Chapter - 1

Physical Setting of North Bihar Plain
A. STRUCTURE AND RELIEF

The North Bihar Plain structurally forms part of the Indo-Gangetic Plain, covered with a thick mantle of alluvium of varying depth, which lies between the north Gondwanaland of Peninsular India in the south and the recently built young fold mountain chains of the Himalayas in the north. The Indian plain extends with a maximum width of 400 km. and about 2400 km. in length\(^1\), consisting of the sedimentary deposits brought down by the great Himalayan rivers through geological times. The detritus brought by the rivers ranges from big boulders to silt and clay. The arrangement of the beds and general form of the surface is due to sedimentation in inclined layers\(^2\). This sedimentation is believed to have taken place in the Gangetic trough of post-Tertiary formation and formed by Pleistocene alluviation.

The genesis and nature of this depression is a much disputed matter among the geologists. The Australian geologist, Edward Sues (1956), holds that it is a 'foredeep' formed in front of the resistant mass of the peninsula when the Tethyan sediments were thrust southward and compressed against them. The foredeep was gradually filled in by the eroded material from the Himalayas and Gondwana shield from south and this led to the formation of the plain\(^3\).

Burrard (1912), on the basis of geological data, postulates the origin of the depression in a totally different way. He holds the view, that

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the north Indian Plain represents a rift-valley bounded by parallel faults on either side with a maximum down throw of 32 km. Burrard's theory is based on geodetic observations and deductions but the Indian geologists have not accepted this view of the origin of Indo-Gangetic depression, because it is not much supported by geological facts and is not in conformity with the geo-physical observations.

A third and more recent view regarding this region is that it is a sag in the crust formed between the northward drifting of Indian continent and the comparatively soft sediments accumulated in the Tethyan basin when the later were crumpled and lifted up into a mountain system. The depression perhaps began to form in the upper Eocene and attained its greatest development during the third Himalayan upheaval in middle-Miocene. Since then it was gradually filled up by sediments to form a level plain with a very gentle seaward slope. Geological and geodetic data appear to support this view of the northward drift of the Indian continent and is more acceptable. Krishna and Aiyangar (1956) believe, that the available evidence indicates that this depression was a contiguous lagoon or foredeep formed in front of the Himalayan ranges. It is almost certain that Siwaliks extend down for several kilometers underneath the alluvial cover of the Indus and Gangetic valley. On the basis of the

6. Ibid., p. 529.
characteristics the Gondwana rocks formed on the northern rims of the alluvial belt of the plain. Wadia and Auden (1956), maintain that poninsular rocks consisting of the Archean geneses are continuous inside the plain. Continued loading of this belt by sedimentation, since the first upheaval of the mountain may have accentuated the sinking of the Archean floor, but as the process of sedimentation kept place with that of depression and led to the formation of the great plains of India. Since no boring has reached this Archean floor, it is difficult to ascertain its configuration. On the basis of geological and geodetic evidences several contradictory estimates of the depth of this depression are made. Oldham (1917), finds the depth of Gangetic trough to be 4.6 to 7 km at its northern edge. Cowle (1921), while criticising the above findings postulated even higher figures from the same data. However, the estimation has made it clear that the deepest part is near to the northern edge than the southern. It becomes shallower towards the peninsular margin.

The North Bihar plain, as it forms part of North Indian Plains, comprises the alluvial deposits of clay, silt and sand with occasional beds of gravel, calcareous nodules and peaty organic matter. Geologically, these deposits may be classified into two broad categories: the 'bhangar' or the older alluvium and the newer alluvium commonly known as

12 Krishna, M.S., op.cit., p. 512.
'khadar'. The bhanger corresponds to the deposits of Pleistocene age of the geological history, while the khadar belongs to the recent age. A clear distinction between these two depends on the fossils found with respective to ages which they show rarely and a distinct line of demarcation between these two divisions can hardly be drawn in the absence of full information regarding their fossil characteristics. The bhanger contains the remains of extinct species of animals including Rhinoceros, Hippopotamus, Palaeolaxoden, Elephas and Equus. The fossils in the newer alluvium are mostly those of animals still living\(^\text{13}\).

The alluviums of North Bihar plain are of varying depth. The greatest depth is thought to be within a few kilometres of the Himalayan foothills in a trough that extends from northwest to southeast through Motihari where the thickness of the deposits may be 1.8 km\(^\text{14}\). North of the Motihari - Purnia trough line, the deposits belong to the bhanger, which are dark in colour and usually rich in concretions and nodules of impure calcium carbonate known as 'kankar' which vary in shape and size. Generally speaking, bhanger forms the elevated lands almost above the flood level in the Gopalganj, Siwan, Saran, East and West Champaran, Muzaffarpur districts and the border zone along Nepal where the rivers have out thrown them to a lower level. This bhanger land is seldom inundated by rivers during floods. Some 'reh' a saline efflorescence mainly composed of the sulphate, carbonate and chloride of sodium is found in

\(^{13}\) Ibid., p 574.

the western part of the region in the Gopalganj, Siwan and Saran districts. The khadar, on the other hand, is still in the process of formation and belongs especially to the late or upper Pleistocene to recent age. These deposits occur along the river basins occupying comparatively shallow parts and is flooded during months of heavy rainfall. It is generally poor in calcareous matter and is lighter in colour. A third division may be added to these two broad divisions, which is known as 'bhat', quite unique in its character, the distinguishing feature being its remarkable whiteness. This is mainly found in the East and West Champaran districts. The bhangar land is mostly a levelled plain which stretches above the flood level of the main rivers and their tributaries. The presence of nodules of impure calcium carbonate or kankar in the bhangar land is due to the segregation of the calcareous material of the alluvial deposits into lumps somewhat like the formation of flint in the limestone (Wadia, 1939).

