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Areal rainfall in the Kathmandu valley*

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ABSTRACT. The mesoscale variation of rainfall in the Kathmandu valley and surrounding regions have been estimated for 1225 grid points by computer program, which considers the effect of orography, an important factor in areas like the Kathmandu valley where sharp topographical variations occur within small distances.

1. Introduction

The Kathmandu valley lies in the hilly region of Nepal where a number of mountain ranges extend generally east-west parallel to the Great Himalayas. The east-west and north-south axis of this valley are about 30 and 20 kilometres respectively. The catchment area is approximately 607 square km. The valley floor which lies at between 1280 & 1400 m, is surrounded by hills and mountain ranges rising steeply on all sides completely enclosing the valley. The most prominent peaks rising from the valley are Sheopuri (2689 m) in the north and Phulchowki (3132 m) in the south. The Kathmandu valley is situated at Lat. 27 deg. 32′-27 deg. 49′N and Long. 85 deg. 12′-85 deg. 32′E.

The mesoscale study of rainfall in Kathmandu valley and surrounding regions has been undertaken. Rainfall is the primary data for hydrological, agricultural, forestry and water management studies. Generally, areal rainfall data are required rather than single point observations. It is mainly done by drawing isohyets in the data field, considering terrain features. Here, the mathematical approach has been taken to generate the areal rainfall data and analyse the patterns.

2. Methods for areal rainfall analysis

The variation of rainfall over a region that has few observation sites can be estimated by computer analysis. Cressman (1959) introduced the technique for determining a regular scalar field of grid values for an irregular field of observation to analyse the pressure in the atmosphere at various levels. Since then, this technique has been widely developed and extensively used in the numerical prediction in synoptic meteorology and in climatological studies. Gandin (1963) modified the above technique by the direct use of the distance autocorrelation function and fields of mean and standard deviation of the element being analysed. Maine and Gauntlett (1968) presented the application of this procedure to the determination of grid point field for monthly rainfall. The idea behind these techniques is to successively adjust a first guess field, so that the grid point values are consistent with the station observations in their vicinity. The error which is determined between the first guess field and observed rainfall, is applied at the grid point in accordance with the following influence function:

$$I = (r^2 - l^2) / (r^2 + l^2) \quad (1)$$

where r is the radius of influence adopted to grid scale units and l is the distance of the subject grid point from the station in grid scale units.

Body (1973) developed an approach to estimating areal rainfall distribution, considering the orographic influence on rainfall. A regression relationship is determined between the rainfall observed at a station and two parameters related

*This work has been done in the Australian National University, Canberra.

TABLE 1

Mean rainfall (mm) from Kathmandu valley and surrounding regions (1971-76)

Station	Elev. (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean (mm)
Bhaktapur	1330	18.0	23.3	34.6	66.1	122.1	320.4	340.3	335.0	235.7	86.2	5.3	1.9	1588.9
Godavari	1440	19.5	23.5	32.2	63.2	123.9	400.7	564.2	407.6	345.0	88.5	4.9	2.1	2075.3
Indian Embassy	1324	18.3	19.0	28.5	68.1	123.7	325.1	392·7	312.7	218.8	67.8	5.3	1.6	1581.6
Kakani	2064	15.6	22.8	51.8	71.9	171.9	521.6	701.0	703.2	502.6	139.4	5.3	1.8	2908.9
Khumaltar	1350	19.5	19.8	21.0	57.0	95.0	235.4	328.5	232.4	178.0	65.4	2.9	2.1	1257.0
Nagarkot	2150	17.2	26.0	48.0	74.4	143.6	456.6	569.4	566.5	357.9	124.6	9.0	2.7	2395.9
Saankhu	1463	18.5	23.2	43.8	64.5	123.3	376.4	489.5	475.5	311.4	109.0	6.9	2.2	2044.2
Sundarijal (Water Reservoir)	1576	13.4	18.9	40.4	67.0	173.5	391.1	556.7	579.1	360.9	91.2	18.6	3.0	2313.8
Thankot	1630	23.5	25.4	33.0	77.5	187.4	425.0	539.5	405.8	373.9	103.0	6.4	2.3	2202.7
Tokha	1790	12.7	16.9	36.0	84.4	183.0	464.1	635.6	733.9	316.5	73.7	20.4	0.5	2577.7
Tribhuwan International Airport	1336	17.6	18.3	31.4	60.9	97.3	284.4	375.4	299.2	195.7	65.1	5.9	1.9	1453.1

