Frequency of wet years during the past century in Sri Lanka; an analysis in relation to earth slips.

BY

B.K.Basnayake.*

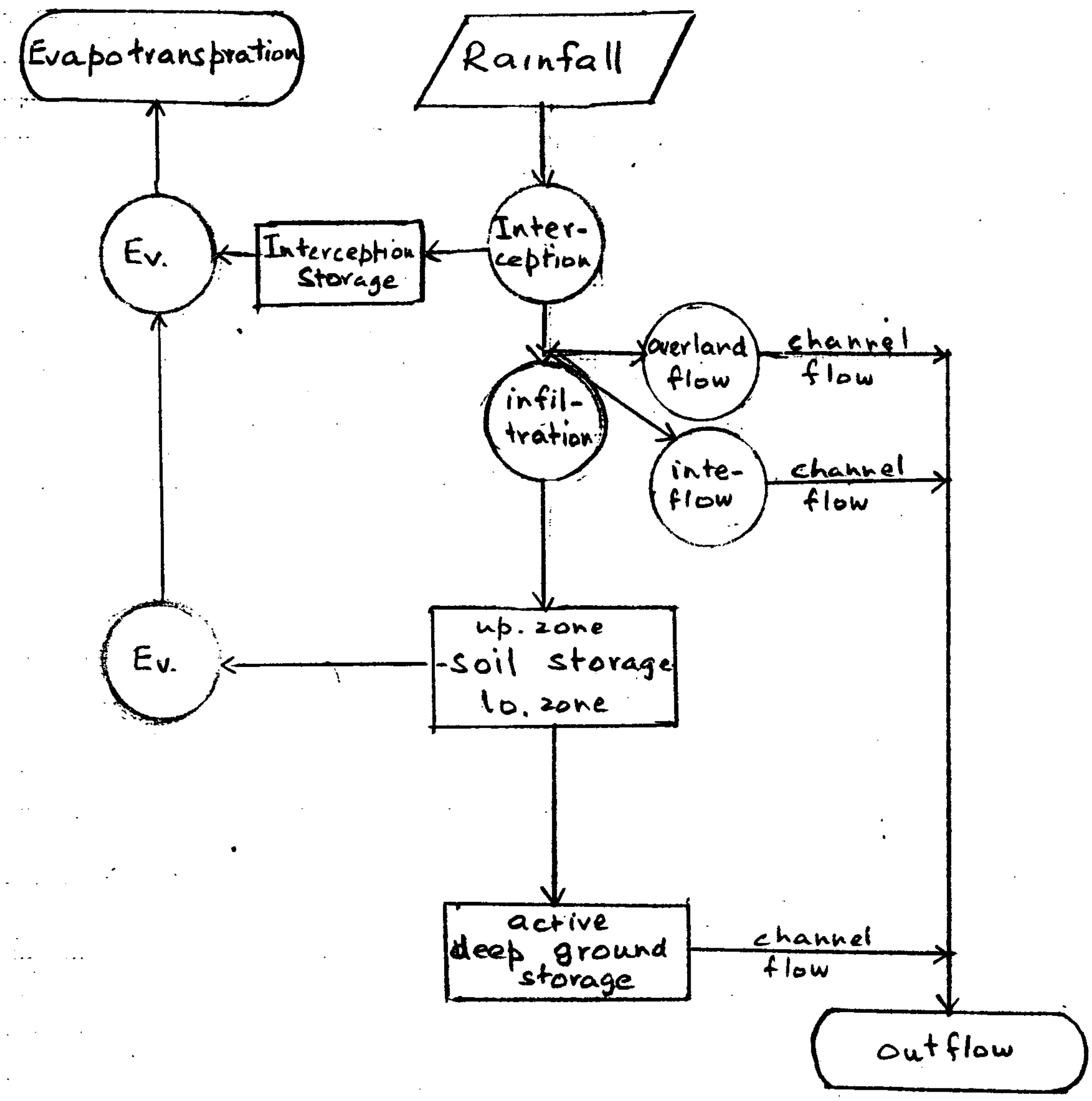
While many factors such as gradient of slope, soil and rock type, geological structure and nature of the surface cover control the tendency to earth slips, the immediate cause of earth slips is often meteorological, namely, excessive rainfall. Heavy rainfall serves to overload the soil storage of water, and other conditions being favourable to slope failure, earthslips occur.

