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Rainfall erosion potential and iso-erodent map of MadhyaPradesh

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ABSTRACT

Monthly, seasonal and annual Erosion Index (EI) values of 32 stations in Madhya Pradesh are presented. Iso-Erodent values for 97 stations were computed using relationship between mean annual rainfall and mean annual EI. Iso-Erodent maps for M.P. for annual and seasonal (June-September) periods are shown. Distribution curves expressing average monthly EI values as percentage of average annual values are given for 24 stations. Values of Erosion Index for return periods of 2,5 and 10 years are indicated to assist in assessing soil loss with 10, 20 and 50% probability.

Key words : Rainfall erosion, Iso-erodent, Erosion index (EI), EI distribution curve.

Erosivity of rain, which is its potential to cause soil erosion, is a function of its physical characteristics. Energy of rain is used in all phases of soil erosion. In this the Universal Soil Loss Equations of Wischmeier and Smith (1965) is held to be good enough to predict soil erosion in a manner similar to the process based models like RUSLE and WEEP (Laflen *et al*, 1997).

Quantitative evaluation of the erosivity of rain besides increasing our understanding of water erosion of soils would provide guidelines for designing of soil conservation structures. Soil loss measurements during rain storms made in many places in United States showed that when factors other than rainfall remain constant, the quantum of soil losses from cultivated fields during storms was not related to amount or intensity-frequency of storm but were directly proportional to the product of total kinetic energy of the storm and its maximum 30-minute intensity (Wischmeier and Smith, 1958). In Rhodesia, Hudson (1971) found that the kinetic energy of individual storms falling at intensities of 25 mm per hour or greater were closely related to soil loss.

Sum of the storm erosion index (EI) values for a given time period provides a numerical evaluation of the erosivity of the rainfall within the period. Therefore, annual totals of storm EI values are referred to as the rainfall erosion index (Wischmeier, 1961). At present, 30 minute erosion index value (EI_{30}) is the most precise single estimate of rainfall erosion potential (Wischmeier, 1959). Erosion index is one hundredth of the products of the kinetic energy of the rainstorm (KE) and its maximum 30 minute intensity (I_{30}). The importance of the parameter (EI_{30}) in soil conservation programmes is well recognized in India. EI values had been determined for only 8 stations in M.P. (Ram Babu *et al*, 1978). In the present study mean monthly, seasonal and annual EI_{30} values were computed for 32 stations in M.P. and relationships between mean annual rainfall and erosion index (EI) were established. Computation of 2,5 and 10 year return period values of EI, preparation of seasonal Iso-erodent maps and EI distribution curves for Madhya Pradesh are the other objectives.

MATERIALS AND METHODS

The recording raingauge data for storm spells greater than 12.5 mm were obtained from the India Meteorological Department, Pune for 24 stations located in Madhya Pradesh. For computation of EI values only 15 years' record for 19 stations and 8-12 years' data for five stations were available. The erosion index data for Indore was obtained through Indo-U.K. Dry Farming Project (ICAR), Indore. The data for all the stations were checked for adequacy of length of record through 'R' test following Ogrosky and Mockus (1957) and was found to satisfy the relevant test. Average annual rainfall data for the stations under study were obtained from the publications of India Meteorological Department, (IMD 1962, 1995).

Computation of erosion index (EI_{30})

The method suggested by Wischmeier and Smith (1958) was used for estimating the erosion index value of each storm. Storms greater than 12.5 mm of rain were considered for computation of EI value. The storms separated by more than 6 hours, were considered as different storms. The EI_{30} can be expressed as:

$$EI_{30} = \frac{KE \times I_{30}}{100} \quad \ldots\ldots (1)$$

where, EI_{30} = erosion index, KE = kinetic energy of the storm and I_{30} = maximum 30-minute rainfall storm intensity.

Kinetic energy for the rainstorm was computed by the equation proposed by Wischmeier and Mannering (1969), defined as

$$KE = 210.3 + 89 \log I \quad \ldots\ldots (2)$$

where,
KE = kinetic energy in metre-tonnes per hectare centimeter and I = rainfall intensity in centimetres per hour.

For obtaining monthly and annual EI values, the storm EI for that length of period were added. In case erosion index values are desired for any particular week, season, or crop growing period etc. the storm EI values for that length of time are summed up.

