based on various soil properties and their interaction, a multiple regression equation was developed which is as follows :

$$\begin{aligned} K = 0.013\,(18.82 + .62X_1 + .043X_2 - .07X_3 + .0082X_4 - .10X_5 - .214X_6 + 1.73X_7 \\ - .0062X_8 - .26X_9 - 2.42X_{10} + .30X_{11} - .024X_{12} - 21.5X_{13} - .18X_{14} + \\ 1.0X_{15} + 5.4X_{16} + 4.4X_{17} + .65X_{18} - .39X_{19} + .043X_{20} - 2.82X_{21} + 3.3X_{22} \\ + 3.29X_{23} - 1.38X_{24}). \quad \dots \qquad \dots \qquad \dots \qquad (8) \end{aligned}$$

where,

$X_1 = \%$ silt x $1/\%$ organic matter;
$X_2 = \%$ silt x reaction;
$X_3 = \%$ silt x structure strength;
$X_4 = \%$ silt x $\%$ sand;
$X_5 = \%$ sand x $\%$ organic matter;
$X_6 = \%$ sand x aggregation index;
$X_7 =$ Clay ratio;
$X_8 =$ Clay ratio x $\%$ silt;
$X_9 =$ Clay ratio x $\%$ organic matter;
$X_{10} =$ Clay ratio x $1/\%$ organic matter;
$X_{11} =$ Clay ratio x aggregation index;
$X_{12} =$ Clay ratio x 1/aggregation index;
$X_{13} =$ Aggregation index;
$X_{14} =$ Antecedent soil moisture;
$X_{15} =$ Increase in acidity below plow zone;
$X_{16} =$ Structure;
$X_{17} =$ Structure strength;
$X_{18} =$ Structure change below plow layer;
$X_{19} =$ Thickness of 'granular' material;
$X_{20} =$ Depth from 'friable' to 'firm';
$X_{21} =$ Loess$=1$; other $= 0$
$X_{22} =$ Other calcareous base$=1$; other $= 0$
$X_{23} = \%$ organic matter x aggregation index; and
$X_{24} =$ Reaction x structure.

The equation (8) is statistically accurate and technically valid for a broad range of medium textured soils, but it has proven too complex as a working tool for technicians. Furthermore, relationship of some factors on which the equation is based are not valid when the sand fraction exceeds 65% and clay fraction exceeds 35%. The equation is so cumbersome and require the determination of so many properties that it has remained an equation good for academic purposes and is not used extensively.

With the above limitations, work was further carried out to simplify the procedure for determination of K and a simple nomograph based on five soil parameters has been developed by Wischmeier *et al* (1971)

3.13 Determination of K with Soil Erodibility Nomograph

A new soil particle size parameter was found and used to derive a convenient erodibility equation (Wischmeier *et al* 1971). A simple nomograph has also been developed to provide quick solution to the equaiion. Only five soil parameters need to be known viz. percent silt plus very fine sand, percent sand greater than 0.10 mm, organic matter content, structure and permeability. They found that particles in the very fine sand classification (0.05 to 0.10 mm) behave more like silt than that like larger sand. When silt was redefined to include very fine sand and the sand was defined as particles from 0.05 to 2.0mm the prediction value of the two parameters improved appreciably. A new particle size parameter, which was designated as M is the product of percent silt and percent sand-and-silt.

For soils containing less than 70 percent silt and very fine sand, the soil erodibility factor, K can be calculated from the equation :

$$100\,K = 2.1 M^{1.14} (10^{-4}) (12 - a) + 3.25 (b - 2) + 2.5 (c - 3) \ldots \qquad (9)$$

where, M = the particle size parameter defined above;

a = percent organic matter;

b = the soil-structure code used in soil classification, and

c = the profile-permeability crass.

(Parameter b and c are further explained in Fig. 11)

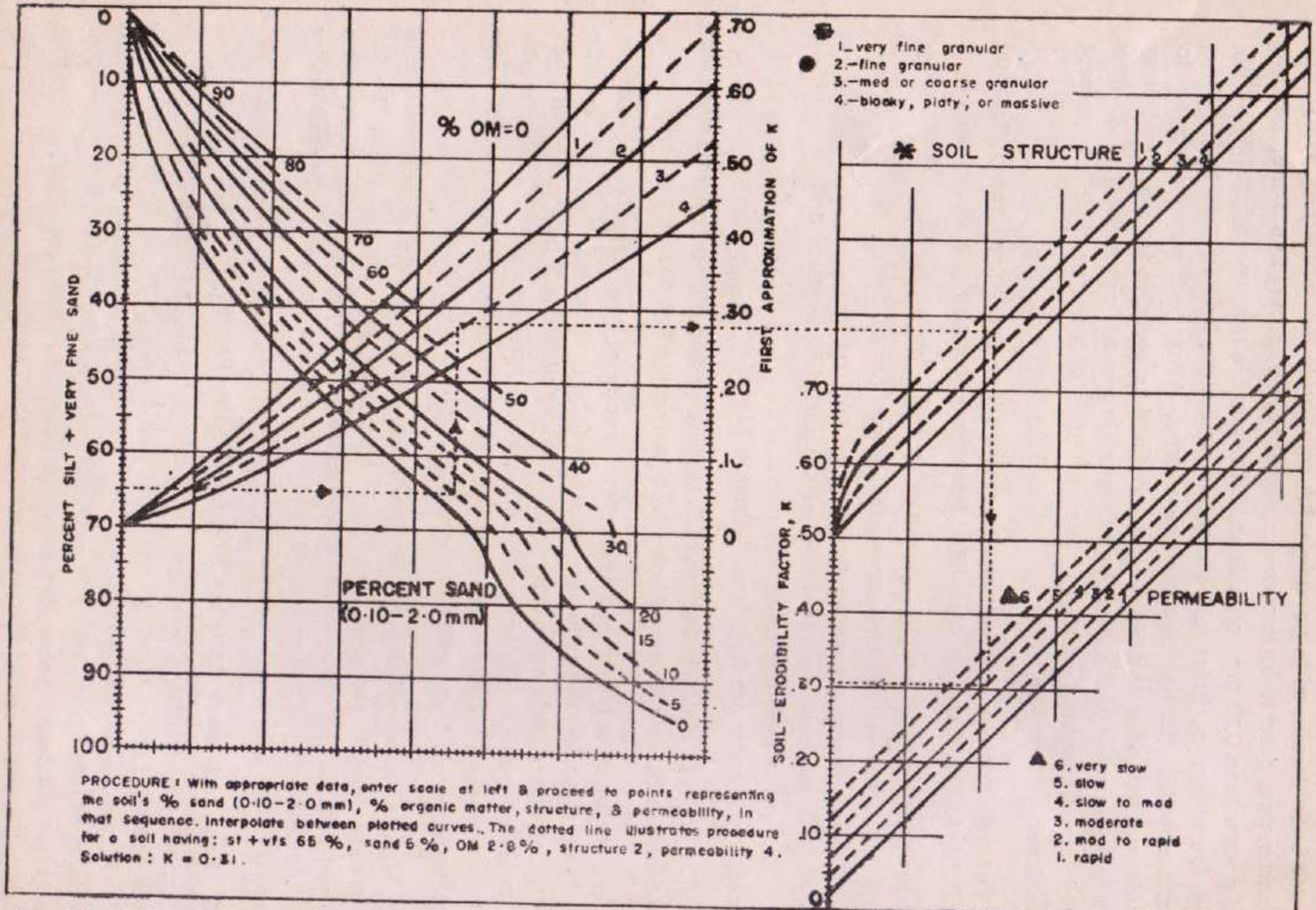
The process of determination of K is further simplified by transforming the equation (9) into a nomograph which is given in Fig. 11.

For solution of the nomograph enter the scale at the left and proceed to points representing the soils, percent sand (0.10 to 2.0 mm), percent organic matter, structure code and permeability class as illustrated by the dotted lines on the nomograph. The horizontal and vertical moves must be made in the listed sequence. Use linear interpolations between plotted lines. The structure code and permeability classes defined on the nomograph.

Many soils have fine granular structure and moderate permeability. In such cases, the K can be read only from the left hand portion of the nomograph. In all other cases, K should be determined by taking both sides of the nomograph in consideration The mechanical analysis, organic matter and structure data are required only for top soil.

3.2 Research work done on Soil Erodibility Factor, K

Soil conservation research in India started as early as 1923 with the establishment of dry farming scheme at Manjri near Pune (Kanitkar *et al*, 1960). The experiments carried out at Manjri from 1929 onwards to detemine the quantity of rain water lost by runoff and the quantity of soil lost by erosion were laid out on the same plan as was followed by Duley and Miller in their classical experiments at Missouri in the USA. Later on, a systematic approach



PROCEDURE : With appropriate data, enter scale at left & proceed to points representing the soil's % sand (0·10–2·0 mm), % organic matter, structure, & permeability, in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: si + vfs 65 %, sand 5 %, OM 2·8 %, structure 2, permeability 4. Solution : K = 0·31.

Fig. 11. Soil erodibility nomograph (after Wischmeier et al, 1971). 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 = (perçent si + vfs) (100 – percent c), a = percent organic matter, b = structure code and c = profile permeability class.

was adopted on soil conservation research when 8 Soil Conservation Research, Demonstration and Training Centres were established at Dehradun, Ootacamund, Chandigarh, Bellary, Kota, Vasad, Agra and Ibrahimpatnam, (Hyderabad) late in the I Five Year Plan and early in the II Five Year Plan. Besides these Centres, some State Governments. and other Institutions have also done useful studies in these lines. Some important findings emerged from these Soil Conservation Research Centres; State Soil Conservation Research Centre, Rehmankhera (Lucknow); Damodar Valley Corporation, Hazaribagh; I. .T., Kharagpur; and T.N. Agricultural University, Coimbatore. In all these research stations, runoff plots of various sizes and gradients were installed and studied. As the runoff plots at various stations had size different than 22.13 m (72.6′) long and 9 percent slope, the soil loss data from these plots had to be adjusted to the unit plot size of 22.13 m × 1.83 m (72.6′ x 6′). An example for working out the soil erodibility factor, K from these plots is given below :

Length of the runoff plot = 30 m
Slope gradient = 5 percent
R factor = 800
Soil loss from the plot = 50 tonnes/ha

The above data has to be adjusted to the plot size of 22.13 m long on 9 percent slope. For this adjustment, the Length Slope (LS) factor should be obtained from Fig. 15. By referring the Fig. 15, we see that the LS factor for a plot of 30 m length on 5 percent slope comes to 0.54, The calculations for K factor are given as below :

$$\text{Adjusted soil loss (tonnes/ha)} = \frac{\text{Observed soil loss (tonnes/ha)}}{\text{LS Factor}}$$

$$= \frac{50}{0.54} = 92.6$$

$$K = \frac{\text{Adjusted soil loss (tonnes/ha)}}{R}$$

$$= \frac{92.6}{800} = 0.116$$

The work done in India related to the soil erodibility factor, K has been reviewed and summary of these studies and the soil erodibility factor, K for some of the stations have been described below :

Dehradun—At Dehradun, the studies were conducted on Dhulkot silt loam soil on 8% slope. The value of K has been found to vary from 0.06 to 0.28 tonnes/ha/R with an average of 0.15 (Khybri *et al* — unpublished data). The yearly values of K are given in Table—7.

Table—7 : *Soil erodibility factor for Dehradun*

Year	Soil loss causing rainfall (mm)	Rainfall factor (R)	Soil loss (tonnes/ha)	Adjusted soil loss* (tonnes/ha)	Estimated K
1968	833	966	44.9	53.5	0.06
1969	588	462	42.7	50.8	0.11
1970	608	491	96.0	114.3	0.23
1971	1099	975	123.3	146.8	0.15
1976	876	393	92.8	110.5	0.28
1978	1895	2047	185.3	220.6	0.11
1979	938	778	83.6	99.5	0.13
Average					0.15

*LS factor for 22.13 m length and 8% slope = 0.84

Kota—The studies were conducted on Kota clay loam soil at 1% slope on plot of 22.13 m length. The value of K has been determined and vary from 0.03 to 0.23 tonnes/ha/R with average of 0.11 (Pratap Narain *et al*, 1980).

Table—8 : *Soil erodibility factor for Kota*

Year	Rainfall factor (R)	Observed soil loss (tonnes/ha)	Adjusted soil loss* (tonnes/ha)	Estimated K (tonnes/ha/unit R)
1957	202	3.17	27.27	0.13
1958	182	1.69	14.52	0.08
1960	139	0.48	4.15	0.03
1965	97	0.65	5.57	0.06
1966	148	1.10	9.47	0.06
1967	579	9.90	85.05	0.15
1968	174	4.60	39.52	0.23
1969	416	2.00	17.18	0.04
1971	991	12.30	105.67	0.11
1976	421	10.06	86.43	0.21
1977	652	13.31	114.35	0.18
1978	1063	10.62	91.24	0.09
1979	299	1.75	15.03	0.05
				Average K = 0.11

*LS factor for 1% slope = 0.1164

Vasad—At Vasad, the value of K has been determined by Nema *et al* (1978) which varied from 0.052 to 0.066 with an average of 0.059 on 2% slope. The soil of Vasad is sandy loam, deep calcareous.

