Venkateswarlu Nagineni

Indian Geography

Venkateswarlu Nagineni

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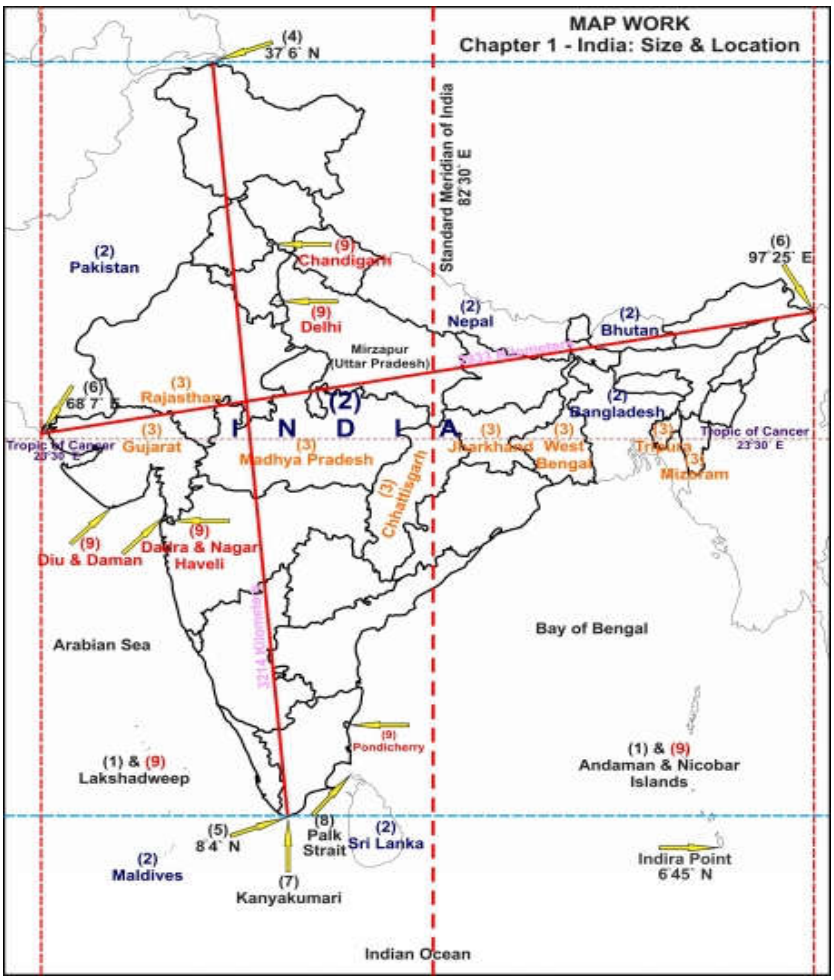
1. Geography of India: An Introduction

As the 7th largest country in the world, India stands apart from the rest of Asia, marked off as it is by mountains and the sea, which give the country a distinct geographical entity.

Bounded by the Great Himalayas in the north, it stretches southwards and at the Tropic of Cancer, tapers off into the Indian Ocean between the Bay of Bengal on the east and the Arabian Sea on the west.



Map-key:

1. The island groups of India lying in the Arabian Sea and the Bay of Bengal.
2. The countries constituting Indian Subcontinent.
3. The states through which the Tropic of Cancer passes.
4. The northernmost latitude in degrees (Indira Col in Jammu and Kashmir).

5. The southernmost latitude of the **Indian mainland** in degrees (Kanyakumari in Tamil Nadu). Note that the southernmost point of **India** is the Indira Point which is the southernmost point of Great Nicobar Island of the Andaman and Nicobar archipelago. The Indira Point was previously known as the Pygmalion Point or the Parson Point.
6. The eastern and the westernmost longitudes in degrees.
7. The place situated on the three seas.
8. The strait separating Sri Lanka and India.
9. The Union Territories of India.

