CLASSROOM STUDY MATERIAL

GEOGRAPHY

Part - 3

VISIONIAS
INSPIRING INNOVATION

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GEOGRAPHY PART 3

Student Notes:

INDIA: PHYSICAL FORMATION, PHYSIOGRAPHY, DRAINAGE, STRUCTURE AND RELIEF AND BASICS OF SOILS

Contents

Student Notes:

1. India Location

Student Notes:

India is a vast country lying entirely in the Northern hemisphere. The main land extends between latitudes 8°4'N and 37°6'N and longitudes 68°7'E and 97°25'E (figure 1). The Tropic of Cancer (23° 30'N) divides the country into almost two equal parts (figure 2). The southern part of the country lies within the tropics and the northern part lies in the sub-tropical zone or the warm temperate zone. This location is responsible for large variations in land forms, climate, soil types and natural vegetation in the country. To the south east and south west of the mainland, lie the Andaman and Nicobar islands and the

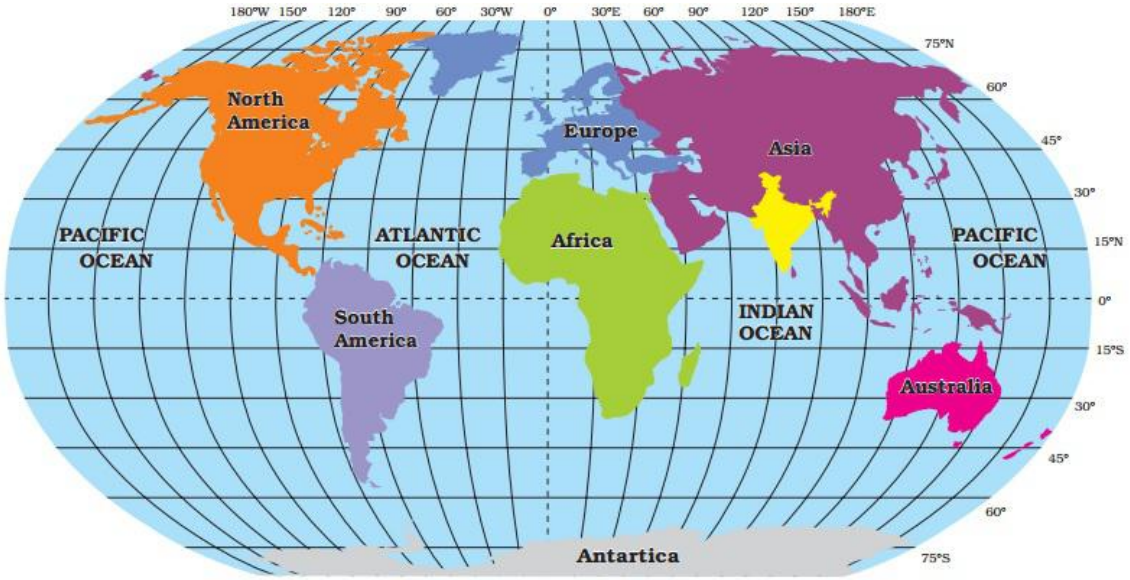

Figure 1 – India in the world

Lakshadweep islands in Bay of Bengal and Arabian Sea respectively. Andaman and Nicobar islands make southern boundary of India Union at 6°45'E in Bay of Bengal. The southernmost point of the India Union "Indira Point" got submerged under the sea water in 2004 during the Tsunami.

If you work out the latitudinal and longitudinal extent of India, they are roughly about 30 degrees, whereas the actual distance measured from north to south extremity is 3,214 km, and that from east to west is only 2,933 km (figure 2). Why is it so? This is because the east-west distance between two successive meridians of longitude along the equator is at its maximum - 111 km. This, however, goes on decreasing as one moves from the equator to the poles, where it is zero. This is because all the meridians of longitude merge in a single point at the poles - both North and South. On the other hand, the north-south distance between any two successive parallels of latitude along any meridian of longitude remains almost uniform, i.e., 111 km.

1.1. Indian Standard Time (IST)

While the sun rises in the northeastern states about two hours earlier as compared to Jaisalmer, the watches in Dibrugarh, Imphal in the east and Jaisalmer, Bhopal or Chennai in the other parts of India show the same time. Why does this happen? What is Indian Standard Time (IST)? What is the use of standard meridian (figure 2)? Variation of nearly 30degree in longitude causes a time difference of

Student Notes:

Figure 2 – India: Extent and Standard Meridian

nearly two hours between the easternmost and the westernmost parts of our country. Standard meridian is an imaginary line used for reckoning standard time. For the convenience of all, each country chooses its standard meridian in a multiple of 7°30'. India's standard meridian passes through 82° 30'E.Time along this Standard Meridian of India passing through Mirzapur (in Uttar Pradesh) is taken as the standard time for the whole country and known as IST with a time offset of UTC + 5:30.

There is a continuous demand from northeastern states to have separate time zone. Currently, the single time zone causes problems for them, especially in summers when daybreak comes as early as 4:30am around the summer solstice. A farmer in Assam can start work one hour before her or his counterpart in a state like Gujarat. Tea gardens in Assam have for years set their clocks an hour ahead of the rest of the country.

1.2. Size

The land mass of India has an area of 3.28 million square km. India's total area accounts for about 2.4 per cent of the total geographical area of the world; whereas it sustains17.5per cent of the world population. India is the seventh largest country of the world. India has a land boundary of about 15,200 km and the total length of the coast line of the mainland including Andaman and Nicobar and Lakshadweep is 7,516.6 km.

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Figure 3 – India: Administrative Division

India is bounded by the young fold mountains in the northwest, north and north east. South of about 22° north latitude, Indian Landmass begins to taper, and extends towards the Indian Ocean, dividing it into two seas, the Arabian Sea on the west and the Bay of Bengal on its east. The Peninsular shape of India makes climate of southern India differ from that of Northern India. Vast sandy expanse of Marusthal in Rajasthan and marshy great Rann of Kachchh make western boundary of the India.

1.3. India's Administrative Division

India, that is Bharat, is a union of states. India has total twenty-eight[1] states and seven Union Territories (Figure 3). New Delhi is the capital of India. Rajasthan is the largest state while Goa is the smallest state in terms of geographical area. The Tropic of Cancer (23° 30'N) passes through Mizoram, Tripura, West Bengal, Jharkhand, Chhattisgarh, Madhya Pradesh, Rajasthan and Gujarat (8 states). Jammu and Kashmir makes northern border while Tamil Nadu makes southern border. Similarly, Gujarat and Arunachal Pradesh are the western most and eastern most states respectively. Except Madhya Pradesh, Chhattisgarh, Jharkhand, Haryana, all states share international or marine boundary.

1.4. India and the World

The Indian landmass has a central location between the East and the West Asia. India is a southward extension of the Asian Continent. The Trans Indian Ocean routes provide a strategic central location to India. It is India's eminent position in the Indian Ocean which justifies the naming of an Ocean after it.

[1] As of Jan 2013 Telangana is in process.

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India is part of Indian sub-continent and shares boundary with every country of this region. Land neighbours of India include Pakistan, Afghanistan, China, Nepal, Bhutan, Myanmar and Bangladesh. Most of our boundary with Pakistan and Bangladesh is almost **man-made** while boundary with other countries largely form a **natural boundary**. Sri Lanka and Maldives are the two island countries located in the Indian Ocean, which are our neighbours. Sri Lanka is separated from India by the Gulf of Mannar and Palk Strait.

2. Physical Formation of India

Earth of the distant past was a very different planet than the one we know today. Over these long years, it has undergone many changes brought about primarily by the endogenic and exogenic forces. We have already studied about the movement of Indian plate which started its northward journey about 200 million years ago. This northward movement of the Indian plate is still continuing and it has significant consequences on the physical environment of the Indian subcontinent. Here, we will study about geological structure of India. The geological regions of India are broadly divided into three parts - (i) The Peninsular Block; (ii) The Himalayas; and (iii) Indo-Ganga-Brahmaputra Plain.

2.1. The Peninsular Block

The plateau of Peninsular India exhibits a complex system of geological structures. It has some of the oldest rocks of the world from the Precambrian period and the youngest rocks of the Quaternary period. The features of this block have developed over period of time. Since the Cambrian period, the Peninsula has been standing like a rigid block with the exception of some of its western coast which is submerged beneath the sea and some other parts changed due to tectonic activity without affecting the original basement. It has been subject to various vertical movements and block faulting. The rift valleys of the Narmada, relict and residual mountains like the Aravali hills, and block fault like Malda fault in the Eastern India are example of it.

Figure 4 – Peninsular block

This region contains all types of rocks - igneous, metamorphic and sedimentary rocks. For instance, limestone, sandstone sedimentary rocks are found in river valleys. Coal belts of Peninsular India were developed during the Gondwana period. The black soil of Deccan is due to outpouring of huge quantity of lava during Cretaceous period.

The northern boundary of the Peninsular Block may be taken as an irregular line running from Kutch along the western flank of the Aravali Range near Delhi and then roughly parallel to the Yamuna and the Ganga as far as the Rajmahal Hills and the Ganga delta (figure 4). Apart from these, Rajasthan in the west and the Karbi Anglong and the Meghalaya Plateau in the northeast are also extensions of this block. The northeastern parts are separated by the Malda fault in West Bengal from the Chotanagpur plateau. In Rajasthan, the desert and other *desert–like* features overlay this block.

2.2. The Himalayas

The Himalayas are geologically young, weak and flexible and structurally fold mountains unlike the rigid and stable Peninsular Block. The disintegration of Pangaea, about 200 million years ago, led to the formation of a long Tethys sea between the Lauretian Shield and Gondwanaland. This sea was occupying the region of Himalayas called geosyncline. About 65-30 million years ago, the Indian plate came very close to the Eurasian plate and started subducting under it (figure 5). This caused lateral compression due to which the sediments of the Tethys were squeezed and folded into three parallel ranges of the Himalayas. Since the northward movement of the Indian plate is still continuing, these mountains are still subjected to endogenic forces apart from exogenic forces. It is said that the height of the Himalayan peaks is still increasing.

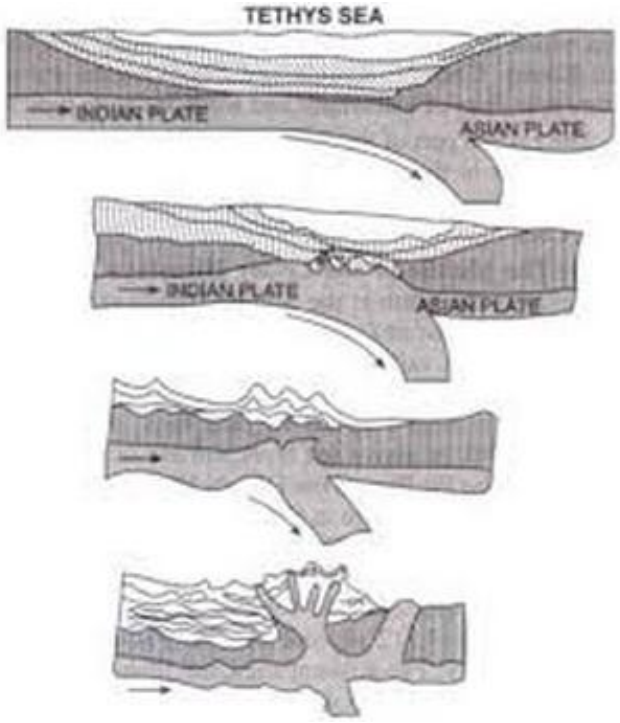

Figure 5 – Plate tectonics and evolution of Himalayas

The Himalayas consist of four litho tectonic mountain ranges, namely (i) the Trans-Himalaya; (ii) the Greater Himalaya; (iii) the Lesser Himalaya; and (iv) the Shiwalik. The first phase of uplift produced the ranges of Trans Himalayas around 65 million years ago. Subsequent uplift led to formation of Greater Himalayas, Lesser Himalayas and Shiwalik mountain ranges.

2.2.1. Syntaxial Bends of the Himalayas

The structures and trends of the Himalaya change sharply at both ends of the range, defining bends called "syntaxes." It develops along the edges of two colliding plates near the zone of active collision. The western syntaxial bend is near Nanga Parbat where the Indus has cut deep gorge. The geological formations here take sharp hair-pin bends as if they were bent around pivotal points obstructing them. There is a similar hair-pin bend in Arunachal Pradesh where

the mountains take a sharp bend from the eastern to southern direction after crossing the Brahmaputra river.

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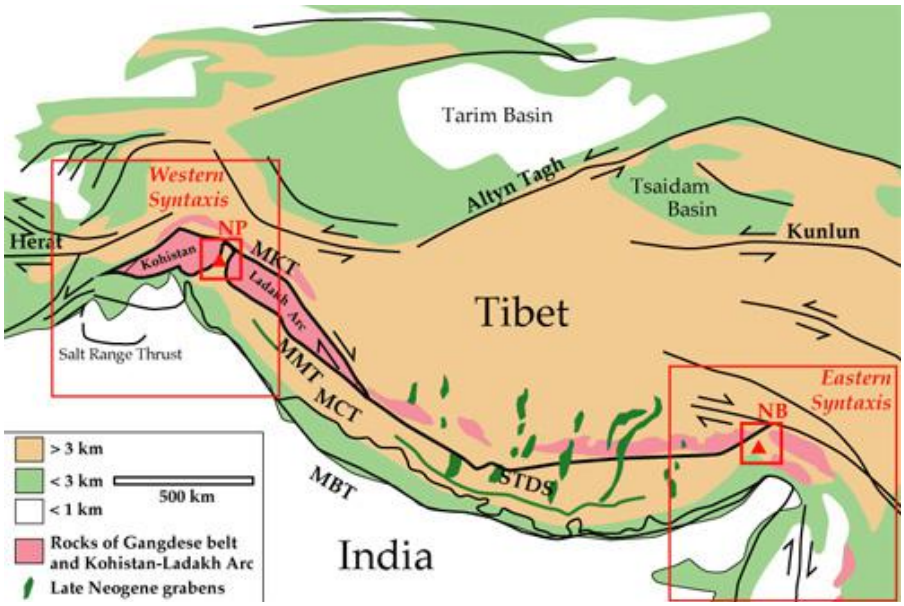

Figure 6 – Himalaya's syntaxes at NP (Nanga Parbat) and NB (Namcha Barwa)

2.3. Indo-Ganga-Brahmaputra Plain

The third geological division of India comprises the plains which lie to the south of Shiwalik formed by the river system Indus, the Ganga and the Brahmaputra. Originally, it was a geo-synclinal depression which attained its maximum development during the third phase of the Himalayan mountain formation approximately about 64 million years ago. It is an aggradational plain formed by the alluvial deposits of rivers originating in Himalayas in north and the Peninsular plateau in South. Since then, it has been gradually filled by the sediments brought by the Himalayan and Peninsular rivers. Average depth of alluvial deposits in these plains ranges from 1,000-2,000 m. Some geologists are of the opinion that Great plains are a remnant of the Tethys Sea. After the upheaval of Shiwalik, the remaining part of the Tethys was left as a large trough. Because the Himalayas were rising during that period, rivers experienced rejuvenation and greater quantity of eroded material which increased the thickness of alluvium in this trough (figure 7).

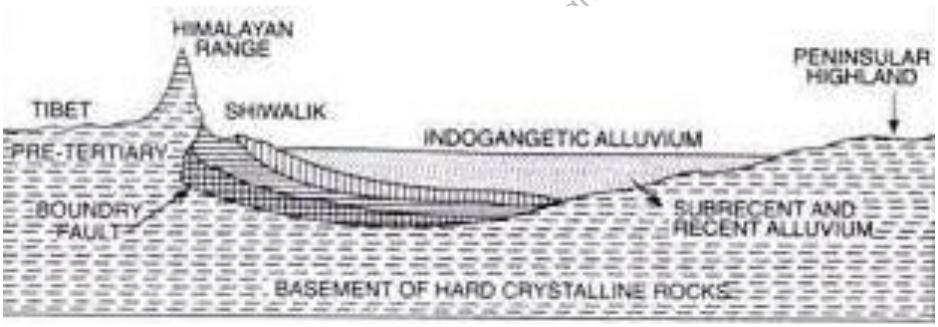

Figure 7 – The great plains of India

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CENEZOIC ERA	HOLOCENE		
	PLEISTOCENE	From upper Pliocene to Plistocene.	Upliftment of Outer Himalays (Siwalik). Main Boundary Thrust (MBT) formed.
	PLIOCENE MIOCENE	From Miocene to Plioceen.	Main Central Thrust (MCT) formed. Upliftment of Lesser Himalaya (Second Phase).
	OLIGOCENE EOCENE	From Eocene to Oligocene.	Upliftment of Central Himalaya.
	PALAEOCENE	From late Cretaceous to Eocene.	Collision of Indian and Eurasion plate begins. (Continent collision)— Indus Tsangpo Suture Zone formed (ITSZ) formed.
MESOZOIC ERA	CRETACEOUS (LATE)		Extensive eruption of basalt leading to formation of Deccan Lava Plateau. Enclosure of Tethys which started shrinking.
PALAEOZOIC ERA	UPPER	From Caboniferous to Permian.	Deposition in three great graben like basin-Mahanadi, Damodar and Godavari known as Gondwana deposits. (Region with rich cola reserves).
	LOWER	From Cambrian to Carboniferous (Early).	Formation conspicusouly absent.
PRECAMBRIAN	UPPER PROTEROZOIC		Vindhyan syneclise - devoid of metalliferous minerals. Vindhyan Mountain — formed of shales, slates, clay and limestone.
	MIDDLE PROTEROZOIC		Satpura, Shillong Plateau. Formation and deposition in Cuddapah depression.
	EARLY PROTERZOIC		Delhi and Aravalli orogeny took place.
	CLOSE ARCHEAN		Dharwar system—cover whole length of Karnataka. (Region with iron ore reserves).
	LATE ARCHEAN		Peninsular Gneiss and Eastern Ghat formation.
	MIDDLE ARCHEAN		Singhbhum and Keonjhar Orogeny (rich iron ore reserves).

Table 1 – Geological Time Scale of India

3. Physiography

'Physiography' deals with the study of the surface features and landforms of the earth. It is the outcome of structure, process and the stage of development. There are significant variations among the different regions of India in terms of their geological structure. The relief and physiography of India has been greatly influenced by the geological and geomorphological processes active in the Indian subcontinent. The land of India is characterized by great diversity in its physical features. The north has a vast expanse of rugged topography consisting of a series of mountain ranges with varied peaks, beautiful valleys and deep gorges. The south consists of stable table land with highly dissected plateaus, denuded rocks and developed series of scarps. In between these two lies the vast north Indian plain. Based on these macro variations, India can be divided into the six physiographic divisions as shown in figure 8.

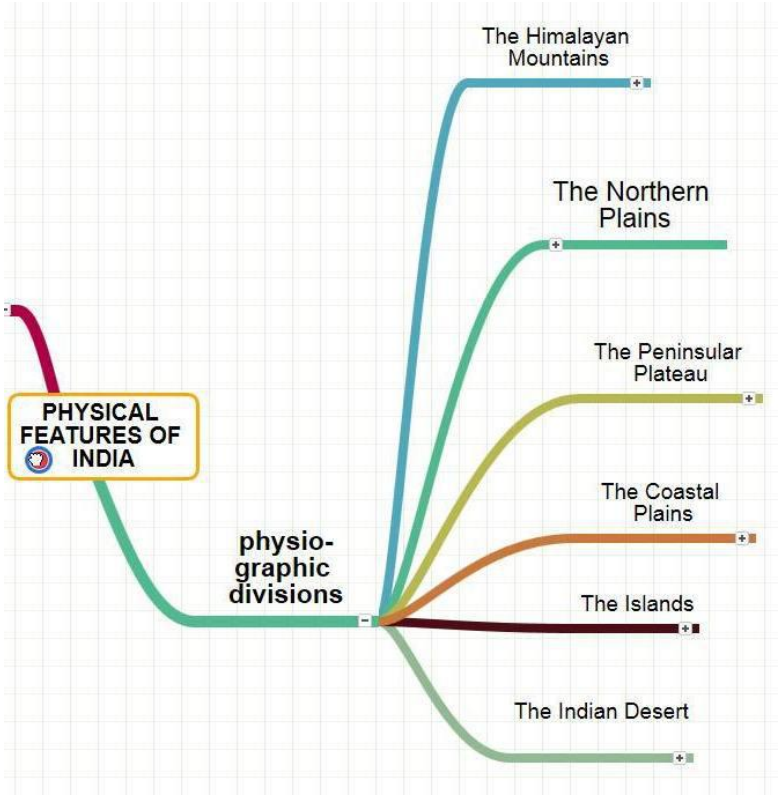

Figure 8 – Physiographic division of India

3.1. Himalayan Mountains

The North and Northeastern Mountains consist of the Himalayas and the Northeastern Hills. The Himalayas represent the loftiest and one of the most rugged mountain barriers of the world. The altitudinal variations are greater in the eastern half than those in the western half. They are steeper at their southern side as compared to northern side. They are separated from the plains by the Himalayan Front Fault (HFF).Himalayas are not only the physical barrier, they are also a climatic, drainage and cultural divide.

The general orientation of these ranges is from northwest to the southeast direction in the northwestern part of India. Himalayas in the Darjiling and Sikkim regions lie in an east west direction, while in Arunachal Pradesh they are from southwest to the northwest direction. In Nagaland, Manipur and Mizoram, they are in the north south direction. They form an arc, which covers a distance of about 2,400 Km. Its width varies from 400 Km in Kashmir to 150 Km in Arunachal Pradesh.

Longitudinal division of Himalayas include – Trans-Himalayas, the Greater Himalayas, the Lesser Himalayas and the Shiwaliks (Figure 9). The trans-Himalayas are about 40km wide and contain Tethys sediments which are underlain by 'Tertiary granite'. Trans-Himalayas in clue Karakoram, Ladakh and Zaskar Mountain ranges in India. The Greater Himalayas rise abruptly like a wall. They are 25 km wide with an average height above 6100m. Almost all the lofty peaks of the Himalayas Mt. Everest, Kanchenjunga, Nanga-Parbat lies in this zone. This mountain range has very few gaps mainly provided by the antecedent rivers, otherwise it is the most continuous range in the Himalayan system. The width of lesser Himalayas is about 80 km with an average height of 1300 – 4600 m. This region is subjected to extensive erosion due to heavy rainfall, deforestation and urbanization. The Shiwalik extend over a width of 10-50 Km and have an altitude varying between 900 and 1100 metres. These ranges are composed of unconsolidated sediments brought down by rivers from the main Himalayan ranges

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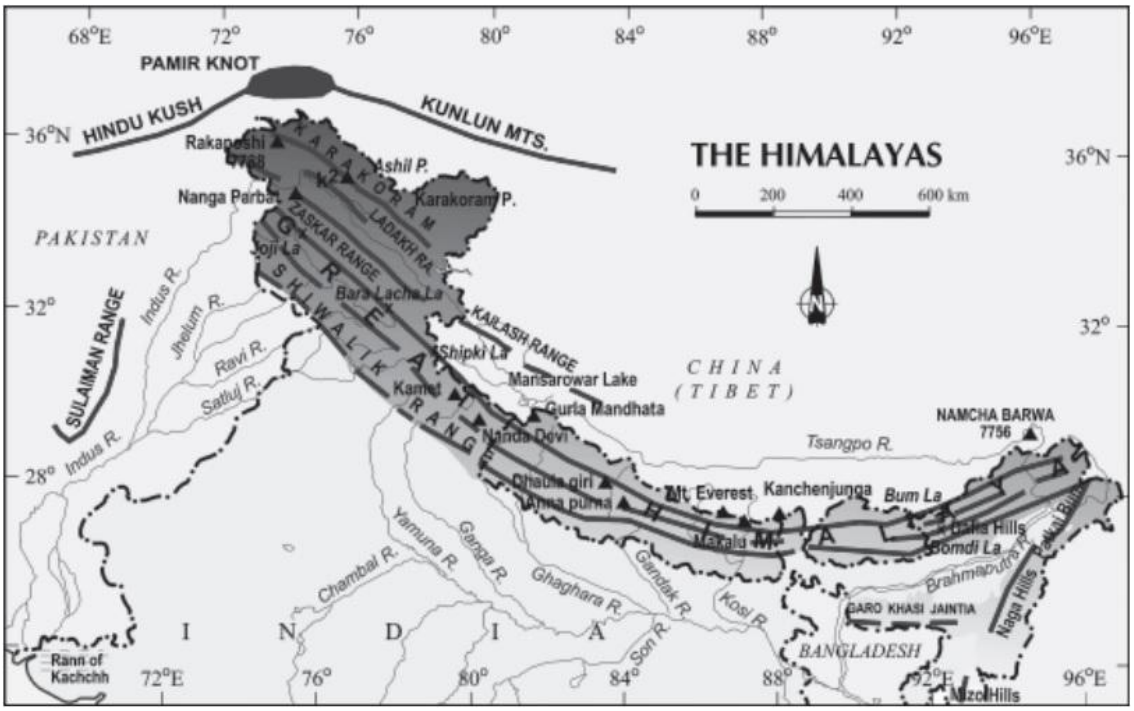

Figure 9 – Himalayas and Northeastern Hills

located farther north. Shiwalik are absent beyond Nepal. Landforms like gorges, V-shaped valleys, rapids, waterfalls etc. are indicative of youthful stage of Himalayas. Cross sectional view of Himalayan system is given below (figure 10).

Figure 10 - Cross sectional view of Himalayan system

Besides the longitudinal divisions, the Himalayas have been divided on the basis of regions from west to east. These divisions have been generally demarcated by river valleys. On the basis of relief, alignment of ranges and other geomorphologic features, the Himalayas can be divided into the five sub-divisions as shown in figure 11.

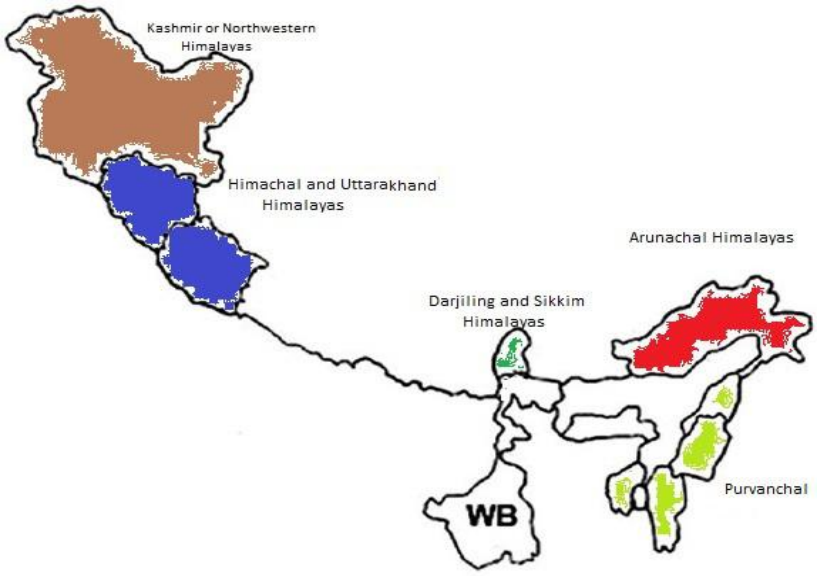

Figure 11 – Himalayan – Longitudinal Divisions

3.1.1. Kashmir or Northwestern Himalayas

Sprawling over an area of about 350,000 sq km, the range stretches about 700km in length and 500 km in width. This division is lying between Indus and Ravi rivers. With an average height of 3000m, it has the largest number of glaciers in India such as Baltoro, Siachen glaciers. Kashmir Himalayas comprise a series of ranges such as the Karakoram, Ladakh, Zaskar and Pir Panjal. The northeastern part of the Kashmir Himalayas, Ladakh, is a cold desert, which lies between the Greater Himalayas and the Karakoram ranges. It is one of the loftiest inhabited regions of the world. Between the Great Himalayas and the Pir Panjal range, lies the world famous valley of Kashmir and the famous Dal Lake.

A special feature of Kashmir valley is **Karewas** formation which is thick deposits of glacial clay and other materials embedded with moraines and useful for saffron cultivation. The southernmost part of this region consists of longitudinal valleys known as **'duns'** such as Jammu duns and Pathankot duns etc. Some of the important passes of the region are Zoji La on the Great Himalayas, Banihal on the Pir Panjal, Photu La on the Zaskar and Khardung La on the Ladakh range. Important fresh lakes such as Dal and Wular and salt water lakes such as Pangong Tso and Tso Moriri are also in this region. Some famous places of pilgrimage such as Vaishno Devi, Amarnath Cave, Charar -e-Sharif, etc. are also located here. Srinagar, capital city of the state of Jammu and Kashmir is located on the banks of Jhelum river.

3.1.2. Himachal and Uttrakhand Himalayas

Stretching over Himachal Pradesh, it occupies an area of about 83,000 sqkm. All the three ranges – the Greater, the Lesser (which is locally known as Dhaoladhar in Himachal Pradesh and Nagtibha in Uttaranchal) and the Shiwalik Himalayas – are well represented in this region. This division lies between Ravi and Kali rivers. It is drained by two major river systems of India, i.e. the Indus and the Ganga. Tributaries of the Indus include the river Ravi, the Beas and the Satluj, and the tributaries of Ganga flowing through this region include the Yamuna and the Ghaghara. The northernmost part of the Himachal Himalayas is an extension of the Ladakh cold desert. Gangotri, Milam and Pindar are the main glaciers of Uttarakhand.

The northern slopes of this region are clothed with thick forests and show plains and lakes, while the southern slopes are rugged and forest clad. The famous Valley of flowers is also situated in this region of Himalayas. The two distinguishing features of this region from the point of view of physiography are the 'Shiwalik' and 'Dun formations' such as Chandigarh-Kalka dun, Nalagarh dun. Dehra Duns the largest of all the duns with an approximate length of 35-45 km and a width of 22-25 km.

In the Great Himalayan range, the valleys are mostly inhabited by the Bhotias. These are nomadic groups who migrate to 'Bugyals' (the summer grasslands in the higher reaches) during summer months and return to the valleys during winters. The places of pilgrimage such as the Gangotri, Yamunotri, Kedarnath, Badrinath and Hemkund Sahib are also situated in this part. The region is also known to have **five famous Prayags - Vishnu Prayag, Nand Prayag, Karn prayag, Rudra Prayag and Dev Prayag,** in the descending flow sequence of their occurrence. In this section of Lesser Himalayas, the altitude between 1,000-2,000 m especially attracted to the British colonial administration, and subsequently, some of the important hill stations such as Dharamshala, Mussoorie, Shimla, and the cantonment towns and health resorts such as Shimla, Kasauli etc. were developed in this region.

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3.1.3. Darjiling and Sikkim Himalayas

The Darjiling and Sikkim Himalayas are flanked by Nepal Himalayas in the west and Bhutan Himalayas in the east. It is relatively small but is a most significant part of the Himalayas. As compared to the other sections of the Himalayas, these along with the Arunachal Himalayas are conspicuous by the absence of the Shiwalik formations. In place of the Shiwaliks here, the 'duar formations' are important, which have also been used for the development of tea gardens. Known for its fast-flowing rivers such as Tista, it is a region of high mountain peaks and deep valleys. Kanchenjunga (8598 m), 3rd highest peak of the world, is situated on the border of India and Nepal. This region has very few passes. The passes of Nathu-La and Jelep-La connect Gangtok (Sikkim) with Lhasa, Tibet (China).

The higher reaches of this region are inhabited by Lepcha tribes while the southern part, particularly the Darjiling Himalayas, has a mixed population of Nepalis, Bengalis and tribals from Central India. The British, taking advantage of the physical conditions such as moderate slope, thick soil cover with high organic content, well distributed rainfall throughout the year and mild winters, introduced tea plantations in this region. Sikkim and Darjiling Himalayas are also known for their scenic beauty and rich flora and fauna, particularly various types of orchids.

3.1.4. Arunachal Himalayas

Arunachal Himalayas extend from the east of the Bhutan Himalayas up to the Diphu pass in the east. The general direction of the mountain range is from southwest to northeast. In this part, the Himalayas rise very rapidly from the plains of Assam. Some of the important mountain peaks of the region are Kangtu and Namcha Barwa. These ranges are dissected by fast-flowing rivers from the north to the south, forming deep gorges. Brahmaputra flows through a deep gorge after crossing Namcha Barwa. Some of the important rivers are the Kameng, the Subansiri, the Dihang, the Dibang and the Lohit. These are perennial with the high rate of fall, thus, having the highest hydro-electric power potential in the country. Due to heavy rainfall, fluvial erosion is quite pronounced here. Few important passes of this region are Bomdi La, Diphu , Pangsau La etc.

An important aspect of the Arunachal Himalayas is the numerous ethnic tribal communities inhabiting in these areas. Some of the prominent ones from west to east are the Monpa, Daffla, Abor, Mishmi, Nishi and the Nagas. Most of these communities practise Jhumming (shifting cultivation). This region is rich in biodiversity which has been preserved by the indigenous communities. Due to rugged topography, the inter-valley transportation linkages are nominal. Hence, most of the interactions are carried through the duar region along the Arunachal-Assam border.

3.1.5. Eastern Hills and Mountains or Purvanchal

Eastern hills or Purvanchal are part of the Himalayan mountain system. On the southern border of Arunachal Pradesh, the Himalayas take a southerly turn and the ranges are arranged in a north-south direction. They are known by different local names. In the north, they are known as Patkai Bum (Arunachal Pradesh), Naga hills (Nagaland), the Manipur hills (Manipur) and in

the south as Mizo or Lushai hills (Mizoram).

Most of these ranges are separated from each other by numerous small rivers. The Barak is an important river in Manipur and Mizoram. The physiography of Manipur is unique by the presence of a large lake known as 'Loktak' lake at the centre, surrounded by mountains from all sides. Mizoram which is also known as the 'Molassis basin' is made up of soft unconsolidated deposits. Most of the rivers in Nagaland form the tributary of the Brahmaputra. These are low hills, inhabited by numerous tribal groups practicing Jhum cultivation.

3.2. The Northern Plains

The northern plains of India are remarkably homogeneous surface with an imperceptible slope. In fact, they are a featureless alluvial fertile plains formed by the alluvial deposits brought by the rivers – the Indus, the Ganga and the Brahmaputra along with their tributaries and Vindhyan rivers flowing towards north. The plain extends from the arid and semi-arid areas of Rajasthan in the west to Brahmaputra valley in the east. The average width of these plains varies between 150-300 km. The maximum depth of alluvium deposits varies between 1,000-2,000 m. Its average height is 200 metres above the mean se level. Due to a very gentle slope towards the sea, the rivers in this plain flow very leisurely and at times even sluggishly. The slope from Varanasi upto the mouth of Ganga is only 10 cm. per km. The land around Ambala is a bit more elevated.

Due to almost flat land, changing river courses in the areas of frequent floods is a unique geomorphic process in the plains. The Kosi (The Sorrow of Bihar) is one of two major tributaries of Ganga, the other river being Gandak, draining the plains of north Bihar, the most flood-prone area of India. Over the last 250 years, the Kosi River has shifted its course over 120 kilometres and the unstable nature of the river is attributed to the heavy silt which it carries during the monsoon season (figure 12).From north to south, northern plains can be divided into three major zones: the Bhabar, the Tarai and the alluvial plains. The alluvial plains can be further divided into the khaddar and the Bhangar.

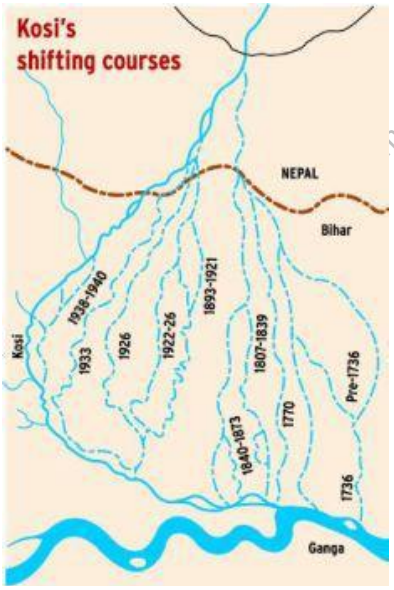

Figure 12 – Shifting course of river Kosi in last 250 years

3.2.1. The Bhabar Plain

Bhabar is a narrow belt ranging between 8-10 km parallel to the Shiwalik foothills at the break-up of the slope. Its width is, however, more in the western plains than in the eastern plains of Assam. The streams and rivers coming from the mountains deposit heavy materials of rocks and boulders, and at times, disappear in this zone due to high porosity. These rivers carry very coarse load with them. This load becomes too heavy for the streams to be carried over gentler

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gradients and gets dumped and spread as a broad low to high cone shaped deposit called alluvial fan ath the foothills of Shiwalik. Usually, the streams which flow over fans are not confined to their original channels for long and shift their position across the fan forming many channels called distributaries. The Bhabar tract is not suitable for cultivation of crops. Only big trees with large roots thrive in this region. The inhabitants are largely the cattle keeping Gujjars.

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3.2.2. The Tarai Tract

South of the Bhabar is the Tarai belt, with an approximate width of 10-20 km where most of the streams and rivers re-emerge without having any properly demarcated channel, thereby, creating marshy and swampy conditions known as the Tarai. Unlike Bhabar tracts, Tarai is wider in the eastern parts of the Great plains, especially in Brahmaputra valley due to heavy rainfall.

This has a luxurious growth of natural vegetation and houses a varied wild life. Many parts of the Tarai, especially in Uttarakhand, Uttar Pradesh, Haryana, Punjab and Jammu, have been reclaimed, for agricultural crops such as sugarcane, rice, wheat, maize etc. This marshy tract is infested with mosquitoes and infamous for Japanese Encephalitis (JE) disease.

3.2.3. Bhangar Plains

The south of Tarai is a belt consisting of old and new alluvial deposits known as the Bhangar and Khadar respectively. The Bhangar represents the upland alluvial tracts formed by the older alluviums. The largest part of the northern plains is formed of this older alluvium. The Bhangar formations were deposited during the middle Pleistocene period. The Bhangar land lies above the flood limits of the rivers. The soil is dark in colour, rich in humus content and productive. It contains concentration and nodules of impure calcium carbonate or kankar.

3.2.4. Khadar Plains

New alluvial deposits along the courses of the rivers are known as the khadar lands. Himalayan rivers have more flood area in the eastern India and thus, Khadar plains are wider here as compared to western area. The khadar tracts are enriched by fresh deposits of silt every year during the rainy season. The khadar land consists of sand silt, clay and mud. Most of the Khadar land has been brough under the cultivation and devoted to sugarcane, rice, wheat, maize, oilseeds.

Together alluvial plains (Khadar and Bhangar) are stretched over 100kms from north to south direction. These plains have characteristic features of mature stage of fluvial erosional and depositional landforms such as sand bars, meanders, oxbow lakes and braided channels. The Brahmaputra plains are known for their riverine islands and sand bars. It is also home to first green revolution that took place in 1960s-70s in India.

3.2.5. The Delta Plains

The mouths of these mighty rivers also form some of the largest deltas of the world, for example, the famous Sunderbans delta. Otherwise, this is a featureless plain with a general elevation of 50-150 m above the mean sea level. The deltaic plains are extension of the Khadar land. It covers 1.9 lakh sqkm of area in lower reaches of the Ganga River. In fact, it is an area of deposition as the river flows in this tract sluggishly. The deltaic plain consists of old mud, new mud and marsh.

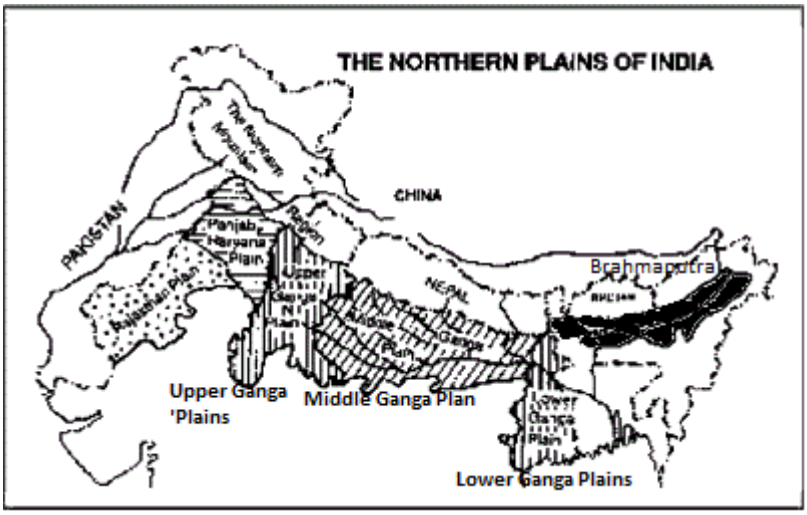

Figure 13 – Different section of northern plains of India

On the basis of geo-climatic and topographical characteristics, the northern plains of India may be divided into the following four meso-regions, namely (i) the plains of Rajasthan; (ii) the Punjab-Haryana plains; (iii) the Ganga plains; and (iv) the Brahmaputra Plains (figure 13).

3.2.6. The Plains of Rajasthan

They lie to the west of Aravallis. These plains cover a total area of about 175,000 sqkm. A substantial part of this plain has been formed by the recession of the sea as is evidenced by the presence of salt water lakes such as Sambhar lake near Jaipur city. During the Permo-carboniferous period, the greater part of the Rajasthan plain was under the sea. It has several dry beds of rivers like Saraswati which indicate that the area earlier was fertile. At present, the greater part of these plains is a desert covered with sand dunes and barchans. The Indira Gandhi canal has led to intensive agriculture in north-western Rajasthan.

3.2.7. The Punjab Haryana Plains

Stretching over an area of about 650km from northeast to southwest and 300km from west to east, the Punjab-Haryana plain is an aggradational plain, deposited by Satluj, Ravi and Beas rivers. Delhi ridge divides plains from the Gangetic plain. The height of the plains varies from 300 m in the north to 200 m in south east. The general direction of slope is from northeast to southwest and south. A plain between two rivers is called doab such as Bist doab between the Beas and Satluj.

3.2.8. The Ganga Plains

The Ganga plains lie between the Yamuna catchment in the west to the Bangladesh border in the east. It is about 1400km in length and has an average width of 300km. the general gradient of the plain is about 15cm per km. The ganga plains can be subdivided into the following sub-regions

- The upper Ganga plain – includes the Ganga-Yamuna Doab, Rohilakhand division and parts of the Agra division. The catchment area of the Yamuna river makes its western boundary, Shiwalik in the north. Its height varies from 100m to 300m. Kali, Sharda are other rivers feeding these plains. It is one of the most productive plains of India in which the Green revolution is a big success. Main crops grown here are sugarcane, wheat, rice, maize, mustard, vegetables etc.
- The middle Ganga plain – sprawling over an area of 150, 000 sqkm, it includes central and eastern Uttar Pradesh, Bihar up to Muzaffarpur and patna. It has thick alluvial deposits with less kankar. Being a low gradient plain, the rivers often change their courses in this region as described above about Kosi river. Son, Gandak are major tributaries of Ganga.

- The lower ganga plain – extends from Patna to the Bay of Bengal. It is bordered by Assam, Bangladesh in the east and Chotanagpur plateau in the west and Sundarban delta in the south. It is drained also by Tista, Sankosh, Mahananda, Damodar, Subarnarekha rivers. These plains have filled faults with sediment created during movement of Indian plate. Ganga is divided into several distributaries in the delta region. Hooghly is the best example of a distributary of Ganga.

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3.2.9. The Brahmaputra Plain

Stretching over an area of around 56,000sqkm, it is the eastern most part of plains. It is about 720 km long, 80 km wide and altitude varies from 30 m to 130 m. The region is surrounded by high mountains except in western side. Assam valley is characterized by a steep slope along northern margin. **Majuli with area of around 930sqkm is the largest river island of India and the second largest of world.** But this island is undergoing severe erosion and needs special protection. The tributaries descending from Himalayas form a series of alluvial fans. The fertile valley is conducive to grow rice and jute. It is also famous for its tea and two national parks – Kaziranga and Manas.

3.3. The Peninsular Plateau

The Great Peninsular plateau is a tableland composed of the old crystalline, igneous and metamorphic rocks. It lies to the South of the Great Northern Plains. It covers an area of about 16 lakh square km, i.e., about half of the total area of the country. It is an irregular triangle rising from the height of 150 m above the river plains up to an elevation of 600-900 m. Delhi ridge in the northwest, (extension of Aravalis), the Rajmahal hills in the east, Gir range in the west and the Cardamom hills in the south constitute the outer extent of the peninsular plateau. However, an extension of this is also seen in the northeast, in the form of Shillong and Karbi-Anglong plateau separated from Peninsular by Malda fault. One of the distinct features of the peninsular plateau is the black soil area known as Decean Trap. This is of volcanic origin hence the rocks are igneous. When Indian plate was moving over Reunion hotspot, basalt lava spread to form these igneous rocks. Actually these rocks have denuded over time and are responsible for the formation of black soil.

The Peninsular India is made up of a series of patland plateaus such as the Hazaribagh plateau, the Palamu plateau, the Ranchi plateau, the Malwa plateau, the Coimbatore plateau and the Karnataka plateau, etc. This is one of the oldest and the most stable landmass of India. The general elevation of the plateau is from the west to the east, which is also proved by the pattern of the flow of rivers. Rivers such as Krishna, Kaveri, Godavari, all rise from Western Ghats, makes delta in the Bay of Bengal side. Plateau has been subjected to large scale denudation. Its mountains are generally of relic type. Because of their old age, all the rivers have almost attained their base level and have built up broad and shallow valleys. Some of the important physiographic features of this region are tors, block mountains, rift valleys, spurs, bare rocky structures, series of hummocky hills and wall-like quartzite dykes offering natural sites for water storage.

This Peninsular plateau has undergone recurrent phases of upliftment and submergence accompanied by crustal faulting and fractures. These spatial variations have brought in elements of diversity in the relief of the peninsular plateau. The northwestern part of the plateau has a complex relief of ravines and gorges. The ravines of Chambal, Bhind and Morena are some of the well-known examples. On the basis of the prominent relief features, the peninsular plateau can be divided into three broad groups: (i) The Deccan Plateau; (ii) The Central Highlands; and (iii) The Northeastern Plateau.

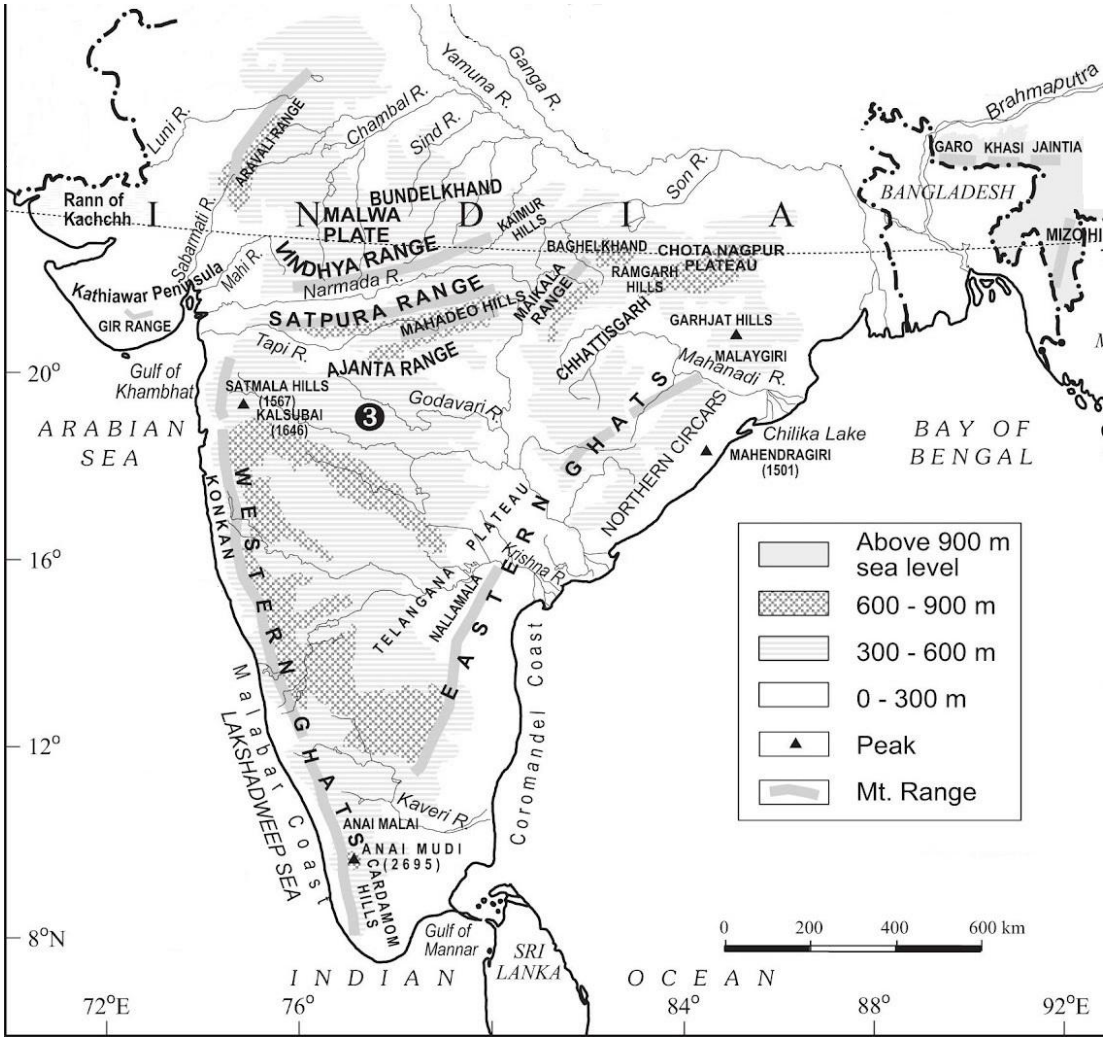

Figure 14 – Peninsular India: Relief

3.3.1. The Deccan Plateau

This physiographic division is the largest region (about 7 lakh square km) of the Great Indian Plateau. The shape of this plateau is triangular and lies to the south of the river Narmada. This is bordered by the Western Ghats in the west, Eastern Ghats in the east and the Satpura, Maikal range and Mahadeo hills in the north.The Satpura range is formed by a series of scarped plateaus on the south, generally at an elevation varying between 600-900 m. It is a classic example of the relict mountains which are highly denuded and form discontinuous ranges. The Deccan Plateau is higher in the west and slopes gently eastwards.

Western Ghats are locally known by different names such as Sahyadri in Maharashtra, Nilgiri hills in Karnataka and Tamil Nadu and Anaimalai hills and Cardamom hills in Kerala. These are block mountains formed due to the downwarping of a part into the Arabian Sea. Western ghats lie parallel to the western coast from mouth of Tapi rover to Kanyakumari. The western slope is steeper as compared to gentle eastern slope. Thal, Bhor and pal Ghats are major passes of Western Ghats. The Eastern Ghats stretch from the Mahanadi Valley to the Nigiris in the south. The Eastern Ghats are discontinuous and irregular and dissected by rivers such as Mahanadi, the Godavari, the Krishna, the Kaveri draining into the Bay of Bengal. Shevroy Hills and the Javadi Hills are located to the southeast of the Eastern Ghats.

Western Ghats are comparatively higher (900-1600m) in elevation and more continuous than the Eastern Ghats (600m). Their average elevation is about 1,500 m with the height increasing from north to south. 'Anaimudi' (2,695 m), the highest peak of Peninsular plateau is located on the Anaimalai hills of the Western Ghats followed by Dodabetta (2,637 m) on the Nilgiri hills.

Mahendragiri (1,501 metres) is the highest peak in the Eastern Ghats. The Eastern and the Western Ghats meet each other at the Nilgiri hills.

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3.3.2. The Central Highlands

It extends between Vindhayalchal range in South and Great Northern Plains in nroth. The Aravallis form the west-northwestern edge of the Central Highlands. An eastern extension of the Central Highland is formed by the Rajmahal hills. Malwa plateau forms the dominant part of the Central Highlands. The part of the Central Highlands which extends to the east of Malwa Plateau is known as Bundelkhand and is further followed by Baghelkhand and the well known Chhotanagpur Plateau with large mineral reserves. Chhotanagpur is drained by Damodar river. The Mahadeo Hills, Kaimur Hills and Maikal Range lie towards further east. The valley of Narmada has been formed due to the subsidence of the land mass between the Vindhyas and the Satpuras.

The general elevation of the Central Highlands ranges between 700-1,000 m and it slopes towards the north and northeastern directions. Most of the tributaries (Chambal, Sind, Betwa, Ken) of the river Yamuna have their origin in the Vindhyan and Kaimur ranges. Banas, tributary of the river Chambal, originates from the Aravalli in the west.

The extension of the Peninsular plateau can be seen as far as Jaisalmer in the West, where it has been covered by the longitudinal sand ridges and crescent-shaped sand dunes called barchans. Aravallis hills extend from Gujarat, through Rajasthan to Delhi in the northeasterly direction for a distance of about 700 km till Delhi. The highest peak of the Aravalli hills is Gurushikhar (1722 m) near Mt. Abu, hill station.

3.3.3. The North-Eastern Plateau

It is an extension of the main Peninsular plateau in the northeast– locally known as the Meghalaya and Karbi-Anglong Plateau. It is separated by Malda fault from the Chotanagpur Plateau. Later, this depression got filled up by the deposition activity of the numerous rivers. The Meghalaya plateau is further sub-divided into three: (i) The Garo Hills; (ii) The Khasi Hills; (iii) The Jaintia Hills, named after the tribal groups inhabiting this region. An extension of this is also seen in the Karbi Anglong hills of Assam. Shillong is the highest peak in this plateau.

Similar to the Chotanagpur plateau, the Meghalaya plateau is also rich in mineral resources like coal, iron ore, sillimanite, limestone and uranium. This area receives maximum rainfall from the south west monsoon. As a result, the Meghalaya plateau has a highly eroded surface

3.4. The Indian Desert

The Indian desert lies towards the western margins of the Aravali Hills. It is a land of undulating topography dotted with longitudinal dunes and barchans. This region receives low rainfall below 150 mm per year; hence, it has arid climate with low vegetation cover. Low precipitation and high evaporation makes it a water deficit region. Streams appear during the rainy season. Luni is the only large river in this region. It is believed that during the Mesozoic era, this region was under the sea. This can be corroborated by the evidence available at wood fossils park at Aakal and marine deposits around Brahmsar, near Jaisalmer. Land features present here are mushroom rocks, shifting dunes and oasis. the desert can be divided into two parts: the northern part is sloping towards Sindh and the southern towards the Rann of Kachchh.