Frequency analysis of erosion index (EI)

There are several theoretical interpretations or reasoning for the preference of one method over the other (Chow, 1964). Mathematical or graphical methods are generally used for frequency analysis. According to Dalrymple (1960) a rigid mathematical treatment is not justified when the data available are for less than 30 years. As our EI data were of shorter duration, graphical method was preferred. Gumbler's extreme value technique was applied for computation of the return period values (Ogrosky and Mockus, 1957) and the frequency line was drawn through the plotted points by computing methods. The computed method, eliminates subjectivity and is considered to be mathematically sound.

RESULTS AND DISCUSSION

Monthly and seasonal erosion index

The monthly, seasonal and annual EI values for 32 stations (including 8 earlier developed) were computed and presented in Table 1. It is observed that 75 to 98% of total EI value is concentrated during the period of June to September (rainy months).

Iso-erodent map of Madhya Pradesh

Iso-erodents are lines joining areas with equally erosive rainfall (Wischmeier, 1962). The annual erosion index values of 32 stations given in Table 1 were not sufficient to establish a closer path of iso-erodents. To get additional computed values of erosion index, linear relationships were established between annual and seasonal (June - September) EI values and average annual and seasonal (June - September) rainfall respectively in Madhya Pradesh. Derived relationships are as follows:

$$Y_a = 132.0 + 0.317 X_a$$

(S.E. = 0.047, r = 0.851) . . . . . (3)

$$Y_s = 128.1 + 0.318 X_s$$

(S.E. = 0.056, r = 0.811) . . . . . (4)

where,

Y_a, Y_s = average annual/seasonal erosion index

X_a, X_s = average annual/seasonal rainfall (mm) respectively.

The regressions were used to obtain the erosion index values from average rainfall data for 50 years at 97 locations well distributed spatially in M.P. Finally 129 EI values were used to prepare iso-erodent maps for annual and seasonal periods for M.P. (Figures 1 and 2). The iso-erodent values show that the annual EI ranged from 301 at Betul to 675 at Satna while the seasonal (June - September) EI values ranged from 248 to 654 respectively for these stations. Location values of rainfall factor 'R' for its use in the Universal Soil Loss Equation (USLE) may be taken directly from the iso-erodent map. Most of the erosive rain occurs during June - September period, hence, special attention is required to give adequate protection to soil during these months.

Probability values of the erosion index

Wischmeier (1959) states that annual values of the EI follow a log-normal frequency distribution. Range of EI relative to average erosion index and specific probability values for 50% (2 year return period), 20% (5 year return period) and 10% (10 year return period) are given (Table 2).

In order to estimate average annual

Table 1 : Average monthly and annual erosion index values for Madhya Pradesh.

