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RAINFALL CHARACTERISTICS IN NORTH-EAST INDIA

NORTH-EASTERN REGIONAL CENTRE
NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE-247667 (U.P.)

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PREFACE

A most important factor in understanding hydrology of a region is rainfall. Rainfall plays a vital role in hydrology, because all hydrological processes are directly related to rainfall. Rainfall is a unique phenomena varying in space and time due to several factors like topography, nature of weather system, geography, aerosol content in the atmopshere and dropsize distribution in clouds etc. The level of rainfall varies from place to place depending on local topography and is affected by wind fluctuation, orientation of hill slope with respect to wind flow etc.

Study of characteristics of rainfall in north-east india is very interesting because rainfall in north-east India is quite different than the other parts of the country. Rich forest and other topographical features directly affect the rainfall in different meteorological sub-divisions of the region.

The state of Assam experiences flood every year in monsoon season due to the flood water of the river Brahmaputra. The annual rainfall in the Brahmaputra valley is one of the sources of water in the river. Out of this seasonal rainfall has the major contribution to flood water in the region. Thus the study of seasonal rainfall in the Brahmaputra valley is important for studying the flood problems in the valley.

The technical note on 'characteristics of rainfall in north-east India' has been prepared by the north-eastern regional centre of National Institute of Hydrology in Guwahati. The report gives the information of annual/seasonal rainfall in different meteorological sub-divisions of N-E India which covers the seven states (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram and Tripura) including sub-Himalayan West Bengal & Sikkim. The annual/seasonal rainfall in Brahmaputra catchment in Assam and in Kulsi basin are also described in the report.

The scientific staff of the north-eastern regional centre of NIH in Guwahati contacted relevant state/central Govt. offices for collecting the required data and related informations. The report has been prepared by Umesh Kumar Singh, RA under guidance of Dr. K.K.S. Bhatia, Scientist 'F'.

(SATISH CHANDRA)

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ABSTRACT

Rainfall plays a vital role in hydrology, because all hydrological processes are directly related to rainfall. To study the hydrological problems of a region, a hydrologist focuses his attention on the study of characteristics of rainfall in the region as it is the basic input to the system. Rainfall is a unique phenomena varying in space and time due to several factors like topography, nature of weather system, geography, aerosol content in the atmosphere and dropsize distribution in clouds etc. The level of rainfall varies from place to place depending on local topography and is affected by wind fluctuation, orientation of hill lslope with respect to wind flow etc.

In this technical note characteristics of rainfall have been discussed in four meteorological sub-divisions which cover the regions of seven states of North East India and the regions of Sub-Himalayan West-Bengal and Sikkim. Studies of characteristics of rainfall in Brahmaputra valley and Kulsi Basin are also included in this technical note, because the catchments of Brahmaputra valley and Kulsi basin are hydrologically important in North-East India.

The rainfall data and other informations have been collected from various journals/reports and the characteristics of rainfall have been discussed over the regions (as mentioned above) of North-East India.

1.0 INTRODUCTION

Study of characteristics of rainfall in North-east India is very interesting because rainfall in North-East India is quite different than the other parts of the country. Rich forest and other topographical features directly affect the rainfall in the different meteorological sub-divisions of the region.

North-East region is a land which has been blessed with a large Brahmaputra river and its tributaries, the water of which can be put to many uses such as drinking, other domestic needs, agriculture, industrial uses, nevigation, recreation, power generation etc. The annual rainfall in the Brahmaputra Valley is one of the sources of water in the Brahmaputra river. Out of this, seasonal rainfall has the major contribution to flood water in the region. Flood in the region is a major hydrological problem. Thus the study of seasonal rainfall in the region has the great importance to the study of flood problem of the region. The river Kulsi is one of the main tributaries of Brahmaputra river. Basin area of river Kulsi is hydrologically important. Thus the study of characteristics of rainfall in the Kulsi basin is also important for hydrological point of view.

1.1 Physiography of North-East India

The N-E India comprising seven states (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram and Tripura) covers an area of 255,036 km2 and lies between 22^{o} N and 29^{o} 5'N latitudes and 89^{o}70'E and 97^{o}30'E longitudes. Physiographically, N-E India is divided in three major parts, viz Plateaus, Hills and Mountains and Plains.

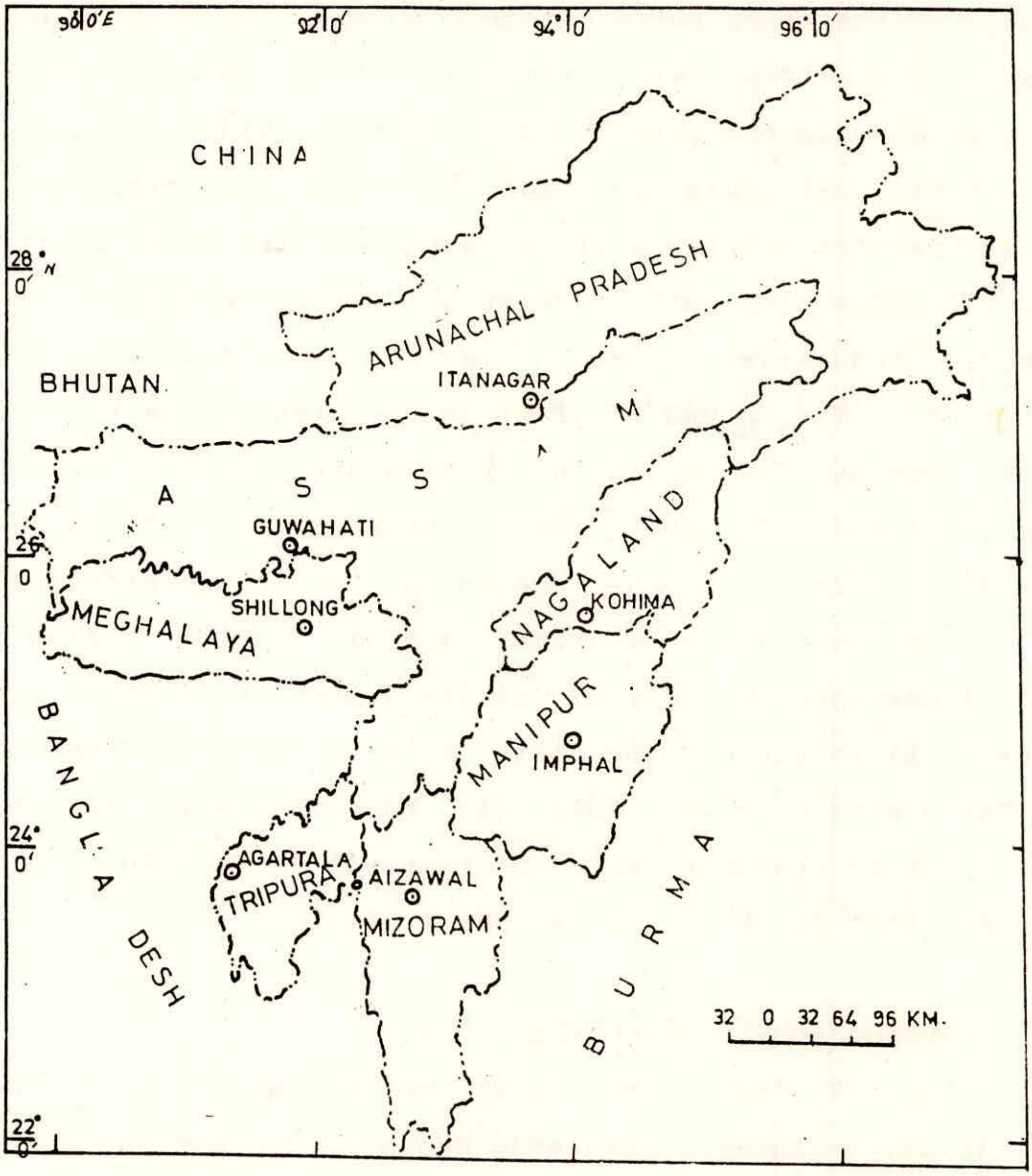

FIG. 1. MAP SHOWING STATES OF N-E INDIA
[Source: Jr. of N-E India Geographical Society, Vol. 18, No. 1&2]

The Plateaus:

In N-E India, Meghalaya and Karbi are the two important plateaus. The Meghalaya-Karbi plateaus covering an area of 32,821 km2 (12 percent), although denuded, still retain a hilly character unlike the Deccan. These can be compared to the eastern or western ghats rather than the central Deccan plateau. The Meghalaya plateau rises abruptly for about 1000 m above the Sylhet plain due to an upthrust and retains a uniform outline towards south except in places where it is dissected by south flowing streams through gorges and waterfalls. From this margin the plateau rises slowly north-ward to the central part where there are distinct ranges of east-west alignment like the Tura-Kylas range and Shillong range. In Garo hills, former attains a maximum height of 1412 m at Nokrek Peak while in the east Khasi hills, the latter reaches up to 1961 m at Shillong peak. The Meghalaya plateau then begins to lose height, but through successive ranges thrown out in all directions, still retaining hilly character which is particularly prominent to the north of the middle part i.e. the Khasi hills. The Western and eastern ends, i.e. Garo and Jaintia hills are more dissected and denuded and merge with the Brahmaputra plain through gentle gradients and isolated hills and hillocks.

The Karbi hills, which projected north ward up to the bank of the Brahmaputra causing constriction to the valley, lies to the east of the Meghalaya plateau. It is almost separated from Meghalaya by the degradation of the Kapili and its headstreams like Diyung, Lumding, Lankajan, etc. On the south-eastern side it is separated from the Nagaland hills by the Dhansiri and its head streams. Moreover, its southern part is denuded by the Jamuna. It is only in the heart land that this plateau rises high up to 1359 m at Chenghehison peak and 1361 m at Dambukso. The Karbi plateau has assumed a roundish shape, giving out numerous streams radially to Dhansiri, Kalang and Kopili that surround it. These streams often extend finger-like plain embayments into the plateau, which otherwise descends to the plain through terraces. Such terraces made of older alluvium and residual soils support rich tea gardens in Gola ghat and Nagaon regions.

While the northern, western and eastern margins of the Meghalaya plateau proper are dissected and denuded, its southern faulted margin is precipitions and high. The out flowing streams cut funnel shaped gorges across the margin through which rush in and climb up moisture laden south-west monsoon winds, causing a heavy rainfall.