The entire tract of the North Bihar Plain is monotonously a flat plain without a single hill appearing above it. The only diversities seen are due to river action, a series of river side uplands are found which are known as levees. The general direction of the slope of the plain is from north to south towards the Ganga, but it is gentler in the west than in the east. North Bihar Plain is traversed by a series of southward flowing rivers namely, the Ghaghara, the Gandak, the Burhi Gandak, the Kamla and the Kosi, and their tributaries. The Himalayan streams originating mainly in the outer Himalaya deposit a huge load in the shape of alluvial fans at the foot-hills of mountain due to the sudden change in the gradient which

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15 Wadia, D N. *Geology of India*. New Delhi. 1939, p 369
becomes gentle. These rivers namely, the Kosi and the Gandak generally scour their beds and banks and remove the older alluvium from the higher northern tracts and deposit it further down streams in the southern section. The deposits are laid down in the southern part because of the greater flatness and lowlying nature of the region. Forced by new deposits the streams have developed a tendency to change their courses very oftenly. Sometimes they cut across the meanders and split off in a number of channels, so that there is not only the tendency of redistributing the alluvium within their beds and banks, but rather the alluvium seems to be spread far beyond the river banks, over a greater part of the surrounding country during the floods. Flooding of these rivers is, thus, a characteristic feature of the southern part of the North Bihar Plain.

North Bihar Plain can be divided into five district geographic divisions: (I) The Western Bhangar Plain; (II) The Burhi Gandak-Bhagmati Doab; (III) The Sub-Montane Bhangar Tract; (IV) The Kosi Flood Plain, and (V) The Ganga Riverine Strip.

1. The Western Bhangar Plain

This plain lies north of the Ganga river and spreads from west to the river Burhi Gandak. It covers the entire area of the Gopalganj, Siwan and Saran districts, southern part of the East Champaran, southern half of the Muzaffarpur, and west-central part of the Samastipur districts. This plain has a slightly higher elevation than the adjacent areas and is a level plain. It slopes gradually from northwest corner of the Gopalganj district which has an elevation of 68 m. above the sea level towards southeast
where the elevation is 30 m in the Begusarai district. The slope is imperceptible but the flatness of the surface is broken by the presence of mounds which mark the sites of old fortresses or deserted villages. The *khadar* villages are cut by major streams draining through the area. The uniformity of this level plain is also broken by the depressions and marshes that dot the entire area. These depressions are marked in southeastern part of the Muzaffarpur district where there are small *chaurs* (semi-circular or marshy low lands) or *tals* (natural depressions filled with water during rain).

**II. The Burhi Gandak-Baghmati Doab**

It is a narrow but long belt of *khadar* land running in north-west to southeast direction from Motihari in East Champaran to the confluence of the rivers Kosi and Ganga near Karhagola village in the Katihar district. It is a lowland area with an average elevation of 29 m. above the sea level, the lowest point in the North Bihar Plain region. It consists of *khadar* land traversed by the rivers of Burhi Gandak, Baghmati and Kosi. These rivers passing through this region are relatively narrow in their upper parts but open out and become broader in their lower courses. The Burhi Gandak - Baghmati Doab land of central Champaran, Muzaffarpur, Darbhanga is more or less level and forms a distinct lowland section studded with innumerable long semi-circular lakes formed due to the shifting course of the river Burhi Gandak. This low land section is subjected to inundation during rains. The Turki embankment has been constructed toward off the flood water of the river Burhi Gandak. The old bed of the Great Gandak and its depth varies from 1 to 6 m. The *doab* extends further eastwards to
include the Rosera-Bahera lowland in the Darbhanga district and Kabor Tal depression of the Khagaria district. Eastwards from Khagaria subdivision upto Naugachia subdivision of the Bhagalpur district, it may be called the Ganga-Kosi Doab because it is occupied mainly by the present channels of the river Kosi.

III. The Sub-Montane Bhangar Tract

An elongated belt of entirely different structure from the remaining part of North Bihar Plain runs parallel to the foot-hills from Sumeshwar and Dun ranges in the west in West Champaran district to the Kishanganj district in the east. It is an elongated tract formed of bhangar deposits. There are, however, some lowlying areas near the streams and marshes that are conspicuous amongst the highly elevated areas.