Let's take a look at India's geographical setting:

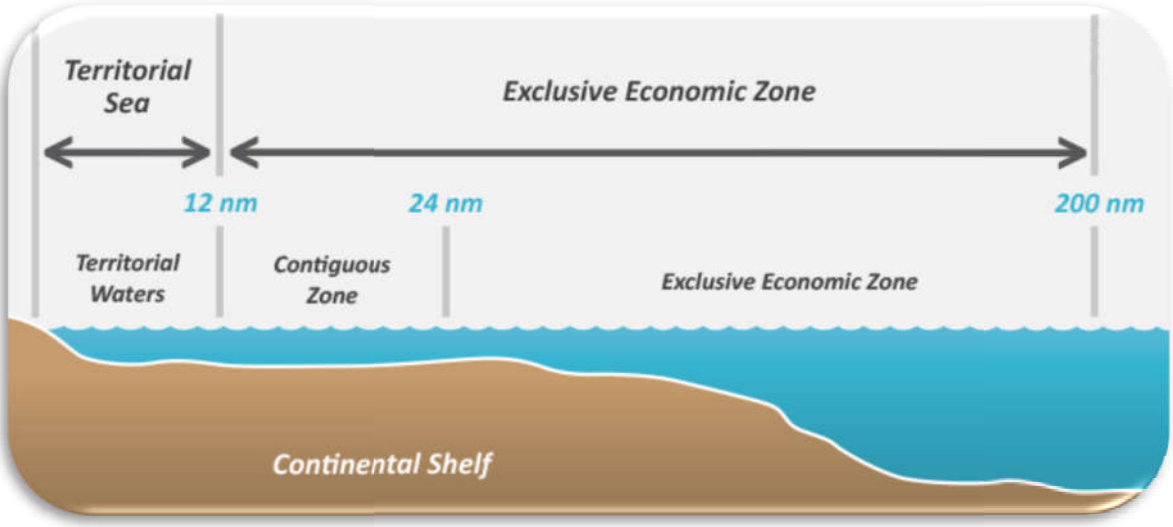
Various Geographical facts at a glance	
Location	India lies to the north of the equator in Southern Asia

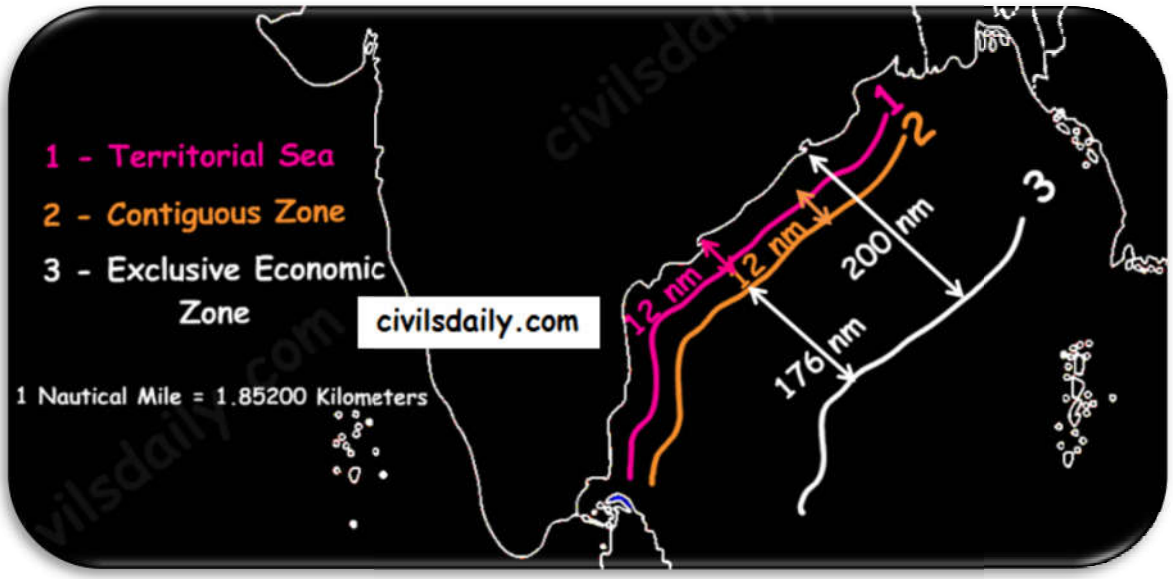
Geographical Extent	• The Indian mainland:
	  ○ **Latitude:** 8°4´N to 37°6´ North
	  ○ **Longitude:** 68°7´ E to 97°25´ East
	• India's territorial sea is 12 nautical miles (about 21.9 km) from the main coastline. India has absolute rights to use this area.*(See the note below this table)
	• Our southern boundary extends up to 6°45' N latitude in the Bay of Bengal (the Indira Point in Andaman and Nicobar islands).