There are three important reasons as to why the Meghalaya-Karbi plateau still retain largely hilly character. Firstly, the southern part of the Meghalaya plateau was uplifted as late in the tertiary period rejuvenating the earlier cycle of erosion. Secondly, the plateaus are under the regime of heavy rainfall feeding the streams and rivers perennially. Thus the slopes and stream beds are perpetually eroded ever maintaining a hill and gorge topography. Thirdly, the plateaus always have thick vegetable covering which effectively retard the denudation process.

The Hills and Mountains:

The hills and mountains which cover about 150,000 Km^2 account for about 60 percent of the total area, of north-east India. This physiographic region can be divided into two main units, viz. the Arunachal Himalaya from Orkhala range along Bhutan Arunachal border to Siang-Dihang river, and the eastern hills comprising Dibang-Lohit-Patkai-Naga-Manipur-Mizo ranges.

The Arunachal Himalayan part again has two distinct physiographic sub-divisions, viz. the lesser Himalayan Zone and the great Himalayan Zone. The lesser Himalayan Zone rises from a mere 300m along the margin of the Brahmaputra Valley to about 5000 m through a confused labyrinth of hills and ranges intervened by deep gorges. This Zone receives heavy rainfall and hence clothed with a thick vegetation. There are hardly any open valley. The streams normally run in the east-west direction to open ultimately to occasional south-flowing master streams. Two important, although restricted, tablelands are Bomidila in west Kameng and Apatani plateau in lower subansiri. These are of immense human significance. As one goes to the north, one begins to find periglacial features made of fluvioglacial deposits with thick layers of transported boulders, rocks and soils.

Beyond the transitional peri-glacial region with increasing altitude, there appears the Great Himalayan region devoid of significant vegetal cover and roundish topographic features. Rocky surface, alpine vegetation and snow-capped high peaks dominate the physical landscape of this zone. The great Himalayan range, running along the Indo-Chinese border has an average height of 6500 m in Tawang, west Kameng and lower Subansiri districts. But its altitude decreases north eastward in upper Subansiri and west Siang Districts to an average of 5200 m. The range regains altitudes only on entering Tibet and culminates at Namcha Barwa (7755 m). In Arunachal, the highest Himalayan peak is Kangto (7089 m). The Great Himalayan region has predominantly glacial physiography with rounded outline and thick layers of unassorted fluvio-glacial transported deposits. The cold and wind swept surfaces hardly have any tall vegetation.

The eastern hills may be said to start from the Dibang-Lohit hill mass between the Siang and Burhi Dihing. This hill mass can be called mountain knot sending out the Himalayas to the west, the Namkin mountains to the east and the Patkai to the south. The hills in this part are relatively low ranging from 1000 m towards the Brahmaputra Valley to 5000 m towards China.

The Patkai reaches its highest altitude at Saramati Peak (3826 m) in Nagaland. To the west of patkai there is the high Barail range stretching from Tuensang to the south-west to North Cachar hills district across Nagaland. The average height of this range is 2000 m in Nagaland and it reaches its highest at Japvo (3016 m).

The south-eastern physiographic region, comprising a part of the district of Tuensang and whole of Phek, lies between the Barail and Patkai ranges. This intermontane hill tract has an average elevation of more than 1400 m while its eastern part falls within the catchment area of Chindwin, the western part is washed by the heads-streams of the Barak. This physiographic sub-region presents an impression of a series of rounded hills and flat-bottomed valleys. The hills of Nagaland including the Barail range continue westward to cover the North Cachar hills district. The Barail range retains its height even in this part with an average altitude above 1600 m and reaching a maximum of 1953 m in a peak east of Mahadeo peak to the east of Haflong. The Barail range divides north Cacher Hills into two parts: a northern part falling under the Brahmaputra Catchment basin and a southern part falling under the Barak basin. The hills of north Cachar rise from about 500 m in the area lying to the south of the Karbi plateau to the central Barail range and then fall in height southward to the Barak Valley. The chain of hills cover, Manipur Mizoram, and Tripura and after tripura hills continue to the chittangong hill tracts of Bangladesh.

The Plains:

There are four important plains in North-East India, viz. the Brahmaputra plain (56480 km^2), the Barak plain (6962 km^2), the Manipur Basin (1843 km^2) and the Tripura piedmont plain (3500 km^2).

The Brahmaputra plain is narrow and elongated with a length of about 660 km and an average width of about 70 km. The plain is at its widest in the upper part where it is about 90 km. and narrow west in the middle part where the Karbi plateau projects northward to the bank of the Brahmaputra, constricting the plain to a mere 50 km. width. To the west of it, the plain widens, but becomes narrow near Guwahati and opens up again as the Meghalayaplateau recedes south ward. While the northern margin of the plains is fairly regular, the southern margin is not so, as there are plain embayments, created by the larger tributaries entering in to the plateaus and hills.

The Barak plain is the head ware piedmont part of the Barak Surma Kushiyara plain which lies largely in Bangladesh. It's area within North-East India is about 6962 sq.km. The plain slopes down gently to the west and its middle part is the lowest, through which flows the river Barak, sluggishly in an extremely meandering course leaving a series of ox-bow lakes and swamps.

The Manipur basin or plain is perhaps of lacustrine origin like Kashmir valley. The topography of the plain is affected by two important features: there are, firstly, some gravel patches occurring in small strips by the side of some streams. Such gravel patches may attain a height of about 30 m above the surrounding plain. The second feature is the presence of isolated hills like ching-meirong, Langthaban, waithou, Langathel, etc. in the plain. They are aligned north-south and can be found even in the Laktak Lake region standing as islands.

The Tripura plain is again a piedmont plain, representing a part of the margin of the Bangladesh plain. The tertiary ranges aligned north-south in Mizoram extend parallely to Tripura. But they are lower and situated progressively wider apart. Towards the western part of Tripura there are only low isolated hillocks worn down by the tributaries like Gomti, which have created this piedmont plain. The area of the plain within north-east India is about 3500 sq.km. and contain both erosional and depositional features with worn-down hillocks, piedmont terraces and thick alluvial deposits covering the structural synclines.

1.2 Climate of N-E India

The presence of the great mountain mass formed by the Himalayas and its spurs on the north along Arunachal Pradesh and of the Ocean on the south are the two major influences operating on the climate of N-E India. The climate of N-E India is different than the rest part of the country due to presence of rich forests and mountains-hills ranges along the three boundary sides of the region. These mountains-hills ranges are Himalayan ranges from north boundary side along Arunachal Pradesh, Patkai range of hills from east side running along Indo-Burmese boarder and Garo Khasi-Jayantia range of hills from south side along Assam Meghalaya. In the region rainfall activity increases from the month of March and stays up to last week of Sept. or first week of October. Maximum rainfall is observed between the month of June and September.

In N-E India maximum rainfall is observed due to orographic effect. Convective type of rainfall due to tunder clouds is also observed in the region of N-E India.

The annual average humidity in the plain area of the region is 72% ranging from monthly average of 70% in the month of March and 85% in the month of August.

1.2.1 Different seasons over the region of N-E India

Barthakur, M. in 1986 (Ref. No.3) has discussed the weather and climate of N-E India. He has described the various seasons over the region of N-E India as summarised below:

Winter Season:

The months of December, January and February constitute the Winter season. The season is not homogeneous for all parts of the north-east. During this season the weather is controlled by the sub-tropical jet stream and consequent development of central Asiatic high pressure centres, and the high pressure centres over northern Burma. These high pressure centres extend their outer tongue beyond hills, thereby lowering the diurnal temperature below freezing point over the higher reaches of the mountains. Over the lower slopes fair weather prevails occasionally associated with fogs and haze. In the Brahmaputra plain. parts of Meghalaya, Manipur valley, Barak valley and in parts of Tripura, day temperature rises. Occasionally thermal lows are locally developed which disturb the fair weather. During the winter months up to a height of 2 to 3 kms above m.s.l. the surface wind are north-easterly; beyond this the westerlies prevail. Due to wind shear at the junction of surface winds and westerlies, and at times when the pulses of western disturbances are carried under the impact of the jet stream, the weather becomes cloudy and rainy which may continue for a couple of days. Such deterioration increases the severity of cold especially over the high lands. The easterly winds are of local origin and are identified as mountain wind. Fair weather days are marked by mountain and valley winds over the entire north-east which reduces the diurnal range of temperature. December and January are the driest months and January is the coldest month for all the states. Normally Manipur remains absolutely dry in winter where as Arunachal Pradesh receives about 50 mm of rainfall. Due to low rainfall in winter, floods are not seen in the region. Except in Mizo hills, other hilly areas having an altitude of more than 1216 m altitude, the average temperature for these months remain below freezing point where as over the rest of the areas the temperature ranges between $8^{o}C$ to $15^{o}C$. One of the notable features of winter weather is the wide spread fogs in the morning hours over the low-lying areas and evening fogs over the hills. Due to mountain winds the fogs are usually brought down to the lower regions in the morning hours. On the south bank of the Brahmaputra, dense fogs remain for long duration over the low-lying areas, winter season is endurable and pleasant.

Pre-Monsoon season:

The months of March, April and May constitute the pre-monsoon season of N-E India. In this season most of the rainfall over the region is due to thunderstorm activities. From the month of March, the land surface is steadily heated and the temp. rises.

Local depressions are formed over the Brahmaputra plain where strong convection develops, especially in the afternoon and casually stormy weather follows. In the lower Brahmaputra valley strong north-east wind rises dust from the dry river banks. Besides the continued influence of the western disturbances, not only brings rain but also reduces the shooting temperature. Ice over the lofty northern and eastern hills melts and this melting ice supplies moisture and potential energy for development of thunderstorms. With the migration of the depression over Bay of Bengal and incursion of the air masses over the entire region, the frequency of storms increases. The nor' westers locally called 'Bordoichilla' start during this period. The nor'westers move to the north-east by the 2nd week of April and by the first week of May it takes western movement. On both the cases thunder showers casually associated with hails occur over the plains and the foot hills of the entire region. During this period, dry sunny warm days are occasionally interrupted by cloudy and stormy weather. Rainfall ranges between 25 cm and 40 cm and the temperature ranges between 19°C to 26°C. In this season rainfall increases the water levels of the rivers. Major floods are not uncommon in this season especially towards the later half of the season.

Monsoon Season:

June to September months constitute the monsoon season. This is the season which is more prone for devasting floods over the region as major rainfall over the region takes place during the season with the onset of monsoon in early June, heavy rainfall occurs and the rising temperature is considerably arrested. Wide spread low clouds and high humidity maintains uniform temperature over uniform terrains. Over the plain average temperature ranges between 20° C and 29°C. Rainfall varies according to the orographic situations. On the windward sides of the hills, the rainfall is heavier than on the leeward slopes. The average rainfall during monsoon season in different states is as follows: Arunachal Pradesh 185 cm, Assam and Meghalaya 180 cm, Mizoram and Tripura 130 cm, Nagaland and Manipur 170 cm. The most conspicusous characteristics of monsoon weather in N-E India is the association of thunder storms. From June to September the frequency of thunder is highest (119 days) over the southern bank of the Brahmaputra and lowest over the Arunachal Pradesh (34 days). Over Nagaland, Manipur and Tripura, the thunder days vary between 40 to 100 days.