3.5. The Coastal Plains

The Peninsular plateau is flanked by stretch of narrow coastal strips, running along the Arabian Season the west and the Bay of Bengal on the east.

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3.5.1. Western Coastal Plains

West Coastal Plain extends along the Arabian Sea from the Rann of Kutchch in the north to Kanyakumari in the south. These plains are an example of submerged coastal plain. Because of this submergence it is a narrow belt and provides natural conditions for the development of ports and harbours. Kandla, Mazagaon, JLN port Navha Sheva, Marmagao, Mangalore, Cochin, etc. are important natural ports.

Extending from the Gujarat coast in the north to the Kerala coast in the south, the western coast may be divided into following divisions – the Kutch and Kathiawar coast in Gujarat, Konkan coast in Maharashtra, Goan coast and Malabar coast in Karnataka and Kerala respectively. The plains of Gujarat are made up of black soil. There are a number of long and narrow lagoons on Malabar Coast. Kochi port is situated on one of the lagoons. These plains are narrow in the middle and get broader towards north and south. The rivers flowing through this coastal plain do not form any delta. The Malabar coast has got certain distinguishing features in the form of 'Kayals'(backwaters), used for fishing, inland navigation, tourism.

3.5.2. Eastern Coastal Plains

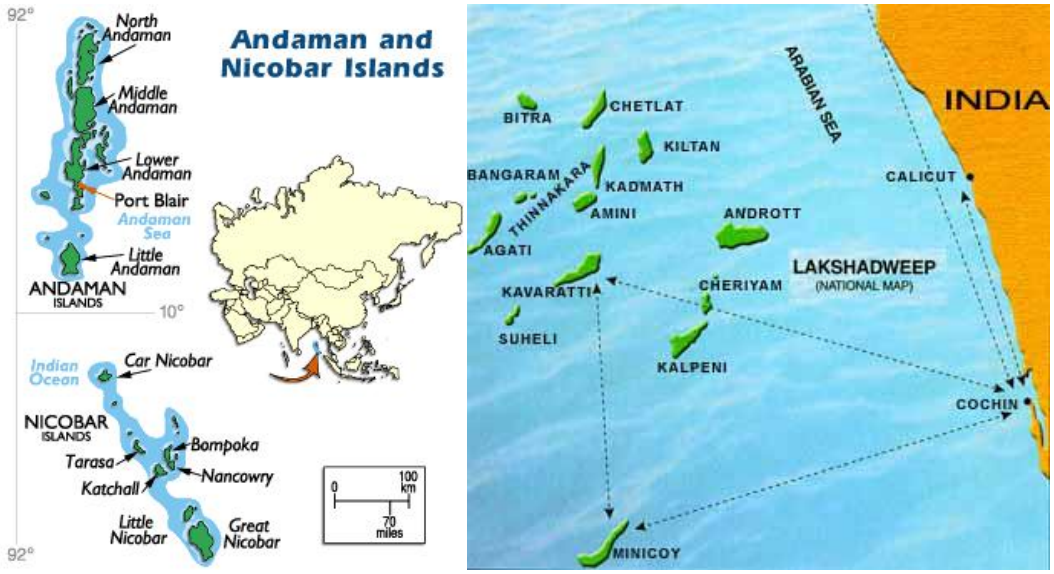
The eastern coastal plain is broader, leveled and is an example of an emergent coast. These plains are formed by the alluvial fillings. The monotony of plains is broken by the numerous hills. In the northern part, it is referred to as the Northern Circar, while the southern part is known as the Coromandal Coast. There are well developed deltas here, formed by rivers Mahanadi, Krishna, Godavari, Kaveri etc.Lakes such as Chilika, Pulicat, and Kolluru are the famous lagoons of this plain. Because of its emergent nature, it has less number of ports and harbours. The continental shelf extends up to 500 km into the sea, which makes it difficult for the development of good ports and harbours. Paradip, Visakhapatnam, Ennor, Chennai, Tuticorin are important ports along eastern coast. Rice is the intensively grown here.

3.6. The Islands

There are two major island groups in India – one in the Bay of Bengal and the other in the Arabian Sea.

3.6.1. Andaman and Nicobar Islands

The Bay of Bengal island groups consist of about 572 islands/islets. These are situated roughly between 6°N-14°N and 92°E -94°E (Figure 15a). The entire group of island is divided into two broad categories – the Andaman in the north and the Nicobar in the south. They are separated by a water body which is called the Ten degree channel. It is believed that island group is an extension of submarine mountains. However, some smaller islands are volcanic in origin. Barren island, the only active volcano in India is also situated here. The coastal line has some coral deposits, and beautiful beaches. These islands lie close to equator and thus, experience equatorial climate. The islands have thick forest cover due to heavy convectional rainfall.



(a) – Andaman and Nicobar Islands **(b) Lakshadweep Islands**

Figure 15 – Island groups of India

3.6.2. Lakshadweep Islands

Lakshadweep Islands are situated in the Arabian Sea, at a distance of 280-480km off the coast of Kerala. These are scattered between 8°N-12°N and 71°E -74°E (Figure 15b). All these islands are of coral origin. They have been built up by corals. Only 11 out of 36 islands are inhabited. The largest island among these, the Minicoy, has an area of 4.5 square km only. The entire group of islands is broadly divided by the Eleventh degree channel, north of which is the Amini Island and to the south of the Canannore Island. Landform features are storm beaches consisting of unconsolidated pebbles, shingles, cobbles and boulders.

In overall, it would be clear that each region complements the other and makes the country richer in its natural resources. The northern mountains are the major sources of water and forest wealth. The northern plains are the granaries of the country. They provide the base for early civilisations. The plateau is a storehouse of minerals, which has played a crucial role in the industrialisation of the country. The coastal region and island groups provide sites for fishing and port activities.

4. Drainage

Rivers have always been of supreme importance to man, providing focal points for habitation, water for cultivation and avenues to travel, water power and recreation. A river or stream is a body of water flowing in a channel. The term '**drainage'** describes the river system of an area. It is an integrated system of a river and its tributaries which collect and funnel surface water to the sea. The area drained by a single river system is called a **drainage basin**. The boundary line separating one drainage basin from the other is known as the **watershed**. A river drains the water collected from a specific area, which is called its '**catchment area'**. The catchments of large rivers are called **river basins** while those of small rivulets and rills are often referred to as watersheds. Watersheds are small in area while the basins cover larger areas.

4.1. Drainage Pattern

A geometric arrangement of streams in a region; determined by slope, differing rock resistance to weathering and erosion, climate, hydrologic variability, and structural controls of the landscape is known as drainage pattern. The rivers that existed before the upheaval of the Himalayas and cut their courses by making gorges in the mountains are knows as the **antecedent rivers**. Indus, Satluj, Ganga are some important antecedent rivers. The rivers which

follow general direction of slope are known as the **consequent rivers**. Godavari and Krishna etc. rivers descending from the Western Ghats are some consequent rivers.

The drainage pattern resembling the branches of a tree is known as "**dendritic**" the examples of which are the rivers of northern plain. It develops where the river channel follows the slope of the terrain. When the rivers originate from a hill and flow in all directions, the drainage pattern is known as '**radial'**. The rivers originating from the Amarkantak range present a good example of it. When the primary tributaries of rivers flow parallel to each other and secondary tributaries join them at right angles, the pattern is known as '**trellis'**. It develops where hard and soft rocks exist parallel to each other. Right bank tributaries of Brahmaputra rivers make trellis pattern while the left bank tributaries exhibit the

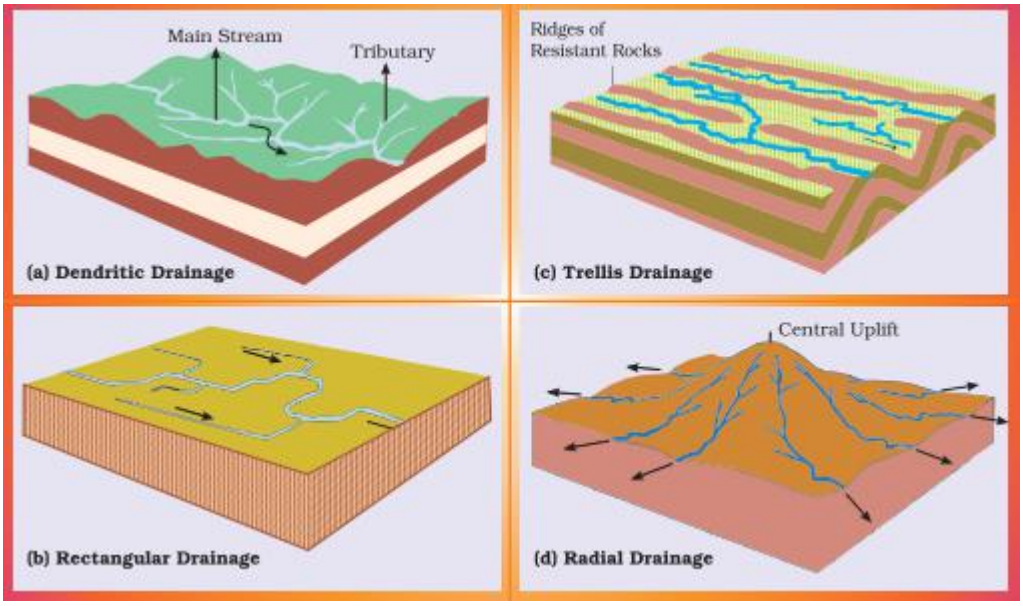


Figure 16–Drainage patterns

dendritic pattern. When the rivers discharge their waters from all directions in a lake or depression, the pattern is known as '**centripetal'**. It is reverse of radial and occurs in the areas of karst topography. A combination of several patterns may be found in the same drainage basin.

4.2. Drainage System of India

The drainage systems of India are mainly controlled by the broad relief features of the subcontinent. Indian drainage system may be divided on various bases. On the basis of discharge of water (orientations to the sea), it may be grouped into: (i) the Arabian Sea drainage; and (ii) the Bay of Bengal drainage. They are separated from each other through the Delhi ridge, the Aravalis and the Sahyadris (water divide is shown by a line in Figure 17).Many rivers have their sources in the Himalayas and discharge their waters in the Bay of Bengal except Indus river system which discharge into Arabian Sea. Ganga, Yamuna, Gandak, Tista and Brahmaputra rivers are major example of it.

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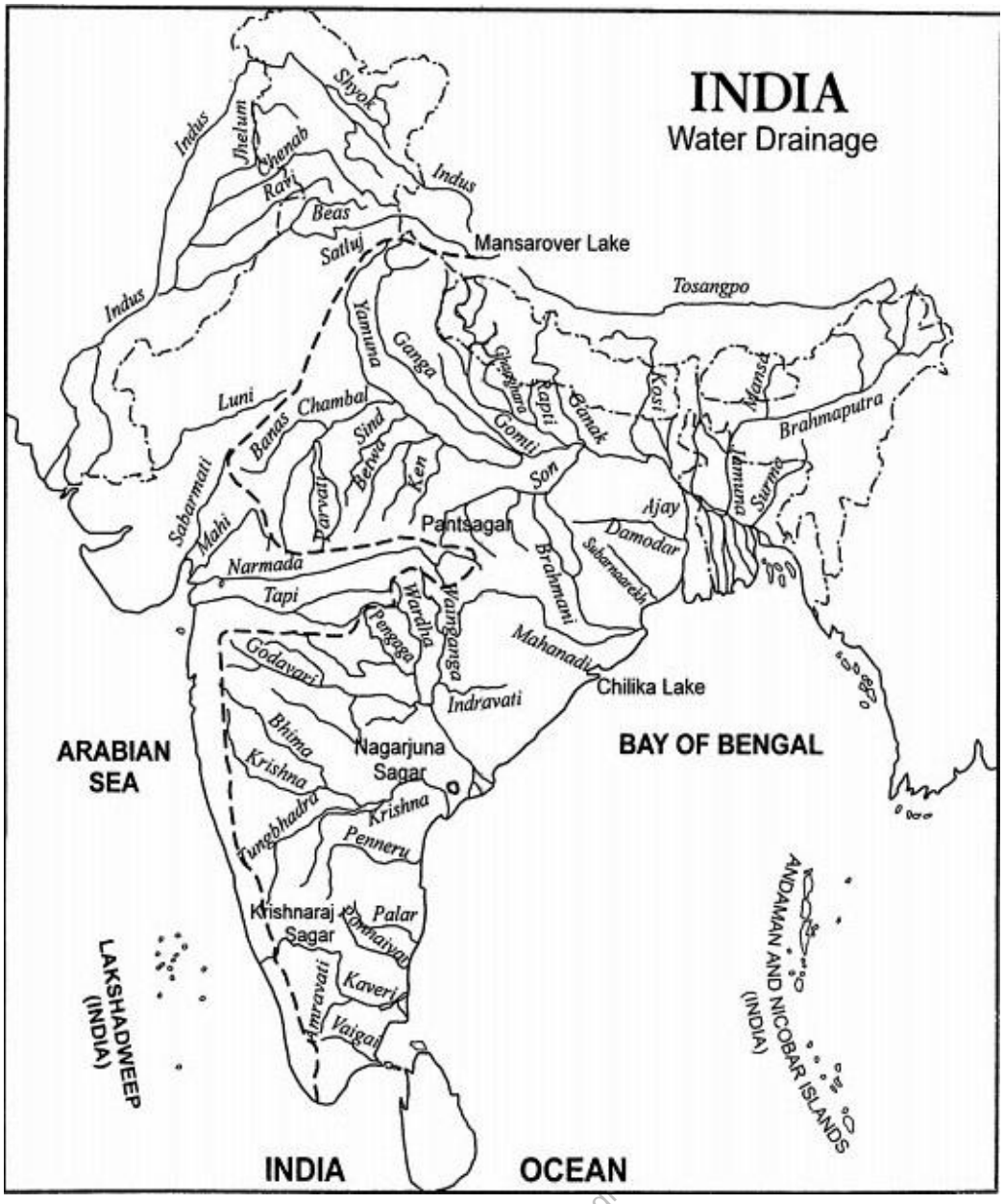

Figure 17 – Water divide between east flowing and west flowing rivers

Large rivers flowing on the Peninsular plateau have their origin in the Western Ghats and discharge their waters in the Bay of Bengal. Krishna, Godavari, Kaveri, Tungabhadra are some example of it. The Narmada and Tapi are two large rivers which are exceptions. They along with many small rivers discharge their waters in the Arabian Sea. These small rivers have origin in Western Ghats such as Mandavi, Netravati, Sharavati, and Periyar rivers.

Nearly 77 per cent of the drainage area consisting of the Ganga, the Brahmaputra, the Mahanadi, the Krishna, etc. is oriented towards the Bay of Bengal while 23 per cent comprising the Indus, the Narmada, the Tapi, the Mahi and the Periyar systems discharge their waters in the Arabian Sea.

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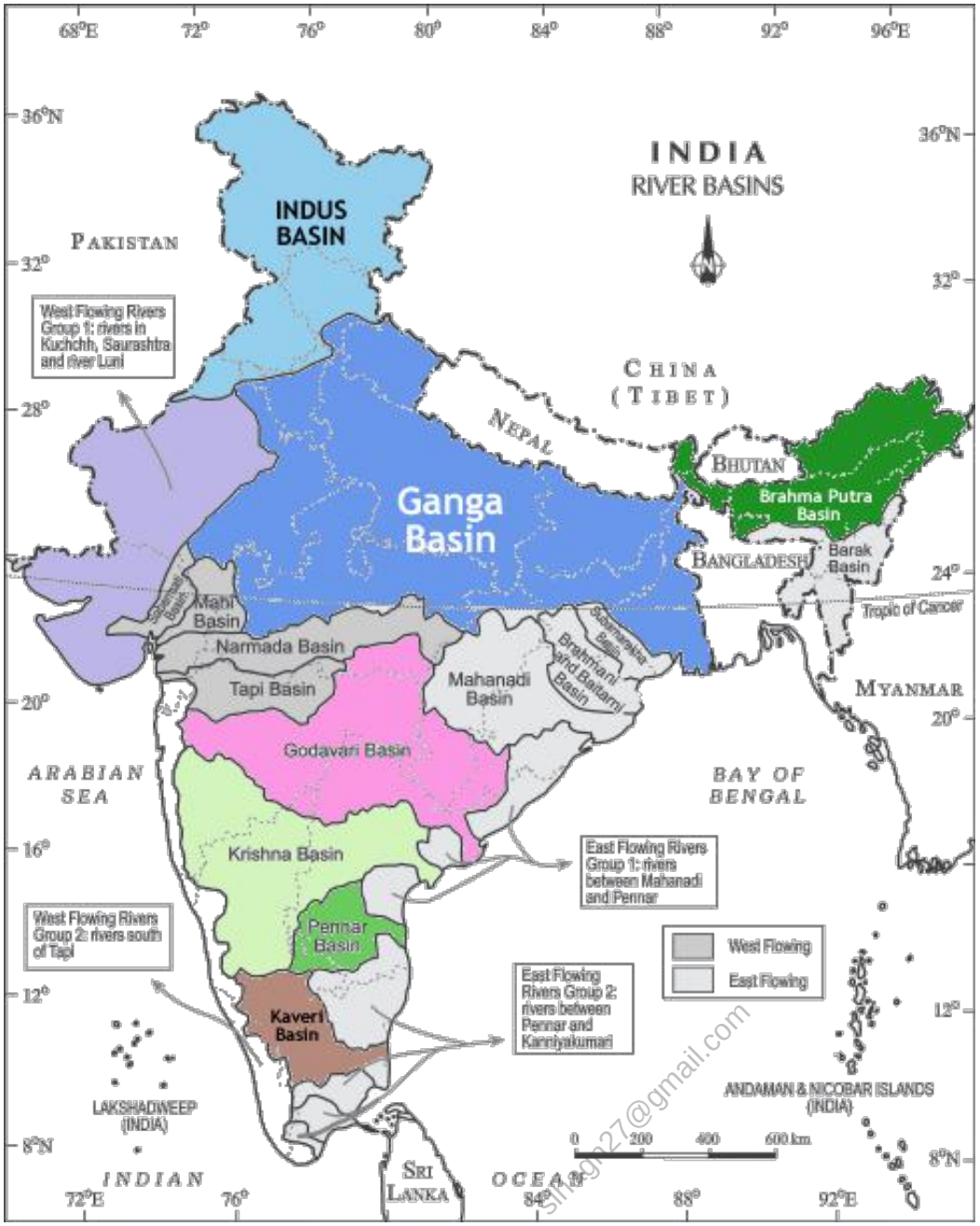

Figure 18 – Major river Basins of India

On the basis of mode of origin, the drainage of India may be divided into (i) Himalayan Drainage; and (ii) Peninsular drainage. However, many of the Peninsular rivers like the Chambal, Betwa, Ken, Son are tributaries of Ganga river system which originate in Himalayas (figure 17).

On the basis of the size of the watershed, the drainage basins of India are grouped into three categories: (i) Major river basins with more than 20,000 sq. km of catchment area (figure 18). It includes 14 drainage basins such as the Ganga, the Indus, the Godavari, the Krishna, the Brahmaputra, the Mahanadi, the Narmada, the kaveri, the Tapi, the Pennar, the Brahmani, the Mahi, the Sabarmati, the Barak, the Suvarnarekha; (ii) Medium river basins with catchment area between 2,000-20,000 sq. km incorporating 44 river basins such as the Kalindi, the Periyar, the Meghna, etc.; and (iii) Minor river basins with catchment area of less than 2,000 sq. km include fairly good number of rivers flowing in the area of low rainfall.

4.3. The Himalayan Drainage System

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The Himalayan drainage system has evolved through a long geological history. There is no unanimity among geologists about the origin of the Himalayan rivers. However, it is believed that a mighty river, namely Shiwalik or Indo-Brahma was flowing west from Assam to Sind and finally discharged into Gulf of Sind during Miocene period. The remarkable continuity of the Shiwalik and its lacustrine origin and alluvial deposits consisting of sands, silt, clay, boulders and conglomerates support this viewpoint.

This mighty Shiwalik river was dismembered into three main systems which are now called as Indus, Ganga and Brahmaputra systems (figure 19).The dismemberment is attributed to upheaval in the Western Himalayas including uplift of the Potwar Plateau (or Delhi Ridge). This ridge act as a water divide between Indus and Ganga river systems. Similarly, the down thrusting of the Malda fault (area between Rajmahal Hills and the Meghalaya Plateau) caused the Ganga and the Brahamputra systems to flow towards Bay of Bengal. The giant gorges, sudden bends towards South and other such features are evidence in support that these rivers are older than the Himalayas.

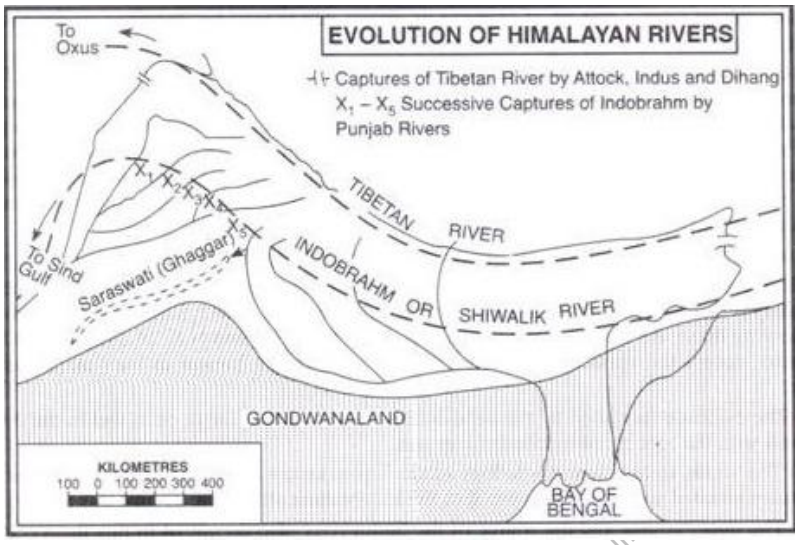


Figure 19 – evolution of Himalayan Drainage

Currently, Indus, Ganga and Brahamputra with their respective tributaries make major drainage systems of Himalayas. Since these are fed both by melting of snow and precipitation, rivers of this system are perennial.

4.3.1. Landforms of Himalayan Rivers

The Himalayan rivers are in their youthful stage carving out a number of erosional landforms. These rivers pass through the giant gorges carved out by the erosional activity carried on simultaneously with the uplift of the Himalayas. Satluj, Indus forms great gorges near Gilgit and Sukkur respectively. Besides deep gorges, these rivers also form V-shaped valleys, rapids and waterfalls in their mountainous course. While entering the plains, they form depositional features like flat valleys, ox-bow lakes, flood plains, braided channels, and deltas near the river mouth. In the Himalayan reaches, the course of these rivers is highly tortuous, but over the plains they display a strong meandering tendency and shift their courses frequently.

4.3.2. The Indus System

The Indus (Sindhu) is one of the most important drainage systems of the Indian subcontinent and one of the largest in the world. It covers an area of 11, 65,000 sq. km and length of 2,880 km, out of which 321, 289 sqkm area and 1,114 km length is in India. The Indus is the westernmost of the Himalayan rivers in India. Indus has origin from a glacier near Bokar Chu in

Student Notes:

the Kailash Mountain range in the Tibet province of China. In Tibet, it is known as 'Singi Khamban; or Lion's mouth. After flowing in a constricted valley in Tibet, it follows a long, nearly straight course between the Ladakh and Zaskar ranges in the northwest direction where it receives Zaskar below Leh town. It cuts across the Ladakh range, forming a spectacular gorge near Gilgit which is 5200m in height. In this region, transverse glaciers and landslides periodically dam the river. River passes Nanga Parbat and turns south-west to enter Pakistan near Chillar in the Dardistan region. In the Jammu and Kashmir, Indus receives a number of Himalayan tributaries such as the Shyok, the Gilgit, the Hunza, the Nubra, the Shigar, the Gasting and the Dras. Right bank tributaries such as the Khurram, the Tochi, etc. originate in Sulaiman ranges. Down in the Punjab province of Pakistan, Indus receives **'Panjnad'**, five rivers of Punjab, namely the Satluj, the Beas, the Ravi, the Chenab and the Jhelum. River finally drains into the Arabian Sea, east of Karachi city. These rivers do not meet Indus separately but as a single river.

The Jhelum (Vitasta) rises from a spring at Verinag Spring situated at the foot of the Pir Panjal. It flows through Srinagar and the Wular lake before entering Pakistan through a deep narrow gorge. It joins the Chenab in Pakistan. It is the most important river of Kashmir.

The Chenab (Asikni) flows in India for about 1180km draining around 26,755 sqkm area. It is the largest tributary of the Indus. It is formed by two streams, the Chandra and the Bhaga, which join at Tandi near Keylong in Himachal Pradesh. Hence, it is also known as Chandrabhaga. Major hydro power plants installed in Chenab are Salal, Baghliar, and Dulhasti.

The Ravi (Parushni) river flows for about 725 km and drains 6000 sqkm area in India. It rises near the Rohtang Pass in Kullu hills in Himachal Pradesh, very close to the source of the Beas river. It flows through the famous Chamba valley. It drains an area lying between Pir Panjal and Dhauladhar ranges. It also cuts a gorge in Dhaula Dhar range. In plains of Punjab, it runs along the Indo-Pak border and joins Chenab near Sarai Sidhu in Pakistan.

The Beas (Vipasa) river originates from the Beas Kund near the Rohtang Pass at an elevation of 4,000 m. The river flows through the Kullu valley and forms gorges at Kati and Largi in the Dhaula Dhar range. Further down, it flows through the Kangra valley. It enters the Punjab plains where it meets the Satluj near Harike in India's Punjab. Indira Gandhi Canal that feeds western Rajasthan has origin at Harike, confluence of Beas and Satluj.

The Satluj (Satadru) river rises from the Rakas Lake near Mansarovar (4,555m) in Tibet. This is an antecedent river. It flows almost parallel to the Indus for about 400 km before entering India, and comes out of a gorge across the Great Himalayas. It passes through the Shipki La (4300 m) on the Himalayan ranges at India-China border. It cuts the Zaskar ranges, Dhaula Dhar range, Shiwalik and finally enters the Punjab plains. It feeds the canal system of the Bhakra Nangal project.

The Ghaggar (Saraswati) is an inland drainage which rises in the talus fan of the Shiwalik near Ambala, Haryana. After entering the plains, it disappears but reappears at Karnal. Further on, the stream disappears near Hanumargarh in Bikaner. It is believed that it is an old tributary of the Indus.

4.3.3. The Ganga System

The Ganga is the most important river of India both from the point of view of its basin and cultural significance. The river has a length of 2,525 km. It is the largest river basin in India with about one-fourth area of the country under it. It rises in the Gangotri glacier near Gaumukh (3,900 m) in the Uttarakhand where it is known as the Bhagirathi. At **Devprayag**, the Bhagirathi meets the Alaknanda and both makes Ganga. The Alaknanda consists of the Dhauli and the Vishnu Ganga which meet at **Vishnuprayag**. Pindar joins Alaknanda at **Karnaprayag** while Mandakini meets it at **Rudraprayag**. At Haridwar, Ganga enters into plains. Further on, it moves in west-east direction and split into two distributaries, namely the Bhagirathi and the Hugli in

Bengal. Along with Brahmaputra, it makes largest delta of the world. The Ganga river is having a number of perennial and non-perennial rivers originating in the Himalayas in the north and the Peninsula in the south, respectively. It flows through major cities of India – Kanpur, Allahabad, Patna, and Kolkata.

The Yamuna river, the western most and the longest tributary of the Ganga, has its source in the Yamunotri glacier on the western slopes of Banderpunch range (6,316 km). It flows parallel to Ganga and finally meets the same at Allahabad (Prayag). The right bank tributaries involves the Chambal, the Sind, the Betwa and the Ken which originates in the Peninsular plateau while the Hindan, the Rind, the Sengar, the Varuna, etc. join it on its left bank. It is a major source to feed the canals of Haryana and Uttar Pradesh. It flows through cities such as Karnal, Delhi, and Agra.

The Gandak river comprises two streams, namely Kaligandak and Trishulganga. It rises in the Nepal Himalayas between Dhaluagiri and Mt. Everest. It enters the Ganga Plains of India in Champaran, Bihar and joins Ganga at Sonpur near Patna. This river changes its course frequently.

The Ghaghara originates in the glaciers of Mapchachungo. It comes out of the mountain, cutting a deep gorge at Shishapani. The river Sarda joins it in the plain before it finally meets the Ganga at Chhapra. It flows through famous Ayodhya town.

The Ramganga is the first major tributary to join the Ganga from its left near Kannauj. It rises in the Garhwal hills near Gairsain. A large dam has been built on this river near Kalagarh.

The Damodar drains the eastern parts of the Chotanagpur Plateau where it flows through a rift valley and finally joins the Hugli at Falta. The Barakar is its main tributary. Once known as the 'sorrow of Bengal', the Damodar has been now tamed by the Damodar Valley Corporation, a multipurpose project.

The Chambal rises near Mhow in the Malwa plateau from Vindhyan range and flows northwards through a gorge up wards of Kota in Rajasthan. From Kota, it traverses down to Bundi, Sawai Madhopur and Dholpur, and finally joins the Yamuna at Etawah. The Chambal is famous for its badland topography called the Chambal ravines. Ravines are being reclaimed for agricultural and pastoral activities. Banas river is its main tributary. The main dams across the river are Gandhi Sagar (Kota), Rana Pratap Sagar and Jawahar Sagar.

The Son originates from the Amarkantak plateau. It has length of 780km and drains areas of around 54,000 sqkm. After forming a series of waterfall at the edge of plateau, it reaches Arrah, west of Patna to join the Ganga.

The Sarda or Saryu river rises in the Milan glacier in the Nepal Himalayas where it is known as the Goriganga. Along the Indo-Nepal border, it is called Kali or Chauk, where it joins the Ghaghara. The Mahananda is another important tributary of the Ganga rising in the Darjiling hills. It joins the Ganga as its last left bank tributary in West Bengal.

4.3.4. The Brahmaputra System

The Brahmaputra is one of the largest river of not only India but the world. Its total length is 2900km and basin area is 5,80,000 sqkm (916 km and 1,87,00 sqkm in India). Its origin is in the Chemayungdung glacier of the Kailash range near the Mansarovar lake. From here, it flows parallel to the Greater Himalayas in the dry and flat Tibetan region where it is known as Tsangpo. It emerges as a turbulent and dynamic river after carving out a deep gorge in the Central Himalayas near Namcha Barwa (7,755 m). The river emerges from the foothills under the name of Siang or Dihang. It enters India west of Sadiya town in Arunachal Pradesh. It receives its main left bank tributaries, viz., Dibang or Sikang and Lohit; thereafter, it is known as the Brahmaputra.

In the Assam valley, its major left bank tributaries are the Burhi Dihing, Dhansari (South) and Kalang whereas the important right bank tributaries are the Subansiri, Kameng, Manas and

Student Notes:

Sankosh. The Brahmaputra enters into Bangladesh near Dhubri and flows southward. In Bangladesh, the Tista joins it on its right bank from where the river is known as the Yamuna. The Brahmaputra is well-known for floods, channel shifting and bank erosion. This is due to the fact that most of its tributaries are large, and bring large quantity of sediments owing to heavy rainfall in the region

Student Notes:

4.4. The Peninsular Drainage System

The Peninsular drainage system is older than the Himalayan one. This is evident from the broad, largely-graded shallow valleys, and the maturity of the rivers. Rivers follow the relief pattern of the plateau. Except for the rivers flowing through fault valleys, the slope of all rivers is very gentle.

4.4.1. Evolution of Peninsular Drainage System

Three major geological events in the distant past have shaped the present drainage systems of Peninsular India: (i) Subsidence of the western flank of the Peninsula leading to its submergence below the sea during the early tertiary period. Generally, it has disturbed the symmetrical plan of the river on either side of the original watershed. Earlier the area to the west of the Western ghats was also a landmass in ancient times. At that time, rivers flowed in both directions from the water divide formed by the Ghats and there was a symmetrical distribution of rivers. (ii) Upheaval of the Himalayas when the northern flank of the Peninsular block was subjected to subsidence and the consequent trough faulting. The Narmada and The Tapi flow in trough faults and fill the original cracks with their detritus materials. Hence, there is a lack of alluvial and deltaic deposits in these rivers. (iii) Slight tilting of the Peninsular block from northwest to the southeastern direction gave orientation to the entire drainage system towards the Bay of Bengal during the same period.

4.4.2. River Systems

The Western Ghats situated near the western coast form the major water divide between the major Peninsular rivers, discharging their water in the Bay of Bengal and as small rivulets joining the Arabian Sea. Except Narmada and Tapi, all major rivers flow in east direction. The other major river systems of the Peninsular drainage are – the Mahanadi the Godavari, the Krishna and the Kaveri. Peninsular rivers are characterised by fixed course, absence of meanders and ephemeral flow of water. The Narmada and the Tapi which flow through the rift valley are, however, exceptions. Peninsular rivers receive water from Southwest monsoon and Tamil Nadu rivers gets water from retreating or northeast monsoon also.

4.4.3. East Flowing Rivers

The Mahanadi rises near Sihawa, Amarkantak hills in the highlands of Chhattisgarh and runs through Orissa to discharge its water into the Bay of Bengal. It is 851 km long and its catchment area spreads over 1.42 lakh sq. km. Some navigation is carried on in the lower course of this river. Deltaic stretch of this river is part of National Waterways 5(NW5).

The Godavari is the largest Peninsular river. It rises from the slopes of the Western Ghats in the Nasik district of Maharashtra. It is also called Dakshinganga. It is 1,465 km long with a catchment area spreading over 3.13 lakh sq. km 49 per cent of this, lies in Maharashtra. The Penganga, the Indravati, the Pranhita, and the Manjra are its principal tributaries. It forms a picturesque gorge in Eastern Ghats. The Godavari is subjected to heavy floods in its lower reaches. It is navigable only in the deltaic stretch. The river after Rajamundri splits into several branches forming a large delta.

The Krishna is the second largest east-flowing Peninsular river which rises from a spring near Mahabaleshwar. Its total length is 1,401 km. The Koyna, the Tungbhadra and the Bhima are its major tributaries. Its drainage basin is shared by Maharashtra, Karnataka and Andhra Pradesh.

The Kaveri rises in Brahmagiri hills (1,341m) of Kogadu district in Karnataka. Its length is 800 km and it drains an area of 81,155 sq. km. Since the upper catchment area receives rainfall during the southwest monsoon season (summer) and the lower part during the northeast monsoon season (winter), the river carries water throughout the year. It flows into the Bay of Bengal at Kaveripatnam. It drains parts of Tamil Nadu, Karnataka and Kerala. Its important tributaries are the Kabini, the Bhavani and the Amravati.

The Brahmani and the Subernarekha rivers drain a part of area between the Ganga and the Mahanadi into the Bay of Bengal. Their drainage area extends over parts of Bihar, Odisha, West Bengal and Madhya Pradesh. It supplies water to the Tata steel plant at Jamshedpur.

4.4.4. West Flowing Rivers

The Narmada originates on the western flank of the Amarkantak plateau at a height of about 1,057 m. Flowing in a rift valley between the Satpura in the south and the Vindhyan range in the north, it forms a picturesque gorge in marble rocks and Dhuandhar waterfall near Jabalpur. It meets the Arabian Sea south of Bharuch, forming a broad 27 km long estuary. Its length is 1312 km and catchment area of 98,796 sqkm. All the tributaries are very short and make trellis pattern. The Sardar Sarovar Project has been constructed on this river. Narmada has been joined with other Gujarat rivers to shift its water.

The Tapi is the other important westward flowing river. It originates from Multai in the Betul district of Madhya Pradesh and discharge in Surat district, Gujarat. It is 724 km long and drains an area of 65,145 sq. km. The Purna, Girna and Panjhra are its important tributaries.

Luni is the largest river system of Rajasthan, west of Aravali. It originates near Pushkar in two branches, i.e. the Saraswati and the Sabarmati, which join with each other at Govindgarh. It flows towards the west till Telwara and then takes a southwest direction to join the Rann of Kutch.

The Mahi river rises in the Satmala hills of the Vindhyan mountains. After flowing for 533km, it drains into the Gulf of Khambhat. The Sabarmati riverrises in the Aravalli hills and flows into Arabian Sea after flowing over a distance of 300km.

Small west flowing rivers are numerous which rises in the Western Ghats and have short runoff. The Shetruniji is one such river which rises near Dalkahwa in Amreli district. The Bhadra originates near Aniali village in Rajkot district. The Dhadhar rises near Ghantar village in Panchmahal district. The Vaitarna rises from the Trimbak hills in Nasik district at an elevation of 670 m. The Kalinadi rises from Belgaum district and falls in the Karwar Bay. The Sharavati is another important river in Karnataka flowing towards the west. The Sharavati originates in Shimoga district of Karnataka. Goa has two important rivers which can be mentioned here. One is Mandovi and the other is Juari. The longest river of Kerala, Bharathapuzha rises near Annamalai hills. It is also known as Ponnani. It drains an area of 5,397 sq. km. The Periyar is the second largest river of Kerala. Its catchment area is 5,243 sq. km.

4.5. Comparison Between Himalayan and Peninsular Rivers

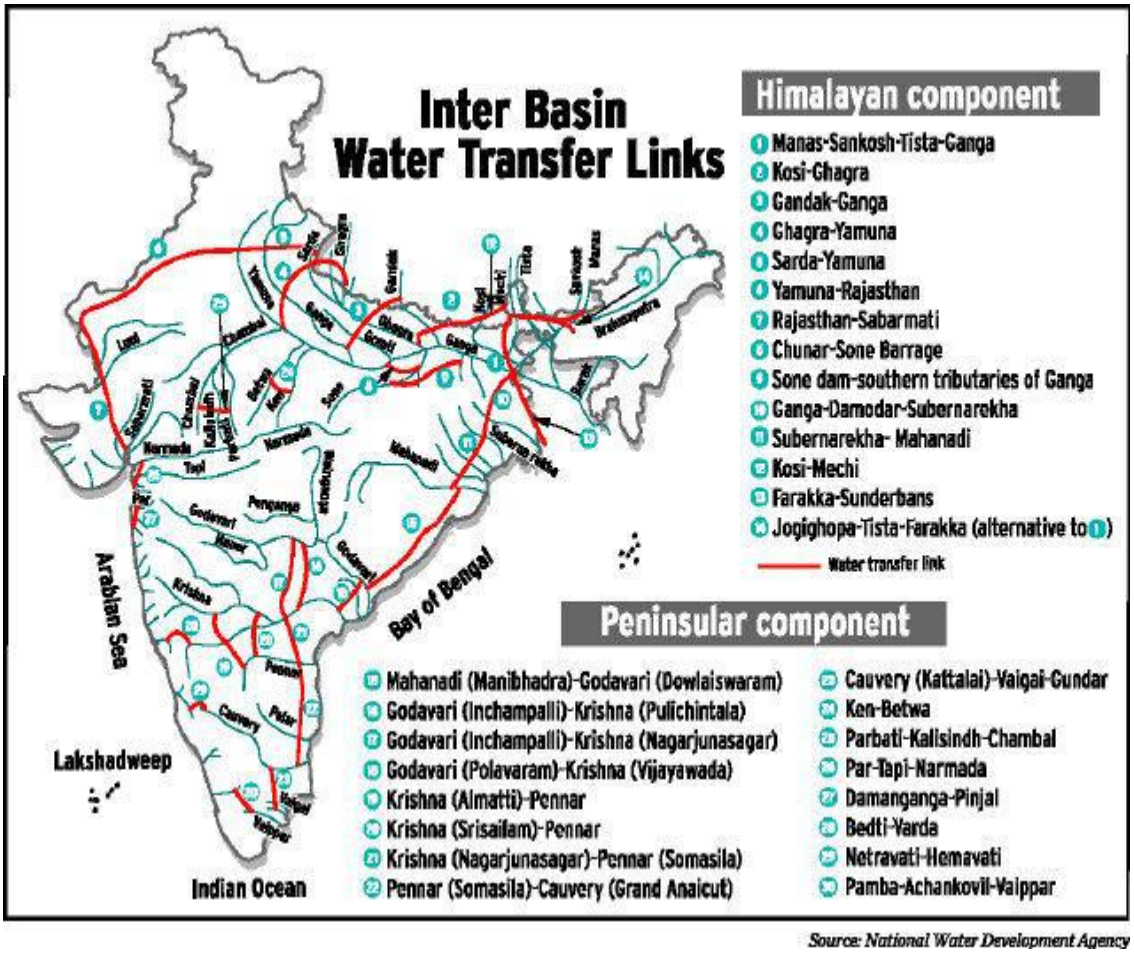
Difference between the rivers rising in the Himalayas and those rising in the Peninsular plateau are primarily a result of the differences between the two areas in terms of relief and climate. Following table shows major differences between these two groups.

S.N.	Aspects	Himalayan River	Peninsular River
1	Place of Origin	Himalayan mountain covered with glaciers	Peninsular plateau and central highland
2	Nature of flow	Perennial	Ephemeral
3	Type of drainage	Antecedent and Consequent leading to dendritic pattern	Super imposed, rejuvenated resulting in trellis, radial and

			rectangular Patterns
4	Nature of river	Long course, flowing through the rugged mountains experiencing headward erosion and river capturing; In plains meandering and shifting of Course;	Smaller, fixed course with well-adjusted valleys;
5	Catchment area	Very large basins	Relatively smaller basin
6	Age of the river	Young, active and deepening of valley	Old rivers with graded profile and lateral erosion
7	Irrigation	Flows through plains and canal system	Flows over uneven plateau; canals only in deltaic region
8	Hydro-electricity	Eastern region has very high potential and large dams are building up	Natural waterfalls for generating electricity

4.6. National River Linking Project

The idea of linking water surplus Himalayan rivers with water scarce parts of western and peninsular India has been doing the rounds for the past 150 years. The rivers of India carry huge volumes of water per year but it is unevenly distributed both in time and space. There are perennial rivers carrying water throughout the year while the non-perennial rivers have very little water during the dry season. During the rainy season, much of the water is wasted in floods and flows down to the sea. Similarly, when there is a flood in one part of the country, the other area suffers from drought. Such linkage is said to provide major benefits such as irrigation, assured drinking water, flood and draught prevention, generation of electricity, and inland navigation. Nevertheless, project is facing several challenges in its implementation. Project involves hundreds of billions of dollars that India could not afford. Water shortage Peninsular plateau has higher altitude compare to water surplus Ganges plains. Carrying water to higher level required either electricity to pump water or create chain of deep channels which seems very difficult in rocky Peninsular. Project will have to acquire lakhs of hectares of land. It will affect the ecosystem(submergence of forest land, deforestation, flora and fauna) and rehabilitation issue of lakhs of displaced persons.



Source: National Water Development Agency

Figure 20 – Inter-linking of rivers

Ironically, rivers of northern plains have water surplus during or just after monsoon. This time Peninsular rivers also have sufficient water. While the water availability in the southern rivers may be increased, the main reason why such project is not being put to implementation is the apprehension of future water shortage in the Northern plains as a result of Climate change, whose effects are now not known. Shifting huge quantity of water would have affect on heat balance of Indian subcontinent which may affect monsoon pattern and intensity also. It will also affect the temperature and salinity of Bay of Bengal water near Bengal region.

NDA government's proposal of river interlinking met with stiff opposition from several quarters. The Supreme Court cleared the river-linking project. A group of citizens has filed review petition in the Supreme Court. Recent report of planning commission also does not support the project due to environmental and monsoon issues. Rivers linkage crosses political boundaries of states. Consensus among states is another challenge.

Linkage at small scale is feasible and few links of this river projects are under analysis or under construction. For instance, many links in Gujarat are connected. Five Peninsular links namely (i) Ken – Betwa, (ii) Parbati – Kalisindh – Chambal, (iii) Damanganga – Pinjal, (iv) Par – Tapi – Narmada & (v) Godavari (Polavaram) - Krishna (Vijayawada) have been identified as priority links for taking up their Detailed Project Reports (DPRs) by ministry of water resources in 2012. DPR of one priority link namely Ken-Betwa has been completed and was communicated to the party states. Solution envisaged in the 12thfive year plan is the water management. Locally available water needs to be managed with proper conservation techniques and by use of best available technologies in agriculture, industry with full incentive to be given for recycling of water.

4.7. National Waterways

Student Notes:

An efficient transport sector is vital for development of the economy of any country. Compare to European countries, China etc., India has poor performance in using Inland river navigation for goods

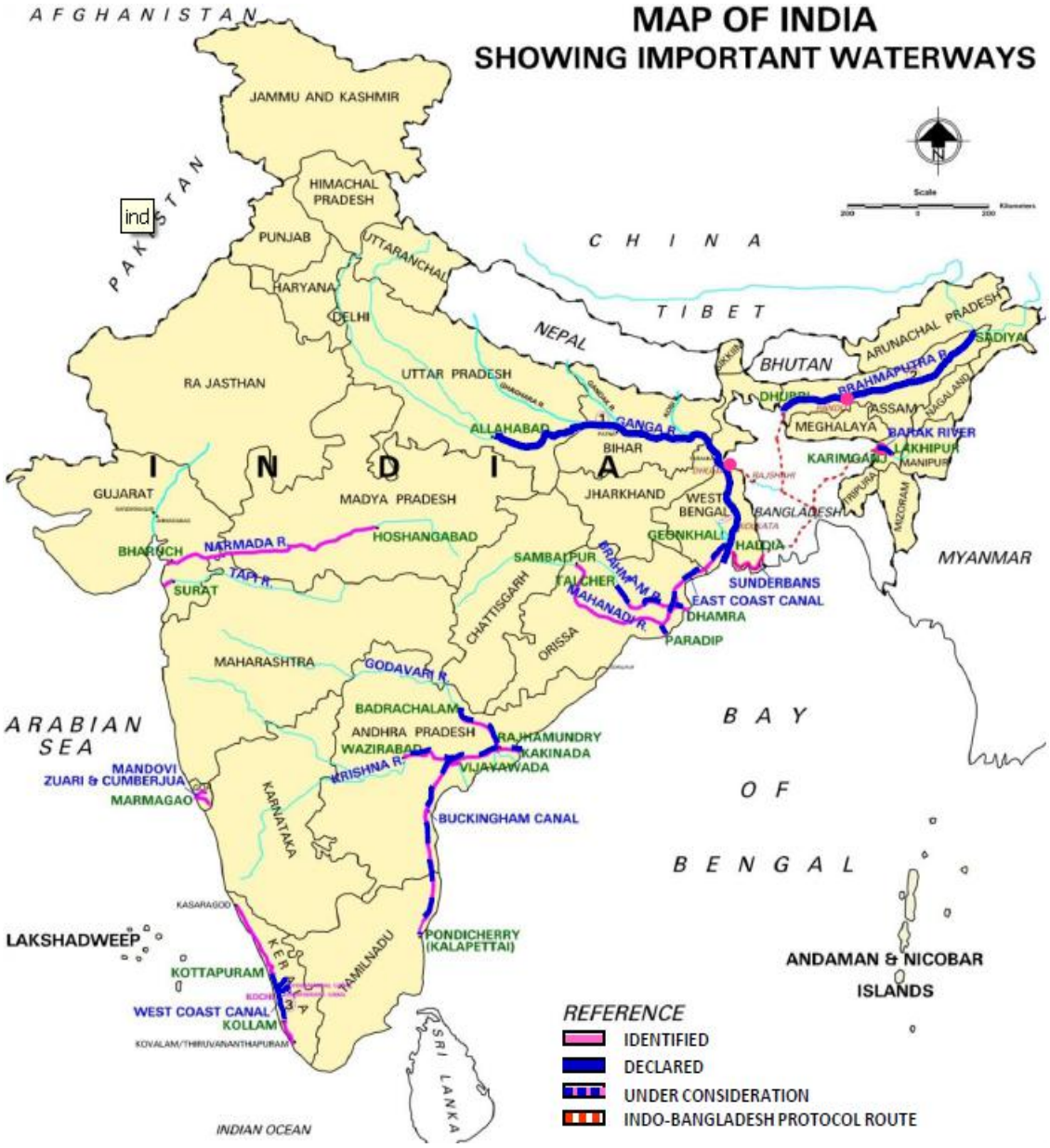


Figure 21 – NATIONAL WATERWAYS (NWS) OF INDIA

transportation. Inland Water Transport (IWT) is a fuel efficient, environment friendly and cost effective mode of transport. Currently, there are five national waterways(NW) and sixth is being under consideration(figure 21). Following is the details of NWs:

NW1 is from Allahabad to Haldia with total length of 1620 kms. It is being used by tourism vessels, ODC carriers, IWAI vessels. Many coal based plants are located along Ganga and thus, are potential revenue source for inland navigation sector. **NW2** waterways is from Sadiya town in Assam to Dhubri at Bangladesh border with total length of 891 km. it is used by tourism vessels, Border security forces, Assam government, and private vessels. **NW3** waterway involves multiple canals on the western coast. It involves West coast canal(168km), Udyogmandal canal(23km), and Champakara canal (14km). **It** is one of the most navigable and tourism potential area in India. Raw material for fertilizer plants is major part of movement. Similarly,

Student Notes:

NW4 waterway involves Kakinada-Puducherry canala (767km), Godavari river (171 km), and Krishna river (157 km). Coal on Godavari river, Cement on Krishna river and rice on both rivers, and other such food commodities are major transport on this waterway. **NW5** waterway consists of stretches such as Mahanadi Delta(101km), Brahmani and others (265km), Matai river(40km) and Geonkhali-Charbatia(217km). Coal is the major commodity on transportation here. Declaration of Barak river from **Bhanga to Lakhipur (121 km)** in the State of Assam as National Waterway is under consideration of Govt. Budget 2013 stressed on waterways connectivity for northeast India. Poor maintenance of NW is a major challenge for the government. Inland water navigation is cheaper as compared to other transport modes but does not get same level of subsidy by the government for transporting various commodities such as PDS food etc.

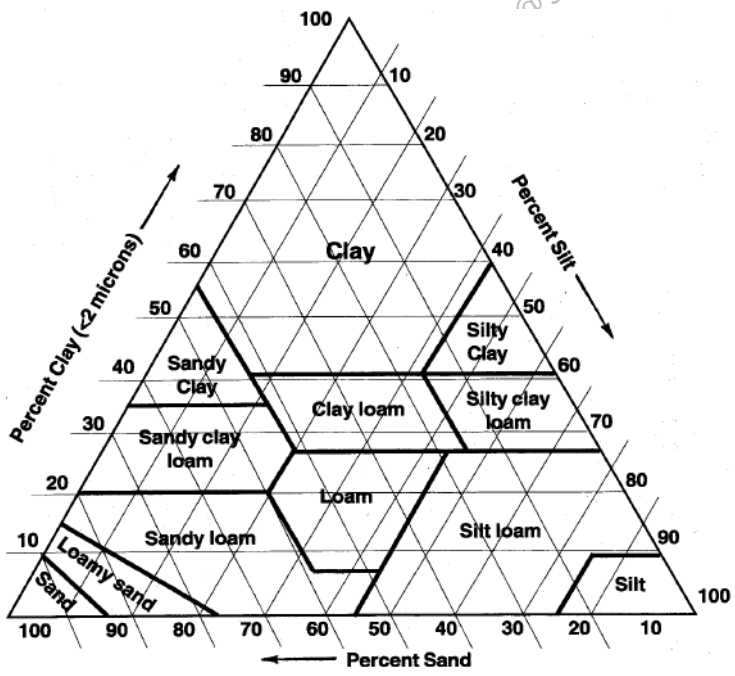
5. Soil

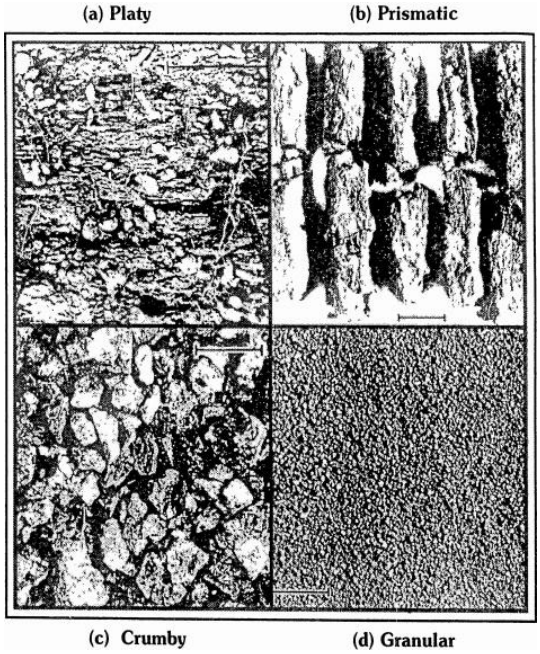
Soil constitutes a major element in the natural environment, linking climate and vegetation, and they have a profound effect on man's activities through their relative fertility. It is a valuable resource and the most important layer of the earth's crust. Soils are very much dynamic entities in which physical, chemical and biological activities are continually taking place.

5.1. Soil Properties

Soil is the mixture of rock debris and organic materials which develop on the earth's surface. It contains matter in all three states: solid, liquid and gaseous. The solid portion is partly organic and partly inorganic. The inorganic part is made up of particles derived from the parent material, the rocks which weather to form the soil. The organic portion consists of living and decayed plant and animal materials such as roots and worms. Soil water is a dilute but complex chemical solution derived from direct precipitation and from run-off, and groundwater. The soil atmosphere fills the pore spaces of the soil when these are not occupied by water. Soil atmosphere and water are present in inverse proportion to each other. The actual amounts of each of these components depend upon the type of soil.

The **Texture** of a soil refers to the sizes of the solid particles composing the soil. The sizes range from clay (less than 0.002mm) to gravel (more than 2mm). The proportions of the different sizes present vary from soil to soil and from layer to layer. Texture largely determines the water-retention properties of soil. Loam texture is best for plant growth (figure 22(i)).





