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AAP ESTIMATION OF JALDHAKA CATCHMENT FOR FLOOD FORECASTING USING RAINFALL DATA FROM KEY STATIONS

1. On rapidly responding small catchment like Jaldhaka in North Bengal, Sikkim and Bhutan, where time of travel is less than 6 hours, intense rainfall can create flash floods even before the hydrometeorologists are able to evaluate and dessiminate average areal precipitation to the river gauge forecasting authority. Considerable time is involved in collecting daily rainfall from a large number of stations and in evaluating average areal precipitation. For operational flood forecasting, hydrometeorologist has to provide a forecast with sufficient lead time to be effective for flood rescue measures etc. In this note, the author has developed a multiple linear regression equation involving only 4 key stations under condition of $\sum_{i=1}^{n} A_i=1$, where A_i represents regression coefficient for ith station, to estimate areal precipitation for the catchment.

2. *The catchment and raingauge network* — The river *Jaldhaka* originates at Bidang lake in Sikkim at an altitude of about 4420 metres and then it flows through

TABLE 1

Percentage accuracy of AAP estimation by regression equation (within 25% error of AAP by isohyetal method)

Year	Jun	Jul	Aug	Sep	Oct	Jun-Oct
1984	85.7	70.8	85.7	80.0	—	80.5
1985	81.8	80.0	90.0	69.2	100.0	84.2
1986	80.0	88.2	70.0	85.7	80.0	80.8

Bhutan and North Bengal before its confluence with river *Brahmaputra* in Bangladesh. It drains an area of about 78 sq km in Sikkim, 940 sq km in Bhutan and 3750 sq km in North Bengal. It lies within latitude 26°0′ to 27°22′ N and longitude 88°30′ to 89°30′ E. Out of its total length of about 189 km; 26 km lies in Bhutan and about 19 km lies along border between West Bengal and Bhutan. The rest of 144 km lies in North Bengal. The longitudinal slope of the basin in the first 11 km is very high and later it varies between 36 & 13 metres per km.

A network of 8 raingauge stations within Jaldhaka catchment, namely, Mathabhanga, Falakata, NH-31 Road Bridge, Murti, Nagrakata, Diana (Chengmari), Samsing and Rongo and an equal number of stations in the neighbourhood of the basin are used for evaluation of AAP by isohyetal method. For selection of key stations within the catchment, monthly rainfall of 8 raingauge stations for 7-12 years period up to 1985 have been used for obtaining inter-correlation coefficients amongst the raingauge stations.

3. *Procedure of selection of key-stations* —In selection of key-stations by the method suggested by Rao *et al.* (1974), it is likely that several rainfall stations having very high inter-correlation coefficients amongst themselves for monthly rainfall are inducted as key stations. This possibility could be minimised if very high inter-correlation coefficients between two or more stations is used to designate a station as key station. Here inter-correlation coefficient for monthly rainfall is used in comparison to inter-correlation coefficients for daily rainfall due to its persistence and steadiness. If a station A has a very high correlation coefficients with stations B and C, then

$p_1 x_A + p_2 x_B + p_3 x_C$, the contribution of the rainfall (x_A, x_B and x_C) at stations A, B and C to the areal estimate of average rainfall, may be reasonably replaced by $k\ x_A$ where k is a regression coefficient involving weight factors p_1, p_2 and p_3. This method is utilised in this study for selection of key stations for inclusion in the multiple linear regression equation.

4. *Formulation of multiple regression equation* — If E is the estimate of average areal rainfall based on objective method and $x_1, x_2, \ldots\ldots\ldots\ldots, x_n$ are the point rainfalls observed at stations 1,2,3, etc then E can be expressed as :

$$E = A_1 x_1 + A_2 x_2 + A_3 x_3 \ldots\ldots\ldots\ldots A_n x_n \qquad (1)$$

where, A_1, A_2 etc. are the regression coefficients derived from the sample of observed data. Here, the intercept has been made zero which satisfies the condition that the regression expression should give an average of zero when all the individual stations report zero rainfall.

