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HYDROLOGICAL REGIONS OF BIHAR

BINAYA PANDEYA, and N. PRASAD, Varanasi

ABSTRACT: The study area Bihar (21° 55' N to 27° 31' N and 83° 20' E to 88° 17' E) covers parts of the Himalayan foot–hills, the Ganga plain and the Chhotanagpur plateau. Its climate is characterised by the seasonal change of temperature, humidity and rainfall. The soil moisture holding capacity in the state varies from 150 mm to 400 mm. This paper deals with the spatio–temporal variation of water balance components, i. e., Potential Evapotranspiration, Precipitation, Soil Moisture Storage and Moisture Deficiency and excess which have been computed by Thornthwaite's (1955) method for the 16 meteorological stations of Bihar based on the monthly normal data ave- rage of 1931–60 as well as on the basis of data for indiv idual years (1951–68). Representation of moistness and dryness of climate have also been introduced after the schemes of Kira, De–Martonne, Lang. Koppen and Thornthwaite. Finally, the hydrological regoins of Bihar have been delineated in association with the water blance components. Two main regions are distinguished (i) A region of no water surplus; (ii) A region in which both annual water surplus and annual water deficit occur.

The study area 'Bihar' containing part of two major structural divisions of India, The Peninsular block and the Ganga Plain, extends from 21° 55' to 27° 31' N and 83° 20' to 88° 17' E and embraces an area of 173876 km². The northern, eastern, southern south-western and western boundaries of Bihar touch Nepal, West Bengal, Orissa, Madhya Pradesh and Uttar Pradesh respe-ctively. The Ganga is the main artery of Bihar. Gandak, Burhi Gandak, Kosi, Sankh' South koel, Subarn Rekha etc. are the other major rivers of the state which find their outlet into the Bay of Bengal. About 26% of the cultivable area of the state is under irrigation. Forest covers about 17 per cent of the geographical area.

Climate – The climate of Bihar is chara-cterised by monsoon climate showing seasonal rhythm with respect to all the elements of weather. According to Koppen's (1936) classification, the study area lies under Humid Mesothermal (CWg) and Tropical Wet and Dry Climate (AWg). According to Thornthwaite's moisture indices, Bihar has been clssified into 3 moisture regions viz. (f) Moist Sub-Humid, (ii) Dry Sub–Humid and (iii) Semi-Arid, Rainfall, the most important climatic ele-ment, specially in the assessement of climatic water balance, varies from, over 1800 mm near the north-eastern corner of thes tate to less than 1200 mm in the western part of the state along the Ganga axis. The area of miuinm rainfall stretches over Gaya, Nawada, Nalanda, Patna and Bhoj-