(i) Soil textural classes (ii) Four basic soil structures

Figure 22 – soil texture and structure

The soil **structure** is the way the soil particles are arranged. Because of cementing action of ions in the soil, individual particles in a soil tend to aggregate together in lumps. According to the shape of the lumps, soils can be described as having a platy, prismatic, crumby and Granular structure (figure 22(ii)). The presence of humus helps the formation of a crump structure. The soil structure has an important bearing on its east of cultivation. Soils with a crumb structure are best for seed germination. Forking, raking, ploughing and harrowing are few techniques to improve the soil structure.

Soil **colloids** - tiny particles with unusual chemical properties – may be organic (very finely divided humus) or mineral (minute thin flakes called clay mineral). Together, the two types make up a clay-humus complex. Clay minerals have a vast surface area in relation to their weight and are net negatively charged. This is invariably neturalised by the attraction to their surface of positively charged ions (cations) of calcium, magnesium, potassium and sodium (bases). They are only held loosely in an exchangeable position by the clay minerals and may be given up in the process of exchange to plants in forms of nutrients which require them for growth. These cations are generally replaced by hydrogen ions. Over a period of time, this process makes soil more acid, unless the bases are replenished in some way. It is possible naturally with decomposition of animals and plants or artificially in form of fertilizer.

Soil acidity is a property related to the proportion of exchangeable hydrogen in the soil in relation to other elements. A pH value of about 6.5 is normally regarded as the most favourable for the growth of cereal crops.

Colour varies considerably in soil and can tell us much about how a soil is formed and what it is made of. In recently formed soils, the colour will largely reflect that of the parent material, but in many other cases, the colour is different from the underlying rocks. Soils can range from white to black, usually depending on the amount of humus. In cool humid areas, most soils contain relatively high humus content and are generally black or dark brown, wheras in desert or semi-desert areas, little humus is present and soils are light brown or grey. Reddish colours in soills are associated with the presence of ferric compounds and usually soil is well drained. In humid climates, grayish colours relect poor drainage conditions.

Student Notes:

5.2. Soil Horizons

A vertical section of soil from the surface down to the bedrock consisting of many layers is collectively known as soil profile. These different sections are called soil horizons. We can easily observe different horizons in a mine or roads dug under the ground. The recognition of different soil horizons is based on the physical and chemical characteristics of soils. Scientists have divided the soil into three main horizons (figure 23). '**Horizon A'** is the topmost zone, where organic materials have got incorporated with the mineral matter, nutrients and water, which are necessary for the growth of plants. '**Horizon B**' is a transition zone between the 'Horizon A' and 'Horizon C', and contains matter derived from below as well as from above. It has some organic matter in it, although the mineral matter is noticeably weathered. '**Horizon C**' is composed of the loose parent material. This layer is the first stage in the soil formation process and eventually forms the above two layers. Underneath these three horizons is the rock which is also known as the parent rock or the bedrock.

Figure 23 – cross section of Soil profile along a tree

5.3. Soil Forming Factors

There are five main factors which controls the operation of soil processes, namely (i) parent material; (ii) topography; (iii) climate; (iv)biological activity; and (v) time. Climate and biological activity active control factors while Time, Topography and Parent Material are passive control factors. Active factors are those which supply energy that acts on the mass for the purpose of soil formation.

Parent Material

Parent material can be any in-situ or on-site weathered rock debris or transported deposits. Soil formation depends upon the texture, structure as well as the mineral and chemical composition of the rock debris. Nature, rate and depth of weathering are important considerations under parent materials. There may be differences in soil over similar bedrock and dissimilar soils above them. Generally young soils or the lowermost horizon shows similarity with the parent

material. Ultimately, parent material's effect is seen through the texture and fertility. For instance, soils of limestone area show clear relation with the parent rock.

Student Notes:

Topography

The influence of topography is felt through the amount of exposure of a surface to sunlight, drainage condition, and slope angle etc. In middle latitudes pole-facing slopes may have slightly different soil conditions from equator-facing slopes due to poor exposure to sunlight. Soils on hillsides tend to be much better drained than those in valleys, where gleying may take place. The susceptibility of soil to erosion increases with gradient, and soils on steep slopes are normally thinner than those on flat sites.

Climate

This factor has a major influence in governing the rate and type of soil formation, particularly through precipitation in terms of its intensity, frequency, duration; and temperature in terms of seasonal and diurnal variations. The effect of temperature is to influence the rate of chemical and biological reactions. In cool climates, bacterial action is relatively slow while in tropics, bacteria thrive. Soil of hot tropical region show deeper profiles as compared to soils of cold tundra region. Although the leaf fall in tropical forest is great, much of this is consumed and translocated down the soil profile. This is the reason why soil in tropical forests is poor in nutrients. It is the net precipitation (after subtracting evapo transpiration) that works on the soil.

Biological Activity

The vegetative cover and organism that occupy the parent materials from the start to later stages help in adding organic matter, moisture retention, nitrogen (nitrogen fixation by bacterias such as Rhizobium) etc. Dead plants provide humus. Some organic acids which form during humification aid in decomposing the minerals of the soil parent materials. Humus accumulates in cold climate as bacterial growth is low and thus layers of peat develop in sub-arctic and tundra climates.

The organisms affecting soil development range from microscopic bacteria to large mammals, including man. Besides providing much of the humus, vegetation influences the soil in several other ways. By intercepting direct rainfall and binding the soil with roots, plants check soil erosion. They counteract percolation by transpiration, reducing the effectiveness of the rainfall. They also help in maintaining the fertility of soil by brining bases (calcium, Magnesium) from the lower parts of the soil into stems and leaves, and then releasing them into the upper soil horizons. A change in vegetation may cause a change in soil.

The influence of animals on soils is both mechanical and chemical. For example, earthworms rework the soil by burrowing and also change its texture and chemical composition by passing it through their digestive systems. Equally, soil characteristics closely determine the type of animal present in the soil.

Time

Generally, the length of time the soil forming processes operate, determines maturation of soils and profile development. However, it is difficult to be precise about the role of time in soil formation, since soils vary greatly in their rates of development. On porous materials such as sandstones, soil formation is much more rapid than on impermeable materials, at least initially. On glacial hills, a few hundred years may be enough to form a soil; on dense basalt very much longer is likely to be required. Renewed evolution takes place in soils when climate or other factors change, causing the soil to adjust. In practice, many soils in mid-latitude regions are polycyclic.

5.4. Soil Classification

Soil is not found same everywhere. A soil of one place is different from that of the other. Early classifications followed biological principles to group soils. One of the most important

classifications of soils has been the zonal system. This was proposed by Russian pedologists who recognized the strong relationship between climate, vegetation and soil zones throughout the world. Three main classes of soil are recognized.

Student Notes:

Zonal soils are those that are well developed and reflect the influence of climate as the major soil-forming factor. They can be subdivided into podzol soils, Tundra soils, brown earth, Ferralsol, Chernozem, Chestnut and Prairie soils. Sierozem of desertic and semi-desertic areas is extreme form of chestnut.

Intrazonal types are well-developed soils formed where some local factor such as parent material, terrain or age is dominant. They can be subdivided into Calcimorphic soil(on calcareous parent material), Halomorphic soils(saline), and Hydromorphic soil (marshes, swamps or poorly drained upland).

Azonal soils are those that are immature or poorly developed. It lacks a B-horizon. Thus, A-horizon likes immediately above the C-horizon of weathered parent material. This may happened because of characteristics of parent material or nature of terrain or simply the lack of time for development. It is commonplace on active flood plains, volcanic soils, newly deposited glacial drift, windblown sand, marine mud-flats. Azonal soils are subdivided into Lithosol (erosion removes soil almost as fast as it is formed on steep slopes), Regosol (dry and loose dune sands) and alluvial soils(regular supply of sediments).

5.4.1. Soil Classification in India

In ancient times, soils used to be classified into two main groups – Urvara and Usara, which were fertile and sterile, respectively. The National Bureau of Soil Survey and the Land Use Planning an Institute under the control of the Indian Council of Agricultural Research (ICAR) did a lot of studies on Indian soils. ICAR has classified Indian soils into eight types on the basis of their formation, colour, composition and location. These are described shortly below.

- **Alluvial Soil** – it is formed by rivers by depositing sediments brought from the mountains. The new alluvium is called Khadar while older deposited one is called Bangar. Khadar is renewed annually with fresh floods. Alluvial soils are most widespread in the northern plains and the covers about 40 per cent of the total area of the country. Through a narrow corridor in Rajasthan, they extend into the plains of Gujarat. In the Peninsular region, they are found in deltas of the east coast and in the river valleys. These soils are more loamy and clayey in the lower and middle Ganga plain and the Brahamaputra valley. The sand content decreases from the west to east. They are generally rich in potash but poor in phosphorous. Alluvial soils are intensively cultivated.
- **Black Soil** – it is formed from the volcanic lava. On account of high iron content and humus it is of black colour. It is also known as the Regur soil or black cotton soil. It covers most of the Deccan Plateau. In the upper reaches of the Godavari and the Krishna, and the north western part of the Deccan Plateau, the black soil is very deep. Black soil is spread over 5.18 lakh sqkm area of the country. These soils are known for their 'self ploughing' nature. The black soils are generally clayey, deep and impermeable. They swell and become sticky when wet and shrink when dried. So, during the dry season, these soils develop wide cracks. the black soil retains the moisture for a very long time, which helps the crops, especially, the rain fed ones, to sustain even during the dry season.
- **Red and Yellow Soil** – it is formed from weathering of crystalline granite (igneous rocks) and gneiss (metamorphic rocks) in areas of low rainfall in the eastern and southern part of the Deccan plateau. Along the piedmont zone of the Western Ghat, long stretch of area is occupied by red loamy soil. The soil develops a reddish colour due to a wide diffusion of iron in crystalline and metamorphic rocks. It looks yellow when it occurs in a hydrated form. They are generally rich in minerals like Iron, lime and potash but poor in nitrogen, phosphorous and humus.

Student Notes:

- **Laterite Soil** – it is formed under specific monsoon conditions of climate. The dry season after rainfall is one of the speciality of monsoon climate. Under such conditions, leaching of soils is accelerated. This process reduces the silica content of rocks in soils leaving the soil rich in iron and aluminum content. Humus content of the soil is removed fast by bacteria that thrive well in high temperature. These soils are poor in organic matter, nitrogen, phosphate and calcium, while iron oxide and potash are in excess. Hence, laterites are not suitable for cultivation; however, application of manures and fertilizers are required for making the soils fertile for cultivation. Red laterite soils in Tamil Nadu, Andhra Pradesh and Kerala are more suitable for tree crops like cashewnut. Laterite soils are widely cut as bricks for use in house construction.
- **Arid Soil** – in the deserts, accelerated weathering of rocks take place on account of heating during day and cooling during night. In this type of soil mainly sand grains are found with little or no humus. In some areas, the salt content is so high that common salt is obtained by evaporating the saline water. It has also less capacity to hold moisture. Its colour varies from red to brown. Nitrogen is insufficient and the phosphate content is normal. Arid soils are characteristically developed in western Rajasthan and semi-arid type in southern Punjab and Haryana.

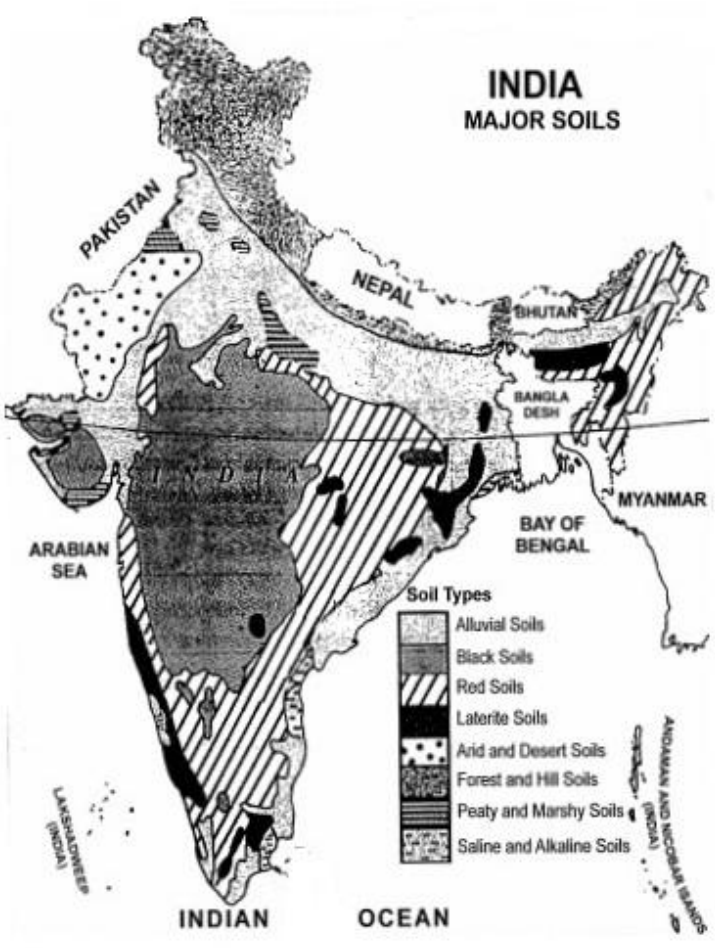


Figure 24 – Major Soil types of India

- **Forest Soil** – it is formed in the mountain ranges of Himalayas, Purvanchal, Sahaydri etc. where sufficient rainfall is available. Soil is loamy and silty on valley sides and coarse-grained in the upper slopes. The lower valleys soil is fertile. On steep slopes, soil is very thin and less productive. This soil is spread over approximately 3 lakh sqkm area of the country.
- **Saline Soil or Usara Soil** – it contain a larger proportion of sodium, potassium and magnesium, and thus, they are infertile, and do not support any vegetative growth. They

have more salts, largely because of dry climate and poor drainage. Their structure ranges from sandy to loamy. They lack in nitrogen and calcium. They are found in arid and semi-arid regions, western Gujarat, deltas of the eastern coast and in Sunderban areas of West Bengal. Seawater intrusions in the deltas promote the occurrence of saline soils. In the areas of intensive cultivation with excessive use of irrigation, especially in areas of green revolution, the fertile alluvial soils are becoming saline. In such areas, especially in Punjab and Haryana, farmers are advised to add gypsum to solve the problem of salinity in the soil.

- **Peaty and Marshy Soil** – it is found in areas of heavy rainfall and high humidity such as Kerala, Odisha, Bengal, Coastal areas of Tamil Nadu. Large quantity of dead organic matter accumulates in these areas, and this gives a rich humus and organic content to the soil. Organic matter in these soils may go even up to 40-50 per cent. The vegetation grows very dense in these areas. At many places, they are alkaline also due to presence of salt.

5.5. Soil Degradation

In simple terms, soil degradation is defined as the decline in the soil quality or the soil fertility. It can happen either by declining share of nutrients or low population of micro-organism in the soil such as earthworms or change in soil structure or change in pH (alkinity) or addition of toxic elements and pollutants etc. For instance, animals walking on the land or human removing upper layers of soil may results into soil degradation. Soil degradation is the main factor leading to the depleting soil resource base in India. The degree of soil degradation varies from region to region according to the topography, wind, precipitation and anthropogenic factors. Soil degradation includes soil erosion, physical deterioration, chemical deterioration and biological deterioration.

5.6. Soil Erosion

It is the removal of soil at a greater rate than its replacement by natural agencies. Soil forming and erosional processes go on simultaneously. When the balance between these two different processes is disturbed by natural or human factors, result into net removal of soil. Some soil erosion occurs without the intervention of human activities but the latter often accelerates the natural processes, e.g. vegetation clearance, over-grazing, some land-drainage schemes. Problem of soil erosion increases with pressure of increasing population on the land. Natural vegetation is cleared for agricultural, pastoral and construction activities.

Topography, rainfall, wind, lack of vegetation cover, land use practices etc. are the causes of soil erosion. The rugged topography and steep slopes affect soil erosion rate through its morphological characteristics. Two of these, namely gradient and slope length, are essential components in quantitative relationships for estimating soil loss. Erosion increases dramatically because the increased angle facilitates water flow and soil movement.

Two main elements of climate – **wind and rainfall** – are powerful agents of soil erosion. Erosive processes are set in motion by the energy transmitted from either rainfall or wind or a combination of these forces. Wind erosion is significant in arid and semi-arid regions. Regions with heavy rainfall have dominance of water in erosional processes. Removal may be in the form of splash erosion, Sheet wash, Rill erosion, gullying erosion (figure 25). Splash erosion is the first stage in soil erosion and it occurs when raindrop hit bare soil. Sheet erosion, takes place on level of lands after a heavy shower, removes finer and fertile top soil. Gullies cut the agricultural lands into small fragments and make them unfit for cultivation. Chambal region of central India is infamous for its ravines (large number of deep gullies).

Student Notes:

Figure 25 – Gully erosion

The lowest soil erosion rate is found in undisturbed forests. However, once forest land is converted to agriculture, erosion rates increase because of **vegetation** removal, over-grazing, and tilling. Vegetation cover reduces erosion. Living and dead plant biomass reduces soil erosion by intercepting and dissipating raindrops and wind energy. Plant roots physically bind particles, thus stabilising the soil and increasing its resistance to erosion. The uptake of water by plant roots also depletes the soil water content and thereby further increases infiltration rates.

Land use practices such as agricultural and pastoral activities are causes of soil erosion. Croplands are vulnerable because the soil is repeatedly tilled and left without a protective cover of vegetation. Excessive grazing by animals lead to poor vegetation cover and thus, enhances wind and water-led soil erosion processes. Over-irrigation results into removal of top nutrient soil with excess water. It also brings salts to the surface and destroys fertility. Without proper humus, addition of chemical fertilizer hardens the soil.

5.7. Soil Management

Soil management is not a single and straight process. It concerns all operations, practices that are used to maintain the quality of soil. If soil erosion and exhaustion are caused by humans; by corollary, they can also be prevented by humans. Soil erosion is essentially aggravated by faulty practices. For instance, recommended ratio of nitrogen, phosphorus and potassium (NPK) fertilizer in India is 4:2:1 but actual usage is in the ration of 10:4:1. Lands with a slope gradient of 15 - 25 per cent should not be used for cultivation. If at all the land is to be used for agriculture, terraces should carefully be made.

Over-grazing and shifting cultivation are other major faulty practices. It should be regulated and controlled by villagers collectively. Contour bunding, Contour terracing, check dams, regulated forestry, cover cropping, mixed farming and crop rotation are some other sustainable methods to manage soil quality. In arid and semi-arid areas, shelter belts or green belts should be constructed around the cultivable land to protect them from progressive sand dunes.

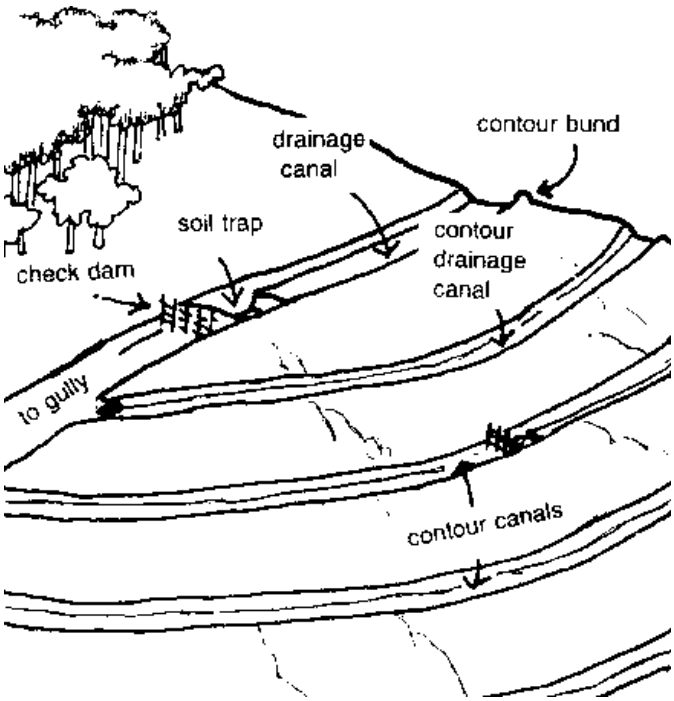


Figure 26 – soil management techniques

The Central Soil Conservation Board, set up by the Government of India, has prepared a number of plans for soil conservation in different parts of the country. These plans are based on the climatic conditions, configuration of land and the social behaviour of people.

Centrally sponsored scheme entitled "National project on management of soil health and fertility (NPMSF)" has been formulated by the centre in 2008-09. It aims to facilitate and promote Integrated Nutrient Management (INM) through judicious use of chemical fertilizers in conjunction with organic fertilizers. It also aims to strengthen soil testing facilities by installing more soil testing laboratories. One of the components is to build up capacity through training of farmers and field demonstration etc. Project also envisages preparing database for balanced use of fertilizer, which is site specific. Other project/missions such as National Mission on Sustainable Agriculture (NMSA), National project on promotion of organic farming, Mahatma Gandhi national rural employment guarantee act (MGNREGA), soil and land use survey projects of centre etc. have bearing on managing the quality of soil.

6. UPSC Prelim Previous Year Question

1. The latitudes that pass through Sikkim also pass through. (2010)
(a) Rajasthan (b) Punjab
(c) Himachal Pradesh (d) Jammu and Kashmir

2. If there were no Himalayan ranges, what would have been the most likely geographical impact on India? (2010)
1. Much of the country would experience the cold waves from Siberia.
2. Indo-gangetic plain would be devoid of such extensive alluvial soils.
3. The pattern of monsoon would be different from what it is at present.
Which of the statements given above is/are correct?
(a) 1 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

3. Rivers that pass through Himachal Pradesh are (2010)
(a) Beas and Chenab only (b) Beas and Ravi only
(c) Chenab, Ravi and Satluj only (d) Beas, Chenab, Ravi, Satluj and Yamuna

Student Notes:

4. With reference to the river Luni, which one of the following statements is correct? (2010)
(a) It flows into Gulf of Khambhat
(b) It flows into Gulf of Kuchchh
(c) It flows into Pakistan and merges with a tributary of Indus
(d) It is lost in the marshy land of the Rann of Kuchchh

5. Which one of the following pairs is not correctly matched? (2010)

	Dam		**Lake River**
(a)	Govind Sagar	:	Satluj
(b)	Kolleru Lake	:	Krishna
(c)	Ukai Reservoir	:	Tapi
(d)	Wular Lake	:	Jhelum

6. Consider the following statements: (2010)
1. Biodiversity hotspots are located only in tropical regions.
2. India has four biodiversity hotspots i.e., Eastern Himalayas, Western Himalayas, Western Ghats and Andaman and Nicobar Islands.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

7. When you travel in certain parts of India, you will notice red soil. What is the main reason for this colour? (2010)
(a) Abundance of magnesium (b) Accumulated humus
(c) Presence of ferric oxides (d) Abundance of phosphates

8. The Himalayan Range is very rich in species diversity. Which one among the following is the most appropriate reason for this phenomenon? (2011)
(a) It has high rainfall that supports luxuriant vegetative growth
(b) It is a confluence of different bio-geographical zones
(c) Exotic and invasive species have not been introduced in this region
(d) It has less human interference

9. The Brahmaputra, Irrawady and Mekong rivers originate in Tibet and flow through narrow and parallel mountain ranges in their upper reaches. Of these rivers, Brahmaputra makes a "U" turn in its course to flow into India. This "U" turn is due to (2011)
(a) Uplift of folded Himalayan series
(b) Syntaxial bending of geologically young Himalayas
(c) Geo-Tectonic disturbance in the tertiary folded mountain chains
(d) Both (a) and (b) above

10. Two important rivers- one with its source in Jharkhand (and known by a different name in Odisha), and another, with its source in Odisha- merge at a place only a short distance from the coast of Bay of Bengal before flowing into the sea. This is an important site of wildlife and biodiversity and a protected area. Which one of the following could be this? (2011)
(a) Bhitarkanika (b) Chandipur-on-sea
(c) Gopalpur-on-sea (d) Simlipal

Student Notes:

11. A person stood alone in a desert on a dark night and wanted to reach his village which was situated 5 km east of the point where he was standing. He had no instruments to find the direction but he located the polestar. The most convenient way now to reach his village is to walk in the (2012)
(a) direction facing the polestar
(b) direction opposite to the polestar
(c) direction keeping the polestar to his left
(d) direction keeping the polestar to his right

12. A particular State in India has the following characteristics:
1. It is located on the same latitude which passes through northern Rajasthan.
2. It has over 80% of its area under forest cover.
3. Over 12% of forest cover constitutes Protected Area Network in this State.

Which one among the following States has all the above characteristics? (2012)
(a) Arunachal Pradesh (b) Assam
(c) Himachal Pradesh (d) Uttarakhand

13. When you travel in Himalayas, you will see the following: (2012)
1. Deep gorges
2. U-turn river courses
3. Parallel mountain ranges
4. Steep gradients causing land-sliding.

Which of the above can be said to be the evidence for Himalayas being young fold mountains?
(a) 1 and 2 only (b) 1, 2 and 4 only
(c) 3 and 4 only (d) 1, 2, 3 and 4

14. With reference to the wetlands of India, consider the following statements:
1. The country's total geographical area under the category of wetlands is recorded more in Gujarat as compared to other States.
2. In India, the total geographical area of coastal wetlands is larger than that of inland wetlands.

Which of the statements given above is/are correct? (2012)
(a) 1 only (b) 2 only
(c) Both 1 and 2 (b) Neither 1 nor 2

15. Consider the following pairs:

	Glacier		**River**
1.	Bandarpunch	:	Yamuna
2.	Bara Shigri	:	Chenab
3.	Milam	:	Mandakini
4.	Siachen	:	Nubra
5.	Zemu	:	Manas

Which of the pairs given above are correctly matched? (2012)
(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2 and 5 (d) 3 and 5

16. The Narmada river flows to the west, while most other large peninsular rivers flow to the east. Why? (2013)
1. It occupies a linear rift valley.
2. It flows between the Vindhyas and the Satpuras.
3. The land slopes to the west from Central India.

Select the correct answer using the codes given below.
(a) 1 only (b) 2 and 3
(c) 1 and 3 (d) None

17. Consider the following pairs:
1. Nokrek Biosphere Reserve: Garo Hills
2. Logtak (Loktak) Lake: Barail Range
3. Namdapha National Park Dafla Hills

Which of the above pairs is/are correctly matched? (2013)
(a) 1 only (b) 2 and 3 only
(c) 1, 2 and 3 (d) None

18. Which of the following leaf modifications occurs/occur in desert areas to inhibit water loss? (2013)
1. Hard and waxy leaves
2. Tiny leaves or no leaves
3. Thorns instead of leaves

Select the correct answer using the codes given below.
(a) 1 and 2 only (b) 2 only
(c) 1 and 3 only (d) 1, 2 and 3

19. Which of the following statements regarding laterite soils of India are correct?
1. They are generally red in colour.
2. They are rich in nitrogen and potash.
3. They are well-developed in Rajasthan and UP.
4. Tapioca and cashew nuts grow well on these soils.

Select the correct answer using the codes given below: (2013)
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1 and 4 (d) 2 and 3 only

20. Consider the following pairs:

	National Park		**River flowing through the Park**
1.	Corbett National Park	:	Ganga
2.	Kaziranga National Park	:	Manas
3.	Silent Valley National Park	:	Kaveri

Which of the above pairs is/are correctly matched? (2013)
(a) 1 and 2 (b) 3 only
(c) 1 and 3 (d) None

21. Which of the following adds/add nitrogen to the soil? (2013)
1. Excretion of urea by animals
2. Burning of coal by man
3. Death of vegetation

Select the correct answer using the codes given below:
(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

22. Contour bunding is a method of soil conservation used in (2013)
(a) desert margins, liable to strong wind action
(b) low flat plains, close to stream courses, liable to flooding
(c) scrublands, liable to spread of weed growth
(d) None of the above

Student Notes:

Student Notes:

23. If you travel through the Himalayas, you are likely to see which of the following plants naturally growing there? (2014)
1. Oak
2. Rhododendron
3. Sandalwood

Select the correct answer using the code given below.
(a) 1 and 2 only (b) 3 only
(c) 1 and 3 only (d) 1, 2 and 3

24. Consider the following pairs: (2014)

	Hills		**Region**
1.	Cardamom Hills	:	Coromandel Coast
2.	Kaimur Hills	:	Konkan Coast
3.	Maadeo Hills	:	Central India
4.	Mikir Hills	:	North-East India

Which of the above pairs are correctly matched?
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 2 and 4

25. Which of the following have coral reefs?
1. Andaman and Nicobar Islands
2. Gulf of Kachchh
3. Gulf of Mannar
4. Sunderbans

Select the correct answer using the code given below. (2014)
(a) 1, 2 and 3 only (b) 2 and 4 only
(c) 1 and 3 only (d) 1, 2, 3 and 4

26. Consider the following rivers :
1. Barak
2. Lohit
3. Subansiri

which of the above flows/flow through Arunachal Pradesh? (2014)
(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

27. Which one of the following pairs of islands is separated from each other by the 'Ten Degree Channel'? (2014)
(a) Andman and Nicobar (b) Nicobar and Sumatra
(c) Maldives and Lakshadweep (d) Sumatra and Java

28. In India, the problem of soil erosion is associated with which of the following?
1. Terrace cultivation
2. Deforestation
3. Tropical climate

Select the correct answer using the code given below. (2014)
(a) 1 and 2 only (b) 2 only
(c) 1 and 3 only (d) 1, 2 and 3

29. Consider the following pairs:

	Wetlands		**Conference of rivers**
1.	Harike Wetlands	:	Confluence of Beas and Satluj/ Sutlej
2.	Keoladeo Ghana National Park	:	Confluence of Banas and Chambal

3. Kolleru Lake : Confluence of Musi and Krishna

Which of the above pairs is/are correctly matched? (2014)

(a) 1 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3

30. What can be the impact of excessive/inappropriate use of nitrogenous fertilizers in agriculture?

1. Proliferation of nitrogen-fixing microorganisms in soil can occur.
2. Increase in the acidity of soil can take place.
3. Leaching of nitrate to the ground water can occur.

Select the correct answer using the codes given below. (2015)

(a) 1 and 3 only (b) 2 only

(c) 2 and 3 only (d) 1, 2 and 3

31. Consider the following rivers :

1. Vamsadhara
2. Indravati
3. Pranahita
4. Pennar

Which of the above are tributaries of Godavari? (2015)

(a) 1, 2 and 3 (b) 2, 3 and 4

(c) 1, 2 and 4 (d) 2 and 3 only

32. Which one of the following pairs of States of India indicates the easternmost and westernmost State? (2015)

(a) Assam and Rajasthan (b) Arunachal Pradesh and Rajasthan

(c) Assam and Gujarat (d) Arunachal Pradesh and Gujarat

33. Consider the following States:

1. Arunachal Pradesh
2. Himachal Pradesh
3. Mizoram

In which of the above States do 'Tropical Wet Evergreen Forests' occur? (2015)

(a) 1 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3

34. Consider the following pairs: (2016)

	Famous Place		**Region**
1.	Bodhgaya	:	Baghelkhand
2.	Khajuraho	:	Bundelkhand
3.	Shirdi	:	Vidarbha
4.	Nasik (Nashik)	:	Malwa
5.	Tirupati	:	Rayalaseema

Which of the pairs given above are correctly matched?

(a) 1, 2 and 4 (b) 2, 3, 4 and 5

(c) 2 and 5 only (d) 1, 3, 4 and 5

35. Recently, for the first time in our country, which of the following States has declared a particular butterfly as 'State Butterfly'? (2016)

(a) Arunachal Pradesh (b) Himachal Pradesh

(c) Karnataka (d) Maharashtra

Student Notes:

Student Notes:

36. Recently, our scientists have discovered a new and distinct species of banana plant which attains a height of about 11 metres and has orange-coloured fruit pulp. In which part of India has it been discovered? (2016)
(a) Andaman Islands (b) Anaimalai Forests
(c) Maikala Hills (d) Tropical rain forests of northeast

37. Which of the following is/are tributary/ tributaries of Brahmaputra? (2016)
1. Dibang
2. Kameng
3. Lohit

Select the correct answer using the code given below.
(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

38. Recently, linking of which of the following rivers was undertaken? (2016)
(a) Cauvery and Tungabhadra (b) Godavari and Krishna
(c) Mahanadi and Son (d) Narmada and Tapti

39. Which of the following is geographically closest to Great Nicobar? (2017)
(a) Sumatra (b) Borneo
(c) Java (d) Sri Lanka

40. Consider the following statements:
The nation-wide 'Soil Health Card Scheme' aims at
1. expanding the cultivable area under irrigation.
2. enabling the banks to assess the quantum of loans to be granted to farmers on the basis of soil quality.
3. checking the overuse of fertilizers in farmlands.

Which of the above statements is/are correct? (2017)
(a) 1 and 2 only (b) 3 only
(c) 2 and 3 only (d) 1, 2 and 3

41. At one of the place in India, if you stand on the seashore and watch the sea, 'you will find that the sea water recedes from the shore line a few kilometres and comes back to the shore, twice a day, and you can actually walk on the sea floor when the water recedes. This unique phenomenon is seen at (2017)
(a) Bhavnagar (b) Bheemunipatnam
(c) Chandipur (d) Nagapattinam

42. If you travel by road from Kohima to Kottayam, what is the minimum number of States within India through which you can travel, including the origin and the destination? (2017)
(a) 6 (b) 7
(c) 8 (d) 9

43. Consider the following statements:
1. In India, the Himalayas are spread over five States only.
2. Western Ghats are spread over two States only
3. Pullicat Lake is spread over two States only.

Which of the statements given above is/are correct? (2017)
(a) 1 and 2 only (b) 3 only
(c) 2 and 3 only (d) 1 and 3 only

Student Notes:

44. With reference to river Teesta, consider the following statements:
1. The source of river Teesta is the same as that of Brahmaputra but it flows through Sikkim.
2. River Rangeet originates in Sikkim and it is a tributary of river Teesta.
3. River Teesta flows into Bay of Bengal on the border of India and Bangladesh.

Which of the statements given above is/are correct? (2017)
(a) 1 and 3 only (b) 2 only
(c) 2 and 3 only (d) 1, 2 and 3

45. From the ecological point of view, which one of the following assumes importance in being a good link between the Eastern Ghats and the Western Ghats? (2017)
(a) Sathyamangalam Tiger Reserve (b) Nallamala Forest
(c) Nagarhole National Park (d) Seshachalam Biosphere Reserve

46. Consider the following pairs: (2017)

Place of Pilgrimage		**Location**
1. Srisailam	:	Nallamala Hills
2. Omakareshwar	:	Satmala Hills
3. Pushkar	:	Mahadeo Hills

Which of the above pairs is/are correctly matched?
(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

47. With reference to agricultural soils, consider the following statements:
1. A high content of organic matter in soil drastically reduces its water holding capacity.
2. Soil does not play any role in the sulphur cycle.
3. Irrigation over a period of time can contribute to the salinization of some agricultural lands.

Which of the statements given above is/are correct? (2018)
(a) 1 and 2 only (b) 3 only
(c) 1 and 3 only (d) 1, 2 and 3

48. Consider the following statements:
1. The Barren Island volcano is an active volcano located in the Indian territory.
2. Barren Island lies about 140 km east of Great Nicobar.
3. The last time the Barren Island volcano erupted was in 1991 and it has remained inactive since then.

Which of the statements given above is/are correct? (2018)
(a) 1 only (b) 2 and 3
(c) 3 only (d) 1 and 3

49. Among the following cities, which one lies on a longitude closest to that of Delhi?(2018)
(a) Bengaluru (b) Hyderabad
(c) Nagpur (d) Pune

50. Which one of the following is an artificial lake? (2018)
(a) Kodaikanal (Tamil Nadu) (b) Kolleru (Andhra Pradesh)
(c) Nainital (Uttarakhand) (d) Renuka (Himachal Pradesh)

51. What is common to the places known as Aliyar, Isapur and Kangsabati? (2019)
(a) Recently discovered uranium deposits (b) Tropical rain forests
(c) Underground cave systems (d) Water reservoirs

Student Notes:

52. Consider the following pairs:

	Famous Place		River
1.	Pandharpur	:	Chandrabhaga
2.	Tiruchirappalli	:	Cauvery
3.	Hampi	:	Malaprabha

Which of the pairs given above are correctly matched? (2019)

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

7. UPSC mains Previous Year Question

1. There is no formation of deltas by rivers of the Western Ghat. Why? (2013)
2. Bring out the causes for more frequent landslides in the Himalayas than in Western Ghats. (2013)
3. Whereas the British planters had developed tea gardens all along the Shivaliks and Lesser Himalayas from Assam to Himachal Pradesh, in effect they did not succeed beyond the Darjeeling area. Explain. (2014)
4. "The Himalayas are highly prone to landslides." Discuss the causes and suggest suitable measures of mitigation. (2016)
5. Why is Indian Regional Navigational Satellite System (IRNSS) needed? How does it help in navigation? (2018)

8. Vision IAS Previous Years Mains Questions

1. State the geographical and economic importance of Hindukush-Himalayan region. How are the critical geographical features of this region changing and what possible consequences will it have?

Approach:

- Give a brief overview of the Hindukush-Himalaya region.
- Mention the geographical and economic importance of the region.
- Discuss the changing geographical features of the region.
- Mention its consequences.
- Conclude with brief suggestions.

Answer:

The Hindu Kush Himalayan (HKH) region extends about 3,500 square km over eight countries- India, Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. It is a part of the 'Third Pole' due to its extensive permanent snow cover.

Geographical and economic importance of the region:

- The region is the **source of ten large Asian river systems** – the Amu Darya, Indus, Ganges, Brahmaputra, etc. which provides water, sustain critical ecosystem services, and serves as the basis of livelihood for 240 million people living in the mountains and hills. It acts as a heat source in summer and a heat sink in winter. Further, the Tibetan Plateau in the region **influences the Indian summer monsoon**.
- Countries such as Bangladesh, Bhutan, India etc. in the region have **commercially feasible hydropower potential**, which still remains untapped.
- The region provides **habitat to a diverse group flora and fauna** such as tigers, elephants, musk deer, red panda, snow leopard, rhododendrons, orchids, rare medicinal plants etc. having ecological as well as economic significance.
- The region has **some of the highest mountain peaks** in the world such as Mt Everest, K2, Kangchenjunga, Makalu etc. providing avenues for adventure tourism.

Student Notes:

However, the HKH region is geologically fragile, with young and rising mountains that are vulnerable to erosion and landslides. The region is undergoing rapid change, driven by forces such as climate change, disasters, infrastructure development, land use change, urbanization etc. A recent report "The Hindu Kush Himalaya Assessment" by the International Centre for Integrated Mountain Development reveals that even if global warming is limited to 1.5˚C, warming will likely be at least 0.3˚C higher in the HKH.

Currently, the region is experiencing following **changes in critical geographical features**:

- **Glacier melting**: Since the 1970s, about 15 per cent of the ice in the HKH region has disappeared as temperatures have risen.
- **Glacier fragmentation**: The number of glaciers in the Himalaya is reported to have increased over the past five decades due to splitting of big ones into smaller ones.
- **Glacier mass changes**: Glaciers in the extended HKH show mass loss at a predominant rate since last two decades.
- **Increased river stream flow**: Due to faster retreating glaciers, water flows in rivers have increased. For instance, in Tibetan Plateau region, river run off has increased by 5.5 per cent.

The consequences of unprecedented melting of glaciers in the region include:

- Faster snow and glacier melting will lead to increased occurrences of **glacial lake outburst floods**, which can cause huge casualties and loss to local infrastructures.
- As ice sheets put huge amounts of weight on the landmasses they cover, melting of glaciers may lead to **isostatic rebound** i.e. rising of land upward due to unloading of weight.
- As per a NITI Aayog report, **30% of springs in the Indian Himalaya have dried up** due to reasons including receding glaciers which would put additional pressure on available water resources.
- The region is crucial as it **influences the Indian monsoon system**. Shifting monsoon patterns may lead to **intense precipitation** in some regions, which would increase the risk of floods, landslides and soil erosion.
- 70-80% of the region's original habitat has been lost and that **may increase to 80-87% by 2100, resulting into severe biodiversity loss**.
- It may also cause **sea level rise** due to increased stream flow having its own consequences.

The HKH region is sensitive to climate change and variability. More than 35% of the glaciers in the region could retreat by 2100, even if the global temperature rise is capped at 1.5º C.

Thus, international level cooperation is needed for adapting to short-term and long-term climate-related problems to collectively prevent rapid melting of glaciers in the region. Such cooperation must go alongside meeting the Paris Climate Change Pact's goals.

2. Illustrating the mountain building process that led to the formation of Himalayas, elaborate why they are often referred to as young and restless mountains.

Approach:

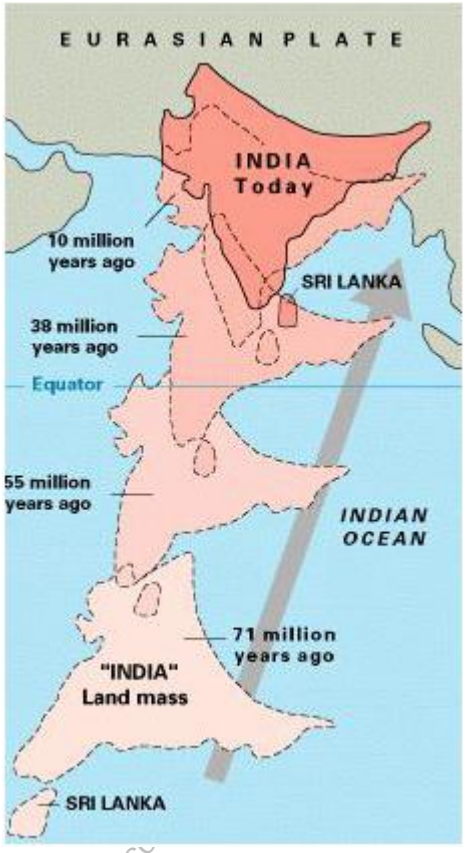
- Briefly describe Himalayas.
- Explain its formation over the years.
- Discuss why they are called young and restless.

Answer:

Student Notes:

Himalayas are one of the loftiest and rugged mountain systems of the world. Along the Northern borders of India, they stretch in west-east direction from Indus to Brahmaputra.

225 million years ago (Mya) India was a large island situated off the Australian coast in a vast ocean. It was separated from Asia by the Tethys Sea. India started a northward drift towards Asia due to tectonic plate movement at the time when super-continent Pangea began to break up about 200 Mya.



80 Mya India was 6,400 km south of the Asian continent but moving towards it at a rate of between 9 and 16 cm per year. At this time Tethys Sea floor would have been subducting northwards beneath Asia and the plate margin would have been a Convergent oceanic-continental one just like the Andes today.

Most of the thick sediments on the Indian margin of the ocean were scraped off and accreted onto the Eurasian continent in what is known as an accretionary wedge. These scraped-off sediments are what now form the Himalayan mountain range.

From about 50-40 Mya the rate of northward drift of the Indian continental plate slowed to around 4-6 cm per year. This slowdown is interpreted to mark the beginning of the collision between the Eurasian and Indian continental plates, the closing of the former Tethys Sea, and the initiation of Himalayan uplift.

The Eurasian plate was partly crumpled and buckled up above the Indian plate but due to their low density/high buoyancy neither continental plate could be subducted. This caused the continental crust to thicken due to folding and faulting by compressional forces pushing up the Himalaya and the Tibetan Plateau. The thickening of the continental crust marked the end of volcanic activity in the region as any magma moving upwards would solidify before it could reach the surface.

It is important to note that the Himalayas do not comprise a single range but a series of at three ranges running more or less parallel to one another. They are supposed to have emerged in three different phases following one after the other. After the Great Himalayas were formed, the second phase took place about 25-30 Mya when the Middle Himalayas were formed. The Shiwaliks were formed in the last phase of the Himalayan orogeny.

The Himalayas are still rising by more than 1 cm per year as India continues to move northwards into Asia, which explains the occurrence of shallow focus earthquakes in the region today. However, the forces of weathering and erosion are lowering the Himalayas at about the same rate. This shows that Himalayas are still in the process of formation. That's why Himalayas are considered young and restless.

Student Notes:

3. Elaborate on the factors responsible for the evolution of the current drainage system in Indian sub-continent, with special emphasis on the characteristic features of Himalayan and Peninsular rivers.

Approach:

- Briefly write about the current drainage system in Indian sub-continent.
- Mention the earlier drainage system and discuss its evolution citing the important factors responsible for the evolution of current drainage system.

Answer:

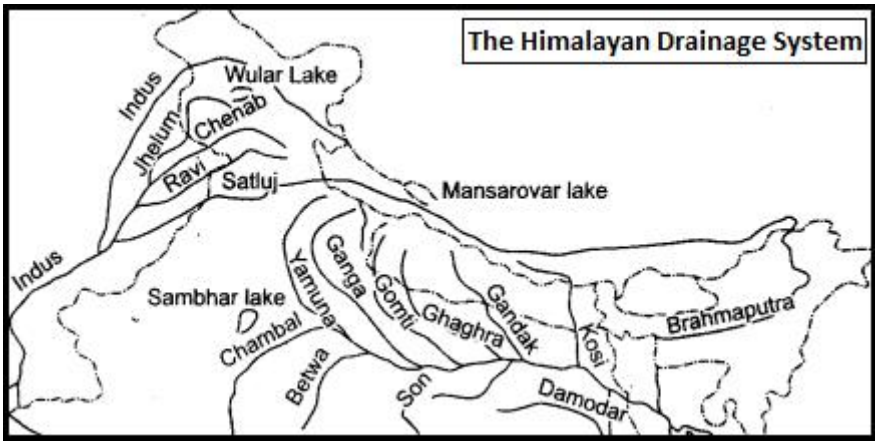
The current drainage system can be divided into Himalayan and the Peninsular rivers. The Himalayan rivers are perennial as they are fed by snow melting and precipitation. On the other hand, the peninsular rivers are dependent on precipitation, hence known as ephemeral.

Characteristic Features and Evolution of the current drainage system

Himalayan Drainage System	***Peninsular Drainage System***
These rivers originate from the lofty Himalayan ranges.	These rivers originate in the Peninsular Plateau.
These rivers have large basins and catchment areas.	These rivers have small basins and catchment areas.
Young, active and deepening the valleys	Old rivers with graded profile
These are examples of antecedent drainage.	These are examples of consequent drainage.
Long course with meanders, river capturing and shifting	Fixed and small course
Perennial: Receive water from glacier	Seasonal: Dependent on monsoon rainfall

Evolution of the current drainage system in Indian-subcontinent is the result of interplay of factors, like change of relief, precipitation etc. On this basis, drainage system in Indian-subcontinent is divided into - Himalayan and Peninsular drainage system.

Himalayan Rivers – During the Miocene period the Himalayas from Assam to Punjab and Sind was drained by the river Shiwalik or Indo-Brahma. Later it is dismembered due to the following factors:

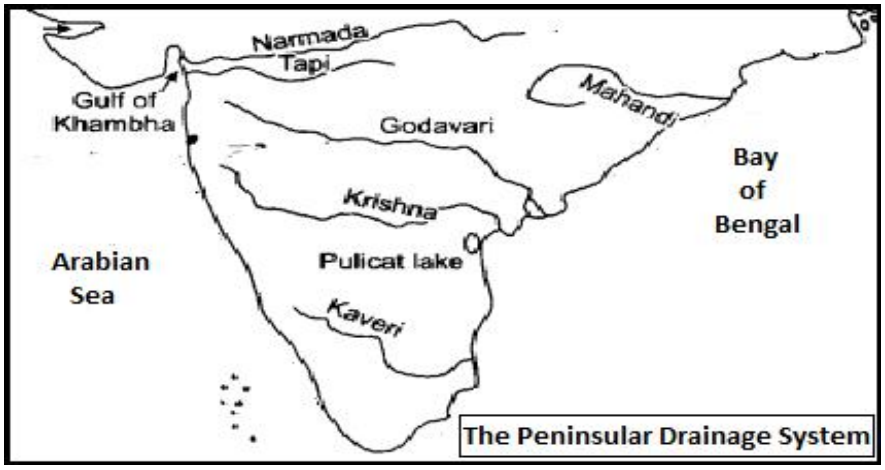


- In the **Pleistocene period**, western Himalayas witnessed upheaval, including the uplift of the Potawar Plateau (Delhi Ridge), which caused dismemberment of Indus and Ganga river system by acting as a water divide.

Student Notes:

- During the same period, the crustal down thrusting occurred in the area between the Rajmahal hills and the Meghalaya Plateau. It resulted into dismemberment of the Ganga and Brahmaputra river system. It led to diversion of the Ganga and the Brahmaputra towards the Bay of Bengal.

  Peninsular Rivers – They are older than Himalayan Rivers, which is evident from the broad valleys and the maturity of rivers. Western Ghats act as the main water divide. It is the outcome of following 3 major events:



The Peninsular Drainage System

- In the **early Tertiary period**, the western flank of the peninsula subsided leading to its submergence below the sea. Consequently, the direction of the river on either side of the original watershed got disturbed.
- Later during the **Pleistocene period**, at the time of upheaval of Himalayas the northern flank of the peninsula subsided beneath the Eurasian plate thereby resulting into trough faulting. The Narmada and Tapi flow through these trough faults.
- Subsidence of northern flank has also resulted into slight tilting of the peninsular block from the northeast to the south-eastern. It changed orientation of major peninsular rivers towards the Bay of Bengal.
  Thus, the interplay between the three major physiographic units and the nature and characteristics of precipitation finally shaped the current drainage system in the Indian sub-continent.

4. A developed Inland Waterway Transport (IWT) will not only augment the overall transport capacity of the country, but also help correct the multi-modal transport mix. Discuss.

Approach:

- Briefly discuss about the potential of IWT.
- Highlight the benefits of Inland waterways in terms of augmenting capacity.
- Discuss about the imbalance in modal mix of transport sector.
- Write some steps being taken in this regard.

Answer:

At present, India has about 14,500 km of navigable waterways comprising of different river systems, canals, backwaters, creeks and tidal inlets across different physiographic regions. Despite their various economic and environmental advantages, the logistic share of waterways in India remains only at about 1.5%, as compared to China having 8.7% share.

Developing Inland Waterway Transport (IWT) will **augment the overall transport capacity** in following ways:

- **Carrying more freight volumes**: It can augment cargo transportation manifold. For eg: Maharashtra Waterways alone transported more than 33.29 MMT in 2016- 17. Similarly, fly ash to the tune of more than 1000 tonnes was transported from Bihar to Assam through waterway.
- **Enhancing connectivity through new routes:** For eg**:** NW-1 (being developed under Jal Marg Vikas Project) along with the proposed Eastern Dedicated Freight Corridor and NH-19 will function as a link between South Asian and South-East Asian countries and New Delhi.
- **Enable efficient bulk cargo movement:** Adopting state of the art vessel designs would enable movement of bulk cargo carriers at one go, thereby removing almost 150 truckloads of pressure from road or one full rail rake.

IWTs would also help **correct the multi-modal transport mix.** It will form part of a larger multi-modal transport network having linkages with railways, roadways, coastal shipping and airways. Being fuel efficient and environment friendly, it can supplement and complement the over-burdened rail and congested roads network, which cater to lion's share of passenger and freight traffic in India.

As per the World Bank, the cost of transport of one tonne of freight over a km by road is Rs 2.28, by rail Rs 1.41 and Rs 1.19 for waterways. Hence, besides correcting modal share, IWT would provide faster alternate transportation facility at comparatively lower costs. Recognizing this potential, government launched **Sagarmala programme** which aims to double the share of domestic waterways in the modal mix in the next ten years.

However, developing IWT alone is not sufficient. Other measures also need to be undertaken to promote it, such as financial incentives for transportation through IWT, higher road taxes on transportation of coal and inflammable material over longer distances, enhancing terminal facilities, promoting industrial corridors along riverbanks etc.

5. Giving an account of various soil forming factors, explain the process of pedogenesis.

Approach:

- Bringing out the meaning of pedogenesis, explain the process of pedogenesis.
- Then discuss various soil forming factors and how does it affect the process of soil formation.
- Give brief conclusion highlighting the role of human activities as well in the soil forming factors.

Answer:

Pedogenesis means soil formation, that is, the process of acquisition of chemical characteristics and other attributes like texture, colour, size of granules etc. by the soil.

Process of soil formation

Weathering is an important process in the formation of soils. It is responsible for breaking down the rocks into smaller fragments which provides the basic input for the soil formation. The accumulation of material through the action of water, wind and gravity also contributes to soil formation.

- This weathered material or transported deposits are colonized by bacteria and other inferior plant bodies like mosses and lichens.

Student Notes:

Student Notes:

- Several minor organisms may take shelter within the deposits. Minor grasses and ferns followed by bushes and trees starts growing through seeds brought in by birds and wind.
- Plant roots penetrate down, burrowing animals bring up particles, mass of material becomes porous and sponge-like with a capacity to retain water and to permit the passage of air which finally leads to formation of a mature soil, a complex mixture of mineral and organic products forms.

Thus, a number of factors affect the process of soil formation as explained below:

- ***Parent Material:*** Soil formation depends on texture and structure as well as the mineral and chemical composition of the rock debris and deposits. It also impacts the nature, rate and depth of weathering.
- ***Topography*****:** It determines the amount of exposure of a surface to sunlight and amount of surface and subsurface drainage and thus affects pedogenesis. For e.g.
  - In the Northern Hemisphere, south facing slopes tend to be warmer and drier than north facing slopes resulting in the soils of the two areas being different in terms of depth, texture, biological activity, and soil profile development.
  - Soils developing on moderate to gentle slopes are often better drained than soils found at the bottom of valleys. Under conditions of poor drainage, soils tend to be immature.
  - Steep slopes are prone to erosion which retards soil development through continued removal of surface sediments.
- ***Climate:*** Main climatic elements involved in soil developments are moisture and temperature and their seasonal and diurnal variations.
  - High moisture availability in a soil promotes the weathering of bedrock and sediments, chemical reactions, and plant growth. It also influences soil pH and the decomposition of organic matter.
  - Temperature has an influence on rates of bedrock weathering which generally increase with higher temperatures due to increased activity of soil microorganisms, the frequency and magnitude of soil chemical reactions, and the rate of plant growth.
- ***Biological activity:*** Living organisms influence organic matter accumulation, profile mixing, and biogeochemical nutrient cycling (for e.g. carbon and nitrogen cycle).
  - Through litter-fall and the process of decomposition, organisms add humus and nutrients to the soil which influences soil structure and fertility.
  - Surface vegetation also protects the upper layers of soil from erosion by way of binding the soils surface and reducing the speed of moving wind and water across the ground surface.
- ***Time:*** The length of time for which the soil forming processes operate, determines maturation of soils and profile development.

