CHAPTER I
CHAPTER I

PHYSICAL SETTING

Structure and Relief

Structurally Uttar Pradesh forms part of the Indo-Ganga Plain. From its geographical shape and configuration and also from the studies available, the Ganga trough points to a possible relationship between southern peninsular shield and the Himalayan mountain chains. A study of the basement rocks below the Gangetic alluvium suggests a northerly slope with a thickening of sediments in the same direction. On the basis of the aeromagnetic, gravity, seismic and other geophysical and geodetic studies, the floor of the Indo-Ganga plain in found to be uneven and the thickest sediments lie below the outer Himalaya. Eduard Suess, the Austrian geologist, suggests that the plain constituted a 'fore deep' in front of the high crust waves of the Himalayas as in their southward advance they were checked by the inflexible solid land mass of the peninsula. The rivers rising from the Himalayas brought an immense amount of detritus and deposited it in this depression. The deposition of the alluvium continued although the Pleistocene period up to the present and led to the formation of the plain.¹ 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. The total thickness of the alluvium is not known. Oldham estimated the depth of the alluvium between 4000-6000 m and Burrard considered the existence of a fault with 32 km downthrow near the Himalaya. Later Glennie estimated the thickness at about 2,000 m. The aeromagnetic survey of the Ganga Valley\(^2\), thrown much light on the depth of the alluvium and nature of the trough. The alluvial filling on an average is 1300-1400 m, decreasing gradually southward, a zone of over 8000 m depth runs all along the Himalayas. The extensive pre-existing basins, such as Kathgodam-Lakhimpur basin and Bahraich basin and similar others such as Gorakhpur and Motihari basins falling in the middle Ganga Plain and connected together with narrow necks, probably between the peninsular projections, have been indicated within the 8000 m depth zone. The westward decrease of the depth is well marked as the small basin lying to the west of the Moradabad-

Kathgodam alignment has less than 6000 m depth of the alluvium. The Doab South of Bulandshahr has in general, less than 1500 m alluvial depth. Thus in the south, the alluvial cover gradually thins out to a mere veneer, finally merging with the irregular edge of the peninsular block. The alluvial depth is, at places is less than 3000 m thick probably on the detached protrusions of the peninsular block as around Shahjahanpur and is less than 1500 m near Faizabad and Gonda (Middle Ganga Plain). Although nearly half of the Upper and Middle Ganga Plain lying roughly South of the Hapur-Etah-Unnao-Pratapgarh-Bhadoli-Ghaziipur-Jagdishpur-Hajipur and Purnea alignment has less than 1500 m thick alluvial deposit. The subterranean crustal dislocations, the probable causes of earthquakes, have been identified more or less separating the aforesaid basins, notable being Moradabad-Kathgodam, Balamau-Kheri.³

The general relief of Uttar Pradesh (Fig. 3) shows that one-sixth area of the state lies in the Himalayan region covering the districts of Dehra Dun, Uttarkashi, Chamoli, Pithoragarh, Almora, Nainital, Garhwal and Tehri Garhwal. The general slope is from north-west to south-east. The whole of the mountainous tract is highly

dissected and rugged. This region may be divided into three zones, viz. Greater Himalaya, Lesser Himalaya or Kumaon Himalaya and Sub-Himalaya or Siwalik. Greater Himalaya is the northernmost zone with an average height of 6000 metre and above. Districts of Uttarkashi, Chamoli and Pithoragarh lie in this zone. The main peaks of the region are Nanda Devi (7817 m), Kamet (7756 m), Badrinath (7138 m) and Trisul (7120 m). The Lesser Himalaya has an average height of 3000 metre, with a width varying from 80 to 100 kilometres. These ranges abruptly rise from the Siwaliks. There are spurs in these ranges where important hill stations such as Mussorie, Nainital, Ranikhet, Almora, Lansdowne etc. are situated. Sub-Himalaya or Siwaliks are constituted of small hills which run along the Ganga Plain. The height of these ranges vary between 300 to 600 metre. In between the Lesser Himalaya and Siwaliks, there are discontinuous valleys called 'duns' the width of which is upto 24 kms. Some important 'duns' are Dehra Dun, Kota Dun, Patli Dun, etc.

About three-fourth of the total area of the state is an alluvial plain lying between Himalaya in the north and the uplands in the south. The average height of the Ganga Plain in the state ranges between 300 to 60 metres. The northern part of the plain or upper Ganga plain has a height between 300 to 150 metres. The land in this part
slopes in an approximately southeasterly direction from Bijnor (260 m), Meerut (240 m), through Moradabad (221 m), Bulandshahr (207 m), Aligarh (185 m), Mainpuri (170 m), to Farrukhabad (160 m).

The other part of the Ganga plain lying in Uttar Pradesh is part of the Middle Ganga Plain. Here again the height decreases in a southeasterly direction. The lowest height of the plain is 58 metre recorded at Ballia in the extreme eastern corner of the state.