Important synoptic features responsible for heavy precipitation during monsoon season are monsoon trough lying close to foot-hills of Himalayas, low pressure area or east-west trough at the surface, cyclonic circulation and upper air trough at various levels of atmosphere and approach of monsoon depressions and high or intense system from north Bay. Occasionally the rainfall activity increases due to passage of western disturbances in the north seen as westernly trough in the middle and upper levels of the troposphere. It has been observed that the major floods over the region most commonly occur when (a) the monsoon trough lies close to foot-hills of Himalayas for two to three days or more (this is called as break monsoon situation) (b) the depressions and cyclones in north Bay move north or north-east and approach the region. Some times low pressure area or east-west trough at the surface with a favourable combination of deep westerly trough in the upper air lying over the region and its neighbourhood produce copious rainfall and floods. However it has also been observed that the region received less rainfall whenever monsoon depression forms over the north Bay as then the moist Bay winds do not reach the region.

Past monsoon season:

Months of October and November constitute the past monsoon season. During this season N-E region receives generally light to moderate rains with rainfall decreasing as the monsoon marches. The monsoon withdraws from the N-E India in the last week of September or first week of October. After withdrawal of the monsoon, light unsteady winds are experienced which become north-easterly. The cool north-easterly winds having origin over the lofty mountains, bring down the temperature. The orographic low pressure centres are replaced by high pressure and a flat pressure gradient is established over the entire region. Rainfall abruptly decreases and it ranges between 20 cm to 25 cm. From the month of October the weather becomes progressively drier. Nagaland, Manipur and Mizoram remain absolutely dry in November. In Assam, southern parts of Arunachal and Barak valley including Tripura experience occasionally thundery weather in the early part of November and due to escalation of the western disturbances and shifting of the easterly jet stream to the south, cloudy weather associated with mild rain prevails for short duration. With the advance of the season, the ground cooling begins and morning fogs appear. Dense haze over the hills is a common phenomenon. The weather progressively clears up and fair, sunny days prevails till the end of November. This is the shortest season in the north-east, but most endurable and pleasant period of the year.

2.0 RAINFALL IN METEOROLOGICAL SUB-DIVISIONS OF N-E INDIA

North-East India is mainly divided in four meteorological sub-divisions (including Sub-Himalayan West Bengal & Sikkim) for acquiring the meteorological informations of the region. Due to difference in topographical features, the annual/seasonal rainfall observed in the different meteorological sub-divisions are also different. Characteristics of rainfall in the different meteorological sub-divisions are mainly affected by the forest density, elevation of the place, orientation of the hill slope with respect to wind flow, type of storms etc.

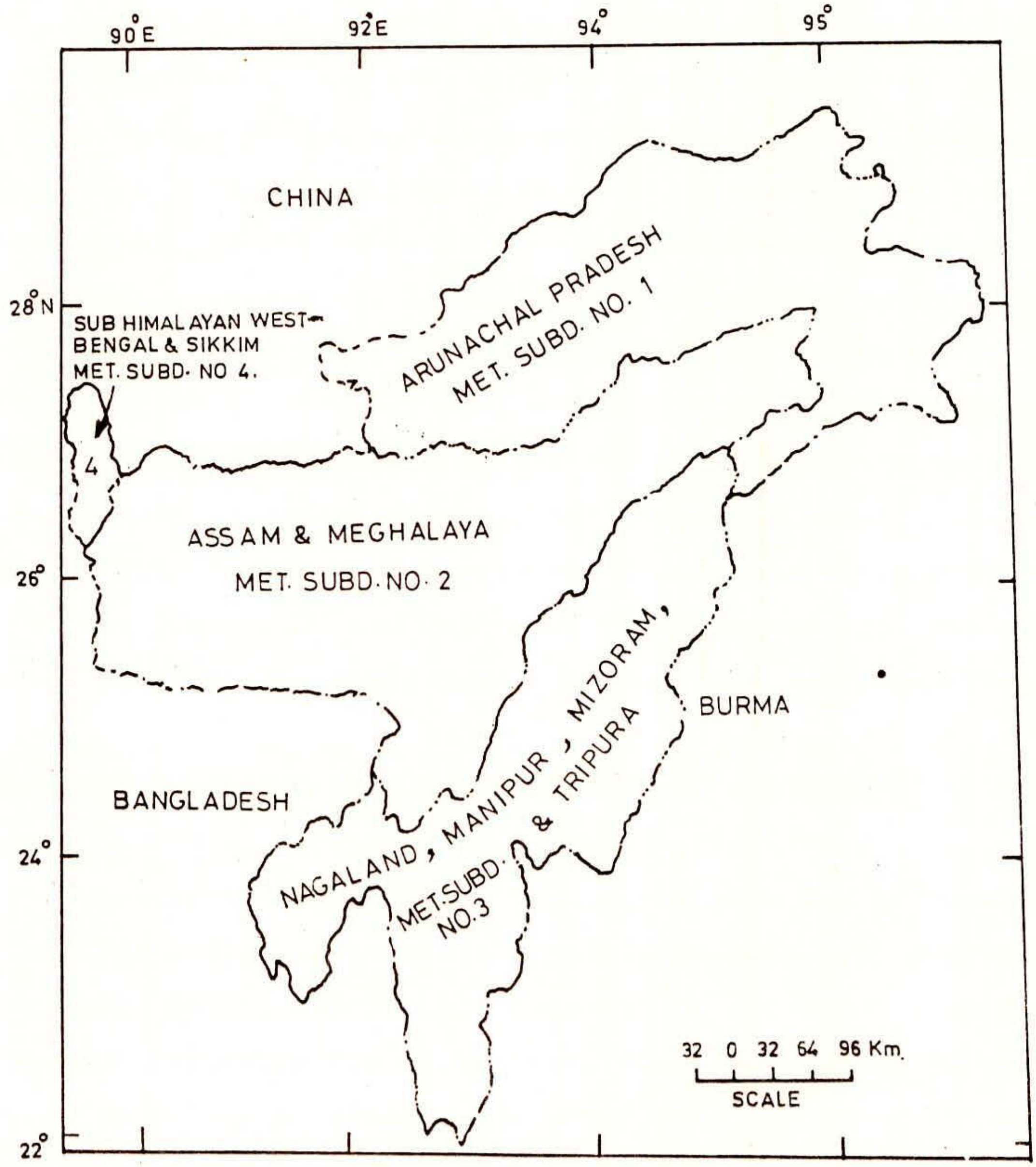

FIG 2 MAP SHOWING METEOROLOGICAL SUB-DIVISIONS OF N-E INDIA [Source: Fig.1 & Table 1]

2.1 Annual and Seasonal Rainfall in Different Meteorological Sub-Divisions of N-E India

The annual and seasonal rainfall have been worked out by CWC (Ref.No.5) for different meteorological sub-divisions of India. In table 1, we have shown the annual/seasonal rainfall in different meteorological sub-divisions of North-East India only

Table 1 : Annual/seasonal rainfall in meteorological sub-divisions of N-E India

Sl. No.	Met.Sub.-divisions	Geographical Area(Sq.Km.) Ref.No.1	Forest area (Sq.Km.) 1976-77 Ref.No.1	Annual Rainfall (mm) Ref.No.5	Seasonal Rainfall (mm) (June-Sep.) Ref.No.5
1.	Arunachal Pradesh	83580	51540	2997	2085
2.	Assam & Meghalaya	101010	36840	2497	1624
3.	Nagaland, Manipur, Mizoram & Tripura	70460	31190	2314	2092
4.	Sub-Himalayan West-Bengal & Sikkim	N.Av.	N.Av.	2779	2172

(Source : Ref. No. 1 & 5)

From the help of table 1, a bar chart showing annual/ seasonal rainfall in different meteorological sub-divisions has been prepared and is shown in fig.3. Bar chart of annual rainfall shows that the maximum annual rainfall is observed in Arunachal Pradesh while minimum annual rainfall is observed in the regions of Nagaland, Manipur, Mizoram and Tripura. The chart also indicates that the annual rainfall decreases from the area of Arunachal Pradesh to the area of Nagaland, Manipur, Mizoram and Tripura and again it increases towards the area of Sub- Himalayan West-Bengal and Sikkim.