Table—9 : *Soil erodibility factor for Vasad*

Year	Rainfall factor (R)	Observed soil loss (tonnes/ha)	Slope gradient factor (S) for 2% slope	Adjusted soil loss (tonnes/ha)	Estimated K
1966	402.2	0.02	0.182	0.11	0.003
1967	511.1	4.88	0.182	26.83	0.052
1968	571.1	6.14	0.182	37.63	0.066
					Average 0.059

Agra –The value of soil erodibility factor for deep alluvial light texture soil of Agra has been worked out based on 7 years runoff plot data from 1971-79 having 2% slope (Sharma *et al*, 1975 and Sharma *et al*, 1979). The value of K has been worked out to be 0.07 based on average soil loss from these plots and average value of rainfall factor, R of 277 taken from Table 1.

Table—10 : *Soil erodibility factor for Agra*

Year	Rainfall factor (R)	Observed soil loss (tonnes/ha)	Adjusted soil loss (tonnes/ha)	Estimated K
1971		2.15	11.81	
1972		4.05	22.25	
1973		8 47	46.54	
1974	Average	2.01	11.04	
1975	R=277	2.34	12 86	
1978		2.31	12.69	
1979		2.02	11.10	
Average		3.34	18.34	0.07

Ootacamund –The lateritic soils of Ootacamund have low erosion ratio and low dispersion ratio. The soils are generally non-erodible in nature. The value of K was obtained from six years' average soil loss of 39.3 tonnes/ha from up and down cultivation of potato-after potato. The value of K was calculated to be 0.04 tonnes/ha/R from runoff plot of 25% slope and 11 m long (Tejwani *et al* 1975).

Hyderabad—The soil erodibility factor for red *chalka* sandy loam soil was worked out from runoff plots of 25 m length having 3% slope. The four years' (1976-79) average soil loss from cultivated fallow was 5.0 tonnes/ha (Shri Niwas, *et al*, 1980). The average EI for Hyderabad has been taken as 215 (Table-5). Based on these information, the average value of K for red *chalka* sandy loam soil comes to 0.08.

Rehmankhera (Lucknow)—At Rehmankhera, the studies were conducted on medium texture alluvial soil on runoff plot of 18.3 m (60′) length and varying slopes of 0.5, 1.5 and 3.0 percent. The EI value of Rehmankhera was not available and hence the value of nearest station i.e. Lucknow has been used while calculating the K factor. The average annual EI for Lucknow is 484 (Table 1). *Jowar-arhar* rotation was followed in these runoff plots. In order to work out the valve of K, the C factor for *jowar* has been taken as 0.619 as worked out at Kota (Pratap Narain *et al* 1980). The average value of K comes to 0.17. The annual soil loss values (Anonymous, 1961-62 to 1977-78) alongwith details for calculating K are given in Table-11.

Table—11 : *Soil loss (tonnes/ha) and estimation of soil erodibility factor for Rehmankhera*

Year	Soil loss (tonnes/ha)		
	0.5% slope	1.5% slope	3.0% slope
1961–62	4.09	5.95	11.45
1962–63	3.34	4.59	9.54
1963–64	8.35	8.18	18.63
1964–65	4.47	4.03	11.56
1969–70	2.65	5.68	13.30
1970–71	5.54	13.13	28.48
1971–72	8.31	13.99	15.86
1972–73	2.35	5.14	8.60
1974–75	0.81	2.80	3.21
1975–76	2.25	3.48	6.32
Average	4.22	6.71	12.69
LS factor	0.08	0.14	0.25
K	0.18	0.16	0.17
	Average K = 0.17		

Kharagpur—A very systematic study on runoff plots of varying size and slope gradients (25 m x 2 m – 2%; 37.5 m x 2 m – 2%; 50 m x 2 m – 2%; 60 m x 1.5 m – 2%; 45 m x 1.5 m – 3.5% and 30 m x 1.5 m – 5%) was made on soil derived from lateritic rock with high amount of iron and aluminium at Kharagpur. The annual EI values with soil loss data from various sizes and slope gradient plots is given in Table–12 (Rao, 1981).

Table—12 : *Annual EI and soil loss for various sizes and slope gradient runoff plot-Kharagpur*

Year	EI	Soil loss (tonnes/ha)					
		2%				3.5%	5%
		25 m x 2m	37.5 m x 2m	50m x 2m	60m x 1.5 m	45m x 1.5m	30m x 1.5m
1964–65	1228	12.36	14.35	—	11.90	19.77	18.64
1955–66	617	4.80	5.83	6.26	7.18	8.36	12.39
1966–67	965	5.54	6.98	9.65	6.65	9.15	—
1967–68	1086	12.53	—	17.84	10.66	11.41	16.53

Based on the above data, the yearly value of K has been worked out which varies from 0.029 to 0.070. The average value of K comes to 0.04(Table–13).

Table — 13 : *Soil erodibility factor for Kharagpur*

Year	Soil erodibility factor, K					
	2% slope				3.5% slope	5% slope
	25m x 2m	37.5m x 2m	50m x 2m	60m x 1.5m	45m x 1.5m	30m x 1.5m
1964–65	0.053	0.054	—	0.040	0.042	0.029
1965–66	0.041	0.044	0.043	0.048	0.036	0.039
1966–67	0.030	0.033	0.043	0.028	0.025	—
1967–68	0.061	—	0.070	0.040	0.028	0.029
LS factor	0.190	0.217	0.235	0.243	0.380	0.530
Average K	0.046	0.044	0.052	0.039	0.033	0.032
	Over all average K = 0.04					

The values of K determined for 8 stations in India on which erosion plot studies under natural rain were conducted are listed in Table–14.

Table–14 : *Computed value of soil erodibility factor, K from various Research Stations in India*

Station	Soil	Computed K
Agra	Loamy sand; alluvial	0.07
Dehradun	Dhulkot silt loam	0.15
Hyderabad	Red *chalka* sandy loam	0.08
Kharagpur	Soils from lateritic rock	0.04
Kota	Kota-clay loam	0.11
Ootacamund	Laterite	0.04
Rehmankhera	Loam, alluvial	0.17
Vasad	Sandy loam, alluvial	0.06

Except for one station (Rehmankhera, Lucknow), the values of K has been calculated by adjusting the C factor for *jowar* obtained from other sources. A number of other soils, on which valuable erosion studies have been conducted, have not been included because of uncertainities involved in adjustment of the data for effects of cropping and management.

Direct measurement of erodibility factor from runoff plot is costly and time consuming. In India, there is a wide variation in the soils of different agro-climatic regions and it would be impossible to evaluate the soil erodibility factor (K) of these soils from runoff plot studies. It is, therefore, suggested that in future, studies should be undertaken to determine the value of K based on simple method of nomograph (Fig. 11) suggested by Wischmeier *et al* (1971) in which only five simple soil parameters are required. Number of studies have shown that erodibility factor determined by runoff plot and nomograph compare quite well (Wischmeier *et al*, 1971).

4.0 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 begins, or the runoff water enters a well-defined channels (Smith and Wischmeier, 1957). A change in land cover or a substantial change in gradient along the slope does not begin a new slope length for purposes of soil loss estimation.

It is generally accepted that erosion increases with increasing slope length. However, the effect of slope length on annual runoff per unit area of cropland may generally be assumed negligible, although the soil loss per unit area increases substantially as slope-length increases. The greater accumulation of runoff on longer slopes increases its detachment and transport capacities.

In the first comprehensive examination of slope lengte (λ) effects, Zingg (1940) concluded that total soil loss varied as $\lambda^{1.6}$ and thus soil loss per unit area was proportional to slope length to the 0.6 power. 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 22.13 m slope length, its value may be expressed as $L=\left[\frac{\lambda}{22.13}\right]^{m}$, where λ is the field slope length in metres, and m assumes the value of 0.2 to 0.5 and in very rare cases upto 0.9 depending on the gradient of slope. In past, investigations under natural rainfall conditions, the average value of 'm' was about 0.5. This is the value which was used for development of slope length chart by Wischmeier and Smith (1965).

Wischmeier and Smith (1965) had suggested that on slope steeper than 10%, the value of 'm' may be taken as 0.6, but the recent work of Wischmeier and Smith (1978), showed that the existing field plot data do not establish a general value of greater than 0.5 for m on slopes steeper than 10%. However, basic modelling work has suggested that 'm' may appreciably exceed 0.5 on steeper slopes that are highly susceptible to rilling like some steep slopes under construction area. Mutchler and Greer (1980) felt that slope length factor determined by Wischmeier and Smith (1965) are based on the data gathered on slopes of 3 percent and higher and hence, need some adjustment before the USLE is used on flat land slopes. They conducted study on plots of 23, 46, 91 and 183 m length on a slope of 0.2 percent and recommended $m = 0.15$ for slopes less than 0.5 percent.

After taking into consideration the recent work on flat slopes, Wischmeier and Smith (1978) has come out with varying values of exponent 'm' for different slopes and these are as follows :

Slope gradient	*Value of m*
1. <1%	0.2
2. 1–3%	0.3
3. 3.5–4.5%	0.4
4. 5% and more	0.5

4.1 Selected Research work done in India on L factor

The research work on slope length factor in India is very limited and relativelv very small amount of data is available on this aspect. The results of the studies related to the effect of length of slope on soil loss is also not very conclusive. Some of the results obtained are given hereunder :

Rehmankhera (*Lucknow*)—The study was conducted on medium texture alluvial soil on runoff plot of 18.3 m (60'), 36.6m (120') and 54.9 m (180') length having uniform slope of 0.5% (Anonymous 1961-62 to 1977-78). The crops of *urd+arhar* was taken in all the plots. Table—15 gives the soil loss data under different slope length plots.

Table – 15 : *Effect of length of slope on soil loss – Rehmankhera.*

Year	Soil loss (tonnes/ha)		
	18.3m	36.6m	54.9m
1961–62	1.38	1.00	1.13
1962–63	0.73	0.95	1.58
1963–64	0.44	0.64	0.81
1964–65	2.50	1.26	1.65
1969–70	1.08	0.98	0.67
1970–71	0.86	—	0.69
1971–72	1.74	—	1.29
1972–73	2.30	—	1.84
1974–75	0.25	—	0.21
1975–76	1.95	0.77	0.27
1976–77	3.71	1.63	0.79
15 years average	1.79	1.45	1.14

From the above table, it can be seen that the results are not very clear. In some years, the soil loss increases with the increase of length of slope but in most of the years either there is no appreciable difference in soil loss with the change in length of slope or the soil loss has decreased with the increase in length. Average of 15 years data also showed that the soil loss has actually decreased with the increase in slope length. This is quite contrary to the relationship suggested by Wischmeier and Smith (1978) who have clearly showed that the soil loss increases with the increase in slope length.

Chandigarh – The studies were conducted on alluvial soil having 1.5% slope. Maize crop was taken in all the plots. Six years data on 90m, 120m and 150m plot lengths are given in Table – 16 (Sud *et al* 1976 and 1977).

Table 16 : *Effect of length of slope on soil loss-Chandigarh*

Year	Soil loss (tonnes/ha)		
	90m	120m	150m
1972	4.75	3.80	2.10
1973	7.46	5.82	1.66
1974	7.95	3.54	3.23
1975	7.82	5.44	3.23
1976	8.22	7.15	5.50
1977	7.20	5.49	5.31
Average	7.23	5.21	3.50

The data from Chandigarh are not like Rehmankhera. At Chandigarh, the soil loss decreases consistently with the increase in slope length in all the six years of study. This is once again contrary to the general relationship, $L = \left[\frac{\lambda}{23.13}\right]^{m}$ given by Wischmeier and Smith (1978). However, in their earlier studies, Smith and Wischmeier (1962) have stated that the relationship of soil loss to slope length often varied more from year to year on the same plot than it varied among locations. The magnitudes of the slope length exponent appeared to be influenced by soil characteristics, rainfall pattern, steepness slope, cover and residue management.

Kharagpur—Rao (1981) conducted studies on runoff plots of length 25m,—37.5m, 50m, and 60m at 2% slope. The soil was derived from lateritic rock and plots were maintained under bare cultivated fallow treatment. The soil loss data for 4 years and average value are given in Table—17.

Table—17 : *Effect on length of slope on soil loss—Kharagpur*

Year	Soil loss (tonnes/ha)			
	Plot of length			
	25m	37.5m	50m	60m
1964–65	12.36	14.35	—	11.90
1965–66	4.80	5.83	6.26	7.18
1966–67	5.54	6.98	6.95	6.65
1967–68	12.53	—	17.84	10.66
Average	8.81	9.04	10.35	9.10

It is interesting to note in this study, that the soil loss has increased with the increase in length upto 50 m. At 60m length, the soil loss did not exactly followed this pattern. The pattern of soil loss seems similar to the equation suggested by Wischmeier and Smith (1965).

5.0 SLOPE GRADIENT FACTOR (S)

S is the slope steepness factor and is the ratio of soil loss from the field slope gradient to that from the 9% slope under otherwise identical conditions. Zingg (1940) was the first worker to give a comprehensive review of the work on slope factor and concluded that soil loss varies as the 1.49 power of percent slope. Later, in 1947, Musgrave recommended use of the 1.35 power of percent slope.