The southern part of Uttar Pradesh however is an upland area with a general height rarely exceeding 300 metre. The surface slope of this part runs from southwest to northeast.

The alluvial deposits of Uttar Pradesh in general are homogeneous in character. However it is possible to recognize, on the basis of the geological age, two separate types of deposits: the older alluvium and newer alluvium. The older alluvium commonly known as bangar, occupies the higher ground which is beyond the reach of flood waters. The bangar is characterized by the presence of nodules called kankar which contain the carbonate of lime. Patches of saline and alkaline efflorescence appear on bangar land, which is locally known as reh. The formation of reh is the outcome of gentle slope of the
land and the composition of the alluvium. The low gradient leads to a sluggish movement and greater percolation of water. During monsoon rains, nutrient minerals are washed down to the deeper horizons of the soil but in dry summer months the process of leaching is intercepted and extensive evaporation exerts a capillary pull on the solution in the pores of the soil. On reaching the surface these solutions evaporate leaving crystallized salts as a white incrustation on the ground.

The newer alluvium or khadar occupies comparatively low land liable to inundation during floods. It is confined to the riverian tracts of the Ganga, the Yamuna, the Gomati and Sai. The khadar owes its origin to bangar land by the erosion of rivers. The low level of the Khadar land is in conformity with the principle that as a river gets older, more and more of its deposits are found to be of younger age and as the bed of river sinks lower, these younger deposits come to occupy a level lower than that occupied by earlier ones. The khadar is most conspicuous in the eastern half of Uttar Pradesh and forms a belt of varying width along the bank of Ghaghara. There is a difference between the khadar deposits of the Ganga and those of the Ghaghara and the Sarju. The deposits of

the Ganga are principally of mud. A high flood in the Ganga proves useful to the cultivators in the low lands even when it destroys the standing crops, for it leaves in its wake a deposit of fertile silt, but a flood in Ghaghara is certainly undesirable, as it injures the standing crops as well as the soil.

**Drainage**

The rivers of the Uttar Pradesh fall into two broad groups viz. the rivers of Himalayan origin or those arising in the plains near the Himalaya on the one hand and those rising in the Deccan Plateau on the other (Fig. 4). The important rivers of the first group are the Ganga, Gomati, Sarda, Ghaghara, Yamuna, Rapti, Sarju, Ramganga, Kosi and Hindon, while the main rivers of the second group are the tributaries of river Yamuna like Chambal, Betwa, Dhassan, Ken and Baghain, and the tributary of river Ganga viz. Son which passes through a small stretch of Uttar Pradesh in Mirzapur district.

All the rivers follow a general direction of the slope and flow from west-northwest to east-southeast. Right bank tributaries of the river Yamuna are exceptional as they flow from west-southwest to east-northeast. Except for river Ghaghara which flows in more or less straight course, all the other rivers of Ganga plain
UTTAR PRADESH
DRAINAGE

I. GANGLA BASIN
II. YAMUNA BASIN
III. RAMGANGA BASIN
IV. GOMATI BASIN
V. GHAGHARA BASIN

FIG. 4
have a tendency to flow in sinuous course, forming meanders and ox-bow lakes, due to geologically unstable conditions of the mountain formation and small slope in the middle course. The high seismic influence prevalent in ranges often cause land slides which make rivers meander and sometimes change their course and therefore become problem rivers. As there is extensive snow over the Himalaya, the rivers are perennial in nature, while few are non-perennial. Besides main rivers their tributaries have their own importance in agricultural operations especially and their discharge varies from nothing to thousands of cubic centimetres in rainy season. Their beds may remain dry for months and then may be flooded for a few days in the year.

The whole of Uttar Pradesh has been divided into five basins (Fig. 4) namely, Ganga, Yamuna, Ramganga, Gomati and Ghaghara. In each basin there are several other small rivers and rivulets. During monsoon season, almost all the rivers get flooded causing misery to the people, damage to crop and to property.

Ganga Basin:

The river Ganga rises in the Gangotri glacier in the Himalaya at an elevation of about 7,010 m above mean sea level in the Uttarkashi district. At its source the
river is called the Bhagirathi. It comes down the valley upto Dev Prayag where it joins the Alaknanda. After its confluence with Alaknanda the combined stream is called the Ganga. Besides Ganga, several other rivers such as Kali, Isan and Tons etc. also flow in this basin. The river Ganga flows for a distance of 160 km and after cutting through the Siwalik range of hills, it emerges into the plains at Haridwar in Uttar Pradesh. Thereafter, it flows in numerous channels separated from each other by islands. The river bed is rocky upto 20 km. downstream of Haridwar. Usually the bank is high on one side and low on the other and the river is apt to change its course during the annual floods. In Bijnor district, the Ganga takes a wide sweep towards the southwest, maintaining this direction for some kilometres it continues in a southerly/southeasterly direction passing through or forming the boundaries of the districts Bijnor, Muzaffarnagar, Meerut, Moradabad, Bulandshahr and Budaun. During its course through Meerut and Moradabad districts, the river flows in a wide bed constantly changing its course. But continuing to flow south-eastwards, the river forms the boundary between Etah and Budaun districts. The Ramganga, is the first major tributary of the Ganga, which joins it from the left in Hardoi district. To move further down, the Ganga forms the boundary between Kanpur and Unnao districts. In a wide and sandy bed the river changes
its channel almost every year. At Allahabad the Ganga meets its biggest tributary the Yamuna from the right. The Tons, another right bank tributary, joins the Ganga about 30 km below Allahabad. The river Gomati joins the Ganga below Varanasi from the left. The other rivers flowing in this basin are not significant, as these rivers are smaller ones and the flooding from these rivers remains confined to comparatively smaller areas lying along their banks and does not create havoc. Ganga and Tons are the major rivers of this basin which inundate vast areas during floods. The flooding from Tons occurs in Azamgarh, and Ballia districts only, while Ganga causes flooding in areas all along its course right from district Saharanpur to Ballia. The severely flood affected reach of this river is from Allahabad to Ballia. The previous history of this river reveals that it crosses its danger level almost all the years at Phaphamua, Chhatnag, Mirzapur, Varanasi, Ghazipur and Ballia. During heavy floods sometimes it also crosses its danger level at Haridwar and at Narora, which is upstream. This situation remains only for a day or two and does not create havoc. Tons river also crosses its danger levels at Azamgarh and Pipragnath, but only during severe floods which do not occur every year. The river Tons joins the Ganga about 31 km downstream of the confluence of the Ganga and Yamuna. Tons has a total length of 264 km of which 62 km
is in Uttar Pradesh. Similarly son is also a right bank tributary of the Ganga, which cascades through the mountainous areas of the Vindhaya range in its initial stages. After entering Mirzapur district of Uttar Pradesh it flows in an easterly direction and enters Palamau district of Bihar. The total length of son river is 784 km of which 82 km are in Uttar Pradesh.

Yamuna Basin:

The river Yamuna is a tributary of the river Ganga, yet it is the second most important river of the state and therefore commands its own basin. Besides Yamuna, Betwa, Dhasan, Ken, Sind, Pahuj, Chambal, Hindon, Arind, Sirsa and Senger rivers flow in this basin. The origin of river Yamuna is from western side of the snow-peak of Bandarpunch (6,315 m) in Uttarkashi district. River Tons meets the river Yamuna at Hamirpur from the west as it forms part of the northwestern boundary of the state. The river then passing through the Siwaliks enters the western plains and from there flows roughly parallel to the river Ganga and joins it at Allahabad. The total length of the Yamuna from its source at Yamnotri to its confluence with Ganga is about 1,376 km. The river is usually confined within well defined banks. The important tributaries of the Yamuna are Hindon, Chambal, Betwa, Dhasan, Ken, Tons,
Baghain and Paisuni. Except the Hindon, all the other important tributaries of the Yamuna including Chambal join the main river on its right bank. The main flood problem in this basin is caused by river Yamuna, Ken and Betwa. Flood problem is also sometimes caused by Hindon and Dhasan rivers. Other rivers of Yamuna basin are smaller ones and usually do not create flood problem of any significance. However, being smaller, the water carrying capacity of these rivers is quite inadequate and as such whenever heavy rains in short duration take place in their catchment areas, these rivers get flooded and spill their banks for short duration depending upon the duration of rainfall period in the region.

Ramganga Basin:

Ramganga is the major tributary of the river Ganga. The smaller rivers which flow in this basin, are Sarda, Rapti, Little Gandak, Baigul and Gangau. The river Ramganga joins river Ganga on its left bank. It rises in the lower Himalayas at an altitude of about 3,110 m above mean sea level in Garhwal district. In the beginning the river flows in a south-easterly direction for about 32 km through Garhwal district. After it flows in a south-westerly direction through Almora. In its course in these districts, the river flows through mountainous terrain
and has a number of falls and rapids. The river emerges from the hills into the plains in Kalagarh near the boarder of Garhwal district. Beyond Kalagarh, the river flows in a south-easterly direction through the districts of Bijnor, Moradabad, Budaun, Rampur, Bareilly and Shahjahanpur. The river Ramganga flows for a total length of about 1,080 km, the upper half of which is in Nepal and the lower half in Uttar Pradesh. Most of the rivers of this basin have reservoirs constructed across them. A major portion of the run off of this basin gets collected in these reservoirs, reducing the chances of flooding.