Besides these, human activities such as cultivation, mining, artificial drainage etc. also influence the process of formation to a large extent by influencing one or more of the factors mentioned above.

6. Arresting the deterioration of soil health is key to achieve food security. Discussing the regional variations in soil quality, mention some measures taken by the government for its improvement.

Approach:

- Highlight the context of the given statement.
- Discuss in brief the regional variations that have occurred in the soil quality.
- Mention the measures taken by the government for tackling the above problems.

Answer:

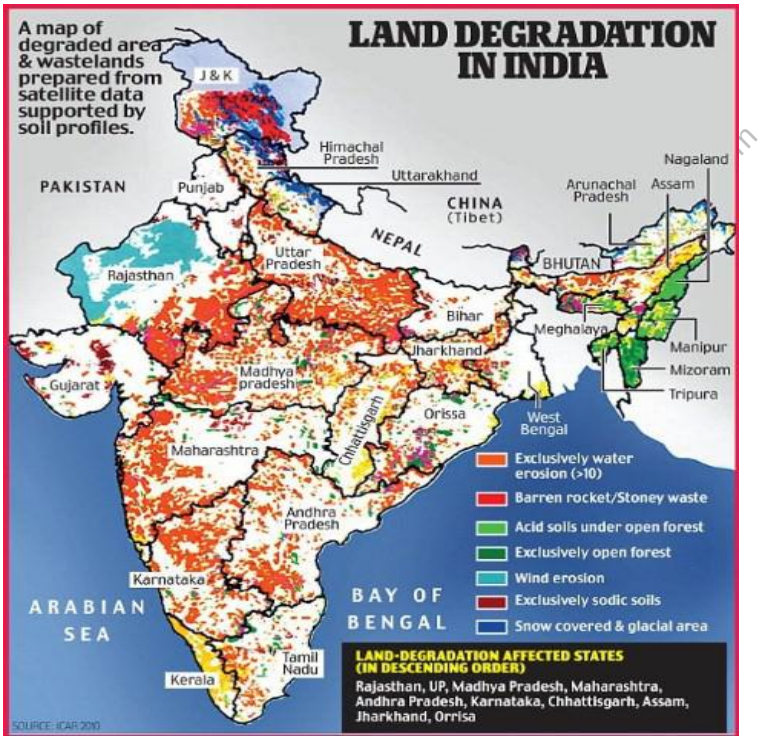
Student Notes:

Healthy soils are crucial for achieving sustainable global food security, fighting climate change, and protecting biodiversity. With rising population, limited availability of agricultural land, small land holdings, industrialization, urbanization and declining soil fertility, India is under serious threat of losing its food surplus status in the near future.

The most prevalent land degradation in India is soil erosion, followed by soil degradation due to salinity, water logging and shifting cultivation among others.

Regional variations are as follows:

- **Central India is** prominently affected by **water induced soil erosion.** North-Eastern and Southern regions are also affected.
- **Western India** particularly Rajasthan and adjoining areas of Punjab, Haryana, Gujarat and Western Uttar Pradesh, is affected by **wind erosion**.
- **Canal-irrigated areas in Indo-Gangetic Plains, Haryana, Rajasthan, Maharashtra, and Karnataka are affected by salinization and/or alkalisation** due to inadequate drainage, inefficient water management and subsidized energy pricing**.** Intensive farming practices, particularly with wheat and rice, initiated during the Green Revolution in 1970s, have also adversely affected soil.
- **Coastal areas** suffer from **coastal erosion with highest percentage** of the shoreline under erosion in Nicobar Islands. **Coastal land salinization and salt water ingress** are also major hazards encountered along the Indian coast.
- **Areas with heavy dependence on fertiliser** due to low phosphorus content in Indian soil also leads to soil deterioration.
- Excessive deforestation coupled with shifting cultivation practices have resulted in tremendous soil loss in **North East region**.



Government initiatives to improve soil health:

- Being a signatory to the **United Nations Convention to Combat Desertification, India** has taken a holistic approach in dealing with soil degradation by implementing programmes like **Integrated Watershed Management Programme (IWMP), MGNREGA and Swach Bharat Mission**.

Student Notes:

- **Under the Soil Health Card Scheme,** Soil Health cards are being issued that carry crop-wise recommendations of nutrients and fertilisers required for the individual farms to help farmers to improve productivity through judicious use of inputs.
- Encouragement of **Social Forestry**, promotion pf **organic farming** through initiatives like **Paramparagat Krishi Vikas Yojana, National Mission on Sustainable Agriculture** etc.
- **Krishi Vigyan Kendras** and schemes like **Mera Gaon Mera Gaurav** to connect farmers with agricultural scientists for accessing information, knowledge and advisories.
- **National Mission on climate Resilient Agriculture** have been started to inculcate the ideology of clean and good agricultural practices to improve soil health.

The above initiatives are in line with international developments such as the Rio+20 outcome document's land-degradation-**neutral world**, Target 15.3 of the SDGs to achieve **Land Degradation Neutrality (LDN) worldwide by 2030** and the formation of Global Soil Forum (GSF) which envisions a world in which soil is sustainably managed and responsibly governed.

7. Explain the concept of soil liquefaction. Illustrate how it manifests during seismic events. What preventive steps can be taken to minimise its impact?

Approach:

- Briefly explain the concept of soil liquefaction.
- Mention the pre-requisite conditions for its occurrence and related liquefaction prone regions.
- Elaborate how it gets manifested during seismic events with an explanatory diagram.
- Highlight some of the preventive steps which can be taken so as to minimize its impact.

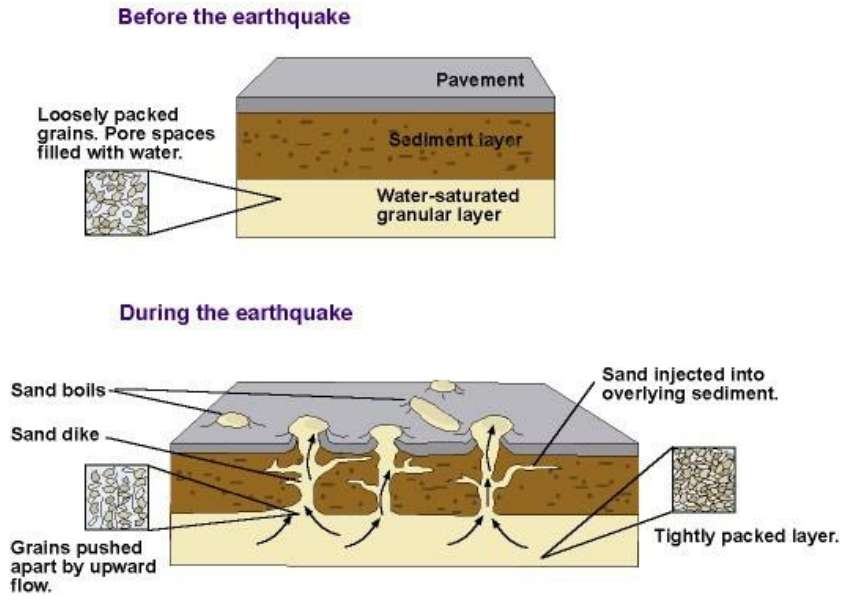
Answer:

- Soil liquefaction is a phenomenon whereby a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied or sudden change in stress condition, causing it to behave like a 'liquid'.
- Most commonly observed in shallow, loose, moderately saturated granular soils with poor drainage such as silts and gravels. Most of these areas are located near an inland water body.
- Regions which exhibit soil liquefaction are geographically dispersed and mainly located in active seismic zones.

Manifestation during seismic events

- Seismic events increases the water pressure to the point at which the soil particles can readily move with respect to one another.
- Strong vibrations released at the time of earthquake in the ground can induce water logging which increases the liquidity of the soil.
- The contact forces between individual soil particles causes weakening of soil deposit which cannot sustain stresses of its load from the foundations.
- As a result, soil loses its cohesion and reduces the ability of a soil deposit to support the construction above it resulting into structural failures.
- It increases the urban seismic risk as its occurrence results into buckling of piles, quick sand effect, spreading of ground, formation of sand volcanoes, failure of retaining walls and loss of bearing capacity

Student Notes:



EARTHQUAKE-INDUCED LIQUEFACTION

Preventive measures to minimize the impact:

- **Avoid construction in liquefaction susceptible soils**: by adhering to zone restrictions and conducting soil mapping.
- **Build liquefaction-proof structural system**: if at all buildings are to be constructed in hazard prone zone.
- **Increasing liquefaction resistance**: loss to existing buildings can be mitigated by injecting grout into the soil to stabilize the layer of soil that is prone to liquefaction.
- **Deploying soil compaction techniques**: Methods such as Vibro compaction (compaction of the soil by depth vibrators), dynamic compaction and Vibro stone columns for improving the soil strength and quality.
- **Earthquake Drain**: They are corrugated pipe wrapped in a filter fabric installed with a vibrating mandrel in a grid pattern. It allows a path for excess pore pressure to rapidly dissipate during an earthquake, providing sufficient discharge capacity to mitigate liquefaction.

8. Explaining the reasons for formation of saline soils, mention the areas where they are found in India. What measures can be taken to restore their fertility?

Approach:

- Define saline soils and explain how they are rich in salts, which make them infertile.
- Illustrate their geographical distribution with corresponding reasons.
- Discuss some measures to amend saline soils.

Answer:

Soils with presence of excess soluble salts, primarily sodium, potassium and magnesium are known as saline soils (or usara). These soils are not fit for arable farming. The surfaces of such soils often have white residues because of salt precipitation. . The presence of excess salt leads to higher osmotic potential of soil, and restricts the water uptake by plants. Hence, they are also called as 'physiologically dry soils.'

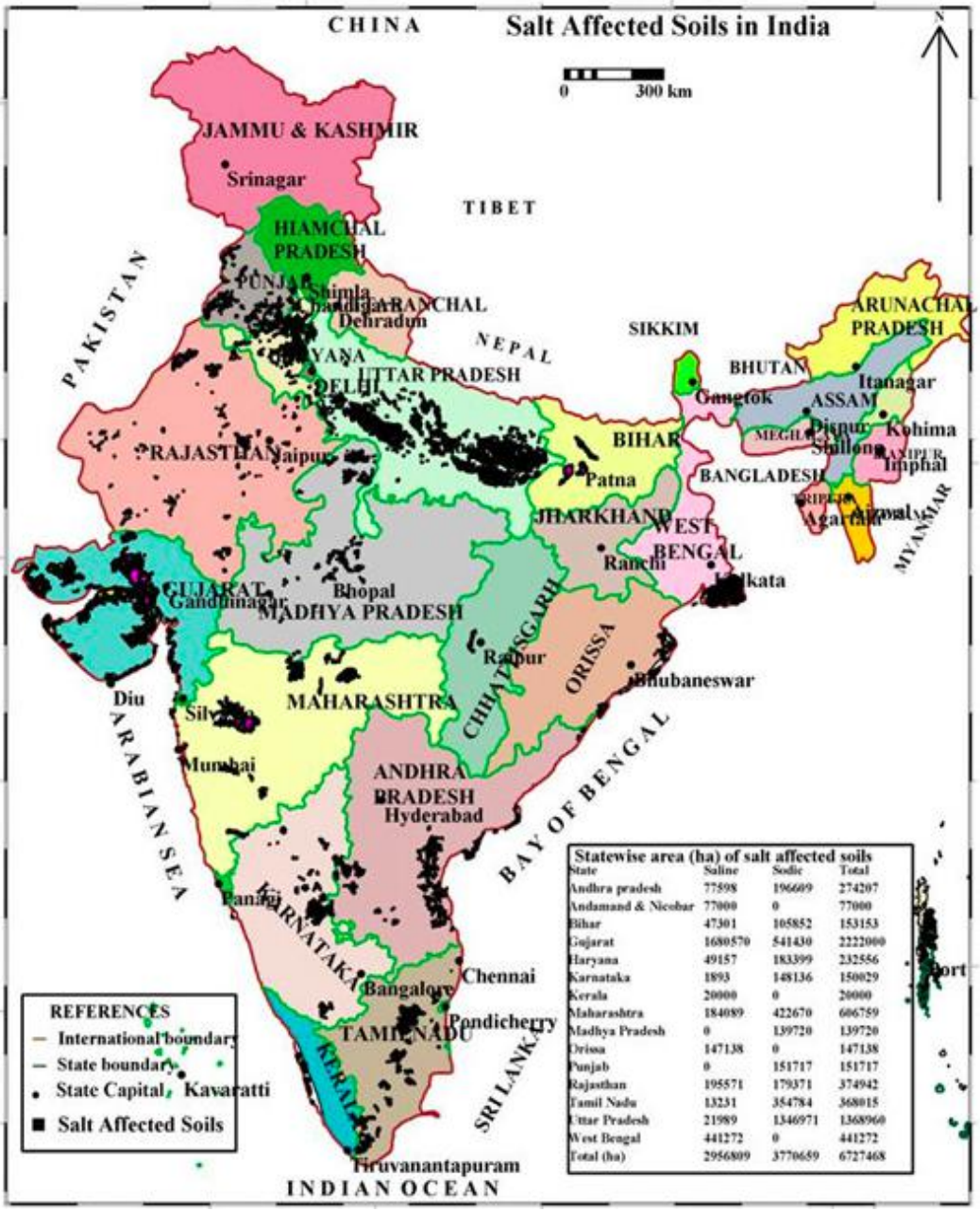
Genesis of soil salinity is a consequence of the following:

- **Parent material** like basalt has high proportion of bases, which leads to saline soil formation.

Student Notes:

- **Climatic Conditions** – Arid and semi-arid areas experience low rainfall, and as a result the excess soluble salts are not leached.
- **Upward movement of salt** – from the sub-surface layers and groundwater is common in dry climatic areas. This phenomenon, capillary action, is often seen in waterlogged and poor drainage soils.
- **Deposition of salts** – can be because of continuous and excessive use of water and especially salt water for irrigation, or in low-lying areas where rain leaches soluble salts from upland.
- **Seawater intrusion** into the ground water in coastal areas.
- **Irrigation practices:** Areas with canal irrigation are prone to salinity because of intrusion of water into areas alongside canals, which rises through capilary action with salts.

Saline soils are naturally found in arid and semi-arid region, and some ecotones like - deltas and mangroves. The intensive cultivation as practiced in green revolution areas, with unscientific management of fertilizer and water inputs, has led to soil salinization. Hence, the distribution of saline soils is as depicted in the map -



Student Notes:

Saline soils, though barren, are potentially productive soils and can be remedied. Removal of excess salt is the basic principle of reclaiming such soils.

1. **Physical Reclamation:**
   a. Removal of excess salt by good quality irrigation water helps in leaching of soluble salts.
   b. Adequate drainage for removal of the salts from the surface and sub-surface layers.
   c. Proper water-management in the next few cropping cycles is critical for sustaining the soils.
2. **Chemical Reclamation:** Application of calcium containing materials like gypsum, which binds with the excess sodium.

9. What is Soil Organic Carbon (SOC)? Identify various factors affecting SOC levels. Also, highlight the beneficial impacts of SOC on soil health and functionality.

Approach:

- Explain what you understand by SOC.
- Mention various factors which affect SOC levels.
- Highlight the beneficial impacts of SOC on soil health and functionality.

Answer:

Soil Organic Carbon (SOC) is the amount of carbon stored in soil. It is the major component of soil organic material and enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. SOC is one of the most important constituents of the soil due to its capacity to **affect plant growth** as both a **source of energy** and a **trigger for nutrient availability** through mineralization.

The factors affecting soil carbon level are:

- **Climate:** Rainfall and temperature have the strongest influence on SOC levels as they affect **vegetation and biomass production** of the region.
  - In the cold wet climates, the rate of photosynthesis exceeds that of decomposition resulting in high levels of SOC.
  - Arid regions have low levels of SOC mostly due to low primary production.
  - The tropics often have intermediate SOC levels due to high rates of both primary productivity and decomposition.
  - Temperate ecosystems can have high primary productivity. With cool temperatures during the rest of the year, slowing decomposition rates such that SOC slowly builds up over time.
- **Soil moisture:** Moist soils and water-logged soils tend to have more carbon than their drier counterparts.
- **Soil type:**
  - Soils that are naturally more fertile will tend to have higher SOC levels due to their greater productivity. Basaltic and clay soil have a higher SOC level than granitic and sandy soil. Organic carbon tends to increase as the clay content increases.
  - Salinity, toxicity and extremes in soil pH (acid or alkaline) result in poor biomass production and, thus decreased SOC level.
- **Erosion and deposition:** The processes of erosion and deposition redistribute soil carbon. Low-lying areas such as floodplains often have increased SOC relative to upslope positions.

Student Notes:

- **Management effects:** Land-use and land management practices can also influence the amount of organic matter in the soil. For example, the conversion of native ecosystems (forests, grasslands, wetlands) into agricultural uses decreases the SOC levels.

Beneficial impacts of SOC on soil health and functionality:

- **Carbon sequestration:** Soils are important reservoirs of active carbon and play a major role in the global carbon cycle.
- **Soil nutrients:** Decomposition of compounds of carbon in the biomass present in the soil releases soil nutrients such as nitrogen, phosphorus etc. A higher SOC level ensures reduced nutrient losses by leaching, volatilisation and erosion.
- **Soil structure:** Soil organic carbon promotes good soil structure by binding soil particles together in stable aggregates. Improved structure aids aeration, water holding capacity, etc. and protects soil during extreme natural phenomena such as floods and droughts.
- **Soil biology:** Organic matter and organic carbon in the soil are food sources for a range of soil organisms (releases nutrients) and so enhance soil biodiversity and biological health thus enhancing agricultural yields.
- **Water management:** Higher SOC levels help in root system proliferation, soil temperature moderation and hence results in water conservation.
- **Soil tilth or suitability for growing crops:** Soil with higher carbon content have favourable porosity and better aeration. These reduce the risk of crusting and compaction.

As per the United Nation Convention to Combat Desertification (UNCCD), SOC is a fundamental ecosystem health indicator and one of the key criterias for achieving **land degradation neutrality**. The 2015 Status of the World's Soil Resources report highlights that more carbon resides in soil than in the atmosphere and all plant life combined. Capturing carbon in the soil helps improve soil health and productivity, stabilize the global carbon cycle, and ultimately help to mitigate climate change.

10. Examine the factors responsible for causing soil pollution in India. Discussing its impact on various ecosystem services, suggest some remedial measures to restore polluted soil.

Approach:

- Briefly explain soil pollution.
- Examine the factors responsible for causing soil pollution in India.
- Discuss the impact of soil pollution on various ecosystem services.
- Suggest some remedial measures.

Answer:

Soil pollution refers to the presence in the soil of chemicals or substances out of place or present at a higher than normal concentration that has adverse effects on any non-targeted organism.

The main factors responsible for soil pollution in India are

- **Anthropogenic factors**
  - the chemicals used in or produced as byproducts of industrial activities
  - domestic and absence of proper disposal mechanism for the same,
  - livestock and municipal wastes (including wastewater),
  - agrochemicals, pharmaceutical waste, biological pollutants and petroleum-derived products.

Student Notes:

- Chemicals released to the environment accidentally, for example from leaks, oil spills or leaching from landfills, or intentionally, like the use of fertilizers and pesticides, irrigation with untreated wastewater.
- Soil pollutants resulting from atmospheric deposition from smelting, transportation, spray drift from pesticide applications and incomplete combustion of many substances.

- **Natural Factors**
  - Natural Soil pollution caused due to events such as forest fires.
  - The natural processes may also have an influence on the human released toxic chemicals into the soil, overall decreasing or increasing the pollutant toxicity and/or the level of contamination of the soil.

Impact on various ecosystem services

- Soil pollution affects food security by reducing crop yields due to toxic levels of contaminants and by causing crops produced from polluted soils to be unsafe for consumption by animals and humans.
- Many contaminants are transported from the soil to surface waters and ground water causing great environmental harm through eutrophication and direct human health issues due to polluted drinking water.
- Pollutants also directly harm soil microorganisms and larger soil-dwelling organisms and hence affect soil biodiversity and the services provided by the affected organisms.

Remedial measures

Soil Remediation techniques can be divided in two main groups: in situ (on the site) and ex-situ (removal of contaminated soil for treatment off the site) remediation. Available remediation options include:

- **Physical remediation**: it includes techniques like vapour extraction, air sparging, washing/pump and treat, electro-remediation and particle sorting.
- **Chemical remediation**: it includes techniques like oxidation, reduction, hydrolysis, dichlorination and pH manipulation
- **Biological treatments:** it includes techniques like microbial activity, landfarming, bio-piling, composting, bioreactor, bioleaching and phytodegradation

Also, strong regulatory programs to minimize soil contamination need to be introduced. The government also needs to regulate its policies on fertilizers to prevent agricultural soil pollution. In addition, reducing the volume of refuse or waste in landfills by recycling materials such as plastics and various other materials can be an effective check against soil pollution.

CLIMATE OF INDIA

Student Notes:

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Student Notes:

1. Introduction

Climate is an important element of the physical environment of mankind. It is the aggregate of atmospheric conditions involving heat, moisture and air movement. In a developing country **like India climatic characteristics have a dominant role in affecting the economic pattern**, way of life, mode of living, food preferences, costumes and even the behavioural responses of the people. In India despite a lot of scientific and technological developments our dependence on monsoon rainfall for carrying out successful agricultural activities, has not been minimized.

The climate of India belongs to the '**tropical monsoon type**' indicating the impact of its location in tropical belt and the monsoon winds. Although a sizeable part of the country lying north of the Tropic of Cancer falls in the northern temperate zone but the shutting effects of the Himalayas and the existence of the Indian Ocean in the south have played significant role in giving **India a distinctive climatic characteristics.**

1.1. Salient Features of Indian Climate

Following are the salient features of the Indian climate:

- **Reversal of winds** – the Indian climate is characterized by the complete reversal of wind system with the change of season in a year. During the winter season winds generally blow from north-east to south-west in the direction of trade winds. These winds are dry, devoid of moisture and are characterized by low temperature and high pressure conditions over the country. During summer season complete reversal in the direction of the winds is observed and these blow primarily from south-west to north-east.
- **Formation of Alternatively High and Low pressure areas over the land** – there is a change in the atmosphere pressure conditions with the change of season. During **winter season** due to low temperature conditions **high pressure areas is formed over the northern part** of the country. On the other hand the intense heating of the land during **summer season** leads to the formation of a thermally induced **low pressure cell** over the north-western part of the country. These pressure areas control the direction and intensity of wind.
- **Seasonal and variable rainfall** – In India over 80 per cent of annual rainfall is obtained in the latter part of the summer whose duration ranges from 1-5 months in different parts of the country. Since the rainfall is in the form of heavy downpour, it creates problems of floods and soil erosion. Sometimes there is continuous rain for many days and sometimes there is a long spell of dry period. Similarly, there is a spatial variation in the general distribution of rainfall. Cherrapunji has received in a single day an amount equal to 10 years of rainfall at Jaisalmer, Rajasthan.

  In fact Indian climate is so varied and complex that it denotes climatic extremes and climatic varieties. While it provides enough heat to grow crops and carry on agricultural activities all over the country it also helps in the cultivation of a number of crops belonging to tropical, temperate as well as frigid[1] areas.

- **Plurality of seasons** – the Indian climate is characterized by constantly changing weather conditions. There are **three main seasons** but on broader consideration their number goes to six a year (winter, fall of winter, spring, summer, rainy and autumn).
- **Unity of Indian Climate** – the Himalayas and the associated mountain ranges extend to the north of India from east to west. These tall mountain ranges prevent the cold northerly winds of Central Asia from entering into India. Therefore, even the parts of India extending north of the Tropic of Cancer experience a tropical climate. These ranges force the monsoon winds to cause rainfall over India and the entire country comes under the

[1] The Polar Regions have a very cold climate. These places are sometimes called the Frigid Zones.

influence of the monsoon winds. In this manner the climate in the entire country becomes monsoon type.

- **Diversity of Indian Climate** – In spite of the unity of Indian climate, it is characterized by regional differences and variations. For example, while in the summer the mercury occasionally touches 55°C in the western Rajasthan, it drops down to as low as minus 45°C in winter around Leh. These differences are visible in terms of winds, temperature, rainfall, humidity and aridity etc. These are caused by differences in the location, altitude, distance from the sea, distance from mountains and general relief conditions at difference places.
- **Characterized by natural calamities** – Due to its peculiar weather conditions especially rainfall the Indian climate is characterized by natural calamities like floods, droughts, famines and even epidemics.

2. Factors Determining the Climate of India

India's climate is controlled by a number of factors which can be broadly divided into two groups –

- Factors related to Location and Relief
- Factors related to air pressure and winds

2.1. Factors Related to Location and Relief

- **Latitude** - the Tropic of Cancer passes through the central part of India in east-west direction. Thus, northern part of the India lies in sub-tropical and temperate zone and the part lying south of the Tropic of Cancer falls in the tropical zone. The tropical zone being nearer to the equator, experiences high temperatures throughout the year with small daily and annual range. Area north of the Tropic of Cancer being away from the equator, experiences extreme climate with high daily and annual range of temperature.
- **The Himalayan Mountains** – as already discussed, the lofty Himalayas in the north along with its extensions act as an effective climatic divide between central Asia and Indian subcontinent. The cold and chilly winds that originate near the Arctic Circle are obstructed by the Himalayas and give a distinctive taste to climate of India.
- **Distribution of Land and Water** – India is flanked by the Indian Ocean on three sides in the south and girdled by a high and continuous mountain-wall in the north. **As compared to the landmass, water heats up or cools down slowly**. This **differential heating of land and sea creates different air pressure zones** in different seasons in and around the Indian subcontinent.
- **Distances from the Sea** – With a long coastline, large coastal areas have an equable climate. Areas in the interior of India are far away from the moderating influence of the sea. Such areas have extremes of climate. That is why, the people of the Konkan coast have hardly any idea of extremes of temperature and the seasonal rhythm of weather. On the other hand, the seasonal contrasts in weather at places in the interior of the country such as Kanpur and Amritsar affect the entire sphere of life.
- **Altitude** – Temperature decreases with height. Due to thin air, places in the mountains are cooler than places on the plains[2]. For example, Agra and Darjiling are located on the same latitude, but temperature of January in Agra is 16°C whereas it is only 4°C in Darjiling.
- **Relief** – The physiography or relief of India also affects the temperature, air pressure, direction and speed of wind and the amount and distribution of rainfall. The windward sides of Western Ghats and Assam receive high rainfall during June-September whereas the southern plateau remains dry due to its leeward situation along the Western Ghats.

[2] Thin air=> low pressure=> low temperature

Student Notes:

2.2. Factors Related to Air Pressure and Wind

Air pressure and wind system is different at different altitude which affects the local climates of India. Consider the following factors:

- Distribution of pressure and surface winds.
- Upper air circulation and the movement of different air masses and the jet stream.
- Rainfall caused by the westerly disturbances in winter and the tropical depressions in south-west monsoon season.

The mechanism of these three factors can be understood with reference to winter and summer seasons of the year separately.

2.3. Weather Conditions in Water

- **Surface Pressure and Winds** – During northern hemisphere's winter, high pressure is built up in the Central and West Asia. This centre of high pressure gives rise to the flow of air at the low level from the north towards the Indian subcontinent, south of the Himalayan mountain range, in the form of a dry continental air mass. These continental winds come in contact with trade winds over northwestern India. The contact zone is not stable and sometimes it shifts up to the middle Ganga valley thus bringing the entire north-western India under the influence of the north-westerly winds.

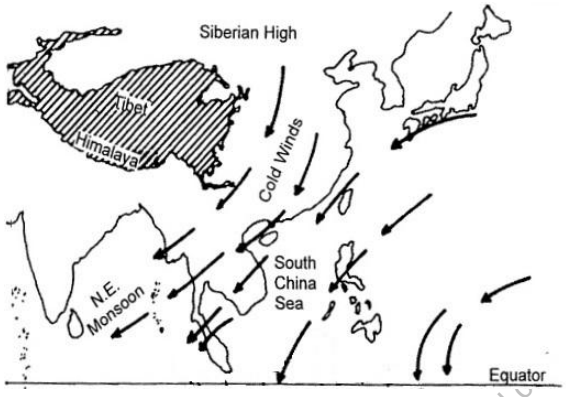

Figure 1 – Winter Monsoon: Surface Winds

- **Jet stream and Upper Air Circulation** – a different pattern of air circulation is observed at a height of about 3 km above the surface. Direction and velocity of winds at this height are different from those of the surface winds. All of Western and Central Asia remains under the influence of westerly winds along the altitude of 9-13 km from west to east (Figure 2). These winds blow across the Asian continent at latitudes north of the Himalayas roughly parallel to the Tibetan highlands. These are known as Jet Streams[3]. Tibetan highlands act as a barrier in the path of these jet streams. As a result, jet streams gets bifurcate – one to the south and other to the north of this mountain chain along 25° N latitude. This jet stream is responsible for bringing western disturbances[4] from the Mediterranean region into Indian sub-continent. Winter rain and hail storms in northwestern plains and occasional heavy snowfall in hilly regions are caused by these disturbances.

[3] For more details about jet stream, See document "INSOLATION, EARTH'S HEAT BALANCE, DIFFERENT ATMOSPHERIC…"

[4] For more details about extra-tropical cyclones (known as western disturbances in Indian subcontinent), See document "INSOLATION, EARTH'S HEAT BALANCE, DIFFERENT ATMOSPHERIC…"

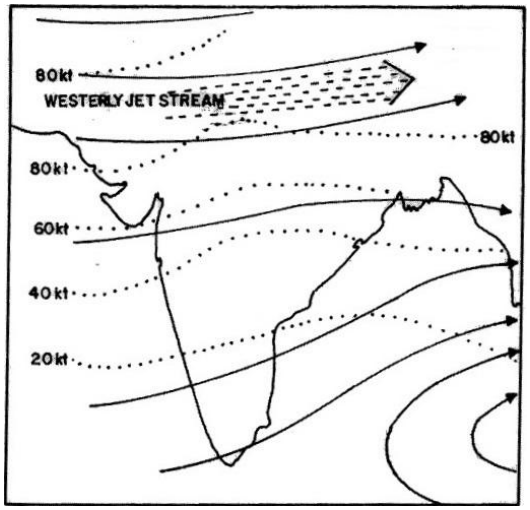

Figure 2 - Direction of Winds in India in winter at the Height of 9-13 km

- **Western Cyclonic Disturbance and Tropical Cyclones** – The western cyclonic disturbances which enter the Indian subcontinent from the west and the northwest during the winter months originate over the Mediterranean Sea and are brought into India by the westerly jet stream. An **increase in the prevailing night temperature** generally indicates an advance in the arrival of these cyclones disturbances. It brings little rain in winter months. This rain is considered to be very good for wheat crops in northern plains.

  Tropical cyclones originate over the Bay of Bengal and the Indian Ocean. These tropical cyclones have very high wind velocity and heavy rainfall and hit the Tamil Nadu, Andhra Pradesh and Orissa coast. Most of these cyclones are very destructive due to high wind velocity and torrential rain that accompanies it.

2.4. Weather Conditions in the Summer Reason

- **Surface Pressure and Winds** - As the summer sets in and the sun shifts northwards, the wind circulation over the subcontinent undergoes a **complete reversal** at both, the lower as well as the upper levels. By the middle of July, the low pressure belt nearer the surface, termed as Inter Tropical Convergence Zone (ITCZ), shifts northwards, roughly parallel to the Himalayas between 20° N and 25° N (Figure 3). It extends from Punjab to the Chota Nagpur plateau. By this time, the westerly jet stream withdraws from the Indian region. There is a cause and effect relationship between the northward shift of the ITCZ and the withdrawal of the westerly jet stream from over the North Indian Plain.

  Being an area of low pressure, the ITCZ attracts winds from all around. The maritime tropical airmass (mT) from the southern hemisphere, after crossing the equator, rushes to the low pressure area in the general southwesterly direction (Figure 4). These winds cross the Equator between 40°E and 60°E longitudes. Blowing over the ocean for a long distance, they pick up a large amount of moisture. It is this moist air current which is popularly known as **the southwest monsoon**.

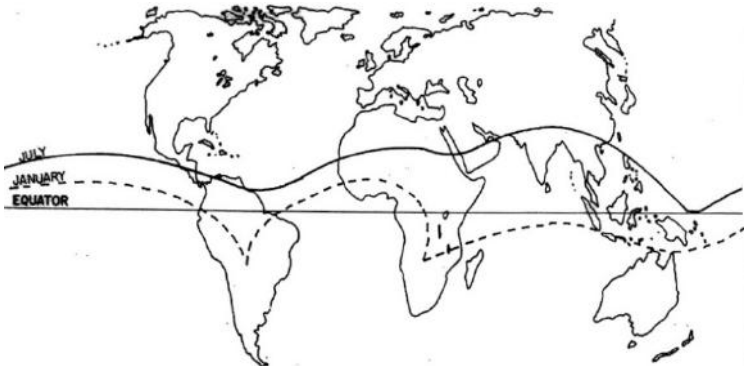

Figure 3 – position of Inter-tropical Convergence Zone (ITCZ) in the month of January and July

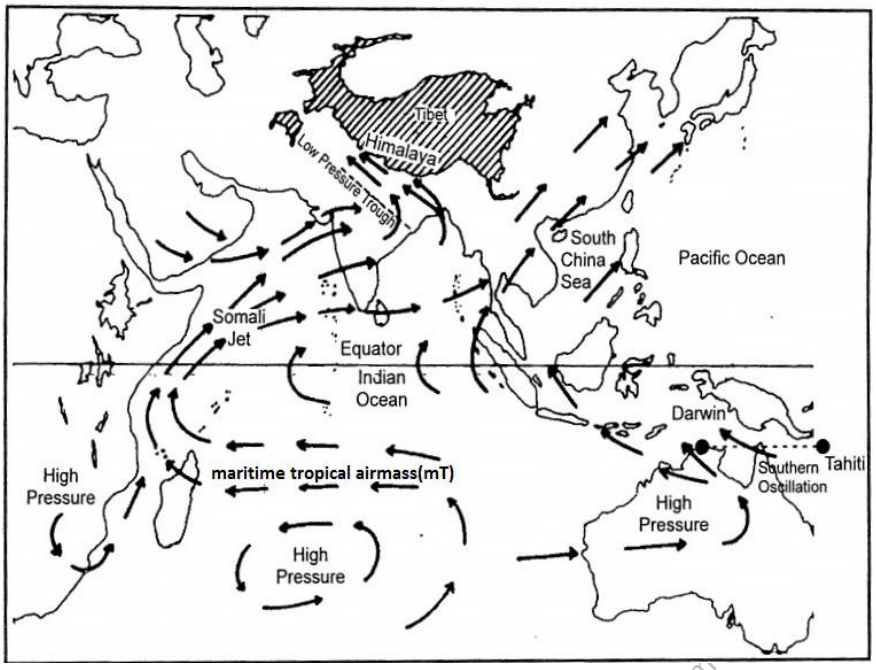

Figure 4 – summer monsoon winds: Surface circulation

- **Jet Streams and Upper Air Circulation** – at the upper layers of the troposphere, the winds blow in a direction reverse to that of the surface winds. An easterly jet stream flows over the southern part of the Peninsula in June, and has a maximum speed of 90 km per hour (Figure 5). In August, it is confined to 15° N latitude, and in September up to 22° N latitudes.

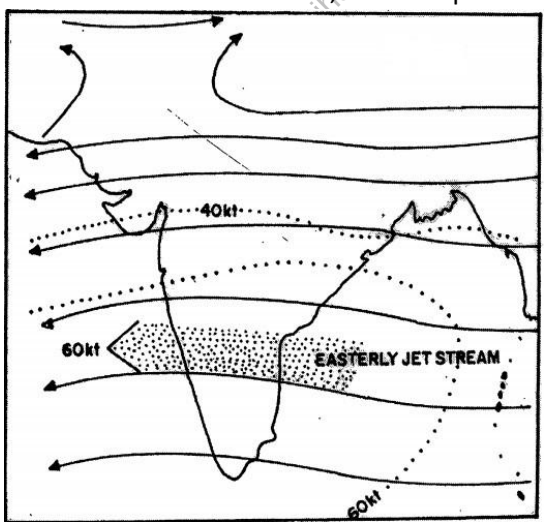

Figure 5 – The direction of winds at upper atmosphere in summer season

- **Tropical cyclones** – The easterly jet stream steers the tropical depressions into India. These depressions play a significant role in the distribution of monsoon rainfall over the Indian subcontinent. The tracks of these depressions are the areas of highest rainfall in India. Their frequency, direction and intensity determine the rainfall pattern during the southwest monsoon period.

3. Indian Monsoon

We already know that India's climate is 'tropical monsoon' type. The word '**monsoon'** has been derived from the Arabic word 'Mausim' which **means 'season'**. Originally, this word was used by Arab traders to describe a system of seasonal reversal of winds along the shores of the Indian Ocean. Monsoons are especially prominent within the tropics on the eastern sides of the great landmass, but in Asia, it occurs outside the tropics in China, Korea and Japan.

Monsoon is a complex meteorological phenomenon. Experts of meteorology have developed a number of concepts about the origin of the monsoon. Some of the important concepts about the origin of monsoon have been given as under.

3.1. Thermal Concept

Halley, a noted astronomer, hypothesized that the primary cause of the annual cycle of the Indian monsoon circulation was the differential heating effects of the land and the sea. According to this concept monsoon are the extended land breeze and sea breeze on a large scale. During winter the huge landmass of Asia cools more rapidly than the surrounding oceans with the result that a strong high pressure centre develops over the continent. On the other hand, the pressure over adjacent oceans is relatively lower. As a consequence the pressure-gradient directed from land to sea. Therefore there is an outflow of air from the continental landmass towards the adjacent oceans so that it brings cold, dry air towards the low latitudes.

In summer the temperature and pressure conditions are reversed. Now, the huge landmass of Asia heats quickly and develops a strong low pressure centre. Moreover, the pole-ward shift of the Inter-tropical Convergence Zone (ITCZ) to a position over Southern Asia reinforces the thermally induced low pressure centre. The pressure over the adjacent oceans being high, a sea-to-land pressure gradient is established. The surface air flow is, therefore, from the highs over the oceans towards the lows over the heated land. The air that is attracted into the centers of low pressure from over the oceans is warm and moist.

Halley's concept is **criticized** on following lines:

- It **fails to explain the intricacies of monsoon** such as sudden burst of monsoon, breaks in monsoon, spatial and temporal distribution of monsoon.
- The low pressure areas are not stationary. The rainfall is not only convectional but a mix of orographic, cyclonic and convectional rainfall.

3.2. Recent Concept about the Origin of Indian Monsoon

After world war second, the upper atmospheric circulation has been studied significantly. It is now believed that the differential heating of sea and land alone can't produce the monsoon circulation. Apart from it, **recent concept of monsoon** rely heavily on the role of

- Himalayas and Tibetan plateau as a physical barrier and a source of high-level heat.
- Circulation of upper air jet streams in the troposphere.
- Existence of upper air circum-polar whirl over north and south poles in the troposphere.
- The occurrence of ENSO (El-Nino and Southern Oscillation) in the South Pacific ocean
- Walker cell in Indian Ocean.
- Indian Ocean Dipole

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3.2.1. Role of Himalayas and Tibetan Plateau

In 1970s, it was found that Tibet plateau plays a crucial role in initiating the monsoon circulation. The plateau of Tibet extends over an area of about 4.5 million sq. km. The average height of these highlands is 4000 m. Due to its enormous height it receives 2-3°C more insolation than the neighbouring areas. Heating of these areas leads to a clockwise air circulation in the middle troposphere and two-wind streams originate from this area. One of these wind streams blow southward and develops into the tropical easterly jet stream (TEJ). The other stream blows in an opposite direction towards the North Pole and becomes the westerly jet stream over Central Asia.

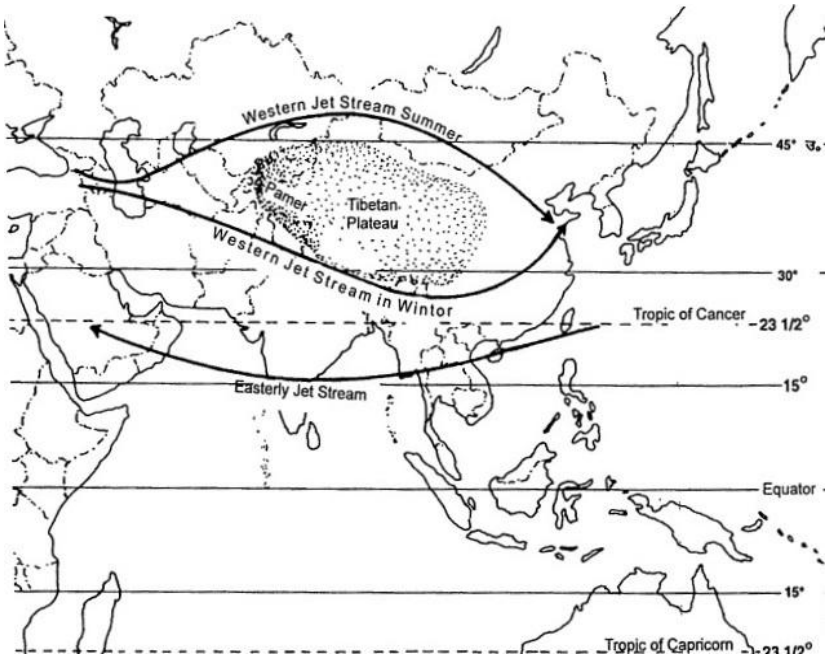

Figure 6 – Tibet anti-cyclone and Easterly Jet stream

3.2.2. Role of Jet Stream

As already discussed, sub-tropical westerly jet stream is bifurcated by the high-land Tibet in winters. Northward branch extends up to 20°N-35°N (Figure 6). Tropical easterly jet stream (TEJ), that branch off from anticyclone developed over Tibet, sometimes reaches to the tip of Peninsular India. Apart from this, Jet speed winds are also reported over other parts of Peninsular. This jet descends over the Indian Ocean and intensifies its high pressure cell known as **Mascarene High**. It is from this high pressure cell that the onshore winds start blowing towards the thermally induced low pressure area, developed in the northern part of the Indian subcontinent. After crossing the equator such winds become south-westerly and are known as the south-westerly summer monsoon.

3.2.3. Role of ENSO

The Indian monsoon is also influenced by EL-Nino, southern oscillation and Somalian current. We know that El Nino is the reversal of normal condition in the Pacific Ocean's sea surface temperature. Though there is no direct correlation between bad monsoon and El Nino, but both are generally associated. There are years when India faced severe drought and those are not El Nino years and vice-versa. Southern Oscillation is the see-saw pattern of atmospheric pressure between the eastern and western Pacific Ocean. The oscillation has a period varying from 2-7 years. It is measured with **Southern Oscillation Index (SOI)** by measuring pressure difference between two points in Pacific Ocean (Tahiti and Darwin). A negative value of SOI implies high pressure over north Indian Ocean during the winter season and a poor monsoon.

The **Somalian current** changes its direction of flow after every six months. During the North-

East Monsoon the Somali Current flows to the south-west, while during the South-West Monsoon it is a major western boundary current, comparable with the Gulf Stream (Figure 7). Normally, there remains a low pressure area along the eastern coast of Somalia. In exceptional years, after every six or seven years, the low pressure area in western Arabian Sea becomes a high pressure area. Such a pressure reversal results into a weaker monsoon in India.

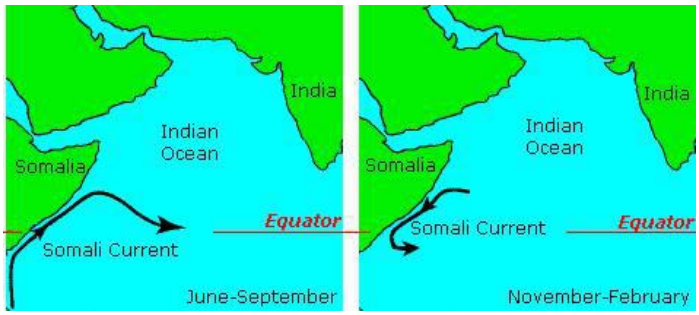

Figure 7 – Somali current

3.2.4. Walker Cell

It is observed that there is an **east-west atmospheric circulation** over the tropical oceanic regions. Such circulation in Pacific Ocean is generally called walker cell. However, many scientists use the term 'walker cell' for all east-west circulations in different oceans. Walker cell is associated with southern oscillation and its strength fluctuates with that of Southern Oscillation Index (SOI). With a high positive SOI, there would be a zone of low atmospheric pressure over Australia and Indonesian archipelago. The rising air from this region deflects in upper atmosphere in both directions towards Africa and South America. In Indian Ocean, the air descends down at high pressure zone from where surface winds blow as Southwest monsoon towards Indian sub-continent in summers. During La-Nina Indian ocean branch of walker cell get strengthen and surface winds are more intense. **La-Nina condition is generally associated with good monsoon.**

During appearance of El-Nino or negative SOI, the ascending branch of the walker cell shifts to the central regions of the Pacific Ocean from west pacific region (Figure 8). In result, the Indian Ocean cell shifts towards east. The surface winds or Southwest monsoon winds are weaker than normal conditions.

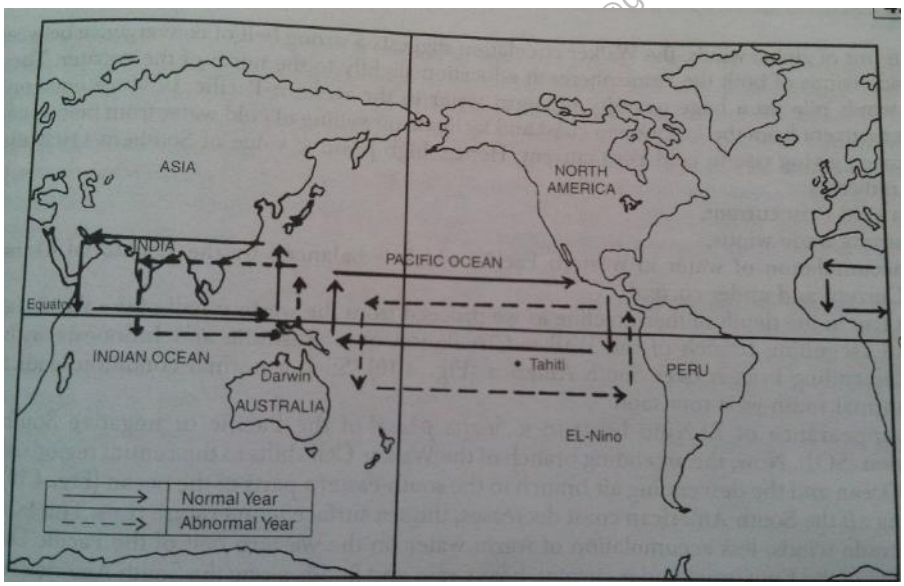

Figure 8 – walker cell and Indian Monsoon

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3.2.5. Indian Ocean Dipole

The Indian Ocean Dipole (IOD) also known as the Indian Nino is a coupled Ocean-atmosphere phenomenon in the Indian Ocean. It is defined by the difference in sea surface temperature between two areas (or poles, hence a dipole) – a western pole in the Arabian Sea (western Indian Ocean) and an eastern pole in the eastern Indian Ocean south of Indonesia. The IOD involves a periodic oscillation of sea-surface temperatures (SST), between "positive", "neutral" and "negative" phases. A **positive phase** sees greater-than-average sea-surface temperatures and greater precipitation in the western Indian Ocean region, with a corresponding cooling of waters in the eastern Indian Ocean—which tends to cause droughts in adjacent land areas of Indonesia and Australia (Figure 9). The negative phase of the IOD brings about the opposite conditions, with warmer water and greater precipitation in the eastern Indian Ocean, and cooler and drier conditions in the west.

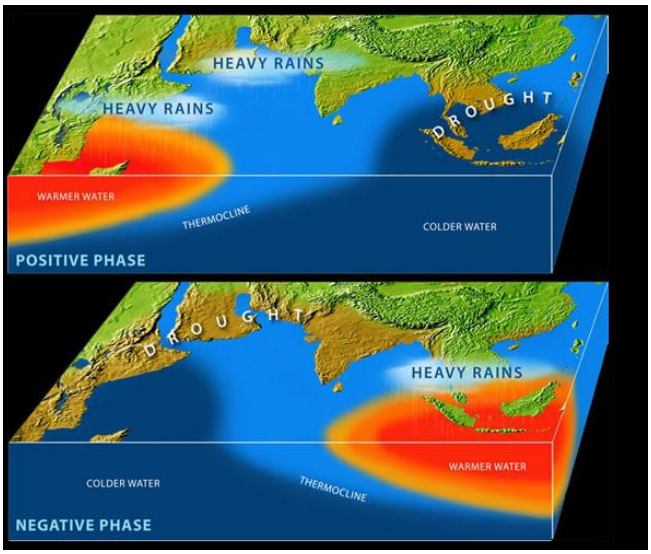

Figure 9 – Indian Ocean Dipole

The IOD is one aspect of the general cycle of global climate, interacting with similar phenomena like the El Niño-Southern Oscillation (ENSO) in the Pacific Ocean. Positive and negative IOD both has been seen coupled with La Nina. Thus, there is no direct correlation between IOD and ENSO.

The IOD also affects the strength of monsoons over the Indian subcontinent. Positive IOD which is associated with warm sea-surface temperatures of western Indian Ocean is favourable for monsoon in Indian subcontinent.

3.3. Nature of Indian Monsoon

Systematic studies of the causes of rainfall in the South Asian region help to understand the salient features of the monsoon, particularly some of its important aspects, such as:

- Onset and advance of monsoon
- Rain-bearing systems and the relationship between their frequency and distribution of monsoon rainfall.
- Break in the monsoon
- retreat of the monsoon

3.4. Onset and Advance of Monsoon

The differential heating of land and sea is still believed to be the primary cause of the monsoon by many meteorologists. Low pressure at ITCZ which is located over north India in month of May becomes so intense that it pulls the trade winds of the southern hemisphere northwards

(Figure – summer monsoon winds). These southeast trade winds cross the equator and enter the Bay of Bengal and the Arabian Sea, only to be caught up in the air circulation over India. Passing over the equatorial warm currents, they bring with them moisture in abundance. With the northwards shift of ITCZ, an easterly jet stream develops over 15°N.

The rain in the south-west monsoon season begins rather abruptly. One result of the first rain is that it brings down the temperature substantially. This sudden onset of the moisture-laden winds associated with violent thunder and lightning, is often termed as the "break" or "burst" of the monsoons.

Southwest monsoon first of all reaches in Andaman-Nicobar Islands on 15th May. Kerala coast receives it on 1st June. It reaches Mumbai and Kolkata between 10th and 13th June. By 15th of July, Southwest monsoon covers whole of India (Figure 10).

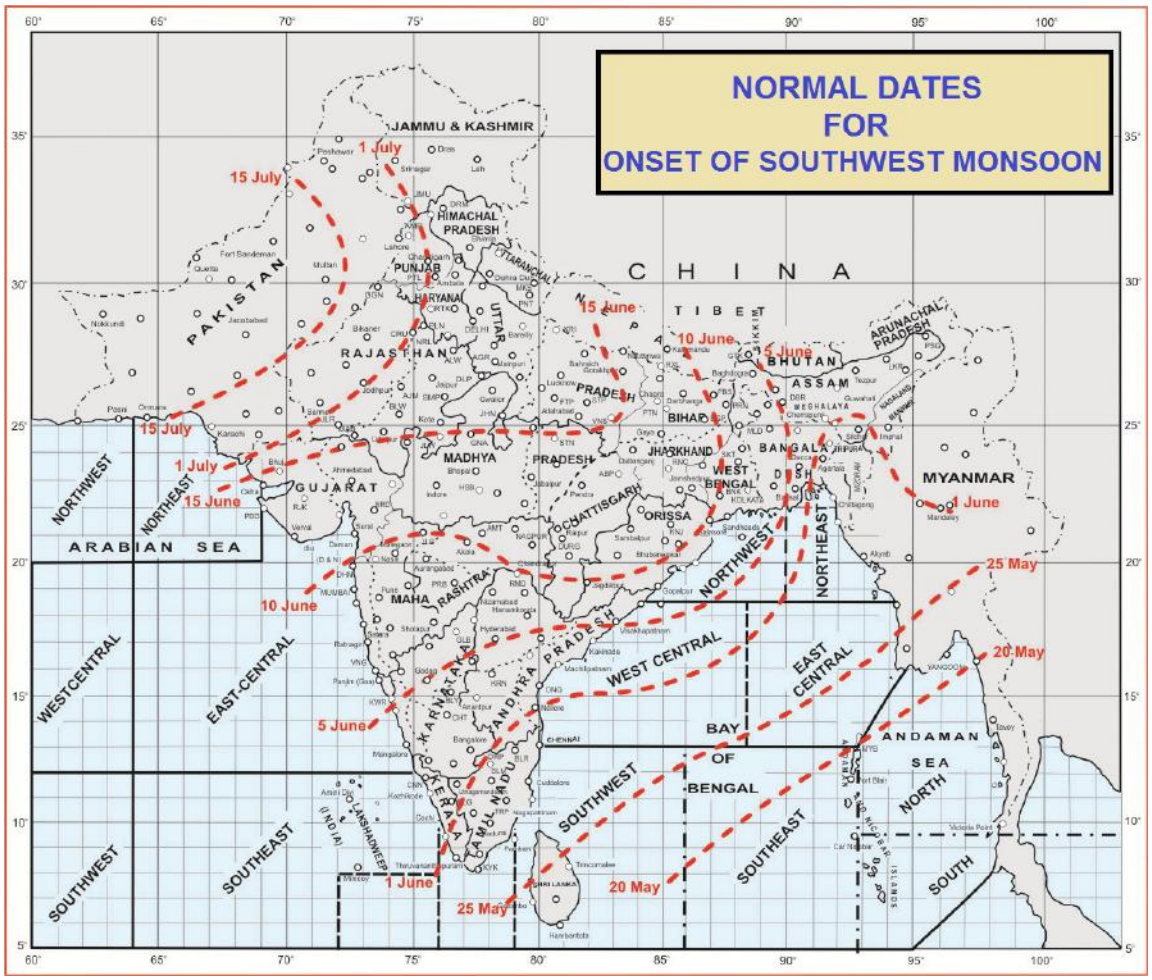

Figure 10 – India: Normal dates of Onset of the Southwest Monsoon

3.5. Rain Bearing Systems and Distribution of Rainfall

The southwest monsoon splits into two branches, the Arabian Sea Branch and the Bay of Bengal Branch near the southernmost end of the Indian Peninsula. Hence, it arrives in India in **two branches: the Bay of Bengal branch and the Arabian Sea Branch** (Figure 11). First originate in the Bay of Bengal causing rainfall over the plains of north India. Second is the Arabian Sea current of the southwest monsoon which brings rain to the west coast of India. The latter extends toward a low-pressure area over the Thar Desert and is roughly three times stronger than the Bay of Bengal branch.