Smith and Wischmeier (1962) combined the data of several workers and found a very good least squares fit to the equation :

$$A = 0.43 + 0.30S + 0.043S^2 \quad \ldots \quad \ldots \quad (10)$$

where, A is soil loss and S is percent slope. This equation was further modified for determination of the S factor of the USLE and is as below :

$$S = \frac{0.43 + 0.30_s + 0.043_s^2}{6.613} \quad \ldots \quad \ldots \quad (11)$$

where, S is the slope gradient factor and s is percent slope of the land.

The slope gradent equation has been recently modified by Wischmeier and Smith (1978) and the latest equation is :

$$S = 65.41 \sin^2\theta + 4.56 \sin\theta + 0.065 \quad \ldots \quad (12)$$

where, S = slope gradient factor; and
θ = angle of the slope.

5.1 Research on Slope Gradient Factor

Bellary—In black soil of Bellary, the soil loss data was collected for 6 years (1957-63) from runoff plots of 1% and 2% slopes. It was observed that the soil loss followed the pattern suggested by Zingg (1940) and the value of exponent 'm' for Bellary was found to be 1.39 with standard error of 0.127. The high variability is attributable to the difficulty in collecting quantitatively the runoff from plots in black soil which, due to their wide cracks, leave gaps at the junction of soil and cement structures through which runoff escapes without entering the collection tank (Tejwani *et al*, 1975).

Rehmankhera—At Rehmankhera (Lucknow), 18.3 m(60') long and 2.44m (8') wide runoff plots were established on medium textured soil having slopes of 0.5, 1.5 and 3.0 percent (Anonymous, 1961-62 to 1977-78). *Jowar-arhar* rotation was followed in the plots. The study was run for number of years and the data for 10 available years is reproduced in Table-18.

From the table, it is quite clear that the soil loss increases with the increase in degree of slope. The pattern of soil loss seems quite similar to the equation suggested by Wischmeier and Smith (1965). The relationship of average soil loss against the degree of slope is shown in Fig. 12.

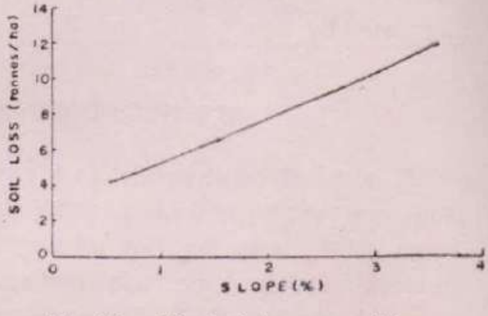


Fig. 12. Effect of slope on soil loss—Rehmankhera.

Table—18 : *Effect of slope steepness on soil loss (tonnes/ha)-Rehmankhera*

Year	0.5% slope	1.5% slope	3.0% slope
1961-62	4.09	5.95	11.45
1962-63	3.34	4.59	9.54
1963-64	8.35	8.18	18.63
1964-65	4.47	4.03	11.56
1969-70	2.69	5.68	13.30
1970-71	5.54	13.13	28.46
1971-72	8.31	13.99	15.86
1972-73	2.35	5.14	8.60
1974-75	0.81	2.80	3.21
1975-76	2.25	3 48	6.32
Average	4.22	6.71	12.69

Kharagpur—At Kharagpur, runoff plots at 2.0, 3.5 and 5.0 percent were established on soils derived from lateritic rock (Rao, 1981). The four year soil loss data from bare cultivated fallow plots are given in Table-19.

Table—19 : *Effect of slope on soil loss (tonnes/ha).—Kharagpur*

Year	Soil loss (tonnes/ha)		
	2% slope	3.5% slope	5% slope
1964-65	11.90	19.77	18.64
1965-66	7.18	8.36	12.39
1966-67	6.65	9.15	—
1967-68	10.66	11.41	16.53
Average	9.10	12.17	15.85

From table, it is observed that the slope gradient has similar effect on soil loss as has been obeerved in case of Rehmankhera. The relationship has been shown in Fig. 13.

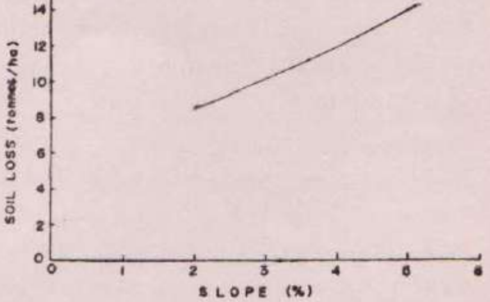


Fig. 13. Effect of slope on soil loss—Kharagpur.

Coimbatore—At Coimbatore, the investigations were undertaken on bare runoff plots of size approximately 1/175 ha with 0,2,3 and 4 percent slopes to determine the extent of soil erosion as influenced by the degree of slope and rainfall. The soil was sandy clay loam. Exponential relationship was noticed between soil erosion and the degree of slope and the rainfall (Balasubramanian and Sivanappan, 1981). The equation fitted is given below :

$$E_s = -0.296\, R^{1 \cdot 325}\, S^{1 \cdot 514}$$

$$n = 56;\ R^2 = 0.896^{**} \qquad \ldots \qquad \ldots \qquad (13)$$

where, E_s = soil loss in kg per ha;

R = daily rainfall in mm;

S = slope in percent; and

$**$ = significant at 1 percent level.

From the above equation, it is clear that 90 percent of variation in the soil loss was due to rainfall and slope. Further, soil loss was found to increase significantly with the increase in degree of slope and rainfall. It could be seen from the results that for one percent change in rainfall, the soil loss would change by 1.325 percent while for 1 percent change in slope, the change in soil loss was 1.514 percent. Wischmeier *et al* (1958) also obtained a non-linear form relationship between soil loss and slope.

5.2 Topographic Factor (LS)

LS is the expected ratio of soil loss per unit area from a field slope to that from a 22.13 m length of uniform 9 percent slope under otherwise identical condition. Although L and S factors can be determined separately by the method described in earlier sections, the procedure has been further simplified by combining the L and S factor together and considering the two as a single topographic factor. The Fig. 14 which was developed earlier by Wischmeier and Smith (1965) has now been modified after taking into consideration the results of recent research in this line. The new equation combining the effect of L and S factors is as follows :

$$LS = \left[\frac{\lambda}{22.13}\right]^m \left[65.4\, \mathrm{Sin}^2\theta + 4.56\, \mathrm{Sin}\theta + 0.065\right] \qquad \ldots \qquad (14)$$

where, λ = slope length in m;

θ = angle of slope; and

m = exponent factor varying from 0.2 to 0.5 as described earlier.

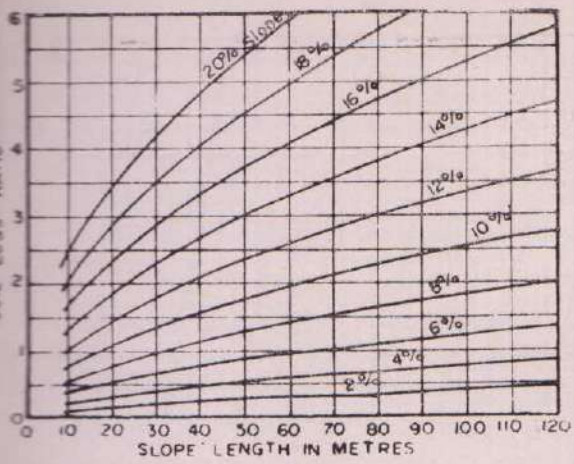


Fig. 14. Chart for adjusting plot soil loss to length & degree of slope (after wischmeier et al. 1965).

Based on equation (14), a nomograph (Fig. 15) for determining LS factor was developed for convenience (Wischmeier *et al*, 1978). LS factor can be easily read from this nomograph.

After critical examination of the data on various slope lengths and degree of slopes, it is felt that the relationship between the slope length and soil loss is not very clear, under Indian condition. The data for degree of slope is also not sufficient to draw any definite conclusions. It would be therefore, advisable to undertake a systematic study under various soil climatic regions of India to determine the effect to length of slope and degree of slope on soil loss. The original length and slope factor which were determined by Wischmeier and Smith (1978) were based on soil loss data collected under temperate rainfall conditions where the intensity of rainfall is generally low. The rainfall characteristics in India are entirely different as far as their intensity and duration are concerned and it would be worthwhile to validate the Wischmeier's relationship for our conditions.

6.0 CROPPING MANAGEMENT FACTOR (C)

The cropping management factor, C is the expected ratio of soil loss from land cropped under specified conditions to soil loss from clean tilled fallow on identical soil and slope and under the same rainfall. This item reflects the combined effect of cover. crop sequence, productivity level, length of growing season, tillage practices. residue management and the expected time distribution of erosive rain storm with respect to seeding and harvesting date in the locality.

This factor is the most complicated because there is an almost infinite number of different ways of managing the growing crops. In the early system, such as the slope-practice equation, a single value for this crop factor was used to give the average effect over the whole season.

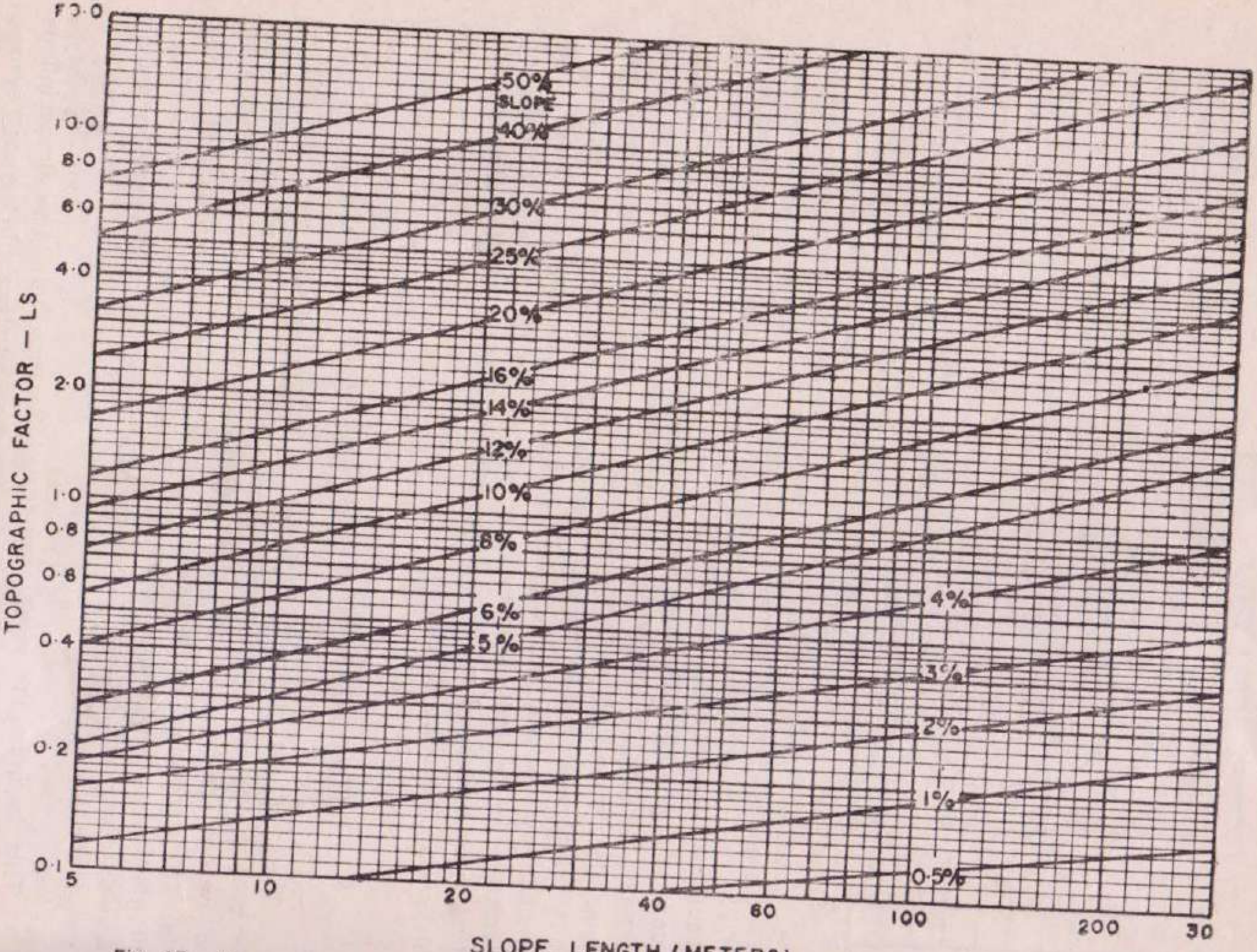


Fig. 15. Slope—effect chart—Topographic

The soil loss that would occur on a particular field if it were continuously in fallow conditions is computed by the product of RKLS in the Soil Loss Equation. Actual loss from the cropped field is usually much less than this amount. This reduction depends on the particular combination of cover, crop sequence and management practices. It also depends upon the particular stage of growth and development of the vegetal cover at the time of rain. C adjusts the soil loss estimate to suit these conditions (Wischmeier and Smith, 1978).