Gomati Basin:

The river Gomati rises near Mainkat, about 3 km. east of Pilibhit town in the Pilibhit district at an elevation of 200 m and drains the area lying between Ramganga and the Sarda in the upper reaches and lower down the area between the river Ganga and the Ghaghara. After flowing in a southerly course it joins the Ganga, near about Kannauj in the Farrukhabad district. The tributaries of Gomati are Khoh, Aril, Sai and Saryan. The river Sai is important tributary of the river Gomati joining it on its right bank. It rises in the Hardoi district and traverses the districts of Rae Barelli and passing between Lucknow and Unnao districts it flows through Jaunpur district before joining the Gomati at about 60 km.
upstream of the confluence of the latter with the river Ganga. The drainage area is about 11,115 sq.km. The flooding from river Gomati is mainly caused in Lucknow, Sultanpur, and Jaunpur districts, while from Sai in Unnao, Lucknow, Rae Bareli, Pratapgarh and Jaunpur districts.

Ghaghara Basin:

Most part of the river Ghaghara in the upper portion lies across international border in Nepal and China. River Sarda and Rapti are the major rivers of this basin while Little Gandak, Burhi Rapti, Anie, Rohin are other smaller rivers. The river Ghaghara is known variously by the names of Sarju and Dehwa and contains the combined waters of the two separate streams viz. Sarda and the Kauriala, which unite near Bahramghat in the Bara Banki district. The Karnali, as the Ghaghara is known in the upper reaches, has its source in the Himalayan glaciers about (60 km.) southwest of Mansarowar at an elevation of 4,800 m. After flowing for about 72 km in a southeasterly direction, the river enters Nepal territory. The river bed from Bahraich onwards is sandy and its course is liable to abrupt changes. Near Gularia the river receives the Sarju on its right and further downstream Baberi Sarju on its left. The Sarda, the most important tributary of the Ghaghara, joins the Kauriala
at Rampur Mathura. After the junction with the Sardā, the river is known as the Ghaghara and flows southeastward. It forms the boundary between Bahraich and Gonda and then between the Bara Banki and Gonda districts. The lower Sarju and the Tirhi join the Ghaghara in Gonda district. During its course through Gonda district, the river inundates a large area on its left by spilling its flood water into the river Sarju, Tirhi etc. which join the river on its left bank. The Tirhi joins the Ghaghara near Nawabganj. Then flows through Ayodhya. It then forms the boundary between Faizabad and Ballia districts and flows in continually shifting channels within a broad sandy bed about 6 km. in width. During monsoons it carries an enormous volume of water. Even during the winter it flows in more than one channel. The entire area on the right of the Ghaghara in Azamgarh and Ballia districts is liable to inundation from floods. The banks of Ghaghara consists of soft sandy alluvial soil. Flowing through Shahjahanpur district the Ghaghara receives more tributaries. The river flowing in a southeasterly direction passes through Lucknow, Kheri, Gorakhpur, Deoria, Sultanpur, Jaunpur and finally before its confluence with the Ganga forms the boundary between Varanasi and Ghazipur districts. The total length of the river is about 940 km and it drains a total area of 30,433 sq.km. The river flows entirely in the state of Uttar Pradesh from its origin to its
confluence. The river Rapti is a tributary of the Ghaghara which joins it on its left bank. It rises in the lower ranges of Nepal at an elevation of 3,600 m. It enters Uttar Pradesh in the district of Bahraich. It then flows in a southeasterly direction through the districts of Gonda and Basti and joins Ghaghara in the district of Gorakhpur. Rapti inundates large territory on both the banks. But the floods of Rapti are beneficial because of the fine silt left behind, which makes the land fertile and productive. Ghaghara is a mighty flood causing river. Every year it causes havoc during rainy season submerging vast stretches of land.

**Climate**

Uttar Pradesh has tropical monsoon climate. The climate is characterized by the reversal of winds causing a succession of seasons in the whole year. During northeast monsoon the winds are of continental origin, while during the southwest monsoon they are oceanic in origin. Taking into account the variations in temperature and precipitation, the whole year is divided by India Meteorological Department into four seasons grouped under the two monsoons as follows:
(a) The seasons of the Northeast Monsoons:

(i) Cold Weather Season from November to February.
(ii) Hot Weather Season from March to mid-June.

(b) The Seasons of the Southwest Monsoon:

(i) Season of General Rain from mid-June to mid-September.
(ii) Season of Retreating Monsoons from mid-September to October.

The Cold Weather Season:

During November a high pressure belt extends from northwest India and covers the Ganga Plains. The wind direction is from west to east. As the pressure gradients are not steep the breeze blows gently in November but in December, dry and chilly westerlies considerably lower the temperature. The mean minimum temperature in the month of November at Roorkee, Aligarh, Bareilly, Allahabad, and Bahraich ranges between 5° to 10°C. But the mean maximum temperature ranges between 29° and 33°C. In the month of January mist and fog occur due to very low temperature conditions. The dry and chilling westerlies are by now occasioned by the western depressions associated with rain and cold waves. January records lowest temperature at
times below 4°C at some places mostly in west Uttar Pradesh. But on an average in this month temperatures remain below 20°C in the state. The rain in the months of January and February varies from 157 mm to 38 mm in the state, of which most of it is concentrated in west Uttar Pradesh. By end of February or March temperatures tend to increase heralding the hot weather.

