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QUANTITATIVE PRECIPITATION FORECASTS OVER GANDAK CATCHMENT

1. Hydrometeorology is an important branch in hydrology to estimate amount of rain particularly Quantitative Precipitation Forecast (QPF) in various river catchments to predict tendency of water level in the river. With a view to determine rise/fall of water level in the river resulting from rainstorm, QPF is issued using synoptic analogue technique and Areal Average Precipitation (AAP) is estimated by arithmatic mean, isohyetal and Thiessen method. Number of studies have been made to estimate QPF dealing with synoptic weather system (Ram and Pangasa 2000; Rao, l973; Abbi *et al.*, 1979; Singh *et al.*, 1995) over Ghaghara, Bhagirathi and Sone catchment along with verification of forecast. No synoptic analogue study has been made for the Gandak catchment. The objective of this paper is to investigate frequency of weather system at different location and to identify the system which can produce average rain depth in the range of 1-10, 11-25, 26-50 and 51-100 and more than 100 mm over the catchment. The results has been verified using the data of 1987 delineating the weather system.

2. The Gandak catchment mainly comprises of two important rivers namely the Gandak and the Burhi Gandak. The Gandak catchment is situated close to the foot-hills of Himalayas a pproximately between Latitude

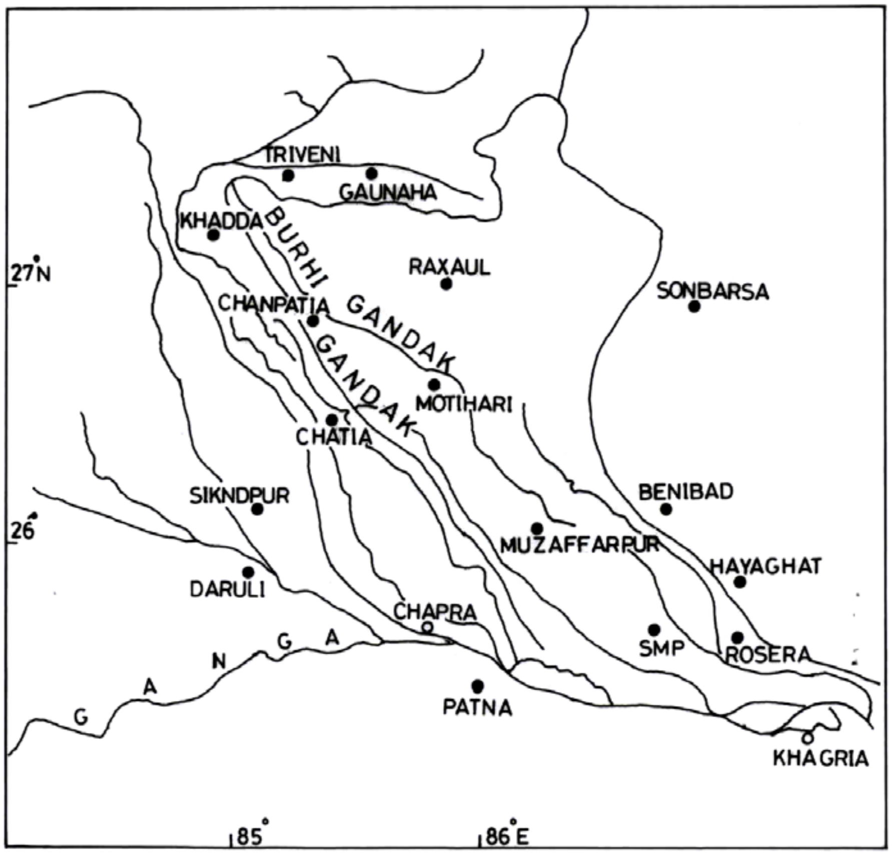

Fig. 1. Gandak-Burhi Gandak catchment area

25.4° N and 27.5° N and Longitude 83.5° E and 86.0° E in South and 83.5° E and 85.5° E in the North (Fig. 1). The Gandak rises in the glacial region at an altitude 7620 meters of the South Tibet - Nepal border approximately 29.3° N and 83.6° E and debauches in the plains of west Champaran district of Bihar at Triveni (CWC 1998). After traversing 380 km in Tibet - Nepal and 250 km in India, it falls at northern bank of the Ganges near Hajipur. The Burhi Gandak rises in the West Champaran district of Bihar at an altitude 300 m of the Someshwar hills and falls in the Ganges at Khagaria. The expanse of the watershed of both the river is located in east/west Champaran, Gopalganj, Muzaffarpur, Siwan, Saran, Samastipur and Khagaria districts of Bihar. The catchment area of river Gandak up to Hajipur is 7288 sq km and that of Burhi Gandak up to Khagaria is 10370 sq km.