Source : Climatological Records, Nepal, 1975, Published by Department of Irrigation, Hydrology & Meteorology, Kathmandu

TABLE 2

Seasonal rainfall (mm) in Kathmandu valley and surrounding regions

Station	Elev.	Winter (Nov-Feb)		Pre-monsoon (Mar-May)		Monsoon (Jun-Sep)		Post monsoon (October)		Annual (mm)
	(m)	(m)	(%)	(mm)	(%)	(mm)	(%)	(mm)	(%)	
Bhakatpur	1350	48.5	3.1	222.8	14.0	1231.4	77.5	86.2	5.4	1588.9
Godavari	1400	50.0	2.4	219.3	10.6	1717.5	82.8	88.5	4.3	2075.3
Indian Embassy	1324	44.2	3.0	220.3	13.9	1249.3	78.9	67.8	4.3	1581.6
Kakani	2064	45.5	1.6	295.6	10.2	2428.4	83.5	139.4	4.8	2908.9
Khumaltar	1350	44.3	3.5	173.0	13.8	974.3	77.5	65.4	5.2	1257.0
Nagarkot	2150	54.9	2.3	266.0	11.1	1950.4	81.4	124.6	5.2	2395.9
Saankhu	1463	50.8	2.5	231.6	11.3	1652.8	80.9	109.0	5.3	2044.2
Sundarijal (Water Reservoir)	1576	53.9	2.3	280.9	12.1	1887.8	81.6	91.2	3.9	2313.8
Thankot	1630	57.6	2.6	297.9	13.5	1744.2	79.2	103.0	4.7	2202.7
Tokha	1790	50.5	2.0	303.4	11.6	2150.1	82.5	73.7	2.8	2577.7
Tribhuwan International Airport	1336	43.7	3.0	189.6	13.0	1155.0	79.5	65.1	4.5	1453.1
Average percentage			2.3		12.3		80.5		4.6	