The Hot Weather Season:

It is a season of continuously rising temperature accompanied by falling humidity and pressure till May. March records between 21°C to 26°C as mean monthly temperature at Roorkee, Aligarh, Bareilly, Jhansi, Allahabad, Gorakhpur and Bahraich. The mean maximum temperature ranges between 34° to 39°C. Thereafter temperature keep rising and May registers 30.5° to 34.5°C as mean monthly temperature. The mean maximum temperature reaches over 40°C in some parts of the state. The hot and dry winds are known as loo, which at times are associated with dust storms. The humidity goes down to 35 per cent in May and occurrence of dust storm are a significant feature of the season. These storms are short lived and mostly end up in light showers of rain. The month of May and half of June is the period of intense heat. The trend of temperature recordings show an increase
from east to west of the state.

The Seasons of General Rains and the Season of Retreating Monsoons:

By mid or end of June monsoon normally breaks in Uttar Pradesh and with it there is a complete change in the weather with immediate fall in the temperature and an upward trend in humidity. July and August are the rainiest months of the year as they receive more than 50 per cent of the total annual rainfall. In the month of September the rains normally slacken and rainless intervals become longer. Humidity remains high with little movement of air due to it and due to cloudy weather the heat becomes intolerable. The continuous rainfall for several days lead to flood conditions, which result in sheet and gully erosion and generally bring floods in the rivers which destroy the crops and cause loss to life as well as to property.

In 1975 there have been widespread but scattered heavy rains in the state during the monsoon season. Out of 55 districts, the rain were normal in 38 districts. The maximum rainfall was in Tehri Garhwal district in the hill zone but the one day heavy rainfall has been at Bulandshahr, recording 431.80 mm of rains in a day. The distribution of rainfall in the season has been 6.26
per cent below normal in the hill zone, 27.60 per cent above normal in western zone, 2.15 per cent above normal in eastern zone, 21.60 per cent above normal in central zone, 24.10 per cent above normal in Bundelkhand zone in the state.

There have been wide scattered rains in the State during the 1976 monsoon season. Out of 55 districts, the rainfall has been above normal in 28 districts. The maximum rainfall was in Dehra Dun district in the hill zone. The distribution of rainfall from June 1976 to October 1976 in the state was 2.2 per cent below normal. But it was 22.7 per cent above normal in western zone.

There were scattered rains in the state during monsoon season in 1977. The heaviest rainfall was recorded in the month of July when 22 districts received rains above normal. The maximum rainfall of 2189.5 mm was observed in district Dehra Dun, against the normal rainfall of 1049.4 mm. The minimum rainfall was recorded in district Rae Bareli which was 422.0 mm against the normal rainfall of 857.6 mm. The distribution of rainfall from June to October 1977 was 3.95 per cent below normal. It was maximum in western zone which was 22.89 per cent above normal and minimum in central zone which was 20.35 per cent below normal.
In the year 1978 rains were fairly widespread over the state. Maximum rainfall was in western zone while the central zone got the minimum rainfall. The maximum rain was in district Saharanpur which reached 1735.1 mm rain as against 811.4 mm of the normal rainfall. District Pilibhit recorded minimum rainfall of 850.1 mm as against 1120.7 mm.

The year 1980 experienced a more intensive and concentrated rainfall several rivers of the state remained in floods continuously for weeks. The pressure of floods was severe and devastating in the central and eastern parts of the state. Rainfall was maximum in eastern zone.

The year 1981 got maximum rainfall in the eastern zone accounting for 38.04 per cent of rainfall in the state. This zone was followed by western zone which accounted for 24.33 per cent of rainfall in the monsoon season of 1981. The overall distribution was fairly widespread.

In 1982 the state received well distributed rainfall, with western zone recording 29.65 per cent of rainfall,, and eastern zone 25.57 per cent of rainfall. In all 44 districts received heavy rainfall. The months of July and August recorded the maximum rainfall.
The monsoon season of 1983 witnessed widespread rains. The western zone got maximum rains and accounted for 33.10 per cent of the state rainfall. Nearly all the districts were affected by heavy rains. In the months of July, August and September most of the districts received rainfall above normal.

The monsoon came in the state during the 2nd week of June in 1984. In the month of July, the state received well distributed heavy rains. These rains resulted in the rise of water levels of all the rivers of the state. Hill zone received maximum rainfall recording 34.11 per cent of the total rainfall of the state.

In 1985 monsoon reached Uttar Pradesh by the third week of June. There were widespread rains all over the state in the month of June, July and August. The continuous rains in the state had affected many districts by the end of July. There was landslide in Uttarkashi and flash floods in Almora district. The downpour in Lucknow was 635 mm, in Sitapur 367 mm and Bara Banki 154 mm, during a span of two to three days against the respective normal rainfalls of 195 mm, 188 mm and 204 mm for the entire month of September.

