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Rainfall In Nepal*

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Rainfall is a most important climatic element for agricultural development. Conventional 30 year rainfall data are available at only a few places in Nepal. Therefore, a study has been undertaken to find the average normal rainfall period compared to a 30 year normal rainfall in Nepal, and the available rainfall data has deen standardized for a large number of places. The nature of the rainfall-its amount, seasonal distribution, intensity, frequency of occurrence, variability and areal variation is a major factor affecting agricultural potential. To understand the nature of the rainfall it is essential to have an understanding of its general causes.

General Features of the Atmospheric Circulation over Nepal

Studies of lower and upper tropospheric atmospheric circulation in Nepal suggest that rainfall distribution can be analysed with four distinct seasons[1] pre-Monsoon (March to May); summer monsoon (June to September); post-monsoon (October); and winter (November to February).

In the pre-monsoon season, moderate to strong westerly winds prevail throughout Nepal. Scattered rainfall occurs during this period

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1. J. L. Nayava, "The summer monsoon in Nepal and Southern Asia" Unpublished M. Sc. dissertation, Birmingham University, (U. K.) 1974.

and there is marked increase in temperature of about 3–4° in the month of March. Due to the outbreak of warm air and the atmospheric instability, the subtropical westerly jet-stream weakens over Nepal. As summer approaches, fogs become less frequent in the Valley and haze predominates from the southern to the Hill Regions of Nepal.

The summer monsoon is the most important season in Nepal for agriculture with nearly 60 to 90 percent of annual precipitation falling between June and September (Fig. 1). The author, in an earlier study of the summer monsoon in Nepal and South Asia was able to detect the basic types of monsoonal circulation patterns which allow the summer monsoon to be generally classified according to (a) active or normal (b) very active and (c) weak.

(a) During the summer monsoon, the easterly wave dominates the upper level of the atmosphere and the subtropical westerly jet stream shifts to the northern side of the Tibetan plateau, around an anticyclone called the Tibetan High produced by the thermal effect of this heat source.[2] At the surface, an elongated zone of low pressure develops along the Indogangetic plains of North India, which lies northwest to southeast. This area of low pressure is known as the monsoon trough or equatorial trough, which, of course, advances northwards in the summer monsoon months and retreats southwards in the post-monsoon period. Therefore the onset and withdrawal of monsoons are associated with northward and southward movement of the equatorial trough.[3]

Generally, depressions form in the Bay of Bengal twice per month,

2 P. Koteswarm "The Asian Summer Monsoon Circulation over the Tropics" **Monsoons of the World** (New Delhi: India Met. Dept., 1958), pp. 105-110; H. Flohn, "Contributions to the meteorology of the Tibetan Highlands" **Atmos Sci.** Paper No. 130, Dept. of Atmos. Sci , Colorado State Uni., 1968.

3. R. Ananthakrishnan and C. J. Rajagopalachari "Patterns of Monsoon Rainfall Distribution Over India and Neighbourhood". **Proc. of Symposium on Trop. Meteor.** (Wellington: New Zealand Met. Service, 1964), pp. 192-200.

during the summer monsoon season corresponding to a period of about 17 days.[4] Depressions usually move WNW and cease activity as they move over the Indogangetic plain. On rare occasions, a depression may move due north from the Bay of Bengal and Assam at the height of the monsoon season, bringing heavy rainfall to the north and northeast of the monsoon depression. The recurvature of such a depression is often found to be due to the effect of a westerly wave moving east, north of latitude 30° N. Recurvatures of monsoon depressions are common towards the end of the summer monsoon.[5]

(b) During the period of very active monsoon, the westerlies occasionally move south to the Tibetan plateau and even as far as Delhi and the easterly jetstream often shifts northwards. The easterlies are very strong up to 20°N. During that time, Pacific anticylone circulation extends up to the northwest of Burma and the mid-latitude Saudi Arabian Subtropical high extends a ridge eastwards even to the northwest of India. Hence, Nepal finds itself in the col position (Fig 2) If the Saudi Arabian ridge pushes more towards the east, i.e. WNW (200 mbs) wind dominates western Nepal, then rainfalls are heavy towards the central and the eastern part of Nepal. If the Pacific ridge pushes more towards the west, higher intensity of rainfall occurs all over Nepal. At that time, the monsoon through lies over 25°N latitude. Examples of three dimensional circulation over Nepal are shown in Figs. 2 and 3. During such periods less rain falls in central India, being instead concentrated either in part or the whole of Nepal de-

4. F. R. Miller and R. N. Keshavmurthy, "Structures of an Arabian sea summer monsoon system" Eastwest centre, Honolulu. Intl. Indian Ocean Exp. Meteorol. Monogr., 1965.

5. K. Parathasarathy, "Some aspects of the rainfall in India during southwest monsoon season", **Monsoons of the World** (New Delhi; India Met. Dept 1958), pp. 185-194; C. S. Ramage, "Monsoon Meteorology" **Int'l. Geophy.** Series, 15 (London Academic Press, 1971), pp. 296; Y. P. Rao and B. W. Desai, "The Indian Summer Monsoon" **Met. Geophys. Rev,** Vol. 4, (1973), pp. 1-18; J. L. Nayava, "Heavy monsoon rainfall in Nepal", Weather, Vol. 29 (1974), pp. 443-450.