IV. The Kosi Flood Plains

In between the Bagmati river in the west and the Mahananda river in the east excluding the Mahananda upland in the northwestern Kishanganj district and Mahananda lowland in the south of Purnia district, the entire area is an extensive lowlying plain intersected by numerous small streams and marshes. It is a region which is liable to floods from the rivers traversing the area. These rivers are interconnected by numerous deep and wide channels called 'chaurs'. The only elevated land of the area is formed by levees of the large rivers from which the land gradually slopes outwards often meeting a similar slopping surface from some other rivers. The interfluvial plains are usually studded with numerous marshes which frequently have great areal extent. The whole of this eastern section can be
regarded as the flood plain of the Kosi. The river kosi and other Himalayan streams that drain this part have independent river basins or catchment area is very active because of active steep gradient, with the result that the enormous quantities of silt are brought down by each river. These rivers have great fluctuations in containing volume of water. The Kosi, for instance, is especially notorious with a rise of 9 m. from its level in 24 hours\textsuperscript{16}. It is worthwhile to note, that this river does not make deposits of silt like the Ganga but, on the contrary, brings enormous amount of coarse sand which is spread over the fields making them infertile. Sometimes the amount of detritus and sand is so great that the beds of the river are raised above the surrounding land. The Kosi has been responsible for enormous devastation by flood or by spread of micaceous sands\textsuperscript{17}. The Kosi flood plain is, thus, a 'sandy flat' full of dead channels of the Kosi river. In the vast expanse of the sandy deposits there develops pastures of fine grasses. These Prairie-like plains are called 'ramnas' that support a sizeable number of cattle and sheep. The newly formed alluvial deposits or chaurs are covered with dense jungles of coarse grass forming a good cover for wild animals\textsuperscript{18}.

V. The Ganga Riverine Strip

It is a narrow strip of lowland which extends along both sides of the main bed of the river Ganga from 3 to 16 km wide. It is a low plain where the Ganga takes an intricate meandering and often makes sharp bends leaving at places semi-circular channels forming ox-bow lakes called

\textsuperscript{17} Spate, O H K., \textit{India and Pakistan}, London. 1967, p. 565.
called *charas*. The braided pattern of streams and shifting of channels are the main characteristics of the streams is subjected to great variation with respect to width and aggradation at one end and degradation at the other. At one place the river appears to cut into its bank and wash away village sites and groves, at another the shore is receiving a new alluvial deposits to fill up the void space left by the receding waters, wherever the banks are high they present an effective barrier against the degradational action of the streams. Several such high banks occur close to the Ganga standing as natural levees and these afford good reparian sites for human settlements. One such high bank runs from Chapra to Dighwara and Pahleza ghat in the Saran district. The highlands are always liable to cutaway and the lowlands which lie behind these natural levees or high banks are regularly inundated every year by the river Ganga floods which find their way through the drainage openings on its banks and while spreading over the inland country to fill the large marshes or *chaurs* which are so prominent features behind these high banks in the Saran, Khagaria, and Bhagapur districts, where the banks are slopping, the river beds set up an eddy in the current which become sufficiently stationary to deposit a portion of the sand which it holds in solution. The level of the *diara*, which is so far nothing but a heap of sand, then gradually rises as the water lying stagnant spreads a thin layer of clay and silt over the sand and this deposit of silt increases at every high flood until the *diara* rises above flood level. The soil of *diara* land is very fertile and grows a number of crops. The southern fringes of the Vaishali, Samastipur, Begusarai,
Khagaria, and Katihar districts and the central part of the Bhagalpur district allow flood waters to spread sometimes upto 14 km. of area in the interior portions. The water of Ganga spreads over the lowlying tract to the extent of about 32 km. to the north of the main channel. At places the Ganga not only overflow the country on its bank but also forces back the waters of the Gandak river and inundates the land between the two Gandak embankments far above the Hajipur. Extensive sandy beds and diara lands have emerged out in the Ganga riparian tract.

B. DRAINAGE

All the rivers of North Bihar Plain, rising in Himalayas, flow from north to south along the slope of the region and ultimately discharge themselves in the Ganga river. The important rivers of this region are the Ghaghara and its tributaries, the Jhorahi and the Daha, the Gandak, the Burhi Gandak with its tributaries, the Baghmati, the Kosi and its tributaries, the Kamla and the Balan and the Mahananda.

The Ghaghara

The river Ghaghara also known as the Sarju is a mighty river commanding a large catchment area in the Himalayas. It has its source in the Himalayan glaciers about 60 km. to the southwest of Manosarowar at an elevation of 4,800 m. The Ghaghara is joined on its left bank by the little Gandak about 3 km. south of village Gothini where it forms the boundary between the states of Bihar and Uttar Pradesh. After receiving the Jhorahi and the Daha rivers on its left, it finally joins the Ganga a few kilometres down stream from Chapra. The course of the river Ghaghara is
liable to great fluctuations. It has an average gradient of 21 cm. per km. in this region. The banks at many places are high but, like the river Ganga, it inundates the countryside by forcing its way up the small tributary rivers. The total length of the river Ghaghara in the Saran district is about 88 km. and it commands a drainage basin of 3,000 sq. km. in Bihar.

The Gandak

The river Gandak, known as the Saligrami in Nepal, and Narayani or Kali in Indian Plains, is one of the important rivers of North Bihar Plain. The main source of the river is in the northeastern part of Dhaulagiri in Tibet. It flows across the districts of East and West Champaran, Gopalganj, Saran, Vaishali and Muzaffarpur for about 250 km. in North Bihar Plain and drains a total area of about 7,620 sq.km. It joins the river Ganga at Sonepur. Its banks are generally higher than the adjacent land, often overflow and inundates large tracts of land during the floods. The Gandak has no tributary all through its course in the plains. The total length as it attains reaches to 630 km. The Gandak project has been contracted at Tribeni which irrigates about 1.47 million hectares of land in North Bihar Plain, Uttar Pradesh and Nepal. This project has reduced the revages from the floods and has been helpful for the establishment of small scale industries through the supply of cheap hydro-power. The total command area of the project in North Bihar Plain accounts for about 9.53 lakh hectares in the districts of East and West Champaran, Gopalganj, Saran, Siwan, Muzaffarpur and Vaishali.