Monsoons arrived in the state during the third week of June again in 1986 and spread all over the state in
the first week of July. In the month of July the state received well distributed rains which resulted in the rise of water level of all important rivers. Pratapgarh received 1057.8 mm of rainfall in the monsoon season as against its normal of 907.3 mm. Likewise Rae Bareli recorded 1369.5 mm of rainfall as against its normal of 857.6 mm.

In 1987, the monsoons arrived in the state in the first week of July. Rainfall was below normal in all the zones except in eastern zone where rainfall was recorded above normal in some districts. Eastern zone received 44.15 per cent of the total rainfall in the state. Basti district recorded rainfall of 1260.30 mm as against 1160.0 mm, Gorakhpur had a rainfall of 1519.50 mm as against 1251.6 mm, Faizabad had 1056.90 mm of rainfall against its normal of 932.2 mm, Jaunpur also had 1215.40 mm of rainfall as against its normal rainfall of 931.5 mm in the entire season. Gorakhpur also recorded one day maximum rainfall of 255.20 mm.

In 1988 the rains in monsoon months were above normal in hill zone, western zone and central zone. While they were above normal in one of two districts of eastern zone and Bundelkhand zone. But major part of eastern zone received below normal rains. Deoria received 143.4 per cent of rainfall in the monsoon season and Etah
142.6 per cent. These two districts recorded maximum rainfall of the season.

During 1989, the monsoon arrived in the state in the third week of June and remained active up to July. It was sluggish in August but was active in September again. Rainfall in the western part of the state had been less than the normal, while they were near normal in eastern part of the state. In eastern Uttar Pradesh, the districts Gorakhpur, Deoria, Basti and Gonda had unprecedented high intensity rainfall. In Gonda one day maximum was 947 mm as against 1062 mm average of district for full monsoon season.

Monsoon begins to retreat in mid-September and by the end of October the state becomes fair from any activity of the southwest monsoon. In late September or early October the mean maximum temperature remains as high as in early September but rainfall gradually looses its grip in the state.

Soil

The soils of Uttar Pradesh are by and large homogeneous due to almost uniform topography. The alluvial soils with the variants, the usar and bhur, depending on the drainage conditions, chemical constituents and the
climatic characteristics are observed in different parts. The two common types i.e. the Khadar and bhangar with different local names are quite widespread. The khadar soils, relatively rich in plant nutrients, occupy the narrow frequent siltation tracts in the floodplains of the rivers. The Ganga Khadar soils have immature profiles with sandy to silty loam texture, lack of concretion, fair proportion of lime and other soluble salts and are alkaline in reaction (pH 8) with imperfect drainage, while the Yamuna khadar soils have sub-mature profile with predominance of clay and concretion and very high lime and other soluble salt contents under poor drainage condition.5

The bhangar soils are more extensive in areal spread. In the proximity of the Ganga these are loamy to sandy loam in texture while near the Yamuna the silt content decreases giving sandy to sandy loam texture. Among the variants, the usar (reh) soil are in sizeable tract in the Ganga Ghaghara Doab from Sultanpur, Pratapgarh, through Rae Bareli, Lucknow, Hardoi, Shahjahanpur etc, contiguous with the tract of the Middle Ganga Plain. The other variant, the bhur, the sandy river deposit, is highly localised in Ramganga tract and in the

narrow belt along the Ganga, the soil is more sandy in texture. Bhangar is the submontane soil where two physiographic units, the bhabar and tarai meet. The bhabar soil is sandy to gravelly, highly porous, while tarai soil is rich clayey, with some proportion of fine sand, moisture and rich humus.

The soils in Uttar Pradesh tend to become heavier from the northwest to the southeast. In the districts of Agra, Mathura, Aligarh and Meerut, where the conditions are semi-arid, patches of alkaline soils as well as of alluvium covered by wind-borne sand are quite common. In eastern Uttar Pradesh, the areas are relatively lowlying and subject to damage by floods.\(^6\)

The soils of Uttar Pradesh can basically be grouped into seven types, as a wide range of soils both of residual and alluvial origin are found in the state. It is seen that major part of the state is occupied by the alluvial soils while the residual soils cover the hilly areas, Bundelkhand and Vindhyan regions in the north and south of the state. Alluvial soils are found mainly in the central portions comprising mostly Ganga-Yamuna Doab. The soil groups and their distribution in Uttar Pradesh is given in Table I and illustrated in Fig. 5.

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UTTAR PRADESH
SOILS

100 Kms

HILL SOILS
BHABAR SOILS
TARAI SOILS
ALLUVIAL SOILS
VINDHYAN SOILS
BUNDELKHAND SOILS
ARAVALI SOILS

SOURCE: BASED UPON MAP OF STATE SOIL SURVEY ORGANISATION KANPUR.