Fig. 1 shows a simplified hydrological model of the earth's surface-soil system. Input of water to the system is by rainfall, and there are two outputs, namely, Evapotranspiration and river outflow. Within the system are various storages, the main one being that of soil storage. Transfers between storages and to the outputs occur by means of various processes such as evaporation, infiltration, interflow and overland flow. Heavy rainfall imposes stress on this water storage-transfer system which may lead to destruction of the existing equilibrium, i.e., an earthslip, and re-establishment of equilibrium at a different level. In an undisturbed natural ecosystem such instances of disequilibria are probably rare, but in the present context of Sri Lanka, where nearly all landscapes show various degrees of human interference, earthslips are common.

..... p 3.

* Senior Fellow, IFS, and Senior Lecturer, Dept. of Geography, University of Petadeniya.

Fig. 1. A simplified hydrological model.



adapted from Crawford & Lindsay 1966.

The incidence of rainfall must be studied over two time scales: on the short time scale of Meteorology, and in the long time scale of Climatology. The former works through monitoring, synoptic analysis and forecasting, and the latter through an accumulated data bank, seasonal, annual and long period analysis, and probability estimates.

The high risk area for landslides in Sri Lanka, selected in relation to steep slopes and heavy rainfall, is the Central hill country, together with the Sabaragamuwa ridge country of the South West. Four rainfall stations within this area with records of more than a century have been selected for study ~~within this area~~. The core of the wettest area in Sri Lanka is situated in the south west flanks of the Central hill country and extends to the Sabaragamuwa ridge area. Ratnapura may be selected to represent this area. Kandy and Nuwara Eliya are take to represent the wetter north central and central parts, respectively, of the Central hill country. Badulla represents the drier or 'Intermediate' eastern half.

Method:

Statistically, rainfall data is found to fluctuate about a mean, with some extremes. When a long enough record is taken, the sample will contain a fair population of of extremes. In this analysis for application to earthslips, it is the high extreme of rainfall that is relevant. The present analysis uses

(a) Annual rainfall totals.

(b) Monthly rainfall totals.

.... p4.

The analysis of annual totals is useful to give the broad trends of long-period fluctuations. This is a necessary first step before more detailed work is undertaken. In this analysis, attention is focussed on the long period trends of the 'High' extreme falls. The rainfall extremes have selected using the 'Decile method' proposed by Gibbs & Maher 1967. In this method, the selection of extreme years is made such that not only the year must fall in the highest (or lowest) decile, but must also satisfy an area criterion, namely that the area affected must be sufficiently extensive as to be significant. In the present case, where the analysis involves 4 stations, an 'extreme year' is defined as one involving at least two stations in the highest decile of that year.

The analysis of annual totals, while being useful to clarify the broad trend of extreme fluctuations, and therefore indirectly, of the trends of earthslip hazard, it is probably xxx x of limited use in direct application because the hydrological aspects of of earthslips appear to operate on short time scales. Here the most important aspect is probably the water storage-discharge rates of the soil in relation to the water input rate by heavy rain. Meteorologically, heavy rain spells occur over time scales of a few minutes to several days; out of which what is relevant here is probably continued heavy rain spells ocurring over one to several days.

As a preliminary step in this kind of short term analysis, it may be useful, first, to analyse monthly rainfall totals, on the assumption that heavy rain spells of the order