The monsoon winds originating over the **Arabian Sea** further split into **three branches**:

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- One branch is **obstructed by the Western Ghats**. These winds climb the slopes of the Western Ghats and as a result of orographic rainfall phenomenon, the windward side of Ghats receives very heavy rainfall ranging between 250 cm and 400 cm. After crossing the Western Ghats, these winds descend and get heated up. This reduces humidity in the winds. As a result, these winds cause little rainfall east of the Western Ghats. This region of low rainfall is known as the **rain-shadow area.**
- Another branch of the Arabian Sea monsoon **strikes the coast north of Mumbai**. Moving along the Narmada and Tapi river valleys, these winds cause rainfall in extensive areas of central India. The Chotanagpur plateau gets 15 cm rainfall from this part of the branch. Thereafter, they enter the Ganga plains and mingle with the Bay of Bengal branch.

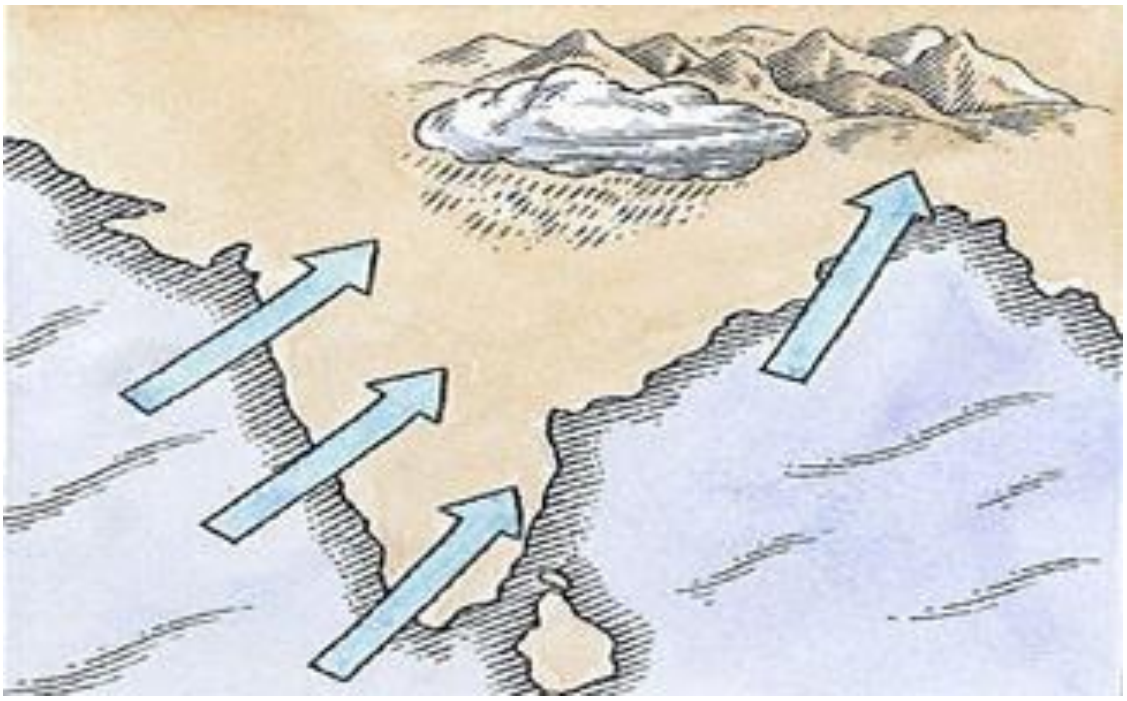


Figure 11 – Arabian Sea and Bay of Bengal branches of Southwest Monsoon

- A third branch of this monsoon wind **strikes the Saurashtra Peninsula and the Kutch**. It then passes over west Rajasthan and along the Aravallis, causing only a scanty rainfall. In Punjab and Haryana, it too joins the Bay of Bengal branch. These two branches, reinforced by each other, cause rains in the western Himalayas.
- The intensity of rainfall over the west coast of India is, however, related to two factors:
  - The offshore meteorological conditions.
  - The position of the equatorial jet stream along the eastern coast of Africa.

The Bay of Bengal branch strikes the coast of Myanmar and part of southeast Bangladesh. But the Arakan Hills along the coast of Myanmar deflect a big portion of this branch towards the Indian subcontinent. The monsoon, therefore, enters West Bengal and Bangladesh from south and southeast instead of from the south-westerly direction. From here, this branch splits into two under the influence of the Himalayas and the thermal low is northwest India.

- One branch moves westward along the **Ganga plains** reaching as far as the Punjab plains.
- The other branch **moves up the Brahmaputra valley** in the north and the northeast, causing widespread rains. Its sub-branch strikes the Garo and Khasi hills of Meghalaya. **Mawsynram**, located on the crest of Khasi hills, receives the **highest average annual rainfall** in the world.
- The Tamil Nadu coast remains dry during this season because it is situated in rainshadow area of Arabian Sea branch of the south-west monsoon and lies parallel to the Bay of Bengal branch of south-west monsoon.

Frequency of tropical depressions originating over the Bay of Bengal varies from year to year. The path of these depressions also keeps changing with the position of the ITCZ, also known as **monsoon trough** (Figure – position of Inter-tropical Convergence Zone (ITCZ) in the month of January and July). As the axis of the monsoon trough oscillates with the apparent movement of sun between Tropic of Cancer and Tropic of Capricorn, there are fluctuations in the track and direction of these depressions, and the intensity and the amount of rainfall vary from year to year. The amount of rainfall in north India varies with the frequency of the tropical depressions. On an average, one to three depressions are observed every month and the life span of one depression is about one week [4].

The rain which comes in spells, displays a declining trend from west to east over the west coast, and from the southeast towards the northwest over the North Indian Plain and the northern part of the Peninsula. Rajasthan desert receives low rainfall in spite of being in the path of Arabian Sea branch of monsoon. This branch blows parallel to Aravalis mountain chain without obstruction and thus, does not release moisture here.

3.6. Break in the Monsoon

During the south-west monsoon period after having rains for a few days, if rain fails to occur for one or more weeks, it is known as break in the monsoon. These dry spells are quite common during the rainy season. These breaks in the different regions are due to different reasons:

1. In northern India rains are likely to fail if the rain-bearing storms are not very frequent along the monsoon trough or the ITCZ over this region.
2. Over the west coast the dry spells are associated with days when winds blow parallel to the coast.

3.7. Retreat of Monsoon

Monsoon starts retreating in September (Figure 12). On the first of September it starts retreating from north-western part of India. This day is the last day of rainy season in Jaisalmer and Barmer in Rajasthan. By 15th September, monsoon leaves Punjab, Haryana, Rajasthan and Gujarat. The area under the monsoon influence shrinks slowly and the monsoon retreats from all parts of India except the southern peninsular region. Monsoon winds in most parts of the country are replaced by the north-easterly trade winds. These winds blowing over the Bay of Bengal pick up moisture from there and cause rainfall in Tamil Nadu.

Student Notes:

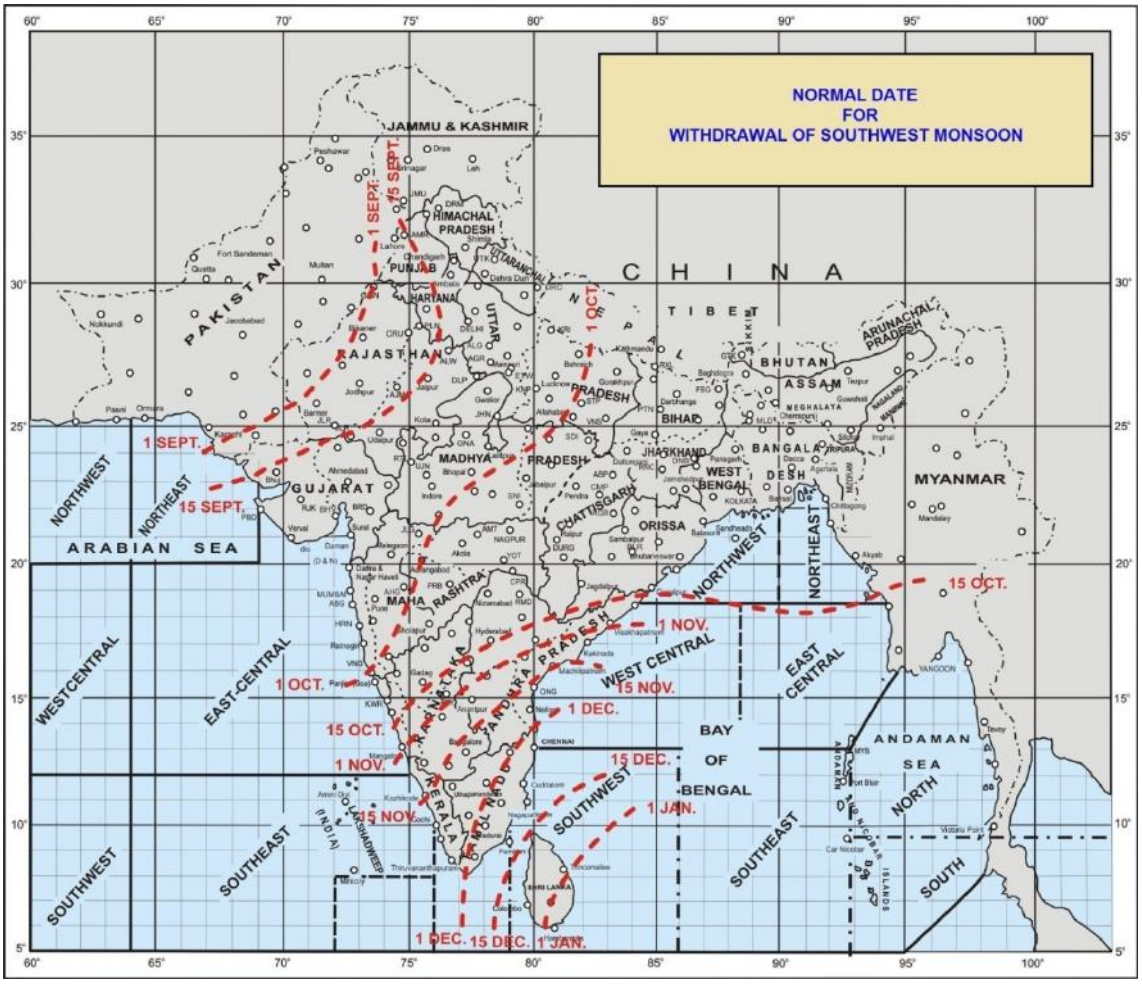


Figure 12 – India: Normal dates of withdrawal of the Southwest Monsoon

3.8. Features of Monsoon Rainfall

- Monsoon rain is **seasonal** in character which occurs between June and September.
- Spatial distribution of rainfall is largely **governed by relief** or topography. For instance the windward side of the Western Ghats registers a rainfall of over 250 cm. Again, the heavy rainfall in the northeastern states can be attributed to their hill ranges and the Eastern Himalayas. Rainfall ranges from 20 cm in western Rajasthan to more than 400 cm in certain parts of Western Ghats and North-East India.
- The monsoon rainfall has a declining trend with increasing distance from the sea. Rainfall decreases from east to west in plains as one branch of monsoon enters from eastern side. Kolkata receives 119 cm, Allahabad 76 cm and Delhi 56 cm only.
- Breaks (discussed above) in rainfall are related to the cyclonic depressions mainly formed at the head of the Bay of Bengal, and their crossing into the mainland. Besides the frequency and intensity of these depressions, the passage followed by them determines the spatial distribution of rainfall.
- The rains sometimes end considerably earlier than usual, causing great damage to standing crops and making the sowing of winter crops difficult.

3.9. Monsoons and the Economic Life in India

- Monsoon is that axis around which revolves the entire agricultural cycle of India. It is because about 64 per cent people of India depend on agriculture for their livelihood and agriculture itself is based on southwest monsoon.

Student Notes:

- Except Himalayas all the parts of the country have temperature above the threshold level to grow the crops or plants throughout the year.
- Regional variations in monsoon climate help in growing various types of crops.
- Agricultural prosperity of India depends very much on timely and adequately distributed rainfall. If it fails, agriculture is adversely affected mainly in areas where irrigation is not developed.
- Sudden monsoon burst creates problem of soil erosion over large areas in India.

4. Seasons

Seasons are a special feature of Indian climate. Temperature, pressure, wind direction and the amount and duration of rain varies from one season to the other. Meteorologists identify four seasons in India. They are described briefly in table 1 below

Season	Duration	General characteristics	Temperature	Wind, disturbances	rainfall
Winter season	Mid-November to February	Clear skies, fine weather, low humidity	Mean daily temperature below 21°C in North India. Some part experience temperature below freezing point. Temperature increases from north to south.	High pressure over north-western India. Winds blow from north-west to south-east. Around four or five westerly disturbances are carried by westerly jet stream.	Westerly disturbances cause rainfall in northern plains. Rainfall decreases from west to east in plains but increases in north-east again as it catch water from Bay of Bengal. North-east monsoon causes winter rainfall in southern Andhra Pradesh, Tamil Nadu etc.
Summer season	April, May, June	Excessive heat, hot loo, dust storms and dryness	Temperature rises up to 45°C in north India. Temperature has increased to 50°C in Ganganagar earlier. Summer in south India is not so extreme.	Low pressure over north-western part of India and high pressure over southern parts of Bay of Bengal. ITCZ shifts to Ganges plain. Wind direction varies from one part of India to the other. Dust storms are frequency experienced in the afternoon in northern plains.	Completely dry season. Dust storms and thunder storms provide some rainfall. Eastern regions receives more rainfall comparatively.
South-west monsoon	June – September	Whole of India under south-west monsoon.	June is the hottest month. Temperature	Winds are south-westerly over mainland	India receives its 80% precipitation in

		India faces severe cyclones, thunderstorms etc.	remains low during July and August which rises high in September with decreasing amount of precipitation.	India.	this season. There is decline of rainfall from east to west in plains. Details are discussed under 'monsoon' above.
Retreating monsoon	October-November	Monsoon winds are retreating gradually and sudden rise of temperature with October heat.	Day temperature is high and nights are cool and pleasant. The average minimum temperature fall below 20°C.	Winds are north-easterly. Clear skies and gentle breeze are characteristics of this season.	Southern Peninsular region (Tamil Nadu, Kerala, and Southern Andhra Pradesh) receives rain. Cyclonic activities are more frequent in Peninsular region.

Table 1 – Different seasons of India with their characteristics

4.1. Traditional Indian Seasons

In the Indian tradition, a year is divided into six two-monthly seasons. This cycle of seasons, which the common people in north and central India follow is based on their practical experience and age-old perception of weather phenomena. However, this system does not match with the seasons of south India where there is little variation in the seasons.

Season	Months according to Indian Calendar	Months according to English Calendar
Vasanta	Chaitra-Vaisakha	March-April
Grishma	Jyaistha-Asadha	May-June
Varsha	Sravana-Bhadra	July-August
Sharada	Asvina-Kartika	September-October
Hemanta	Margashirsa-Pausa	November-December
Shishira	Magha-Phalguna	January-February

Table 2 – Indian seasons

5. Distribution of Annual Rainfall

The distribution of average annual rainfall in India is shown in figure 13. A glance on this map indicates that the distribution of rainfall in India is uneven. On the basis of the distribution of rainfall, India can be divided into the following four regions as shown below in table 3.

Category	Rainfall in cms	regions
Heavy Rainfall	More than 200	Western coast, western ghats, sub-Himalayan region of north-east, Garo, Khasi and Jaintia hills of Meghalaya. In some parts, rain exceeds 1000 cm.
Moderate rainfall	Between 100 to 200	100 cm isohyet extends from Gujarat to south up to Kanyakumari parallel to western ghats. Northern Andhra Pradesh, eastern part of Maharashtra, Madhya Pradesh, Odisha, some parts of Jammu and Kashmir
Low rainfall	Between 60 to 100	Most parts of Tamil Nadu,

		Karnataka, Andhra Pradesh, eastern Rajasthan, south-western Uttar Pradesh
Inadequate rainfall	Less than 60	Punjab, Haryana, north-western Rajasthan, Kachchh, Kathiawar

Table 3 – Different rainfall regions of India

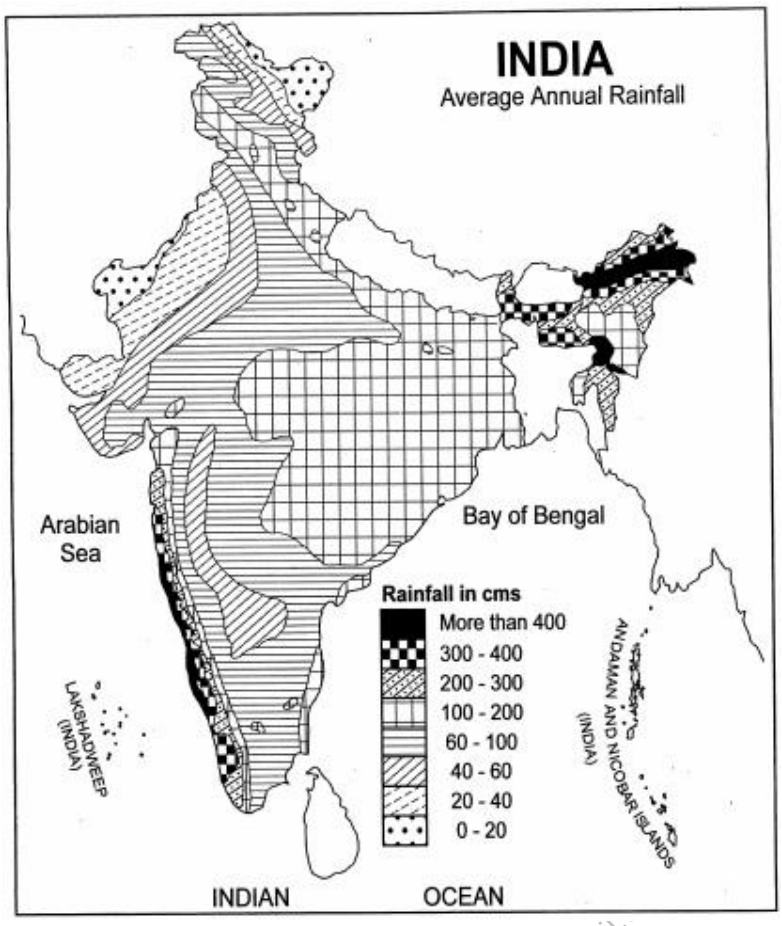


Figure 13 – India: Annual rainfall

6. Variability of Annual Rainfall

Variability of rainfall refers to **variations in rainfall from the average amount**. The variability of rainfall is computed with the help of the following formula:

C.V. = (Standard Deviation / Mean) x 100; where C.V. is the coefficient of variation.

Study of variability of rainfall in an agricultural country such as India is very important. The rainfall in India is highly variable. The actual rainfall of a place in a year deviates from its average rainfall by 10 to over 60 per cent. The mean annual rainfall variability of rainfall in India has been plotted in figure 14. Description of annual rainfall's variability is details as:

- It may be noted from figure 13 and figure 14 that the highest variability is found in the areas where the average annual rainfall is the lowest such as desert areas of Rajasthan. Here, variability of rainfall is around 60 per cent.
- Contrary to this, in the areas where the average annual rainfall is over 200 cm (Meghalaya plateau, Western Ghats), the annual variability of rainfall is less than 10 per cent.
- A very large part of India falls in the category of 15 to 30 per cent annual variability of rainfall. Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra etc. fall in this category
- Variability of annual rainfall increases from the western coast to the interior of the Peninsular region and from West Bengal and Odisha towards north and north-west.

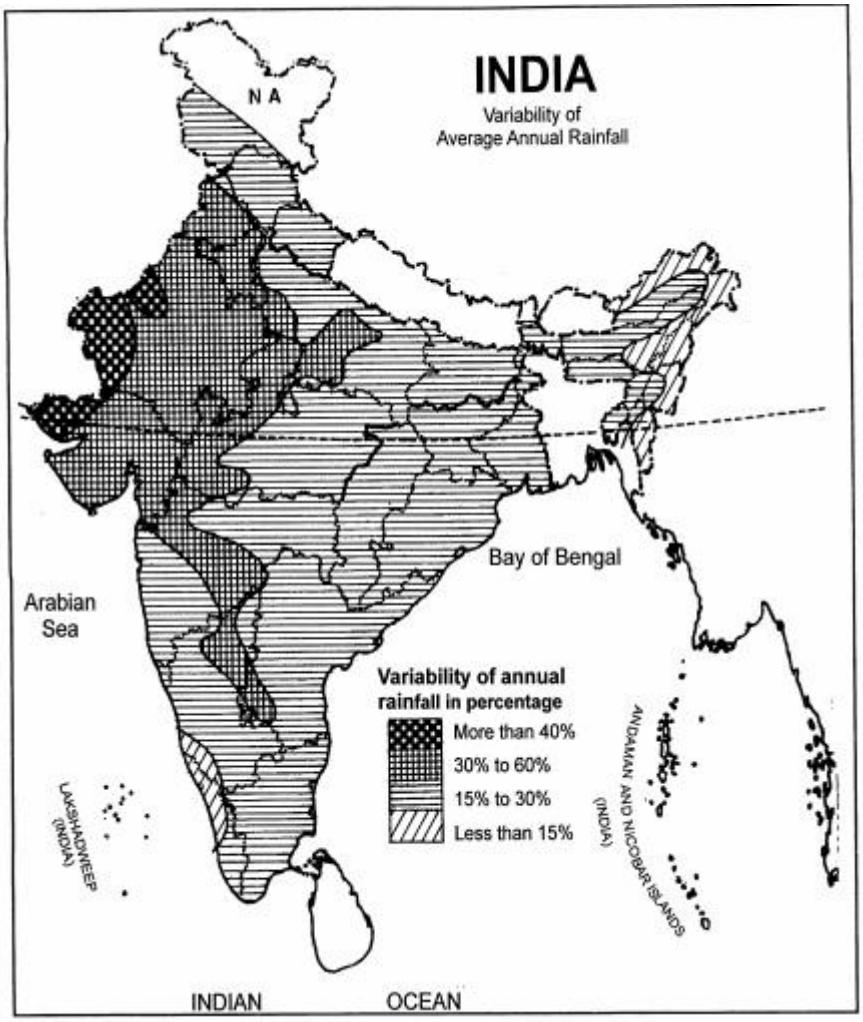


Figure 14 – India: variability of annual rainfall

7. Climatic Regions of India

India is often referred to as a country with tropical monsoon type of climate. However, the large latitudinal extent, the presence of Himalayas in the north, the India Ocean in the south have resulted in great variations in the distribution of temperature and precipitation in the India. The **climate of north is different from that of south** and so is the climate of east from that of the west.

To study the variations of climate in various parts, India is divided into a large number of climatic regions of small size. A climatic region is that area which possesses a broad uniformity of climatic conditions caused by the combined effects of climatic elements – temperature, pressure, winds, humidity and precipitation. Temperature and rainfall are two important elements which are considered to be decisive in all the schemes of climatic classification. There are different schemes of classification of climate. Major climatic types of India based on **Koeppen's scheme** have been show in figure 15.

Figure 15 – India: Climatic regions according to Koeppen scheme

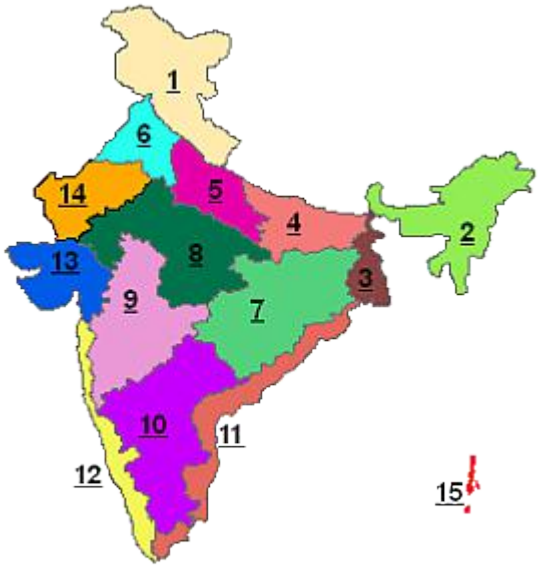
Koeppen based his scheme of Climatic classification on monthly values of temperature and precipitation. India's climate is divided into the following climatic regions:

- Monsoon type with short dry season (Amw) – the western coastal region south of Goa experiences this type of climate.
- Monsoon type with dry season in summers (AS) – the region of this type of climate extends along the coromandel coast.
- Tropical Savannah type (Aw) – almost the entire peninsular region except for some coastal parts experiences this type of climate.
- Semi-arid steppe climate (BShw) – this climatic region includes the interior parts of the peninsular plateau and some parts of Gujarat, Rajasthan, Haryana, Punjab and Jammu & Kashmir.
- Hot desert type (BWhw) – this type of climate is found only in the western part of Rajasthan.
- Monsoon type with dry winters (Cwg) – Largely Northern plains of India experiences this type of climate.
- Cold-humid winter type with short summer (Dfc) – this climate of characterized by a short summer season. This region covers the north-eastern parts of India.

- Polar type (E) – this type of climate is experienced in Jammu & Kashmir and the neighbouring mountain ranges.

7.1. Agro Climatic Zones of India

The agro-climatic classification is nothing but an extension of the climate classification keeping in view the suitability to agriculture. Generally, the climate types may be distinguished on the rainfall, temperature and as these two characteristics are influenced by altitude, the climate can also be classified on the basis of above three parameters. National commission on agriculture (1971) classified the country into 127 agro-climatic zones. The planning commission, as a result of mid. term appairasal of planning targets of VII plan (1985 - 90) divided the country into 15 broad agro - climatic zones based on physiographic and climate. The emphasis was given on the development of resources and their optimum utilization in a suitable manner with in the frame work of resource constraints and potentials of each region.



Agro climatic zones of India: (Planning commission 1989)

1	Western Himalayan Region	Ladakh, Kashmir, Punjab, Jammu etc.brown soils & silty loam, steep slopes.
2	Eastern Himalayan Region	Arunachal Pradesh, Sikkim and Darjeeling. Manipur etc. High rainfall and high forest covers heavy soil erosion, Floods.
3	Lower Gangatic plants Regions	West Bengal Soils mostly alluvial & are prone to floods.
4	Middle Gangatic plans Region	Bihar, Uttar Pradesh, High rainfall 39% irrigation, cropping intensity 142%
5	Upper Gangatic Plains Region	North region of U.P. (32 dists) irrigated by canal & tube wells good ground water
6	Trans Gangatic plains Region	Punjab Haryana Union territory of Delhi, Highest sown area irrigated high
7	Eastern Plateaus & Hills Region	Chota Nagpur, Garhjat hills, M.P, W. Banghelkhand plateau, Orissa, soils Shallow to medium sloppy, undulating Irrigation tank & tube wells.
8	Central Plateau & hills Region	M. Pradesh
9	Western Plateau & hills Region	Sahyadry, M.S. M.P. Rainfall 904 mm Sown area 65% forest 11% irrigation 12.4%
10	Southern Plateau & Hills Region	T. Nadu, Andhra Pradesh, Karnataka, Typically semi and zone, Dry land Farming 81% Cropping Intensity 11%
11	East coast plains & hills Region	Tamil Nadu, Andhra Pradesh Orissa, Soils, alluvial, coastal sand, Irrigation

12	West coast plains & Hills Region	Sourashtra, Maharashtra, Goa, Karnataka, T. Nadu, Variety of cropping Pattern, rainfall & soil types.
13	Gujarat plains & Hills Region	Gujarat (19 dists) Low rainfall arid zone. Irrigation 32% well and tube wells.
14	Western Dry Region	Rajasthan (9 dists) Hot. Sandy desert rainfall erratic, high evaporation. Scanty vegetation, femine draughts.
15	The Island Region	Eastern Andaman, Nikobar, Western Laksh dweep. Typical equatorial, rainfall 3000 mm (9 months) forest zone undulating.

Student Notes:

8. UPSC Previous Years Mains Questions

1. List the significant local storms of the hot-weather season in the country and bring out their socio-economic impact. (2012)
2. What do you understand by the phenomenon of temperature inversion in meteorology? How does it affect the weather and the habitants of the place? (2013)
3. Bring out the relationship between the shrinking Himalayan glaciers and the symptoms of climate change in the Indian sub-continent. (2014)
4. Most of the unusual climatic happenings are explained as an outcome of the El-Nino effect. Do you agree? (2014)
5. How far do you agree that the behavior of the Indian monsoon has been changing due to humanizing landscapes? Discuss. (2015)
6. What characteristics can be assigned to monsoon climate that succeeds in feeding more than 50 percent of the won population residing in Monsoon Asia? (2017)

9. UPSC Previous Years Prelims Questions on Climate

1. The jet aircrafts fly very easily and smoothly in the lower stratosphere. What could be the appropriate explanation? (2011)
1. There are no clouds or water vapour in the lower stratosphere.
2. There are no vertical winds in the lower stratosphere.

Which of the statements given above is/are correct in this context?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

2. La Nina is suspected to have caused recent floods in Australia. How is La Nina different from El Nino?
1. La Nina is characterised by unusually cold ocean temperature in equatorial Indian Ocean whereas El Nino is characterised by unusually warm ocean temperature in the equatorial Pacific Ocean.
2. El Nino has adverse effect on south-west monsoon of India, but La Nina has no effect on monsoon climate.

Which of the statements given above is/are correct? (2011)
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

3. Consider the following statements:
1. The duration of the monsoon decreases from southern India to northern India.
2. The amount of annual rainfall in the northern plains of India decreases from east to west.

Which of the statements given above is/are correct? (2012)
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Student Notes:

4. The seasonal reversal of winds is the typical characteristic of (2014)
(a) Equatorial climate (b) Mediterranean climate
(c) Monsoon climate (d) All of the above climates

5. "Each day is more or less the same, the morning is clear and bright with a sea breeze; as the Sun climbs high in the sky, heat mounts up, dark clouds form, then rain comes with thunder and lightning. But rain is soon over."
Which of the following regions is described in the above passage? (2015)
(a) Savannah (b) Equatorial
(c) Monsoon (d) Mediterranean

6. With reference to Ocean Mean Temperature (OMT), which of the following statements is/are correct?
1. OMT is measured up to a depth of 26°C isotherm which is 129 meters in the south-western Indian Ocean during January–March.
2. OMT collected during January–March can be used in assessing whether the amount of rainfall in monsoon will be less or more than a certain long-term mean.

Select the correct using the code given below: (2020)
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

10. Vision IAS Previous Years Mains Questions

1. Explaining the origin and mechanism of Indian monsoon account for the uneven distribution of monsoonal rainfall in India.

Approach:

- Define the phenomena of monsoon in Indian context.
- Explain the origin and mechanism of Indian monsoon.
- Give an account of uneven distribution of monsoonal rainfall in India.
- Discuss the factors behind this uneven distribution.

Answer:

Monsoon is the phenomena of seasonal reversal of wind along with corresponding change in the precipitation. In Indian context, the summer monsoon (June to September) causes rainfall across the country, whereas the other phase i.e. the retreating monsoon, causes rainfall in south-eastern coast of India during winter.

There are various factors behind the origin of Indian Monsoon-

- The **differential heating and cooling** of land and water creates low pressure on the landmass of India while the seas around experience comparatively high pressure.
- The **shift of the position of Inter Tropical Convergence Zone (ITCZ)** in summer, over the Ganga plain (this is the equatorial trough normally positioned about 5°N of the equator).
- Presence of the **high-pressure area** in the east of Madagascar.
- Intense **heating of the Tibetan plateau** during summer causing strong vertical currents.
- **Movement of the westerly jet stream** to the north of the Himalayas and the presence of the tropical easterly jet stream over the Indian peninsula during summer.

Student Notes:

Mechanism of Indian monsoon:

The seasonal reversal of wind is due to the shifting of **Inter-Tropical Convergence Zone** (ITCZ), the low-pressure region near the equator. As a result,

- In July, when the ITCZ is located in the north, it creates the Monsoon Trough. This encourages the development of thermal low over the North and Northwest India. Due to this shift of the ITCZ, trade winds of the southern hemisphere cross the equator between 40oE and 60oE longitudes and start blowing from southwest to northeast due to the Coriolis force. It becomes Southwest monsoon.
- In winter, the ITCZ moves southward, and so the reversal of winds, from the northeast to south and southwest takes place thus leading to Northeast monsoon.

The moisture is picked up from water bodies, mostly the Arabian Sea and the Bay of Bengal. The shape of the landmass and mountains (Western Ghats in the south and Himalayas in the North) guide the winds' direction.

Uneven distribution of monsoonal rainfall in India

- **Temporal distribution-** The monsoon may burst in the first week of June in the coastal areas of Kerala, Karnataka, Goa and Maharashtra while in the interior parts of the country; it may be delayed to the first week of July. Monsoonal rainfall is largely governed by **relief or topograph**y and rainfall has a declining trend with increasing distance from the sea. By the end of September, the monsoon becomes weak in response to the southward march of the sun.
- **Spatial distribution-** In terms of intensity, maximum rainfall (above 200 cm) occurs on the western coast and north-eastern hills. Moderate rainfall (100-200cm) occurs in some parts of the Western Ghats and West Bengal. Inadequate rainfall (Less than 60cm) occurs in western part of Rajasthan and Gujarat, Ladakh and south-central part receives rainfall of less than 20cm.

Factors behind this uneven distribution-

- **Distance from the sea** (Continentality)**:** As the distance from the sea increases, the moisture content of the wind decreases. E.g. Patna receives more rainfall than Delhi from the Bay of Bengal branch of monsoon winds.
- **Relief:** The windward side of mountains and hills receive more rainfall than leeward side. E.g. Western Ghats as compared to Eastern Ghats.
- **Physical obstacles-** Those areas which have no mountains to check the rain bearing winds get scanty rainfall. E.g. Aravalli hills standing parallel to monsoon bearing winds.
- **El-Nino:** This warming of tropical Pacific waters affects the global pattern of pressure and wind systems. Strong El Nino causes dry conditions and deficient monsoon in Indian continent.
- **Indian Ocean Dipole:** Also called Indian Nino, it is a condition where sea surface temperature of the western region of Indian Ocean becomes abnormally colder (negative) and hotter (positive) than the eastern region in alternative phases. The positive' IOD phase brings more rain during monsoon and vice versa. Further, the phenomenon of **Madden Julian Oscillation (MJO)** also contributes in a good monsoon.
- **Cyclonic disturbances:** such as cyclonic depressions over the Andaman Sea causing rainfall over the Eastern coast.

Over recent decades the uneven nature of the monsoon or rainfall pattern has **aggravated causing unprecedented rainfall**. Of late, climatic changes because of global warming have resulted in unpredictable rainfall pattern all over the world including India.

Student Notes:

2. Highlighting different factors affecting Indian monsoon, explain why it is difficult to predict it.

Approach:

- Briefly explain the phenomena of monsoon in Indian context.
- Mention the various factors that influence Indian monsoon.
- Bring out the factors that make predictability of monsoon a difficult task.

Answer:

Monsoon is defined as the seasonal reversal of wind along with corresponding change in precipitation. In Indian context, summer monsoon lasts from June to September i.e. southwest monsoon causing rainfall across the country. Other branch of Indian monsoon is retreating monsoon, which is also North East monsoon causing rain in south-eastern coast of India during winter. With about 65% of the net sown area being rainfed, monsoon is very significant for Indian agriculture and economy.

Monsoon, just like any other rain-bearing wind, depends on pressure difference between two areas, the distance between them, humidity/saturation and physical obstacles in between. The latitudinal location of the high pressure/ low pressure regions is the basic driving force. The moisture is picked up from water bodies, mostly the Arabian sea and the Bay of Bengal. The shape of the landmass and mountains (Western Ghats in the south and Himalayas in the North) guide the winds' direction. However, like any natural phenomenon, Monsoon winds are greatly influenced by a host of factors which guide pressure difference. Some prominent ones are:

Factors affecting Indian monsoon

- **Role of Tibetan Plateau and Jet stream**: The formation of anticyclone over the Tibetan Plateau weakens the western sub-tropical jet stream south of Himalayas and produces tropical easterly jet on the southern side of the anticyclone. Blowing along Kolkata-Bangalore axis the air under this jet descends over the Indian Ocean and intensifies the Ocean's high pressure cell. Study shows that higher the intensity of the tropical easterly jet, greater would be the potency of the high pressure cell over the Indian Ocean and stronger would be the impact of south west monsoon.
- **El-Nino:** This warming of tropical Pacific waters affects the global pattern of pressure and wind systems. Strong El Nino causes dry conditions and deficient monsoon in Indian continent.
- **La-Nina:** It is opposite of El-Nino causing cooling of water in the Eastern Pacific Ocean. It results in better than normal monsoon in India.
- **Southern Oscillation**: It is a seesaw pattern of meteorological changes which occur between the Pacific and the Indian Ocean. Whenever the surface pressure is higher over the Pacific (positive SO), the pressure over the Indian Ocean is low and vice versa. Positive SO is associated with strong monsoon spells.
- **Indian Ocean Dipole:** Also called Indian Nino, it is a condition where sea surface temperature of the western region of Indian Ocean becomes abnormally colder (negative) and hotter (positive) than the eastern region in alternative phases. The positive' IOD phase brings more rain during monsoon and vice versa.
- **Madden Julian Oscillation (MJO):** It is a phenomenon that occurs at a certain intersection of winds, clouds and pressure which brings rain to the different parts of the world as it moves around the equator. Good monsoon in India is attributed to MJO passing over the Indian Ocean.
- **Global Warming**: Rising sea surface temperature of Indian Ocean causes erratic rainfall in India.

As evidenced above, Indian monsoon is the result of the interplay for several global and regional events, making its predictability a difficult task:

Student Notes:

- **Complex weather system**: Meteorologists consider the Indian monsoon to be one of the most complex weather system in the world. Many influencing factors such as Madden Julian Oscillation are not fully understood yet, therefore it is difficult to estimate their impact.
- **Technological constraints:** Though IMD uses dynamical model along with a statistical model using supercomputers, there are still less-studied or unkown factors whose impact is not fully understood and hence, not integrated fully in the system. Unpredictability of extreme events is a result of such limitations.
- There are major data gaps like those involving dust, aerosols, soil moisture and maritime conditions. More technological advancements are required to collect precipitation data at the wider and vertical levels in the atmosphere.
- **Climate Change:** It has triggered many events ranging from melting of glaciers to rising ocean temperature. The current model can't estimate their impact on the monsoon.
- Most of the weather predicting models are brought from the Western countries and they are lacking fine tuning in terms of data feed as per Indian conditions.
- **Climatic Events:** Events like El-Nino and La-Nina do not always have expected influence on the monsoon.

Scientists are using a variety of techniques to better forecast the monsoon, from monitoring changes in land use to sending underwater robots and ships into the Bay of Bengal. Given the significant change in the arrival of monsoon in the last decade, IMD also plans to revise the onset and withdrawal date of monsoon.

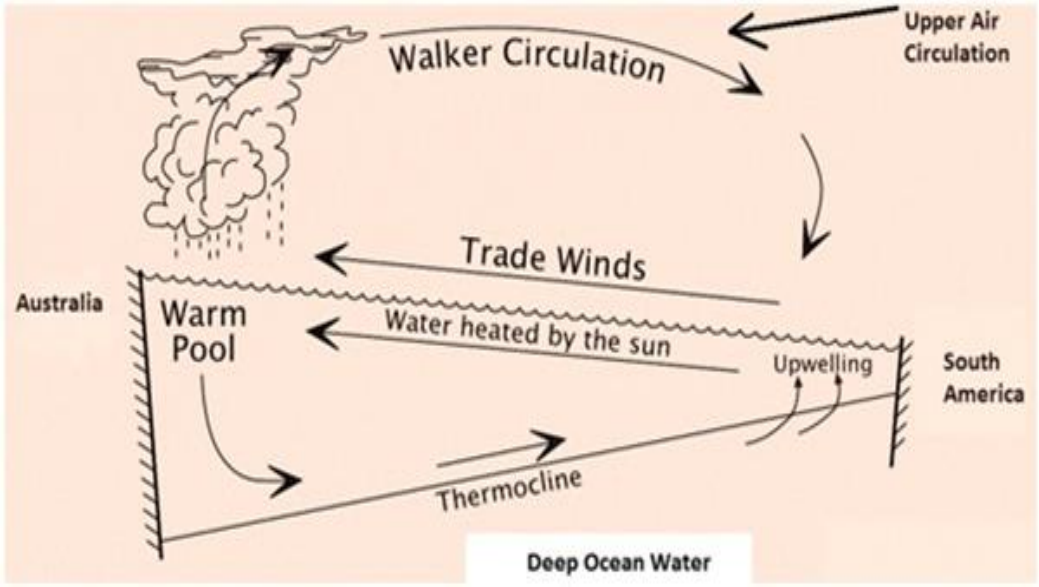
3. Explain Walker Circulation. Discuss how it influences Indian Monsoon.

Approach:

- Briefly explain the Walker Circulation. You can also use a diagram to depict the flows.
- Explaining relationship between Walker Circulation and ENSO in brief, discuss how changes in the Walker Circulation influence the Indian monsoon.

Answer:

The Walker circulation, also known as the Walker cell, is a conceptual model of the air flow in the tropics in the lower atmosphere (troposphere). It refers to an east-west circulation of the atmosphere above the tropical Pacific Ocean.

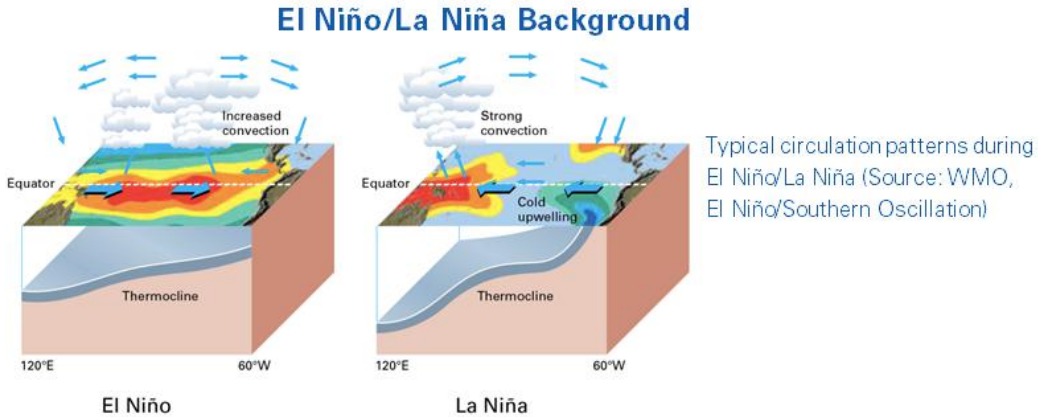


Student Notes:

The lower part of the loop (as seen in the diagram) flows east to west across the tropics near the surface while the upper part flows west to east at higher altitudes. Rising air in the west and sinking air in the east connect the flow in one big, continuous loop. The Walker Circulation also represents the fundamental link between the changes in **sea surface temperatures** in the eastern Pacific and the **variability of the Indian monsoon**.

The mechanisms that are responsible for the interactions between the monsoon and ENSO (El Niño Southern Oscillation) have been attributed, in part, to the changes in the Walker Circulation.

During El Niño, Walker Circulation is weakened and shifted eastward owing to reduced east– west sea surface temperature gradient across the Pacific Ocean. Trade winds weaken or may even reverse, allowing the area of warmer than normal water to move into the central and eastern tropical Pacific Ocean. This suppresses broad-scale convection over the western Pacific and eastern Indian Ocean and leads to weaker Indian monsoon.



Typical circulation patterns during El Niño/La Niña (Source: WMO, El Niño/Southern Oscillation)

During a La Niña, the Walker Circulation intensifies with greater convection over the western Pacific and stronger trade winds. As the trade winds strengthen, the pool of warmer water is confined to the far western tropical Pacific, resulting in warmer than usual sea surface temperatures in the region north of Australia. Sea surface temperatures across the central and eastern tropical Pacific Ocean become cooler than usual and the thermocline moves closer to the surface – cool waters from the deep ocean are drawn to the surface as upwelling strengthens. Convection and hence cloudiness over the region north of Australia increases as stronger winds provide more moisture to the overlying atmosphere and the Walker Circulation intensifies.

Also, it has also been suggested that Walker Circulation may have connections with Indian Ocean Dipole as well. Therefore, we see that modifications in Walker Circulation influences Indian Monsoon in both positive and negative manner. More research and studies should be conducted to further understand the relationship between the two.

4. Give a brief account of the following phenomenon and their influence on Indian Monsoon:(a) ENSO (b) Madden-Julian Oscillation (c) Indian Ocean Dipole.

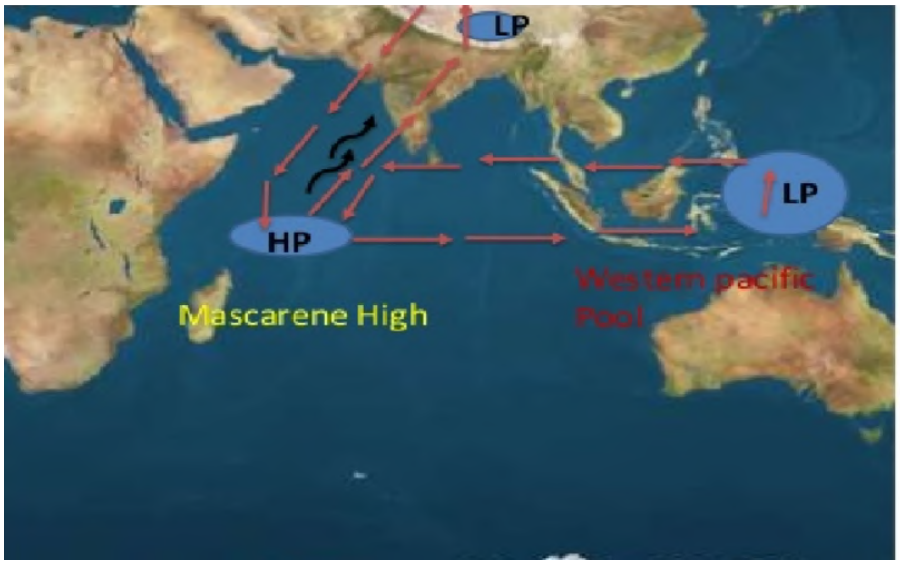
Approach:

- In the first part, explain ENSO and its influence on Indian Monsoon.
- In the second part, explain Madden-Julian Oscillation and its influence on Indian Monsoon.
- In the last part, explain Indian Ocean Dipole and its influence on Indian Monsoon.

Answer:

Student Notes:

ENSO and its influence on Indian Monsoon:



The El Nino Southern Oscillation (ENSO) is a scientific term that describes the fluctuations in sea surface temperature and air pressure in the East-Central Equatorial Pacific, and its impact on normal Walker cell.

It consist of El Nino and La Nina events

- The Walker cell of South Pacific plays a very important role in the Indian Monsoon. During normal Walker Cycle, rising limb of Australia is coupled with sinking limb of Mascarene High, which strengthens the monsoon.
- During El Nino, sea surface temperatures around northern Australia are cooler than normal. The Walker Cell weakens or reverses and thus, weakens the Mascarene high pressure. This causes weakening of Indian Monsoon.
- During LA-Nina, sea surface temperatures around northern Australia are warmer than normal. The Walker usually becomes very strong, and thus weakens the Mascarene high pressure. This causes the strengthening of Indian Monsoon.

Madden-Julian Oscillation (MJO) and its influence on Indian Monsoon:

- MJO is a massive weather event consisting of deep convection coupled with atmospheric circulation, moving slowly eastward over the Indian and Pacific Ocean. Each cycle lasts approximately 30–60 days. It involves variations in wind, sea surface temperature, cloudiness, and rainfall.
- As it moves, strong MJO activity often splits the planet in to two — one in which the MJO is in active phase and brings more than average rainfall, and the other in which it suppresses rainfall.
- The effect of the MJO is witnessed mainly in the tropical region. An active MJO passing through the Indian Ocean strengthens the monsoon and results in very good rainfall in most parts of the country.

Indian Ocean Dipole (IOD) and its influence on Indian Monsoon:

- IOD is an atmosphere-ocean coupled phenomenon in the tropical Indian Ocean, characterised by a difference in sea-surface temperatures.
- A positive IOD occurs when the sea surface temperatures are greater than normal in the Arabian Sea and less than normal in the tropical eastern Indian Ocean. When the reverse is the case, a negative IOD is said to have developed.

- Studies have shown that during a positive IOD the combined effect of Arabian sea evaporation and Mascarene high pressure strengthen the monsoon activity over the Indian subcontinent. Also, there are fewer breaks in monsoon conditions during early IOD events. A positive IOD also minimize the impact of El Nino on Indian monsoon.

Student Notes:

5. What is inter-tropical convergence zone? How does it influence the Indian monsoon?

Approach:

- Explain in brief the inter-tropical convergence zone.
- Discuss its influence on the Indian monsoon.

Answer:

The Inter Tropical Convergence Zone (ITCZ) is a low pressure area where convergence and ascendance of air from subtropical high pressure belts occurs. It is located at equator around 10°N and S. It shifts north and south of the equator according to the movement of sun towards tropic of cancer and tropic of Capricorn respectively. The maximum shift is noticed in the northern hemisphere as compared to the southern hemisphere due to land and ocean configuration.

Influence on the Indian Monsoon:

In India, the Inter Tropical Convergence Zone influences both the southwest and the northeast monsoon.

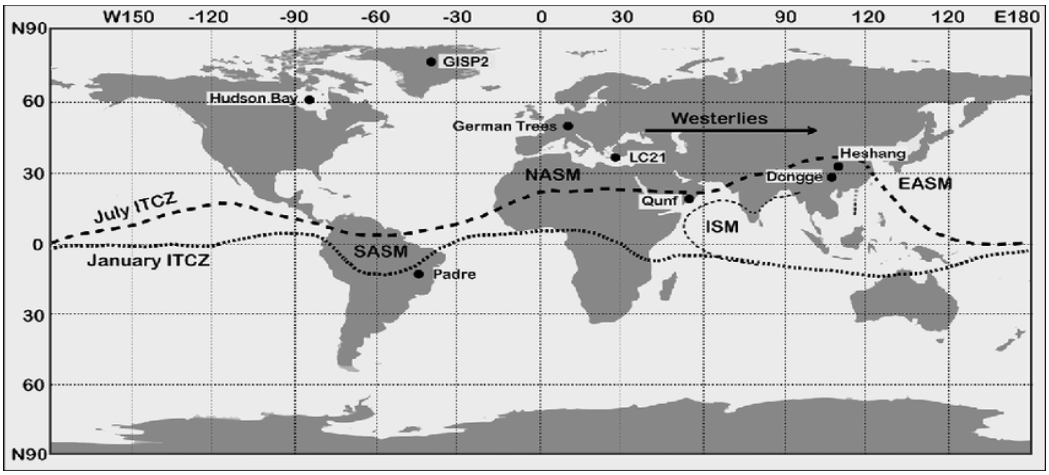
Southwest Monsoon:

- During the southwest monsoon, low pressure exists on the Indian continent and high pressure lies on the Indian Ocean.
- After the autumn equinox, the movement of the sun towards the tropic of Cancer causes a shift of ITCZ towards the north. In July, it is located around 20°N-25°N latitudes (over the Gangetic plain) in the Indian sub-continent. It is also known as the monsoon trough. It encourages the development of thermal low over north and northwest India.
- The shift of ITCZ over Gangetic plain guides the trade winds of the southern hemisphere crossing the equator between 40° and 60°E longitudes towards the Indian sub-continent. Therefore, it starts blowing from northeast to southwest due to the Coriolis force and becomes southwest monsoon.

Northeast Monsoon:

- During northeast monsoon, low pressure lies on the Indian Ocean and high pressure on the Indian subcontinent.
- After spring equinox, the movement of the sun towards the tropic of Capricorn causes a shift of ITCZ southwards. Thus in winters, it is located in the southern hemisphere. It directs winds from southwest to northeast. This reversal of winds is called northeast monsoon.

Location of ITCZ during Southwest Monsoon and Northeast Monsoon



Student Notes:

6. What are jet streams? How do they influence rainfall in India?

Approach:

- Define jet streams and list their properties.
- Highlight the role of jet streams in southwest monsoon, western disturbances and cyclones.
- Draw diagrams to illustrate.