FIG. 5
TABLE - I

Extent of various soils in Uttar Pradesh

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<th>Soils groups</th>
<th>Area in percentage</th>
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</tbody>
</table>

Hill Soils:

The districts of Almora, Chamoli, Tehri Garhwal, Pauri, Nainital, Pithoragarh, Uttarkashi and Dehra Dun comprise the hill soils and cover 14.33 per cent area of the state in the northern montane tract. Except Pithoragarh no other district reported the presence of alkaline soils in the area, whereas the district of Uttarkashi, Chamoli and Pauri have a fair proportion of the acidic soils. Potash is found in Tehri Garhwal, Dehra Dun and Uttarkashi, while organic carbon is distributed well in Uttarkashi, Tehri Garhwal, Pithoragarh.
and Dehra Dun districts. The region is by and large devoid of the problem of high soluble salt contents.

**Bhabar Soils:**

This type of soil occupies a narrow strip at the foothills of Himalayas, extending from east to west. It covers the districts of Dehra Dun, Saharanpur, Bijnor, Garhwal and Nainital and accounts for nearly two per cent of the state total area. The soils are formed by the transported alluvium from the Siwaliks and the Himalayan ranges comprising small pebbles and coarse gravels. These soils are dark in colour and moderately alkaline in reaction.

**Tarai Soils:**

This soil is found south of the bhabar soil from Dehra Dun in the northwest to the extreme northeastern district of Deoria, and covers 5.73 per cent area of the state. These soils remain saturated during the monsoon months and continue to be moist during the winter due to very high level of underground water. Principally tarai means the moist humid area. The soils of tarai tract have generally a normal reaction and salt content.
**Bundelkhand Soils:**

The area on the southwest of the river Yamuna is under Bundelkhand soils, and occupies 10.85 per cent area of the state. These soils are in the districts of Jhansi, Lalitpur, Jalaun, Hamirpur and Banda. These soils have their origin in Vindhyan rocks of the Deccan trap abounding in gneiss and granites with highly ferruginous beds and soft lime stone. The soils of the area have generally normal reaction with fair soluble salt content. In respect to phosphorus, potash and organic carbon content, the soils are predominantly of moderate category. The soils of this tract are further sub-divided into four types on the basis of their colour, texture, parent material and crop adoptability. They are

(i) Grained reddish brown
(ii) Coarse grained grey too greyish brown
(iii) Black clayey-loam
(iv) Clayey black soil.

All the soils are poor and have low water content.

**Vindhyan Soils:**

These soils are residual in origin and are found in the south of the river Ganga. They cover nearly
5 per cent of the state and extend over the districts of Mirzapur, Varanasi and Allahabad. These soils are formed by the decomposition of subadjacent rocks of Vindhyan system containing sandstones, haematitic slates, schists, gneiss, granites, quartzite, carboniferous rocks and limestone. Topographically these soils are subdivided into three. The Vindhyan upland soils occupy higher ground and are alluvial in nature, formed under excessive drainage. These soils are dark brown in colour and gravelly to sandy loam in texture. The soils of Vindhyan flats developed under restricted drainage conditions are yellowish in colour and are loam to clay loam in texture. The soils of Vindhyan lowlands are alluvial in character and are considered most fertile among them.

Aravalli Soil:

These soils are not much significant as regards their distribution. They cover 0.21 per cent of the total area of the state. These soils are confined to south-western portion of Agra district. The soils contain coarse sand gravel or even loamy sands depending on the topography and location.
Alluvial Soils:

These soils cover 61.78 per cent of the total area of the state. They occupy the central, western and the southern portions of the state. These soils have developed from the alluvium deposited by the rivers Ganga and Yamuna and their tributaries mainly the Ghaghara, the Gandak, the Gomati and the Ramganga. But being alluvial in nature, they differ widely from district to district on the basis of soil associations. The soils of a particular river system comprise of two types: (i) riverine soils, (ii) soils of flat lands. These differences originate from the regions where the two rivers flow. The Ganga covers a wide range of the Himalayan rocks while the Yamuna flows for a considerable distance through rocks of basaltic origin. The recent alluviums of it are black in colour and fine in texture with the uniform depth of soil profile. The alluvium found in Ganga plain is normally highly calcareous than the alluvium deposits of Gandak and the Ghaghara found in the northeastern tract of the state.

The soils of the state correspond largely to the climate, vegetation and relief to a considerable extent.
Physical Division

The state of Uttar Pradesh on the basis of its relief and drainage can be divided into four broad physical division, as follows (Fig. 6):

(a) The Montane Tract

(i) The Great Himalaya
(ii) The Lesser Himalaya
(iii) The Siwalik

(b) The Submontane Tract

(i) The Bhabar
(ii) The Tarai

(c) The Ganga Plain

(d) The Trans-Yamuna Tract

Montane Tract:

The montane tract is situated in the extreme northern part of the state. This region is separated by the river Tons from Himachal Pradesh in the west and by the river Kali Ganga from Nepal in the east. It rises abruptly from the submontane tract in the south, the region extends up to the snow-clad peaks of Himadri. This region of Uttar Pradesh is marked with gradual changes in physical features of climate and vegetation. The
UTTAR PRADESH
PHYSICAL DIVISIONS

I. MONTANE TRACT
II. SUB-MONTANE TRACT
III. GANGA PLAIN
   a. GANGA-YAMUNA DOAB
   b. GANGA-GOMATI INTERFLUVE
   c. GOMATI-GHAGHARA INTERFLUVE
   d. TRANS-GHAGHARA TRACT
   e. ROHILKHAND TRACT
IV. TRANS-YAMUNA TRACT

FIG. 6
montane tract is clearly divided into three divisions: The Greater Himalaya, the Lesser Himalaya and the Siwaliks.