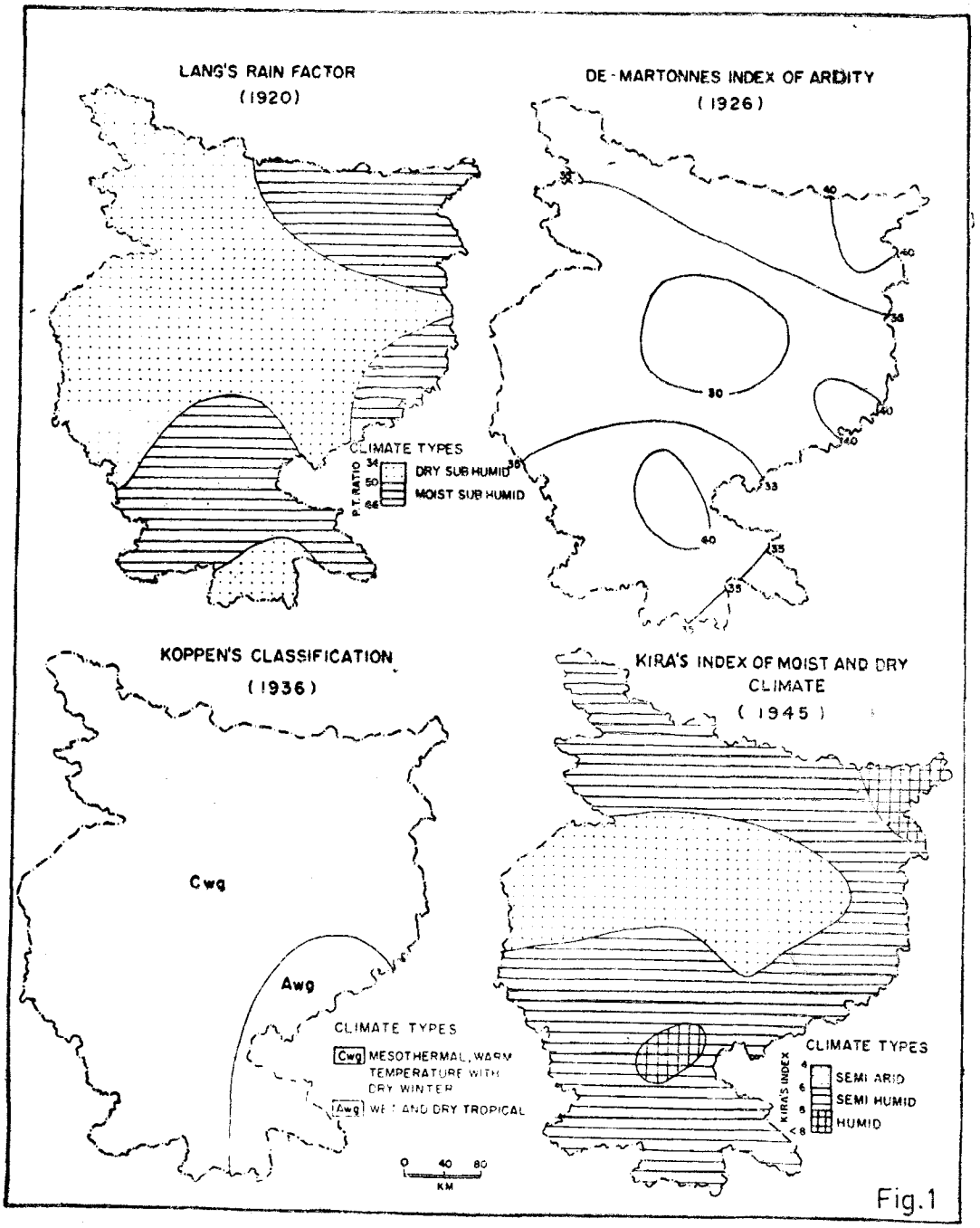


Fig.1

pur districts. The mean annual temperature throughout the state is more than 19° C and varies from 19.8° c at Ranchi to 26.1° C at Dehri-On-Son. Although the mean summer maximum touches 38° C and exceeds 42°C in the month of May during the spells of hot westerly wind 'Loo'.

Miost and Dry Climate

Representation of climate is divided into two main categories, viz., thermal regimes and water economy. In this paper, the latter has been emphasised. Representation of

moistness and dryness of an area has been introduced by Lang, Martonne, Koppen. Reichel, Emberger, Mayer, Prescott, Wang, Angstrom, Kira, Thornthwaite, of whom, the schemes of five selected scientists have been applied to the 16 comparatively old meteorological stations in Bihar and their distribution has been discussed and depicted in Fig. 1.

Demartonne's Index of Aridity

He applied slight modification in Lang's rain factor, in which he suggested to divide the annual precipitation (mm) by the mean annual temperature (°C) + 10. The index of aridity varies from 43.34 at Ranchi to 26.2 at Jamui. As this index of aridity does not come below 20 at any station, it clearly shows that arid condition does not prevail anywhere in this state (fig . 1).

Kira's Index of moist and Dry Climate

Although this method has not gained popularity in geographical literature, its application in this state gives a generalised but convincing result as illustrated in Fig. 1. The Kira's Index (1945) ranges from 8.01 at Ranchi (Humid) to 4 81 at Jamui (Semi-Arid). The plain area along the Ganga axis lies under the Semi-Arid type of Climate whereas the rest of the state falls under Humid type of climate (Fig. 1).

Lang's Rain Factor (1915)

The relationship of precipitation and temperature values is generally obtained by empirical equations the simplest of which is the Lang's Rain factor (1915). A number below 20 is the symbol of aridity. According to Lang's Rain factor the Ranchi district, major part of Singhbhum district except Chaibasa plain, Purnea district, part of Katihar and Saharsa and North Santhal Paragana come under moist sub-humid type and the rest of the state under Dry Sub-humid (Fig.1).