Answer:

Jet streams are concentrated narrow bands of fast flowing and strong winds in the upper troposphere of the earth that significantly affect global weather phenomena. There are three types of jet streams:

- Polar jet stream – between Ferrel and Polar cells
- Sub-Tropical jet stream – between Hadley and Ferrel cells
- Temporary jet streams – e.g.- Somali Jet Stream, Tropical Easterly Jet Stream

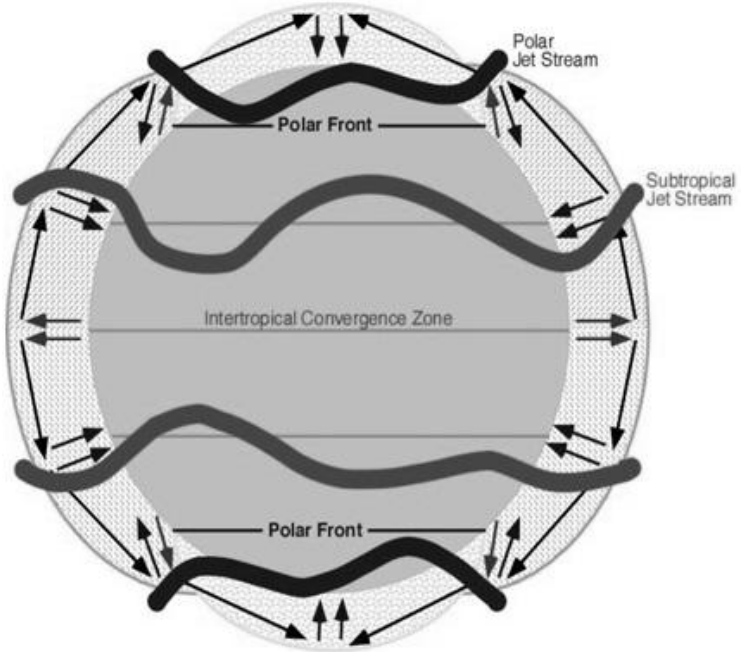


Fig.1 – Types of Jet Stream

Student Notes:

Properties

- Geostrophic winds – due to Coriolis force, they blow in a direction perpendicular to the pressure gradient force.
- Circumpolar – circle around the earth with poles as their centres.
- Westerlies – i.e. blow in west to east direction
- Rossby waves because of meandering path
- High velocity – 150-250 kmph
- Upper atmospheric wind circulation – blow just below the tropopause

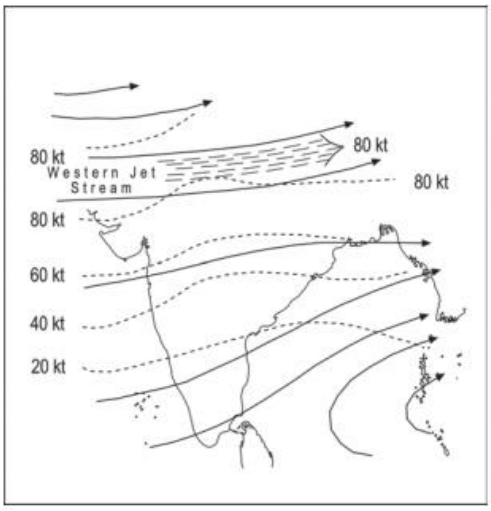
Role of Jet Streams in Weather Phenomenon

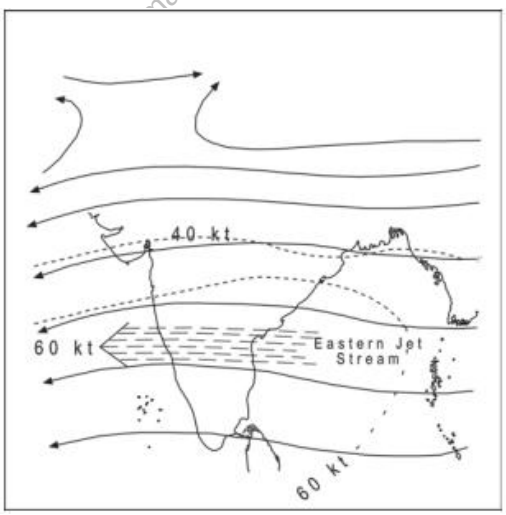
- Help in maintenance of latitudinal heat balance by mass exchange of air.
- Influence the weather of mid-latitudes by influencing the path of temperate cyclones and the distribution of precipitation.
- Impact the movement of air masses, which may cause prolonged drought or flood conditions. Eg. polar vortex cold wave over North America in 2014 winters.

Role of Jet Streams in Rainfall in India

Sub-tropical jet stream and some temporary jet streams together influence Indian Monsoon patterns, winter rainfall and tropical cyclones.

1. **Winter rainfall:** The Sub-Tropical westerly jet stream transports the western disturbances (temperate cyclones) originating over the Mediterranean Sea and brings rain to northwestern regions of India – Punjab, Haryana, Himachal Pradesh.
2. **Southwest monsoon:** The sub-tropical jet stream and easterly jet stream play an important role in the monsoon system of India.
   a. The withdrawal of sub-tropical jet stream from the south of Himalayas paves the way for the onset of monsoon in Indian sub-continent.
   b. The easterly jet stream steers the tropical depressions into India, which play a significant role in the distribution of rainfall during the SW monsoon period.
3. Tropical cyclones – The Easterly jet stream steers tropical depressions and cyclones from the Pacific ocean towards Indian Ocean region causing rainfall predominantly over the eastern coastal region. Eg. cyclone Mora in 2017.





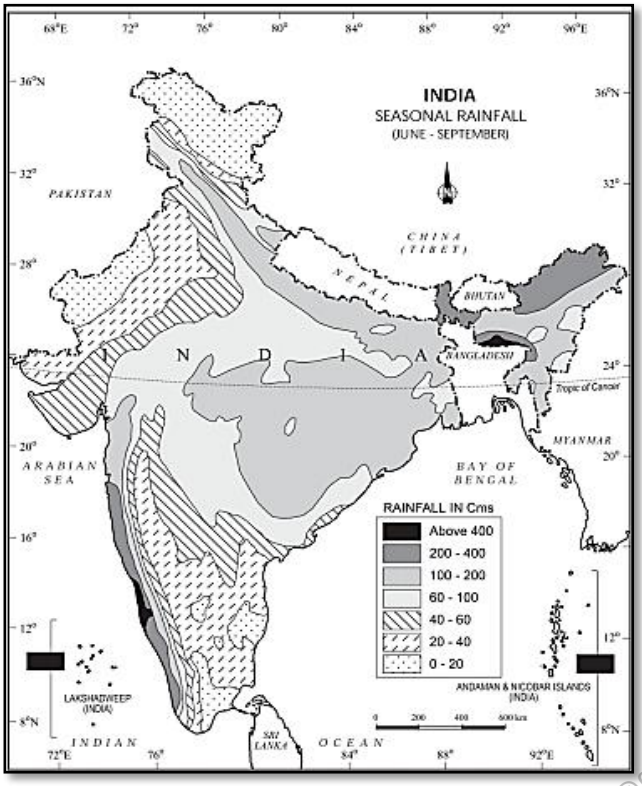
Student Notes:

7. *Discuss the spatial and temporal variation of rainfall in India. Has this pattern been changing in recent years? Examine.*

***Approach**:*

- In the first part of the answer, discuss the distribution of rainfall over a year across major regions in India and the reasons behind this variation.
- In the second part, discuss the recent changes in rainfall pattern and reasons behind it.

***Answer**:*



The average annual rainfall is about 125 cm, but it has great spatial and temporal variations.

Temporal variation:

The distribution of rainfall varies temporally as per an annual cycle of seasons. The meteorologists recognise four seasons.The rainfall in these seasons varies in the following manner:

1. **Cold Weather Season:**
   - Little rainfall in some parts of India.
   - Some weak temperate cyclones from the Mediterranean Sea cause rainfall in north-western India, which are called Western Disturbances.
2. **Hot weather season**
   - A sudden contact between dry and moist air masses gives rise to local storms which are associated with torrential rains.
3. **Southwest Monsoon season**
   - Over 80% of the annual rainfall is received in the four rainy months of June to September.

Student Notes:

- The monsoon may burst in the first week of June in the coastal areas of Kerala, Karnataka, Goa and Maharashtra while in the interior parts of the country; it may be delayed to the first week of July.
- Monsoonal rainfall is largely governed by relief or topography and rainfall has a declining trend with increasing distance from the sea.

4. **Retreating Monsoon**
   - By the end of September, the monsoon becomes weak in response to the southward march of the sun.
   - The weather is dry in north India but is associated with rain in the eastern part of the Peninsula.

Spatial Distribution

- **Areas of High Rainfall (Over 200cm):** Highest rainfall occurs along the mountain ranges obstructing the approaching moist winds, like the west coast, as well as in the sub-Himalayan areas in the northeast
- **Areas of medium Rainfall (100-200 cm):** In the southern parts of Gujarat, east Tamil Nadu, north-eastern Peninsula covering Orissa, Jharkhand, Bihar, eastern Madhya Pradesh, northern Ganga plain along the sub-Himalayas and the Cachar Valley.
- **Areas of low Rainfall (50-100 cm):** Most of the regions having the effect of continentality like Western Uttar Pradesh, Delhi, Haryana, Punjab, Jammu and Kashmir, eastern Rajasthan, Gujarat and Deccan Plateau.
- **Areas of inadequate Rainfall (Less than 50 cm):** These are arid regions lying in the interior parts of the Peninsula, especially in Andhra Pradesh, Karnataka and Maharashtra, Ladakh and most of western Rajasthan.

In the north India, rainfall decreases westwards and in Peninsular India, except Tamil Nadu, it decreases eastward.

Changing pattern of rainfall in India:

There is a general consensus that monsoon pattern in India is changing in terms of intensity, duration, frequency and spatial distribution:

- Rainfall extremes have increased threefold over the last few years.
- The frequency of floods in northwest and the northeast while rainfall deficit in south has increased.
- The onset of the monsoon has been delayed due to a regime shift in climate i.e. from a weak to a strong El Niño period.
- Monsoons have also been ending sooner thereby reducing the length of the rainy season.
- Monsoon seasons are witnessing random 'break periods' when there is little to no rainfall.

Though it's difficult to attribute exact reasons for changing pattern, the following factors have affected the Monsoon pattern:

- The ripple effects of global warming and climate change
- Frequent El-Nino and La-Nina, the Indian Ocean Dipole and the Atlantic Nino
- Break periods are associated with rainfall systems moving northwards from the equatorial region.
- The high rate of deforestation

Thus it becomes imperative for India to work towards restoring the balance of nature in collaboration with other countries, so that monsoon pattern doesn't change permanently.

Student Notes:

MISCELLANEOUS TOPICS LIKE EL NINO, LA NINA, ENSO, URBAN CLIMATE, APPLIED CLIMATOLOGY, HEAT ISLAND ETC.

Contents

Student Notes:

1. El Niño

Near the end of each year as the southern hemispherical summer is about to peak, a weak, warm counter-current[1] flows southward along the coasts of Ecuador and Peru in the eastern equatorial Pacific Ocean, replacing the cold Peruvian current (an eastern boundary current along South America). In the past, local residents referred to this annual warming as "El Niño," (Spanish: meaning "The Boy Child") due to its appearance around the Christmas season. For Peruvian fishermen, it signifies the end of the fishing season. Normally, these warm counter-currents last for at most a few weeks when they again give way to the cold Peruvian current.

However, every three to seven years, this counter-current is unusually warm and strong. It lasts for several months and is often accompanied by heavy rainfall in the arid coastal regions of Ecuador and northern Peru. Over time the term El Niño began to be used in reference to these major warm episodes.

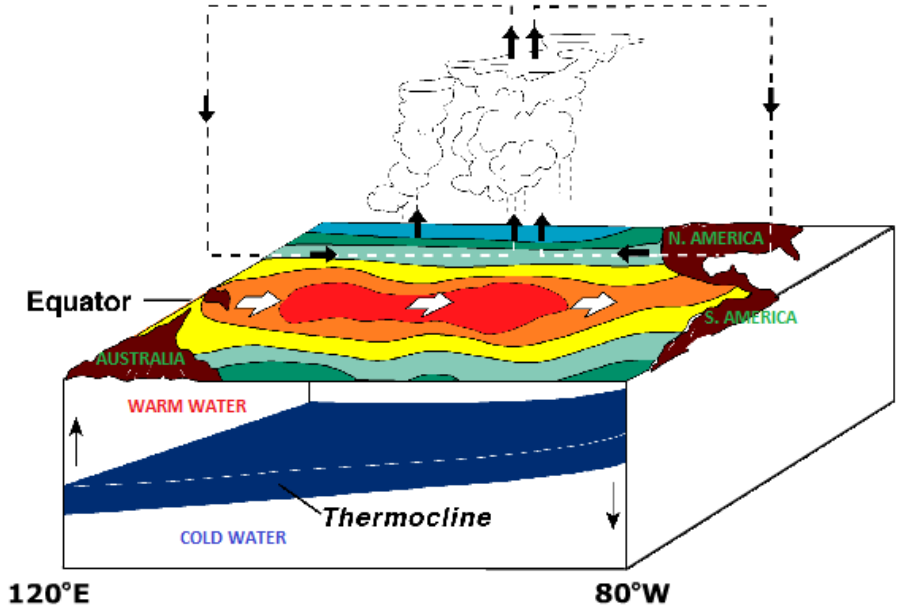


Figure 1 – El Nino conditions: Warm water pool approaches the South American coast. The absence of cold upwelling increases warming.

Under normal conditions, the cold Peruvian current flows equatorward along the coast of Ecuador and Peru (figure 2). The Peruvian current is slow and thus not very strong. Near the coast, it is only about 200m deep, while increasing to 700m offshore. In the absence of an El Niño, prevailing surface winds deviates water considerably to the left or away from the coast, with subsequent upwelling of cold water from below. This upwelling of deep, nutrient-filled waters is the primary food source for millions of fish, particularly anchovies along the Pacific Coast of South America.

During El Niño, surface winds are weaker than their average value. Weaker surface winds are beneficial for warm counter-equatorial current that becomes strong and replaces Peruvian current along the coast of South America. This current carries warm water of west Pacific Ocean to central and eastern Pacific Ocean. It increases the Pacific Ocean's sea surface temperature

[1] Counter-equatorial current - Between the North and South Equatorial currents, there is a surface current moving down slope west to east, the Equatorial Countercurrent. This current helps to return surface water accumulated against the eastern coast of continents by the Equatorial currents. It is this counter-current in Pacific Ocean that increases in strength and triggers an El-Niño event.

(SST).

Student Notes:

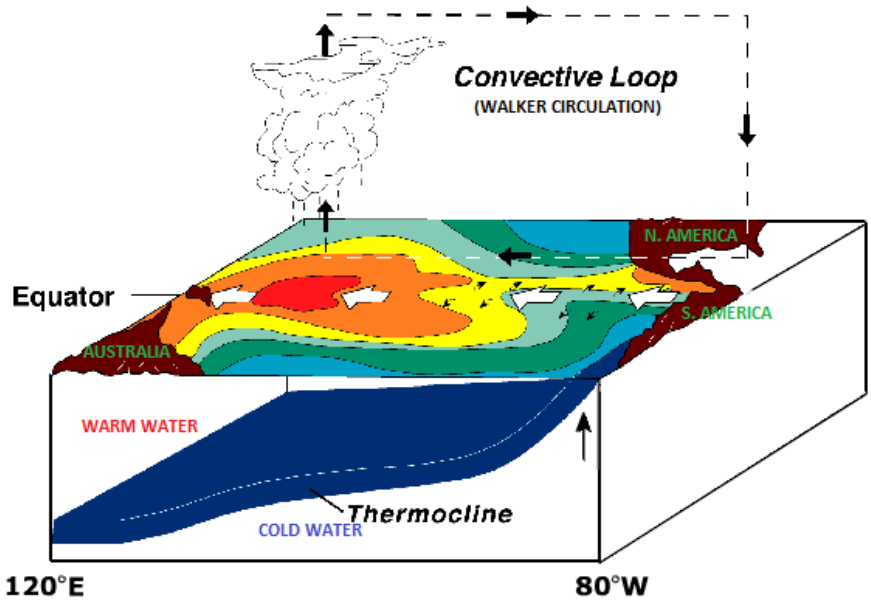


Figure 2 – Normal Pacific pattern: Equatorial winds gather warm water pool toward the west. Cold water upwells along South American coast.

1.1. El Niño – Southern Oscillation (ENSO)

ENSO consists of **two components**. The first, mainly oceanic, is known as **El Niño**. The second, mainly atmospheric, component of ENSO has been described as the **Southern Oscillation**. We already know that El Niño is the unusual warm oceanic water at pacific coast of South America.

Major El Niño events are intimately related to large-scale atmospheric circulation. Each time an El Niño occurs, the barometric pressure drops over large portions of the south-eastern Pacific, whereas in the western Pacific, near Indonesia and northern Australia, the pressure rises. Then, as a major El Niño event comes to an end, the atmospheric pressure difference between these two regions swings back in the opposite direction. This see-saw pattern of atmospheric pressure between the eastern and western Pacific is known as the "Southern Oscillation".

The strength of the Southern Oscillation is measured by the **Southern Oscillation Index** (SOI). The SOI is computed from fluctuations in the surface air pressure difference between Tahiti, French Polynesia and Darwin, Australia. El Niño episodes are associated with negative values of the SOI, meaning there is below normal pressure over Tahiti and above normal pressure of Darwin.

ENSO appears to be a necessary mechanism for maintaining long-term global climate stability by transporting heat from the Tropics to the higher latitudes.

Effects of EL NINO/ENSO

- The abnormally strong winds originating from the west push masses of warm surface water from the equatorial region against the South-American coast, and are ultimately deflected towards Mexico, Peru, and Ecuador, creating an area of warm water thousands of kilometers in length. The sun warms the surface layer still further, thus enhancing the effect. The thermocline[2] falls, and along with it the pool of nutrient rich water.

[2] Thermocline – is a thin but distinct layer in a large body of fluid (e.g. water, such as an ocean or lake, or air, such as an atmosphere) in which temperature changes more rapidly with depth than it does in the layers above or below.

Student Notes:

- In an immediate effect, this warm blob of water blocks off the upwelling of colder along South American coast, nutrient rich water driving anchovies fish into starvation. These fish do no longer support large population of fish-feeding birds, whose droppings (guano) are mined for fertilizer. With the disappearance of anchovies and other marine organisms, predators like seabirds, further up the food-chain, experience a drastic decline in nutritional resources.
- In a long-lasting ENSO event, the dissolved seawater oxygen content becomes depleted. This favours production of foul-smelling hydrogen-sulfide and other gases, blackening the "lead paint" on ships and producing other discoloring effects
- During El Nino, some inland areas of South America that are normally arid receive an uncommon abundance of rain. Here pastures and cotton fields have yields far above the norm.
- Most important aspect of an ENSO event is the change in the precipitation patterns over the globe (Figure 3).

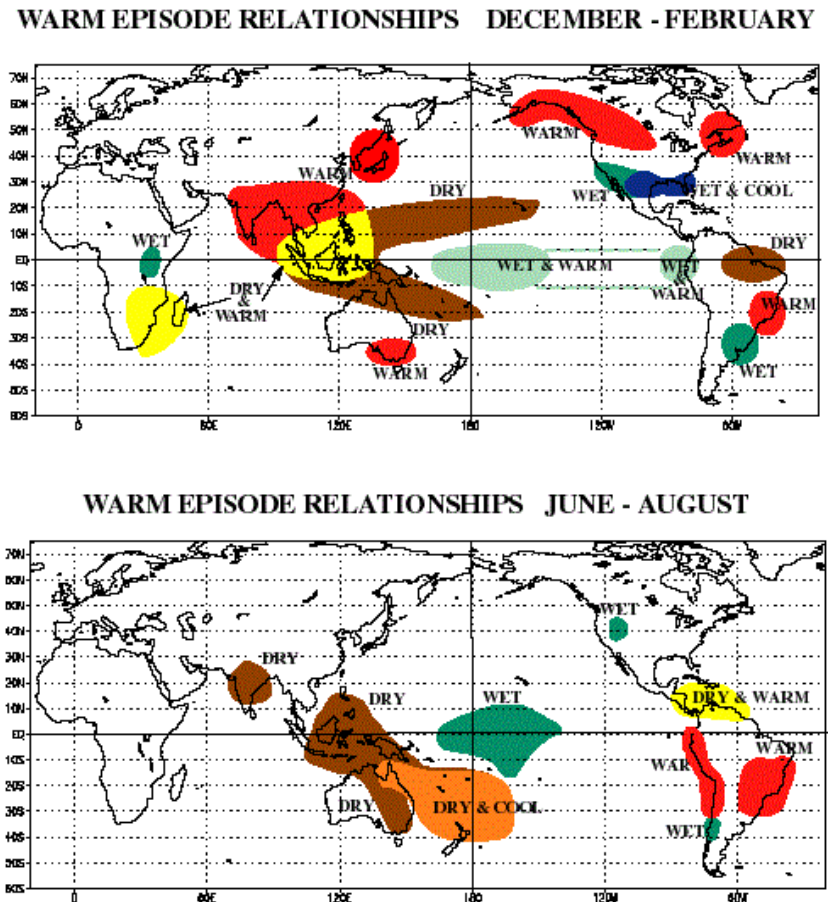


Figure 3 – global precipitation pattern during El Nino

1.2. La Niña

La Niña (Spanish: meaning "The Girl Child") is a counterpart of El Niño. During La Niña, the cold pool in the eastern tropical Pacific intensifies and the trade winds strengthen. During a period of La Niña, the sea surface temperature (SST) across the equatorial Eastern Central Pacific Ocean will be lower than normal by 3–5 °C.

Effects of LA NIÑA

- **Africa** - La Niña results in wetter-than-normal conditions in Southern Africa from December to February, and drier-than-normal conditions over equatorial East Africa over the same period.

Student Notes:

- **Asia** - During La Niña years, the formation of tropical cyclones, along with the subtropical ridge position, shifts westward across the western Pacific ocean, which increases the landfall threat to China. Generally, South Asian monsoon is good during La Nina events as it strengthens the Indian Ocean loop of walker cell.

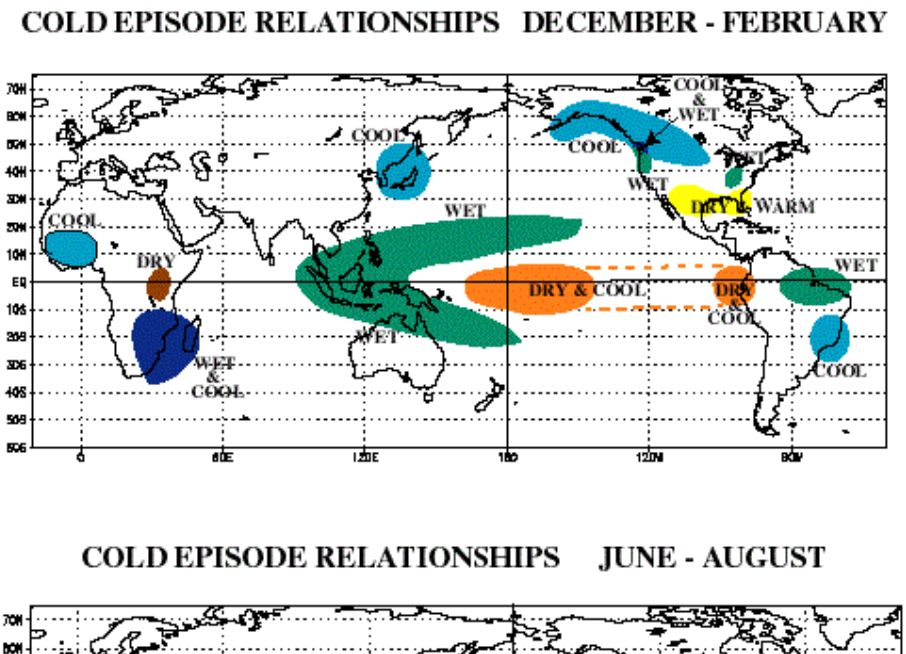


Figure 4 – global precipitation pattern during La Nina

- **South America -** During a time of La Niña, drought plagues the coastal regions of Peru and Chile.
- **North America** - La Niña causes mostly the opposite effects of El Niño, above-average precipitation across the Northern California, and the northern Rockies etc. There are above average hurricanes in the Atlantic and less in the Pacific.

1.3. Walker Circulation

The Walker Circulation refers to an east-west circulation of the atmosphere above the tropical Pacific, with air rising above warmer ocean regions (normally in the west), and descending over the cooler ocean areas (normally in the east). Its strength fluctuates with that of the Southern Oscillation. The characteristics of the Walker Circulation were largely determined by the coupling between the tropical atmosphere and oceans. Walker Circulation is closely tied to that of the Southern Oscillation and El Niño. The term Walker Circulation was first introduced in 1969 by Jacob Bjerknes. After Bjerknes, there have been reports of similar east–west circulation cells spanning different longitudinal sectors along the Equator. Compared to pacific cell, these cells cover smaller longitude ranges and tend to have weaker vertical motions (figure 5). The Indian Ocean cell is associated with the development of the South Asian monsoon. Generally, walker circulation is associated with only cells of Pacific Ocean.

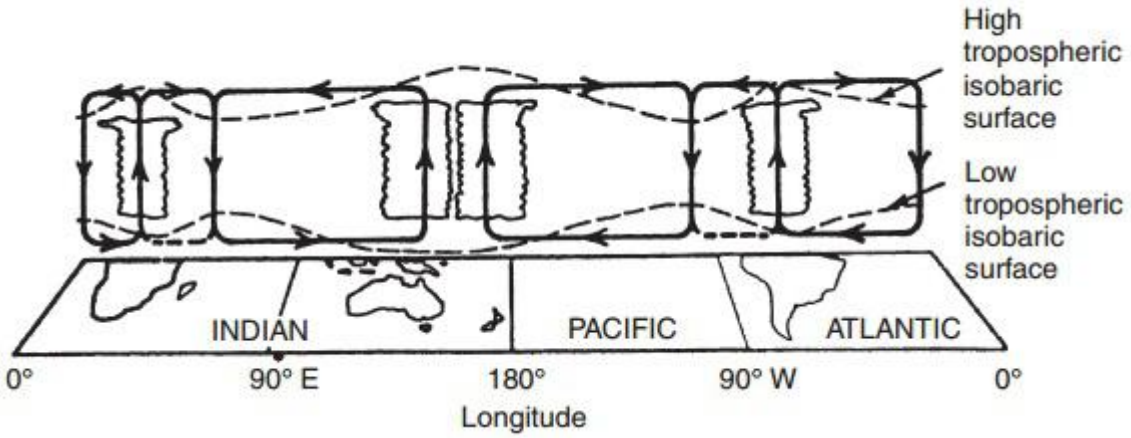


Figure 5 - east–west atmospheric circulation along the longitude–height plane over the Equator. The cell over the Pacific Ocean is referred to as the Walker Circulation.

The easterly trade winds are part of the low-level component of the Walker Circulation. Typically, the trade winds bring warm moist air towards the Indonesian region. Here, moving over normally very warm seas, moist air rises to high levels of the atmosphere. The air then travels eastward before sinking over the eastern Pacific Ocean. The rising air is associated with a region of low air pressure, towering cumulonimbus clouds and rain. High pressure and dry conditions accompany the sinking air. Sinking air completes the loop.

During **El Niño event,** the Walker Circulation and accompanying east–west circulations differ significantly from normal conditions (figure 6a). Rising motions prevailed at almost all longitudes. In particular, strong ascent in the mid-troposphere replaced descending air motion over the central and eastern Pacific, where the water was anomalously warm due to El Niño. The Walker Circulation is weakened and became less organized.

Walker Circulation may even reverse in the more intense episodes of El Niño. In this instance westerly winds are observed over parts of the equatorial western and central Pacific where normally easterly (trade) winds would be expected. Oceans around Australia cool, and slackened trade winds feed less moisture into the region.

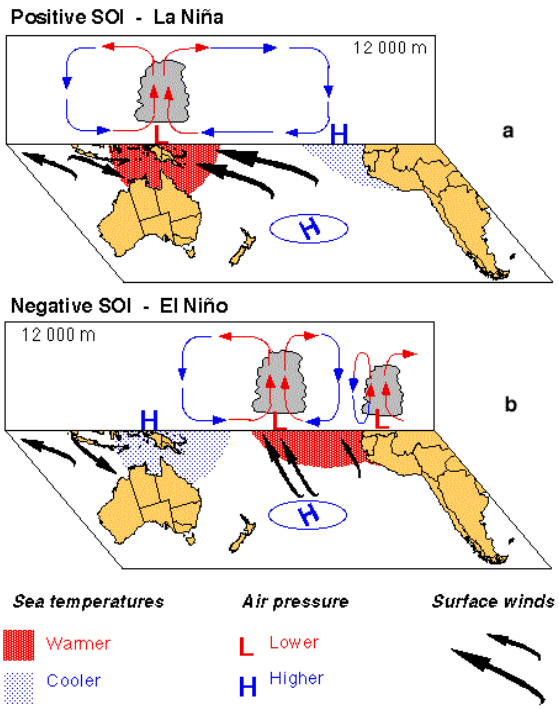


Figure 6 – Walker circulation during La Niña and El Niño

During La Niña, or reverse El Niño, the Walker Circulation is enhanced and became very pronounced, with well-defined rising and sinking branches (figure 6b). While the cells in Pacific and Atlantic Oceans intensify, the Indian Ocean cell weakens.

Student Notes:

Impacts on world climate

The Walker Circulation regulates global exchange of momentum, heat, and water vapor within the tropics via massive overturning motions. In doing so, it plays an important role in the balance of atmospheric energy in the equatorial region and in determining the characteristics of weather and climate in the tropics.

The strongest atmospheric impacts associated with the fluctuations of the Walker Circulation are found over tropical and subtropical regions around the Pacific Rim. During an El Niño, the weakening Walker Circulation causes widespread drought in Indonesia/maritime continent, drought in northeastern Brazil, severe floods in Peru and Ecuador, and in south-eastern Brazil and northern Argentina. During a La Niña, the Walker Circulation intensifies and leads to rainfall anomalies with reverse sign compared to El Niño.

The Walker Circulation also represents the fundamental link between the changes in sea surface temperature in the eastern Pacific and the variability of the Asian–Australian monsoon. The mechanisms that are responsible for the interactions between the monsoon and El Niño Southern Oscillation have been attributed, in part, to the changes in the Walker Circulation. During El Niño, Walker Circulation is weakened and shifted eastward owing to reduced east–west sea surface temperature gradient across the Pacific Ocean. This suppresses broad-scale convection over the western Pacific and eastern Indian Ocean and leads to weaker South Asian monsoon.

Walker circulation interacts with the Hadley cell[3] in the form of an **inverse variation** between the two circulations. When the cold water belt along the Equator is well developed, the air above it will be too cold and heavy to join the ascending motion in the Hadley circulations. Instead, the equatorial air flows westward between the Hadley circulations of the two hemispheres to the warm west Pacific. These changes are the causes for severe weather and climate anomalies in the Asian–Pacific–American regions.

1.4. El Niño & La Niña Modoki

Like El Niño, El Niño **Modoki** (Japanese: meaning 'similar, but different') is a coupled ocean-atmosphere phenomenon in the tropical Pacific. El Niño is characterized by strong anomalous warming in the eastern equatorial Pacific. On the other hand, El Niño Modoki is associated with strong anomalous warming in the **central tropical Pacific** and cooling in the eastern and western tropical Pacific (figure 7b).

[3] Hadley Cells are the low-latitude overturning circulations that have air rising at the equator and air sinking at roughly 30° latitude.

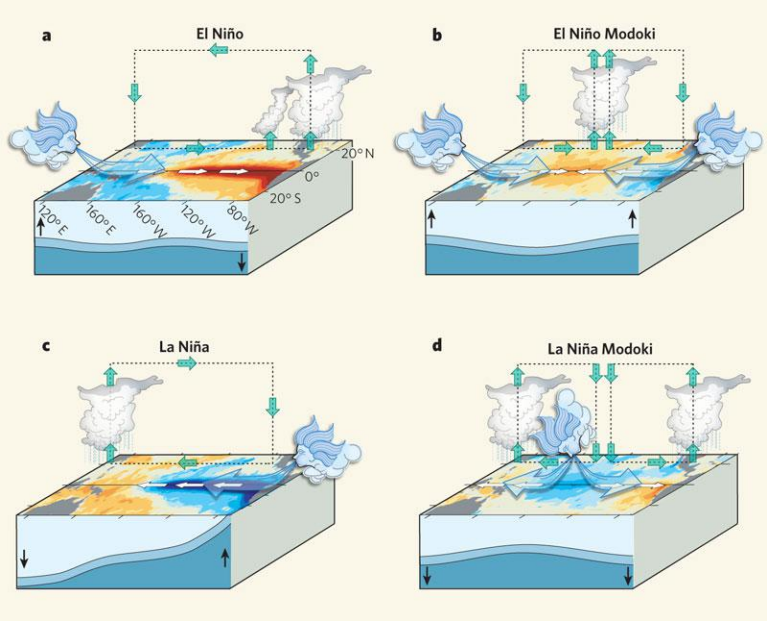


Figure 7 – El Nino Modoki and La Nina Modoki

La Nina Modoki is associated with low sea surface temperature (SST) in central tropical Pacific Ocean while eastern and western tropical pacific are warm relatively. It produces two walker cells with rising limbs at both ends of tropical pacific and descending limb of both cells fall at central equatorial pacific (figure 7d).

Together El Nino Modoki and La Nina Modoki forms **'ENSO Modoki'.** Several studies have shown that the ENSO Modoki has become more prominent in recent times, as compared to ENSO, and thereby changing the teleconnection pattern arising from the tropical Pacific. The ENSO Modoki has distinct teleconnections and affects many parts of the world. For example, the West Coast of United States of America is wet during El Nino but dry during El Nino Modoki. Recent studies show that teleconnections associated with ENSO Modoki influence the rainfall over India and South Africa.

El Nino results in anomalous two-cell Walker Circulation over the tropical Pacific, with a wet region in the central Pacific. During pre-monsoon and post-monsoon seasons in the North Indian Ocean, more cyclones form in the Bay of Bengal compared with the Arabian Sea. El Nino is found to suppress cyclone formation in the Arabian Sea. While in some years **more cyclones form in the Arabian Sea than usual. This is due to El Nino Modoki.** During El Nino Modoki, one of the descending limbs of the walker cell is over the Bay of Bengal which causes dry conditions not conducive for cyclone formation. On the other hand, there is large convergence over the Arabian Sea during an El Nino Modoki explaining the large number of cyclones in that region.

2. Urban Climate

The urban areas across the world experience a climate distinctive from the regional pattern. The process of urbanization changes the physical surroundings and induces alterations in the energy, moisture, and motion regime near the surface. The agglomeration of buildings interferes with the wind and atmospheric characteristics to a degree at least equal to that of a large forest. An urban area changes the air's composition, temperature and precipitation graphs etc.

Wind speed is lower in cities than in open areas due to obstructive nature of structure of cities. Actual effect varies with the street design, the season and the time of day. The wind tends to channel down streets parallel to the general direction of flow, especially in a city with canyon like streets (high rise buildings). While if street pattern is at right angle to the wind, strong lee effects may be experienced. During the day, city wind speeds are considerably less than surrounding areas, but at night, turbulence over the city makes contrasts less apparent. Rural-

urban contrasts are most marked with strong winds, and the effects are therefore more evident in winter[4] than in summers.

Cities absorb much less **water** per area than rural areas, as much of city area is paved or built on. In some areas this creates a need for specific measures to reduce the risk of localised flooding during periods of heavy rainfall. Heavy construction activities in flood plains of rivers flowing through cities increase the period and intensity of flooding.

Cities tend to have **lower humidity** in contrast to rural or forested areas. Due to concrete surface, rapid surface run-off removes water. The lower density of vegetation and general absence of water bodies etc. also contribute for lower humidity and evaporation. On the other hand, it seems likely that under certain conditions, thermal and turbulences over cities may trigger off precipitation or thunderstorms. Many cities encounter more light rain and thunder than surrounding areas, resulting in a slight increase in total precipitation.

2.1. Urban Heat Island

The term "heat island" describes built up areas that are hotter than nearby surrounding areas. An **urban heat island (UHI)** is a metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The phenomenon was first investigated and described by Luke Howard in the 1810s. The **temperature difference usually is larger at night** than during the day, and is most apparent when winds are weak. The typical temperature difference is several degrees between the center of the city and surrounding fields. It can be as high as 10 °C.

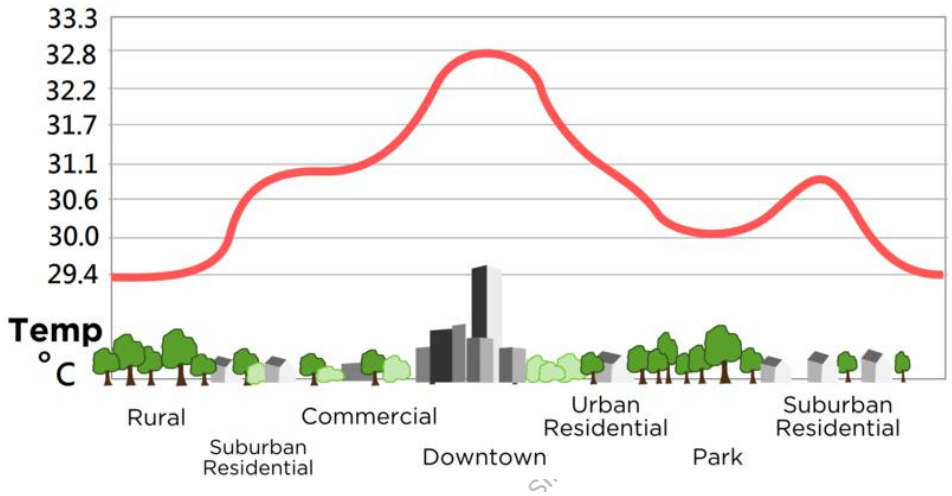


Figure 8 – Urban Heat Island Profile

There are **three main factors** responsible for this:

- The **direct production of heat** in city from fires, industry, home
- Heat conserving properties of the **bricks and fabric** of the city
- **Blanketing effect** by atmospheric **pollution** on outgoing radiation

Heat trapped in concrete buildings, pavements during day time is released very slowly in the form of long wave radiations, making cooling a slow process. With a decreased amount of vegetation, cities also lose the shade and cooling effect of trees, the low albedo of their leaves,

[4] There is much greater variation in barometric pressure during the winter than during the summer. On average, high pressure systems are higher pressure and low pressure systems are lower pressure. This leads to a more rapid flow of air between the systems. This fluctuation is caused by much greater variation in temperature during the winter. While most summer days are roughly the same temperature, winter temperatures fluctuate dramatically.

Student Notes:

and the removal of carbon dioxide. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. Tall buildings also inhibit cooling by convection and pollution from dissipating. Chemicals emitted by cars, industries affect sunshine in different ways, often trapping it and creating more heat. All these factors cause a change in the energy balance of the urban area.

As a population center grows, it tends to expand its area and increase its average temperature. For instance, Los Angeles has been very much affected by its urban heat island. The city has seen its average temperature rise approximately 0.5 °C every decade since the beginning of its super-urban growth since the World War II era. Other cities have seen increases of 0.1°-0.4°C each decade.

Each city's urban heat island varies based on the city structure and thus the **range of temperatures within the island varies** as well (figure 8). Parks and greenbelts reduce temperatures while the Central Business District (CBD), commercial areas, and even suburban housing tracts are areas of warmer temperatures. Every house, building, and road changes the microclimate around it, contributing to the urban heat islands of our cities.

Impact on urban dwellers

- The increased heat of our cities **increases discomfort** for everyone
- Homes require an increase in the amount of **energy used for cooling** purposes.
- The UHI **decreases air quality** by increasing the production of pollutants such as ozone, and decreases water quality as warmer waters flow into area streams and put stress on their ecosystems.
- Increased heat enhances photochemical reactions, which increases the particles in the air and thus contributes to the **formation of smog and clouds.** For instance, London receives approximately 270 fewer hours of sunlight than the surrounding countryside due to clouds and smog.

The heat island effect can be counteracted in several ways:

- Most prominent is to use light color or white or reflective materials in construction work – roof top, houses, road, and pavements – to increase the albedo. Dark/Black surfaces can be up to 21°C hotter than light surfaces and that excess heat is transferred to the building itself, creating an increased need for cooling. By switching to light colored roofs, buildings can use 40% less energy.
- Mitigation of the UHI effect can be accomplished through the use of **green roofs (figure 9).** The roof of a building is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. Rooftop ponds are another form of green roofs which are used to treat grey-water. Apart from mitigating the UHI effect, Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, and helping to lower urban air temperatures. Financially, it reduces energy usage, bring tax incentives provided by the government, increases life span of roof etc.

Student Notes:

Figure 9 – green roof

- **Green Building** is constructed in a manner that is resource-efficient, environmentally sustainable. Sun light is used efficiently within the building. It lowers the overall energy usage of the building and thus, helps in reducing the effect of UHI.
- Another way is to increase the amount of **well-watered vegetation.** It is empirically tested that the cooling potential per area was highest for street with higher tree density. They increase evapotranspiration, which decreases the air temperature. Trees can reduce energy costs by 10-20%.

Typically heat island mitigation is part of a community's energy, air quality, water, or sustainability effort. Activities to reduce heat islands range from voluntary initiatives, such as cool pavement demonstration projects, to policy actions, such as requiring cool roofs via building codes. Most mitigation activities have multiple benefits, including cleaner air, improved human health and comfort, reduced energy costs, and lower greenhouse gas emissions.

2.2. Atmospheric Pollution Over Cities

Generally any substance that people introduce into the atmosphere that has damaging effects on living things and the environment is considered air pollution. A city atmosphere is affected by **soot, ash, gases, fumes, smoke and oxides of sulphur, carbon, nitrogen**. Carbon dioxide and other greenhouse gases such as Methane are the main pollutant that is warming Earth. Sulfur dioxide and closely related chemicals are known primarily as a cause of acid rain. These have effect of blanketing the radiation over a city, increasing the city's albedo. These also act as a condensation nuclei. Under normal conditions, much of this polluted part is diffused upwards by turbulence and removed by stronger winds at height. However, high rise buildings of cities act as obstruction in free movement of these particles. The greatest concentrations of smoke occur with low wind speeds, temperature inversion and high relative humidities.

It requires multifold strategies with the active participation of civil society and individual city people. On a larger scale, governments are taking measures to curb the air pollution through legislation, tax benefits and other schemes. Civil society can play its part by spreading environmental awareness among people and helping people in urban forestry etc.

2.3. Urban Climate and Global Climate Change

The changes in urban Climate are strongly linked to global climate change. As centres for socio-economic activities, cities produce large amounts of Green House Gases, most notably CO_2 as a consequence of human activities such as transport, development (e.g. concrete production), and waste related to heating and cooling requirements etc. cities are the top consumer of energy produced largely through fossil fuels.

Many cities are vulnerable to the projected consequences of climate change (sea level rise, changes in temperature, precipitation, storm frequency) as most develop on or near coast-lines, nearly all produce distinct urban heat islands and atmospheric pollution.

Student Notes:

3. Microclimate

A microclimate is the distinctive **climate of a small-scale area, such as a garden, park, valley or part of a city**. The weather variables in a microclimate, such as temperature, rainfall, wind or humidity, may be subtly different to the conditions prevailing over the area as a whole and from those that might be reasonably expected under certain types of pressure or cloud cover. Indeed, it is the mixture of many, slightly different microclimates that actually makes up the climate for a town, city or wood.

Microclimate can be caused by several **factors** such as

- Near water bodies
- Heat retaining capacity of urban areas
- Slope of mountains
- Absence of vegetation such as in central business districts
- Large presence of vegetation such in protected areas
- Soil type

There is a distinctive microclimate for every type of environment on the Earth's surface:

Upland regions

Upland areas have a specific type of climate that is notably different from the surrounding lower levels. **Temperature usually falls with height** at a rate of between 5 and 10 °C per 1,000 metres, depending on the humidity of the air. This means that even quite modest upland regions can be significantly colder on average.

Occasionally, a **temperature inversion**[5] can make air warmer in upland regions, but such conditions rarely last for long. With higher hills and mountains, the average temperatures can be so much lower that winters are longer and summers much shorter. Higher ground also tends to be windier, which makes for harsher winter weather. **Katabatic wind**[6] also creates cold conditions in the valley. The effect of this is that plants and animals are often different from those at low levels.

Coastal regions

The coastal climate is influenced by both the land and sea between which the coast forms a boundary. The thermal properties of water are such that the **sea maintains a relatively constant day to day temperature compared with the land.** The sea also takes a long time to heat up during the summer months and, conversely, a long time to cool down during the winter. Coastal microclimates display different characteristics depending on where they occur on the earth's surface. In the tropics, sea temperatures change little and the coastal climate depends on the effects caused by the daytime heating and night-time cooling of the land. In temperate latitudes, the coastal climate owes more to the influence of the sea than of the land and coasts are usually milder than inland during the winter and cooler in the summer. Around the poles, sea temperatures remain low due to the presence of ice, and the position of the coast itself can change as ice thaws and the sea re-freezes.

[5] Temperature inversion – It is a deviation from the normal change of an atmospheric temperature with altitude i.e., an increase in temperature with height, or to the layer ("inversion layer") within which such an increase occurs.

[6] Katabatic wind - a wind that carries high density air from a higher elevation down a slope under the force of gravity.

Student Notes:

Forest regions

Tropical rainforests cover only about 6% of Earth's land surface, but it is believed they have a significant effect on the transfer of water vapour to the atmosphere. This is due to a process known as **evapotranspiration** from the leaves of the forest trees. Woodland areas can be cooler and less windy than surrounding grassland areas, with the trees acting as a windbreak and the incoming solar radiation being 'filtered'.

Urban regions

These are perhaps the most complex of all microclimates. **Temperature is higher relative to surroundings** (see 'Urban Heat Island' topic for details). The distribution of rainfall over a town or city is very much influenced by topography with the largest values occurring over the more hilly regions and lowest values in more low—lying areas. The nature of rainfall varies during the year. In summer, rainfall is often of a showery nature, falling over short periods, and is normally more intense than in winter.

4. Applied Climatology

Weather and climate are important factors in determining our day to day and longer term activities and life styles. The ways in which the climatic elements affect every form of economic and social activity are now receiving increasing attention from climatologists. 'It is since second world war that new consciousness arose about the potentialities of climatology as an active subject with immense practical utility for planning almost all human requirements ranging from the development of water resources to the eradication of diseases.

4.1. Climate and Natural Vegetation

Natural vegetation is an indicator of the climate. But they are **interrelated as one influences the other to a great extent**. The knowledge of optimum climatic conditions in different stages of the growth of forest trees is essential for those engaged in the task of afforestation for timber, watershed management. In silvicultural[7] practices the interrelationship between forests and climate must be taken into account. Microclimate of forest is taken into account for getting higher yields.

4.2. Climate and Agriculture

Food is the first and foremost need of humans. As a matter of fact, climate and vegetation are complementary to each other. Weather components – temperature, precipitation, humidity, wind etc. – play the most prominent role in the crop production. For instance, crops like coffee, bananas and sugar cane are very sensitive to frosts. Coconuts and pineapples need temperature above 21°C for their best growth. In hilly areas, the citrus and other sensitive crops are planted on the slopes exposed to the sun avoiding the valleys which are subject to winter frosts at night.

4.3. Climate and Animal Husbandry

Meat and Milk products are obtained by animals which are dependent on pastures and feed crops. Pasture land and crops are highly influenced by climatic factors. Of all the climatic elements affecting the animal husbandry temperature factor is indeed the most important. If the temperature is very high, milk produced from animals is less. It is required to maintain the temperature otherwise continuous high temperature reduces yield of flesh and fat from animals. Precipitation has direct effect on animals. Availability of grass in the pastures is much reduced because of snowfall. Animals feel discomfort in extreme relative humidity conditions.

[7] Silviculture is the practice of controlling the establishment, growth, composition, health, and quality of forests to meet diverse needs and values.

In animal husbandry, natural or **artificial shelters** are built to keep the animals safe from the negative effect of climate. By heating or air conditioning, temperature is controlled in animal shelters.

Student Notes:

4.4. Climate and Housing

It is the climate which determines the house types. **Igloo** in polar region (the house of Eskimos), and **open houses** in tropical areas are the glaring examples. In terms of building or architectural climatology, the micro-climatic conditions are influenced by a number of factors such as local relief, nearby buildings, landscaping, existing water bodies and industrial wastes. Climate is an important input in **green buildings which tries to maximize usage of sunshine, winds** etc.

In tropical countries, double roofs to ensure free movement of air reduce the flow of absorbed solar heat into a building. The type of roofs designed for houses in different climatic conditions take care of precipitation or snowfall.

4.5. Air Pollution and Health

Medical climatology studies the relationship between human health and climate or weather. Some of the **local winds** like the loo, cold wave etc are said to be the causes of irritability, depression, dizziness and hypertension. **High concentration of pollens** in air (such as in Bangalore) causes breathing problems to some people. For instance, local Bangalore government put ban on planting flowering saplings in its parks for certain period of the year to reduce the concentration of pollens in air.

All the cities are discharging huge quantity of pollutants into the atmosphere. These pollutants convert into acids through chemical reactions and fall as **'acid rain'** with rainwater. Study of the atmospheric percentage of these chemical helps in regulating the industries. For instance, vehicular traffic and industry is banned in surrounding of Taj Mahal, Agra. Acid rain is also harmful for plant and marine life.

Certain diseases are, indeed, associated with certain climates or with a particular season. Cold season controls the insects' population by forcing hibernation. That's the reason **tropical diseases** such as Dengue and Malaria etc. are prevalent in tropical and subtropical regions. There are certain diseases which are closely associated with seasons. Pneumonia, influenza, measles etc can be cited as examples here. Such close association of diseases with season or climate helps in issuing warnings to people or taking other measures by the government to reduce the impact of same. Municipal bodies in cities of South Asia ensure that water is not logged in parts of cities during monsoon seasons to avoid Malaria and other vector born diseases.

4.6. Climate and Economy

Climate research benefits the following industries:

- Insurance
- Tourism
- Construction
- Energy
- Transport
- Sport
- Retail Food
- Retail Clothing

The **insurance** industry offers financial protection against climate-related damage. This includes direct impacts from damage due to flood, frost, wind etc. Climate research can help reduce the costs to insurers by quantifying the probability of extreme events, providing year-ahead forecasts and identifying vulnerable regions. There is a peak time of **tourists** to a particular

place. This peak time is directly related to the climate of that particular place. For instance, hilly cold areas' peak time coincide with summer time.

Wind is a potential renewable source of **energy** in every country. Wind atlas of different region and at different altitude is a crucial input to decide the location and height of wind turbines. Similarly, hydro-electricity plants are established in areas which have continuous supply of water either through glacial or rain.

Transport sectors such as air, shipping etc. are directly impacted by the climate or weather. High altitude ports are frozen during winter season which makes them inaccessible for such period. Atmospheric disturbances, extreme weather conditions such as fog, cold waves etc. interrupts the flights' schedule. Roads are specially designed for areas which faces extreme weather conditions.

Student Notes:

4.7. Climatic Adaptation

Humans and many other mammals have unusually efficient **internal temperature regulating systems** that automatically maintain stable core body temperatures in cold winters and warm summers. In addition, people have developed cultural patterns and technologies that help them adjust to extremes of temperature and humidity. Less massive individuals are more often found in warm climates near the equator, while those with greater bulk, or mass, are found further from the equator in colder regions. This is due to the fact that big animals generally have larger body masses which result in more heat being produced. People living in cold climates prefer drinking alcohol as it increases blood flow to the body extremities, thereby providing a feeling of warmth. With the help of technology, researches are able to stay throughout the year in extremely cold Antarctica and Arctic regions. People are able to live in extremely hot climate of tropical region by using air conditioners.

5. UPSC Previous Years Mains Questions

1. Bring out the causes for the formation of heat islands in the urban habitat of the world. (2013)
2. What do you understand by the phenomenon of temperature inversion in meteorology? How does it affect the weather and the habitants of the place? (2013)
3. Most of the unusual climatic happenings are explained as an outcome of the El-Nino effect. Do you agree? (2014)

6. UPSC Previous Years Prelim Questions

1. For short-term climatic predictions, which one of the following events, detected in the last decade, is associated with occasional weak monsoon rains in the Indian sub-continent? (**2011**)

(a) La Nina
(b) Movement of Jet Streams
(c) El Nino and Southern Oscillation
(d) Greenhouse effect on global level

2. With reference to 'Indian Ocean Dipole (IOD)' sometimes mentioned in the news while forecasting Indian monsoon, which of the following statements is/are correct?

1. IOD phenomenon is characterised by a difference in sea surface temperature between tropical Western Indian Ocean and tropical Eastern Pacific Ocean.
2. An IOD phenomenon can influence an El Nino's impact on the monsoon.

Select the correct answer using the code given below: (2017)

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Student Notes:

3. La Nina is suspected to have caused recent floods in Australia. How is La Nina different from El Nino? (2019)

1. La Nina is characterised by unusually cold ocean temperature in equatorial Indian Ocean whereas El Nino is characterised by unusually warm ocean temperature in the equatorial Pacific Ocean.
2. El Nino has adverse effect on south-west monsoon of India, but La Nina has no effect on monsoon climate.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

7. Vision IAS Previous Years Mains Questions

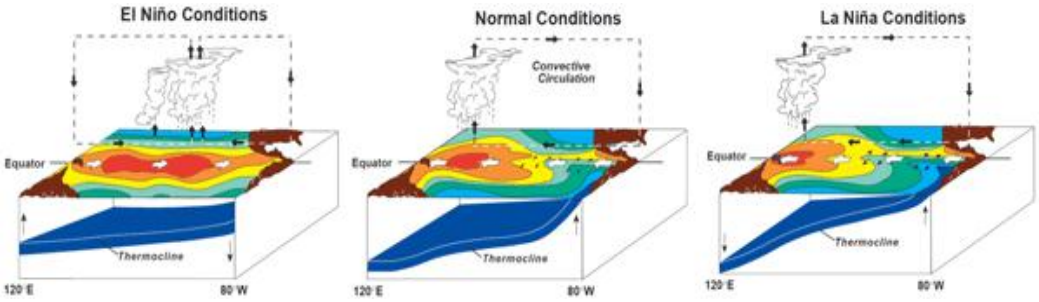
1. Explain the phenomenon of El Nino and La Nina. How do they affect the weather system in various parts of the world?

Approach:

- Briefly explain ENSO and Walker Circulation and their link to El Niño and La Niña
- Explain the phenomenon of El Niño and its impacts in the weather systems in various parts of the world
- Similarly, give a brief explanation of La Niña and state its impacts in the global weather system

Answer:

El Niño and La Niña are opposite phases of the El Niño-Southern Oscillation cycle (ENSO). The ENSO cycle describes fluctuations in temperature of the ocean surface and the fluctuations in the atmospheric pressure in the East-Central Equatorial Pacific. These phases relate to variation in Walker Circulation, which refers to an east-west circulation of the atmosphere above the tropical Pacific, with air rising above warmer ocean regions and descending over cooler ocean areas.



El Niño: A warm ocean current develops along Peruvian coast replacing cold Peruvian current, leading to increase in sea surface temperatures and weakening of trade wind, which weakens the Walker circulation and El Niño results. This normally occurs every 3-5 years, close to Christmas across central and East-Central Equatorial Pacific region.