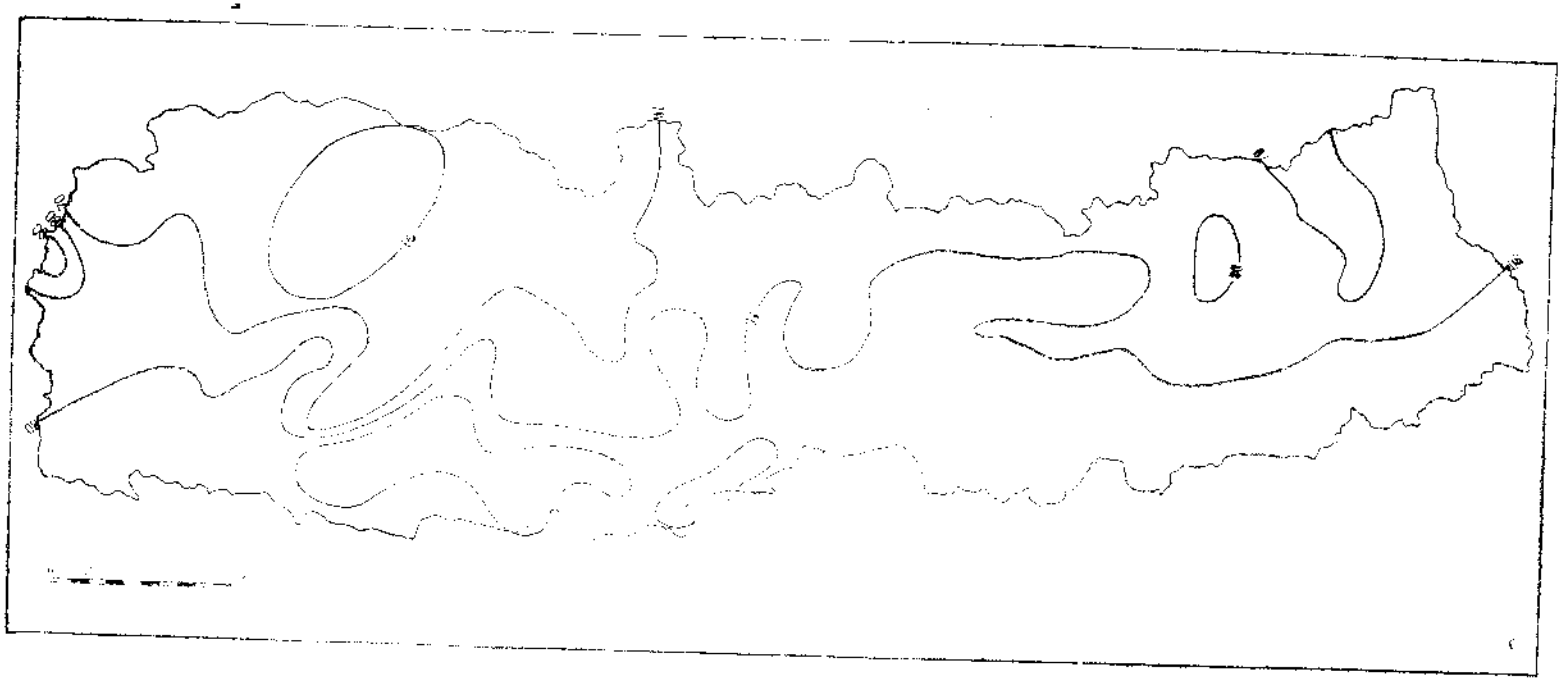
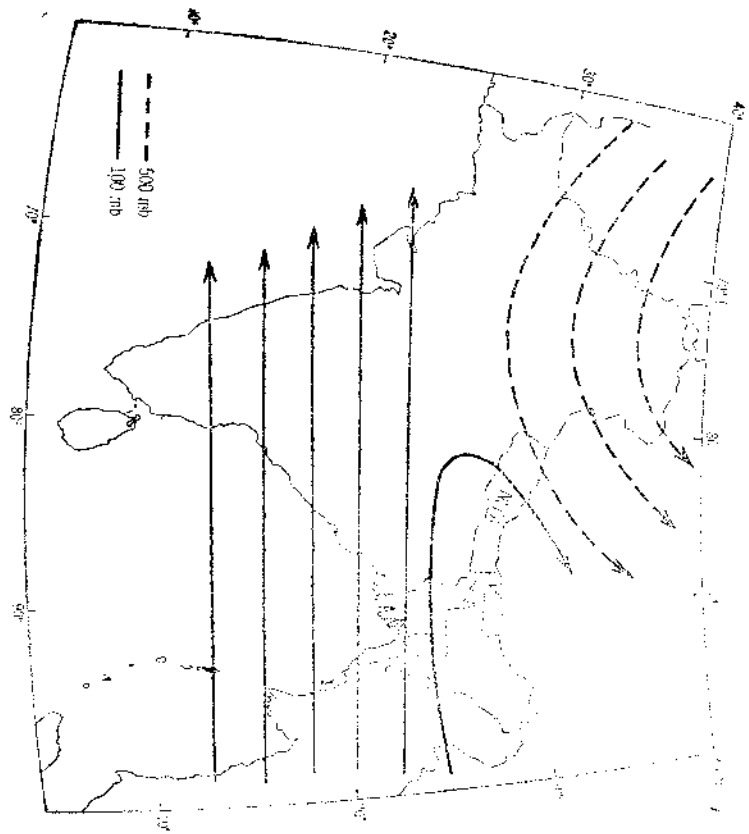


Fig. 1. Monsoon rainfall as a percentage of annual rainfall.



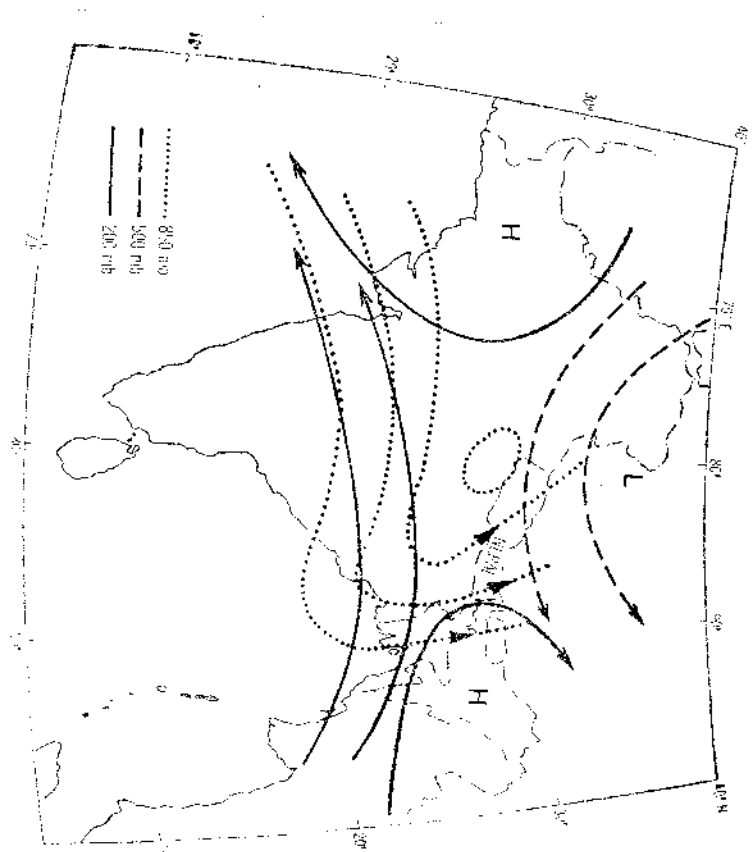


Fig. 2 Three dimensional atmospheric circulation over Nepal and adjacent countries on 20th June 1975, 00GMT.