3. Daily rainfall data of Triveni, Ramnagar, Gaunaha, Lalbegiaghat, Motihari, Ahirwalia, Chatia, Muzaffarpur, Samastipur, Darauli, Chapra, Khagaria, Chanpatia, Khadda, Sikandarpur, Rewaghat, Rosera, Gangpursiswan and Hazipur have been collected and prevailing synoptic situation based on 0300 UTC surface and 0000 UTC upper air chart from 1982-2003 have been extracted. Daily rainfall of the station Sonbarsa, Benibad and Hayaghat in the Bagmati/the Kamala catchments is also used for computation. The river catchment and location of the station is shown in Fig. 1.

4. In view of analyzing average rainfall under the influence of different synoptic systems, the following classifications are made to represent area and weather system from northwest Bay to east Uttar Pradesh.

Code	*Location*
1	North West Bay, Gangetic West Bengal
2	Chattishgarh, Jharkhand and Orissa
3	East U.P., Chattishgarh
4	Bihar and Sub-Himalayan West Bengal
5	Bihar and Gangetic West Bengal
6	Bihar

TABLE 1

Monthly synoptic situation, location, frequency and mean rainfall (mm) during flood season

Synoptic	June		July		August		September	
code	Frequency	Rainfall	Frequency	Rainfall	Frequency	Rainfall	Frequency	Rainfall
$S_{1,1}$	7	5	11	5	18	8	5	18
$S_{1,2}$	3	12	5	14	7	15	3	21
$S_{1,3}$	-	-	-	-	-	-	1	26
$S_{1,4}$	-	-	1	44	-	-	-	-
$S_{1,6}$	2	20	2	96	-	-	-	-
$S_{2,1}$	25	10	35	13	48	7	32	10
$S_{2,2}$	23	15	31	14	37	19	43	12
$S_{2,3}$	9	26	7	29	5	45	16	40
$S_{2,4}$	-	-	1	59	1	70	-	-
$S_{2,5}$	1	17	1	25	4	35	2	31
$S_{2,6}$	9	35	11	40	11	49	8	35
$S_{3,1}$	13	4	19	8	9	7	13	6
$S_{3,2}$	6	8	8	12	15	23	6	15
$S_{3,3}$	4	18	10	24	15	54	12	44
$S_{3,4}$	1	16	2	33	-	-	-	-
$S_{3,5}$	-	-	4	56	-	-	2	16
$S_{3,6}$	13	33	7	37	5	27	3	37
$S_{4,1}$	2	5	6	27	3	21	3	28
$S_{4,2}$	3	17	5	18	2	27	6	29
$S_{4,3}$	-	-	-	-	1	14	-	-
$S_{4,4}$	4	29	43	38	34	41	9	26
$S_{4,5}$	1	19	29	24	15	19	11	17
$S_{4,6}$	6	41	40	36	21	27	12	19

TABLE 2

Frequency and areal average precipitation range (1-10 / 11-25 mm)

Synoptic	June		July		August		September	
code	1-10	11-25	1-10	11-25	1-10	11-25	1-10	11-25
$S_{1,1}$	7	-	11	-	17	1	4	-
$S_{1,2}$	2	1	3	2	5	1	1	2
$S_{1,3}$	-	-	-	-	-	-	-	-
$S_{1,4}$	-	-	-	-	-	-	-	-
$S_{1,6}$	-	2	-	-	-	-	-	-
$S_{2,1}$	21	3	30	4	43	3	29	1
$S_{2,2}$	11	10	15	14	15	20	15	22
$S_{2,3}$	-	-	-	2	-	-	-	4
$S_{2,4}$	-	-	-	-	-	-	-	-
$S_{2,5}$	-	1	-	1	-	1	-	1
$S_{2,6}$	-	-	-	1	-	1	-	3
$S_{3,1}$	13	-	13	4	8	1	12	1
$S_{3,2}$	4	2	3	5	3	9	1	5
$S_{3,3}$	1	3	-	4	1	8	1	6
$S_{3,4}$	-	1	-	-	-	-	-	-
$S_{3,5}$	-	-	-	-	-	-	-	2
$S_{3,6}$	-	-	-	1	-	2	-	1
$S_{4,1}$	2	-	-	1	-	2	-	2
$S_{4,2}$	1	2	-	1	-	1	-	2
$S_{4,3}$	-	-	-	-	-	1	-	-
$S_{4,4}$	-	-	-	4	-	7	-	2
$S_{4,5}$	-	1	4	24	1	13	3	8
$S_{4,6}$	-	1	1	7	1	14	4	4