Coastline	7,517 km, including the mainland, the coastlines of Andaman and Nicobar Islands in the Bay of Bengal and Lakshadweep Islands in the Arabian Sea. Gujarat has the longest coastline in comparison to other coastal states followed by Andhra Pradesh.
Area	India measures 3,214 km from north to south and 2,933 km from east to west with a total area of 3,287,263 sq km. Areawise, Rajasthan is the largest state and Goa the smallest.
Bordering Countries:	• Afghanistan and Pakistan in the north-west. (**Durand Line** – the border line between India and Afghanistan, presently separates PoK and Afghanistan; **Radcliffe Line** – the border line between India and Pakistan, and India and Bangladesh) • China, Bhutan and Nepal in the north. (**McMohan line** – the border line between India and China) • Myanmar in the east; and • Bangladesh in the east of West Bengal. • Sri Lanka is separated from India by a narrow channel of sea, formed by Palk Strait and the Gulf of Mannar.

***Note:** [**Contiguous Zone** – The area ahead of the territorial sea frontier and 24 nautical miles from the main coastline is known as the contiguous zone. In this area, India has the fiscal rights, excise duty rights, rights related to pollution control and right to implement immigration laws.

The nautical region ahead of the contiguous zone which is up to 200 nautical miles from the main coastline is known as the **Exclusive Economic Zone (EEZ).** In this region India has rights to survey, exploitation, conservation and research on mineral resources, marine life etc.]





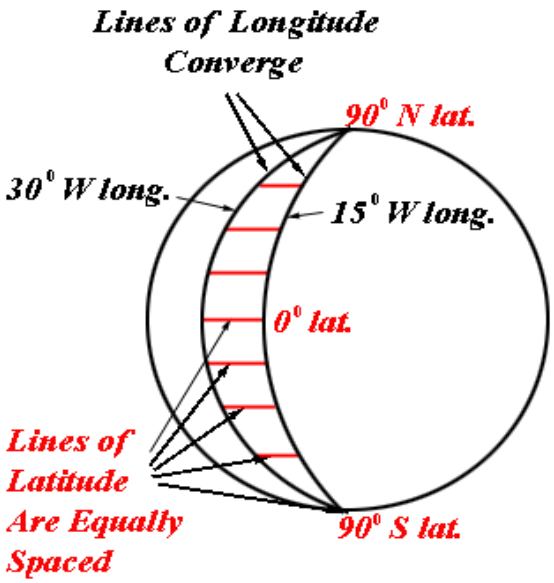
Observe India's latitudinal and longitudinal extent. Do you notice that while both the latitudinal and longitudinal extent are roughly about 30 degrees, the actual distance

measured from north to south extremity is 3,214 km and that from east to west is only 2,933 km!

What is the reason for this difference?

This is because:

Degrees of latitude are parallel so the distance between each degree remains almost constant but since degrees of longitude are farthest apart at the equator and converge at the poles, their distance varies greatly. See the following figure to understand better:



The longitudinal extent and its implications:

The longitudinal extent of India is 30 degrees. As the sun rises in the east and sets in the west; it takes 4 minutes for the sun to move across 1 longitude.

Thus, the easternmost point of India would be 2 hours ahead of the westernmost point (30 x 4 = 120 minutes), in accordance with the local time.

This difference in time might create confusion in air and rail timings and so many other things across the two states. To avoid this confusion, 82°30′ East longitude is taken as the Standard Time Meridian of India and its local time is taken a standard throughout the country.

The latitudinal extent and its implications:

- The difference between the lengths of day and night in southern most part of India is much less only about 45 minutes as they are situated near the equator. This difference

between day and night in the northern parts of India steadily goes on increasing till it becomes as much as 5 hours.