Global weather impacts of El Niño:

- **Increased Rainfall:** Heavier rainfall occurs during El Niño years in China, Peru, Chile, Equador, Northern Argentina, Equatorial East Africa, Southern USA, etc.
- **Reduced rainfall:** Due to El Niño, there is reduced rainfall and drier conditions in the Indian subcontinent (Generally, Indian monsoons and El Niño are inversely related), Indonesia, Australia, Southern Africa, Saudi Arabia, etc.
- El Niño events produce more tropical storms and hurricanes in the Eastern Pacific.

La Niña: La Niña is associated with cooler-than-average sea surface temperatures in the central and eastern tropical Pacific Ocean due to strong, eastward-moving trade winds

and ocean currents that bring the cold water to the surface through upwelling. During La Niña, the Walker Circulation is enhanced and becomes very pronounced with well-defined rising and sinking branches.

Global weather impacts of La Niña:

- **Increased rainfall:** La Niña leads to increased rainfall in the Indian subcontinent, particularly India and Bangladesh, Southern Africa region, Indonesia, Australia, Saudi Arabia, Pacific North-West and Western Canada, among others.
- **Decrease in rainfall:** Due to La Niña, there is reduced rainfall inEquatorial East Africa, China, Southern USA, Argentina, Peru, Chile, etc.
- La Niña cycles produce more Atlantic and Caribbean Sea hurricanes.

In this way, it atmospheric circulations show that changes at one place affects the weather in other parts of the world.

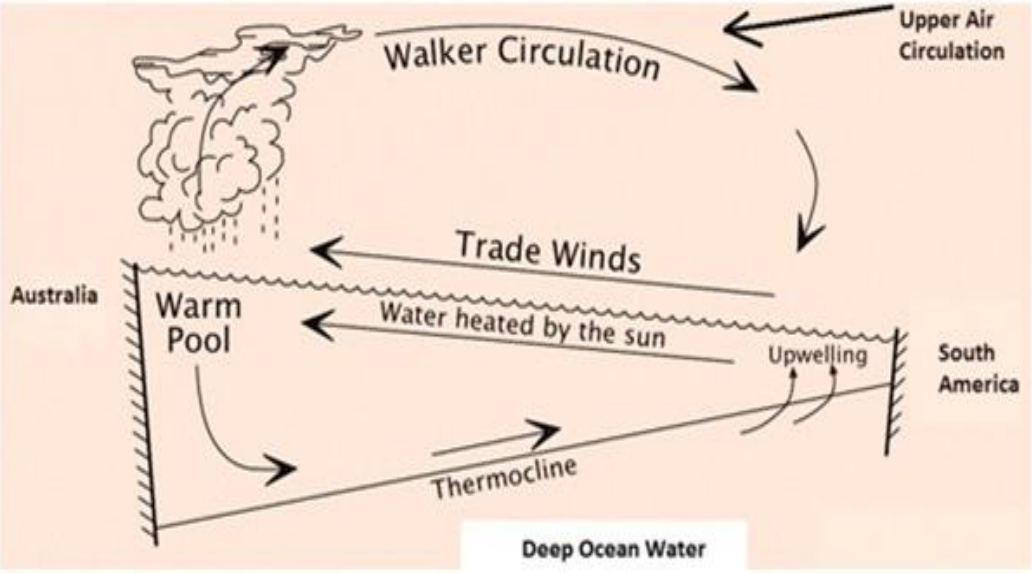
2. Explain Walker Circulation. Discuss how it influences Indian Monsoon.

Approach:

- Briefly explain the Walker Circulation. You can also use a diagram to depict the flows.
- Explaining relationship between Walker Circulation and ENSO in brief, discuss how changes in the Walker Circulation influence the Indian monsoon.

Answer:

The Walker circulation, also known as the Walker cell, is a conceptual model of the air flow in the tropics in the lower atmosphere (troposphere). It refers to an east-west circulation of the atmosphere above the tropical Pacific Ocean.

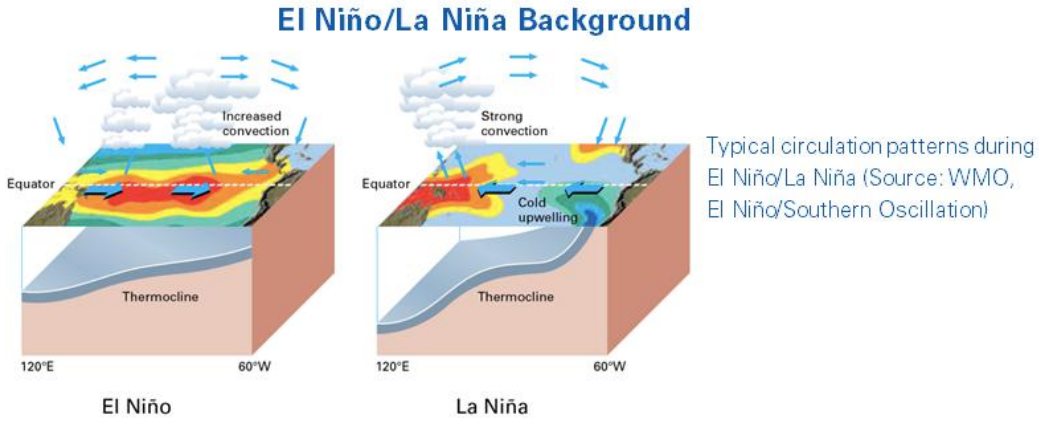


The lower part of the loop (as seen in the diagram) flows east to west across the tropics near the surface while the upper part flows west to east at higher altitudes. Rising air in the west and sinking air in the east connect the flow in one big, continuous loop. The Walker Circulation also represents the fundamental link between the changes in **sea surface temperatures** in the eastern Pacific and the **variability of the Indian monsoon**.

The mechanisms that are responsible for the interactions between the monsoon and ENSO (El Niño Southern Oscillation) have been attributed, in part, to the changes in the Walker Circulation.

Student Notes:

During El Niño, Walker Circulation is weakened and shifted eastward owing to reduced east– west sea surface temperature gradient across the Pacific Ocean. Trade winds weaken or may even reverse, allowing the area of warmer than normal water to move into the central and eastern tropical Pacific Ocean. This suppresses broad-scale convection over the western Pacific and eastern Indian Ocean and leads to weaker Indian monsoon.



Typical circulation patterns during El Niño/La Niña (Source: WMO, El Niño/Southern Oscillation)

During a La Niña, the Walker Circulation intensifies with greater convection over the western Pacific and stronger trade winds. As the trade winds strengthen, the pool of warmer water is confined to the far western tropical Pacific, resulting in warmer than usual sea surface temperatures in the region north of Australia. Sea surface temperatures across the central and eastern tropical Pacific Ocean become cooler than usual and the thermocline moves closer to the surface – cool waters from the deep ocean are drawn to the surface as upwelling strengthens. Convection and hence cloudiness over the region north of Australia increases as stronger winds provide more moisture to the overlying atmosphere and the Walker Circulation intensifies.

Also, it has also been suggested that Walker Circulation may have connections with Indian Ocean Dipole as well. Therefore, we see that modifications in Walker Circulation influences Indian Monsoon in both positive and negative manner. More research and studies should be conducted to further understand the relationship between the two.

3. Give a brief account of the following phenomenon and their influence on Indian Monsoon:(a) ENSO (b) Madden-Julian Oscillation (c) Indian Ocean Dipole

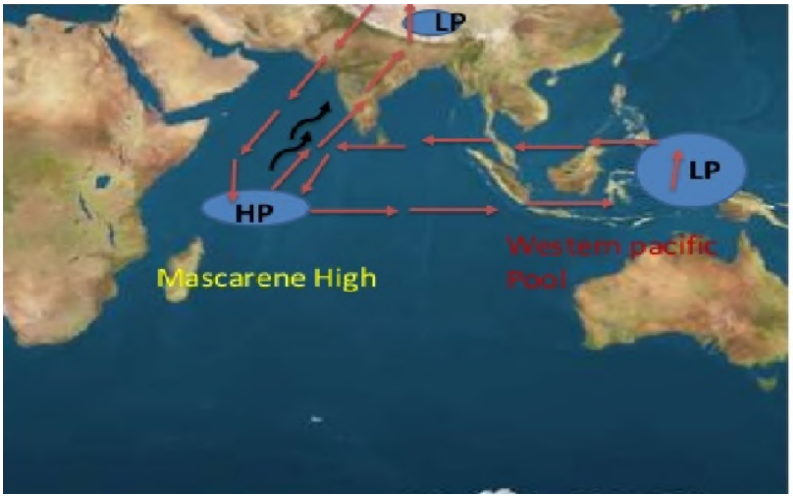
Approach:

- In the first part, explain ENSO and its influence on Indian Monsoon.
- In the second part, explain Madden-Julian Oscillation and its influence on Indian Monsoon.
- In the last part, explain Indian Ocean Dipole and its influence on Indian Monsoon.

Answer:

ENSO and its influence on Indian Monsoon:

Student Notes:



The El Nino Southern Oscillation (ENSO) is a scientific term that describes the fluctuations in sea surface temperature and air pressure in the East-Central Equatorial Pacific, and its impact on normal Walker cell.

It consist of El Nino and La Nina events

- The Walker cell of South Pacific plays a very important role in the Indian Monsoon. During normal Walker Cycle, rising limb of Australia is coupled with sinking limb of Mascarene High, which strengthens the monsoon.
- During El Nino, sea surface temperatures around northern Australia are cooler than normal. The Walker Cell weakens or reverses and thus, weakens the Mascarene high pressure. This causes weakening of Indian Monsoon.
- During LA-Nina, sea surface temperatures around northern Australia are warmer than normal. The Walker usually becomes very strong, and thus weakens the Mascarene high pressure. This causes the strengthening of Indian Monsoon.

Madden-Julian Oscillation (MJO) and its influence on Indian Monsoon:

- MJO is a massive weather event consisting of deep convection coupled with atmospheric circulation, moving slowly eastward over the Indian and Pacific Ocean. Each cycle lasts approximately 30–60 days. It involves variations in wind, sea surface temperature, cloudiness, and rainfall.
- As it moves, strong MJO activity often splits the planet in to two — one in which the MJO is in active phase and brings more than average rainfall, and the other in which it suppresses rainfall.
- The effect of the MJO is witnessed mainly in the tropical region. An active MJO passing through the Indian Ocean strengthens the monsoon and results in very good rainfall in most parts of the country.

Indian Ocean Dipole (IOD) and its influence on Indian Monsoon:

- IOD is an atmosphere-ocean coupled phenomenon in the tropical Indian Ocean, characterised by a difference in sea-surface temperatures.
- A positive IOD occurs when the sea surface temperatures are greater than normal in the Arabian Sea and less than normal in the tropical eastern Indian Ocean. When the reverse is the case, a negative IOD is said to have developed.
- Studies have shown that during a positive IOD the combined effect of Arabian sea evaporation and Mascarene high pressure strengthen the monsoon activity over the Indian subcontinent. Also, there are fewer breaks in monsoon conditions during early IOD events. A positive IOD also minimize the impact of El Nino on Indian monsoon.

Student Notes:

4. Analyze the impact of climate change on the third pole of the world.

Approach:

- Introduce by stating the importance of the region.
- Mention the impact of climate change in the region.
- Conclude by briefly mentioning the steps that can be taken to mitigate the impact.

Answer:

The **Tibetan Plateau,** which holds the Hindu Kush Himalaya (HKH) ice sheet, is known as the world's **"Third Pole."** It is home to the world's highest peaks, unique cultures, diverse flora, fauna, and a vast reserve of natural resources. It is the **source of 10 major river basins**, and provides ecosystem services (including water, food, and energy) that directly sustain the livelihoods of 240 million people.

The region is experiencing rapid changes primarily driven by climate change. This would result in catastrophic changes in the region such as:

- The mountains are already **prone to natural disasters** such as landslides/avalanches etc. Climate change induced extreme weather events will increase the vulnerability of the inhabitants**.**
- As a result of the HKH **glacial melt**, more water is expected to surge through the Indus, Ganges and Brahmaputra rivers, **forcing a change to the agricultural practices** in the valleys around them. Even the traditional mountain food systems are under threat from rapid environmental changes.
- When glaciers melt, they flow into lakes and rivers. Changes to the timing and magnitude of this melting leads to an **increase in the number and size of glacier lakes, which can suddenly flood.**
- The western disturbances **significantly impact temperature patterns of the Himalayan regions besides precipitation.** The changes in the westerly disturbance due to climate change are also believed to increase the mass of some glaciers in the Karakoram and western Himalayas, popularly known as the "**Karakoram Anomaly**".
- Climate change is also adversely impacting ecosystems and **leading to biodiversity loss** in the HKH region.
- Air pollutants originating within and near the HKH **amplify** the effects of greenhouse gases and **accelerate melting of the cryosphere through the deposition of black carbon and dust.**

Therefore, the HKH is sensitive to global climate change through its impacts on atmospheric dynamics and thermal forcing. Some of the steps that can be taken to mitigate and adapt to the climate change are-

- **Mainstreaming policy instruments** on adaptation in their planning and budgeting processes.
- **Institutional capacity on adaptation** needs to be built and fit to purpose at each level of governance.
- **Local-level autonomous responses** to climate variability and extreme events must be systematically studied, documented, and validated.
- HKH countries and institutions must work together to build mechanisms and fora to address key challenges, such as **data sharing**, and incentivize **regional cooperation** and cross-learning at the regional scale.

5. What is ice-albedo feedback and how is it related to climate change?

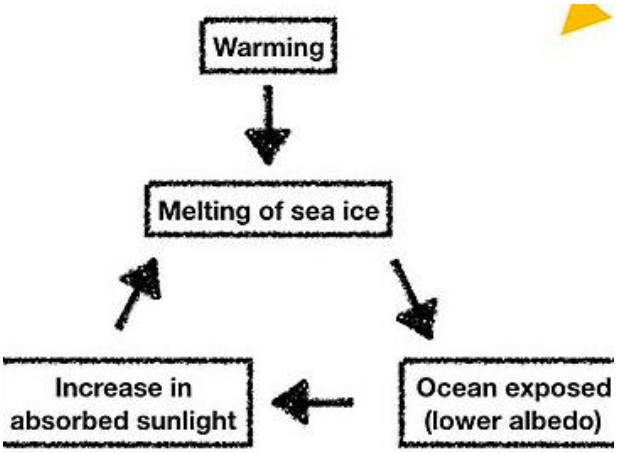
Student Notes:

Approach:

- Explain ice-albedo feedback.
- Discuss its relationship with climate change.
- Conclude appropriately.

Answer:

Ice–albedo feedback is a positive (exacerbating) feedback climate process where a change in the area of ice caps, glaciers, and sea ice alters the albedo and surface temperature of Earth. It is prominent in areas where a **patch of sea ice completely melts**, and results in **uncovering darker seawater surface** that **absorbs more sunlight than ice**. Ice reflects some of the solar energy back to space because it is highly reflective. If an equivalent area of ice is replaced by water or land, (having a lower albedo value) reflects less and absorbs more energy, resulting in a warmer Earth.



Recently, it was reported that the Arctic Ocean may become functionally ice-free for part of each year between 2044 and 2067. Further, the Arctic region is heating up twice as fast as the rest of the globe. One reason for this was attributed to ice-albedo feedback mechanism**.**

Ice albedo feedback's relationship with climate change:

- Due to increase in temperature, the process results in more melting of ice from underneath, while greenhouse gases in the atmosphere warm the surface resulting in increased humidity. This leads to further melting of ice, which exposes more water to sunlight. Thus, **climate change reinforces ice albedo feedback and vice-versa.**
- Ice-albedo feedback tends to **amplify regional warming** due to anthropogenic climate change. Due to this amplification, the cryosphere is sometimes called the **"natural thermometer"** of the earth because changes in each of its components have long lasting effects on biological, physical and social systems on Earth.
- There is also potential for **increased methane and carbon dioxide release** as a result of warming of terrestrial permafrost. Also, with sea ice melting earlier, algae and phytoplankton populations peak earlier and start to decline sooner. For instance, in the Arctic region, crustaceans and fish like the Arctic cod struggle to find enough food and as a consequence impact food chains.

It must be noted that sea ice loss is not just a warning sign of climate change –it is a phenomena that **actively drives ecological change.** Thus, global efforts must be taken to prevent further melting of sea ice by constantly monitoring sea ice loss and taking adequate measures to prevent human-induced climate change.

INDIAN AGRICULTURE

Student Notes:

Contents

1. Land Resources and Agriculture

Student Notes:

Land is an important natural resource, which serves variety of functions. Different types of lands are suited to different uses. Human beings thus, use land as a resource for production as well as residence and recreation. Though, land seems to be in vast amount but its usage pattern and category makes it a limited resource.. There are two main factors determining land-use:

1. ***Physical Factors****:* These factors are like topography, soils, climate etc.
2. ***Human Factors****:* Growth of human population, duration of land control, technology, land rights, social, economic and cultural factors are some of the human factors.

1.1. Land Use Categories

In India, land-use records are maintained by land revenue department. The land use categories add up to *reporting area,* which refers to the total area reported by the land revenue department. At a surprising note, it is often different from the *geographical area* which is the total area as measured by the Survey of India and remains fixed as per the international boundaries.

Survey of India

Survey of India, The National Survey and Mapping Organization of the country under the Department of Science & Technology, is the OLDEST SCIENTIFIC DEPARTMENT OF THE GOVT. OF INDIA. It was set up in 1767 to help consolidate the territories of the British East India Company. In its assigned role as the National Principal Mapping Agency, Survey of India bears a special responsibility to ensure that the country's domain is explored and mapped suitably to provide base maps for expeditious and integrated development and ensure that all resources contribute their full measure to the progress, prosperity and security of India.

Besides being grouped under ''Scientific Surveys'' in Government of India Business Rule 1971, it has also been called upon extensively to deploy its expertise in the field of geodetic and geophysical surveys, study of seismicity and seismotectonics, glaciology, participation in Indian Scientific Expedition to Antarctica and projects related to digital cartography and digital photogrammetry, etc., to provide basic data to keep pace with Science and Technology Development.

Botanical Survey of India (BSI), Zoological Survey of India (ZSI) and Archaeological Survey of India (ASI) are some other important surveying agencies of government of India.

The land-use categories as maintained in the Land Revenue Records[1] are as follows:

(i) **Forests**: According to Survey of India report, *forest area* is one that is **notified by the department** as land under forests, **irrespective of whether it has any tree *cover* or not**. The land under ***forest cover*** is the land **exceeding one hectare** area having a minimum of 10 per cent tree *cover irrespective* of any other land-use. Thus, the area under actual forest cover may be different from area classified as forest. Hence, there may be an increase in this category without any increase in the actual forest cover.

(ii) **Land put to Non-agricultural Uses:** This includes the part of the geographic area that is put to non-agricultural uses like settlements, **both rural and urban**, infrastructure development like roads, railway lines, canals, industries, shops and other similar uses.

(iii) **Barren and Wastelands:** The land classified as a wasteland such as barren hilly terrains, desert lands, ravines, etc. are normally can not be brought under cultivation

[1] As per the records of Land Revenue Department

with the available technology. They remain non suitable for agriculture and generally remain fallow.

(iv) Area under Permanent Pastures and Grazing Lands: The above type land is generally owned by the village 'Panchayat' or the Government (Forest & Revenue Department). Only a small proportion of this land is privately owned. These lands are not used for cultivation. The land owned by the village panchayat comes under 'Common Property Resources'. The benefits of this land accrue to the members of the community as a whole.

(v) Area under Miscellaneous Tree Crops and Groves: These areas are not included in net sown area. The land under orchards and fruit trees is included in this category. Most of this land is privately owned by the people.

(vi) Culturable Waste-Land: Any land which is left **fallow** (uncultivated) for more than **five years** is categorised as a culturable wasteland. This land may be marshy, saline land having degraded soil on account of soil erosion or under dense bushes. Such land can be brought under cultivation after improving it through reclamation practices.

(vii) Current Fallow: The land which has been left without cultivation for **one or less than one agricultural year** is known as current fallow. The practise adopted for giving rest to the culturable land is called fallowing. The land recoups the lost fertility through natural processes in the time duration.

(viii) Fallow other than Current Fallow: These are also the cultivable land which are left uncultivated for **more than a year**. The duration for which the land has been left uncultivated should be less than five years. Most of this land is either of poor quality or the cost of cultivation of such land is very high. If the land is left uncultivated for more than five years, it would be categorised as culturable wasteland.

(ix) Net Area Sown:

Net area sown represents the **area sown with crops at least once in any of the crop season** of the year counting area sown more than once in the same year, only once[2]. Net sown area is of crucial importance for India because it is the land actually under cultivation of crops and India has the highest percentage of Net Sown Area.

1.2. Land-use Changes in India

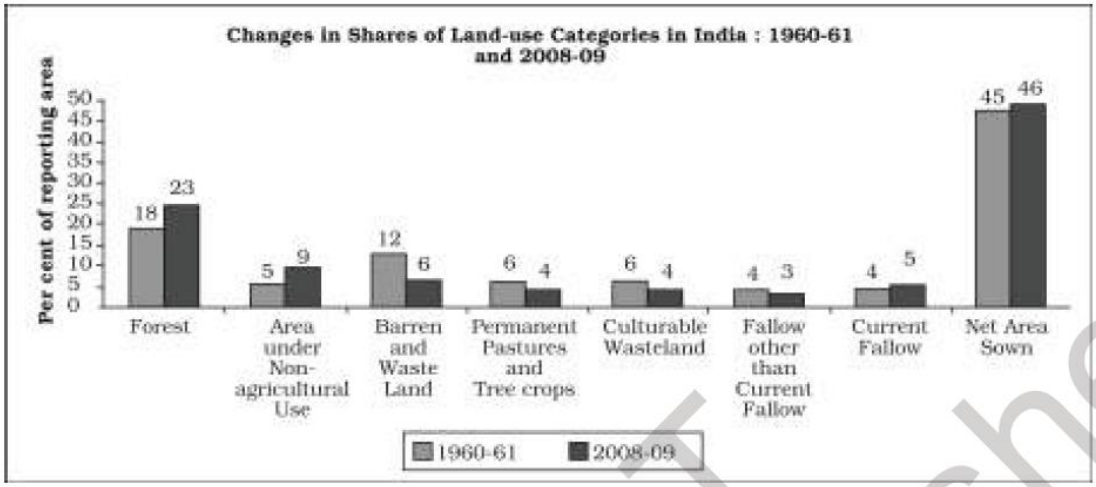
Land-use in a region, to a large extent, is influenced by the **nature of economic activities** carried out in that region. However, while economic activities change over time, land, like many other natural resources, is fixed in terms of its area. The pattern of land use depends on the economy of the region. With the **increase in size of the economy**, due to increasing population, change in income level, and updated technology, the pressure on the land increases many folds. Hence, marginal land also comes under usage. Also, with the **change in composition of economy**, brisk rate of growth of secondary and tertiary sector, there is gradual shift of land from agricultural usage to non-agricultural usage. But, it has been observed that though the share of agricultural land decreases with time, the pressure on land does not decrease. It is so because the number of people that the agricultural sector has to feed is increasing day by day.

India has undergone major changes within the economy over the past four or five decades, and this has influenced the land-use changes in the country. It has been observed that share of area under forest, area under non-agricultural uses and current fallow lands have shown an increase.

[2] Gross Cropped Area: This represents the total area sown once and/or more than once in a particular year, i.e. the area is counted as many times as there are sowings in a year. This total area is also known as total cropped area or total area sown.

The *rate of increase* is the highest in case of area under non-agricultural uses. This is due to the changing structure of Indian economy, which is increasingly depending on the contribution from industrial and service sectors. Thus, the area under non-agricultural uses is increasing at the expense of wastelands and agricultural land.

Barren and wasteland, culturable wasteland, area under pastures and tree crops and net area sown have shown a decline in the areas. With the pressure on land increasing, wastelands and culturable wastelands have declined. Also, putting more area under the non-agriculture usage has caused a decline in net sown areas.



Note : Categories (iv) and (v) of Section I have been clubbed together in the graph.

1.2.1. Intensity of cropping

(To be covered)

1.2.2. Common Property Resources

Land, according to its ownership can broadly be classified under two broad heads – *private land and common property resources (CPRs)*. While the former is owned by an individual or a group of individuals, the latter is owned by the state meant for the use of the community. CPRs can be defined as community's natural resource, where every member has the right of access and usage with specified obligations, without anybody having property rights over them. Community forests, pasture lands, village water bodies and other public spaces are examples of the common property resources. CPRs provide fodder for the livestock and fuel for the households along with other minor forest products like fruits, nuts, fibre, medicinal plants, etc. In rural areas, such land is of particular relevance for the livelihood of the landless and marginal farmers, other weaker sections and women.

1.3. Agricultural Land Use in India

The term 'agriculture' has been derived from two Latin words ager meaning land and culture meaning cultivation. Agriculture thus means cultivation of land. Agriculture also includes horticulture, animal husbandry, forestry, fishing, etc. Agriculture, unlike other secondary and tertiary sectors, depends directly on the on the land use patterns in the country. Quality and fertility of land has a direct bearing on the productivity of agriculture. Besides in rural areas, aside from its value as a productive factor, land ownership has a social value and serves as a security for credit, natural hazards or life contingencies, and also adds to the social status. It has been observed that over the years, there has been a marginal decline in the available total stock of cultivable land as a percentage to total reporting area. The scope for bringing in additional land under net sown area in India is limited. There is, thus, an urgent need to evolve and adopt land-saving technologies. It can be achieved either by increasing the yield of any

particular crop per unit area of land or by increasing the total output per unit area of land from all crops grown over one agricultural year by increasing land-use intensity. A high value of cropping intensity[3] is desirable for improving the agricultural output in India.

Student Notes:

1.4. Salient Features of Indian Agriculture

Indian agriculture has very wide variations throughout the length and breadth of the country. With growth of technology, more area has been brought under cultivation. Increase in irrigation facilities, coupled with use of fertilizers and pesticides and use of high yield variety of seeds has improved the productivity in the country. Despite the variations, there are some salient features which characterize Indian agriculture. They are:

1. **Subsistence agriculture[4]:** In general, the Indian agriculture is subsistence in nature. Farmers generally have a small piece of land and crop production is mostly for family use with surplus sold to market.
2. **Pressure of population:** Agriculture has to provide food for the rapidly increasing population and also employment to a large section of landless labourers. Hence, there is large pressure on agriculture. Besides, the increasing trend of urbanization is diverting the agricultural land to non-agricultural uses.
3. **Importance of animals:** In India, many of the agricultural operations such as ploughing, irrigation, threshing and transporting of the agricultural products are done by the animals. Animals form a major part of farmer's life in India. Complete mechanization of the Indian agricultural system is still a distant goal.
4. **Dependent upon monsoons:** The Indian farmer depends mainly on the monsoons, which are uncertain, unreliable and irregular. Only about 35 per cent of the total cropped area is under perennial irrigation and the rest depends on the monsoons. Thus, the dependency on monsoon makes life of Indian farmers highly vulnerable.
5. **Small land holdings**: The national average size of the land holdings is only 1.7 hectares. It is uneconomical to cultivate small farms and thus is a great hindrance to the progress of agriculture. Most of the farmers in our country are not owners of the land they cultivate.
6. **Variety of crops:** Due to highly suitable environmental conditions, the Indian farmers are able to grow a large variety of tropical and temperate crops. It includes food crops and commercial crops. The food crops score over all other crops for land under agriculture.
7. **Predominance of food crops:** The production of food crops is the first priority of the farmers, as they have to provide enough food for the rapidly increasing population of our country. About two-thirds of the total land under agriculture is devoted to food crops in India.
8. **Less importance to fodder crops:** India has the largest population of livestock in the world. Still the fodder crops are not given due consideration in the cropping pattern. Thus, we have very poor quality of domestic animals, when compared internationally.

1.5. Cropping Season in India

There are three distinct cropping seasons in India, namely Kharif, Rabi and Zaid.

1.5.1. The Kharif Season

largely coincides with Southwest Monsoon in the months of June – September. Major crops cultivated in Northern states include Rice, Cotton, Bajra, Maize, Jowar, and Tur. In southern states, major crops are Rice, Maize, Ragi, Jowar, and Groundnut.

[3] Cropping Intensity is defined as the ratio of Gross Cultivated Area (GCA) to Net Sown Area (NSA). It is generally expressed in percentage.

[4] Subsistence agriculture is self-sufficiency farming in which the farmers focus on growing enough food to feed themselves and their families.

1.5.2. The Rabi Season

begins with the onset of winter in October-November and ends in March-April. The major crops cultivated in northern states include Wheat, Gram, Rapeseeds and Mustard, Barley. In the southern states, major crops include Rice, Maize, Ragi, Groundnut, and Jowar.

1.5.3. The Zaid Season

is a short duration summer cropping season beginning after harvesting of Rabi crops. The cultivation of watermelons, cucumbers, vegetables and fodder crops during this season is done on irrigated lands. However, this type of distinction in the cropping season does not exist in southern parts of the country.

Cropping Season	Duration	Season	Major Crops
Kharif	June-July to Oct.-Nov	Rainy season	Rice, maize, jowar, bajra, cotton, sesamum, groundnut and pulses like mung, urad etc.
Rabi	Oct.-Nov. to March-April	Winter season	Wheat, barley, gram and oilseeds like linseed, rape and mustard, etc.
Zaid	March-April to May-June	Summer season	Vegetables, fruits like watermelon and cucumber and rice, maize etc.

1.6. Type of Farming (On Basis of Moisture for crops)

On the basis of main source of moisture for crops, the farming can be classified as ***irrigated farming*** and ***rainfed farming*** (*barani). Irrigated farming* can be further sub-divided into protective farming or productive farming. ***Protective irrigation farming*** is to protect the crops from adverse effects of soil moisture deficiency i.e. irrigation acts as a supplementary source of water over and above the rainfall. Whereas ***productive irrigation farming*** is meant to provide sufficient soil moisture in the cropping season to achieve high productivity. In such irrigation the water input per unit area of cultivated land is higher than protective irrigation.

Rainfed farming is further classified on the basis of adequacy of soil moisture during cropping season into *dryland* and *wetland* farming. . In ***wetland farming***, the rainfall is in excess of soil moisture requirement of plants during rainy season. These areas grow various water intensive crops such as rice, jute and sugarcane. The ***dryland farming*** is largely confined to the regions having annual rainfall less than 75 cm. These regions grow hardy and drought resistant crops such as *Ragi*, *Bajra*, M*oong*, Gram and G*uar* (fodder crops) and practise various measures of soil moisture conservation and rain water harvesting.

Chief Features **of Dryland Farming** are:

1. The techniques of rainwater harvesting are practised.It helps to reduce the gap of dryness between two rainfall periods.

2. Excess rainfall than needed is allowed to seep underground. It helps in water conservation.
3. Soil and water are the two main resources of dryland farming.
4. On account of long periods of aridity soil erosion sets in.
5. On account of destruction of humus in the top layer the soils become unproductive and infertile.
6. Only very poor farmers practice dryland farming. These persons account of lack of funds, are unable to access irrigation and invest in soil fertility.
7. To supplement income animal husbandry is practised.
8. On account of pressure of population grazing lands are is becoming less and less.

Student Notes:

1.7. Type of Farming (On Basis of Changing Geographical Environment or Historical Background)

Various type of farming patterns have developed in India due to highly variable environmental conditions. Based on changing geographical environment and historical background, we can further classify farming into following categories:

1.7.1. Shifting Agriculture

Shifting agriculture is also known as slash and burn cultivation. It is mostly practised in backward forest areas with heavy rainfall. Covered patchesof ground are cleared by cutting and burning trees and forests. The cleared land is then cultivated for two or three years in a primitive manner. When soil becomes leached and unproductive, the farmers shift to other part of the forest and follow the same pattern. There are certain disadvantages of shifting agriculture. We find that productivity is high in the first year but slowly the productivity decreases with every passing year. With the cutting of forests, soil gets easily degraded and blown away by wind and rain. The recovery period of the soil is long and it takes time to recover to the original state. Shifting cultivation is practised on a small scale in the forested areas of north eastern states, Orissa, Madhya Pradesh, Andhra Pradesh and parts of Kerala. It is known by different mimes such as Jhum in Assam, Podu in Orissa and Andhra Pradesh, Bewar in Madhya Pradesh and Ponam in Kerala.

1.7.2. Subsistence Agriculture

It is practised mainly for consumption purpose and maintenance of one's family. The farmer produces a variety of crops, and the total production is just enough to meet the requirements of the family. The farms are small and the yield is low. All types of manures, such as household waste, animal droppings, green manures, night soil and a little of chemical fertilizers are used. This type of agriculture is generally practised in the tribal areas of Assam and in the Himalayan region.

1.7.3. Intensive Agriculture

It is practised in regions with highly dense populated land with limited cultivable area. The farmer tries to get the maximum possible output from the small piece of land. More than one crop is cultivated in a year. Intensive agriculture is widely practised in the irrigated areas of the northern plains and the coastal plains of India.

1.7.4. Extensive Agriculture

This type of agriculture is practised in areas with low population density and the cultivable land is abundant. The farmer specializes in one or two commercial crops. In India, extensive cultivation is widely practised in the Terai region of the Himalayas and the north-western states.

1.7.5. Plantation Agriculture

This type of agriculture was introduced by the Europeans in the tropical and the subtropical regions of the country. Large tracts of agricultural land are mostly owned by the companies. In India, the main crops produced on plantations are tea, coffee, spices, coconut and rubber. The success of plantation agriculture depends on accessibility, availability of labour and adequate means of transport. Scientific methods of farming are used with an aim of higher yield and superior product quality.

1.7.6. Commercial Agriculture

The main aim of commercial farming is **to produce crops as per the market demands**. It can be either intensive or extensive. To keep the cost of production low, most modern methods of cultivation are employed. It is generally practised in areas of sparse population. In India,

commercial farming is not very common due to heavy pressure of population on land. Commercial agriculture has developed in Punjab, Haryana, Gujarat, Maharashtra, Uttar Pradesh, West Bengal, Assam.

Student Notes:

1.7.7. Mixed Farming

In this type of farming, livestock is reared along with crop farming. Cattle rearing and rotation of crops are important part of mixed farming. It is practised in thickly populated areas. The yields are generally high. Efficient methods of cultivation, quick means of transport and ready markets are seen as promoters of mixed farming in the country.

1.8. Cropping Pattern[5]

Cropping pattern refers to the yearly sequence and spatial arrangement of crops and fallows on a given area. The farmer's decision on crops and cropping pattern depends on several factors – soil and climate, household needs, socio-economic issues, market infrastructure, post-harvest storage and processing facilities, labour availability, technological development, government policies etc. By and large, most of the Indian farmers go for cultivation of a number of crops on their farms and rotate a particular crop combination over a period of 3 -4 years. It results in multiplicity of cropping system which remains dynamic in time and space.

A large diversity of cropping system exist under rainfed and dryland areas with an over-riding practise of intercropping due to greater risk involved in cultivating large area under a particular crop, while in areas of assured irrigation only a few cropping system are followed, they have a considerable coverage across the region and contribute significantly to food grain production at national level.

Three major type of cropping system in India are- **(i) Sequential System-** In this system, we have sequential multiple cropping using short duration crops and intensive input management. **(ii) Intercropping System-** Growing of two or more crops simultaneously on the same field; Crop intensification is in both temporal and spatial dimensions. **(iii) Alley Cropping System –** Growing of annual crops with multipurpose perennial trees or shrubs. It is a way of increasing production potential under fragile environment.

1.9. Food grains

Food grains are the dominant crop in all parts of the country whether it is subsistence or commercial agricultural economy. On the basis of the structure of grain, the food grains can be classified as cereals and pulses.

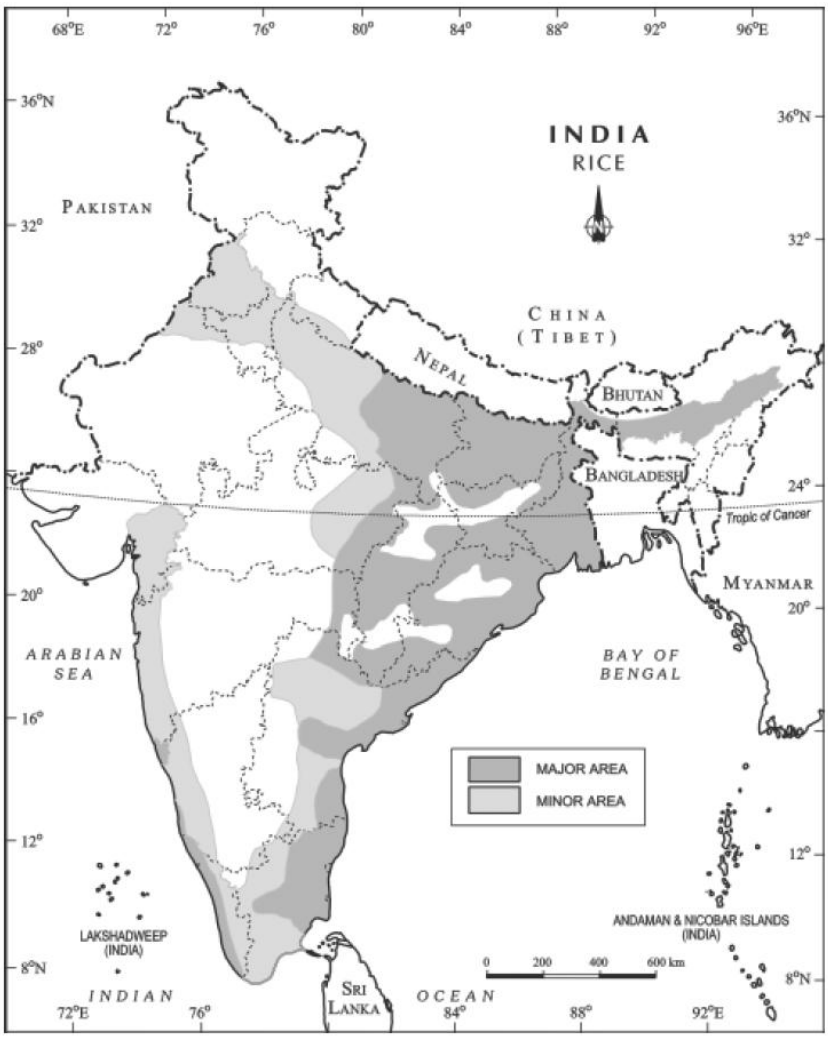
1.9.1. Cereals

The cereals occupy about 54 per cent of total cropped area in India. The country produces about 11 per cent cereals of the world and ranks third in production after China and U.S.A. India produces a variety of cereals, which are classified as fine grains (rice, wheat) and coarse grains (Jowar, Bajra, maize, Ragi), etc.

[5] The crops of India are divided into mainly two types: (a) Food crops (b) Cash crops. A cash crop is an agricultural crop which is grown for sale to return a profit. It is typically purchased by parties separate from a farm. Rice, wheat, maize, millet, barley, mower are the examples of food grains. Jute, cotton, sugarcane, oil seeds and rubber are known as l.

Student Notes:

1.9.1.1. Rice



Rice is the most important cereal crop in India. About 3,000 varieties are grown in different agro-climatic regions of the country. Rice being a tropical and sub-tropical plant requires a fairly high temperature of more than 22°C and amount of rainfall more than 100 cm. Irrigation is necessary in areas of lesser rainfall. *Clayey alluvial soil* in which water can remain standing is ideal for rice. A good crop of rice can be obtained only if the fields are kept filled with water. Cultivation of rice is *labour-intensive.* India contributes 22 per cent of rice production in the world and ranks second after China. About one-fourth of the total cropped area in the country is under rice cultivation. West Bengal, Punjab, Uttar Pradesh, Andhra Pradesh and Tamil Nadu were five leading rice producing states in the country.

Golden Rice

Golden Rice is a new type of rice that contains beta carotene, a source of vitamin A. Golden Rice is being developed as a potential new food-based approach to improve vitamin A status. Vitamin A deficiency is a serious public health problem affecting millions of children and pregnant women globally.

1.9.1.2. Wheat

Wheat is the second most important cereal crop in India after rice. Indian production of wheat is second in the world after China[6]. It is primarily a crop of **temperate zone**. Wheat needs about **75 cm** of water and winter temperature of **10° to 15° C** and summer temperature of **21°C to 26°C** during ripening to produce a good crop. It requires a rainfall of **50 to 75 cm**. Excessive *rainfall* is harmful to wheat crop. Roots of the plant are destroyed in standing water. **Light loam** soil is ideal. Hence, its cultivation in India is done during winter i.e. ***rabi*** season. Cultivation of wheat is not labour-intensive. Uttar Pradesh, Punjab, Haryana, Rajasthan and Madhya Pradesh are five leading wheat producing states.

[6] http://faostat.fao.org/site/339/default.aspx

Student Notes:

1.9.1.3. Jowar (Sorghum)

It is main food crop in **semi-arid areas** of central and southern India. Jowar is grown both as a **Kharif** and as a **rabi** crop. As a Kharif crop, it grows in areas having mean monthly average temperature of **26°C to 33°C**. It requires rainfall of about **30cm** during the growing season. Jowar can be grown in a **variety of soils** including loamy and sandy soils. The **clayey, regur and alluvium** are most suitable for Jowar cultivation. Maharashtra alone produces more than half of the total *Jowar* production of the country. Other leading producer states of *Jowar* are Karnataka, Madhya Pradesh and Andhra Pradesh. The grain also makes for an excellent poultry feed.

1.9.1.4. Bajra

Bajra is sown in **hot and dry** climatic conditions in north-western and western parts of the country. It is grown in areas with rainfall about **40-50 cm** and temperature of about **25°C -30°C**. It is a **hardy crop** which resists frequent dry spells and drought in this region. It is cultivated alone as well as part of mixed cropping. Leading producers of *Bajra* are the states of Maharashtra, Gujarat, Uttar Pradesh, Rajasthan and Haryana.

1.9.1.5. Maize

Maize is a **food as well as fodder crop** grown under **semi-arid** climatic conditions and over **inferior soils**. It requires **50-100cm** of rainfall and a temperature ranging from **21°C to 27°C**. Maize is sown **all over India except eastern and north-eastern regions.** The leading producers of maize are the states of Madhya Pradesh, Andhra Pradesh, Karnataka, Rajasthan and Uttar Pradesh. Yield level of maize is higher than other coarse cereals. It is high in southern states and declines towards central parts.

1.9.1.6. Pulses

Pulses are rich source of **protein** in India. India is a leading producer of pulses and accounts for about **one-fifth** of the total production of pulses in the world. The cultivation of pulses in the country is largely concentrated in the **dryland of Deccan and central plateaus and north-western parts of the country**. Gram and *tur* are the main pulses cultivated in India.

1.9.1.7. Gram

is cultivated in subtropical areas. It is mostly a rainfed crop cultivated during Rabi season in central, western and north-western parts of the country. Preferred temperature range is **20°C – 25°C** and rainfall in the range of **40-50cm**. Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh and Rajasthan are the main producers of this pulse crop. **Tur** is the second important pulse crop in the country. It is also known as *red gram* or *pigeon pea*. It is cultivated over marginal lands and under rainfed conditions in the dry areas of central and southern states of the country. Maharashtra, Uttar Pradesh, Karnataka, Gujarat and Madhya Pradesh are the main producers of Tur.

1.9.2. Oilseeds

The oilseeds are produced for extracting edible oils. Dryland of Malwa plateau, Marathwada, Gujarat, Rajasthan, Telangana and Rayalseema region of Andhra Pradesh and Karnataka plateau are oilseeds growing regions of India. Groundnut, rapeseed and mustard, Soyabean and sunflower are the main oilseed crops grown in India.

1.9.2.1. Groundnut

Groundnut is largely a rainfed *Kharif* crop of dryland. Gujarat, Tamil Nadu, Andhra Pradesh, Karnataka and Maharashtra are the leading producers.

1.9.2.2. Rapeseed and Mustard

Rapeseed and mustard comprise several oilseeds as *rai, sarson, toria* and *taramira*. These are subtropical crops cultivated during rabi season in north-western and central parts of India. Rajasthan contributes about one-third production while other leading producers are Uttar Pradesh, Haryana, West Bengal and Madhya Pradesh. Yields of these crops are comparatively high in Haryana and Rajasthan.

Student Notes:

1.9.2.3. Other Oilseeds

Soyabean and sunflower are other important oilseeds grown in India. Soyabean is mostly grown in Madhya Pradesh and Maharashtra. Sunflower cultivation is concentrated in Karnataka, Andhra Pradesh and adjoining areas of Maharashtra. It is a minor crop in northern parts of the country where its yield is high due to irrigation.

1.9.3. Cash Crops

1.9.3.1. Cotton

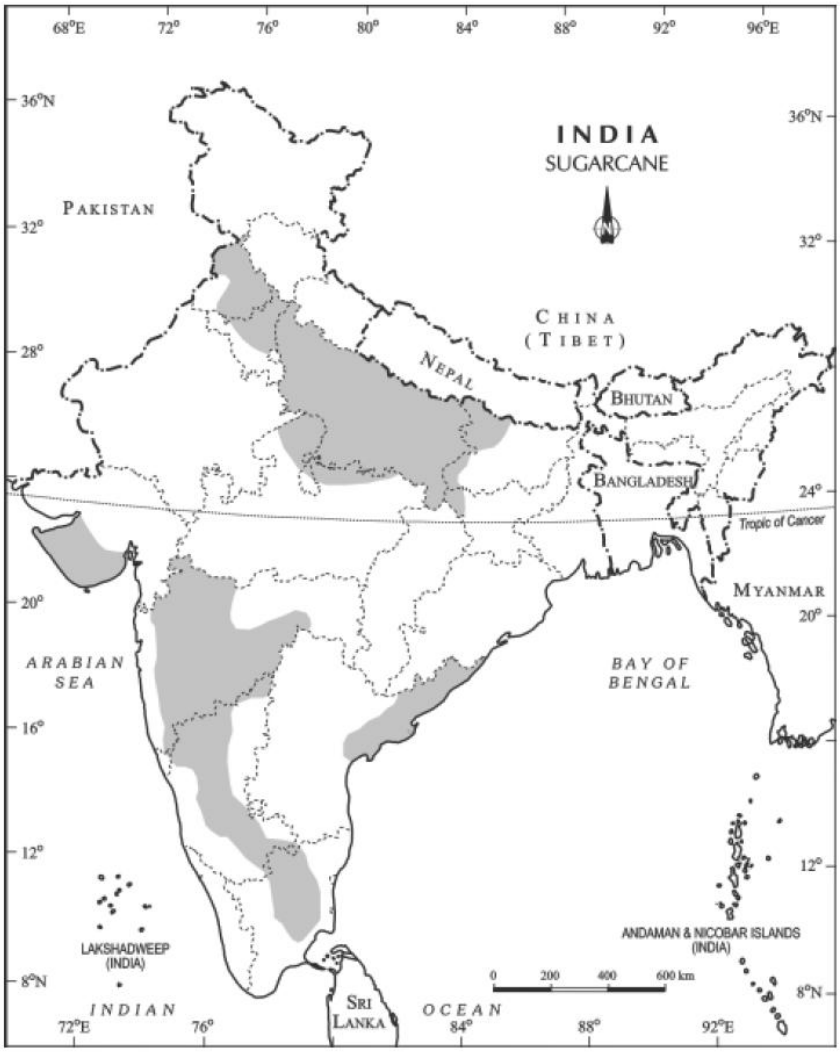
Cotton is a tropical crop grown in ***Kharif*** season in **semi-arid** areas of the country. India grows both **short staple (Indian)** cotton as well as **long staple (American)** cotton called '***narma***' in north-western parts of the country. Cotton requires **clear sky during flowering stage**. Ideal temperature range is **21°C – 30°C** and rainfall in the range of **50 – 100cm**. There are three cotton growing areas, i.e. parts of Punjab, Haryana and northern Rajasthan in north-west, Gujarat and Maharashtra in the west and plateaus of Andhra Pradesh, Karnataka and Tamil Nadu in south. Leading producers of this crop are Maharashtra, Gujarat, Andhra Pradesh, Punjab and Haryana.

Student Notes:

1.9.3.2. Jute

Jute is a cash crop in West Bengal and adjoining eastern parts of the country. West Bengal accounts for about **three-fourth** of the production in the country. Bihar and Assam are other jute growing areas. Ideal growing condition include temperature in range of **24°C – 35°C** and rainfall of **120- 150cm**.

1.9.3.3. Sugarcane



Sugarcane is a crop of **tropical** areas. Under **rainfed** conditions, it is cultivated in **sub-humid and humid climates**. It requires **hot and humid climate** with average temperature of **21°C-27°C** and **75-100 cm** rainfall. In Indo-Gangetic plain, its cultivation is largely concentrated in **Uttar Pradesh**. Sugarcane growing area in western India is spread over **Maharashtra and Gujarat**. In southern India, it is cultivated in irrigated tracts of Karnataka, Tamil Nadu and Andhra Pradesh. Uttar Pradesh produces about two-fifth of sugarcane of the country.

Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh are other leading producers of this crop.

1.9.3.4. Tea

Tea is a **plantation crop** used as beverage. It is grown over undulating topography of **hilly areas** and **well drained soils** in **humid and sub-humid tropics and sub-tropics**. The ideal temperature for growth is **20°C – 30°C** and rainfall around **150-300cm**. In India, tea plantation is done in Brahmaputra valley of Assam, sub-Himalayan region of West Bengal (Darjiling, Jalpaiguri and Cooch Bihar districts) and lower slopes of Nilgiris and Cardamom hills of Western Ghats.

1.9.3.5. Coffee

Coffee is a tropical plantation crop. There are three varieties of coffee i.e. ***arabica***, ***robusta*** and ***liberica***. Coffee is cultivated in the highlands of Western Ghats in Karnataka, Kerala and Tamil Nadu. The ideal temperature for growth is between **15°C and 28°C** and rainfall from **150 cm to 250cm.**

1.9.4. Tabular Representation of Various Crop Requirements in India

Crop	Climatic Conditions	Soil Requirements	Area of Cultivation
Rice	Temp: Higher than 22°C Rain: More than 100cm	Fertile clayey or loamy soil of the river valleys, flood plains, coastal plains and deltas capable of holding water	Lower and middle Ganga Plains, the east and west coastal plains, the Brahmaputra Valley and parts of the Deccan Plateau.
Wheat	Temp: Winter 10°C -15°C Summer 21°C-26°C Rain: 50-75 cm	Well-drained fertile silt and clayey loams	Punjab, Haryana, Uttar Pradesh, Rajasthan and Madhya Pradesh
Jowar	Temp: 26°C – 33°C Rain: About 30 cm	Clayey, regur and alluvium	Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Rajasthan and Gujarat
Bajra	Temp: 25°C – 30 °C Rain: 40 -50 cm	Sandy loams, black and red soils	Maharashtra, Gujarat, Uttar Pradesh, Rajasthan and Haryana.
Maize	Temp: 21°C – 27°C Rain: 50 -100 cm	Deep fertile well drained soil rich in organic matter with good water holding capacity	Madhya Pradesh, Andhra Pradesh, Karnataka, Rajasthan and Uttar Pradesh
Ragi	Temp: 20°C – 30°C Rain: 50 -100 cm	Red, light black sandy loams	Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Gujarat and Maharashtra
Gram	Temp: 20°C – 25°C Rain: 40 -50 cm	Well-drained fertile silt and clayey loams	Madhya Pradesh, Uttar Pradesh, Rajasthan, Haryana and Maharashtra
Tur (Arhar)	Temp: Winter 15°C -18°C Summer 30°C-35°C Rain: 50-70 cm	Sandy loam to clayey loam, Deep well drained soil	Uttar Pradesh, Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh, Odisha, Karnataka and Tamil Nadu
Groundnut	Temp: 20°C – 30°C Rain: 50 -80 cm	Sandy loams and black soil	Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat & Maharashtra.
Rapeseed & Mustard	Temp: 10°C – 20°C Rain: 50 -100 cm	Alluvial soil	Uttar Pradesh, Rajasthan, Punjab, Haryana, Madhya Pradesh and Chhattisgarh
Sesamum (Til)	Temp: 20°C – 25°C Rain: About 50 cm	Well-drained light loamy soils	Orissa, Rajasthan, Gujarat, Tamil Nadu, Maharashtra, West Bengal and Madhya Pradesh.
Sunflower	Temp: 15°C – 25°C Rain: About 50 cm	Well-drained loamy soil	Karnataka, Maharashtra, Andhra Pradesh, Haryana, Bihar and Uttar Pradesh
Soyabean	Temp: 15°C – 25°C	Friable loamy soils can	Maharashtra, Uttar Pradesh,

	Rain: 40-60 cm	retain moisture.	Uttarakhand, Madhya Pradesh, Gujarat and Chhattisgarh.
Linseed	Temp: 10°C – 20°C Rain: 50 -75 cm	Clay loams, deep black soils and alluvial soils	Madhya Pradesh, Uttar Pradesh, Bihar, Chhattisgarh and Maharashtra
Cotton	Temp: 21°C – 30°C Rain: 50 -100 cm	Black soil, Alluvial soil and Red soil	Punjab, Maharashtra, Gujarat and Haryana
Jute	Temp: 24°C – 35°C Rain: 120 -150 cm	Light sandy or clayey loam with annual water supply	West Bengal, Assam, Bihar and Orissa
Sugarcane	Temp: 21°C – 27°C Rain: 75 -100 cm	Deep, well-drained, rich loamy soil with moisture retaining capacity	Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Bihar and Punjab
Coconut	Temp: 20°C – 25°C Rain: Above150 cm	Loose porous or sandy along sea shores	Kerala, Tamil Nadu and Karnataka
Tea	Temp: 20°C – 30°C Rain: 150 -300 cm	Well-drained deep fertile sandy loams	Brahmaputra & Surma valleys of Assam, Darjeeling and Jalpaiguri districts of northern West Bengal and Nilgiris, Palnis and Annamalai hills in South India
Coffee	Temp: 15°C – 28°C Rain: 150 -250 cm	Well-drained loamy soils, rich in humus and minerals	Karnataka , Kerala and Tamil Nadu
Rubber	Temp: 25°C – 35°C Rain: Above 300cm	Deep, rich and well-drained loamy soil, at an elevation of about 400 metres	Kerala, Tamil Nadu, Karnataka and Andaman and Nicobar Islands

1.10. Agricultural Development in India

Agriculture continues to be an important sector of Indian economy. The importance of agricultural sector in India can be gauged from the fact that about **57 per cent of its land is devoted to crop cultivation**, whereas, in the world, the corresponding share is only about 12 per cent. Indian agricultural economy has been largely subsistence in nature. After Independence, the immediate goal of the Government was to increase food grains production by (i) switching over from cash crops to food crops; (ii) intensification of cropping over already cultivated land; and (iii) increasing cultivated area by bringing cultivable and fallow land under plough. Intensive Agricultural District Programme (IADP) and Intensive Agricultural Area Programme (IAAP) were launched in 1950s to improve production. New seed varieties of wheat (Mexico) and rice (Philippines) known as high yielding varieties (HYVs) were available for cultivation by mid-1960s and India took advantage by introducing package technology comprising HYVs, along with chemical fertilizers in irrigated areas of Punjab, Haryana, and Western Uttar Pradesh. This strategy of agricultural development increased the food production at very vast rate; this growth came to be known as ***Green Revol ution***. This strategy of agricultural development made the country self-reliant in food grain production. But green revolution was initially confined to irrigated areas only. This led to regional disparities in agricultural development in the country.