Koppen's Classification

Koppen's climatic types on a regional level are scanty. In the present study, mean annual precipitation (1931-60) and mean monthly temperature of 16 meteorological stations have been used for the classification. The details of the scheme are available in almost all the books on climatology. Two types of climate namely humid mesothermal (CWg) and tropical wet and dry climate (AWg) have been recognized in the state (Fig. 1).

AWg: Tropical rainy with character of tropical wet and dry can be seen in the south-eastern part of the state comprising districts of Singhbhum, Dhanbad, Part of Santhal Parafana and a small part Giridih and Hazaribagh districts.

CWg: Humid mesothermal type, having the character of warm temperature rainy with dry winter, stretches in the rest of the state. The mean monthly temperature of a coolest month is less than 18°C and precipi tation is mainly concentrated in summer months (June, July, August and September).

Thornthwaite's Moisture Index (1955)

On account of irregular distribution of rainfall through the year, a region may experience water deficiency in one season ands urplus in another and therefore Thornthwaite's Moisture Index (1955) is

$$Im = \frac{100\ (S - D)}{P\ E}$$

where Im = Moisture Index
S = Annual water surplus
D = Actual water deficit
PE = Annual water nced (Potentiae Evapotranspiration)

It is thus a ratio and therefore not dimensional.

Moisture Indices of Bihar range from + 11.6 at Ranchi to-38.55 at Jamui. It depicts that climatic type in the state ranges from semi arid to moist sub-humid type of climate According to Thornthwaite's scheme, Bihar has been classified into three moisture regionse g. (i) moist sub humid, (ii) dry sub-humid,(iii) semi-arid. Moist sub-humid climate exists in North eastern Purnea district, over the Ranchi plateau and in a small tract in the Santhal Paragana district around Dumka, whereas semi-arid climate appears along the Ganga axis in the Bihar plain. Rest of the state experiences dry sub-humid type of