- The Tropic of Cancer passes almost halfway through the country. Thus half of the country to the south of the Tropic of Cancer is situated in the Tropical or Torrid Zone and the other half lying north of the Tropic of Cancer falls in the Subtropical zone. This location is responsible for large variations in landforms, climate, soil types and natural vegetation in the country. Wondering how?

Let's try and understand:

Notice that the tropical region is:

1) Closer to equator → availability of heat
2) Closer to water bodies → availability of water

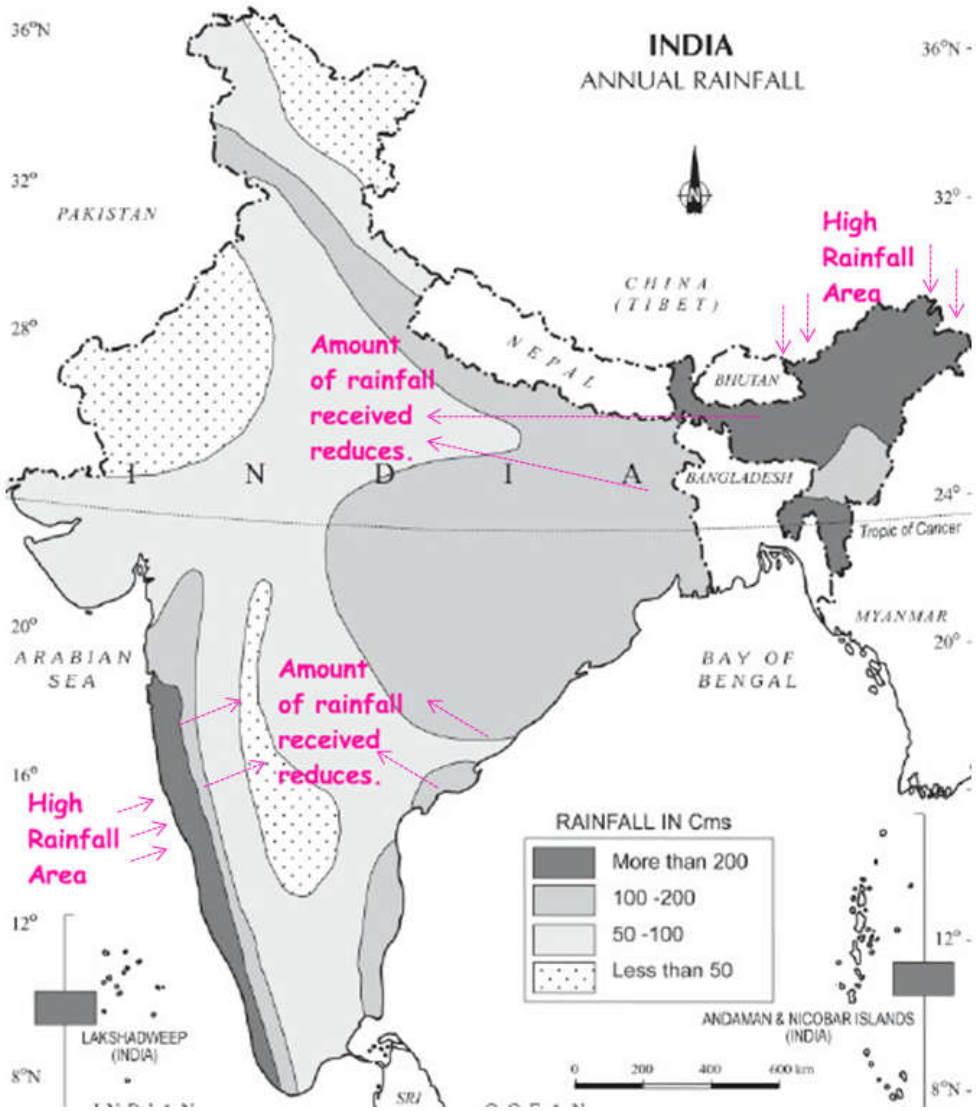
} = conditions favouring greater rainfall.