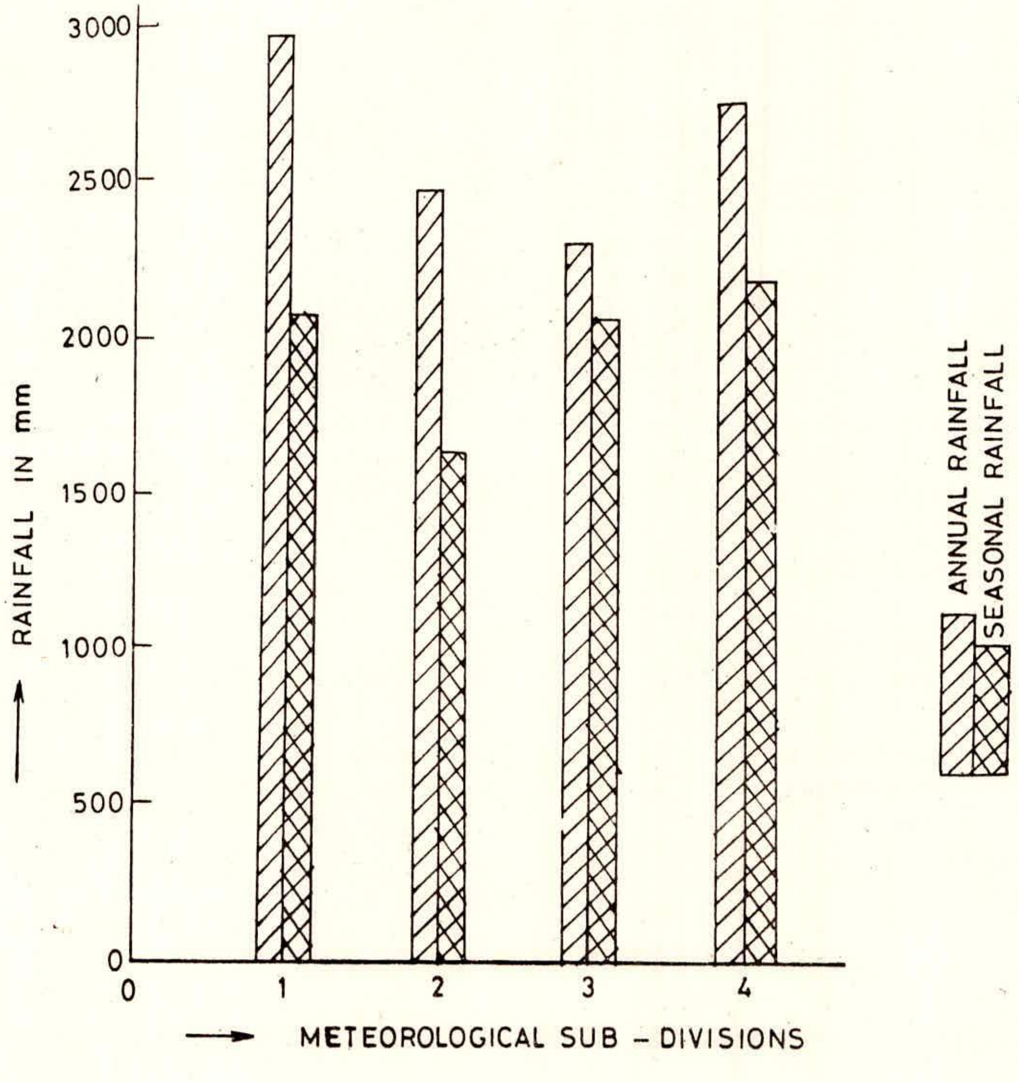

FIG. 3 - BAR CHART SHOWING ANNUAL / SEASONAL RAINFALL IN DIFFERENT METEOROLOGICAL SUB-DIVISIONSOF N-E INDIA [Source : Table 1]

Bar chart of seasonal rainfall shows that the maximum seasonal rainfall is observed in Sub-Himalayan West-Bengal and Sikkim while minimum seasonal rainfall is observed in Assam and Meghalaya. The chart also indicates that the seasonal rainfall decreases from the area of Sub-Himalayan West-Bengal and Sikkim to the area of Assam & Meghalaya and it again increases towards the area of Arunachal Pradesh.

2.2 Heavy rainfall stations in different meteorological sub-divisions of N-E India

Main stations receiving heavy rainfall in N-E India are Cherrapunji, Mawsynram, Denning and Buxa. The stations Cherrapunji and Mawsynram receive heaviest rainfall and are situated in Meghalaya under the range of Khasi & Jayantia hills. Heaviest rainfall in these stations are mainly due to Orographic effect. Because in North-East India (derived from the literature of Ref.No.11), heavy rainfall due to orographic effect is confined to the Khasi & Jayantia hills. In table 2, stations receiving heavy rainfall (rainfall more than 500 cm of annual rainfall) in N-E India are shown together with their elevation and mean annual rainfall.

It may be seen that the heavy rainfall stations (as mentioned in table 2) are located in the hills of the N-E India. However, none are in the Himalayan region. There are some stations in the Darjeeling hills with short period means over 500 cm rainfall which are not included in the table. During the onset of south-west monsoon, the moisture laden monsoon winds first approach the Khasi-Jayantia hills and precipitate most of the moisture over these regions. By the time they approach the Himalayan regions much of the moisture is lost and therefore, the less rainfall in this area.

Table 2: Stations showing heavy rainfall in N-E India

Station	State	Meteorological sub-division	Mean annual rainfall(cm)	Elevation (m)	Period of record
Cherra-punji	Megha-laya	Assam & Meghalaya	1102	1313	1902-1975
Mawsy-nram	Megha laya	Assam & Meghalaya	1221	1401	1941-1969
Denning	Aruna-chal Pradesh	Arunachal Pradesh	528	698	1929-1949
Buxa	West Bengal	Sub-Himalayan West-Bengal & Sikkim	532	N.Av.	1891-1968

(Source: Ref.No.11)

Highest one day rainfall in different stations of Assam & Meghalaya meteorological sub-division are shown in table 2A.

Table 2A : Stations showing highest one day rainfall in Assam and Meghalaya meteorological sub-division.

Stations	Meteorological sub-division	highest one day rainfall (cm)
Cherrapunji	Assam & Meghalaya	103.6
Jawai	-do-	101.9
Mawsynram	-do-	99.0

(Source:Ref.No.11)

2.3 Normal annual and seasonal rainfall in the districts of different meteorological sub-divisions of N-E India

From the charts of district normals (monthly & annual) of rainfall available in Memoirs of the India Meteorological

Department (Ref.No.10), a table has been prepared which shows the annual and seasonal rainfall in the districts of different meteorological sub-divisions of North-East India based on the records from 1901 to 1950 and is shown in table 3. In the memoirs of Indian Meteorological Department (Ref.No.10), the district normals of hill districts are not calculated in consonance with past practice in the India Meteorological Department, because the majority of rainfall stations of hill districts are higher than 3,500 feet above the mean sea level. Averages for these districts would be of little value on account of the great variability of rainfall from station to station. But in our present work, just to show the approximate value of normal annual and seasonal rainfall in the hill districts of different meteorological sub-divisions of North-East India, we have calculated the district normals (annual and seasonal) of rainfall for hill districts. These are united Mikir & North Cachar Hills, Garo Hills, united Khasi & Jayantia Hills, Naga Hills, Mizo Hills and the district Darjeeling. Normal rainfall (monthly and annual) values for the raingauge stations of these hill districts are available in ref. no.10

Normal annual and seasonal rainfall for the districts of different meteorological sub-divisions have been shown in table 3

On the comparison of normal annual and seasonal rainfall figures of table 3, it has been found that the united Khasi and Jayantia hills receive maximum normal (annual and seasonal) rainfall. Because the stations Cherrapunji and Mawsynram are located under united Khasi and Jayantia hills. The normal annual rainfall of the station Cherrapunji (Police station) is 10640.5 mm while Cherrapunji (Post Office) is 10869.2 mm and the station Mawsynram is 11405.8 mm (Ref.No.10).

Table 3: Normal annual and seasonal rainfall in the districts of different meteorological sub-divisions of N-E India (Based on records from 1901-1950)

Name of Met. Sub-Divisions	Name of District	Normal Rainfall in mm Annual	Seasonal (June-Sept)
1. Arunachal Pradesh	Tirap Frontier Tract	4142.1	2742.8
2. Assam & Meghalaya	Goalpara	2801.3	1944.6
	Kamrup	2125.4	1391.8
	Darrang	2194.0	1464.0
	Nowgong	1717.8	1168.5
	Sibsagar	2197.0	1391.1
	Lakhimpur	2929.7	1938.5
	Cachar	3293.9	2041.5
	United Mikir and North Cachar Hills	3071.6	1853.4
	Garo Hills	2735.0	1909.0
	United Khasi and Jayantia Hills	6344.9	4749.6
3. Nagaland, Manipur, Mizoram & Tripura	Naga Hills	2377.3	1581.8
	Manipur	2389.2	1578.7
	Mizo Hills (Lusia Hills)	2821.9	1927.6
	Tripura	2100.7	1325.2
4. Sub-Himalayan West-Bengal & Sikkim	Cooch Behar	3201.3	2454.8
	Darjeeling	2994.1	2407.8
	Jalpaiguri	3944.7	3090.1
	Malda	1540.3	1209.7
	West Dinajpur	1734.8	1281.6
	Sikkim	N.Av.	N.Av.

(Source: Ref.No.10)

3.0 RAINFALL IN BRAHMAPUTRA VALLEY

The Brahmaputra is an important river in North-East India not only for the purpose of irrigation of the region but also for power generation, navigation, recreation etc. Since Brahmaputra is a severe flood prone river a description of characteristics of rainfall (annual & seasonal) in Brahmaputra valley is important for the purpose of flood studies in the regions of North-East India.

3.1 The Brahmaputra river and its valley

The Brahmaputra known as Tsangpo in Tibet originates from an altitude of 5300 m about 63 km south-east of the Mansarovar lake in south-west Tibet. According to Tibetans the source of the riverlies in the Kanglung Kang glacier (82^o-10'E and 30^o - 30'N) near Konggyu Tso lake (4877 m) and the kailash range of Himalayas.

The Brahmaputra is the biggest river in the Indian sub-continent. The total length of river Brahmaputra from its origin in Tibet (China) to its outfall in Bay of Bengal is 2880 kms. It traverses first 1625 kms in Tibet, the next 918 kms in India and the rest in Bangladesh.

The Brahmaputra valley in India is about 880 km in length lying almost east to west in its lower portion but tending somewhat to the north-east in its upper half. It is bounded on the north by the eastern Himalayas, the lower ranges of which rise abruptly from the plains, in the east by the Patkai range of hills running along the India-Burma boarder and on the south by the Assam range of hills. The broadest part of the valley is where the river divides the districts of Sibsagar and Lakhimpur. Below the isolated blocks of Mikir hills to the south and the group to the Dalfa hills to the north suddenly contract it to 40 km. Lower down, it windens out but at the lower end of Nowgong district, it is again encroached upon by the Khasi hills. The hills are close to the river till Guwahati. Thereafter, the hills recede again and they do not approach the Brahmaputra till Goalpara which is situated on a spurs of the Garo hills. Beyond this point, the valley again widens and at Dhubri opens out in to the great delta of Bengal. A few miles down stream of Dhubri the river enters Bangladesh. The width of the Brahmaputra valley between foot hills is only 80 to 90 kms of which the river itself has a width of 6 to 10 km in most places. Forests cover a few kilometers mostly along the foot hills. The tea gardens in some districts occupy much of the higher areas. The remaining width of the valley occupied by populated villages and cultivated fields is very narrow.

The total catchment area of Brahmaputra is 5,80,000 sq.km. The breakup of the catchment area of Brahmaputra in Tibet is 293000 sq.km., in India & Bhutan is 240000 sq.km. and in Bangladesh is 47000 sq.km.

3.2 Meteorological Situations Associated with Major Floods in Assam

The Assam range of hills gradually rise in height east wards from a 300 m in Garo hills to about 3000 m in Naga hills. The low clouds brought in by the south west monsoon gets intercepted on the south ridge and cause extremely heavy rainfall along the Cherrapunji and Mawphlang Pynurala belt. The clouds that pass over this 1800 m ridge along this belt, precipitate in the Brahmaputra valley, their intensity increasing towards the foot hills of the Himalayas.