The Burhi Gandak

It is known as the Sikarana in its upper reaches and rises in East Champaran district from a spring of the Sumeshwar hill at an elevation of 300 m. above the sea level. It has a drainage area of about 10,150 sq. km. and flows for a total length of 320 km. The river is practically a collection of hill torrents rising from springs in the beginning and then assumes a form of river. After flowing for a distance of about 56 km. it takes a southerly direction and then South-easterly turn and flows through the Muzaffarpur district for about 32 km. After passing through Samastipur and Begusarai districts it joins the river Ganga. The rivers which drain the area to the east of the Burhi Gandak and upto the Kosi are known as the Adhwara group of rivers. The most important of these are the Bagmati and the Kamla rivers. These rivers are characterised by steep gradients in the Himalayan region and their flatter slopes lower down. This results in the dropping of silt load in the middle of the channel and a consequential spill over of water leading to the transfer of flood waters from one river to another. These rivers also have a tendency to shift their courses owing to immature topography of the region. The Bagmati, a tributary of the river Burhi Gandak rises in the Shivapuri hills of Nepal at an elevation of 1.5 km. The river Bagmati cuts across the Mahabharat range of hills and enters India at Rasulpur in Sitamarhi district, and later joins the river Burhi Gandak near village Barna in the district of Samastipur. It has a drainage area of 6,320 sq.km. in North Bihar and a length of 396 km. The waters of Bagmati carry vast amounts of silt which, when deposited through floods in the nearby area, increases the fertility of land.
The Kosi

The river Kosi or 'Kausika' of the legends is the widest and the most uncertain among the Indian rivers\(^{21}\). This rises in the Himalayan region of Nepal. It is formed by a confluence of three streams, namely, the Sun Kosi, the Arun Kosi and the Tamur Kosi. With a length of 468 km., it has a drainage area of 74,500 sq. km. of which 11,070 sq.km lie within the country. The river enters Indian territory about 25 km. to the south of Chatra gorge. It is most notorious for changing its course and there is perhaps no river in India which changes its course so frequently as Kosi\(^{22}\). It has a tendency to change its course generally to westwards. During the last 200 years, the river has shifted its course westwards for a distance of about 112 km. and has laid waste by depositing coarse silt extensive tracts of agricultural land in the districts of Darbhanga, Araria, Kishanganj, Purnia, Madhepura, Saharsa and Katihar. A barrage has been constructed at Hanumangarh for preventing the river moving out sides and for storing water for irrigation purposes. Two canals take off on either side of the river and irrigate about 1.04 million hectares of agricultural lands.

River Kamla rises in the Mahabharat range of hills in Nepal at an elevation of 1,200 m. It receives many tributaries of which the Chandala, the Jawakhola and the Thakur are important. After flowing for about 50 km. in Nepal it enters in India near Jayanagar in Madhubani district. The river, thereafter, is known as Kamla-Balan and flows in a southeasterly

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direction until it joins the river Kosi on the border of the Darbhanga and Saharsa districts.

The Mahananda

River Mahananda rises in the Mahaldiran hills of the Himalayas in the Darjeeling district of West Bengal at an elevation of 2,100 m. The river enters in North Bihar plain in the northeastern district of Purnia and after covering a distance of 376 km. finally leaves the area at the eastern tip of Katihar district. On its later journey the river passes through West Bengal and joins the river Ganga at Godagiri.

C. UNDERGROUND WATER

As the alluvial tract of North Bihar plain forms a part of the central Gangetic Basin where unconsolidated sediments have been deposited over the undulating surface of Archean rock. This tract is composed of sand, silt and clay materials which make the whole of North Bihar Plain except a small patch in West Champaran where the Siwalik squad stones are the main formation. The sediments of this region attain a greatest thickness of as much as 2,500 m. in the Saran, Vaishali and Muzaffarpur districts. These alluvial formations are prolific water bearing horizons. Underground water occurs under confined conditions in the deeper reaches. In the northern part of the tract, parallel to the Siwalik ranges, hydrological situation gives rise to the flowing well conditions. In the northern parts, around Begusarai, the confined aquifers exhibit considerable salinity. The sediments show a marked increase in percentage of granular zones northwards. The Central Groundwater Board, which monitors the water level of shallow aquifers, has pointed out that the water levels are comparatively shallower (less than 5 m.) in the alluvial tract.
In the Ghaghara, the Gandak, the Burhi Gandak and the Kosi sub-basins of North Bihar Plain, the ground water level fluctuations are as follows:

- 0 to 5.10 metres in Ghaghara Basin
- 0.79 to 7.00 metres in Gandak Basin
- 0.73 to 8.11 metres in Burhi Gandak Basin
- 0.65 to 7.52 metres in Kosi Basin

The water level records from observation wells indicate that during the months of August and November large tracts of foot-hills and plains of North Bihar have water levels within two metres from the surface. The areal extent of the zone with water levels within 2 metres below ground level during different months is given in Table 1.1.