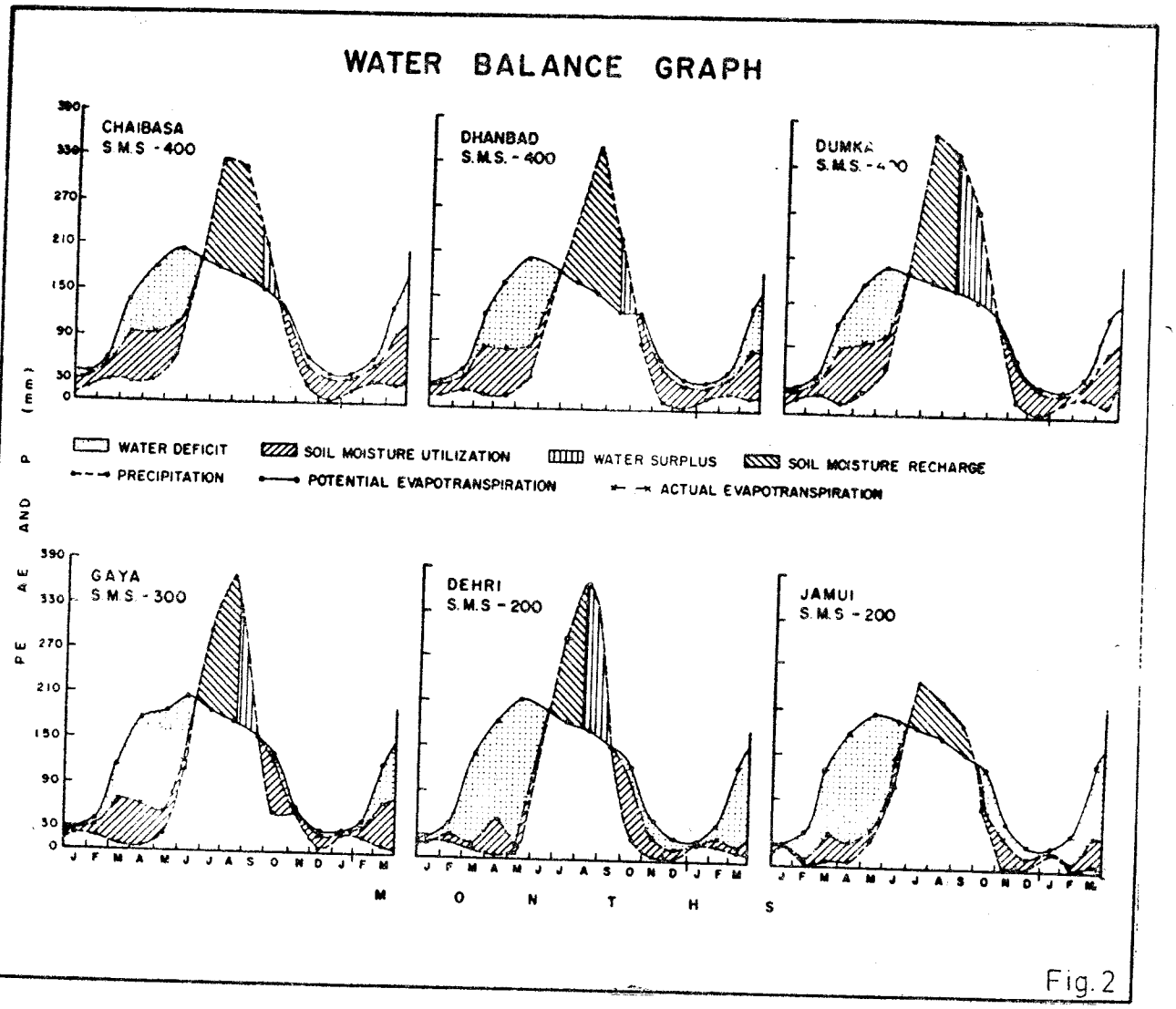


Fig. 2

climate.

Distribution of Water Balance Component in Bihar

The wetness and dryness of a climate cannot vividly reveal the situation of water in an area during any period of time and hence, for a precise understanding of water balance at any station, the precipitation received should be compared with the total water need for the period. The march of precipitation rarely coincides exactly with changing demands of the atmosphere for water, and consequently, water need in one season may be more than precipitation, whereas the former may be much less than the latter in another season. In the present study, water balance refers to the balance between the income of water from precipitation and the outflow of water by evapotranspiration, surface run-off and infiltration. The water balance equation used in this study is after Thornthwaite i. e., precipitation = PE - D + S $\pm$ Δ St. The water baalnce components have been computed for the 16 meteorological stations of Bihar based on the normal data (1930-60) and