A study of the meteorological situations associated with major floods in Assam for the period of 1956 to 1963 has been made by IMD. Altogether 22 major flood situations have been studies, out of which 10 were due to Break monsoon, 6 due to low pressure area, depressions etc. in Bay of Bengal, 3 due to land depressions and 3 due to upper air cyclonic circulations. Break monsoon situations are typical of this regions resulting in exceptionally heavy rainfall. The situation normally occurs when the axis of the seasonal monsoon trough shifts north wards from its normal position and lies close to the foot of the Himalayas with the setting in this situation the easterlies which had a full survey over north India to the north of the axis of the seasonal trough get replaced by the westerlies. This results in marked decrease of the rainfall in the central and northern parts of the country and increase in rainfall activity along the foot hills and sub-mountainous region of the Himalayas. If during a 'Break' period a westerly wave also happens to pass east-wards across Nepal-Assam Himalayas, the Assam hills and plains receive exceptionally heavy rainfall. The study showed that it is mainly during August that floods are caused by the break monsoon conditions. Floods due to monsoon depressions from the bay generally occur in the month of June. Floods in September are rather rare and major floods mostly occured in the month of August. Unlike other parts of the country rainfall associated with the monsoon depressions, the month of June itself is sufficient to cause major floods in this region. This is due to fact that during the premonsoon months of April and May, this part receives a fairly good amount of rainfall on account of large scale thunder storms. Thus saturated ground conditions and bankfull river stages help in producing major floods during June.

3.3 Normal Annual and Seasonal Rainfall in Brahmaputra Catchment in Assam

Normal annual and seasonal rainfall in Brahmaputra catchment in Assam has been described on the basis of the normal (annual/seasonal) rainfall data available in ref.no.4. The chart of normal annual and seasonal rainfall in Brahmaputra catchment in Assam has been shown in table 4.

Table 4 : Normal annual/seasonal rainfall in Brahmaputra Catchment in Assam

	Normal Rainfall in cm	
	Period (1901-1950)	Period (1951-1960)
Annual	274.2	264.3
Seasonal (June to Sept.)	179.3	152.8
June	62.8	47.7
July	65.0	49.4
August	47.4	40.0
September	41.4	29.0

(Source:Ref.No.4)

On the comparison of normal rainfall (annual & seasonal) figures of table 4 for the period 1901-1950 and 1951-1960, it is found that the normal rainfall (annual & seasonal) for the period 1901-1950 is more than for the period 1951-1960.

In table 4, normal rainfall data for the month of January to May and October to December are not available.

However, with the available data of monsoon months (June, July, August and September) a graph of average monthly seasonal rainfall in Brahmaputra catchment in Assam has been plotted for two different periods (1901-1950) and (1951-1960) and is shown in fig.4. The fig.4 shows that the peak value of average monthly seasonal rainfall in the Brahmaputra catchment in Assam for both periods (1901-1950 and 1951-1960) is in the month of July. On the comparison of these two peak values of average monthly seasonal rainfall, it is found that the peak value of rainfall for the period (1901-1950) is greater than the peak value of rainfall for the period (1951-1960).

3.4 Seasonal Rainfall in the Catchments of Dihang, Dibang and Lohit rivers for the years 1958 and 1959

The combined flow of rivers Dihang, Dibang and Lohit forms the Brahmaputra. Actually the name of river Brahmaputra in China is Tsangpo but after crossing the Indo-China boarder, the Tsangpo changes its name to Siang or Dihang in Arunachal Pradesh. It traverses the Arunachal Pradesh in a more or less southern direction for 226 km before reaching the Pasighat ending its journey in the mountains. From Pasighat Dihang travels another 52 km before joining the Dibang and Lohit, two major tributaries from north-east and east respectively as can be seen from fig.4B.

The catchments of these three rivers (Dihang, Dibang & Lohit) lie in the upper Brahmaputra basin. The study of seasonal rainfall in these catchments is important because the study may provide support for estimating the floods in the Brahmaputra basin.

Normal rainfall data (annual and seasonal) for the catchments of rivers Dihang, Dibang & Lohit are not available and due to this we are unable to discuss the distribution of normal

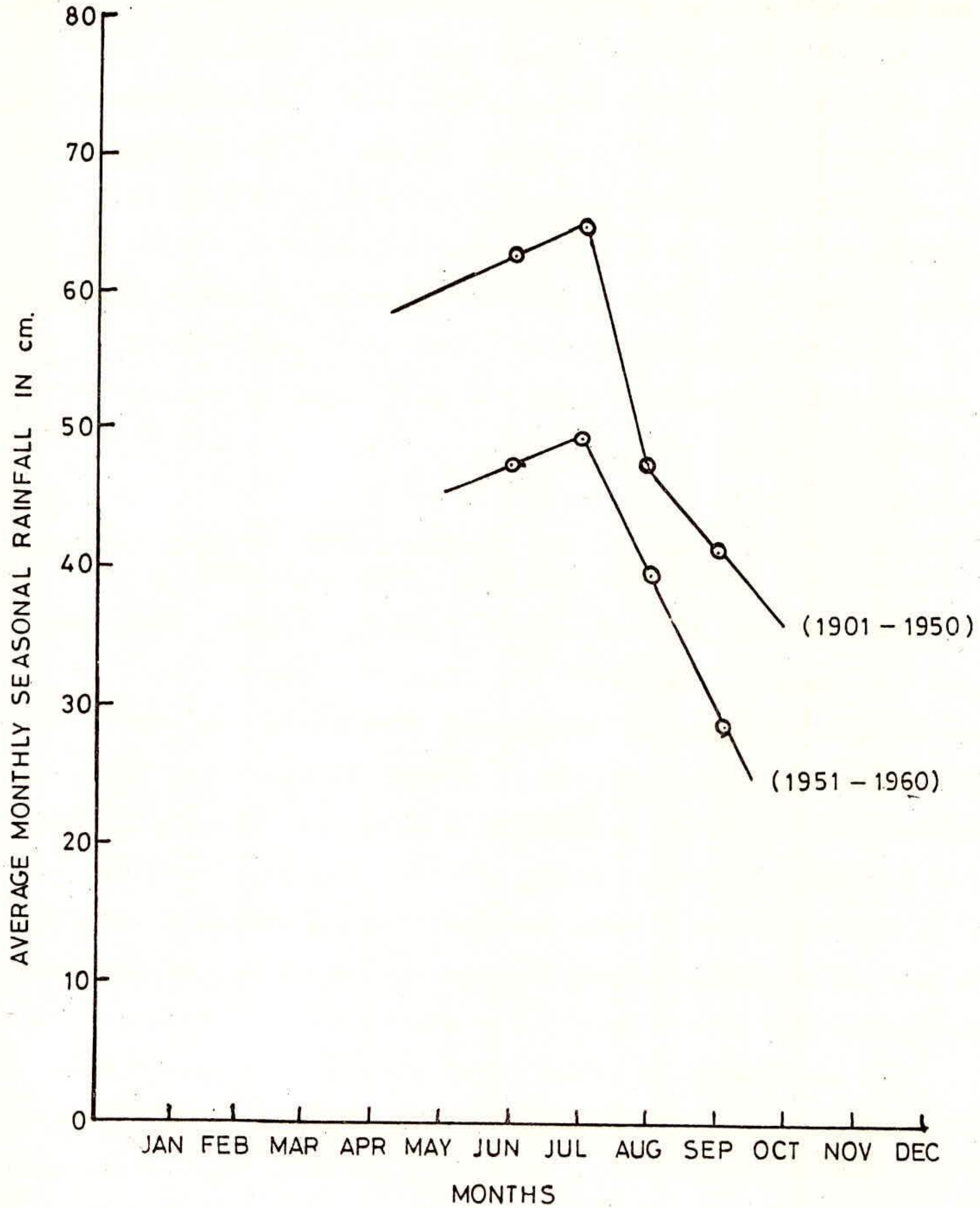

FIG.4. GRAPH SHOWING AVERAGE MONTHLY SEASONAL RAINFALL IN BRAHMAPUTRA CATCHMENT IN ASSAM FOR TWO DIFFERENT PERIODS (1901 - 1950) AND (1951 - 1960). [Source : Table 4]

(annual & seasonal) rainfall in the catchments of the rivers Dihang, Debang and Lohit. Only seasonal rainfall data of these catchments for the two years 1958 and 1959 are available. The distribution of seasonal rainfall (June to Sept.) in the Dihang, Dibang and Lohit basins for the years 1958 and 1959 has been shown in table 5.

Table 5 : Seasonal rainfall in the catchments of Dihang, Dibang and Lohit rivers for the years 1958 and 1959

Catchments	Seasonal (June to Sept.) in cm 1958	1959
Dihang	210.9	142.5
Dibang	173.0	117.0
Lohit	179.8	142.0
Combined Catchment	194.0	135.4

(Source: Ref.No.4)

Seasonal rainfall figures of table 5 for the years 1958 and 1959 show that the maximum seasonal rainfall is observed in the Dihang basin.

3.5 Average rainfall for monsoon & non-monsoon periods in different raingauge stations of Dihang catchment

From available raingauge data (Ref.No.4) of the stations of Dihang catchments, the average value of rainfall (monsoon & non-monsoon periods) in the different raingauge stations of the Dihang catchment has been shown in Table 6. The period of data record for each raingauge station is also shown against each station in the table 6.