It is generally seen that the erosivity of rain may vary considerably during the different stages of crop-growth as well as effectiveness of the crop cover may also vary, at different stages of its growth. It is important to take into consideration the interaction of rainfall erosivity and crop cover at different stages of growth. The changes in effectiveness of plant cover wifhin the crop season is gradual. For purpose of calculation, the season can be divided into various crop stages so that cover and management effects may be considered approximately uniform within each period.

Wischmeier and Smith (1965) sub-divided the crop season into five growth periods. In their recent publication of 1978, they have suggested to subdivide the crop season into six crop-stages for better explanation of the differences due to crop cover and management effects. The six crop-stage periods defined by them are as follows :

Period F (rough fallow) — Inversion ploughing to secondary tillage.

Period SB (seedbed) — Secondary tillage for seedbed preparation until the crop has developed 10% canopy cover.

Period 1 (establishment) — End of SB until crop has developed a 50% canopy cover (Exception : period 1 for cotton ends at 35% canopy cover).

Period 2 (development) — End of period 1 until canopy cover reaches 75% (60% for cotton).

Period 3 (maturing crop) — End of period 2 until crop harvest. This period was evaluated for three levels of final crop canopy.

Period 4 (residue or stubble) — Harvest to ploughing or new seedling.

The above six crop stages defined by Wischmeier and Smith (1978) generally do not fit well to the Indian conditions where the crop growing season is much shorter that the crop season on which the original six crop stages have been defined. In India, it may be quite sufficient to divide the 100-120 days crop growth period of *kharif* season into 3 or 4 uniform crop growth stage periods. A usual way with the Indian workers (Rao, 1981; Pratap Narain *et. al*, 1980) has been to divide the growth period as follows :

Stage 1	Germination and seeding establishment stage	Seeding to 1 month stage of crop growth.
Stage 2	Active vegetative stage	From 1 to 2 months crop growth.
Stage 3	Final growth and maturity stage	End of period 2 to crop harvest.

To obtain the locational value of cropping management factor, C, soil loss ratios for the individual crop stage periods must be combined with erosion distribution data. Ratio of soil loss in each crop stage period of specified cropping and management systems to corresponding losses from basic long-term fallow condition, may be derived from runoff plot data.

The ratio of soil loss under given crop-stage period is combined with percentage rainfall factor, R of that particular period to obtain the C values. Percentage of monthly R factor which can be used with various crop stage period have been determined for 45 stations in India and given in Table-20 (Ram Babu et al 1978 a). C values for various crop growth stages are derived similarly and combined together to obtain average C–value for a particular crop. Further, the C value of a crop rotation may also be determined in a similar fashion. An example for working out cropping management factor, C is given in Table–21.

Table—21 : *Derivation of C-value of maize*

Crop growth stage	Soil loss (tonnes/ha)		Soil loss ratio (%)	Rainfall factor R (%)	C value (Soil loss ratio, % X R, %/100 X 100)
	Cultivated fallow	Under maize			
Stage 1—Seeding to 1 month stage of crop growth	10.0	8.0	80	30.1*	0.241
Stage 2—From 1 to 2 months crop growth	6.0	3.6	60	42.1	0.253
Stage 3—From 2 months to crop harvest	5.0	2.0	40	12.5	0.050
				Total	0.544

*Refer the station—Dehradun (Table-20). Substract the percentage value of EI for the month of June from the value of July i.e. 44.6—14.5=30.1 and similarly for next two crop periods.

Table-20 : *Percentage of the average annual EI for different months in five zones of India*

Stations / Months	January	February	March	April	May	June	July	August	September	October	November	December
1	2	3	4	5	6	7	8	9	10	11	12	13
Northern Zone												
Amritsar	0.3	0.3	0.3	0.3	0.5	3.0	39.4	75.7	96.3	99.7	99.9	100.0
Chandigarh	1.4	2.5	4.0	4.1	7.0	20.5	51.9	83.0	95.7	97.5	97.7	100.0
Dehradun	0.9	1.7	3.1	3.7	5.3	14.5	44.6	86.7	99.2	99.5	99.9	100.0
New Delhi	1.3	1.6	2.5	3.1	3.4	8.6	39.2	73.1	95.8	99.9	99.9	100.0
Jaipur	0.3	1.4	1.6	1.7	3.0	9.3	43.0	82.7	94.7	100.0	100.0	100.0
Agra	0.0	0.1	1.2	1.2	2.4	6.9	29.8	73.5	99.5	99.5	99.9	100.0
Jodhpur	0.3	0.3	0.8	0.8	2.5	10.6	40.4	73.7	96.1	100.0	100.0	100.0
Lucknow	0.2	0.2	0.5	0.8	4.2	12.2	48.4	77.8	94.1	100.0	100.0	100.0
Allahabad	—	0.4	0.7	1.0	1.4	11.9	41.7	81.2	98.1	100.0	100.0	100.0
Central Zone												
Indore	0.1	0.4	0.6	0.6	1.2	17.9	51.6	75.7	95.5	99.0	99.8	100.0
Bhopal	0.3	0.3	0.9	0.9	3.9	16.2	47.3	80.5	98.9	99.7	100.0	100.0
Jabalpur	0.5	1.0	1.9	2.0	4.2	21.4	44.8	86.4	97.8	99.3	99.4	100.0
Punasa	—	—	0.3	0.3	0.4	21.5	48.3	71.2	97.0	99.5	99.7	100.0
Thikri	—	—	—	—	1.5	19.6	46.6	62.4	94.4	98.7	99.3	100.0
Bagra Tawa	0.3	0.3	0.7	0.7	2.5	7.5	33.3	70.3	97.4	100.0	100.0	100.0
Nagpur	—	—	1.6	2.3	4.4	26.9	60.4	78.7	95.7	98.7	98.8	100.0
Raipur	0.3	0.4	1.8	2.1	2.7	34.7	63.1	83.4	97.8	99.6	99.8	100.0
Jagdalpur	0.2	1.8	2.6	8.6	14.7	36.5	51.0	77.8	91.8	99.0	99.2	100.0
Kota	—	0.1	0.3	0.3	0.9	12.2	51.6	83.2	98.8	99.7	99.9	100.0
Eastern Zone												
N. Lakhimpur	0.0	0.2	0.7	2.3	11.0	31.6	56.0	78.7	95.7	99.4	99.8	100.0
Gauhati	—	—	0.9	7.3	19.0	42.1	65.6	87.6	97.9	99.4	100.0	100.0

(Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
Shillong	—	—	1.2	5.5	19.1	49.2	63.1	75.4	96.1	100.0	100.0	100.0
Imphal	—	0.4	1.0	4.5	23.1	45.5	62.2	85.4	94.2	99.5	100.0	100.0
Agartala	0.2	1.7	4.8	13.0	35.0	57.1	73.0	84.0	93.6	99.8	100.0	100.0
Gaya	0.5	0.5	1.2	1.4	4.5	18.4	38.5	74.6	97.5	100.0	100.0	100.0
Jamshedpur	—	0.1	0.6	2.9	6.3	24.8	53.3	78.7	94.6	99.3	100.0	100.0
Dum-Dum	0.1	0.2	1.0	5.2	15.0	34.9	54.4	74.3	94.3	100.0	100.0	100.0
Sagar Island	0.1	1.3	1.7	3.8	8.9	20.4	39.0	58.4	89.0	98.4	100.0	100.0
Jharsuguda	0.7	1.6	2.7	4.2	6.4	23.9	50.0	84.1	96.3	99.9	99.9	100.0
Western Zone												
Bhuj	—	—	0.8	0.8	0.8	10.9	75.5	98.7	100.0	100.0	100.0	100.0
Vasad	—	—	—	—	0.1	23.5	52.5	71.2	100.0	100.0	100.0	100.0
Varaval	—	—	—	—	—	16.2	58.2	78.3	95.6	100.0	100.0	100.0
Nandurbar	—	—	—	1.3	2.3	15.1	57.0	71.0	89.1	99.3	100.0	100.0
Aurangabad	0.8	3.3	3.5	3.5	7.8	41.6	61.6	80.4	88.6	94.9	98.3	100.0
Mahabaleshwar	—	—	0.1	1.1	1.8	11.8	72.4	91.4	96.3	99.5	99.9	100.0
Vengurla	—	—	—	—	7.2	39.8	70.9	86.7	94.6	96.8	98.7	100.0
Southern Zone												
Vishakhapatnam	1.0	1.2	2.4	4.4	7.8	20.0	30.8	44.7	67.3	95.0	99.2	100.0
Hyderabad	—	0.2	2.5	7.7	14.4	24.9	39.5	57.7	86.3	97.9	98.5	100.0
Bangalore	0.0	0.9	1.0	7.9	23.6	31.0	38.0	54.9	76.4	91.7	96.4	100.0
Mangalore	—	—	—	0.7	10.1	34.3	69.6	83.5	90.7	96.3	98.5	100.0
Madras	0.7	0.9	1.4	3.6	4.5	9.3	15.0	29.1	40.1	62.5	93.3	100.0
Tiruchchirappalli	1.4	1.4	1.8	10.1	17.9	24.0	31.4	48.0	70.7	93.7	98.3	100.0
Ootacamund	0.0	0.5	3.1	6.2	30.1	39.2	53.9	62.1	70.4	88.7	97.8	100.0
Kodaikanal	0.4	1.8	6.8	30.9	40.4	45.8	54.2	66.4	78.6	91.5	97.7	100.0
Trivandrum	1.7	4.8	7.0	18.4	32.2	47.0	52.4	54.7	61.8	85.0	94.5	100.0

6.1 Research work done in India on C Factor

Based on the data from runoff plots of various sizes established in different agro-climatic areas of the country, a preliminary evaluation of the factor, C has been made. Although a number of crops have been studied but the detailed data of soil loss for various crop stages is rarely available in the published record. In absence of crop-stage growth period data, average value of C of the crop has been determined in a number of cases based on the total seasonal soil loss data. Roose (1977) had also suggested calculation of C value taking into account only the mean annual values in West Africa. The C values for various stations, except for Kota, Vasad and Kharagpur described below, may be considered only a first approximation till a detailed analysis of the C values is available from a specific growth stage period data.

Kota—The studies on various crops have been under progress for a considerable period and the C values for various common crops of the area have been computed (Pratap Narain *et al*, 1980). The grass cover of *Dichanthium annulatum* permitted almost no soil loss whereas *jowar-arhar* rotation seems to be quite effective with C value of 0.33 and other crops like cowpea, greengram and soyabean etc. were also in the similar range. *Jowar* alone and *gaur* gave maximum soil loss. Details of the data for working out the factor, C for various crops of Kota region are presented in Table—22. (Page 44)

Vasad—Although, soil loss studies were made for a number of crops under various management conditions but the C value is availahle only for *moong*, groundnut and cowpea (Nema *et al*, 1978). It was observed that cowpea is the most effective crop with C value of 0.32 followed by groundnut and *moong* (Table-23).

Table 23—*Crop management factor, C for moong, groundnut and cowpea-Vasad*

Stage	Average R of 15 yrs	R%	Soil loos ratio (%)			Value of C = R% × soil loss%/100×100		
			Moong	Ground nut	Cow-pea	Moong	Ground nut	Cow-pea
Sowing to 30 days (June 22 to July21)	239.2	46.0	58	41	34	0.27	0.19	0.16
30-60 days (July 22 to Aug. 21)	103.7	20.0	91	91	78	0.18	0.18	0.15
60-90 days (Aug. 22 to Sept. 21)	171.0	33.9	5	2	2	0.02	0.01	0.01
90-onwards (Sept. 22 onwards)	5.4	0.1	—	—	—	—	—	—
Total	519.4	100.0				0.47	0.38	0.32

Table—22 : *Crop management factor, C for various vegetational covers-Kota*

Particular	Crop stage periods				
	Sowing to 1 month after (1st July to 31st July)	From 1 to 2 months after sowing (1st Aug. to 31st Aug.)	From 2 months to crop harvest (1st Sept. to 30th Sept.)	Crop harvest onwards (1st Oct. onwards)	Total
Average 'R' for 22 years	139.61	111.91	55.11	3.39	310.02
R% of total R	45.03	36.10	17.78	1.09	100 00
Soil loss ratio (%)					
Green gram	28.76	60.68	24.05		
Black gram	81.45	29.27	36.42		
Groundnut	31.60	46.41	53.94		
Soyabean	61.94	34.07	10.87		
Cowpea	80.19	5 87	1.86		
Guar	64.69	80.69	6.56		
Maize	32 08	77.40	43.72		
Jowar	61.00	61.14	69.30		
Jowar+arhar	72.20	16.55	3.01		
Natural cover	2.73	27.34	16.00		
Cynodon dactylon	9.63	20.05	5.93		
Dichanthium annulatum	0.34	0.71	2.65		
'C' value = $\frac{R\% \times \text{soil loss}\%}{100 \times 100}$					
Green gram	0.130	0.219	0.043		0.392
Black gram	0.367	0.106	0.065		0 538
Groundnut	0.142	0 168	0 096		0.406
Soyabean	0.279	0.123	0 019		0.421
Cowpea	0.361	0.021	0.003		0.386
Guar	0.291	0.291	0.012		0.594
Maize	0.145	0.279	0 078		0.502
Johar	0.275	0.221	0.123		0.619
Jowar+arhar	0.325	0.003	0.005		0.333
Natural cover	0.012	0.099	0.028		0.139
Cynodon dactylon	0.043	0.072	0 105		0.220
Dichanthium annulatum	0 002	0.003	0.005		0.010

Kharagpur—Experiments for the evaluation of cropping management factor, C for cowpea, *Dub* grass (*Cynodon dactylon*), maize, paddy and pigeonpea were conducted on runoff plots of lengths varying from 25 m to 60 m on 2 to 5% slopes at Kharagpur. The soil is derived from the lateritic rocks. *Dub* (*Cynodon dactylon*) gave the best protection with a C value of 0.04 as compared to 0.17, 0.35, 0.28 and 0.38 for cowpea, maize, paddy and pigeonpea respectively (Rao, 1981). Stagewise distribution of crop cover, EI and soil loss for working out C values for different crops are given in Table 24. (Page 46)

Agra—The available soil loss data from 1971-1975 for *guar*, *til*, *bajra* and *Dichanthium annulatum* (Sharma *et al*,, 1975) have been used to work out the first approximation of C values in absence of the crop stage data (Table 25).