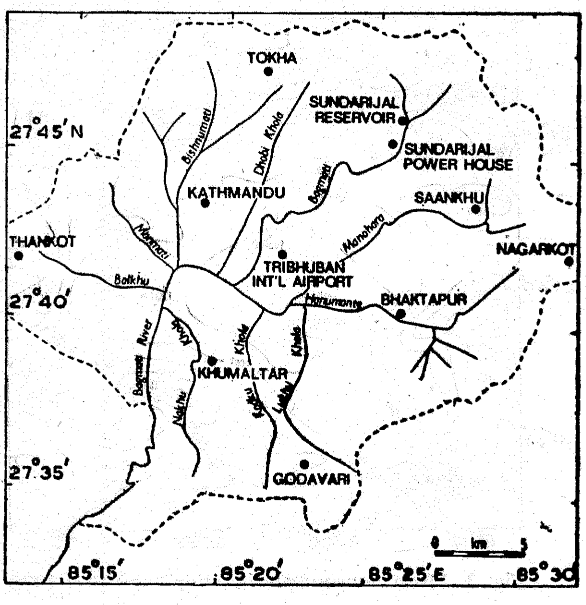

Fig. 1. Operating meteorological stations in Kathmandu Valley

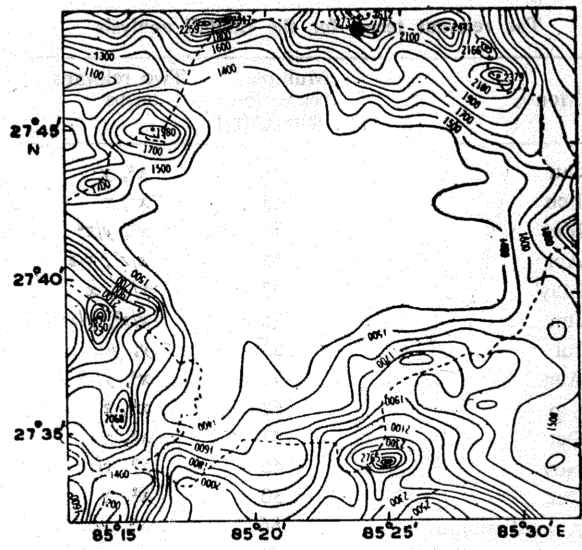

Fig. 2. Topography of the study area (Kathmandu Valley)

to the station's cartesian coordinates. Initially eight possible terms are supplied namely x, y, z, x^2, x/z, y/z, x/z^2, and y/z^2. The terms proved to be the most appropriate set for a study of monthly rainfall conducted by Body (1978) for the South Coast region of New South Wales. Their transposition to the Kathmandu valley was not tested but would appear reasonable as rainfall is affected by orography normal to a generally east-west air flow in each case. For each station, two relevant parameters are selected automatically by the program as those which provide the smallest deviation from the individual station value. Within two parameters, the first plays the primary role and second as a secondary. This is noted here as an order of preference. The number of terms in the equation is limited to two because at higher orders, the field is distorted to fit individual stations and, therefore, contains spurious relations which give incorrect estimates in regions away from observations or in orographic conditions outside these encountered in the data field. Then Body's (1973) program was used to study the rainfall in the Kathmandu valley. The data required by the program was, first, an estimated elevation at points in a grid net. In this case, the grid net contained 35×35 points (1225), each separated by 900 metres. The others were the observed rainfall data and the location of the stations according to the adopted grid net. The elevations of all grid points have been extracted from Nepal, 1 : 63,360 scale map, published by Surveyor General of India, 1957. The main procedures of the programs are as follows.

The program estimates from the multiple regression equation using elevation (z), x and y values, the rainfall at each grid point, thus giving field A. Therefore, field A gives preliminary rainfall values for each grid point, which are further adjusted to get the best fit value in grid points by series of selected radii 25.0, 11.0, 5.5 and 2.0 which are chosen for subsequent passes. The program computes interpolated value for rainfall at each of the observation points from field A on first pass current value at all subsequent passes. For each observation point, the program determines the error, E, between the interpolated and the observed value and for each grid point (x, y). The program determines the correction factor:

$$C_{x,y} = \sum_{i=1}^{m} E_i W_i \,/\, \sum_{i=1}^{m} W_i \qquad (2)$$

where, $W_i = (1-d_i / p)^2$

where d_i is the distance between the point (x, y) and i^{th} observation station within radius p.

The program computes a new value at each grid point, *i.e.*,

$$\text{New rainfall}_{(x,y)} = \text{old rainfall value}_{(x,y)} + (1-Mv_i)\, C_{x,y}$$

where Mv_i is the multiple regression value determined in regression analysis.

This whole procedure is repeated for the number of passes selected and adjusts the value at each grid point and finally the program draws isohyets of given intervals, which are supplied by the program user.

3. Data and constructing the isohyet maps

The basic rainfall data has been computed and checked and missing values have been estimated by linear regression based on the nearest

TABLE 3

The relevant terms for the rainfall analysis

Month	Multiple regression value (Mv_1)	Two relevant terms
Jan	.59	x^2, y
Feb	.61	x^2, x
Mar	.71	x^2, y/z^2
Apr	.53	x/z^2, y/z
May	.73	y/z^2, x
Jun	.78	x/z^2, y/z^2
Jul	.83	y, y/z^2
Aug	.93	x^2, y/z^2
Sep	.68	x^2, z
Oct	.47	x^2, x
Nov	.46	x^2, y/z
Dec	.30	x^2, x
Annual rainfall	.86	x^2, y/z^2
Monsoon rainfall	.86	x, y/z^2