Fig. 3 Three dimensional atmospheric circulation over Nepal and adjacent countries on 22nd June 1975, 00GMT.

pending upon the mid-latitude anticyclones. Under these conditions, one part of Nepal could be drier and the other part may be much wetter. Actually, such a period is known as a "break in the monsoon" in India.

(c) During a weak monsoon over Nepal, easterlies are weak and lie over 15°N in the Indian Subcontinent. The fluctuation and intensity of the monsoon are very much related to variations in the easterly current.

The post-monsoon season is the harvesting season of the main crop, paddy. Strictly speaking, this is the transitional period from one season to another and at this time the subtropical westerly jetstream retreats from the northside of the Tibetan Plateau to the southern side of the Nepalese Himalayas. Frequent fogs again appear over the Valleys.

In the winter season the lower tropospheric wind blows mostly from the west -north- west in the western Nepal and east-north east in the eastern Nepal. They are continental, dry and the wind is calm and brings settled and dry periods in Nepal. On the other hand, in the upper troposphere, the subtropical westerly jetstream lies over the southern side of the Himalayas. Almost daily morning fogs appear in most of the Valleys in Nepal. Occasionally, the westerly disturbances bring cold spells and rain, particularly to the northwest corner of Nepal.

Rainfall Data

Conventional 30 year mean rainfall data are available at only a few places in Nepal. There are, however, 68 stations covering the different regions with a minimum of twenty years of records.[6] To est-

6. Department of Hydrology and Meteorology: "Climatological Records of Nepal, 1966" (Kathmandu: HMG of Nepal 1968); "Climatogical records of Nepal. 1967-68" (Kathmandu: HMG of Nepal, 1974); "Climatological Records of Nepal 1969" (Kathmandu: HMG of Nepal, 1972); Department of Irrigation, Hydrology & Meteorology, Climatological Record of Nepal 1970 (Kathmandu: HMG of Nepal 1973); "Climatological records of Nepal, 1971-75" Vol. I. (Kathmandu: HMG of Nepal 1977); "Climatological records of Nepal, 1921-75", Vol. II (Kathmandu: HMG of Nepal 1977).

ablish whether any bias is introduced by using 20 years averaged data instead of the normal 30 years, the mean rainfall at Kathmandu for 5, 10, 15, ... years starting from 1921 were calculated. The percentages-deviations of these means from the long term mean are plotted against time as shown in Fig. 4. This information indicates that 20 years average rainfall is close to the 30 years normal rainfall. Therefore, the years 1956-1975 inclusive were chosen as the period to investigate the mean monthly and annual rainfall in Nepal. In addition, there are a hundred stations whose records cover only part of this period and the missing data for 100 stations have been estimated by linear regression based on the nearest station which has a longer period of record to develop a complete record for the 168 stations for 1956-1975[7]. The standardized mean monthly values have been used to study the macroscale variation and distribution of rainfall over Nepal. At the same time, the seasonal rainfall at selected places (Table 1) have been shown for better illustration of seasonal rainfall over Nepal. This shows that the percentage of seasonal rainfall is broadly similar except in the far western Mountain Regions, where the percentage of rainfall differs greatly from other places, for example, Jumla receives 69 percent of its rainfall from the summer monsoon, whereas the other regions

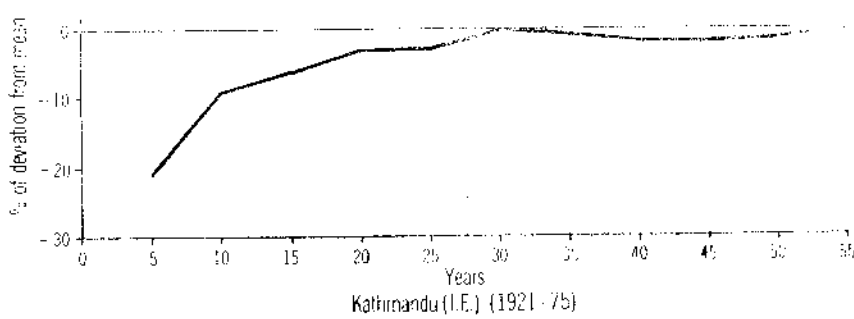


Fig. 4. Percentage deviations from the available long term mean against time.

7. Mean monthly and annual rainfall standardized to 1956-1965 for 168 stations and their locations are under publication (see key Fig. 5 for 168 meteorological station network).

receive 80 to 90 percent from the summer monsoon rainfall. Mean monthly rainfall at the selected places has also been presented to show the pattern of rainfall by fig. 6. This demonstrates that the rainfall falls mostly in the summer monsoon season and this varies greatly from place to place within a small distance. In other words, Nepal has distinct wet and dry seasons.

Analysis

Mean Monsoon and Annual Rainfall

Mean monsoon rainfall and mean annual rainfall are shown in Figs. 7 and 8. The rainfall in Nepal varies greatly from place to place due to sharp topographical variations. As the rain bearing winds approach Nepal from the southeast in the summer monsoon season, heavier rainfall falls in the foothills of the Churiya range increasing with altitude on the windward side and sharply decreasing on the leeward side. The heaviest rainfall falls on the Hill Regions, specially in the Pokhara region. Ultimately, the foothills of the Great Himalayas receive less rain than the other areas (Fig.7).