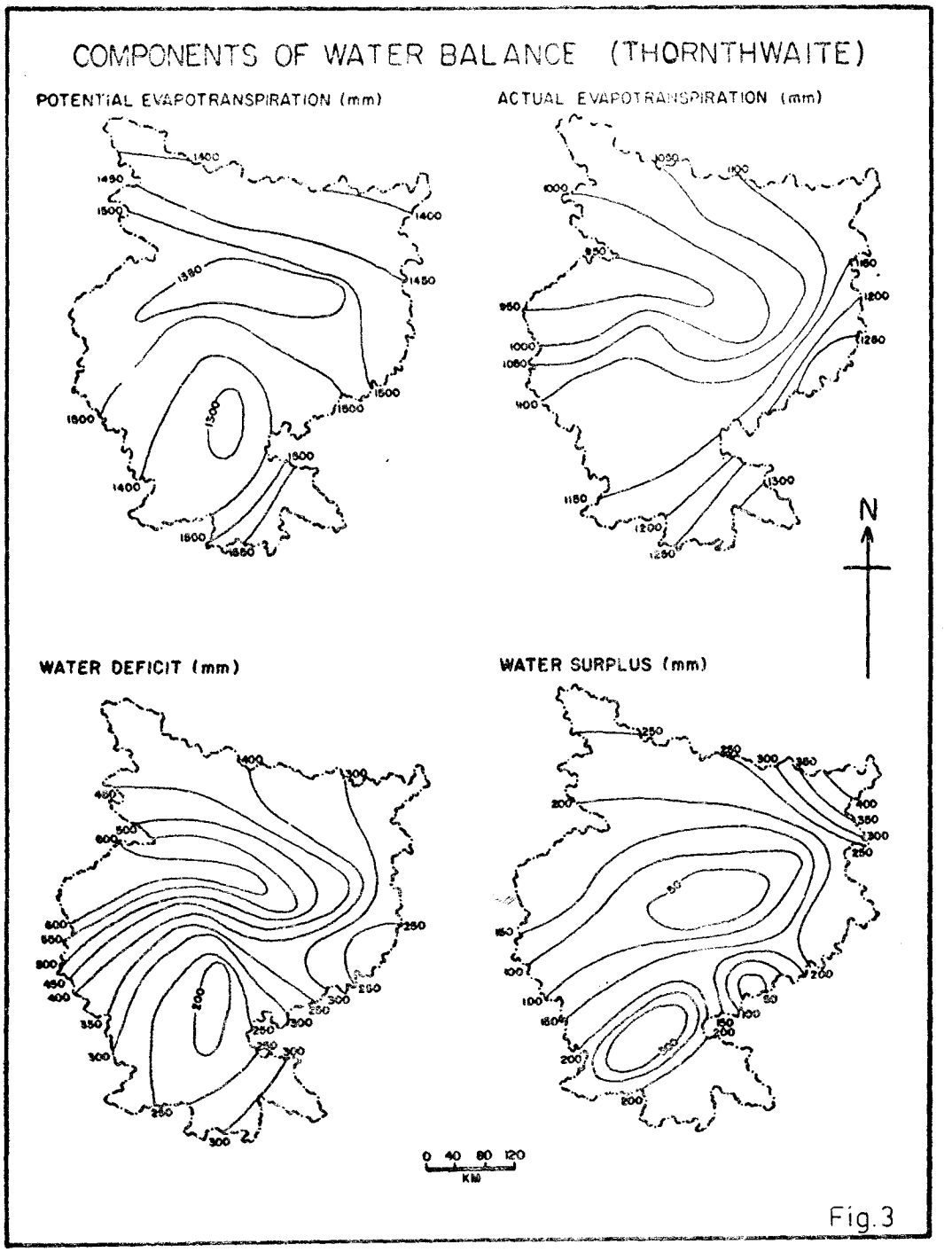


Fig.3

that for the individual years (1951-1968).

It can be observed from Fig. 2 that the water balance graph shows similar characteristics almost at every station except at Jamui where the soil moisture does not reach even the soil's moisture holding capacity (200 mm) throughout the year due to the deficiency of rain. Most of the

stations exhibit the monsoon period (June to September), as period of soil moisture recharge followed by water surplus. The rest of the year is represented progressively by a period of soil moisture utilization and soil moisture deficit. Fig. 3 shows that actual evapotranspiration is higher over the plateau region than the plain region. Plain region is hotter than the plateau region but adequate water is not available for evapotranspiration outside the monsoon months (June to September). The AE varies from 1279 mm at Duinka to 956 mm at Dehri. The AE amount is generally maximum in June at the stations of the plain region but maximum in July at the stations of the plateau region.

It is obvious from Fig. 3 that higher amount of water deficiency occurs over the Gaya, and Jamui regions (500 mm to 600 mm) and lower deficiency over the Ranchi plateau and in the Himalayan foot hill region. The lowest amount 170 mm occurs at Ranchi and highest 598 mm at Jamui. The major (about 90 per cent) of annual deficiency occurs in the dry months of March, April and May.

The annual water need (PE) is higher along the Ganga axis (1661 mm at Gaya) and lower over the Ranchi plateau (1304 mmat Ranchi) and in the Himalayan foothill region (Fig. 3). The climate of the Himalayan foothill region is cooler because of its proximity to the Himalaya, higher latitude and saturated soil because of high water table. The water need is maximum during the three conventional dry summer months (March to May) representing 35 to 40 percent of the annual total.

Figure three shows the annual water surplus of Bihar. It is largest in the north-eastern region (361 mm at Purnea) and in the Himalayan foothill region owing to moderate temperature and higher rainfall. The area of lowest water surplus occurs in the central part of the state, being zero at Jamui. Excepting Jamui it varies from 47 mm at Dhanbad to 361 mm at Purnea and it occurs only in the late monsoon months of August and September.

A sample study of 18 individual years for the period 1951-68 of the 16 selected meteorological stations of Bihar has been made, because any study carried on the basis of long term mean data may fail to present the water problem of an area in true perspective as it is likely to vary from year to year.