**Table 1.1**

<table>
<thead>
<tr>
<th>District</th>
<th>Geographical Area (km²)</th>
<th>Areal Extent of the zone with water table within 2 mgl (km²) in different months of the year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champaran East</td>
<td>3968</td>
<td>Aug. 330</td>
</tr>
<tr>
<td>Champaran West</td>
<td>5228</td>
<td>Aug. 450</td>
</tr>
<tr>
<td>Darbhanga</td>
<td>2279</td>
<td>Aug. 100</td>
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<tr>
<td>Gopalganj</td>
<td>2033</td>
<td>Aug. -</td>
</tr>
<tr>
<td>Katihar</td>
<td>3057</td>
<td>Aug. 50</td>
</tr>
<tr>
<td>Madhubani</td>
<td>3501</td>
<td>Aug. 200</td>
</tr>
<tr>
<td>Muzaffarpur</td>
<td>3172</td>
<td>Aug. 150</td>
</tr>
<tr>
<td>Purnia</td>
<td>7943</td>
<td>Aug. 1200</td>
</tr>
<tr>
<td>Saharsa</td>
<td>5900</td>
<td>Aug. 2000</td>
</tr>
<tr>
<td>Saran</td>
<td>2641</td>
<td>Aug. 665</td>
</tr>
<tr>
<td>Sitamarhi</td>
<td>2643</td>
<td>Aug. 800</td>
</tr>
<tr>
<td>Siwan</td>
<td>2219</td>
<td>Aug. 85</td>
</tr>
</tbody>
</table>


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Table 1.1 indicates that the districts of Saharsa, West Champaran, Gopalganj, Purnia and Saran have substantial areas where underground water table remains below 2 m. during the months of August and November. These areas can pose problems for *rabi* crops due to a progressive rise in water table as a consequence of surface irrigation. In the districts of East and West Champaran, Darbhanga, Madhubani, Samastipur, Muzaffarpur, Sitamarhi and Vaishali, most of the area is underlain by alluvium of recent origin extends down to a depth of 130 to 140 m. The alluvium comprises of a succession of sand beds of varying texture mixed with silt and clay with occasional *kankar*. Underground water occurs in the shallow aquifers. The water table is normally 2 to 6 m. below ground level in winter and 2 to 8 m. in summer.

The area lying in the Kosi sub-basin is underlain by alluvial clay, sand and silt of recent origin. In the western part of the basin, underground water occurs under semi-confined conditions, whereas, in the eastern part, where sand beds persist vertically and laterally underground water occurs between 40 and 100 m. below ground level. The use of ground water for agricultural purpose is much higher in the region.

**D. CLIMATE**

The North Bihar Plain enjoys a tropical monsoon climate which is characterised by a rhythm of seasons produced by the southwest and northeast monsoons. The reversal of pressure takes place regularly twice a year due to prevalent winds. During the northeast monsoon period, the wind blows from west to east, and they are almost dry because of their
continental origin. The weather conditions in this season are marked by clear skies, low humidity, and extremes of temperature. The pressure gradient is gentle and the winds are, therefore, weak. During the southwest monsoon period, the winds blow from the east towards west. They are oceanic in origin and laden with much moisture. The intense heating of the area during this season produces steep gradients owing to which the wind blows relatively with a high speed. The associated weather is characterised by overcast skies, heavy rainfall and high relative humidity. Taking into consideration the nature and direction of these winds, the appropriate terms of dry monsoon and wet monsoon are applied.

The seasonal rhythm of monsoon reversal is the chief characteristic of the region, the slightest variation largely controls the agricultural operations in the area. The two farming seasons of kharif and rabi are associated with the wet and dry monsoons. The dry northeast monsoon extends from the month of November to the middle of June, and temperature variations between the first four months and the last three and half months of the year are so great that they divide this period into cold weather season (to include the months of November, December, January, and February) and hot weather season (to include the months of March, April, May and the first half of the month of June). The cold weather season corresponds with the season of rabi crops, while the hot weather season is generally dry and rarely permits agricultural operations. The wet monsoon season includes the remaining months of the year i.e., from mid-June to October and corresponds with the kharif season. Thus, there are three distinct seasons most commonly recognised in the North Bihar Plain:
The cold weather season (November to February)

The hot weather season (March to mid-June); and

The season of rains (mid-June to October).

1. The Cold Weather Season

With the retreat of southwest monsoon, the region comes gradually under a high pressure belt which develops and extends over the plain due to continued low temperatures. The prevailing winds blow from west to east and their direction is determined by the combined effect of the pressure distribution and the presence of lofty mountain ranges of Himalayas. The pressure gradients are not enough steep to produce strong winds. The breezes are light and have a velocity of about 3 or 4 km/hour during the months of November and December, and the days are warm and nights are cool.