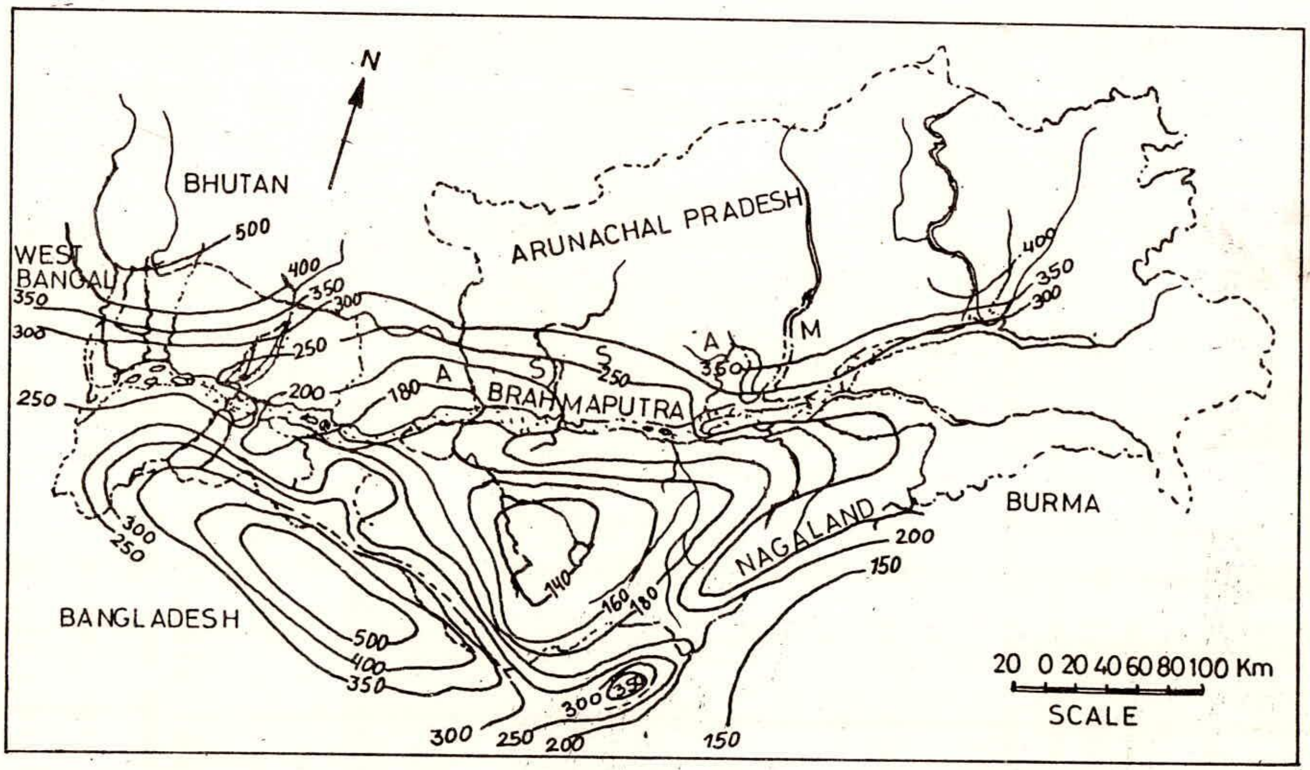

FIG-4A ISOHYETAL MAP OF BRAHMAPUTRA VALLEY AND ADJOINING HIGH LANDS (Based on Meteorological Department of India data)
[Source : Ref. No. 9]

Table 6: Average Rainfall (monsoon & non-monsoon periods) in different raingauge stations of Dihang catchment

Monsoon/Non-monsoon	Average Rainfall in Cm						
	Pasighat 1953-70	Along 1960-70	Kambang 1966-70	Boleng 1969-70	Inkiyong 1968-70	Medhuka 1966-70	Tuting 1966-70
Monsoon (May-Sept.)	421	166	283	223	156	169	275
Non-monsoon Period	86	59	74	66	98	69	122
Total:	507	225	357	289	254	238	397

(Source:Ref.No.4)

The statement of table 6 shows that the rainfall is heavy at Pasighat but to the north of Pasighat it reduces as could be seen from average rainfall figures of Along, Boleng and Inkiyong. The rainfall figure of Tuting shows higher rainfall, near the international boarder where Dihang enters India, when compared to the stations situated in the middle of the catchment. Medhuka on the north western boarder of the Dihang basin shows low rainfall when compared to Pasighat.

The IMD has made of detail study as informations given in Ref.No.4) of the normal annual, seasonal and monthly rainfall distribution in the Brahmaputra valley and drawn the following broad conclusions.

1. Rainfall in the valley is negligible for the period January to March and November to December being on the average less than 10 cms.

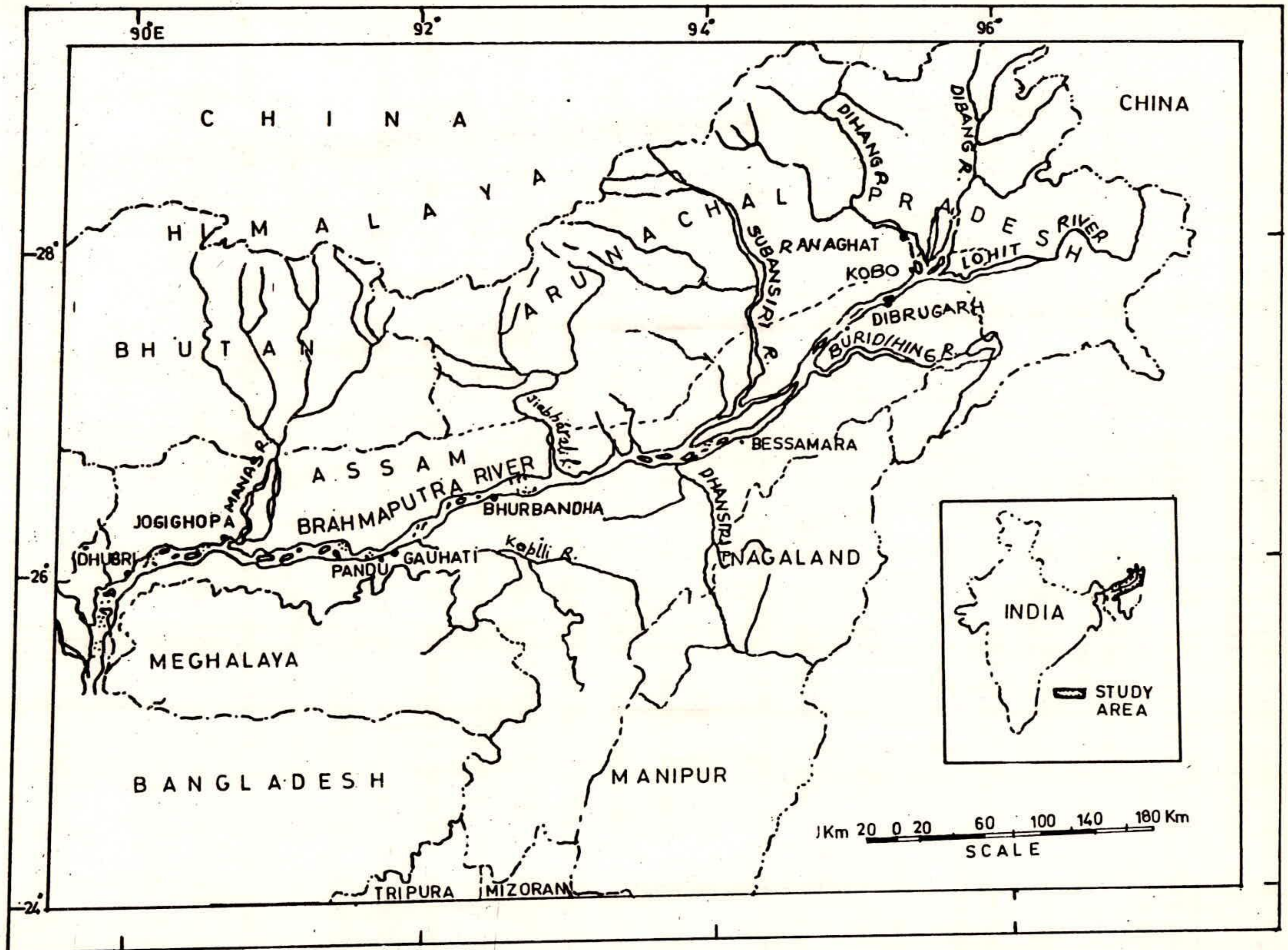

FIG. 4 B. BRAHMAPUTRA RIVER SYSTEM [Source Ref. No. 9]

2. The rainfall increases gradually from April but abruptly towards end of May with the onset of monsoon. The total normal monthly rainfall in descending order during the monsoon season is in July, June, August, May, September & October.

3. The general configuration of Isohyetals pattern for all the months is more or less similar with only noticeable change of general increase or decrease in rainfall from one month to another. This seems to suggest that the rainfall distribution in the area is largely influenced by the topography of the area.

4. The rainfall in the Brahmaputra valley ranges from 175 cm in Kamrup to about 640 cm in the north-eastern Arunachal Pradesh. The Lanka area in Nowgong district to the north of the Khasi and Jayantia hills lies in a rain shadow area, the annual rainfall being about 110 cms.

4.0 RAINFALL IN KULSI BASIN

The river Kulsi is one of the tributaries of the Brahmaputra river and is hydrologically important river for the purpose of flood studies, irrigation, power generation and improvement of drainage system of greater Guwahati. The study of rainfall characteristics in Kulsi basin is very important for the above studies.

4.1 The Kulsi River and Its Basin

The river Kulsi originates from the west Khasi hill ranges, where the elevation is around 1800-1900 m, and flows down north. On reaching the plain area, it branches of into three rivers, all of which take a westerly turn after flowing for about 8 to 10 km north and join together again and then flows by the name Jaljali to meet Brahmaputra near Bahati. From its origin to its outfall with Brahmaputra, the river travels a distance of about 220 km out of which 100 km is in Meghalaya and the rest 120 km is in Assam. The river drains a total area 1860 sq.km. along with old course. The course of river Kulsi from the Gumicut portion to Nagarberra is now dead, because the Kulsi is closed by the Brahmaputra embankment, at Gumicut. The discharge of the Kulsi now follows by the link channel named Jaljali, whose outfall with Brahmaputra is at Bahati. So, if the Jaljali, the new course of Kulsi is considered, the total catchment of the Kulsi up to Bahati will be 2140 sq.km., out of which about 1200 sq.km. is in Meghalaya and the rest 940 sq.km. is in Assam.

The Kulsi river basin drains the western most part of Kamrup district on the south of Brahmaputra. The basin has got the south-north orientation and is bounded on the south by the west Khasi hill ranges and on the north by the Brahmaputra. On the east-west direction, it is bounded by Digaru basin and Bharalu basin on the east and by the Deosila river basin in the west. The area that the Kulsi river drains can broadly divided into three categories;

1. The upper khasi hill reach
2. The middle reserve forest area reach
3. The alluvial or flood plain reach

The upper Khasi hill ranges of the catchment extend from the origin of the river Kulsi to the Ukium (Assam Meghalaya Boarder) and this reach lies entirely in the west Khasi hill range, with the general altitude varying from 1800 m to 150 m. The whole area consists of series of hill range with very small intermittent plain areas. The whole of the reach is covered with evergreen forests. No area in the reach remains under snow cover.

The middle reserve forest area reach consists of two reserve namely Borduar reserve forest and pantan reserve forest running parallel along the river from Ukium to village Kulsi, with the Borduar reserve forest on eastern bank and pantan reserve forest on western bank. The river in this reach has got a very narrow valley running between these two reserve forests. The eastern part of the Borduar reserve forest consists of comparatively plain areas with the famous chandubi beel being located therein.