TABLE 3

Frequency and areal average precipitation range (26-50 / 51-100 mm)

Synoptic	June		July		August		September	
code	26-50	51-100	26-50	51-100	26-50	51-100	26-50	51-100
$S_{1,1}$	-	-	-	-	-	-	-	1
$S_{1,2}$	1	-	-	-	1	-	-	-
$S_{1,3}$	-	-	-	-	-	-	1	-
$S_{1,4}$	-	-	1	-	-	-	-	-
$S_{1,6}$	-	-	-	2	-	-	-	-
$S_{2,1}$	1	-	1	-	2	-	1	1
$S_{2,2}$	2	-	2	-	1	-	5	1
$S_{2,3}$	6	3	3	2	1	4	1	11
$S_{2,4}$	-	-	1	-	-	1	-	-
$S_{2,5}$	-	-	1	-	2	1	1	-
$S_{2,6}$	3	6	7	3	4	6	4	1
$S_{3,1}$	-	-	2	-	-	-	-	-
$S_{3,2}$	-	-	-	-	3	-	-	-
$S_{3,3}$	-	-	6	-	4	2	-	5
$S_{3,4}$	-	-	2	-	-	-	-	-
$S_{3,5}$	-	-	-	4	-	-	-	-
$S_{3,6}$	13	-	6	-	3	-	2	-
$S_{4,1}$	-	-	3	2	1	-	1	-
$S_{4,2}$	-	-	4	-	1	-	2	2
$S_{4,3}$	-	-	-	-	-	-	-	-
$S_{4,4}$	2	2	35	4	18	9	6	1
$S_{4,5}$	-	-	1	-	1	-	-	-
$S_{4,6}$	3	2	26	6	3	3	4	-

The synoptic weather systems are classified as follows.

Code	*Weather system*
S_1	Depression
S_2	Low pressure area
S_3	Upper air cyclonic circulation
S_4	Monsoon trough

$S_{2,6}$ denotes low/well marked low pressure system situated over Bihar and $S_{4,4}$ represents monsoon trough passes through Bihar and adjoining areas of sub-Himalayan west Bengal. Similarly rest weather codes signify its usual meaning.

From the daily rainfall data AAP is computed using arithmetic mean method. Frequency of depression, low pressure, monsoon trough, cyclonic circulation have been worked out from the daily weather inference based on 0300 and 1200 UTC weather charts. Monthly frequency of synoptic code has been made for the month of June, July, August and September with mean monthly rainfall which is shown in Table 1. Areal average of rainfall for each day has been calculated and the average rainfall in the range 1-10, 11-25, 26-50 and 51-100 mm over the catchments with reference to the frequency of synoptic code for the day has been worked out (Linsley *et al*. 1975) which is shown in Table 2 and Table 3.

5. Table 1 shows frequency of S_1, S_2, S_3 and S_4 in June to September with mean rainfall. $S_{2,1}$ occurred 25, 35, 48 and 32 times in June, July, August and September with mean rainfall 10, 13, 7 and 10 mm respectively. $S_{3,6}$ occurred 13, 7, 5 and 3 times during June, July, August and September with mean rainfall 33, 37, 27 and 37 mm respectively. Similarly $S_{4,4}$ occurred 4, 43, 34 and 9 times with mean rainfall 29, 38, 41 and 26 mm during June, July, August and September respectively. From the table one can visualized that the frequency of $S_{4,4}$, $S_{4,5}$ and $S_{4,6}$ are the highest with largest amount of rainfall. Frequency of $S_{1,1}$, $S_{1,2}$ and $S_{1,3}$ have also been examined and found that the frequency of depression is maximum in August while frequency of $S_{1,6}$ is found 2 times in June and July respectively. The AAP is the highest in July associated with $S_{1,6}$ because the depression moved north-northwestward initially in June and July and reached over Bihar. Frequency of $S_{3,3}$ is 10 and 15 times with mean rainfall 24 and 54 mm in July and August respectively.

5.1. Table 2 shows the frequency of synoptic weather code and AAP in the range 1-10 and 11-25 mm. Frequency of $S_{1,1}$ is 7, 11, 17 and 4 times in the range 1-10 in June, July, August and September. Frequency of depression in the range 11-25 is less than 1-10 mm because the system generally move to northwestwards from the Bay across Orissa and adjoining areas of Jharkhand. Similarly $S_{2,1}$ also moves along the same track. $S_{2,2}$ occurred 11, 15, 15 and 15 times in the range 1-10 mm and 10, 14, 20 and 22 times in the range 11-25 mm in the June, July, August and September respectively. Probability of occurrence of rainfall in the range 1-10 and 11-25 mm can be predicted ascertaining the movement of system. When low pressure area lay over Jharkhand and adjoining areas of Gangetic West Bengal and Bihar, AAP is found in the range 11-25 mm while the system lay over Jharkhand and adjoining areas of Orissa, AAP is found in the range 1-10 mm. The frequency of $S_{4,5}$ is found 24, 13 and 8 times in the range 11-25 mm in July, August and September respectively.