There are a few isolated rainfall maxima exceeding 2500mm i.e. Dharan, Barakshetra, Num, Hariharpur-Gadhi, Gumthang, Butwal, Pokhara, Lumle, Rukumkot and Chispani-Karnali. In particular, Lumle near Pokhara receives about 5180mm rain, whereas Pokhara Hospital in the valley floor, receives an annual total of only 3584 mm-a reflection of sharp topographical differences over short distances. In similar situations of heavy rainfall at Cherapungi, Assam, Simpson (1921)[8] remarks that heavy rainfall is due to the rapid rise of warm saturated air blowing with a great velocity so heavy precipitation falls on the top of the hills.

On the other hand, in contrast to the heavy rainfall, there exist very low rainfall areas, such as Jomosom, 273mm, annual total on the northern side of the great Himalaya in a rain shadow area. This lower rainfall is due to the alignment of the neighbouring moun-

8. C.G. Simpson, "The South-west Monsoon" Quart. J. Roy. Meteor. Soc., Vol. 47, (1921), pp. 151-172.

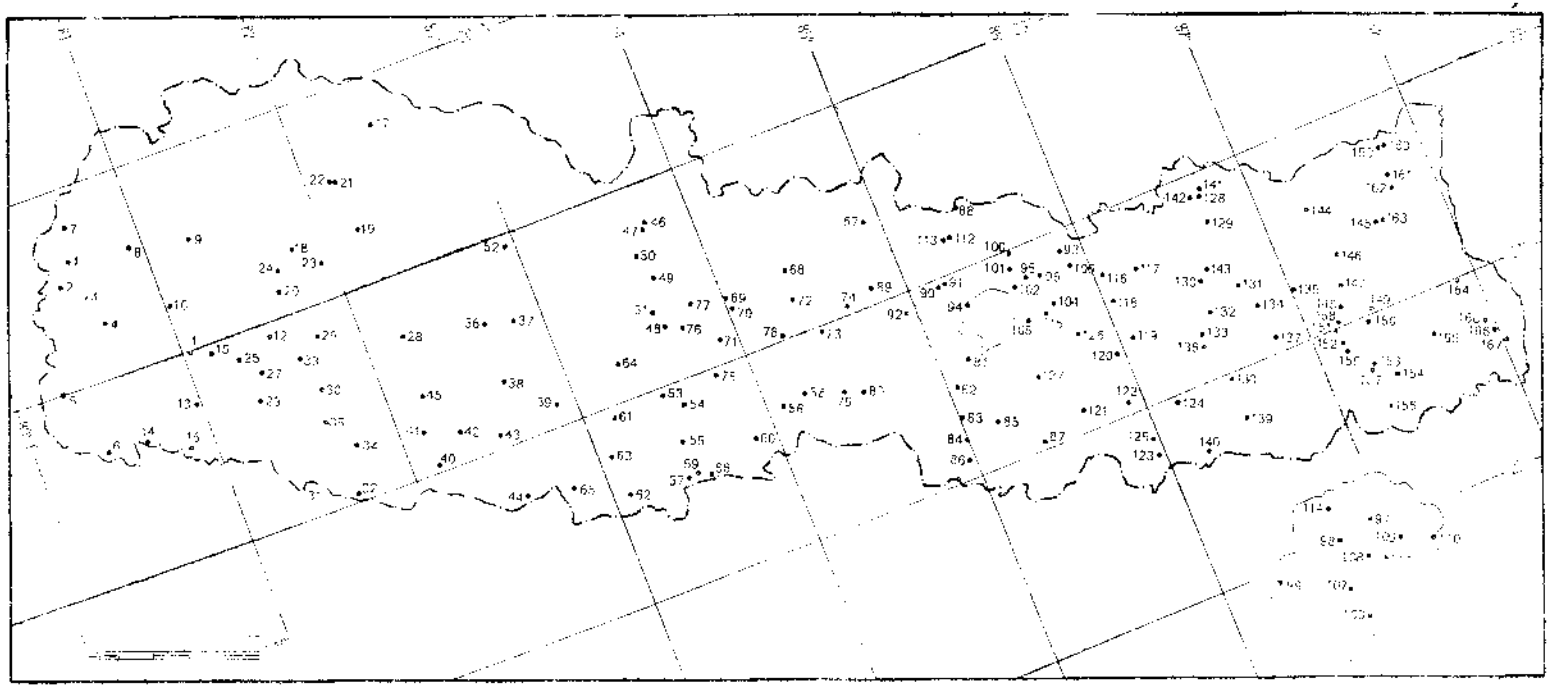


Fig 5. 168 Meteorological Station Net-work.