The alluvial or the plain reach consists of the plain area along the southern bank of river Brahmaputra. Almost half of this reach is affected by the flood of the river Kulsi and Brahmaputra. Just at the starting of this reach i.e. near village Kulsi, the river Kulsi branches of into three channels and all of them join together after flowing a few km and out falls into Brahmaputra near Barak. This area is fullv cultivable area and sufficiently densely populated.

4.2 Climate of the Kulsi Basin

The climate of the basin excluding the upper most reach is similar to that of the other districts in central Assam. The winter is cold and foggy while the summer is oppressively hot and humid. The rainfall is substantially high during the monsoon which extends from May to September. The annual average humidity is 72% ranging from monthly average of 70% in the month of March & 85% in the month of August.

The temperature in the winter goes down to about $7^{o}C$ to $8^{o}C$ and in the month of July and August it shoots upto about $37^{o}C$ to $38^{o}C$.

In the upper most reach, the temperature both in winter and summer is less than that of the lower reaches.

4.3 Meteorological Situations Associated with Major Floods in the Kulsi Basin

Major floods over the Kulsi basin are seen when the major rainfall over the region takes place during the monsoon season. Important synoptic features responsible for heavy precipitation during this period are monsoon trough lying close to foot hills of Himalayas, Lopar or east west trough at the surface, CYCIR and upper air trough at various levels of atmosphere and approach of monsoon depressions and high or intense system from north Bay. Occasionally the rainfall activity increases due to the passage of western disturbances in the north seen as westernly trough in the middle and upper levels of the troposphere. It has been observed that the major floods over the region most commonly occur when (a) the trough lies close to foot hills of the Himalayas for two to three days and more (this is called as break monsoon situation) (b) the depressions and cyclones in north Bay move north or north-east and approach the region. Some times lopar or east-west trough at the surface with a favourable combination of deep westernly trough in the upper air lying over the region and its neighbourhood produce copious rainfall and floods. However it has also been observed that the region received less rainfall whenever monsoon depression forms over north Bay as then the moist Bay winds do not reach the basin.

4.4 Maximum One Day and Average Monthly, Annual & Seasonal Rainfall in the Kulsi Basin

The study of maximum one day and average monthly, annual & seasonal rainfall in the Kulsi basin is important for various objectives like water resources assesment, flood forecasting, design storm estimations and water balance study. For the purpose of these studies raingauge stations and hydrological stations have been setup by the Govt. organisations in the Kulsi basin as shown in fig.5. The number of raingauge stations in the Kulsi basin is four, out of which three numbers are in the plain area and one just in the foot hills. There are another four raingauge stations which do not fall within the basin but are in the contiguous basins, data of which may be utilised for the studies of various objectives of the basin. The distribution of the rain gauge stations in the plain area of the basin is adequate so far as WMO standard (one raingauge for every 500 sq.km.) is considered. The plain catchment area being about 860 sq.km., the three no. of raingauge stations are sufficient. The hilly catchment of the basin is about 1000 sq.km., and only one raingauge station that two just at the boundry of the hilly catchment is there. As per WMO standard (one raingauge for every 250 sq.km.), at least 4 numbers of raingauge stations need to be installed in the hilly catchment, so as to have a good network of raingauge stations in the basin. The existing raingauge stations in the basin and around the basin, and the period of data available are shown in table 7.

Table 7 : Raingauge Stations in and Around the Kulsi Basin with period of Data Available

Name of Raingauge Station	Period of data available
Raingauge station in the basin	
1. Chamaria	April 1983 to February 1987
2. Singra	June 1983 to October 1986
3. Boko Police Station	June 1983 to September 1986
4. Ukium	For 1987 Only
Raingauge Station around the basin	
1. Ajara Airport	January 1975 to March 1987
2. Palasbari (Mirza)	June 1983 to April 1987
3. Rani Tea Estate	June 1983 to March 1987
4. Hahim	June 1983 to October 1986

(Source:Ref.No.2)

From the available (as mentioned in table 7) rainfall data, we have shown the maximum one day rainfall for different stations in and around the Kulsi basin in different years in table 8, average monthly rainfall in different stations of the Kulsi basin in table 9 and average annual & seasonal rainfall in different stations of the Kulsi basin in table 10.

From the available data of max. one day rainfall in table 8, it is clear that the Boko Police Station in the Kulsi basin has received the highest value (219.60 mm) of one day maxm. rainfall on dated 17.6.1984 and Rani Tea Estate Station around the Kulsi basin has received the lowest value (25 mm) of one day maxm. rainfall on dated 26.6.1983.

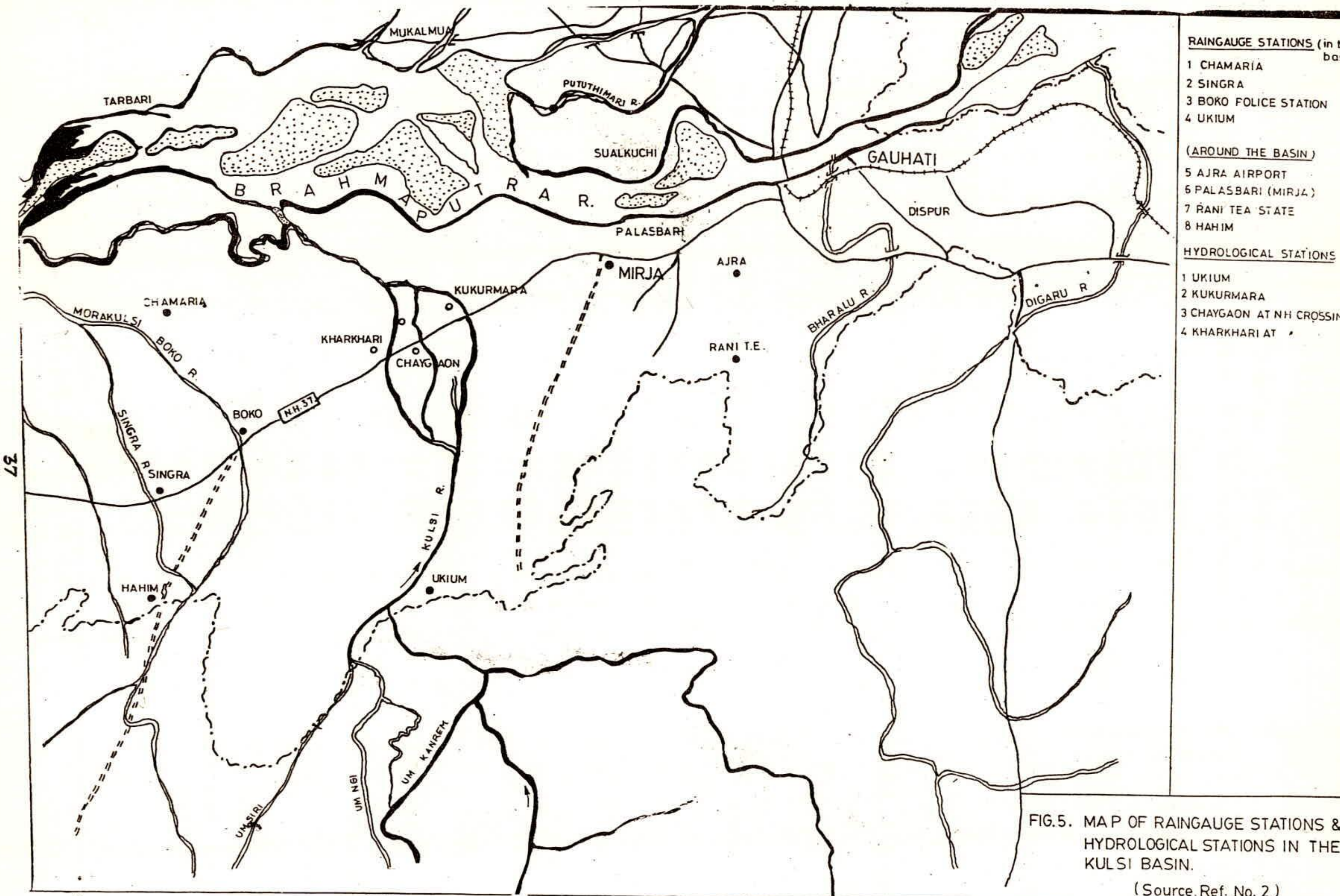

FIG.5. MAP OF RAINGAUGE STATIONS & HYDROLOGICAL STATIONS IN THE KULSI BASIN.
(Source. Ref. No. 2)

Table 8 : Maximum one day Rainfall for Different Stations in and Around the Kulsi Basin in Different Years

Name of Station		Maxm. one day rainfall (in mm)	Date
1. Chamaria	a.	76.00	16.9.1983
	b.	71.00	19.7.1984
	c.	64.00	20.8.1985
	d.	93.00	27.7.1986
2. Singra	a.	78.02	6.10.1983
	b.	158.50	16.5.1984
	c.	101.00	2.6.1985
	d.	60.60	26.4.1986
3. Boko Police station	a.	98.40	9.10.1983
	b.	219.60	17.6.1984
	c.	79.40	20.8.1985
	d.	139.60	28.6.1986
4. Airport	a.	75.20	29.7.1975
	b.	70.20	14.7.1976
	c.	126.00	24.7.1977
	d.	71.00	8.7.1978
	e.	139.00	2.7.1979
	f.	102.30	2.8.1980
	g.	132.00	15.7.1981
	h.	80.20	20.6.1982
	i.	83.40	8.6.1983
	j.	96.40	4.9.1984
	k.	179.60	18.7.1985
	l.	89.10	8.10.1986
5. Palasbari (Mirza)	a.	42.00	22.8.1983
	b.	97.00	10.6.1984
	c.	119.00	10.7.1985
	d.	83.40	24.8.1986
6. Rani Tea Estate	a.	25.00	26.6.1983
	b	125.00	8.6.1984
	c.	122.40	10.7.1985
	d.	148.60	7.10.1986

(Source : Ref.No.2)

Table 9 Average monthly rainfall in different stations of the Kulsi basin
(Unit: mm)