Station	Months												Annual	Jun.-Sept.	Jun.-Sept. as
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	EI	EI	% of Annual
Ambikapur	0.9	1.4	1.0	-	3.6	65.0	81.7	79.9	106.6	36.9	-	1.5	378.5	332.2	88
Betul	-	9.0	0.7	5.0	-	52.0	54.5	124.6	17.0	30.0	5.7	2.6	301.1	348.1	82
Bhopalpatnam	-	0.9	4.1	17.7	22.5	118.9	133.3	258.2	57.5	31.1	0.9	-	645.1	567.9	88
Champa	3.4	1.2	4.9	1.3	2.7	93.5	170.1	236.8	110.9	18.1	0.6	-	643.5	611.3	95
Guna	0.1	-	-	0.2	1.4	51.5	109.7	197.1	94.5	32.8	0.3	-	487.6	452.8	93
Gwalior	0.2	1.5	0.1	0.2	1.9	22.5	151.8	143.7	84.9	20.4	1.6	-	428.8	402.9	94
Illuta	2.1	7.2	2.1	-	19.1	61.7	111.6	67.6	53.0	17.8	2.7	0.1	345.0	293.9	85
Kawardha	5.4	1.1	1.6	-	0.4	43.6	87.3	98.3	108.8	23.4	-	-	369.9	338.0	91
Khandwa	5.4	0.6	1.4	0.1	11.0	66.0	153.9	88.3	80.8	4.9	11.0	-	423.4	389.0	92
Mandla	8.4	13.5	4.1	0.2	1.5	164.1	176.2	181.2	60.0	16.4	5.5	1.6	632.7	581.5	92
Nowgong	1.0	5.3	0.2	0.7	1.4	49.6	148.6	268.9	88.6	61.1	-	-	625.4	555.7	89
Pachmarhi	1.2	5.6	2.7	1.7	-	95.7	90.0	228.1	70.4	37.2	1.5	2.9	537.0	484.2	90
Paralkota	6.9	0.8	2.1	6.5	4.7	101.7	159.0	155.0	124.4	25.4	2.0	0.5	589.0	540.1	92
Pendra	3.0	4.4	7.0	2.7	7.1	81.3	125.4	195.1	81.2	18.9	3.2	3.5	532.8	483.0	91
Rajgarh	4.5	2.2	-	0.2	0.4	67.9	166.9	92.6	67.8	19.4	2.9	1.2	426.0	395.2	93
Ratlam	0.2	1.0	-	0.1	3.3	99.7	190.4	104.3	54.0	15.7	1.0	-	469.7	448.4	95
Satna	2.2	5.2	2.1	0.9	1.7	84.8	29.6	235.6	103.9	8.6	0.1	-	674.7	653.9	97
Seoni	9.5	3.4	6.1	-	5.6	144.2	114.0	148.3	76.3	24.7	114.8	-	646.9	482.8	75
Sheopur	0.5	0.2	-	-	2.4	47.3	280.9	114.7	42.6	16.8	0.2	-	505.6	485.5	96
Sidhi	0.8	1.3	1.3	-	0.6	80.5	194.3	124.6	110.3	3.7	1.2	-	518.6	509.7	98
Shivpuri	0.9	0.6	1.1	0.3	3.1	88.3	176.4	73.3	59.2	6.6	0.1	0.8	410.7	397.2	97
Sukma	-	-	0.1	2.8	22.7	74.4	123.7	116.0	107.9	45.1	0.8	-	493.5	422.0	86
Ujjain	0.4	0.5	0.7	-	1.3	38.2	89.4	159.9	87.8	20.1	1.8	2.2	402.3	373.2	93
Umaria	14.3	6.9	1.4	0.8	0.3	89.5	76.1	167.4	68.9	61.1	5.9	1.1	493.7	401.9	81
Earlier developed															
Bagratawa	1.3	-	2.1	-	9.6	25.7	132.2	190.3	139.4	12.9	0.2	-	513.7	487.6	95
Bhopal	1.6	0.2	3.4	0.1	16.4	69.6	175.4	186.7	103.9	4.6	1.6	-	563.5	535.6	95
Indore	0.3	1.3	0.7	-	2.6	69.2	139.0	99.8	81.8	14.4	3.3	0.9	413.3	389.8	94
Jabalpur	2.5	2.7	4.3	0.5	11.7	87.5	119.9	182.8	88.0	7.6	0.8	3.0	511.3	478.2	94
Jagdalpur	1.1	8.6	4.3	32.2	32.2	116.9	77.3	143.2	74.8	38.4	1.3	4.1	534.4	412.2	77
Punasa	-	-	1.2	-	0.5	79.8	101.8	87.1	97.7	9.7	0.7	1.1	379.6	366.4	97
Raipur	1.7	0.5	8.4	1.9	3.8	193.9	171.8	123.1	87.5	10.4	1.3	1.4	605.7	576.3	95
Thikri	-	-	-	-	5.1	60.2	90.3	52.6	106.8	14.6	2.0	2.2	333.8	309.9	93