5.1.1. Table 3 shows the frequency of depression, low pressure and monsoon trough during June to September with AAP in the range of 26-50 and 51-100 mm. $S_{2,1}$ occurs 1, 1, 2 and 1 times in June, July, August and September respectively in the range of 26-50 mm. The frequency of $S_{1,6}$ is 2 in July and $S_{1,1}$ is 1 time in September in the range 51-100 mm. Similarly $S_{2,6}$ occurs 3, 7, 4 and 4 times in the range 26-50 mm in June, July, August and September respectively whereas the frequency has been found 6, 3, 6 and 1 times in the range 51-100 mm in June, July, August and September respectively. $S_{4,1}$ occurred 3, 1 and 1 times in the range 26-50 mm in July, August and September while 2 times in range 51-100 mm in July. $S_{4,4}$ occurred 2, 35, 18 and 6 times in time range 26-50 mm in June, July, August and September respectively and 4, 9 and 1 times in July, August and September respectively in the range 51-100 mm. Similarly $S_{4,6}$ occurred 3, 26, 3 and 4 times in the range 26-50 mm in June, July, August and September respectively and 2, 6 and 3 times in June, July and August in the range 51-100 mm. The frequency of $S_{4,4}$ is found the highest in the range of 26-50 and 51-100 mm during the flood season in comparison with S_1, S_2 and S_3 in July and August. During time monsoon onset and withdrawal phase $S_{2,3}$ and $S_{2,6}$ give average rainfall in the range 51-100 mm when associated cyclonic circulation extending up to Mid-Tropospheric Level (MTL). In July and August $S_{4,4}$ generally produces average rain depth in the range 26-50 mm when upper air trough extending up to 0.9 km above sea level. The system can produce rain in the range 51-100 mm when embedded cyclonic circulation extending up to MTL. $S_{1,6}$ gives rainfall in the range 51-100 mm in July.

6.1. $S_{1,6}$, $S_{2,6}$ and $S_{4,6}$ are most prominent system to produce average rainfall in the range 51-100 mm over the catchment with embedded cyclonic circulation extending up to MTL in July and August. When circulation extends in the lower level QPF can be issued in the range 26-50 mm.

6.2. $S_{4,4}$ associated with embedded tipper air trough extending up to 0.9 km above sea level. QPF in the range 26-50 mm can be issued and when the cyclonic circulation extending up to MTL, one can issued the QPF in the range of 51-100 mm in July and August.

6.3. $S_{2,3}$ with the circulation extending up to MTL, QPF in the range 51-100 mm can be issued and QPF can be issued in the range 26-50 mm if the circulation in the lower level.

6.4. $S_{3,3}$ with the circulation up to MTL, QPF in the range 26-50 mm can be issued in July and August and QPF can be issued in the range 11-25 mm if the circulation in lower level.

6.5. QPF the range of 11-25 mm can be issued when $S_{1,2}$, $S_{2,2}$ and $S_{3,2}$ move towards the catchment and QPF can be issued in the range 1-10 mm if the systems move away from the catchment.

6.6. Under the influence of $S_{1,1}$, $S_{2,1}$ and $S_{3,1}$ rainfall is generally isolated over the catchment therefore one can issue QPF in the range 1-10 mm invariably.

References

Abbi, S. D. S., Singh, Rajinder, Khanna, B. S. and Katyal, K. N., 1979, "Forecasting of semi-quantitative precipitation over Bhagirathi catchment by synoptic analogue method", *Vayu Mandal*, **9**, 1 & 2, 16-22.

Central Water Commission, 1998 "Appraisal report", Middle Ganga division-V, Vol-1.

Linsley, R. K., Kohler, Max., A. and Paulhus, J. L. H., 1975, "Applied hydrology", Tata Mcgraw Hill Co. Ltd., New Delhi.

Ram, L. C. and Pangasa, N. K., 2000, "Semi-quantitative precipitation forecasts for Ghaghra catchment by synoptic analogue method", *Mausam*, **51**, 1, 85-88.

Rao, D. V. L. N., 1973, "Quantitative precipitation forecasting", Sci. Rep. No. 187.

Singh, K. M., Prasad, M. C. and Prasad, G., 1995, "Semi-quantitative Precipitation forecasts for river Punpun by synoptic analogue Method", *Mausam*, **46**, 149-154.

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