.... p5

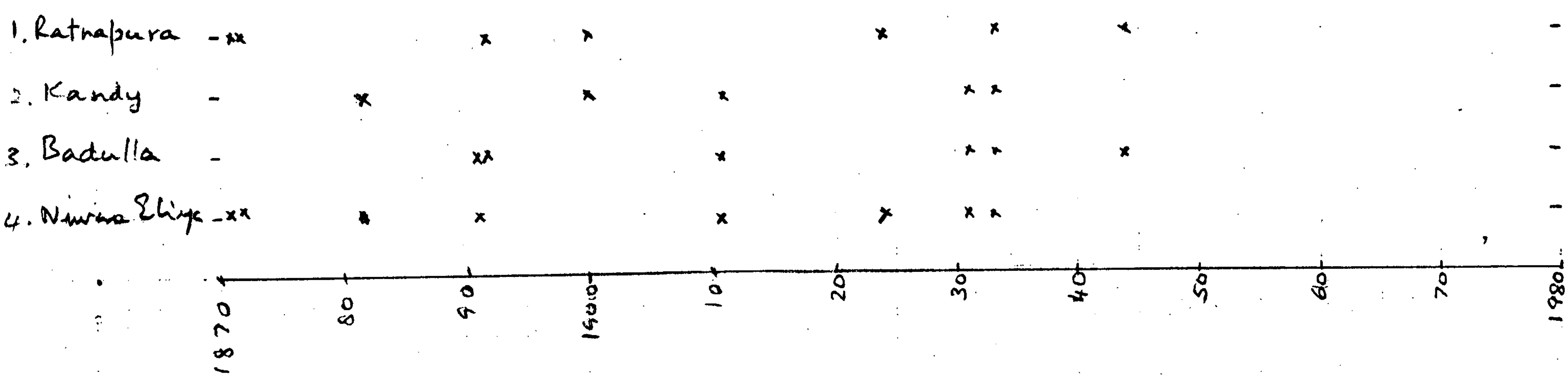
of days will be reflected in high monthly totals. Doubtless some important rain spells will be missed, but it is noted that a characteristic of the time distribution of rain is that it tends to be seasonal because the meteorological systems that bring about rainfall are themselves seasonal. Therefore it is probable that the great majority of the significant heavy rain spells occur within the wet season months, which will be taken into account in this study.

In the analysis of monthly rainfalls, the decile method is less useful because even the highest deciles of dry months are not significantly higher than the average rainfall of the wet months. What is needed is a threshold value above which rainfall can be considered to be significant to the problem of earthslips. In the absence of such values derived from landslide field studies in Sri Lanka, one can use (a) a common scale of arbitrary values, or (b) a scale dependant on the average annual rainfall of each station, e.g, (average annual rainfall/12) X 2...6. As tha average annual rainfall reflects climate, and the other environmental factors such as slope, soil and cover may be assumed to be in balance with climate, the latter may be the more logical choice.

Results:

Fig. 2 shows the distribution of extreme wet years in Central and South West Sri Lanka, using the annual rainfall data of 4 stations, 1871-1980. An extreme wet year is defined as an year in which the the rainfall is in the highest decile at two stations or more. Fig. 2 brings out the following features:

Fig. 2: Distribution of extreme wet years* in Central and South Western Sri Lanka, 1871-1980.



* any year that falls within the highest decile at two or more stations

(a) An extreme wet year covering the whole hill country and the South West is a very rare event. It occured only once during the past century, in 1933. It may mark the middlle of a wet phase in Sri Lanka, a conclusion that is collaborated by the author's study of Droughts of Sri Lanka. (Basnayake, B.K. 1985)

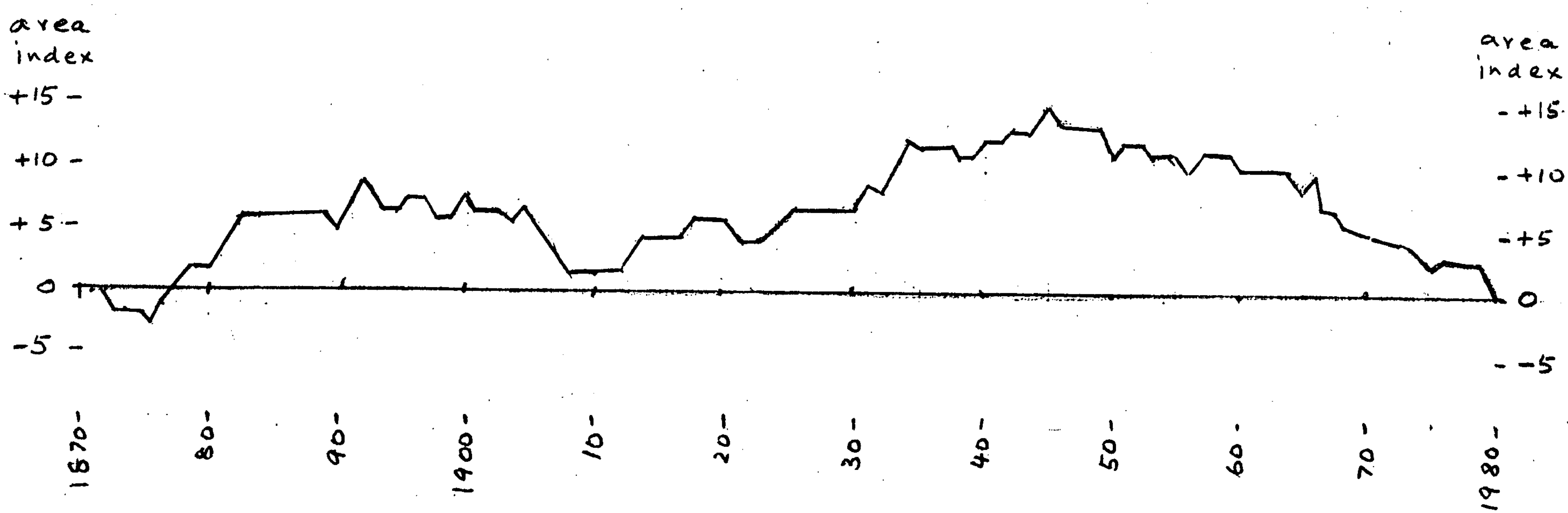
(b) An extreme wet year covering 3/4 of the area of study ocurred 3 times during the past century. These appear to show a periodicity of about 22 years, agreeing with the 'double sunspot cycle'.