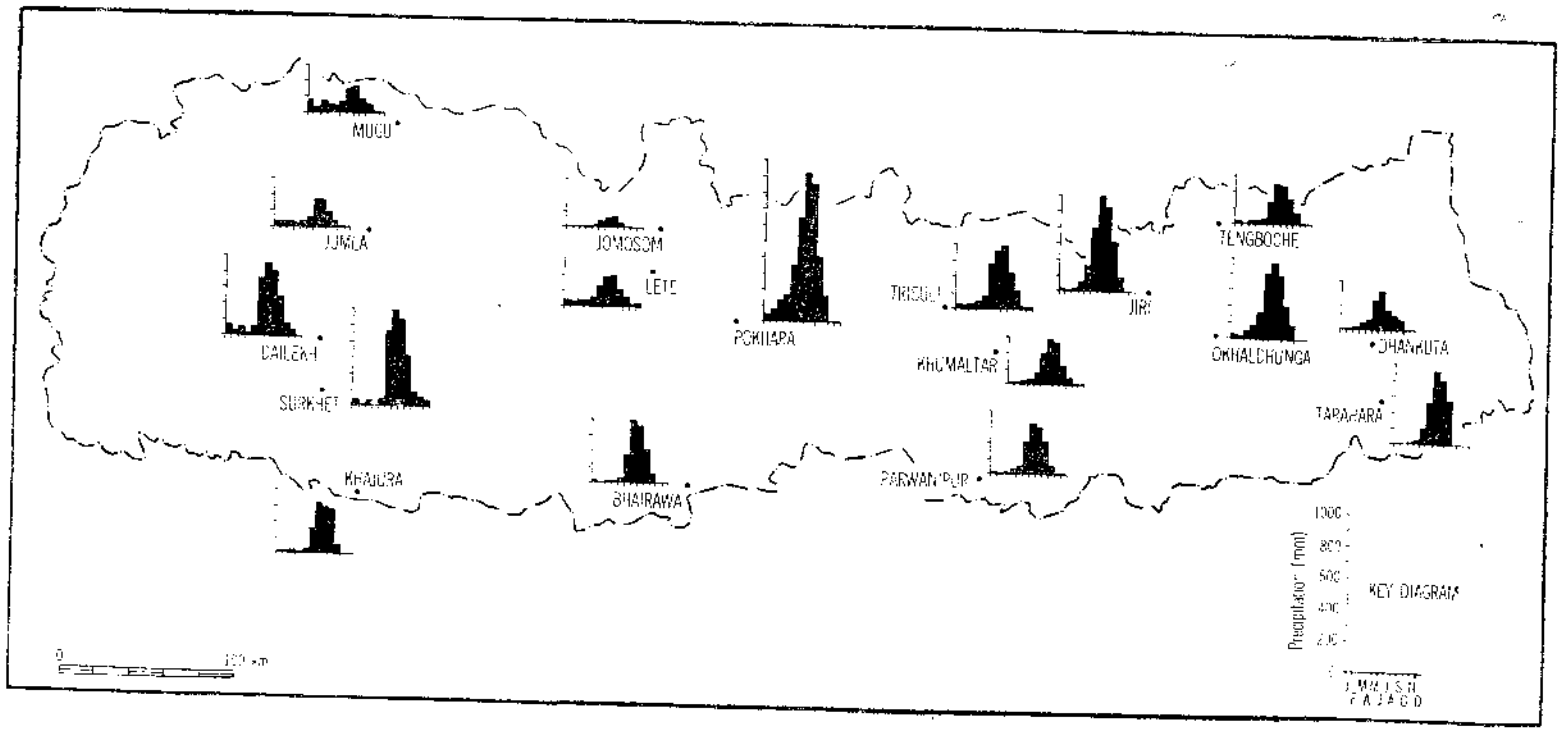


Fig 6 Variations of mean monthly rainfall at selected places

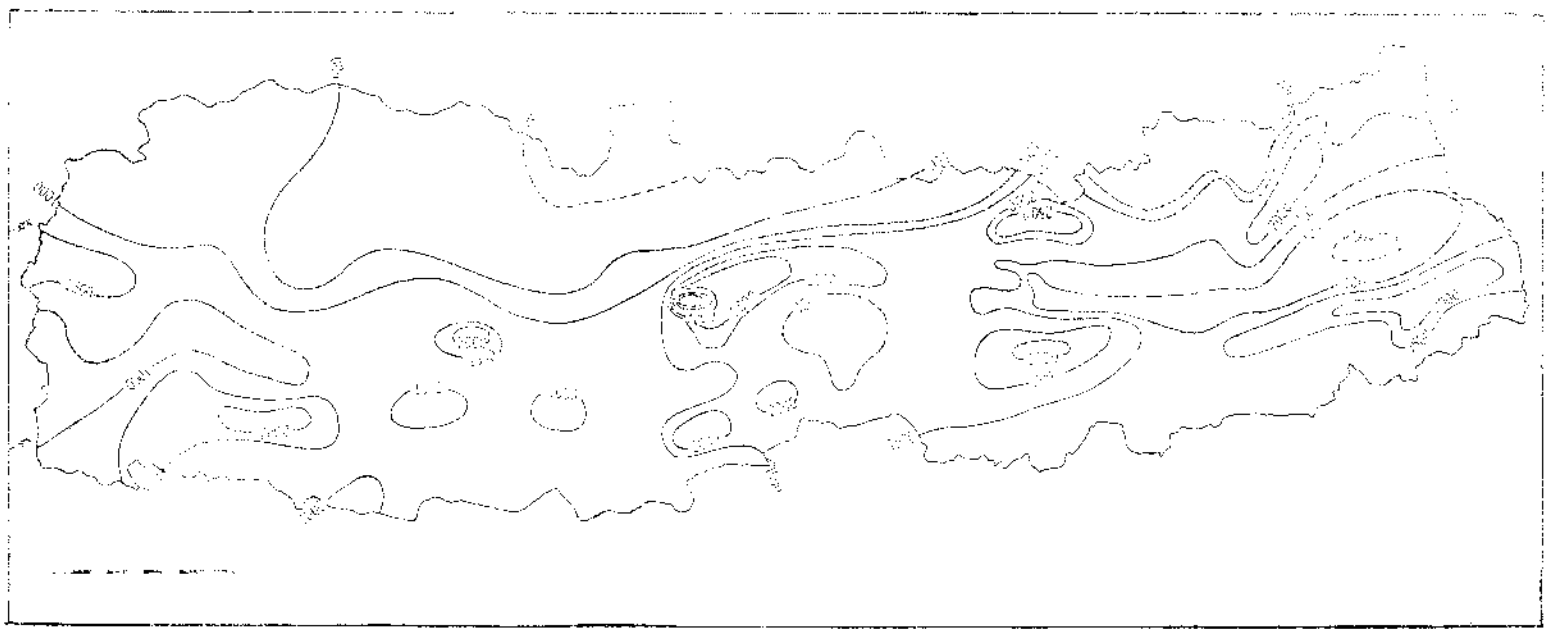


Fig 7. Mean monsoon rainfall (mm) June-September, 1956-1975, Nepal

tains which prevent a large inflow of moist air into the region.

The Date of the Onset and Cessation of Monsoon

The monsoon rainfall is very important from the agricultural point of view. Thus, the intensity of the summer monsoon rains and the date of the onset and cessation of the monsoon are both important factors for the country's economy, because it is the main season for planting paddy. Normally, in Kathmandu, the onset of the monsoon occurs on the 12th June and retreats on the 21st September respectively (Fig. 9) (Department of Irrigation, Hydrology and Meteorology, 1977). Confidence can be placed in these data as they are consistent with the broadcale analysis by Das (1979) on the onset and retreat of the monsoon over the Indian subcontinent (Figs. 10 to 11).