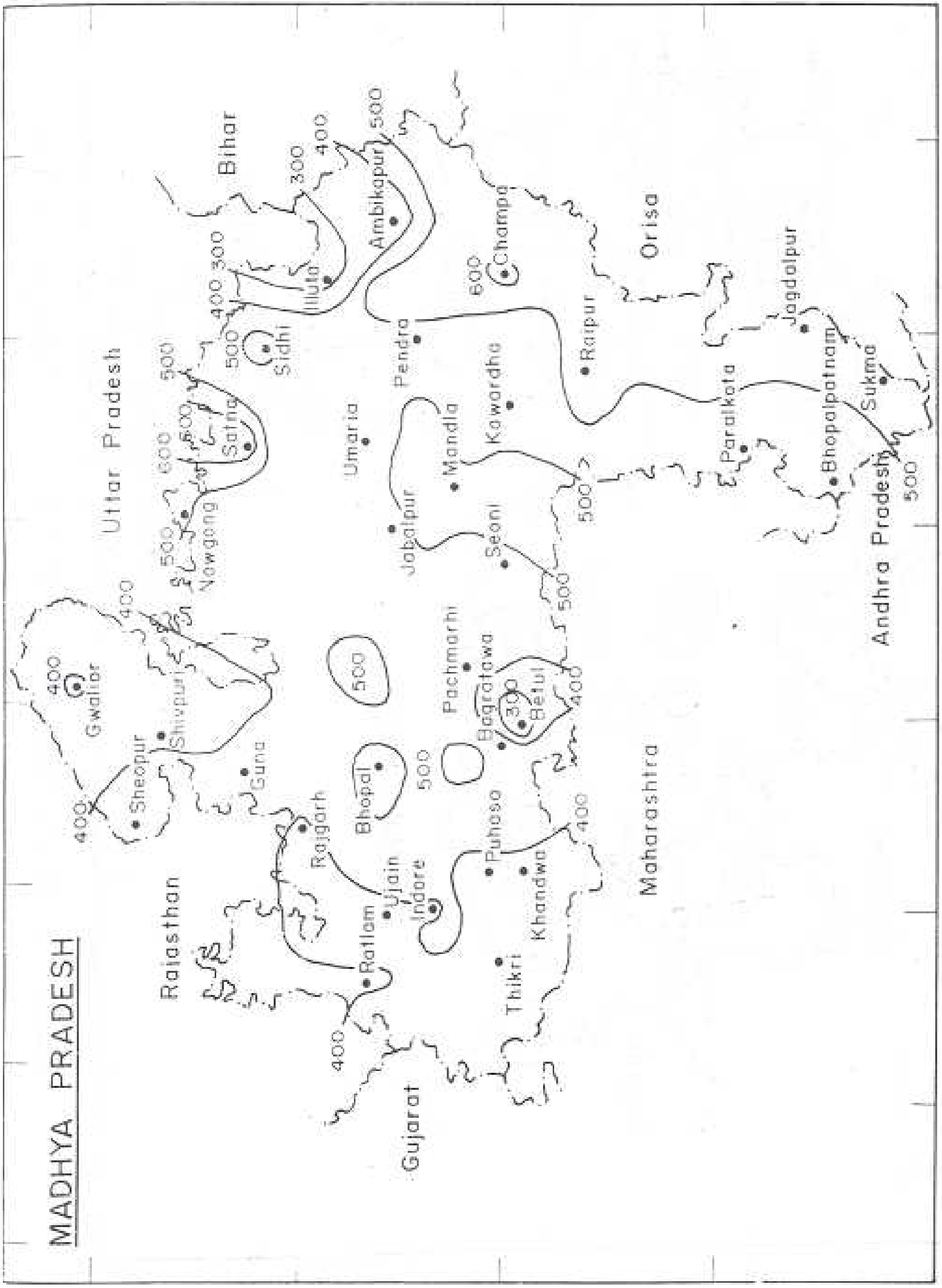

Fig.1 : Iso-erodent map of Madhya Pradesh on annual basis

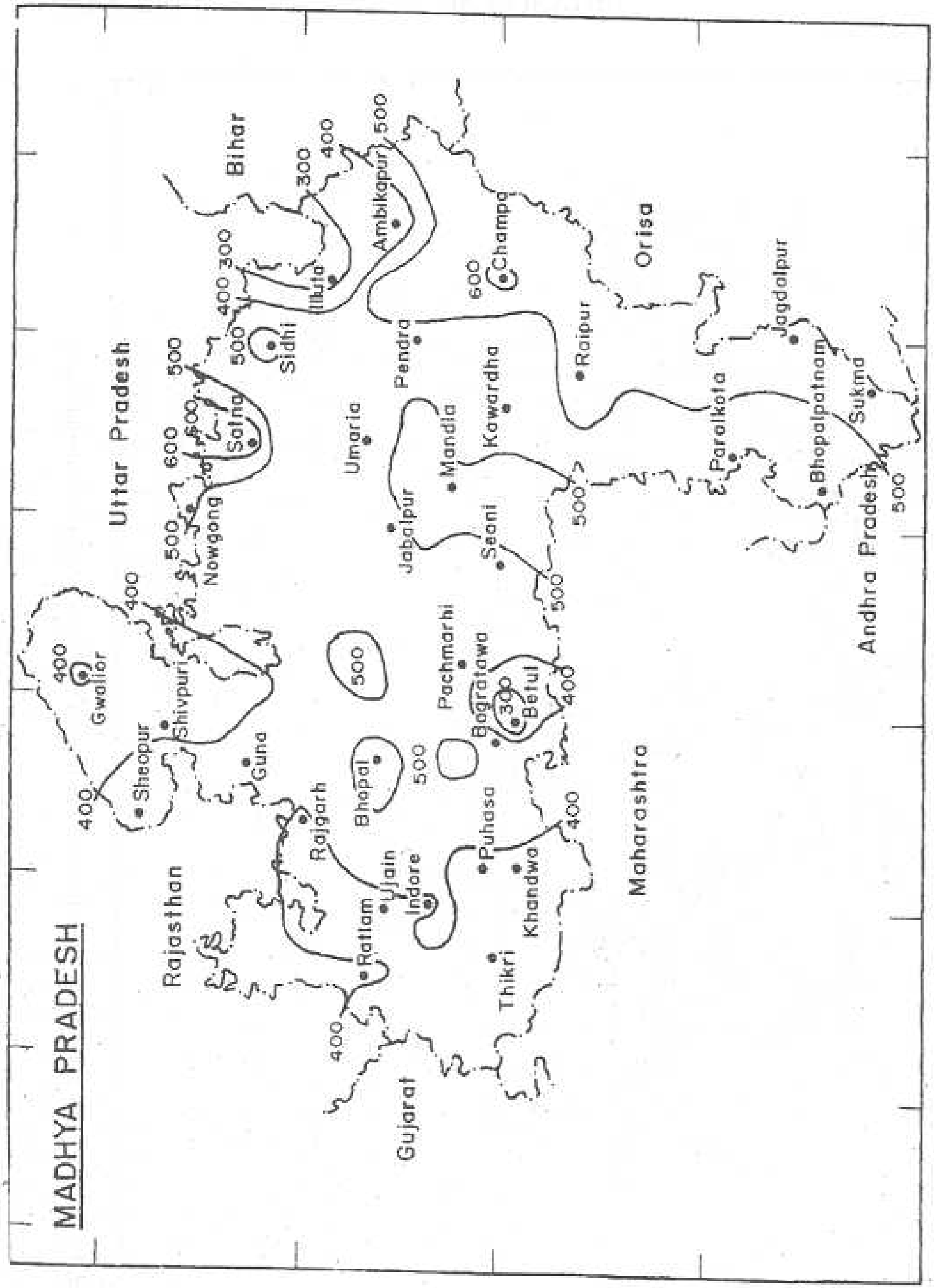

Fig.2 : Iso-erodent map of Madhya Pradesh on seasonal (June-September) basis

Table 2 : Observed range and 2, 5 and 10 year return period values of EI_{30} for 32 stations of Madhya Pradesh.

Location	Average annual EI	Erosion Index (EI)			
		Observed	Return period*		
		range	2 Year	5 Year	10 Year
Ambikapur	378.5	171-704	320	550	740
Betul	301.1	205-647	280	380	450
Bhopalpatnam	645.1	324-903	605	860	1040
Champa	643.5	341-953	615	800	940
Guna	487.6	219-1096	425	680	860
Gwalior	428.8	197-601	404	560	660
Illuta	345.0	221-413	335	430	490
Kawardha	369.9	245-492	360	450	500
Khandwa	423.4	233-927	380	560	700
Mandla	632.7	276-1024	570	860	1100
Nowgong	625.4	270-1076	570	860	1080
Pachmarhi	537.0	271-939	480	770	960
Paralkota	589.0	263-1135	620	820	980
Pendra	532.8	370-641	525	630.	695
Rajgarh	426.0	196-632	405	540	620
Ratlam	469.7	280-772	435	620	740
Satna	674.7	286-1065	605	930	1170
Seoni	646.9	267-818	600	950	1200
Sheopur	505.6	176-1211	430	710	940
Sidhi	518.6	290-799	490	640	740
Shivpuri	410.7	235-595	395	500	575
Sukma	493.5	211-805	455	660	820
Ujjain	402.3	173-709	360	560	700
Umaria	493.7	240-672	470	630	750
Earlier developed					
Bagratawa	513.7	201-998	450	700	840
Bhopal	563.5	188-1209	480	745	920
Indore	413.3	193-751	375	550	680
Jabalpur	511.3	198-967	468	690	830
Jagdalpur	534.4	438-682	527	600	650
Punasa	379.6	173-800	340	525	645
Raipur	605.7	330-1322	555	790	950
Thikri	333.8	89-870	280	500	660

* Return period = 100/Per cent chance.