If all the individual stations report 1 or P mm of rainfall during last 't' hours (or say 24 hours) then, expression (1) for multiple linear regression equation for these two cases will be,

$$E = (A_1 + A_2 + A_3 + \ldots\ldots\ldots\ldots + A_n).\ (1) \qquad (2)$$

$$E = (A_1 + A_2 + A_3 + \ldots\ldots\ldots\ldots + A_n).\ (P) \qquad (3)$$

The expressions (2) and (3) will thus be theoretically true for $E=1$ and $E=P$, provided

$$A_1 + A_2 + A_3 + \ldots\ldots\ldots\ldots\ldots + A_n = 1$$

$$\text{or} \quad \sum_{i=1}^{n} A_i = 1 \qquad (4)$$

i.e., the *sum* of all the regression coefficients is unity. The expression (4) further reveals that the probability of the whole sample space is unity. The expression (1) represents the mathematical expectation of x variate with respective probabilities

A_i ($i = 1, 2\ \ldots\ldots\ldots\ldots\ldots n$) also.

The expression (4) has been utilised to obtain multiple regression relation involving 4 key stations namely Diana, Mathabhanga, Nagrakata and NH-31 Road Bridge. These stations are within the Jaldhaka catchment and its rainfalls are available daily by means of wireless network facilities of Central Water Commission, Jalpaiguri.

The magnitude of inter-correlation coefficients of each of the 4 key stations with other individual stations were between 0.7 and 1, which were evaluated from the monthly rainfall of the period 1973-85. The multiple regression relation arrived as such, is given below:

$$E = 0.27x_1 + 0.15x_2 + 0.23x_3 + 0.35x_4 \qquad (5)$$

5. The flash floods and other flood reports indicated that flash floods never occurred when AAP over Jaldhaka basin fell below 10 mm during the period. The AAP evaluated by isohyetal method and through regression equation (5) were comparable always for the AAP falling below 10 mm.

The results of the estimate of average areal precipitation amount for all the events having AAP 10 mm and above, have been presented in Table 1 for 3 years (1984-86).

The per cent accuracy was about 80 and 84 during 1984 and 1985 respectively within 25 per cent error of isohyetal values of AAP. It is worthwhile to mention here that the regression equation has given quite encouraging test result of about 81 per cent accuracy during 1986 monsoon.

6. The following conclusions may be arrived at from the above study :

(*i*) By keeping the sums of the regression coefficients unity ($\Sigma A_i = 1$), the multiple linear regression equation becomes cent percent acceptable from theoretical considerations and for any amount of rainfall.

(*ii*) The intercept or a constant is automatically removed, which is responsible to limit the accuracy of estimate in regression equation due to its presence as per Rao *et al.* (1974).

(*iii*) The inter-correlation coefficients amongst stations monthly rainfall appears to be an important and persistent parameter in selecting key stations in comparison to inter-correlation coefficient amongst daily rainfall and the technique adopted by Rao *et al.* (1974).

(*iv*) The regression Eqn. (5) does not have any constraint or limitation. The AAP estimation by Eqn. (5) and by isohyetal method separately indicated that average areal precipitation depths were comparable always for mean basin rainfall below 10 mm and the accuracy was 100 per cent. No flash floods or other floods were reported to have AAP below 10 mm. The percentage accuracy of AAP values estimated by Eqn. (5) was above 80 per cent during June-October with respect to AAP values evaluated by isohyetal technique for the average basin rainfall of 10 mm or more. The equation can be used operationally for day to day forecasting also.

(*v*) After receiving the daily rainfall record from 4 key stations through the wireless network facilities of Central Water Commission, Jalpaiguri, the regression Eqn. (5) may be used to estimate AAP instantly with help of a calculator and it should be transmitted to concerned authority immediately. The work may be completed by about 9 : 30 A.M. having ahead sufficient time for pre and post flood management.

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