Intensity of Rainfall

Since most of the rainfall falls in the summer monsoon, the general rainfall intensity is estimated by calculating the ratio of rainfall and wet days (1,0mm) against altitude in each monsoon month (1971-75) as shown in Fig. 12. These average values of rainfall intensities show that the rainfall is not always decreasing or increasing slowly with increasing altitude. This may be due to windward and leeward effects accompanied by the complex nature of topography in Nepal. In other words, this does not show any fixed pattern of trend from which specific conclusions can be drawn.

In addition, the maximum rainfall in 24 hours and average number of rainy days per year (over 1mm) for a few selected stations from Nayava (1974) have been shown in Table 2. This shows that, generally the in tensity of rainfall is much higher in lower elevations than in higher elevation.

Discussion

These mean monthll rainfaly data, standardized for 168 places in Nepal, will be further used to investigate the distinctive feature of rianfall regimes and soil moisture studies which are one of the basic

9. P. K. Das, the "Monsoons", (London: Edwart Arnold Ltd., 1968), pp. 162.

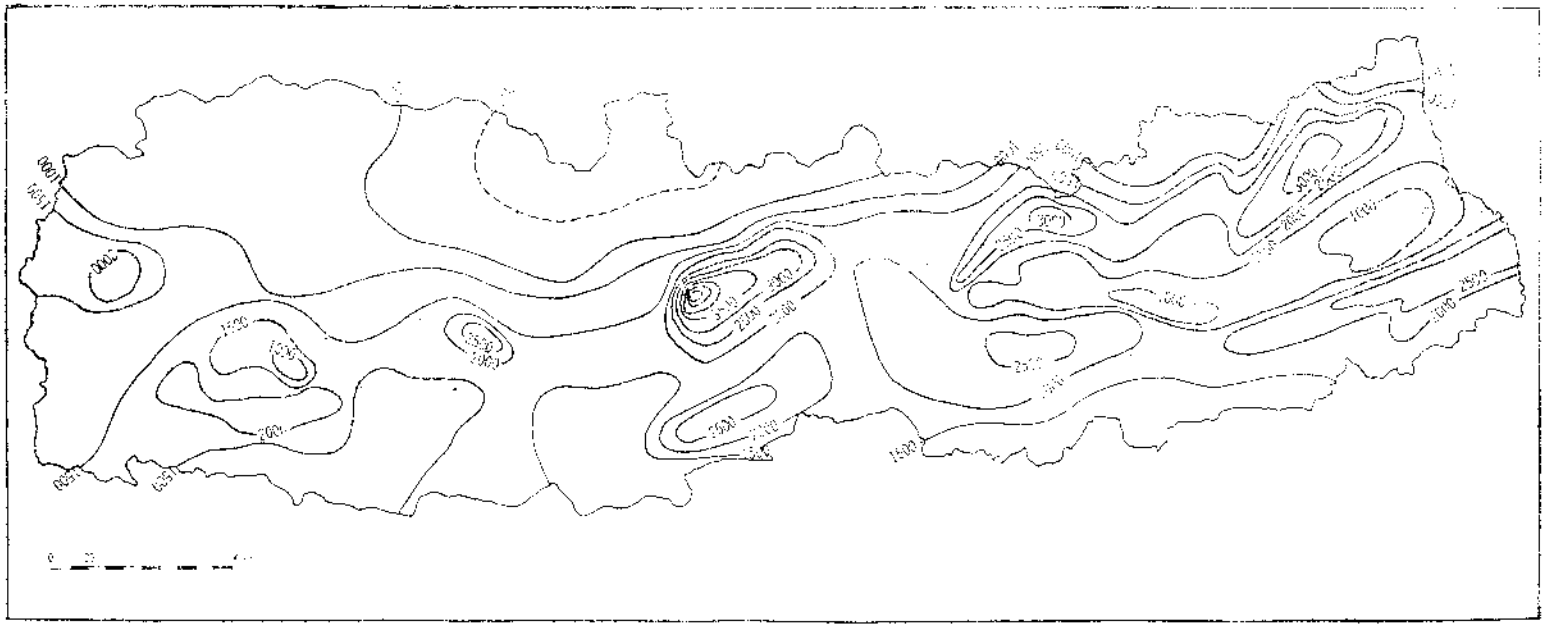


Fig. 8 Mean annual precipitation (mm), 1956 1975, Nepal

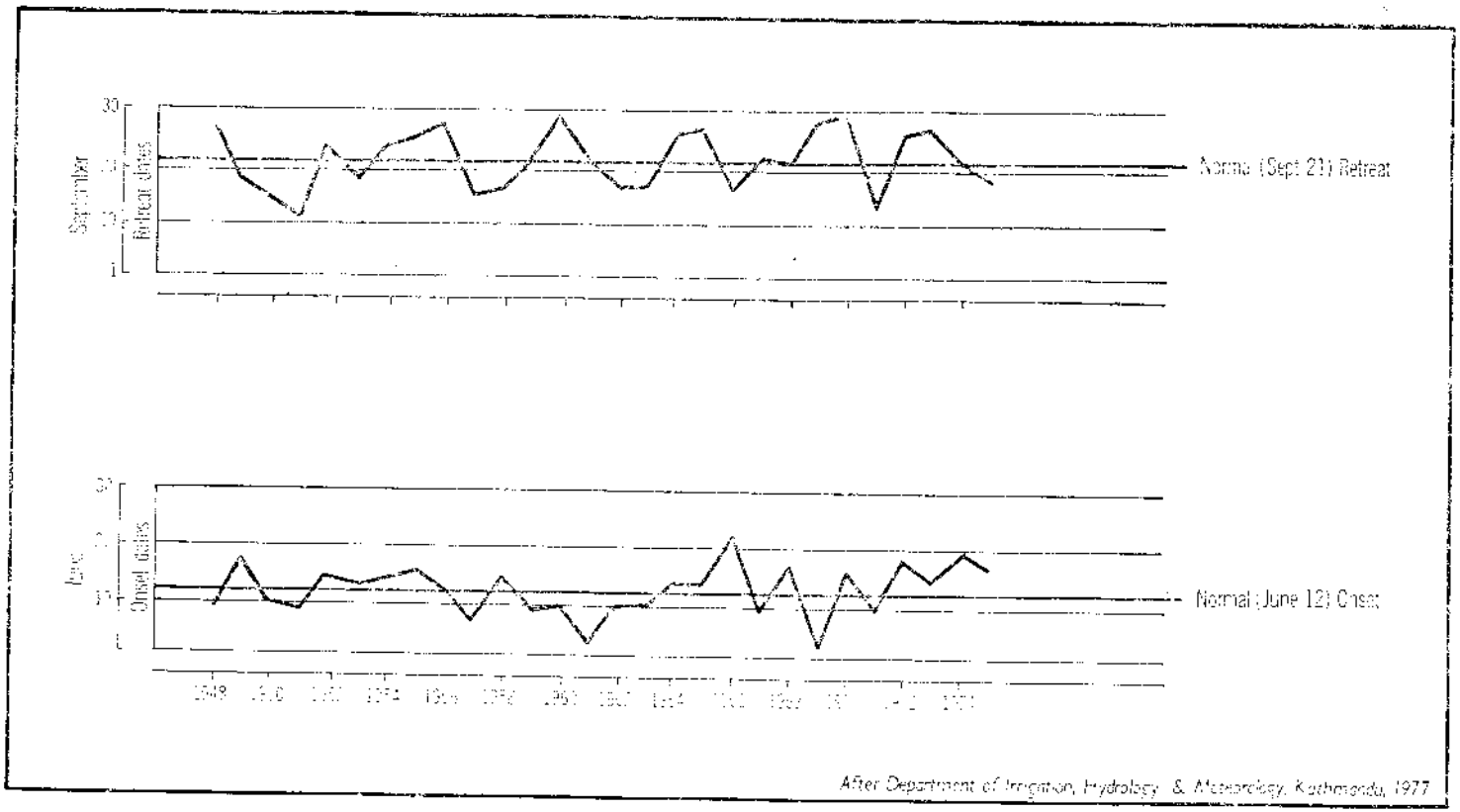


Fig. 9 Normal date of the onset and retreat of summer monsoon

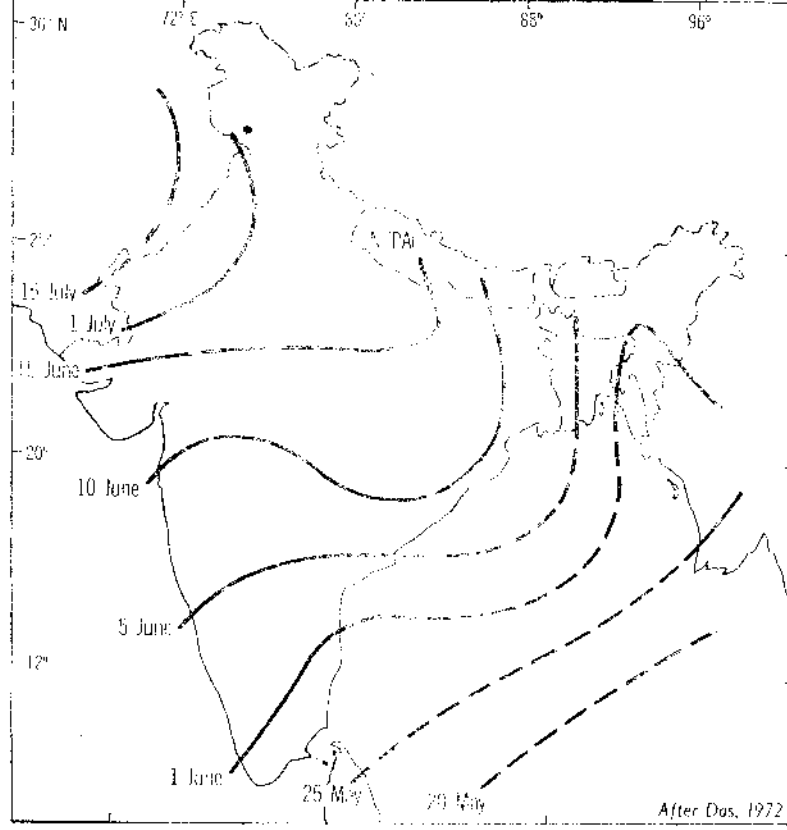


Fig. 10. Normal dates of onset of monsoon.

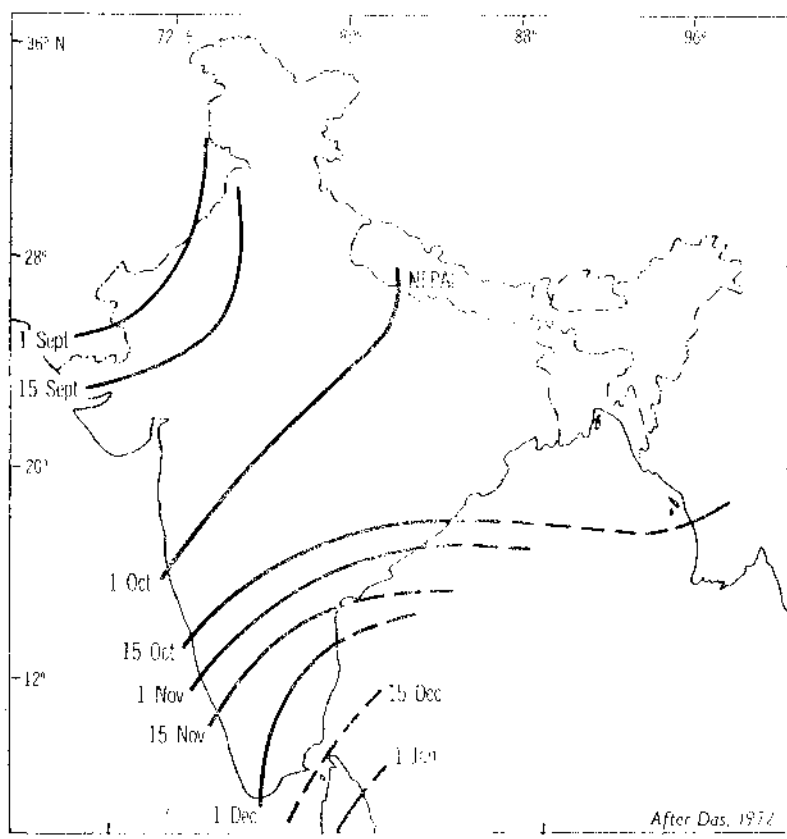


Fig. 11. Normal dates of retreat of monsoon.