It is evident that all the water balance components exhibit great variation from year to year except the Potential Evapotranspiration. Although temperature and precipitation vary but it is the precipitation which varies most widely in space and time and is the most important climatic factor in influencing the water balance components. Monthly and annual distributi on of solar energy, however, shows very little variations. If we compare the water surplus and deficit obtained by averaging the results of the 18 individuals years, we find that the values thus obtained are larger in comparison to that based on the mean temperature and precipitaion of 30 year period 1931-60.

The actual evapotranspiration value computed on the basis of the mean monthly data (1913-60) for each is greater than the AE value computed by averaging those of the 18 individual years (1951-68). The AE value based on the mean data varies from 1288 mm at Jamshedpur to 953 mm at Jamui whereas average AE value (1951-68) ranges from 1162 mm at Dumka to 857 mm at Patna (Table I).

Variability in Water Surplus and Water Deficit

Water balance components vary greatly in time and space. Hence, the importance of this variation of water deficit and water surplus in time is of paramount importance in agriculture, industry as well as as in domestic uses especially since PE is high throughout the year. More than 95% of the total water surplus is confined in the monsoon months and water deficit occurs in the

Table I Comparison of Mean and Yearly Computations of Water Budget (Data 51-68)

Station	Annual PE (mm)		Annual AE (mm)		Annual water deficiency (mm)		Annual water surplus (mm)	
	Means	Average of 18 individual years	Means	Average of 18 individuals years	Means	Average of 18 individual years	Means	Average of 18 individual years
Motiharl	1418	1415	1007	899	411	515	209	310
Darbhanga	1463	1474	1054	935	409	539	204	310
Purnea	1419	1418	1126	1001	293 +	417	361	385
Patna	1545	1541	970	857	575	684	140	167
Dehri	1549	1540	956	865	593	675	186	155
Gaya	1497	1501	1089	932	408	568	55	70
Jamui	1551	1518	953	939	598	579	8	138
Bhagalpur	1555	1535	1046	919	509	617	88	182
Sabauur	1454	1459	1051	930	403	529	85	183
Daltonganl	1497	1468	1136	960	361 +	509	95	63
Hazaribagh	1313	1313	1115	1019	198 +	293	202	215
Ranchi	1310	1330	1140	1061	170 +	274	322	308
Dumka	1516	1525	1279	1162	237 +	363	225	162
Dhanbad	1476	1515	1151	1069	325	444	47	150
Jamshedpur	1587	1563	1288	1151	299 +	412	103	161
Chaibasa	1545	1546	1263	1109	282 +	436	51	63

Table II Variability in Water Balance Components

Station	Annual rainfall Variability (%)	Water Surplus			Water Deficit		
		Average of 18 individual years $\overline{X}$ in cm	Standard deviation = n-1	Variability (%)= $\frac{n-1 \times 100}{\overline{X}}$	Average of 18 individual years $\overline{X}$ in cm	Standard deviation = n-1	Variability (%) = $\frac{n-1}{\overline{X}} \times 100$
Motihari	21· 4	31·0	17·4	56·2	51·5	127·9	24·8
Darbhanga	21·14	22·7	15.6	68·9	53·9	117·6	21·8
Purnea	21·34	38·5	29·1	75·5	41·7	96·6	23·2
Patna	27·84	16·7	19·8	118·6	68·4	113·9	16 7
Debri	23·95	15·5	19·1	122·7	67·5	84·3	12·5
Gaya	21·72	7·0	97·6	139·5	56·8	148·8	26·2
Jamui	19·91	13·8	13·7	99·2	57·9	185·2	21·9
Bhagalpur	24·59	18·2	18·3	100·3	61·7	146·7	23·78
Sabauur	20·51	18·3	16·0	87·8	52·9	134·8	25·5
Daltonganj	21·18	6·3	99·9	158·6	50·9	152·5	29·9
Hazaribagh	18·51	21.5	24.9	115.9	29.9	90.1	80.7
Ranchi	16·21	30·8	24·1	78·1	27·4	66·1	24·1
Dumka	14·51	16.2	20·3	125.4	36·3	81·8	22·5
Dhanbad	12·85	15.0	21·7	144·5	44·4	139·3	31·4
Jamshedpur	13·85	16·1	17·8	110·4	41·2	98·3	23·9
Chaibasa	18·89	6·3	13·1	207·8	43·6	117·3	26·9