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Student Notes:

Agro-climatic planning was introduced in 1988 to induce regionally balanced agricultural development in the country. It also emphasised the need for diversification of agriculture and harnessing of resources for development of dairy farming, poultry, horticulture, livestock rearing and aquaculture. However, lack of development of rural infrastructure, withdrawal of subsidies and price support, and impediments in availing of the rural credits may lead to inter-regional and inter-personal disparities in rural areas. Improvement in technology, better yield crops, expansion in irrigation, improved fertilizers and use of pesticides has significantly improved the agricultural productivity in the country. Government initiated schemes like Rashtriya Krishi Vikas Yojana, Rainfed Farming Systems, National Horticulture mission etc along with National Mission on Oilseeds and Oil palms and Technology Mission on Oilseed, Pulses and Maize has led to improvement in agricultural produce in India.

1.10.1. Indian Council of Agricultural Research (ICAR)

The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India. It was formerly known as Imperial Council of Agricultural Research and it was established on 16 July 1929. The Council is the apex body for co-ordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. The ICAR has played a pioneering role in ushering Green Revolution and subsequent developments in agriculture in India through its research and technology development that has **enabled the country to increase the production of foodgrains by 4 times**, **horticultural crops by 6 times**, **fish by 9 times (marine 5 times and inland 17 times)**,**milk 6 times** and **eggs 27 times** since 1950-51, thus making a visible impact on the national food and nutritional security.

The mandates for the ICAR are to –

- To **plan, undertake, aid, promote** and co-ordinate **education, research and its application** in agriculture, agro forestry, animal husbandry, fisheries, home science and allied sciences.
- To act as a **clearing house** of research and general information relating to agriculture, animal husbandry, home science and allied sciences, and fisheries through its publications and information system; and instituting and promoting transfer of technology programmes.

- To provide, undertake and promote **consultancy services** in the fields of education, research, training and dissemination of information in agriculture, agro forestry, animal husbandry, fisheries, home science and allied sciences.
- To look into the problems relating to broader areas of **rural development** concerning agriculture, including postharvest technology by developing co-operative programmes with **other organizations** such as the Indian Council of Social Science Research, Council of Scientific and Industrial Research, Bhabha Atomic Research Centre and the universities
- To do other things considered necessary to attain the objectives of the Society.

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1.11. Government Steps to Enhance Agricultural Inputs

Government has taken many steps to improve the yield of agriculture in the country. Various steps have been taken to promote efficient use of seeds, fertilizers, pesticides, micronutrients and irrigation. Each of these plays a role in determining yield level and in turn augmentation in level of production.

1.11.1. Seeds

Seeds are a critical input for agricultural crops. In India, farmers typically rely on farm-saved seeds, overuse of which leads to a low seed replacement rate and poor yield. An Indian Seed Programme for encouraging the development of new varieties and protecting the rights of farmers and plant breeders has been put in place with the participation of central and state governments, the Indian Council of Agricultural Research (ICAR), state agricultural universities, seed cooperatives, and private sectors. A central-sector Scheme for development and strengthening of infrastructure facilities for production and distribution of quality seeds, with the aim of making quality seeds of various crops available to farmers at affordable price, is under implementation since 2005-06. A Sub-Mission on Seed and Planting Material under the **National Mission for Agricultural Extension and Technology** has been approved for the Twelfth Five Year Plan.

1.11.2. Mechanization and Technology

Tractors are the main power source for various farm operations. With adoption of appropriate mechanization of farm operations, we can increase production and farm productivity by 10-15 per cent. Steps are taken for setting up of custom-hiring centres/high-tech machinery banks so that small and marginal farmers can reap the benefits of farm mechanization. The government has initiated a Sub-Mission on Agriculture Mechanization in the Twelfth Five year Plan, with a focus on custom hiring.

1.11.3. Integrated Nutrient Management

Over 80% of India's Urea requirements are met from domestic production but we are largely dependent on foreign imports for meeting requirements of potassic (K) and phosphatic (P) fertilizers. Over-use of nitrogenous and limited use of P and K fertilizers are matters of great concern and need appropriate price incentives by reducing fertilizer subsidies so that sustainable practices are encouraged.

The government has notified the New Investment Policy 2012 (NIP-2012) in the urea sector which will encourage investments leading to increase in indigenous capacities, reduction in import dependence and savings in subsidy due to import substitution at prices below import parity price. Under the Nutrient Based Subsidy (NBS) scheme for phosphatic and potassic (P&K) fertilizers implemented in 2010, a fixed amount of subsidy, decided on annual basis, is provided to each grade of P&K fertilizer, depending upon its nutrient content. An additional subsidy is also provided to secondary and micro-nutrients. Under this scheme, manufacturers/marketers are allowed to fix the maximum retail price (MRP).

Student Notes:

1.11.4. Irrigation

Although India has made considerable progress in developing irrigation infrastructure, irrigation efficiency is low for both surface and ground waters. In order to help the rainfed farmers improve productivity and profitability, in situ soil and water conservation practices are developed for different agro-climatic regions with special emphasis on effective rainwater management. The central government initiated the Accelerated Irrigation Benefit Programme (AIBP) in 1996-7 for extending assistance for the completion of incomplete irrigation schemes. Besides, the Command Area Development Programme has also been amalgamated with the AIBP to reduce the gap between irrigation potential that has created and that is utilized.

1.12. Major Schemes/Programmes for the Agricultural Sector

The central government has undertaken many schemes for enhancing productivity and exploring untapped potential of the agricultural sector. The central government supplements the efforts of state governments through centrally sponsored and central-sector schemes.

National Mission on Agricultural Extension and Technology (NMAET)

Agricultural productivity has a positive correlation with level of farm mechanization. For accelerated growth in farm mechanization in the current decade, there is a need to include the large community of small and marginal farmers into the fold of cost effective and remunerative mechanized farming, to help sustain desired agricultural growth and to enhance agricultural productivity.

Agricultural Technology, including the adoption/ promotion of critical inputs, and improved agronomic practices were being disseminated under 17 different schemes of the Department of Agriculture & Cooperation during the 11th Plan. The Modified Extension Reforms Scheme was introduced in 2010 with the objective of strengthening extension machinery and utilizing it for synergizing interventions under these schemes under the umbrella of the Agriculture Technology Management Agency (ATMA).

The NMAET has been envisaged as the next step towards this objective through the amalgamation of these schemes.

NMAET consists of 4 Sub Missions:

1. Sub Mission on Agricultural Extension (SMAE)
2. Sub-Mission on Seed and Planting Material (SMSP)
3. Sub Mission on Agricultural Mechanization (SMAM)
4. Sub Mission on Plant Protection and Plant Quarantine (SMPP)

The common threads running across all 4 Sub-Missions in NMAET are Extension and Technology. Therefore, while 4 separate Sub-Missions are being proposed for administrative convenience, these are inextricably linked to each other at the field level and most components thereof have to be disseminated among farmers and other stakeholders through a strong extension network.

The aim of the Mission is to restructure and strengthen agricultural extension to enable delivery of appropriate technology and improved agronomic practices to farmers. This is envisaged to be achieved by a judicious mix of extensive physical outreach and interactive methods of information dissemination, use of ICT, popularisation of modern and appropriate technologies, capacity building and institution strengthening to promote mechanisation, availability of quality seeds, plant protection etc. and encourage aggregation of Farmers into Interest Groups (FIGs) to form Farmer Producer Organisations (FPOs).

Student Notes:

1.12.1. National Food Security Mission

With an aim to enhance the production of rice, wheat, and pulses by 10, 8, and 2 million tonnes respectively, government had launched NFSM-Rice, NFSM-Wheat and NFSM-Pulses in 2007-08. During 2012-13, a Special Plan to achieve 19+ million tonnes of pulses production during Kharif 2012 was launched by the government. The programme also aimed at area expansion and productivity enhancement; restoring soil fertility and productivity; creating employment opportunities; and enhancing farm-level economy to restore the confidence of farmers of targeted districts.

1.12.2. Rashtriya Krishi Vikas Yojana

The Rashtriya Krishi Vikas Yojana (RKVY) was launched in 2007-8 for incentivizing states to enhance public investment. It permits taking up national priorities as sub-schemes, allowing the states flexibility in project selection and implementation for increased public investment in agriculture by incorporating information on local requirements, geographical/climatic conditions, available natural resources/ technology and cropping patterns. It aims to significantly increase the productivity of agriculture and its allied sectors and eventually maximize the returns of farmers in agriculture and its allied sectors.

1.12.3. National Mission for Sustainable Agriculture

Climate change poses a major challenge to agricultural production and productivity.

National Mission for Sustainable Agriculture (NMSA), under the aegis of the National Action Plan on Climate Change (NAPCC), seeks to transform Indian agriculture into a climate resilient production system through suitable adaptation and mitigation measures in domains of both crops and animal husbandry. NMSA as a programmatic intervention focuses on promotion of location specific integrated/composite farming systems; resource conservation technologies; comprehensive soil health management; efficient on-farm water management and mainstreaming rainfed technologies.

NMSA identifies 10 key dimensions namely seed & culture water, pest, nutrient, farming practices, credit, insurance, market, information and livelihood diversification for promoting suitable agricultural practices that covers both adaption and mitigation measures through four functional areas, namely, Research and Development, Technologies, Products and Practices, Infrastructure and Capacity building. During XII Five Year Plan, these dimensions have been embedded and mainstreamed into Missions/Programmes/Schemes of Ministry of Agriculture including NMSA through a process of restructuring of various schemes/missions implemented during XI Five Year Plan and convergence with other related programmes of Central/State Governments.

1.12.4. Bringing Green Revolution to Eastern India (BGREI)

Bringing Green Revolution to Eastern India, initiated in 2010-11, intends to address the constraints limiting the productivity of **'rice based cropping systems'**[7] in eastern India comprising **seven states, viz. Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, Eastern Uttar Pradesh, and West Bengal**. The BGREI is a subscheme of the Rashtriya Krishi Vikas Yojna (RKVYJ). The following strategies are being adopted, in general, for maximising productivity and production of crops in the eastern region –

i. *In **situ*** **water harvesting/conservation** through adoption of cultural practices like bed furrow in deep black cotton uplands and flat sowing & ridging later in red soils.
ii. **Reclamation of soil salinity** through application of gypsum particularly in oilseed crops along with micro-nutrients like zinc, iron & sulphur in deficient soils.

[7] Current focus is on rice and wheat only.

Student Notes:

iii. **Reclamation of acidic soils** through liming/paper mills sludge/application of organic manures/green manures to improve physical condition of the soil
iv. Promotion of **Integrated Nutrient Management** to ensure balanced use of fertilizers/organic manures/bio-fertilizers.
v. Adoption of **soil & water conservation practices** namely; summer ploughing, broad bed furrow, compartmental bunding, pre-monsoon sowing and rain water harvesting (Farm ponds) to check soil erosion and recycling runoff.
vi. **Enhancement of irrigation Water** Use Efficiency through adoption of micro-irrigation system (Sprinkler & Drip).
vii. **Promotion of high value crops** namely; sweet sorghum, maize, pulses and oilseeds in addition to hybrid rice in the region.

Outcome: Eastern region hitherto known as food deficit region, has with the help of the programme, turned food surplus region. The rice production from the region is estimated at 562.6 lakh tons an increase of 19.8% over last year against an all India increase of 7%. And the foodgrain production from the region is estimated at 1032 tons an increase of 11.9% against an all India increase of 2.2%.

The increased productivity/ production was optimized due to resource allocation and utilization. The significant increase in production of food grains in the region not only offset the decline in production in central and peninsular India but also contributed significantly to the highest ever production of food grains. The growth in food grains i.e. rice and wheat provides an opportunity to procure and create food grain reserves locally reducing the pressure on Punjab and Haryana, and cutting costs on transport and other logistics.

The focus will now be to consolidate the gains with continued emphasis during the 12th Plan. Further steps will be taken to improve the infrastructure for procurement and storage of the produce and to ensure a reasonable price for the farmers.

Evergreen Revolution

The architect of the country's green revolution, M.S. Swaminathan, gave a clarion call for taking up an 'evergreen revolution' that "increases productivity in perpetuity without causing any ecological harm and without using chemical inputs".

"I am against a second green revolution, but I am very much for an evergreen revolution," he said. Pointing out that a majority of food production comes from farmers with small holdings, he said it was essential to increase their income through higher productivity. But it should be done without harming ecological interests, he noted.

Swaminathan is an advocate of moving India to sustainable development, especially using environmentally sustainable agriculture, sustainable food security and the preservation of biodiversity, which he calls an "evergreen revolution."

1.12.5. Integrated Scheme Of Oilseeds, Pulses, Oilpalm & Maize (ISOPOM)

National Mission on Oilseeds and Oil Palm (NMOOP) envisages increase in production of vegetable oils sourced from oilseeds, oil palm and TBOs from 7.06 million tonnes (average of 2007-08 to 2011-12) to 9.51 million tonnes by the end of Twelfth Plan (2016-17). The Mission is proposed to be implemented through three Mini Missions with specific target as detailed below:

MM I on Oilseeds	Achieve production of 35.51 million tones and productivity of 1328 kg/ha of oilseeds from the present average production & productivity of 28.93 million **tonnes** and 1081 kg/ha during the 11th Plan period respectively.

MM II on Oil Palm	Bring additional 1.25 lakh hectare area under oil palm cultivation through area expansion approach in the States including utilization of wastelands with increase in productivity of fresh fruit brunches (FFBs) from 4927 kg per ha to 15000 kg per ha.
MM III on TBOs	Enhance seed collection of TBOs from 9 lakh **tonnes** to 14lakh tonnes and to augment elite planting materials for area expansion under waste land.

Student Notes:

The strategy to implement the proposed Mission includes

- increasing Seed Replacement Ratio (SRR) with focus on Varietal Replacement;
- increasing irrigation coverage under oilseeds from 26% to 36%;
- diversification of area from low yielding cereals crops to oilseeds crops; inter-cropping of oilseeds with cereals/ pulses/ sugarcane;
- use of fallow land after paddy /potato cultivation;
- expansion of cultivation of Oil Palm and tree borne oilseeds in watersheds and wastelands;
- increasing availability of quality planting material enhancing procurement of oilseeds and collection; and
- processing of tree borne oilseeds.

Inter-cropping during gestation period of oil palm and tree borne oilseeds would provide economic return to the farmers when there is no production.

The scheme would be implemented in mission mode through active involvement of all the stakeholders. The Centre and States will bear costs in the ratio of 75:25. Fund flow would be strictly monitored to ensure that benefit of the Mission reaches the targeted beneficiaries in time to achieve the results.

NEED FOR MISSION APPROACH

India is among major oilseed growers and edible oil importers. India's vegetable oil economy is world's fourth largest after USA, China and Brazil. The oilseed accounts for 13% of the gross cropped area, 3% of the Gross National Product and 10% value of all agricultural commodities.

The diverse agro-ecological conditions in the country are favourable for growing 9 annual oilseed crops, which include 7 edible oilseeds (groundnut, rapeseed & mustard, soybean, sunflower, sesame, safflower and niger) and two non-edible oilseeds (castor and linseed). Oilseeds cultivation is undertaken across the country in about 27 million hectares mainly on marginal lands, of which 72% in confined to rainfed farming.

During the last few years, the domestic consumption of edible oils has increased substantially and has touched the level of 18.90 million tonnes in 2011-12 and is likely to increase further. With per capita consumption of vegetable oils at the rate of 16 kg/year/person for a projected population of 1276 million, the total vegetable oils demand is likely to touch 20.4 million tonnes by 2017.

A substantial portion of our requirement of edible oil is met through import of palm oil from Indonesia and Malaysia. It is, therefore, necessary to exploit domestic resources to maximize production to ensure edible oil security for the country.

Oil palm is a comparatively new crop in India and is the highest vegetable oil yielding perennial crop. With quality planting materials, irrigation and proper management, there is potential of achieving 20-30 MT Fresh Fruit Bunches per ha after attaining age of 5 years. Therefore, there is an urgent need to intensify efforts for area expansion under oil palm to enhance palm oil production in the country. Tree-borne oilseeds (TBOs), like sal, mahua, simarouba, kokum, olive,

karanja, jatropha, neem, jojoba, cheura, wild apricot, walnut, tung etc. are cultivated or grow wild in the country under different agro-climatic conditions. These TBOs are also good source of vegetable oil and therefore need to be supported for cultivation.

Student Notes:

Background

In order to provide flexibility to the States in implementation based on regionally differentiated approach, to promote crop diversification and to provide focused approach to the programmes, the four erstwhile schemes of OPP, OPDP, NPDP and AMDP were merged into one Centrally Sponsored Integrated Scheme of Oilseeds, Pulses, Oil palm and Maize (ISOPOM) in 2004.

Now ISOPOM is replaced with National Mission on Oilseeds and Oil Palm (NMOOP) to be implemented during the 12th Plan Period as NFSM absorbed pulses and maize component from the ISOPOM scheme.

1.13. Problems of Indian Agriculture

The nature of problems faced by Indian agriculture varies according to agro-ecological and historical experiences of its different regions. Many of the problems are common to the nation and range from physical constraints to institutional hindrances.

1. **Dependence on erratic Monsoon** is one of the major problems in India. Irrigation covers only about 33 per cent of the cultivated area in India. Hence, the crop production in rest of the cultivated land directly depends on rainfall. Since, rainfall is very fluctuating; the areas are vulnerable to both droughts and floods. Drought is a common phenomenon in the low rainfall areas which may also experience occasional floods.
2. **Low Productivity** is another major concern. Per hectare output of most of the crops such as rice, wheat, cotton and oilseeds in India is much lower than that of other countries in the world. Because of the very high pressure on the land resources, the labour productivity in Indian agriculture is also very low in comparison to international level.
3. The farmers **use outdated techniques**. Most of the agricultural operations are carried out manually using simple and conventional tools. This hampers the production potential of the farmers.
4. **Constraints on financial resources** and indebtedness also make agriculture unmanageable for small and marginal farmers with very meagre or no savings. Crop failures and low returns from agriculture have forced them to fall in the trap of indebtedness.
5. **Lack of land reforms** has led to exploitation of Indian farmers for long time. There are no proper land records which make them susceptible to exploitation.
6. Besides, **small size farms and fragmentation of land holdings** also reduces the productivity and production of the farms. More than **60 per cent** of the ownership holdings have a size smaller than **one hectare (ha)**. Furthermore, about 40 per cent of the farmers have operational holding size smaller than 0.5 hectare (ha). The small size fragmented landholdings are uneconomic. A large number of farmers produce crops for self-consumption. These farmers do not have enough land resources to produce more than their requirement. Most of the small and marginal farmers grow food grains, which are meant for their own family consumption.
7. There is a massive **problem of under-employment** in the agricultural sector in India, particularly in the un-irrigated tracts. In these areas, there is a seasonal unemployment ranging from 4 to 8 months.
8. Another serious problem that arises out of faulty strategy of irrigation and agricultural development is **degradation of land resources**. Large tracts of fertile lands suffer **from soil erosion** due to wind, deforestation, overgrazing and occasional heavy rainfall. Soil's fertility should be conserved at any cost. This is serious because it may lead to depletion of soil fertility. The situation is particularly alarming in irrigated areas. A large tract of agricultural land has lost its fertility due to alkalisation and salinisation of soils and water logging.

Student Notes:

9. Besides, **the marketing of agricultural products**, especially in rural India, is neither adequate nor standardised. Thus, many farmers have to sell their products at low prices through local traders and middle-men.

2. UPSC Mains Previous Year Question

1. Do you agree that there is a growing trend of opening new sugar mills in the Southern states of India? Discuss with justification. (2013)
2. Whereas the British planters had developed tea gardens all along the Shivaliks and Lesser Himalayas from Assam to Himachal Pradesh, in effect they did not succeed beyond the Darjeeling area. Explain. (2014)
3. Why did the Green Revolution in India virtually by-pass the eastern region despite fertile soil and good availability of water? (2014)
4. Given the vulnerability of Indian agriculture to vagaries of nature, discuss the need for crop insurance and bring out the salient features of the Pradhan Mantri Fasal Bima Yojana (PMFBY) (2016)
5. Given the vulnerability of Indian agriculture to vagaries of nature, discuss the need for crop insurance and bring out the salient features of the Pradhan Mantri Fasal Bima Yojana (PMFBY). (2016)
6. How has the emphasis on certain crops brought about changes in cropping patterns in recent past? Elaborate the emphasis on millets production and consumption. (2018)
7. Discuss the factors for localization of agro-based food processing industries of North-West India. (2019)

3. UPSC Prelim Previous Year Question

1. The lower Gangetic plain is characterised by humid climate with high temperature throughout the year. Which one among the following pairs of crops is most suitable for this region? (2011)
   (a) Paddy and cotton (b) Wheat and Jute
   (c) Paddy and Jute (d) Wheat and cotton

2. A state in India has the following characteristics:
   1. Its northern part is arid and semi-arid.
   2. Its central part produces cotton.
   3. Cultivation of cash crops is predominant over food crops.

   Which one of the following states has all of the above characteristics? (2011)
   (a) Andhra Pradesh (b) Gujarat
   (c) Karnataka (d) Tamil Nadu

3. Among the following States, which one has the most suitable climatic conditions for the cultivation of a large variety of orchids with minimum cost of production, and can develop an export oriented industry in this field? (2011)
   (a) Andhra Pradesh (b) Arunachal Pradesh
   (c) Madhya Pradesh (d) Uttar Pradesh

4. Consider the following crops of India:
   1. Groundnut
   2. Sesamum
   3. Pearl millet

   Which of the above is/are predominantly rainfed crop/crops? (2012)
   (a) 1 and 2 only (b) 2 and 3 only
   (c) 3 only (d) 1, 2 and 3

Student Notes:

5. Consider the following crops of India:
1. Cowpea
2. Green gram
3. Pigeon pea

Which of the above is/are used as pulse, fodder and green manure? (2012)
(a) 1 and 2 only (b) 2 only
(c) 1 and 3 only (d) 1, 2 and 3

6. Consider the following crops:
1. Cotton
2. Groundnut
3. Rice
4. Wheat

Which of these are Kharif crops? (2013)
(a) 1 and 4 (b) 2 and 3 only
(c) 1, 2 and 3 (d) 2, 3 and 4

7. Consider the following pairs :

Programme		**Project Ministry**
1. Drought-Prone Area Programme	:	Ministry of Agriculture
2. Desert Development Programme	:	Ministry of Environment and Forests
3. National Watershed Development Project for Rainfed Areas	:	Ministry of Rural Development

Which of the above pairs is/are correctly matched? (2014)
(a) 1 and 2 only (b) 3 only
(c) 1, 2 and 3 (d) None

8. In the context of food and nutritional security of India, enhancing the 'Seed Replacement Rates' of various crops helps in achieving the food production targets of the future. But what is/are the constraint/constraints in its wider/greater implementation? (2014)
1. There is no National Seeds Policy in place.
2. There is no participation of private sector seed companies in the supply of quality seeds of vegetables and planting materials of horticultural crops.
3. There is a demand-supply gap regarding quality seeds in case of low value and high volume crops.

Select the correct answer using the code given below.
(a) 1 and 2 (b) 3 only
(c) 2 and 3 (d) None

9. Consider the following pairs:

Region		**Well-known for the production of**
1. Kinnaur	:	Areca nut
2. Mewat	:	Mango
3. Coromandel	:	Soya bean

Which of the above pairs is/are correctly matched? (2014)
(a) 1 and 2 only (b) 3 only
(c) 1, 2 and 3 (d) None

10. What can be the impact of excessive/inappropriate use of nitrogenous fertilizers in agriculture?
1. Proliferation of nitrogen-fixing microorganisms in soil can occur.
2. Increase in the acidity of soil can take place.

Student Notes:

3. Leaching of nitrate to the ground water can occur.

Select the correct answer using the codes given below. (2015)

(a) 1 and 3 only (b) 2 only
(c) 2 and 3 only (d) 1, 2 and 3

11. Why does the Government of India promote the use of 'Neem-coated Urea' in agriculture? (2016)

(a) Release of Neem oil in the soil increases nitrogen fixation by the soil microorganisms
(b) Neem coating slows down the rate of dissolution of urea in the soil
(c) Nitrous oxide, which is a greenhouse gas, is not at all released into atmosphere by crop fields
(d) It is a combination of a weedicide and a fertilizer for particular crops

12. Recently, which of the following States has explored the possibility of constructing an artificial inland port to be connected to sea by a long navigational channel? (2016)

(a) Andhra Pradesh (b) Chhattisgarh
(c) Karnataka (d) Rajasthan

13. What is/are the advantage/advantages of implementing the 'National Agriculture Market' scheme?

1. It is a pan-India electronic trading portal for agricultural commodities.
2. It provides the farmers access to nationwide market, with prices commensurate with the quality of their produce.

Select the correct answer using the code given below: (2017)

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

14. With reference to agriculture in India, how can the technique of 'genome sequencing', often seen in the news, be used in the immediate future?

1. Genome sequencing can be used to identify genetic markers for disease resistance and drought tolerance in various crop plants.
2. This technique helps in reducing the time required to develop new varieties of crop plants.
3. It can be used to decipher the host-pathogen relationships in crops.

Select the correct answer using the code given below: (2017)

(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

15. Which of the following statements can help in water conservation in agriculture?

1. Reduced or zero tillage of the land
2. Applying gypsum before irrigating the field
3. Allowing crop residue to remain in the field

Select the correct answer using the code given below: (2017)

(a) 1 and 2 only (b) 3 only
(c) 1 and 3 only (d) 1, 2 and 3

16. With reference to the circumstances in Indian agriculture, the concept of "Conservation Agriculture" assumes significance. Which of the following fall under the Conservation Agriculture?

1. Avoiding the monoculture practices
2. Adopting minimum tillage
3. Avoiding the cultivation of plantation crops

Student Notes:

4. Using crop residues to cover soil surface
5. Adopting spatial and temporal crop sequencing/crop rotations

Select the correct answer using the code given below: (2018)

(a) 1, 3 and 4 (b) 2, 3, 4 and 5
(c) 2, 4 and 5 (d) 1, 2, 3 and 5

17. With reference to the cultivation of Kharif crops in which in the last five years consider the following statements:

1. Area under rice cultivation is the highest.
2. Area under the cultivation of jowar is more than that of oilseeds.
3. Area of cotton cultivation is more than that of sugarcane.
4. Area under sugarcane cultivation has steadily decreased.

Which of the statements given above is/are correct? (2019)

(a) 1 and 3 only (b) 2, 3 and 4 only
(c) 2 and 4 only (d) 1, 2, 3 and 4

18. What are the advantages of fertigation in agriculture?

1. Controlling the alkalinity of irrigation water is possible.
2. Efficient application of Rock Phosphate and all other phosphatic fertilizers is possible.
3. Increased availability of nutrients to plants is possible.
4. Reduction in the leaching of chemical nutrients is possible.

Select the correct answer using the code given below: (2020)

(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 1, 3 and 4 only (d) 2, 3 and 4 only

19. What is/are the advantage/ advantages of zero tillage in agriculture?

1. Sowing of wheat is possible without burning the residue of previous crop.
2. Without the need for nursery of rice saplings, direct planting of paddy seeds in the wet soil is possible.
3. Carbon sequestration in the soil is possible.

Select the correct answer using the code given below: (2020)

(a) 1 and 2 only (b) 2 and 3 only
(c) 3 only (d) 1, 2 and 3

20. In the context of India, which of the following is/are considered to be practice(s) of eco-friendly agriculture?

1. Crop diversification
2. Legume intensification
3. Tensiometer use
4. Vertical farming

Select the correct answer using the code given below: (2020)

(a) 1, 2 and 3 only (b) 3 only
(c) 4 only (d) 1, 2, 3 and 4

4. Vision IAS Previous Years Mains Questions

Student Notes:

1. The cropping pattern of a region is influenced by geo-climatic, socio-cultural, economic, historical and political factors. Substantiate with relevant examples.

Approach:

- Briefly explain the concept of cropping pattern.
- Explain with examples how cropping pattern is influenced by various factors such as:
  - Geo-climatic
  - Socio-cultural
  - Economic
  - Historical
  - Political
- Give a brief conclusion.

Answer:

Cropping pattern refers to the proportion of area under different crops at a particular period of time in a unit area. In other words, it is a yearly sequence and spatial arrangement of sowing and fallow on a given area.

Factors affecting cropping pattern of a region:

- **Geo-climatic factors:** It includes factors like nature of soil, climate, rainfall etc. In areas having sufficient rainfall and suitable conditions for water logging like in West Bengal, the most appropriate crop is rice. Jowar and Bajra are grown in in rain deficit areas such as Rajasthan and Gujarat. The fertile well-drained soil of Indo-Gangetic Plains is suitable for growing wheat. The black soil in Deccan and Malwa Plateau supports Cotton cultivation.
- **Socio-cultural factors:** It includes religion, customs, traditions etc. For example Sikh farming community discards the cultivation of tobacco in Punjab despite profitability and favorable environmental conditions suitable for tobacco cultivation. Similarly, poor farmers with small land holdings prefer to grow cereals and other food-grains rather than opting for cash crops.
- **Economic factors:** Prices of agricultural commodities, income of farmers, size of holdings, availability of agricultural inputs and marketing facilities, nature of land tenure, availability of finance etc. also determine cropping pattern. Price incentives like MSP/FRP for crops like sugarcane and wheat can induce the farmers to shift over to that crop.
- **Historical factors**: Crops such as Tea, Coffee, tobacco and cashew nuts were brought to India by British and Portuguese. British were responsible for construction of extensive canal networks in Punjab, Narmada valley, and Andhra Pradesh. It supported agricultural reforms and influenced cropping pattern of these regions.
- **Political Factors:** India's commitment to food security has given the boost to food grains production across the country**.** In socialist countries, even the combination of crops and their precise rotation is dictated by the government.

In addition to above factors, cropping pattern in countries like India is also dictated by infrastructural and technological support and household's need for food, fodder, fuel and fiber.

Student Notes:

2. Integrating ecology and technology is the way forward towards achieving Evergreen Revolution in India. Discuss.

Approach:

- Briefly explain the phrase 'Evergreen Revolution'.
- Explain what integrating ecology and technology implies and its importance in ushering Evergreen Revolution.

Answer:

Prof. M.S. Swaminathan coined the term 'Evergreen Revolution', which pertains to increasing agricultural production and productivity without causing ecological and social harm.

Though Green Revolution made India self-reliant in food grain production, it had negative ecological consequences. It resulted in depletion of groundwater levels, soil erosion and loss of biodiversity. Therefore, the agricultural experts are increasingly advocating for adoption of agricultural technology that is not just economical, but also ecologically sensitive for transition towards Evergreen Revolution.

Integration of Technology and Ecology

Integration of environmentally benign technologies can enhance the spatial and temporal scales over which ecological patterns and processes can be analyzed. In the wake of increasing demand and shrinking resources, technology must focus on increasing productivity per unit area of land and water. Following technologies may help achieve the aforementioned objectives:

- **Integration of Biotechnology:** Modern biotechnology can be used to produce nutritious, higher crop yields and plants that are naturally pest and drought resistant.
- **Integration of ICT and Space Technology:** Satellite farming or site specific crop management (SSCM) can help in utilising resources optimally while lowering the cost of production. For example, remote sensing, soil quality assays, crop yield predictions and marketing using IT can further revolutionize agriculture.
- **Integration of nanotechnology:** It can help in enhancing the ability of plants to absorb nutrients, efficient targeting of inputs, disease detection and control while withstanding environmental changes.
- **Precision agriculture technology**: It aims to achieve optimal crop, livestock, or forestry output by using data/information to adjust inputs accordingly. For example, variable rate Fertigation technique according to soil type.
- **Seawater farming technology:** It can address the lack of freshwater and undesirable soil conditions for agricultural activities in coastal regions.

According to Dr. Swaminathan, move towards Evergreen Revolution is essential to achieve the goals of food and nutrition security with sustainable agriculture and social protection. It can be attained through taking scientific measures that includes **anticipatory research** for climate change adaptation and mitigation, **participatory research** for integrating farmer's wisdom with modern technology and **translational research** to fill the gap between knowledge and application.

Student Notes:

3. Highlight the constraints faced by rainfed agriculture in India. Discuss some agronomic practices that can be adopted for stabilizing agricultural production in rainfed areas.

***Approach*:**

- Introducing the concept of rainfed agriculture, briefly discuss its importance in India.
- Bring out the challenges faced by rainfed agriculture in India.
- Discuss some agronomic practices that can be adopted for stabilizing production in rainfed areas.
- Conclude with further measures.

***Answer*:**

Rain fed agriculture is a form of agriculture that depends on rain water for its irrigation. Rain-fed areas contribute significantly to the India's food production and cover around 65 percent of the net sown area. In addition to contributing to major production of millets, pulses, cotton, oilseeds, and around 40 per cent rice production, rainfed agriculture also supports livestock economy.

However, it is marred by certain challenges such as:

- **Low public investments**: Even though rainfed agriculture contributes to 60 per cent of the value of agriculture GDP of India, it receives little attention when it comes to public policy. This is visible with the lack of public investment in rainfed areas as against irrigated areas.
- **Lower remuneration:** According to statistics from the National Rainfed Area Authority (NRAA), farmers in rainfed areas earn only 20-30 per cent from farm-related activities as against other farmers. Market access is also a major problem due to lack of rural road infrastructure.
- **Low procurement under Minimum Support Price (MSP) regime:** The pricing policy is also biased in favour of certain crops. For instance, the government spent Rs. 5,40,000 crore on procuring rice and wheat at MSP (Minimum Support Price) between 2003-04 and 2012-13, its expenditure on procurement of major rainfed crops such as coarse cereals, millets and pulses during the same period was merely Rs. 3,200 crore.
- **Misalignment of cultivation practices:** Cultivation of water intensive crops in rain fed areas further worsens the situations. For e.g. it is argued that sugarcane cultivation in fact is the main reason for the drought in Marathwada.
- **Lack of research and development:** Lab to land transfer of technology in these areas remains dismal. Also, various hybrid seeds are not suitable for rain fed areas due to lack of water and thus hampering any efforts to attain higher yield.
- **Climate change:** Changing soil composition and variability of rainfall in wake of climate change is also a major challenge.

In order to address these challenges, certain agronomic practices can be adopted which can solve the inequities between rainfed and irrigated agriculture. For example:

- **Agronomic management practices:** Various practices such as inter and multi cropping and crop rotation, shifting to non-farm activities, insurance covers, up scaling techniques such as solar pumps, drip irrigation and sprinklers could be adopted for stabilizing crop production in these areas.
- **Land and water use management:** Practices such as dry land farming, precision farming, and rehabilitation of rainfed wastelands as well as watershed management in these areas.

Student Notes:

- **Holistic soil health management:** Soil-quality improvement through conservation agricultural practices, balanced fertilization, harnessing the potential of biofertilizers and microorganisms, as well as carbon sequestration practices.
- **Crop planning:** Crop varieties for dryland areas should be of short duration and high yielding which can be harvested within rainfall periods and have sufficient residual moisture in soil profile for post-monsoon cropping.
- **Integrated weed management:** Weeds being more aggressive, adaptive and persistent pose serious threat to crop production in dryland areas. Integrated weed control strategies can result in sustainable crop production and provide livelihood security in such regions.

Apart from that there is need to foster the process of climate adaption in agriculture through adoption of **Climate Smart Agriculture**. Also, there is urgent need to educate farmers and reorient **Krishi Vigyan Kendra** and other grass root organizations with specific and more funds for better risk coping measures.

4. Zero Budget Natural Farming (ZBNF) provides an alternative to capital and chemical intensive agriculture currently being practiced in India. Analyze.

***Approach*:**

- Briefly state the current status of conventional farming in India.
- Briefly explain the concept of Zero Budget Natural Farming (ZBNF).
- Discuss how ZBNF provides a viable option to the conventional farming which is capital and chemical intensive.
- Suggest some steps that required to be taken to promote ZBNF.

***Answer*:**

Conventional farming methods in India are heavily dependent on capital and fertilizers. Because of high production costs, high interest rates, volatile markets and the rising costs of fossil fuel based inputs; farmers get trapped in vicious debt cycle and makes farming an unviable vocation for the next cropping season.

Zero Budget Natural Farming (ZBNF) is being seen and developed as an alternative to the conventional farming method. It is a natural farming technique in which farming is done without use of chemicals and without using any credits or spending any money on purchased inputs.

ZNBF reduces the cost of production down to zero due to utilisation of all the natural resources available in and around the crops. It has attained wide popularity in the southern states, especially Karnataka and Andhra Pradesh.

ZBNF as an alternative to commercial farming:

- ZBNF promises to end reliance on loans and drastically cut production costs, ending the debt cycle for the farmers. Use of natural farming methods will also help curb use of fertilizers and pesticides.
- It replaces fertilizers and pesticides with organic inputs to ensure perfect soil conditions for plant growth. Farmers use cow dung, urine, plants, human excreta and other biological fertilizers for crop protection. For instance, a solution made with lilac and chillies can help protect plants from pests.
- It focuses on replenishing local species of earthworms on the farm to increase the organic matter in the soil.
- It promotes adoption of mulching and Waaphasa so as to reduce the loss of natural moisture of the soil, increase soil aeration, enhance soil health and fertility and ensure favourable microclimate in the soil.

Student Notes:

- It also promotes inter-cropping wherein combination of various crops is grown simultaneously to produce greater yield on given piece of land by making use of resources that may be utilised by single crop.
- It will provide resilient agriculture system in wake of climate change and increasing scarcity of water**.**

Mainstreaming ZBNF

ZBNF has been practiced for over a decade at small scale level across India. But in the recent times, it has been adopted at a much larger scale in South India. Andhra Pradesh government in an effort to make transition to 100% chemical free farming became the first state to adopt ZBNF.

However, few steps like scientific validation of ZBNF, policy traction to pull farmers out from corporate sponsored chemical based farming, scaling up of investment, diverting existing subsidies away from chemical fertilizers and strengthening the existing Krishi Vigyan Kendra Network can help in widespread adoption of ZBNF.

According to **UN Environment,** Zero Budget Natural Farming also creates the social capital necessary for vibrant and inclusive agricultural production, by establishing farmers' federations and self-help groups, and placing farmers at the forefront of knowledge creation and dissemination.

5. What do you understand by Seed Replacement Rate? Explaining the concept of breeder, foundation and certified seeds, highlight the major policy initiatives taken in order to address the challenge of quality seed availability to farmers.

Approach:

- Define Seed Replacement Rate.
- Briefly explain concepts of breeder, foundation and certified seeds.
- Enlist the policy initiatives undertaken to address the quality issues.
- Conclude with a way forward.

Answer:

Seed Replacement Rate or Ratio (SRR) is a measure of total cropped area sown with certified/ quality seeds in comparison to farm saved seeds. Since certified/ quality seeds have better productivity, high SRR denotes high production and productivity, and consequently better returns on investment.

Breeder, foundation and certified seeds are three generations in the seed multiplication chain recognized under the Indian seed sector initiatives. This limited generations' system of seeds helps ensure quality and purity of seeds as these flow from breeder to farmer.

Seed	Definition	Producers	Certification
BREEDER	Progeny of nucleus seed of same variety; 100% physical and genetically pure seed for production of foundation seed	Plant breeder instituted, State Agriculture Universities and other **public** bodies, under mandate of ICAR	Issued by producing breeder with golden yellow colour certificate

Student Notes:

FOUNDATION	Progeny of breeder seed, produced from breeder seed or foundation seed that can be clearly traced to breeder seed	Recognized seed producing bodies in **public and private** sector	Issued by seed certification agencies as per **Indian Minimum Seeds Certification Standards, 1988** (IMSCS) with white colour certificate
CERTIFIED	Progeny of foundation seed, as per standards prescribed in the IMSCS, 1988	Registered seed growers under supervision of seed certification agencies	Issued by seed certification agency with a blue colour certificate

Seeds being the starting point of a crop production system, their quality determine the limits of output farmers can harvest. Understandably, the government has taken various initiatives to ensure availability of quality seeds to the Indian farmers. These include:

1. **National Seeds Programme (1976-95)**: It was launched with the aid of the World Bank and was implemented in three phases leading to the creation of State Seeds Corporations, State Seed Certification Agencies, State Seed Testing Laboratories, Breeder Seed Programmes etc.
2. **Protection of Plant Varieties and Farmers Rights (PPV&FR) Authority**, under the PPV&FR Act, 2001 (enacted in compliance with the TRIPS Agreement of the WTO): It is mandated to protect plant varieties, encourage development of new varieties, stimulating investment in R&D and facilitate growth of seed industry
3. **National Mission on Oilseeds and Oil Palm (NMOOP) since 2014**: It is being implemented under three mini-missions. It aims to increase SRR with focus on Varietal Replacement, diversification, inter-cropping and irrigation coverage
4. **Other steps and public organizations**: These include production and distribution subsidy, seed mini-kits, Seed Bank Scheme (2000), National Seeds Policy (2002); National Seed Corporation (NSC) since 1963, Seed Hubs, Seed Summits, Cooperative Institutes and State Departments of Agriculture, nearly 500 private seed agencies and so on

Further, the Ashok Dalwai Committee constituted to suggest ways to double farmers' income, recommended to increase the SRR, replace the older with newer varieties, promote hybrid technology, strengthen seed testing facilities, adopt uniform seed licencing policy across the country, deploy PPP model from R&D, promote export of seeds, and revamp public bodies in this sector. These steps will not only address the challenge of quality seeds but also decrease the production costs for farmers, thus adding to their income.

6. Giving an account of the sources of income growth identified by the government in its action plan for doubling the income of farmers, mention the steps taken by the government in this regard.

Approach:

- Briefly introduce with the government target of Doubling of Farm Income (DFI).
- Mention the sources of income growth identified by the government in its action plan for DFI.
- Highlight the steps taken by the government in this regard.
- Conclude on the basis of the above points.

Answer:

Student Notes:

The Government has set a target of doubling of farmers' income by the year 2022. To achieve it, the Government had constituted an Inter-Ministerial Committee to examine the issues relating to Doubling of Farmers' Income (DFI) and recommend strategies. It has identified **seven sources of income growth** which include:

- Improvement in **crop productivity**
- Improvement in **livestock productivity**
- **Resource use efficiency** or savings in the cost of production
- Increase in the **cropping intensity**
- Diversification towards **high value crops**
- **Improvement in real prices** received by farmers, and
- Shift from farm to **non-farm occupations**.

Steps taken by the government in this regard include:

- **Market reforms:**
  - **Encouraging contract farming** through the State Governments by promulgating of Model Contract Farming Act. This provides farmers with access to markets that would not otherwise have been available to them
  - **Up-gradation of Gramin Haats** to work as centers of aggregation and for direct purchase of agricultural commodities from the farmers.
  - **e-NAM** to provide farmers an electronic online trading platform.
- **Input rationalisation:**
  - **Soil Health Cards** distribution to farmers so that the use of fertilizers can be rationalized.
  - **Pradhan Mantri Krishi Sinchayee Yojana** to increase water efficiency. Also, to conserve water and address irrigation-related problems the government has constituted a new **Jal Shakti ministry.**
- **Reducing risks**: **Pradhan Mantri Fasal Bima Yojana** (PMFBY) by making loan available to farmers at a reduced rate of 4 per cent per annum would lead to better insurance coverage to crops.
- **Availability of credit**: Extending the facility of **Kisan Credit Card (KCC)** for animal husbandry and fisheries related activities as well as Interest Subvention facilities to such categories of farmers.
- **Direct Income support: Pradhan Mantri Kisan Samman Nidhi** income support scheme provides for disbursement of Rs. 6000/year in three equal instalments to an estimated 125 million small and marginal farmers holding up to 2 hectares.
- **Diversification**:
  - Schemes relating **to tree plantation (Har Medh Par Ped), Bee Keeping, Dairy and Fisheries** are also implemented. A **special fund** has been created to develop a fishery industry-related infrastructure.
  - The government has brought **100% FDI in food processing and implemented SAMPADA scheme** to create modern infrastructure with efficient supply chain management from farm gate to retail outlet, thereby providing better prices to farmers and helping in doubling of farmers' income.

Giving a further boost for the farmers' income, the government has approved the increase in the Minimum Support Price (MSPs) for all Kharif & Rabi crops for 2018-19 season at a level of at least one and half times of the cost of production. These steps if implemented effectively, have potential to maximize the income of the farmers.

Student Notes:

7. Fertilizers have been one of the key inputs in the agricultural sector since Green Revolution in India. In this context, give an account of distribution of fertilizer industry in India.

Approach:

- In the introduction, highlight the role of fertilizers in the agricultural sector since the Green Revolution in India.
- Give a detailed account of distribution of fertilizer industries in India.
- Conclude accordingly.

Answer:

- With the advent of the Green Revolution and High-Yielding Variety (HYV) seeds, chemical fertilizers have been a major agricultural input. They have helped India achieve the objective of being self-sufficient in the production of food grains and have accelerated the agricultural growth. As a result, the fertilizer industry has been one of the core industries of Indian economy, as it manufactures some of the most important raw materials required for crop production.

Distribution of fertilizer industry in India:

- In India, both private and public sector fertilizer companies are in operation, and presently there are more than 57 large and 64 medium and small fertilizer production units. Gujarat, Tamil Nadu, Uttar Pradesh, Maharashtra, Andhra Pradesh, Punjab and Kerala are the main fertilizer producing states and **account for about half of the total fertilizers** produced in India.

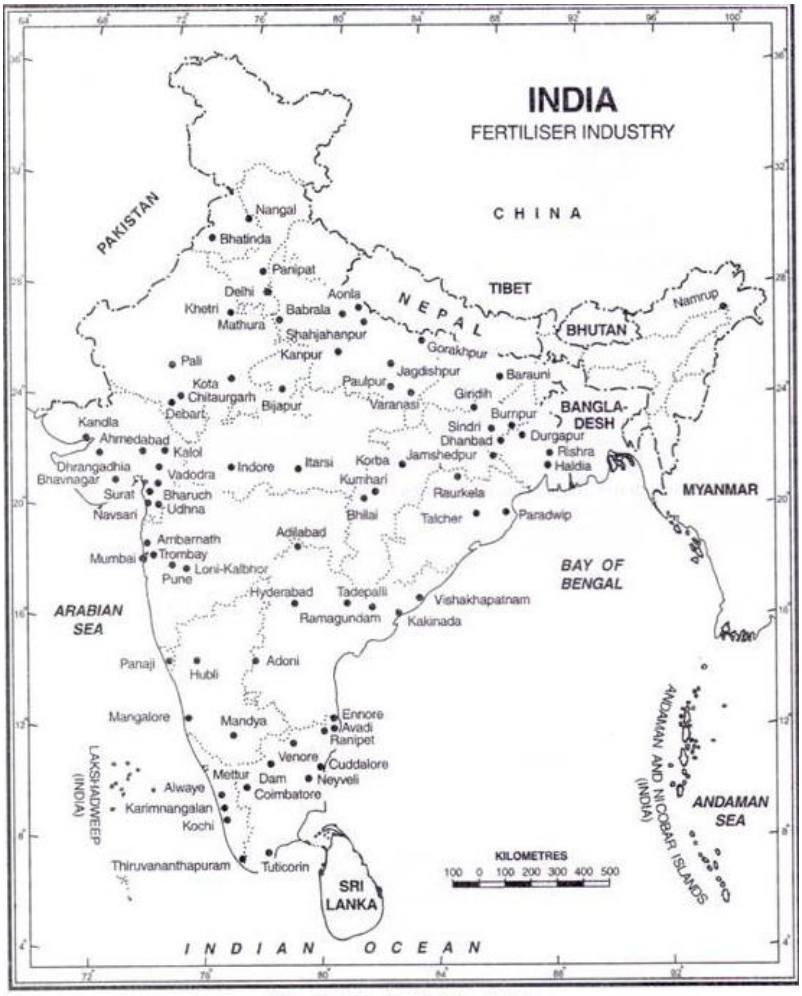

FIG. 27.14. India : Fertilizer Industry

Student Notes:

- The distribution of fertilizer industry is closely related to **petrochemicals**. About 70% of units producing **nitrogenous fertilizers** use **naphtha** as the basic raw material. That is why most of the fertilizer plants are **located near the oil refineries**. Some fertilizer plants, such as ***Neyveli Lignite Corporation Limited***, use steel slug as well as coke and lignite.
- In case of **phosphate fertilizers**, nearly 50% of domestic requirement is met through indigenous production, however, the raw materials and intermediates are largely imported. Phosphate fertilizer plants are close to **phosphate reserves** available in Uttar Pradesh, Madhya Pradesh and Rajasthan. For example, ***FCIL-Arawali Gypsum and Mineral India Limited (FAGMII).***
- Some plants are based on imported phosphate minerals. Therefore, some fertilizers plants are located close to **port locations**. For example, ***Mangalore Chemicals & Fertilizers Limited***. Due to the lack of viable sources/reserves in India for **potash**, its demand is almost entirely met through imports.
- Sulphur is another important mineral used for fertilizers which is readily available in states such as **Tamil Nadu**.
- Fertilizer industries are one of the most **energy-intensive** sectors and are located close to power plants. For example, ***Brahmaputra Valley Fertilizer Corporation Limited*** is located close to Namrup Thermal Power Station.
- Transportation of naphtha or gas through rail or pipelines has facilitated widespread distribution of fertilizer plants. The ***HBJ Gas pipeline*** has given birth to six gas based fertilizer plants at Vijaypur, Jagdishpur, Aonla, Gadipan, Babrala and Shahajahanpur.

India is the third largest producer of nitrogenous fertilizers in the world. The fertilizer industry is now one of the fastest growing basic industries which has taken rapid strides in recent years. It produces a wide range of fertilizers to suit different soil and crop requirements in different parts of the country.

8. Identify the problems faced by Indian agriculture as a consequence of changing land holding pattern as witnessed in the findings of Agriculture census, 2015-16. In light of these problems, suggest suitable ways to resolve such structural issues in agriculture.

Approach:

- Elaborate the status of landholdings in India by highlighting the main findings of the census.
- List the problems faced by agriculture due to this scenario of land holdings.
- Suggest measures to overcome these challenges.

Answer:

The agriculture census 2015-2016 gives an account of the change in nature of agricultural landholding. It indicates a 1.53 per cent decline in total operated area at 157.14 million hectare as compared to 2010-11 data, but a rise in both operational holdings and female participation, thus indicating further fragmentation of land holdings. **Following are the findings of the census vis-a-vis land holdings in India:**

- **Rise in the percentage of female landholding farmers**: Not only is there the rise in the female tillers but the percentage of female operational landholders increased from 12.79% in 2010-11 to 13.87% in 2015-2016.
- **Increase in the number of operational holdings** which has gone up by 5.33 per cent to 146 million in 2015-16 from 138 million in 2010-11.
- **Decline in the average size of operational agricultural holdings:** It has declined to 1.08 hectares (ha) in 2015-16 from 1.15 ha in 2010-11.

Student Notes:

- **Increase in smaller and medium level landholdings**: Out of the total land holdings as much as 86.21% of India's cultivated farmland is held by small and marginal farmers with less than two hectares of land, while those with 10 hectares and more account for just 0.57%. The share of small and marginal farmers in total operational area — both cultivated and uncultivated were 47.34%, up from 44.31% five years earlier.

Problems faced by agriculture associated with prevalent nature of land holdings:

- **Less profitable agriculture:** More profitable crops, like fruit crops, require larger plot areas, so if farmers possess small and fragmented plots they may be forced to grow less profitable crops.
- **Issues with mechanization of agriculture and advanced agricultural practices:** Mechanization makes agriculture profitable, but requires larger areas for operation. Even environmentally friendly farm practices such as organic farming have extremely low yield in the small holdings.
- **Difficulty in access to formal credit** is a prominent drawback related to small farm holdings. Only 14% of **marginal** and 27% of small holdings were able to get credit from institutional sources.
- **Land wastage:** Land fragmentation involves a complicated boundary network among parcels which cause land wastage because a part of a holding remains uncultivated at the margins. This is important given limited availability of land for agriculture considering the structural change Indian economy is going through.
- **Reduction in land productivity**: Farmers employ various treatments and farming methods on small landholdings, which further degrades the quality and fertility of soil, impacting the productivity.

Measures to overcome the prevalent issues

- **Cooperative farming:** A more participative practice can bring in better results. With the growing feminization of agriculture a greater number of women cooperatives are likely to yield fruitful results.
- **Contract Farming and Collaborative Farming initiatives** can be a tool for farmers to collaborate for joint cultivation.
- **Corporate Farming** can be explored wherein they can substantially incentivised to specially invest in arid zones where large tracts of land may be available irrigation facilities are not present.
- **Proper access to institutionalized credit markets** to be able to provide suitable inputs to the small landholdings or to buy more land.
- **Skilling and educating the farmers and providing high yielding variety seeds** to enhance productivity.

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7 IN TOP 10 SELECTIONS IN CSE 2019

2 AIR
JATIN KISHORE

3 AIR
PRATIBHA VERMA

6 AIR
VISHAKHA YADAV

7 AIR
GANESH KUMAR BASKAR

8 AIR
ABHISHEK SARAF

9 AIR
RAVI JAIN

10 AIR
SANJITA MOHAPATRA

9 IN TOP 10 SELECTIONS IN CSE 2018

1 AIR
KANISHAK KATARIA

2 AIR
AKSHAT JAIN

3 AIR
JUNAID AHMAD

DELHI JAIPUR HYDERABAD PUNE AHMEDABAD LUCKNOW CHANDIGARH GUWAHATI

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