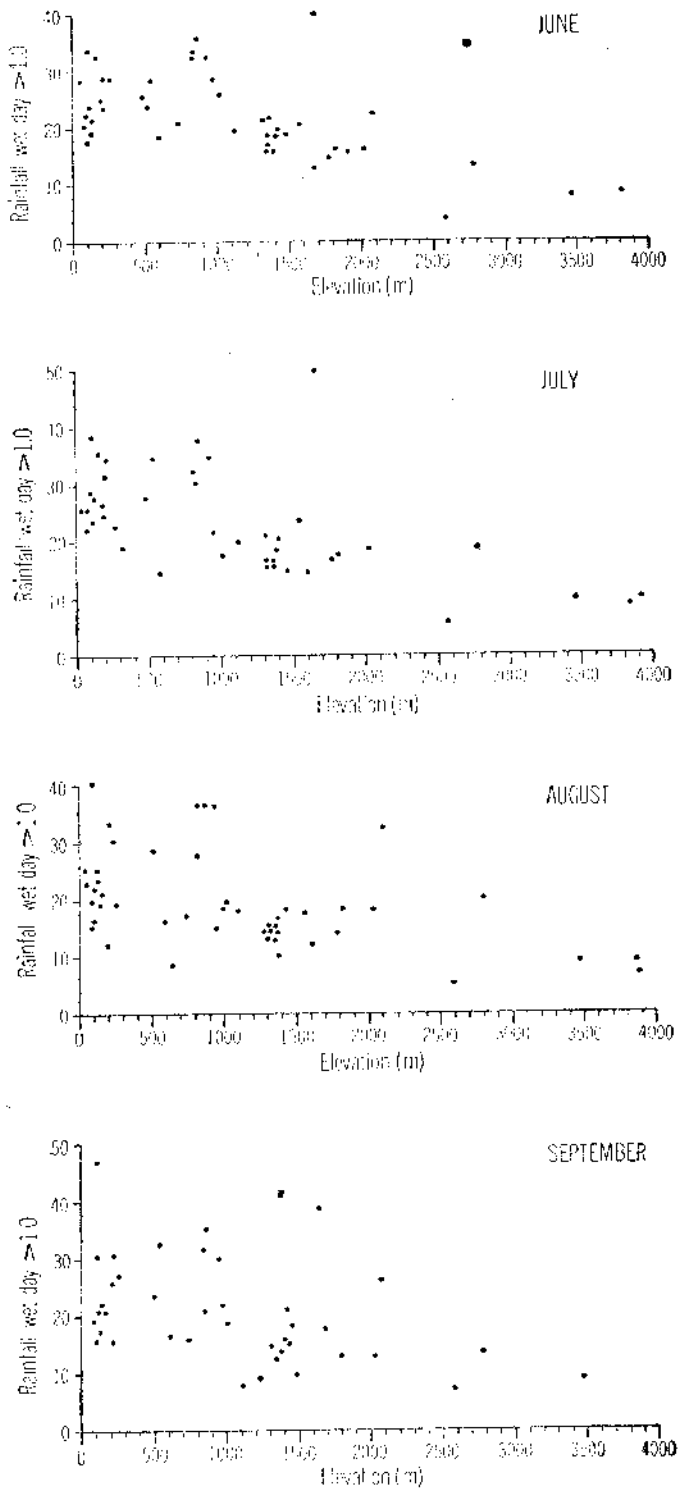


Fig. 12 The ratio of rainfall and wet day 7mm, against altitude, 1971—1975.

Station	Elevation	Winter (Nov-Feb)		pre-Monsoon (Mar-May)		Summer Monsoon (June-Sep)		Post Monsoon October		Annual
	(m)	(mm)	%	(mm)	%	(mm)	%	(mm)	%	(mm)
Bhairawa	120	8	1	41	3	1183	92	59	5	1292
Dailekha	1402	103	5	121	7	1470	83	87	5	1780
Dhankuta	1160	28	3	215	14	646	75	68	8	867
Jari	2003	28	1	247	11	1831	83	94	4	2199
Jomosom	2744	17	6	29	11	212	78	15	5	273
Jumla	2300	89	11	103	14	504	69	45	6	738
Khajura	190	58	5	68	6	968	84	62	5	1155
Khumaltar	1350	34	3	136	12	883	80	48	4	1101
Lete	2384	134	14	141	14	636	65	62	6	973
Mugu	3803	151	17	177	20	483	55	62	7	873
Okhaldhunga	1810	41	2	294	15	1488	78	85	4	1907
Parwanipur	115	33	3	104	9	1031	84	55	4	1223
Pokhara	918	72	2	519	14	2831	79	162	5	3584
Surkhet	720	83	4	90	4	1938	88	92	4	2204
Tarahara	200	0	0	136	8	1419	86	104	6	1659
Tengboche	3857	40	4	86	9	784	80	72	7	982
Trisuli	595	81	5	166	11	1260	80	62	4	1568

Table 1: Seasonal rainfall in Nepal at selected stations.

Maximum rainfall in 24 hours and date where known

Station	Amount (mm)	Percentage of mean annual total	Date	Average number of rainy days per year (over 1mm)
Barakshetra	313	12	21 July 1967	110
Butwal	402	17	Aug. 1968	93
Dhangarhi	168	12	17 Sept. 1968	55
Okhaldhunga	130	7	July 1965	119
Kathmandu	134	10	9 July 8967	106
Pokhara	261	8	July 1965	136
Silgarhi-Coti	135	13	6 June 1967	72
Namchebazzar	115	14	4 Oct. 1968	116
Jumla	91	15	15 July 1969	64
Jomosom	72	28	4 Oct. 1968	32

Table 2 : Maximum rainfall in 24 hours during the period 1965-69 in Nepal, after Nayava (1974).

data to find out the potentiality of agriculture in different regions with respect to availability of weekly rainfall amount. These standardized mean monthly rainfall data are one of my contributions to climatic analysis and agroclimatology. This makes possible a more detailed description on the macroscale variation and distribution of rainfall over Nepal.