It may be seen from Table 1.2, that the mean monthly temperatures recorded at the stations of Motihari in the north western part, and Purnia in the eastern part, during the month of November are 21.1°C and 20.4°C respectively. The mean minimum temperatures in the same month and at the same stations are 10.2°C and 9.7°C, while the mean maximum temperatures recorded are 32.0°C and 31.2°C respectively. The lowest temperature recorded in the month of January at Motihari and Purnia are 5.0°C and 4.1°C respectively. The mean maximum temperatures for the respective stations in the same month are 25.3°C and 26.9°C. By the month of February, temperature begins to rise but still remains low as compared to that of November (Fig.1.2). A significant climatic feature of this season is the
<table>
<thead>
<tr>
<th>Months</th>
<th>Bhagalpur</th>
<th>Chapra</th>
<th>Darbhanga</th>
<th>Motihari</th>
<th>Munafpur</th>
<th>Purma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Max</td>
<td>Mean Min</td>
<td>Mean Monthly</td>
<td>Mean Max</td>
<td>Mean Min</td>
<td>Mean Monthly</td>
</tr>
<tr>
<td>January</td>
<td>27.4</td>
<td>8.4</td>
<td>17.9</td>
<td>26.5</td>
<td>7.1</td>
<td>16.8</td>
</tr>
<tr>
<td>February</td>
<td>32.0</td>
<td>9.8</td>
<td>20.9</td>
<td>32.0</td>
<td>8.3</td>
<td>20.2</td>
</tr>
<tr>
<td>March</td>
<td>38.2</td>
<td>14.4</td>
<td>26.3</td>
<td>37.9</td>
<td>12.5</td>
<td>25.2</td>
</tr>
<tr>
<td>April</td>
<td>41.4</td>
<td>19.3</td>
<td>30.4</td>
<td>41.6</td>
<td>17.7</td>
<td>29.7</td>
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Source: *Climatological Tables of Observatories in India*, Indian Meteorological Department, New Delhi
Mean Monthly Maximum, Minimum and Average Temperatures (°C) of Selected Stations of North Bihar Plain

- **Bhagalpur**
- **Chapra**
- **Motihari**
- **Darbhanga**
- **Purnia**
- **Muzaffarpur**

---

**Fig. 1.2**
occurrence of fog (locally known as kohra) in the early hours of morning which adversely affects the cultivated crops of arhar, peas, gram, rapeseed and mustard.

During this season, the relative humidity remains high during the month of November being 75, 74, 72, 69, 69 and 66 per cent at the stations of Purnia, Motihari, Muzaffarpur, Bhagalpur, Darbhanga and Chapra respectively. The relative humidity never goes below 59 per cent in any of the four months at any station. Motihari records 74, 76, 76 and 65 per cent during the months of November, December, January and February respectively (Table 1.3).

The incidence of rain during the cold weather season is rare, irregular and sporadic. It is locally heavy and sometimes associated with thunderstorms. The average rainfall in the month of January at Motihari is 1.63 cm which is relatively high in the cold weather season (Table 1.3). The rainfall which is received during this season is beneficial to the rabi crops. But the failure or any deficiency in winter rain adversely affects the yield of rabi crops in the region.

Amidst the general fine weather, there occurs some western disturbances during the months of December, January and February. The region is benefitted with the small rain when these depressions appear in this season. Some of these depressions originate in the Mediterranean region and a few comes as far as from the north Atlantic. The rainfall brought by these depressions is preceded by a warm weather with light southerly or easterly winds and cause a slight increases in temperature. The cloudy weather is of temporary nature and lasts for a day or so and is
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Source: *Climatological Tables of Observatories in India*, Indian Meteorological Department, New Delhi.

RF = Rainfall (cm)
RH = Relative Humidity (Per cent)
followed by clean skies. Trewartha (1962)\textsuperscript{24} considered the course of western depressions as that of the presence of a Jet Stream across the northern India. These depressions reach at their maximum development in this season when the Jet Stream lies south of the Himalayan mountains. In rare cases, these cold weather depressions bring with them a phenomena of hailstorms. These hailstorms damage the cultivated \textit{rabi} crops heavily if they occur late in the months of January and February when the flowers and immature ears of the plants are bruised badly. If they occur during the months of November and December the damage done to field crops by them is relatively of low account.

\textbf{II. The Hot Weather Season (March to mid-June)}

The hot weather season starts from the month of March when temperature begins to rise characteristically resulting in a relative fall in pressure and relative humidity. This increase in temperature reaches its highest in the month of May which continues through June until the onset of southwest monsoon. The mean maximum temperatures at Motihari and Purnia in the month of May are 40.9°C and 40.5°C, while the mean minimum temperatures for the same stations in the same month are 18.7°C and 18.4°C respectively (Table 1.2). The velocity of the wind varies from 3.4 km/hour to 9.4 km/hour. The relative humidity is generally far below 60 per cent during the hot weather season. It is important to note, that the heat during these months is greater, not only in the western districts but also in areas lying along the Ganga river.

In the summer months, hot dry winds locally known as "loot" are the regular phenomena and their intensity becomes greater in the months of May and June. The most characteristics feature of hot winds is their intense dryness and excessive temperature of far reaching consequences. Their velocity increases during the afternoon as they blow with violent force (till 4 p.m.) in the evening hours of the day, and thereafter their force is retarded to such an extent that it seems that they have practically disappear from the scene. The humidity on such occasions sometimes falls to as low as 2 per cent from noon hours to 4 p.m. Such conditions persist until the middle of the June prior to the onset of the southwest monsoon.