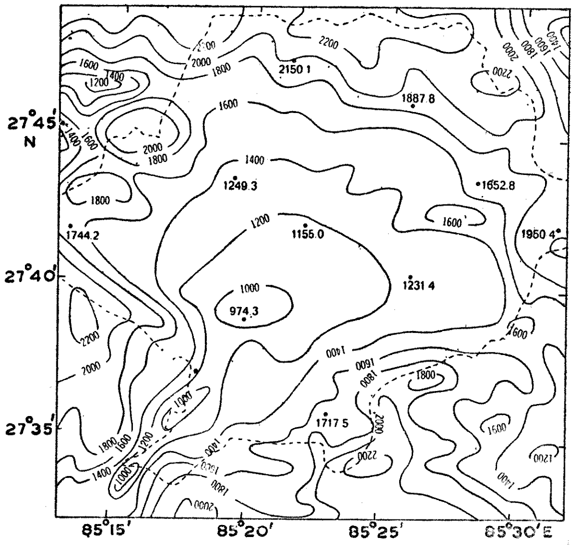

Fig. 3. Mean monsoon precipitation (mm) 1971-1976

station. A complete mean monthly rainfall records for 11 stations for 1971-76 has been standardized. The basic data, the rainfall stations are shown in Tables 1 and 2 and their locations are shown in Fig. 1. The analysis was based for the six year period (1971-76), rather than the conventional 30-year period. The hydrometeorological observation network in Nepal was expanded in the beginning of 1970, providing eleven stations representative of the different altitude and aspects in the Kathmandu valley and surrounding regions. In comparison with the longer period data for 56 years (1921-76) the recent six-year data, for Kathmandu (Indian Embassy) shows 13 per cent higher rainfall. The contour map of Kathmandu valley based on their grid points is shown in Fig. 2.

Maps of mean monthly, mean monsoon and mean annual precipitation for the Kathmandu valley and surrounding regions have been studied based on the grid point values as calculated from the computer program (Body 1973).

During the analysis of preparing the preliminary field *A*, the multiple regression value determined in regression analysis and selected two relevant parameters out of eight possible terms in each month are also produced, which is shown in Table 3. The table shows that the percentage of variance accounted for is very high during the summer months compared with the winter months. It is also interesting to note that the two terms considered in the analysis mostly differ from month to month (*see* Table 3). The rainfall in winter months (December, January, February), and rainfall in the transition season (October), does not relate with the elevation factor. On the other hand, the rainfall from March to August is strongly related with elevation. There is very little difference between the observed station rainfall and rainfall interpolated from the computer produced isohyets with the one exception of the rainfall station at Tokha, although the quality of the observed rainfall data here is poor. The rainfall values in independent data, namely Sundarijal power house has been compared with the interpolated values, which are in a good agreement with actual observation occurs. Similar studies of monthly and annual rainfall for the period 1968-76 for the Kathmandu valley have been studied and these also gave a similar pattern (Nayava 1979). For a matter of convenience, the observed rainfall of the 11 stations in the Kathmandu valley is given in bold numbers in rainfall maps.

4. Distribution of rainfall in the Kathmandu valley

Generally there are four distinct rainfall seasons in the Kathmandu valley. Pre-and post-monsoon rains in Kathmandu are associated with thermal convection combined with orographic uplift and the seasonal shift of the large circulation over Nepal. In winter, precipitation falls as snow on higher peaks of the Kathmandu valley. This precipitation originates from disturbances in in westerlies. In the summer monsoon, as the rain-bearing winds approach Kathmandu from the southeast, most rainfalls on the windward side, increasing with altitude and decreasing on the leeward side.