(c) There is a remarkable absence of wet years after the mid-forties up to 1980. This too is in agreement with the author's study of droughts of Sri Lanka where this period shows up as a dry phase . (Basnayake, B.K., 1985).

Fig. 3 shows a graph of the cumulative area index of rainfall extremes (including both high and low values). The area index is simply the number of stations of a given year when the rainfall values fall in the extreme decile. The reasons for plotting the two values, highest and lowest together are: (1) The accumulation of the two extremes has a self-smoothing effect on the resulting graph, a valuable bonus when investigating long term climatic trends. (2) That relating to the theory of 'index cycles' of the general circulation (Willet, H.C. 1951). During 'low index cycle' of the general circulation there is significant 'meridional' flow when compared to the 'latitudinal' flow. In climatological terms this means an anomalous north-south shift in existing wind belts and therefore of climatic zones, i.e., the results of such anomalous shifts tend towards extremes.

..... p10.

Fig 3. Cumulative Area Index* of Rainfall Extremes° of Central & South West Sri Lanka, 1871-1980



* area index = no. of stations falling within the highest (+) or Lowest (-) Deciles. total no. of stations used = 4.

° any year whos rainfall total falls within the highest decile.

(a) The whole curve is remarkable positive since 1875. This probably reflects the presence of a multi-century long term cycle in the extreme rainfall values.

(b) Within the above major cycle are two secondary cycles which, however are of unequal length.

(c) What is of more significance are the periods of 'rising ' or 'falling' tendancy, a tendency to fall being understood as one in which the wet extremes are overcompensated by the dry and vice versa.

'drier'	'wetter'
1871 to 1876 (6 yrs.)	1876 to 1893 (17 yrs.)
1893 to 1970 (17 yrs.)	1910 to 1943 (33 yrs.)
1944 to 1980 (36 yrs)	

Fig. 4 shows the incidence of high monthly extremes for the pp period 1871 to 1980 of four rppresentative stations of Central and South West Sri Lanka. The scale for each station was calculated from the formula (annual average rainfall/12) X n where n was initaally taken =2, and then increased in steps of .5 up to n=6. The following features are shown:

(a) There is a well marked seasonality in the distribution of high extremes of rainfall:

	Season of no high extremes		Season of high extremes	
Ratnapura	Dec. to April	(5m0,)	May to Nov	(7 mo.)
Kandy	Feb. to Mar.	(2 mo.)	Apr to Jan	(10 mo.)
NuwaraEliya	Feb to Apr	(3 mo.)	May to Jan	(9 mo.)
Badulla	Jan to Sept	(4 mo.)	Oct to May	(8 mo.)