The occurrence of violent storms locally known as 'andhi' is the another phenomena of this season which lasts for a short time giving a redish-yellow glare to the sunlight especially in the afternoon. Sometimes these storms bring a small amount of rain, which is of local nature.

The rainfall received during this season is sporadic and of short duration subjected to greater local variations and very oftenly occur at the same hours of the day, and continue for several days in succession. The rain sometimes is accompanied with the storms that may often take forms of violent squalls. The total rainfall received from these squalls in the months of March to May, ranges from 0.6 cm (at Muzaffarpur) to 9.4 cm (at Purnia). The month of June sometimes may receive the highest amount of rainfall, the amount of rainfall received during this month varies at Purnia, Bhagalpur, Darbhanga, Muzaffarpur, Motihari and Saran stations in the order of 22.7, 18.2, 16.9, 16.6, 19.7 and 11.9 cm respectively (Table 1.3). A low humidity high temperatures and cloudless skies in the
months of March and April favour the ripening of *rabi* crops. An increased speed of wind in the months of April and early May helps much in threshing, and subsequently the winnowing of output of cereal crops.

**III. The Season of Rains (mid-June to October)**

The beginning of the month of June is marked by a more severe characteristics of the hot weather season when the scorching heat coupled with excessive dryness in the atmosphere becomes intolerable. At this time an intense low pressure area develops in northwestern parts of India. As a result, the zonal westerlies over northwestern India begin to move northward but they are resisted by the presence of mountains. Consequently, the Jet Stream which stays south of the mountains at about 30°N latitudes during the winter tends to alternately disappear and then reappear again south of the mountains. This disappearance is associated with the northward advance of the summer monsoon. Finally in late May or early June, the Jet Stream disappears completely from northern India and takes up a position at 40°N to the north of the Himalayas. At the same time, there occurs a northward movement of the low pressure trough from 85°E to 75°E over western India. With the disappearance of Jet Stream over northern India and a northward shift of the trough, monsoon winds enter the plains.\(^{25}\)

These moisture laden winds bring an abrupt change in the weather and a sudden fall in day temperature. The atmosphere becomes cool and pleasant. The mean minimum temperature ranges between 21.1°C

\(^{25}\) Ibid. p 159.
Relative Humidity (in%) of Selected Stations in North Bihar Plain

Motihari

Muzaffarpur

Darbhanga

Chapra

Bhalagpur

Purnia

Fig.1.3
and 23.3°C and mean maximum between 42.5°C and 38.2°C. The mean monthly temperatures during this month ranges from 32.9°C to 28.7°C in North Bihar Plain.

Each of the mean minimum, mean maximum and mean monthly temperatures gradually drop from June to the end of September. Relative humidity records 48 to 85 per cent from May to July. A comparison of relative humidity at different stations shows that in each of the month from July to October it remains generally high (Fig. 1.3). In July at Motihari, it recorded as 83 per cent and at Purnia, it was 85 per cent. At all stations it is highest in the months of July and August which is the period of growth of *kharif* crops.

**RAINFALL - RHYTHM**

The rainfall rhythm of the North Bihar Plain is well marked by the concentration of rainfall during the months of mid-June to September. The remaining months of the year are marked by the dry conditions except the months of January and February which receive a small amount of rain through the western depressions. The rainfall received during the period from June to September is copious because the two main currents of the monsoon, i.e., of Bay of Bengal and Arabian Sea after meeting in central India reach here with an increasing force. The intrusion of the Himalayas bring about heavy rainfall in the immediate neighbourhood of the southern Himalayan slopes. It may be seen from the Fig. 1.4, that the eastern districts namely, Kishanganj, Araria, Katihar, and Purnia receive the highest rain. The rainfall recorded in these districts amounts to more than 150 cm. The
NORTH BIHAR PLAIN
AVERAGE ANNUAL RAINFALL
(in centimeter)

INDEX

Above 150
140 - 150
130 - 140
120 - 130
110 - 120
Below 110

SOURCE: BASED ON COMPUTED DATA, DIRECTORATE
OF STATISTICS AND EVALUATION, PATHA, BIHAR.

FIG. 1.4
northern parts of the Plain receive rainfall between 140 and 150 cm. The rainfall between 120 and 140 cm is received in the central and southeastern parts of the region. The districts of southwestern parts received very low rainfall with the index value below 110 cm. It may be observed from the figure that the rainfall decreases from east towards west and also from north towards south.

It is seen from Table 1.3 that about 86 per cent of the total rainfall is received during the period from June to September, whereas only 3 per cent is received for the months of November to February.

The period of wet monsoon does not constitute a continuation in rainy days, but the continuation of rainy days is altered with the spells of fine and pleasant weather, which are very much advantageous for the kharif crops. These spells of fine weather do not last for many days and are produced by "a shoulder of the high pressure" which embraces the whole region by pushing the axis of low pressure of northern India towards the foothills of the Himalayas.26 The rainless period with clear sky is most welcomed to the farmers of the region because the continued rain with cloudy sky not only damages the crops but also intrupt the agricultural activities.