Table 25 : *Soil loss (tonnes/ha) and cropping management factor, C for various crops—Agra*

Crop	Soil loss (tonnes/ha)						Value of C
	1971	1972	1973	1974	1975	Average	
Fallow	2.15	4.05	8.47	2.01	2.34	3.80	1.00
Guar	1.43	2 97	2.49	0.37	0.85	1.63	0.42
Til	1.00	2.74	4.06	1.04	1.04	1.97	0.51
Bajra	1.01	2.90	6 57	0 77	0.43	2.34	0.61
Dichanthium annulatum	0.33	0.79	1 59	0.78	0.19	0.53	0.13

Dehradun—A considerable amount of work on maize has been done at Dehradun on standard size as well as field size runoff plots. The soil is Dhulkot silt loam. Although the specific information for calculation of 'C' factor was not available, an attempt has been made to utilise the available data from different management situations to find out mostly the combination effect of crop management and the conservation practices. The summary of the results from a number of experiments and the calculations to work out the value of C and P has been presented in the tables described below :

Study 1—The study was undertaken on maize in standard size runoff plots (22.13m × 1.83m) on 8% slope (Khybri *et al*, 1979). The CP factor for various treatments are given in Table-26.

Table 24 : *Stagewise distribution of crop cover and EI for C factor for different treatments – Kharagpur*

	Stages for different years									
	1964-65		1965-66		1966-67		1967-68		1968-69	
	I*	II	I	II	I	II	I	II	I	II
% of annual EI	17.1	37.1	12.5	31.1	20.8	11.1	17.6	55.0	6.3	33.0
Cowpea										
% crop cover	50.0	100.0	23.0	80.0	38.0	89.0	34.0	83.0	16.5	87.0
Soil loss (tonnes/ha)	1·20	2.28	1.59	0.28	1.01	0.29	2.90	1 23	2.41	2.07
C factor	0.23		0.16		0.13		0 21		0.11	
Average of 5 years=0.17										
Maize										
% crop cover	—	—	26.0	70.0	18.0	41.5	12.0	57.0	17.5	60.0
Soil loss (tonnes/ha)	—	—	1.62	0 55	1.55	1.05	4.88	5.05	3.19	4 37
C factor	—	—	0.27		0.29		0.61		0.23	
Average of 4 years=0.35										
Paddy										
% crop cover	15.0	40.0	20.5	70.5	18.0	45.0	25.0	66 0	13 5	29.0
Soil loss (tonnes/ha)	1.45	4.12	2.64	0.37	1.40	0.72	3.55	3.01	2.25	3.87
C factor	0.36		0.25		0.20		0 38		0.20	
Average of 5 years=0.28										
Pigeonpea										
% crop cover	—	—	11.2	30.0	11.4	31.0	10.5	29.3	—	—
Soil loss (tonnes/ha)	—	—	2.74	1.99	2.35	0.98	6.32	4 31	—	—
C factor	--		0.41		0.20		0.53		—	
Average of 3 years=0.38										

*I=Stage I = Germination and seedling establishment stage – Seedling to 1 month stage of crop growth.
II=Stage II = Active vegetative stage—From 1 to 2 months stage of crop growth.

Table 26 : *Effect of crop management (maize) on soil loss (tonnes/ha) and C P factor—Dehradun*

Treatment	Soil loss (tonnes/ha)			Value of C P
	1978	1979	Average	
Normal ploughing	51.75	33.34	42.54	0.31
Normal ploughing + grass mulch @ 4 tonnes per ha	8.88	3.50	6.19	0.05
1/3 strip ploughing along the seed line	39.81	28.02	33.91	0.25
Grass	0.40	0.01	0.21	0.002
Cultivated fallow	185.30	83.59	134.44	1.00

Study 2—The study was conducted in large field size runoff plots (100m × 20m) at 4% slope to find out the effect of maize crop geometry on erosion losses (Bhardwaj *et al*, 1979). The rows were laid across the slope of the land. The C P factor for various treatments are given in Table 27.

Table 27 : *Soil loss under maize grown with different crop geometry and C P factor—Dehradun*

Treatment	Soil loss (tonnes/ha)			C P factor*
	1978	1979	Average	
45 cm × 40 cm spacing	22.3	17.4	19.9	0.19
60 cm × 30 cm spacing	19.8	15.1	17.5	0.17
75 cm × 24 cm spacing	19.0	13.7	16.4	0.16
90 cm × 20 cm spacing	14.2	10.5	12.4	0.12

*Soil loss for bare cultivated follow (A) was estimated as follows :

A = RKLSCP

where, R for Dehradun = 1066 (Table 1)
K ,, ,, = 0.15 (Table 14)
LS ,, ,, = 0.65 (Fig. 15)
C ,, ,, = 1.00 (for bare fallow)
P ,, ,, = 1.00 (for bare fallow)

Hence, A = 1066 × 0.15 × 0.65 × 1.00 × 1.00
= 103.93 tonnes/ha.

In the above experiment, the total population of maize plants was constant at 55500 plants/ha but the intra-row spacing had definite effect on the soil loss. The CP varied from 0.12 to 0.19 depending on row to row and plant to plant distance of maize.

Study 3 – The study was conducted on runoff plots of 20m × 5m size at 11% slope under the covers of three fruit species namely, strawberry (creeping herb) pineapple (dwarf shrub) and pomegranate (small tree type). The data collected on soil loss is given in Table-28 (Ghosh *et al*, 1977). The values of crop management factor, C for various treatments have been worked out and given in Table 28.

Tabie 28 : *Soil loss under various horticultural crops and their C values—Dehradun*

Treatment	Soil loss (tonnes/ha) 1975	C value
Strawberry with weeds (30 cm × 30 cm)	8.89	0.27
Pineapple with weeds (40 cm × 60 cm)	3.29	0.10
Pineapple clean	11.51	0.34
Pomegranate with weeds (2.5m × 2.5m)	2.62	0.08
Pomegranate clean	18.69	0.56
Cymbopogon citratus grass	4.51	0.13
Cultivated fallow	33.42	1.00

From the table, it may be seen that management of grasses has considerable effect on soil loss. Wherever the grass was not removed, the C values reduced appreciably.

Hyderabad - The available soil loss data from miniwatershed of 0.02 ha (25m × 8m) with average land slope of 3% for *jowar, bajra* and castor have been used (Shri Niwas *et al*, 1980) to work out the first approximation of C values in the absence of the crop stage growth data.

Table 29 : *Effect of soil loss under various crops and their C values-Hyderabad*

Crop	Soil loss (tonnes/ha) Av. of 4 years (1976-79)	C Values
Jowar	3.21	0.64
Bajra	2.00	0.40
Jowar followed by horsegram	1.91	0.38
Jowar + redgram	1.59	0.32
Bajra followed by cowpea	1.91	0.38
Castor	3.97	0.79
Grass	0.59	0.12
Cultivated fallow-ridge*	2.67	0.53
Cultivated fallow	5.00	1.00

*In absences of no crop, this value may be treated as P value for contour cultivation.

Rehmankhera—The available soil loss data from 1961-62 to 1964-65 from runoff plots of 18.3m × 3.05m on 3.5% slope having medium textured soil for various crops have been utilized (Anonymous, 1961-62 to 1977-78). Using these data rough estimation of C values for various crops are given as under :

Table-30. *Soil loss under various treatments and their C values—Rehmankhera*

Treatment	Soil loss (tonnes/ha)					C value
	1962-62	1962-63	1963-64	1964-65	Average	
Jowar-arhar	5.93	2.11	1.64	1.63	2.73	0.28
Moong-barley gram	8.44	3.21	1.58	4.77	4.50	0.45
Til-gram	5.37	4.04	3.06	3.14	3.90	0.39
Kodon-gram-*rai*	12.35	9.19	2.80	5.62	7.49	0.75
Groundnut *arhar*	5.27	2.43	1.26	7.78	4.19	0.42
Guar-arhar	5.85	2.86	2.72	2.36	3.45	0.35
Sanai-barley	10-12	5.27	2.79	6.54	6.18	0.62
Cultivated fallow	12.40	14.66	3.53	9.19	9.95	1.00

Shillong—Some recent studies have been made in North-Eastern Hill Region to determine soil and water losses mostly under Jhuming cultivation. This area is very important as far as soil and water management is concerned because not onty the area is under hilly slope but also agriculture practices adopted (Jhuming cultivation) are very conducive to rapid soil erosion. Till now, there was no data available for this area but recently, ICAR Research Complex for Hill Region at Shillong has conducted very good studies on the effect of Jhuming cultivation, different agricultural and horticultural crops and various-management practices on soil loss. As only preliminary studies have been conducted, complete set of data are not yet available for working out various parameters of USLE. However, it would be appropriate to give some details of soil loss under different crop management situations in this area for a general awareness of the state of damage being done in these hilly areas. It would be possible to work out the parameters like K, C and P when some more data is available.

(i) *Shifting cultivation and soil erosion*—Preliminary studies (Singh, 1980) indicated that soil erosion problem in *jhum* land is mainly of splash and wash. As crops are taken in mixture on zero tilled slopes, erosion is a result of initial intensive human activity, disturbance due to weeding, splash and wash. Soil erosion from slopes (60-70%) under first year *jhum*, second year *jhum*, abandoned *jhum* (first year fallow) and natural *bamboo* forest was estimated to be 144.6, 170.2, 30.2 and 8.2 tonnes/ha/ year (Fig. 16). It reveals that second year of *jhum* cultivation is comparatively more hazardous than first year, whereas quick forest regeneration reduces the soil erosion to great extent during first year abandoning of *jhum*.

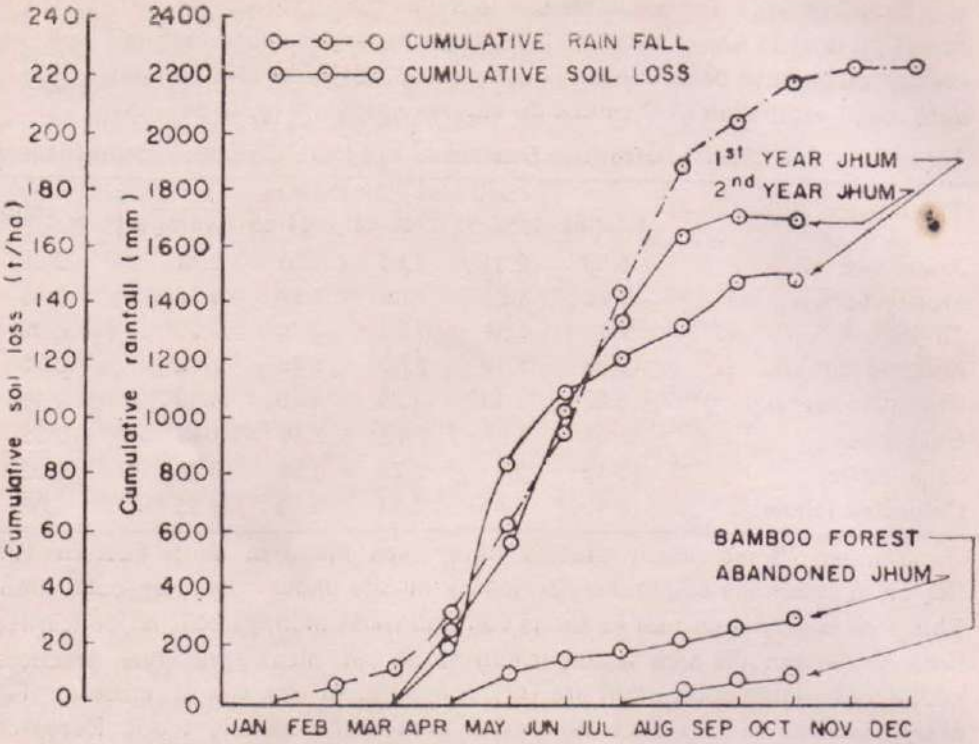


Fig. 16 Soil loss from 60-70% slope under various stages of jhum Cultivation—1977
(after Singh, 1980)

(ii) *Effect of land use*—Preliminary studies on land use effect on soil erosion on 40 to 50% slope were initiated during 1975 on micro-watersheds (Singh 1980). Initial observation on sediment production (Table—31) from

Table—31 : *Effect of land use on sediment yield—Shillong*

Details of landuse	Conservation measures	Soil loss (tonnes/ha)
Agriculture (jhuming)	—	40.95*
Agriculture (food crops)	Bench terracing	2.80*
Agriculture (food crops)	Puertorican type of terracing	27.80*
Agro-horticulture	Bench terracing/half moon terracing	3.90*
Agriculture (fodder crops)	Bench terracing+Puertorican type of terracing	14.23**
Mixed forest+habitat	—	18.85**
Cleared forest (first year of regeneration)	—	6.53**
Forest (bamboo)	—	0.52**

*Average of three years; **First year observation.

slopes under conservation based land uses indicates that combination of bench terrace and slope (as such) with agriculture and fruit crops may be better conservation system, as compared to complete slope or bench terrace alone. The observation gives only an indication, however, long term data would be required for conclusive results.