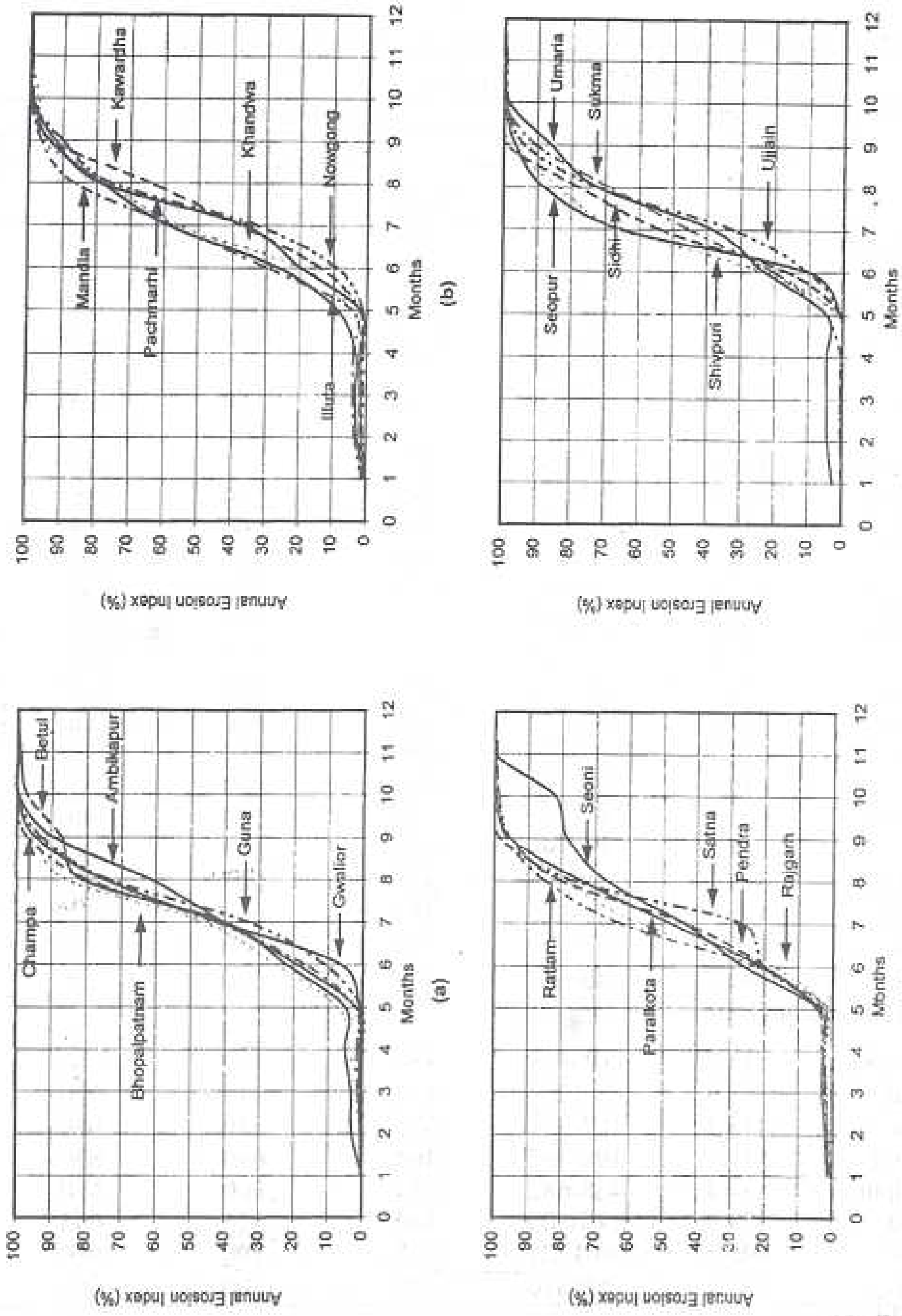

Fig. 3 : Erosion-index distribution curves of different stations in Madhya Pradesh

soil loss, the value of the factor, R, must equal the average annual EI at that location. If desired, however, some specific return period value of EI, 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 year return period EI value for R factor in the universal soil loss equation.

Erosion index distribution curves

The annual erosion index values do not completely describe the differences in rainfall erosion potential during different months of year. Under field conditions, distribution of erosive rainstorms within the year in relation to the existing vegetative cover and crop residue effects is very important. From the EI values given in Table 1, distribution curves were prepared for 24 stations and shown in Figure 3. In this the monthly erosion index values expressed as percentages of average annual values were plotted cumulatively against time. Thus, the percentage of the annual erosion index that is to be expected within any particular crop stage period may be found by reading the curve at the last and first of chosen period and subtraction. This information is useful (i) to determine as to how the erosivity varies during the year at any given location and (ii) for planning of soil conservation farming systems. It is seen that 88% of the total EI is contributed by the rains received in June-September.

This information about rainfall erosivity within the year is essential for planning suitable soil and water conservation measures.

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