The author expresses a certain amount of caution with regard to the 'Season of no high extremes) because the use of monthly totals may have filtered out some significant short

.... p 12

Fig 4: : Incidence of monthly extremes (high) of rainfall of Central & South west Sri Lanka 1871-1980.
Scale: (ann. av./12) x a

RATNAPURA 3838 mm. ann. av.

a	J	F	M	A	M	J	J	A	S	O	N	D
>3.5												
3-3.5					3				2	1		
2.5-3					9	4	1	3	1	1		
2-2.5	0	0	0	0	18	17	3	3	6	11	3	0

KANDY 2078 mm ann. av.

a	J	F	M	A	M	J	J	A	S	O	N	D
>4					2			1				1
3.5-4					0	1		0		1		0
3-3.5	1				1	0		0		2	6	2
2.5-3	2				4	2		1	1	11	8	4
2-2.5	3	0	0	6	3	8	4	1	1	14	9	6

NUWARA ELIYA: 2233 mm ann. av

a	J	F	M	A	M	J	J	A	S	O	N	D
>4					1				1			1
3.5-4					1	3	1	1	0	1		0
3-3.5	2				4	5	2	0	0	0	1	0
2.5-3	0				2	3	3	2	0	4	0	4
2-2.5	3	0	0	0	3	9	12	1	4	10	6	7

BADULLA. 1834 mm ann. av.

a	J	F	M	A	M	J	J	A	S	O	N	D
>6.5	2									1		1
6-6.5	0									0		0
5.5-6	0									0		0
5-5.5	1									0		2
4.5-5	0									0		1
4-4.5	1									0	1	1
3.5-4	1		1	1						3	2	5
3-3.5	3		0	0						1	5	3
2.5-3	4	1	0	2	1					7	7	6
2-2.5	11	1	1	8	10	0	0	1	0	14	22	21

period values. Despite this, the above analysis may be accepted as a first approximation.

(b) Although in absolute terms the wettest station, namely Ratnapura, has the highest extremes, the highest extremes relative to the average annual rainfall are found in the driest station, namely, Badulla. It is a well known principle in climatology that rainfall variablity increases with increasing dryness.

(c) The seasons of Badulla are out of phase with the others,

(d) All stations show a tendancy to a multi-peak distribution:

	Season of extremes	No. & month of peaks
Ratnapura	May to Nov.	Two May Sep/Oct
Kandy	Apr to Jan	Three May Aug Dec
Nuwara Eliya	May to Jan	Three May Sep Dec
Badulla	Oct to May	Three Oct Dec Apr.

(e) The May & December peaks are generally dominant, with the proviso that Ratnapura has no December peak and Badulla no May peak.

(f) Badulla is unique in exhibiting a significant though minor peak in April.

(g) Badulla is also unique in exhibiting to a marked degree very high but infrequent extreme rainfalls which are not only high relative to its annual average but even in absolute terms.

.... p13.

Conclusions:

(a) The increasing number of landslides that is shown in the reports of the last two decades or so is not supported by climatological evidence. Therefore it must be concluded that the increase must be due to other factors such as:

(1) Better reporting.

(2) Increasing disturbance of natural ecosystems by the spread of population to marginal areas.

(3) increasing tempo of economic activity

(4) rapid loss of forest cover.

(5) poor management of agricultural land, esp. plantations, which cover a large segment of the land in the area studied.

(b) The results shown in this paper probably warrant the continuation of more detailed studies using the methodology discussed.

(c) The analysis brings out the need for both field and theoretical studies of earthslips to determine useful threshold values such as that of the effective rainfall that results in earthslips in Sri Lanka.

Acknowledgements

The author is indebted to the Department of Meteorology Colombo, and Yoshino, M.M. et al (1982) for the supply of data on which the article is based.

~~References~~

References

Basnayake, B.K., 1985 'Climatological Droughts in Sri Lanka, 1871-1980', Proceedings, Int. Symp. on Applied Climatology & Oceanography, Andhra University, Waltair, AP, India.

Crawford & Lindsay, 1966, 'The Stanford Watershed Model IV, Tech. Report No 12, Stanford University, USA.

Department of Meteorology, Annual Reports, Colombo.

Gibbs, W.J. & Maher, J.V., 1967, 'Rainfall Deciles as Drought Indicators, Commonwealth Bureau of Met. Bull. No.48, Melbourne.

Willett, H.C., 1951, Jnl. of Met, Vol 8.

Yoshino, M.M. & Suppiah, R., 1982, 'Precipitation, Temperature, & paddy production in Sri Lanka, Climatic Rec. of Monsoon Asia, Climat. Notes, Univ of Tsukuba.