4.1. *Pre-monsoon*

Rainfall during this period, March to May, is only 12 per cent of the annual total in the Kathmandu valley. Most of this is due to scattered thunderstorm activity in the afternoon and late

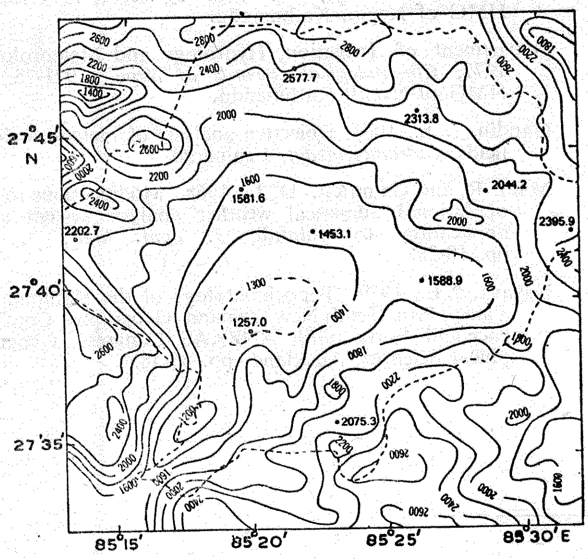

Fig. 4. Mean annual precipitation (mm) 1971-1976

evening. Due to the outbreaks of warm air and atmospheric instability, the sub-tropical westerly jet-stream is weakening over Nepal.

4.2. *Summer monsoon*

In Kathmandu, 81 per cent of the annual precipitation falls between June and September under the influence of summer monsoon. Fig. 3 shows the mean monsoon rainfall in the Kathmandu valley. The rainfall in Kathmandu valley varies greatly from place to place due to sharp topographical variations. In the summer monsoon period, generally, Sundarijal is the windward side of the Kathmandu valley. The intensity of the summer monsoon fluctuates year by year. A delay in the arrival of the summer monsoon and any weakness in its circulation has a significant effect on agriculture. Generally, the average dates on the onset and retreat of the monsoon for the period 1948-1975 are 12 June and 21 September respectively (Dep. of Irrig., Hydrol. & Met. 1977).

4.3. *Post monsoon*

Rainfall during October is only 5 per cent of the annual total and is due to the scattered thunderstorm activity in this transitional season from summer monsoon to winter.

4.4. *Winter*

The period from November to February is almost dry. Western disturbances account for only 2 per cent of the annual rainfall total.

4.5. *Mean annual rainfall*

Mean annual rainfall (Fig. 4) has similar patterns of distribution to that of the mean monsoon

TABLE 4

Variation of seasonal rainfall (mm) in Kathmandu (Tribhuban International Airport)

Year	Pre-monsoon	Monsoon	Post-monsoon	Winter	Total (mm)
1968	180.4	1000.3	160.4	38.6	1379.7
1969	161.9	965.0	40.3	12.0	1179.2
1970	154.6	1081.6	58.2	67.9	1362.3
1971	318.9	1101.7	81.2	9.5	1511.3
1972	160.8	968.0	86.1	46.5	1261.4
1973	154.9	1454.0	119.3	71.6	1799.8
1974	162.2	983.2	45.6	34.0	1225.0
1975	119.2	1221.1	34.2	56.0	1430.5
1976	222.0	1199.6	24.3	44.7	1490.6
	181.7 (13%)	1108.3 (79%)	72.2 (5%)	42.3 (3%)	1404.4

rainfall. Mean annual precipitation varies from 1300-2800 mm as shown in Fig. 4. The observed rainfall data and computer produced isohyetal lines based on rainfall interpolated are as expected in good agreement. The percentage of seasonal rainfall in Kathmandu Tribhuwan Airport (T.A.) is also shown in Table 4.

5. Conclusion

Each grid point is representative of about 0.81 sq. km which contrasts with the distribution of official stations which may be separated by many kilometres. The monthly mean precipitation is estimated for a large number of grid points in a grid net for studying the mesoscale variation and distribution of rainfall in the 936 km area of Kathmandu valley and its surrounding regions. The advantages achieved from examination of rainfall on the close grid net are clearly seen in the diagram in which sharp variations in the topography of Nepal are associated with a large rainfall.

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