The Greater Himalaya is a zone of about 50 km. wide with a mean relief between 4,800 m and 6,000 m. The relief culminates in the peaks of Nanda Devi (7,817 m) and Kamet (7,756 m). The sources of the river Ganga and Yamuna lie in the glaciers of this region. The Bhagirathi and the Alaknanda are the two head waters of the river Ganga. The river Yamuna has its source in the Yamunotri glacier. This mountain wall acts as a barrier to the oncoming monsoon air masses from the east as well as from the south.

The Lesser Himalaya is approximately 75 km. wide and is a tangled mass consisting of a series of ridges separated by deep valleys. The average relief of the ridge in this zone is between 1,500 and 2,700 m and valley bottoms between 500 and 1,200 m. In the outer fringe of the Lesser Himalayas lie the lake basins confined to a belt of 25 km long and 4 km wide.

The Siwaliks extend in the form of a long chain of narrow and low hills stretching from the northwest to southeast direction parallel to the major ranges of Lesser Himalaya. So the Siwaliks form the outer range of the Himalayan system. From the viewpoint of relief they have
a remarkable even crest between 750 m and 1,200 m. On the southern slopes they have steep scarps, while on the north they descend gently to the duns.

**Submontane Tract:**

It is a region which forms a narrow tract along the foothills stretching from Bijnor in the west to Gorakhpur in the east. The region is formed of three distinct portions. The first is the tract of *bhabar* which lies immediately below the foothills with a strip of land about 32 km wide in the west and gradually becoming narrower in the east. Bhabar is a porous, detrital piedmont skirting the Siwaliks with the abrupt flat stream profiles coupled with the coarse detritus boulder deposits of gravel. In the summer months this tract has little surface drainage because streams are lost in the loose gravel and appear only at its outer edge, but during rainy season only the subterranean drainage appears above the boulders and gravels. South of the bhabar is a wider strip of land known as *tarai*, a low marshy land consisting of tall grasses and scrub and the presence of water everywhere. The bulk of water received from the rainfall and of small hill streams that loose themselves in bhabar reappear again on the surface in the *tarai*. As a result this tract is damp and marshy. The Gandak, the Ghaghara, the Gomati and the Ramganga rivers traverse the whole
region with a number of tributary streams of unstable character. Thirdly in the northern portion next to tarai the districts of the plain partake the nature of tarai. The rainfall is heavy and the streams are numerous.

The Ganga Plain:

It covers an area of 86,041 sq.km. It is further subdivided into five regions: the Ganga-Yamuna Doab, Ganga-Gomati Interfluve, Gomati-Ghaghara Interfluve, Trans-Ghaghara Tract, Rohilkhand Tract.

The Ganga-Yamuna Doab is an enriched plain with fertile alluvial deposits. The Doab is about 832 km in length and 104 km wide in the upper part and covers an area of about 58,400 sq.km. The soil is of Khadar type and is renewable by floods and changes in river courses. This region is the most fertile part of the state.

Ganga-Gomati interfluve is less fertile area as compared to Ganga-Yamuna Doab. The reason for it is that most of the area is under the command of the river Gomati and its tributaries, which emanate from a lake. Due to the gentle slope of the plain the river Gomati flows in a tortuous course forming numerous small seasonal lakes, which dry up in summers and are flooded in rainy season and cause water logging. On account of gentle gradient.
this tract receives less of silt and more of sand during floods which reduce the fertility of soil.

Gomati-Ghaghara interfluve has a lesser fertility status of the soil, because Ghaghara brings lots of sand in the plain as it descends from the mountains.

Trans-Ghaghara tract constitutes the northern part of the Ganga plain and lies between the Himalaya and tarai in the north and the Ganga-Ghaghara interfluve in the south. The soils are inferior to that of the Gomati-Ghaghara tract.

Rohilkhand tract adjoins the areas of montane and sub-montane tracts. This region is generally free from floods. The soil is poor. The northern part of the region is quite similar to that of tarai.

Trans-Yamuna Tract:

In the south and south-west of the state the tract is considerably different from the main areas of the state. The general slope of the area is from southwest to northeast. The soil is generally rocky in nature and infertile, interspersed by patches of black soil which is entirely different from the alluvial soils of the great plain. The tract either suffers from an excess or a deficiency of rainfall.