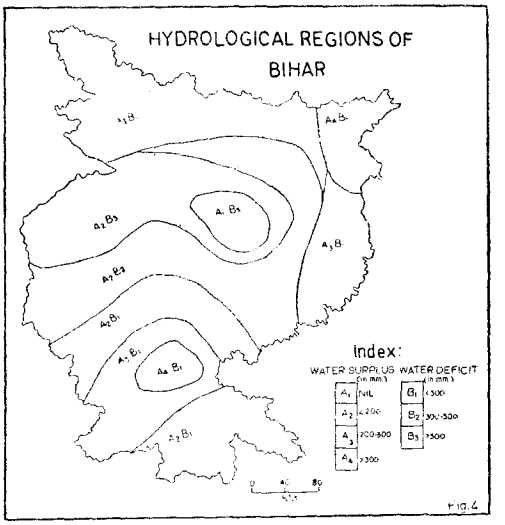
remaining months of the year but their extent based on the mean data is seldom reliable as floods and drougbts are unpredictable phenomena in the state. Variability of water balance components is the percentage by which its amount in any particular year deviates positively or negatively from their average amount.

Table II shows that variability in water surplus is greater than the variability in water deficit at each station. Hence the occurrence of water surplus is less reliable than the occurrence of water deficit. The variability in water surplus is highest at Chaibasa (207 per cent) and lowest at Motihari (56 per cent) The variability in water deficit ranges from 12.5 per cent at Dehri to 31. 4 per cent at Dhanbad. Variability in water surplus is higher in the plain region including the foot zone of the plateau region and lower in the Himalayan foot-hill zone and over the Ranchi plateau of the Chhotanagpur region. Consequently proper water management and arrangement for its distribution in the state appears to be an urgent task for integrated development of the state.

Hydrological Regions on the Basis of Water Balance Components

A hydrological region is a concept similar to that of climatic region. Just as a climatic region is classified on the basis of similarities of climatic conditions taking into account the different climatic elements, so is a hydrological region on the basis of similarities in hydrological conditions. Since climate is an abstract concept, unlike weather or the meteorological phenomena, different parameters can be selected and different systems of classification will result. As a criterion for delimiting a hydrological region, the hydrological condition is more realistic than the climatic one. Amounts of water surplus and water deficit and their spatio-temporal variations are the controlling factors for vegetation as well as for human comfort and activities. Hence, these two main water balance components have been taken for the delimitation of hydrological regions of Bihar.

Combining the maps of water balance components, we can delimit the hydrological regions of Bihar. such an attempt has been made in fig. (4) In which 7 regions have been recognised.



1. A_1B_3 – region mn which there is not annual water surplus but water deficit is more than 500 mm. It occupies the central part of the state around Jamui.
2. A_2B_3 – Region in which annual water surplus is less than 200 mm but water deficit is more than 500 mm It is found in the western part of the state along the Ganga axis.
3. $A_2'B_2$ – Region in which annual water surplus is less than 200 mm but water deficit lies between 300 and 500 mm. It occurs in a strip trending E-W and passing through Daltonganj, Gaya and Dhanbad.
4. A_2B_1 – Region of less than 200 mm water surplus and less than 300 mm water deficit. It occurs in the Singhbhum district and in a strip extending E-W comprising the Hazaribagh Plateau and the 'pat' region of the Palamau district.
5. A_3B_2 – Region in which water surplus ranges between 200 and 300 mm and

water deficit between 300 and 500 mm. It coincides with the Himalayan foot-hill region.

6. A_3B_1 – Region of less than 300 mm annual water surplus and less than 300 mm annual water deficit occurs along the lower slopes of the Ranchi Plateau, its foot zone and in the eastern part of the state.
7. A_4B_1 – Region with more than 300 mm anuual water surplus but less than 300 mm water deficit is located over the Rahchi plateau and in the north eastern part of Purnea district.

Conclusion

It is concluded from the foregoing discussions that in the state, the plain region along the Ganga avis experiences an acute shortage of water throughout the year except the monsoon months (July to September) in which about 80% of thetotal annual rainfall is obtained. Precipitation varies most widely in the state and hence the state demand proper water management fo- the optimum use of water for amelioration in agricultural, industrial and domestic need of water.

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Addresses of the authors

Binaya Pandeya, Room No. 30, Aiyar Hostel, B. H. U., Varanasi—221005

N. Prasad, Reader, Department of Geography, B. H. U., Varanasi—221005