Stations	Jan.	Feb.	Mar.	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Chamaria	14.33	42.40	71.37	200.56	283.73	320.70	398.05	233.60	310.60	100.66	-	19.13
Singra	17.68	17.26	73.26	257.94	376.30	564.40	474.45	293.16	437.51	407.36	87.00	25.20
Boko	14.60	28.60	51.13	205.46	163.33	421.20	428.65	229.50	316.60	100.80	10.53	21.93
Ajara	8.60	16.14	41.25	116.55	195.25	335.05	355.40	228.02	185.38	92.34	21.72	11.74
Palasbari (Mirza)	1.20	20.80	59.75	208.00	164.26	270.55	342.10	258.15	261.25	136.95	11.65	23.46
Rani Tea Estate	12.15	13.70	42.55	174.40	156.40	311.85	385.30	287.30	212.30	136.85	16.15	10.50
Hahim	23.10	9.06	61.50	214.55	238.80	513.15	482.15	361.05	378.45	208.55	14.60	25.75
Total	91.66	147.96	400.79	1377.46	1578.06	2736.90	2866.10	1890.78	2102.09	1183.51	151.65	137.71
Average monthly rainfall in the basin (mm)	13.94	21.12	57.26	196.78	225.43	390.98	409.44	270.11	300.64	197.51	25.28	19.67
Averag monthly rainfall in the basin (cm)	1.39	2.11	5.73	19.68	22.54	39.09	40.94	27.01	30.06	19.75	2.53	1.97

(Source Ref. No. 2)

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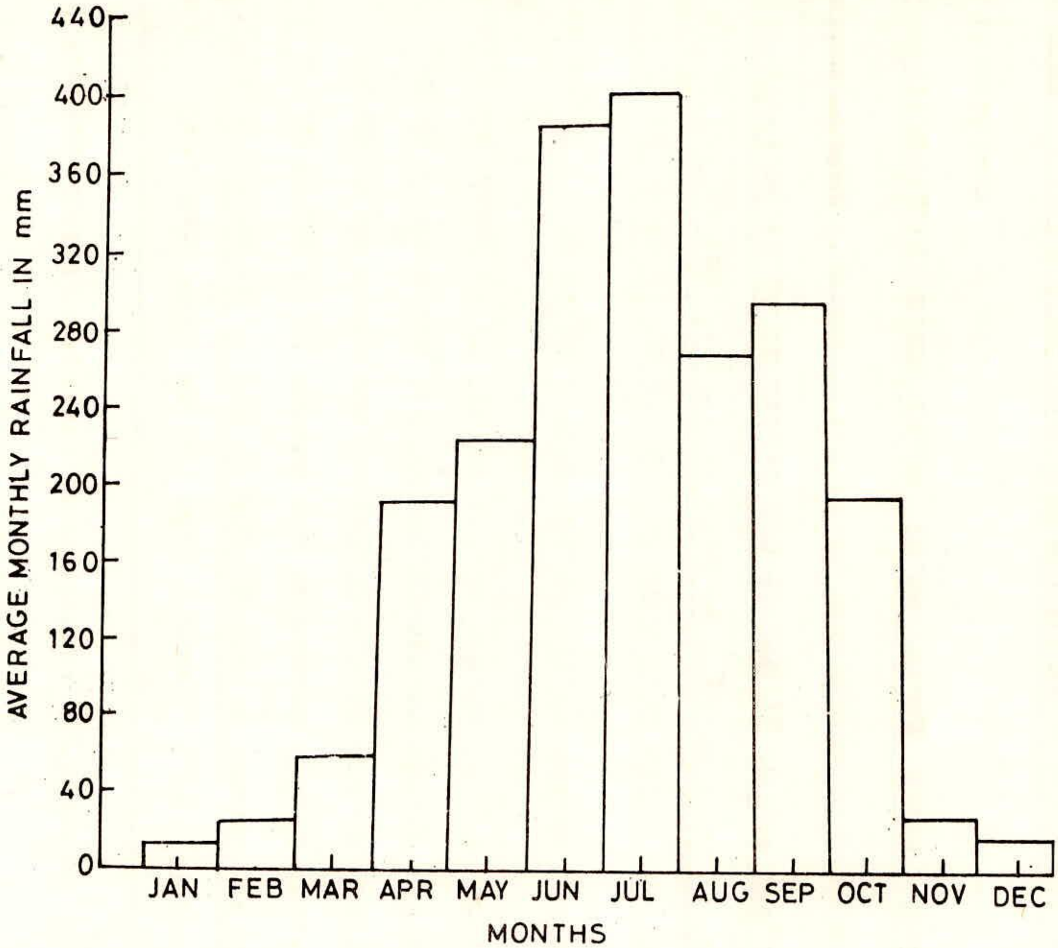

FIG. 6. HISTOGRAM SHOWING AVERAGE MONTHLY RAINFALL IN KULSI BASIN [Source : Table 9]

From the data (as given in table 9) of average monthly rainfall in different stations of the Kulsi basin we have estimated the average values of monthly rainfall in the Kulsi basin by using arithmatic mean method and are presented in the last row of the table 9. These values indicate that the rainfall in the Kulsi basin is very low for the period January to March and November to December being on the average less than 14 cm. The rainfall increases gradually from April but abruptly towards end of May with the onset of monsoon. The average monthly rainfall in the Kulsi basin is maximum for the month of July. The average monthly rainfall in descending order during the monsoon season is as July, June, Sept., August and October

From the data of average monthly rainfall (as given in table 9), a histogram showing average monthly rainfall in the Kulsi basin has been prepared and shown in fig.6.

Table 10 : Average Annual and Monsoon Rainfall in Different Stations of the Kulsi Basin

Name of Stations	Average rainfall in mm	
	Annual	Monsoon
1. Chamaria	1944.80	1475.55
2. Singra	1917.21	1931.76
3. Boko	1843.25	1518.30
4. Ajara Airport	1625.76	1281.54
5. Palasbari (Mirza)	1822.46	1235.00
6. Rani Tea Estate	1341.40	1314.05
7. Hahim	1965.70	1911.85
Total :	12460.58	10668.05
Average rainfall in the basin (using arithmatic mean method)	1780.08	1524.00

(Source:Ref.No.2)

From the average annual rainfall figures of table 10, it is observed that the raingauge station Hahim around the basin receives maximum average annual rainfall while the station Rani Tea Estate around the basin receives minimum average annual rainfall. From the figures of average monsoon rainfall of table 10, it is observed that the raingauge station Singra in the Kulsi basin receives maximum average monsoon rainfall while the station palasbari (Mirza) around the Kulsi basin receives minimum average monsoon rainfall. In the last row of table 10, the average values of annual and seasonal rainfall in the basin have been estimated by taking the mean of average values of annual and seasonal rainfall of each stations of the Kulsi basin.

REMARKS & RECOMMENDATIONS

From the data (as given in table 1) of annual/seasonal rainfall in different meteorological sub-divisions of N.E.India, it is found that the values of annual/seasonal rainfall in different meteorological sub-divisions are not the same. The difference in the values of rainfall in different meteorological sub-divisions are due to the influence of local topography of the meteorological sub-divisions. Arunachal Pradesh receives maxm. annual rainfall due to presence of large rich forest area and other topographic features in the region of Arunachal Pradesh. Maximum seasonal rainfall is observed in the regions of sub-Himalayan West-Bengal & Sikkim. This is due to the fact that during the onset of south-west monsoon, the moisture laden monsoon winds first approach the regions of Sub-Himalayan West-Bengal & Sikkim and precipitate most of the moisture over these regions. By the time they approach Arunachal region much of the moisture is lost, and therefore, the less seasonal rainfall in this area.

From the graph (fig.4) of average monthly seasonal rainfall in Brahmaputra catchment in Assam for two distinct periods (1901-1950) and (1951-1960), it is found that the peak value of average monthly seasonal rainfall in Brahmaputra catchment in Assam for both periods is in the month of July.

In the present study of rainfall in Brahmaputra valley we have not included the study of rainfall characteristics of important sub-basins in Brahmaputra basin due to unavailability of rainfall data of the basins. So there is a need to carry out a study of rainfall characteristics of important sub-basins in Brahmaputra basin.

The study of rainfall in Kulsi basin has been carried out for average monthly, annual and seasonal rainfall and it has been observed that the maximum value of average monthly rainfall in the basin is in the month of July. The average monthly rainfall in descending order during the monsoon season is as July, June, Sept., August and October. The rainfall in the Kulsi basin is very low for the period January to March and November to December being on the average less than 14 cm.

But the studies of average monthly, annual and seasonal rainfall in the Kulsi basin are based on the rainfall data of short period (as mentioned in table 7) duration. For better result, there is a need to carryout a similar study of rainfall characteristics in Kulsi basin based on the data of long period (30 or 35 years) duration.

REFERENCES

1. Abani, K.Bhagabati (1986), 'Aspatial appraisal of land and natural vegetation in north-east India', Jr. of N.E. India Geographical Society, North-Eastern Geographer, Vol.18, No.1 & 2, pp.67-77.

2. Brahmaputra Board, Guwahati (1988), 'Hydrology of Kulsi Basin', A preliminary report on the Kulsi Multipurpose project, pp.8-20.

3. Barthakur, M.(1986), 'Weather and Climate of North-East India', Jr. of N.E. India Geographical Society, North-Eastern Geographer, Vol.18, No.142, pp.20-27.

4. Brahmaputra Flood Control Commission, Guwahati (1977), 'Meteorological conditions and flood producing storms in Brahmaputra Valley', A report on comprehensive plan for Brahmaputra Basin, Vol.I, pp.37-42.

5. Central Water Commission, New Delhi (1987), 'Annual and Seasonal Rainfall in different Meteorological Sub-divisions of India', A Brochure on Water Resources of India, pp. 02.

6. Dhar, O.N. & T.C.Changraney (1977), 'A study of meteorological situations associated with major floods in Assam during monsoon months', A report on comprehensive plan for Brahmaputra basin, Vol.I, pp.203-211, Brahmaputra Flood Control Commission, Guwahati.

7. Dhar, O.N., B.N. Mandal and G.C. Ghose (1978), 'Heavy rainfall stations of India', Indian Journal of Power and River Valley Development, Vol.28, No.2, pp.47-50.

8. Director of Agriculture, Govt. of Assam (1975-76) 'Basic Agricultural Statistics'.

9. Goswami, D.C. (1985), 'Physiography, Basin Denundation and Channel Aggradation of Brahmaputra River, Water Resources Research, Vol.21, No.7, pp.959-978.

10. Memoirs of IMD (1961), 'Monthly and Annual Normals of Rainfall and of Rainy days, 'Based on records from 1901-1950, Vol.XXXI, Part III.

11. Ramasastri, K.S. (1987-88), 'Distribution of precipitation with elevation'., TR-45, NIH, Roorkee (India).

12. Taher, M. (1986), 'Physiographic frame work of North-East India', Jr. of the N-E India Geographical Society, Vol.18, No.142, pp.1-19.

DIRECTOR ... Dr. SATISH CHANDRA

STUDY GROUP

Dr K K S Bhatia, Scientist F

Umesh Kumar Singh, R.A.