E. SOILS

The soils of North Bihar Plain are thick cover of alluvium deposited for ages over Siwaliks and old Tertiary rocks. These drifted alluvial soils are relatively young, and constantly rejuvenated, by the

depositon of silt and sand, through numerous Himalayan streams. They are deficient in phosphoric acid, nitrogen and humus, but rich in potash and lime27.

The soils of the area may be grouped into 3 broad categories: (I) Swampy soils; (II) The Gangetic Alluvium; and (III) Calcareous soils.

I. Swampy Soils

These soils are found in a narrow belt of Tarai in the north of West Champaran district and belong to the sub-montane region. This tract is characterised by excessive moisture not only because of much rainfall but also by reasons of continuous seepage of water from the slopping pebble zone immediately on its north. These soils remain much saturated during the monsoon months and fairly moist during winter due to the presence of high level of underground water-table. The soils are mostly clay or dark grey colour. Being clayey in nature and highly retentive of moisture they are therefore, most suitable for the cultivation of rice crop28.

II. The Ganga Alluvium

The Ganga alluvium covers a vast area along the banks of rivers namely, the Ganga, the Gandak and the Kosi. The soils of this group are generally light textured, light grey in colour and moderately alkaline in reaction with medium to high fertility status. The alluvium is mostly loamy in texture although sand and clay proportions vary from place to place.

27 Royal Commission on Agriculture in India. 1928. p. 72
Saltpetre or potassium nitrate is a natural formation in the soils found in the western districts of North Bihar Plain. The alternative warm and humid climate of the region offers most favourable conditions for the accumulation of this salt in the sub-soil. Large amount of animal and vegetable refuge gathered around the villages is decomposed into amonia and other nitrogenous substances. These are acted upon by certain kinds of bacteria (nitrifying bacteria) in the damp hot weather, with the result that at first nitrous and then nitric acid is produced in the soil. This nitric acid readily acts upon the salts of potassium with which the soil is impregnated on account of large quantities of wood and dump ashes. The nitrate of potassium, thus, produced is dissolved by rainwater and accumulates in the sub-soil, from which salt re-ascends to the surface by capillary action in the period of desiccation which is followed by the rainy season\(^29\). Large quantities of nitre are, thus, left as saline efflorescences on the surface along with some other salts such as chlorine of sodium and carbonate of sodium\(^30\).

The general monotony in the appearance of the alluvium leads to the misconception that it is homogenous while, as a matter of fact, the varying conditions of environment have imparted to them marked variations from place to place. The content of lime varies greatly from a high percentage in the western parts to a very low amount in the eastern parts. The sub-soils are not uniform in texture but consist of well defined layers varying from pure sand to heavy clay. Variations in the fertility of

\(^{29}\) Ibid. p. 62.

soils from place to place especially, in the east (where the rainfall is the heaviest) are not so much due to differences in the surface soil but may be due to varying capacity of moisture retention. The pH value of these soils varies from nearly neutral (7 pH) to alkaline (8 pH) in calcareous zones and alkaline to acidic (6pH) in the non-calcareous zones of Saharsa.

The Ganga alluvium is of two types:

(i) Older alluvium or bhangar; and

(ii) Newer alluvium or khadar

(i) The older alluvium or bhangar is found at some distance away from the main rivers. It is heavier with greater clay proportion than khadar. The bhangar of North Bihar Plain generally lies between the higher levels of streams in lowlying interfluves and is inundated by waters during the rains through spill channels which cut through the levees. Bhangar land forms typical paddy area of North Bihar Plain. It contains much lime and kankar. This group of soil occupies a vast area of the East and West Champaran, Sitamarhi, Madhubani, Darbhanga, Araria, Kishanganj, Purnia, Supaul, Madhepura districts. It also occurs in the district of Muzaffarpur, and in the northern parts of Bhagalpur and Khagaria districts, and a small patch in Begusarai district.

(ii) Newer alluvium or 'khadar' is different from older alluvium or bhangar in terms of texture and chemical composition. Soils comprising the newer alluvium are grey to ash grey in colour, and clay loam to clay in texture. It is generally found along the banks of rivers and streams, is highly leached form, low in humus and nitrogen and poor in lime content. It is found
along the river Gandak in the districts of East and West Champaran, Muzaffarpur and Vaishali and in a narrow belt along the Ghaghara river in Saran district. It covers the largest area in Kosi region. This soil is suitable for the cultivation of sugarcane, paddy and a few rootcrops. The entire Saharsa district is occupied by clayey soils. The soils of this area are low to medium in fertility, and are devoted to paddy and jute cultivation. The clay belt merges to loamy soils in the east and sandy loam soils of the Kosi belt.

III. Calcareous soils

Calcareous soils occur in the Tirhut division of northwestern Bihar Plain. This belt of soil roughly corresponds with the bhangar area of the districts of Gopalganj, Siwan and Saran and also the khadar tract of the Gandak river in the Champaran (East & West). This soil is well developed and occupies the whole of Muzaffarpur and the western part of Darbhanga. The presence of bed of khadar kankar nodules is a common feature in the sub-soil. The clay has not undergone any marked translocation from surface to lower layers and a retarded leaching has led to the accumulation of calcium carbonate which is present even in the surface soil. Calcareous soil is more useful for lichi (Litchi chinensis) plants which are grown in the East Champaran, Vaishali and Muzaffarpur districts. This soil is highly rich in lime content.