(iii) *Soil loss studies on patato and maize crops*—Studies have been conduted at Upper Shillog to find out the soil loss under potato and maize on level bench terraces on hill top. The soil loss data indicated that maize gave more soil loss (12.0 tonnes/ha) as compared to potato spring (7.94 tonnes/ha) (Rai, 1980).

(iv) *Soil loss studies on various crop sequences*—Eight combinations of maize and paddy were tried in mini-watersheds (16m×3m) on an average slope of 55% (Rai, 1980). The results are given in Table—32.

Table—32 : *Soil loss under various crop combinations–Shillong*

Treatment	Soil loss (tonnes/ha)
Mixed crop of maize and paddy on slope	35.00
Paddy on slope	33.92
Maize on slope	30.87
75% area of upper slope under maize + 25% lower bench terrace with paddy	7.24
50% area of upper slope with maize + 50% lower bench terrace with paddy	5.40
25% area of upper slope with maize + 75% lower bench terrace with paddy	1.10
All bench terrace with paddy	0.67
All bench terrace with maize	5.85

The cropping and management situations in various agroclimatic regions of the country need to be further determined. This work is quite important but at the same time lengthy and time consuming. From the details in this chapter, it would appear that C value for only limited situations are available for Indian conditions. Further work is going on in this directions and C value for more crops may be available in the near future. Till that time, the information given by Wischmeier and Smith (1978) may be made use of after carefully considering the cropping system, crops, cropping stages and crop management variations in the United States and in India and making suitable adjustments for these variations.

7.0 SUPPORTING CONSERVATION PRACTICE FACTOR (P)

In general, whenever sloping soil is to be cultivated and exposed to erosive rain, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will slow the runoff and thus reduce the amount of soil it carry. The most important of these supporting practices are contour cultivation, strip cropping, terrace system and water ways for the disposal of excess rainfall.

Factor, P in the Universal Soil Loss Equation is the ratio of soil loss with a specific supporting practice to the corresponding loss with up-and-down cultivation.

The work related to support practice factor, P has been reviewed and summary of these studies and P factor for some of the stations are described below :

7.1 Contour Cultivation and Research work done on P Factor

It is generally true that contour cultivation is effective in reducing soil erosion when compared with up and down cultivation. Its effectiveness varies according to the slope of the land. Contour cultivation is most effective on middle range slopes from 2 to 8% and less effective on flatter slopes and on steeper slopes.

Dehradun—Based on the studies conducted on large field plots of 91.5m × 15.2m (300′ × 50′) on Dhulkot silt loam soil on 4% slope, the value of P factor for contour cultivation on maize has been worked out to be 0.74 (Tejwani *et al*, 1975).

Ootacamund - In the deep lateritic soils of Ootacamund the soil loss data recorded on 25% slope from various land uses during 1960-61 to 1965-66 have been analysed for evaluating supporting conservation practice factor P under various treatments (Tejwani *et al*, 1975).

Treatment	*Supporting conservation practice factor, P*
Potato up and down	1.00
Potato on contour	0.51
Bare cultivated fallow treated with shallow furrows	0.59

Hazaribagh—At Hazaribagh, maize cultivation is practised on up and down the slope upto 5% slope. An experiment was conducted on runoff plot of size 32.8m × 3.28m (100′×10′) on 5% slope (Anonymous, 1972). The value of P factor has been worked out to be 0.31.

P factor for red soils at Hazaribagh

Treatment	*Soil loss (tonnes/ha)* *(Average of 6 years)*	*Factor, P*
UP and down cultivation (maize)	17.57	1.00
Cultivation along contour (maize)	5.34	0.31

Kanpur—At Kanpur, on 2.2% land (plot size : 25m × 4.65m) with alluvial soil, Bhatia and Chaudhary (1977) observed that contour cultivation reduced soil loss by 61% as compared to up and down cultivation. The P factor for contour cultivation under *jowar* crop has been worked out to be 0.39.

Treatment	*Soil loss (tonnes/ha)*	*Factor, P*
Up and down cultivation (*jowar*)	14.11	1.00
Contour cultivation (*jowar*)	5.46	0.39

Based on intensive studies from runoff plots, Wischmeier and Smith (1978) recommended the erosion control factor value for a number of situations. Table-33 give P value for some of the conditions generally encountered in the field. In the absence of detailed information for the various locations under Indian conditions, it is suggested that P value given in Table - 33 may be used till actual P value for specific locations are determined in India.

Table—33 : *P values and slope-length limits for contouring*

Slope (%)	P Value	Maximum length (m)*
1 to 2	0.60	131.2
3 to 5	0.50	98.4
6 to 8	0.50	65.6
9 to 12	0.60	39.4
13 to 16	0.70	26.2
17 to 20	0.80	19.7
21 to 25	0.90	16.4

*Limit may be increased by 25% if residue cover after crop seedlings will regularly exceed 50%.

7.2 Bunding and Terracing and Research work done on P Factor

7.21 Contour Bunding

This practice involves construction of *bunds* passing through the points having same elevation (contour). It is commonly adopted on agricultural lands upto a slope of about 6%.

Chandigarh has worked out the value of P for alluvial soils having 1.5% slope (Aginhotri *et al*, 1976). Maize crop was taken in the *bunded* and *unbunded* plots of 150m long. The *bunded* plot had 67m horizontal spacing. The EI, soil loss and P factor for maize are given in Table-34.

Table—34 : *EI, soil loss and P factor for maize—Chandigarh*

Years	EI for cropping period	Soil loss (tonnes/ha)		P factor
		Bunded	Unbunded	
1973	329	0.41	1.84	0.29
1974	274	0.48	2.93	0.21
1975	451	0.32	1.76	0.23
1976	395	1.13	3.17	0.39
Average	363	0.59	2.56	0.28

7 22 Graded Bunding or Channel Terraces

Channel terraces or graded *bunds* reduce the soil loss by decreasing the length of slope. Graded *bunding* is used in areas having rainfall more than 80 cm per year. In clayey soils, graded *bunding* is to be used for the areas, having annual rainfall of even less than 80 cm.

At Dehradun, the value of conservation practice factor, P for various mechanical measures has been worked out (Table--35) based on the studies conducted on Dhulkot silty clay loam soil in large field size plots (100m × 20m) laid on 4% slope (Gupta *et al*, 1965, 66, 67, 68).

Table-35 : *Soil loss and P factor under different conservation practies-Dehra Dun*

Treatment	Soil loss (tonnes/ha)				P factor
	1965-66	1966-67	1967-68	Average	
Up and down cultivation	11.93	4.20	3.56	6.56	1.00
Contour farming	9.30	2.30	1.89	4.50	0.68
Channel terraces with contour farming	2.97	2.20	2.42	2.53	0.38
Channel terraces (at 1.5 time usual spacing) with graded furrows	2.23	1.96	2.78	2.32	0.35

7.23 Strip Cropping

Strip-cropping, a practice in which contoured strips of sod are alternated with strips of row crops or small grain, is more effective than contouring.

Based on the data collected at Dehradun in large field plots (90m × 15m) on 4% slope, the following erosion control practice factor have been worked out (Tejwani *et al*, 1975).

Treatment	*P factor*
Strip cropping 3:1 (maize : cowpea)	0.51
Strip cropping 4:1 (maize : cowpea)	0.62

There is not much data available for strip cropping P factor in India. In absence of such data it is suggested that the values proposed by Wischmeier and Smith (1978) which are given in Table–36 may be used till such time as our own values are determined for various locations.

Table –36 : *P values for contour-farmed terraced fields*

Land slope (%)	Farm planning	
	Contour factor	Strip crop factor
1 to 2	0.60	0.30
3 to 8	0.50	0.25
9 to 12	0.60	0.30
13 to 16	0.70	0.35
17 to 20	0.80	0.40
21 to 25	0.90	0.45

7.24 Bench Terracing

Bench terracing consists of a series of platform having suitable vertical drops along contours. In rainfed areas, terraces are usually constructed on slopes from 6 to 33%.

The value of supporting conservation practice factor, P for bench terracing (0.5% longitudinal gradient, 2.5% inward gradient) has been worked out to be 0.027 for deep lateritic soil of Ootacamund having 25% land slope (Tejwani *et al*, 1975).

8.0 APPLICATION OF THE SOIL LOSS EQUATION

The conservation planning process is systematic decision making based upon a logical evaluation of the alternatives for land use and treatment.

It involves a careful inventory of soil and water resources and collection of data in a systematic form to determine not only the best practices from a conservation view point, but also the economic consequences of all practical alternatives of use and treatment of the land.

The soil conservation technicians can be helpful to the farmers in developing conservation programmes once they have estimates on soil losses based on an analysis of combined research and observations. They need a yardstick to measure the expected soil loss against a tolerable limit under various situations. There is a need to be able to talk in terms of soil loss in tonnes, or cm of soil so that farmer can understand the destruction caused by erosion. This can also be explain to the farmers the economics of conservation in terms of money.

The USLE can very well serve the above purpose and supply specific and reliable guide for selecting adequate erosion control practices on agricultural land. The system is also useful for computing the upland erosion phase of sediment yield as a step in predicting rates of reservoir sedimentation or stream-loading.

The USLE was basically developed from research data collected from agricultural fields and it is therefore, most suited for soil loss prediction from such areas. The USLE is designed to predict long time average soil loss. This may be the average for crop rotation or a particular crop or a crop-stage period in the growing season of a crop. 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 the soil loss from a given set of conditions on an average basis.

8.1 Working Example

To determine the average soil loss from a particular area, the first step is to find out the values for various factors of the USLE for that specific field. The values for various parameters have already been described in previous chapters. For easily understanding the procedure for calculation of soil loss from an agricultural field, working example has been described in the following para :

Let us assume that we want to work out the soil loss for Dhulkot silt loam soil of Dehradun under fallow conditions having a slope length of 100 m and slope gradient of 4%. For these conditions, the values of various parameters of USLE can be taken from the details given in the previous chapters for individual factor. The values for various factors are as follows :

Rainfall factor, R = 1066 (Table 1)
Soil erodibility factor, K = 0.15 (Table 14)
Topographic factor, LS = 0.65 (Fig. 15)
Crop management factor, C = 1.00 (for bare fallow)
Conservation practice factor, P = 1.00 (for bare fallow)

Then,

$A = RKLSCP$
$= 1066 \times 0.15 \times 0.65 \times 1.00 \times 1.00$
$= 103.9$ tonnes/ha/year

Next, we may like to know the effect of the cropping and management system and support practices existing in the field. This effect is represented by C and P factors. The CP value for maize crop sown across the slope in Dehradun is 0.31 (Table – 26) Then soil loss under maize crop would be :

$103.9 \times 0.31 = 32.2$ tonnes/ha/year

The soil loss for crop rotation can also be calculated in the similar fashion.

From the example discussed above, it is seen that the soil loss of 32.2 tonnes/ha/year is quite high and may deplete the soil fertility in a very short period of time. The soil loss at the rate of 32.2 tonnes/ha/year will remove a soil depth of 2.2 mm in one year or say it will take only 11 to 12 years to loose 25 mm of soil. This is very high rate of erosion which may not be desirable for a sustained production of crop over a long period of time.

For a sustained production, the amount of soil lost should not be more than the soil formed by natural process. The rate of soil formation cannot be precisely measured, but the best estimate of soil scientists is that under undisturbed conditions, it will take of the order of 300 years to produce 25 mm of top soil but that when the disturbances and aeration and leaching actions are speeded up by tilling the land, this will be reduced to something like 30 years (Hudson, 1971).

From this, it can be seen that the soil loss @ 32.2 tonnes/ ha/year will take only 11 to 12 years for the destruction of 25 mm soil and it is nearly 3 times higher than rate of soil formation. It can be therefore, said that not more than about 10 tonnes of soil loss can be permitted in one year in deep-alluvial soil, to keep a balance between the soil formation and soil destruction.

8.2 Soil Loss Tolerance

The terms 'soil loss tolerance' (T value) denotes the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely. Considerable work has been done on this aspect in USA and T values have been assigned ranging from 4.5 to 11.2 tonnes/ha/year (Mannering, 1981). The magnitude of the T values are based on soil depth, prior erosion and other factors affecting soil productivity. Naturally, the acceptable loss will depend on the soil conditions. If the profile consists of a deep soil where fertility is the same at all depths, than to loose 25 mm of soil in 30 years is much less serious than if the profile consists of a few centimeters of soil overlying hardrock. Generally, we allow up to 10 tonnes soil loss/ha/year on deep permeable well-drained alluvial soils and 3 – 5 tonnes on soils having unfavourable sub-soils.

A single T value is normally assigned to each soil series. A lower T value may be assigned to eroded phases of soil series in which the thickness of the effective root zone has been significantly reduced, thus reducing potential of the soil to produce plants over an extended period of time. The following criteria are used by soil scientists and agriculturists for assigning T-values (McCormack and Young, 1981).

1. Adequate rooting depth must be maintained in the soil for plant growth. For soils that are shallow over hard rock or other restrictive layers, it is important to retain the remaining soil; therefore, not much soil loss is tolerated.
2. Soil that have significant yield reduction if the surface layer is removed by erosion are given lower T-values than soils that have only minor yield reductions if the surface layer is removed.

Following is the table assigning soil loss tolerance values (T) to soils having different rooting depths (McCormack and Young, 1981).

Table-37 : *Guide for assigning soil loss tolerance values (T) to soils having different rooting depths*

Rooting depth (cm)	Soil loss tolerance values (annual soil loss tonnes/ha)	
	Renewable soil[1]	Non-renewable soil[2]
0 – 25	2.2	2.2
25 – 50	4.5	2.2
50 – 100	6.7	4.5
100 – 150	9.0	6.7
150 & above	11.2	11.2

[1] Soils with favourable substrata that can be renewed by tillage, fertilizer, organic matter and other management practices. .

[2] Soils with unfavourable substrata such as rock or soft weathered material that cannot be renewed by economical means.

The maximum T-value of 11.2 tonnes/ha/year has been selected for the following reasons :—

1. Soil losses in excess of 11.2 tonnes/ha/year affect the maintenance cost, the effectiveness of water-control structures such as open ditches, ponds, and other structure that can be damaged by sediment.
2. Excessive sheet erosion is accompanied by gully formation in many places. Gullies hinder tillage operations and cause sedimentation of ditches, streams and waterways.
3. Loss of plant nutrients. As per estimations in the United States, the value of nutrient lost with 11.2 tonnes/ha/year would be around $30 (Rs. 250/-) per year.
4. On most soils, conservation practices can keep soil losses below 11.2 tonnes/ha/year.

8.3 Management of Erosion on Agricultural Lands

The working example in para 8.1 gives the soil loss of 32.2 tonnes/ha/year under maize crop which is much higher than the acceptable soil loss tolerance limit. Since the Dhulkot silt loam soil of Dehradun is quite deep in nature, maximum soil loss tolerance limit of 11.2 tonnes/ha year may be acceptable for this region. Soil loss of 32.2 tonnes should therefore, be reduced below the tolerance limit of 11.2 tonnes/ha/year. There may be several ways of reducing the soil loss by managing the crop and conservation practices. For example, if a close growing crop of legume or strip crop or mulching etc. is practiced, it would help in reducing the soil loss considerably. For example, the CP value of maize with 4 tonnes/ha of grass mulch is 0.05 (Table 26). Under this cropping management system, the soil loss will come down to $103.9 \times 0.05 = 5.20$ tonnes/ha/year. This rate of soil loss is much below the tolerance limit and hence, this system of crop production would be appropriate for Dehradun region. Other crops and management practices could similarly be manipulated for selecting the most suitable cropping practice depending on the need of the agriculturist.

9.0 SUMMARY

The soil erosion research on runoff plots in India started as early as 1929, but the systematic study in various soil-climatic regions of the country started in first and second Five Year Plans with the establishment of eight Soil Conservation Research Centres at Dehradun, Chandigarh, Agra, Kota, Vasad, Bellary, Ibrahimpatan (Hyderabad) and Ootacamund. Considerable amount of soil loss data for various soils, crops, management practices etc. have already been collected in these Centres. A reliable estimation of soil loss is necessary for sound planning of soil conservation measures. There are several models for soil loss prediction. However, the Universal Soil Loss Equation (USLE) is the best model available uptil now which has been developed from a huge amount of soil loss-runoff data collected in the United States.

The soil loss data collected at Central Soil & Water Conservation Research & Training Institute, Dehra Dun and its Centres as well as by other agencies like State Governments' Research Centres, Universities etc. have been made use of for developing various factors of Universal Soil Loss Equation. In some of the cases, the factors developed are only the first approximation in this direction because of the paucity of the relevant information.

The available research data for Indian conditions is insufficient to develop any prediction model specifically for the Indian conditions. It is, therefore felt that systematic studies should be continued/undertaken on various parameters effecting soil erosion so that in due course it would be possible to develop a prediction model best suited to the Indian conditions.

The bulletin contains useful information and specific values for various parameters of the Universal Soil Loss Equation under the Indian condition. This information can be used to assess the gross soil erosion under different soil-crop-management condition in India.

10.0 ACKNOWLEDGEMENTS

The authors are grateful to Dr. O.P. Gautam, Director-General (ICAR) and Secretary to Govt. of India, Dr. N.S Randhawa, Dy Director-Generat (SAE) and Dr. N. Patnaik, Asstt. Director-General (S), Indian Council of Agricultural Research, for encouraging the workers in compilation of research work on soil loss under different soil-cropping systems in India. The authors are also thankful to all the workers in the field for having collected the data on various factors individually and collectively over a period of time. Their data has been freely used in this compilation and thankfully acknowledged. Special thanks are due to Shri M.L. Khybri, Senior Soil Scientist and Dr. S.P. Bharadwaj Head of Division (Land & Water) for their cooperation and help in this compilation.

The authors also appreciate the hard work put in by Shri A. N. Mohin, Stenographer in typing the manuscript of this bulletin.

11.0 REFERENCES

Agnihotri, Y., Gupta, R.K., Sud, A.D. and Misra, P.R. (1976)*

Anonymous (1961-62 to 1977-78). Annual Reports of State Soil Conservation Research, Demostration and Training Centre, Rehmankhera, Lucknow; Majhkhali, Almora; Department of Agriculture, U.P., Lucknow.

Anonymous (1972). A review of research works of Deochanda Experiment Station, Vol. II (1959-69), Soil Conservation Department, DVC, Hazaribagh.

Balasubramanian, G. and Sivanappan, R.K. (1981). Effect of degree of slope and rainfall erosivity on soil erosion and the influence of mulching on runoff and soil loss. Proc. South-East Asian Regional Symposium on Problems of Soil Erosion and Sedimentation. Asian Institute of Technology, Bangkok: 29-36.

Barnett, A.P. and Rogers, J.S. (1966). Soil physical properties related to runoff and erosion from artificial rainfall. Amer. Soc. Agril. Engg. Trans. 9:123-125.

Bhardwaj, S.P., Khybri, M.L., Sewa Ram and Prasad, S.N. (1979)*

Bhatia, K.S. and Chaudhary, H.P. (1977). Runoff and erosion losses and crop yields from slopy and eroded alluvial soils of Uttar Pradesh in relation to contour farming and fertilization. Soil Conserv. Digest 5 (2) : 16–22.

Carter, C.E., Greer, J.D., Brand, H.J. and Flayd, J.M. (1974). Raindrop charac, teristics in South Central United States. Amer. Soc. Agril. Engg. Trans. 17:1033–1037.

Das, D.C., Raghunath, B. and Pooranchandran, G. (1967). Rainfall intensity-energy and erosion index. Jour. Indian Soc. Agric. Engg. 4 (2) : 9–18.

Ghosh, S.P. and Ram Babu (1977). Effect of different fruit crops and their management on runoff and soil loss on sloping lands. Soil Conserv. Digest 5 (1) : 15–18.

Gupta, S.K. *et al* (1965, 66, 67, 68)*.

Hudson, N. (1971). Soil Conservation. B.T. Batsford Limited, London WI.

Kanitkar, N.V., Sirur, S.S. and Gokhale, D.H. (1960). Dry Farming in India. 2nd edition. Indian Council of Agricultural Research, New Delhi.

Khybri, M.L., Bhardwaj. S.P., Prasad, S.N. and Sewa Ram (1979)*.

Khybri, M.L., Subhash Chandra and Bhardwaj, S.P. (unpublished data).

Lal, R. (1976). Soil erosion problems on an alfisol in Western Nigeria and their control. IITA Monograph No. 1.

Mannering, J.V. (1981). The use of soil tolerances as a strategy for soil conservation. In Morgan, R P.C. (ed), Soil Conservation : Problems and Prospects. John Wiley & Sons, Chichester : 337 349.

MaCormack, D.E. and Young, K.K. (1981). Technical and societal implications of soil loss tolerance. In Morgan, R P.C. (ed), Soil Conservation : Problems and Prospects. John Wiley & Sons, Chichester : 365-376.

Musgrave, G.W. (1947). The quantitative evaluation of factors in water erosion, a first approximation. Jour. Soil & Water Conserv. 2:133–138.

Mutchler, C.K. (1963). Runoff plot design and installation for soil erosion studies. ARS 47-49, Agri. Res. Serv., USDA.

Mutchler, C.K. and Greer, J.D. (1980). Effect of slope length on erosion from low slopes. Amer. Soc. Agril. Engg. Trans. 23 : 866–870.

Nema, J.P., Verma, Balvir and Patel, A.P. (1978). Predicting universal soil loss parameters. Indian Jour. Soil Conserv. 6 (2) : 75–79.

Pratap Narain, Verma, Balvir, and Rao, D.H. (1980). Prediction of rainfall erosion potential and some parameters of universal soil loss equation at Kota, Rajasthan. (presented at the National Symposium on Soil Conservation and Water Management in 1980's at Dehradun, March 12-13, 1980).

Rai, R.N. (1980). Problems and potentials of runoff harvesting and recycling in north-eastern hill region (presented at the National Symposium on Soil Conservation and Water Management in 1980's at Dehradun, March 12-13, 1980).

Ram Babu, Gupta, S.K. and Tejwani, K.G. (1970). Correlation of soil loss with various energy intensity products. Indian Forester, 96 (10) : 771–774.

Ram Babu, Tejwani, K.G., Agarwal, M.C. and Subhash Chandra (1978a). Rainfall erosion potential and iso-erodent map of India. Central Soil & Water Conservation Research and Training Institute, Dehradun Bull No. 2:1–47.

Ram Babu, Tejwani, K. G., Agarwal, M. C. and Bhushan, L. S. (1978b). Distribution of erosion index and iso-erodent map of India. Indian Jour. Soil Conserv., 6 (1) : 1–12.

Rao, Y.P. (1981). Evaluation of cropping management factor in universal soil loss equation under natural rainfall conditions of Kharagpur, India. Proc. South-East Asian Regional Symposium on Problems of Soil Erosion and Sedimentation, Asian Institute of Technology, Bangkok : 241–254.

Roose, E.J. (1977). Use of the universal soil loss equation to predict erosion in West Africa in Soil Erosion : Prediction and Control. Special Publn. No. 21, Soil Conservation Society of America : 60–74.

Sharma, S.K., Prasad, Rajendra and Raghuvir (1975)*

Sharma, S.K., Misra, D.D. and Prasad, Rajendra (1979)*

Shri Niwas, Gupta, P.D. and Das, S.K. (1980). Runoff and soil loss studies on red 'chalka' soils at Hyderabad (presented at National Symposium on Soil Conservation and Water Management in 1980's at Dehradun, March 12-13 1980).

Singh, A. (1980). Management of agricultural lands for erosion control in N.E.H. region-case study (presented at National Symposium on Soil Coservation and Water Management in 1980's at Dehradun, March 12-13, 1980).

Smith, D.D. and Wischmeier, W.H. (1957). Factors affecting sheet and rill erosion. Amer. Geophys. Union Trans. 38 : 889-896.

Smith, D.D. and Wischmeier, W.H. (1962). Rainfall Erosion Advances in Agronomy, Vol. 14 : 109-148, Academic Press, Inc., New York, N.Y.

Sud, A.D., Gupta, R.K , Mittal, S.P. and Madan Lal (1976 and 1977)*

Tejwani, K.G., Gupta, S.K. and Mathur, H.N. (1975). Soil and Water Conservation Research, 1956-71. Indian Council of Agricultural Research, New Delhi.

Wischmeier, W.H. (1959). A rainfall erosion index for a universal soil loss equation. Soil Sci. Soc. Amer. Proc. 23 : 246-249.

Wischmeier, W.H. (1962). Storms and soil conservation. Jour. Soil & Water Conservation, 17 : 55-59.

Wischmeier W.H. and Mannering, J.V. (1969). Relation of soil properties to its erodibility. Soil Sci. Soc. Amer. Proc. 33 : 131-137.

Wischmeier, W.H. and Smith, D.D. (1958). Rainfall energy and its relationship to soil loss. Amer. Geophys. Union Trans. 39 : 285-291.

Wischmeier, W.H. and Smith, D.D. (1962). Rainfall erosion potential. Agril. Engg., 43 : 212 215.

Wischmeier, W.H. and Smith, D.D. (1965). Predicting rainfall-erosion losses from cropland east of the Rocky Mountains-Guide for selection of practices for soil and water conservation. Agricultural Handbook No. 282, USDA.

Wischmeier, W.H. and Smith, D.D. (1978). Predicting rainfall erosion losses—A guide to conservation planning. Agricultural Handbook No. 537, USDA.

Wischmeier, W.H., Smith, D.D. and Uhland, R.E. (1958). Evaluation of factors in the soil loss equation, Agril. Engg. 39 : 458-462, 474.

Wischmeier, W.H., Johnson, C.B. and Cross, B.V. (1971). A soil erodibility nomograph for farmland and construction sites. Jour. Soil & Water Conservation, 26 : 189-193.

Zingg, R.W. (1940). Degree and length of land slope as it affects soil loss in runoff. Agril, Engg. 21 : 59-64,

---

*Data cited from the Annual Reports of the Central Soil and Water Conservation Research and Training Institute, Dehradun, for the indicated year.

APPENDIX – I

Computation of Erosion Index (EI_{30}) and Working Example

The method suggested by Wischmeier (1959) may be used for estimating the erosion index value of each storm. The storms greater than 12.5 mm of rain should be considered for computation of EI values. If the rains are separated by more than 6 hours, they may be considered as different storms. The EI_{30} can be expressed as :

$$EI_{30} = \frac{KE \times I_{30}}{100} \quad \ldots \quad \ldots \quad \ldots \quad (i)$$

where, EI_{30} = erosion index;

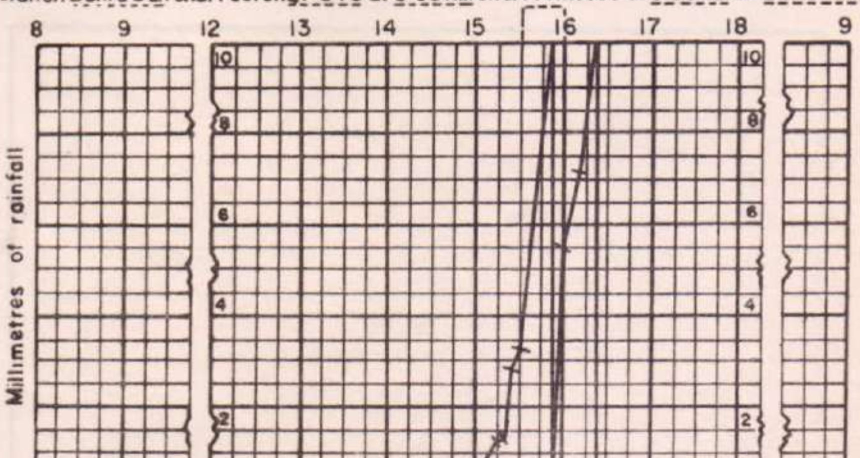
KE = kinetic energy of the storm; and

I_{30} = maximum 30 minute rainfall intensity of the storm.

In the following paragraphs, a working example for calculation of kinetic energy (KE), maximum 30 minute intensity (I_{30}) and erosion index (EI_{30}) are described with the help of Figs. 17 and 18 and Table – 38.

Fig. 17 is a typical example of daily rainfall chart obtained from the automatic recording raingauge. The chart covers a period of 25 hours. In this chart, one division on horizontal axis represents a period of 15 minutes and one division on the vertical axis represents rainfall depth equivalent to 0.5 mm.

Station Dehra Dun chart set on 27-8-70 at 8-30 AM chart removed at 8-30 AM on 28-8-70



Max. 30 min. rainfall = 12·2 mm.

Fig. 17. Sample chart of Syphon type (I.M.D.) automatic recording raingauge.

It can be seen from Fig. 17 that rain started at 1455 hours and continued till 16 22 hours. However, the slope of rainfall line is different at different time intervals during the period of rainstorm. The sections of the rainfall line which have differing slopes are separated as shown in Fig. 17. This information is then transferred in a tabular form as given in Table-38. For example. it is seen that the rain started at 1455 hours and continued till 1515 hours at the same intensity which is represented by a uniform slope (straight line). The line flattens almost horizontally till 1520 hours showing that there was no rain during 1515-1520. The whole rainfall period is fractionated and transferred in the table in this manner. The 1st row information in Table-38 shows that in 20 minutes period the rainfall amount has been 1.3 mm. This comes to an intensity of 3.9 mm/hr on 0.39 cm/hr.

For computing the kinetic energy of the rainstom, the equation proposed by Wischmeier and Smith (1958) is :

$$KE = 916 + 331 \log I \qquad \ldots \qquad \ldots \qquad (ii)$$

where, KE = kinetic energy in foot-tons per acre inch, and
I = rainfall intensity in inches per hour.

The equation (ii) has been converted into metric units by Wischmeier and Mannering (1969). The equation in metric units is :

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

where, KE = kinetic energy in metre tonnes per ha centimetre, and
I = rainfall intensity in centimetre per hour.

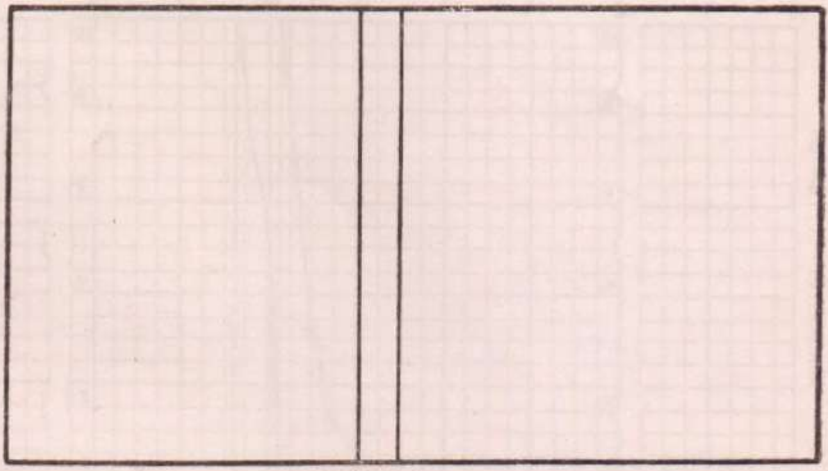


Fig. 18. Sample chart showing 30 minutes boundary for obtaining maximum 30 minutes rainfall depth.

Table-38 : *Rainfall record from recording raingauge and computation of EI_{30} values— Dehradun*

Date	Starting time Hr. Min.	Shifting time Hr. Min.	Time interval (Min.)	Reading at the start (mm)	Reading at the shifting (mm)	Rainfall (cm) (Col. 6- Col. 5)	Rainfall intensity (I) (cm/hr)	K.E * (metre tonnes/ ha-cm)	K.E. of the rain (Col. 9 × Col. 7)	Maximum 30 min. intensity (I_{30}) (cm/hr)	EI_{30} (Total of Col. 10 × Col. 11)/100
1	2	3	4	5	6	7	8	9	10	11	12
27-8-1970	1455	1515	20	0.0	1.3	0.13	0.39	173.9	22.61		
	1520	1525	5	1.3	2.8	0.15	1.80	233.0	34.95		
	1525	1530	5	2.8	3.3	0.05	0.60	190.6	9.53		
	1530	1552	22	3.3	10.0	0.67	1.83	233.7	156.58	2.44	11.42
	1552	1600	8	10.0	15.5	0.55	4.13	265.1	145.81		
	1600	1610	10	15.5	17.1	0.16	0.96	208.7	33.39		
	1610	1622	12	17.1	20.0	0.29	1.45	254.7	65.16		
									468.03		

*KE = 210.3 + 89 log I

Based on equation (iii), Table-39 was prepared in metric units by Wischmeier and Smith (1978) to compute the kinetic energy of the storm. For rainfall intensity of 0.39 cm/hr. the kinetic energy of 173.9 metre tonnes per ha cm is obtained from Table-39. By multiplying the depth of rainfall (0.13 cm) as given in Column 7 of row 1, Table-38 the kinetic energy of this fraction of rainstorm works out to be 22.61 metre tonnes. The kinetic energy of all the fractions of rainstorm are obtained in a similar fashion. By summing up the kinetic energy values given in Column 10 (Table-38), the total kinetic energy of the storm (468.03) is obtained.

There are two methods for calculation of maximum 30 minutes rainfall intensity (I_{30}). The first one is the 'original trace method' where a tracing paper showing 30 minutes boundary (as shown in Fig. 18) is moved horizontly over the rainfall chart (Fig. 17) and the maximum depth of rainfall is read between the 30 minutes boundaries marked on the tracing paper. This rainfall amount (12.2mm or 1.22 cm) is for maximum 30 minutes periods. In second method, rainfall information as given in Table-38 is needed. From Column 8 of Table-38, it is seen that the maximum 30 minutes intensity occurs during the period of 1530 to 1600 hours. By adding up the rainfall amount for this period given in Column 7, a value of 1.22 cm is obtained. The maximum 30 minutes rainfall amount obtained by any of the two methods is doubled to obtain the maximum 30 minutes intensity in cm/hr. The maximum 30 minutes intensity (I_{30}) works out to be 2.44 cm/hr.

The EI_{30} is obtained by multiplying the total kinetic energy value of 468.03 (Col. 10 of Table-38), with I_{30} value of 2.44 (Col. 11 of Table-38) and dividing by 100. The EI_{30} value for the storm of Fig. 17, thus, calculated to 11.42.

In order to obtain monthly and yearly EI values, the storm EI values for that length of period are added. In case erosion index values are desired for any particular week, season, or crop growing period etc., the strom EI values for that length of time may be summed up.

Table-39 : *Kinetic energy of natural rainfall (metre tonnes per ha cm) by equation* $KE = 210.3 + 89 \log I$

Intensity, cm/hour	Intensity, cm/hour									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0	32.3	59.1	74.8	85.9	94.5	101.6	107.5	112.7	117.2
0.1	121.3	125.0	128.3	131.4	134.4	137.0	139.5	141.8	144.0	146.1
0.2	148.1	150.0	151.8	153.5	155.1	156.7	158.2	159.7	161.1	162.5
0.3	163.8	165.0	166.3	167.5	168.6	169.7	170.8	171.9	173.0	173.9
0.4	174.9	175.9	176.8	177.8	178.6	179.4	180.3	181.1	182.0	182.7
0.5	183.5	184.3	185.0	185.8	186.5	187.2	187.9	188.6	189.3	190.0
0.6	190.6	191.2	191.8	192.4	193.1	193.6	194.2	194.8	195.4	196.0
0.7	196.5	197.1	197.6	198.1	198.7	199.2	199.7	200.2	200.7	201.2
0.8	201.7	202.2	202.6	203.1	203.6	204.0	204.5	205.0	205.4	205.8
0.9	206.2	206.7	207.1	207.5	208.0	208.3	208.7	209.1	209.5	209.9
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	210.3	214.0	217.3	220.4	223.3	226.0	228.4	230.8	233.0	235.1
2	237.1	239.0	240.8	242.4	244.1	245.7	247.2	248.7	250.1	251.4
3	252.8	254.0	255.3	256.4	257.6	258.7	259.8	260.9	261.9	262.9
4	263.9	264.8	265.8	266.7	267.6	268.4	269.3	270.1	270.9	271.7
5	272.5	273.3	274.0	274.8	275.4	276.2	276.9	277.6	278.2	278.9
6	279.6	280.2	280.8	281.4	282.1	282.6	283.2	283.8	284.4	285.0
7	285.5	286.1	286.6	287.1	287.7	288.2	288.7*			

*The 289 value also applies for all intensities greater than 7.6 cm/hr.

APPENDIX II

Establishment and Maintenance of Cultivated Fallow Plots

To insure uniformity of runoff and soil loss data for evaluation of the soil erodability factor all cultivated fallow plots need to be operated according to a standard plan.

1. Establish plots on same percent and length of slope as for other plots at the location. Slope length should be 72.6′ (22.13m) unless another length is already in use at the plot site. Determine percent slope to nearest 0.1 percent based on plot elevation.

2 Determine plot sill plate elevation following instructions mentioned in (1). Adjust sill plate to specified elevation each spring. If elevation appears to be in error, resurvey the plot.

3. Measure all individual storm runoff amounts equivalent to 0.1 mm runoff from the plot. Report all runoff amounts to nearest 0.1 mm. Sample all measured storm runoff amounts that contain soil equivalent to 0.01 tonnes per hectare. Report all soil losses to nearest 0.01 tonnes per hectare.

4. Prapare seed bed first by spading, alongwith other plots. Then plough up and down by hand plough with 12 to 15 furrows. Smoothen the furrows by planking. Keep the plot free of weeds by occasional weeding. Whenever there is crust formation lightly hoe the plot up and down the slope by hand hoe or by graden rake. Light hoeing is required to avoid formation of ridges and furrows.

5. All tillage operations are to be up and down slope regardless of row direction on other runoff plots at fhe location or previous plans for contour tillage. No crop will be grown on these plots as they will be continuous cultivated fallow plots.

6. This procedure will apply to both natural rainfall and simulated rain plots that are classed as continuous cultivated fallow. This is the type of check plot to be used in management practices evaluation by the rainfall simulator. In addition, the fallow plots will provide soil loss prediction equation.

7. A written record showing dates of all cultural operations shall be carefully maintained the same as for all other plots. This should include depth of ploughing, disking, and cultivating.

(Modified based on personal communication from C.K. Mutchler, Research Hydraulic Engineer, USDA Sedimentation Laboratory, Oxford, Mississippi, U.S.A.)