Also,

- Areas closer to the coast would experience greater rainfall

- And, as we move towards the interior areas, the moisture content of clouds and hence the rainfall experienced would decrease.

These rules broadly define the distribution of rainfall in the country as can be seen in the map below:



Still wondering how this influences the soil types and vegetation?

Rainfall experienced by a region, in turn, plays an important role in determining the soil type in that region. For example:

- Areas of high rainfall (>200cm) –> Nutrients seep to lower layers –> laterization of soil. **Laterite soils** are thus found in these areas.

Further, in these areas: Hot and humid climate + Abundant rainfall = favorable conditions for vegetation growth. As a result, the vegetation here is very dense and multilayered with evergreens [Also, called Tropical Evergreen Forests as we will discuss later]

- Similarly, in areas with 100-200cm of rainfall –> **Red and Yellow soils**

The upper layer of Red soils appears red due to the presence of iron. When the rainfall is in the range of 100-200cm, the rainwater tends to seep to the second layer of soil. Red soils appear yellow in hydrated form, thus the second layer of soils in these areas is yellow in colour.

- In areas of low rainfall – less than 60cm, we find **Desert Soil (or arid soil):** This soil is derived from the disintegration of adjacent rocks and is largely blown from coastal regions and Indus Valley. The low rainfall dictates the type of vegetation, prominent features of which are small leaves, thick bark and long roots. [Also, called Tropical Thorny Vegetation as we will discuss later]

2. The Geological Structure of India

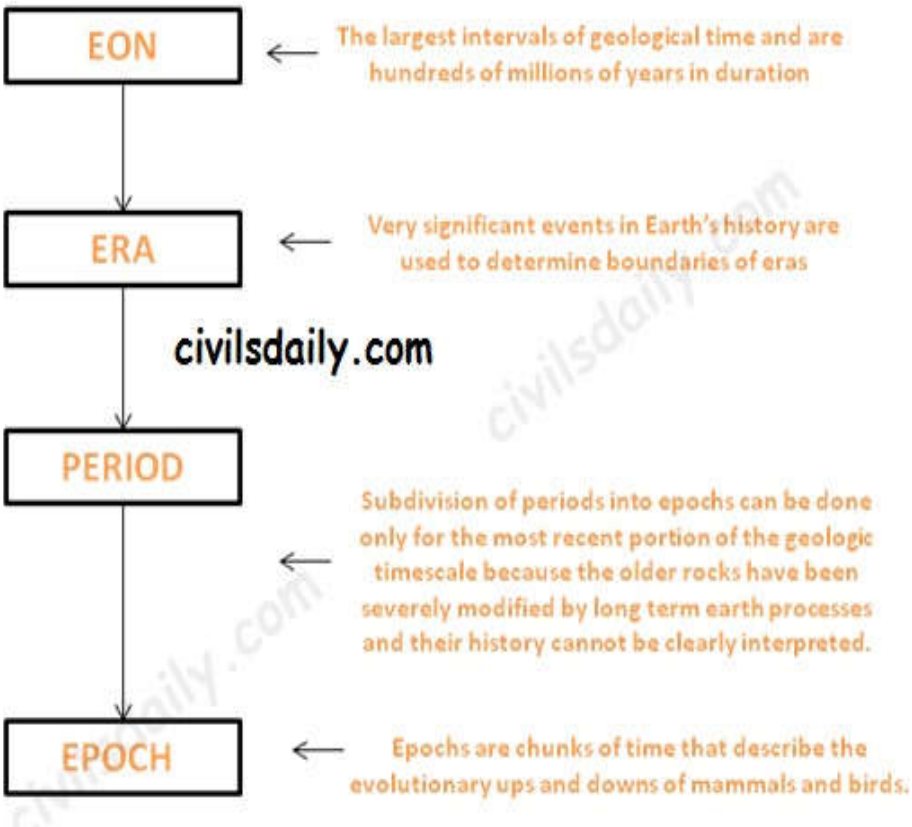
The geological structure of a country helps in understanding the types and character of rocks and slopes, the physical and chemical properties of soils, the availability of minerals, and the surface and underground water resources. But before we can study the geological structure of India, it is important that we understand what a geological time scale means:

The Geological Timescale

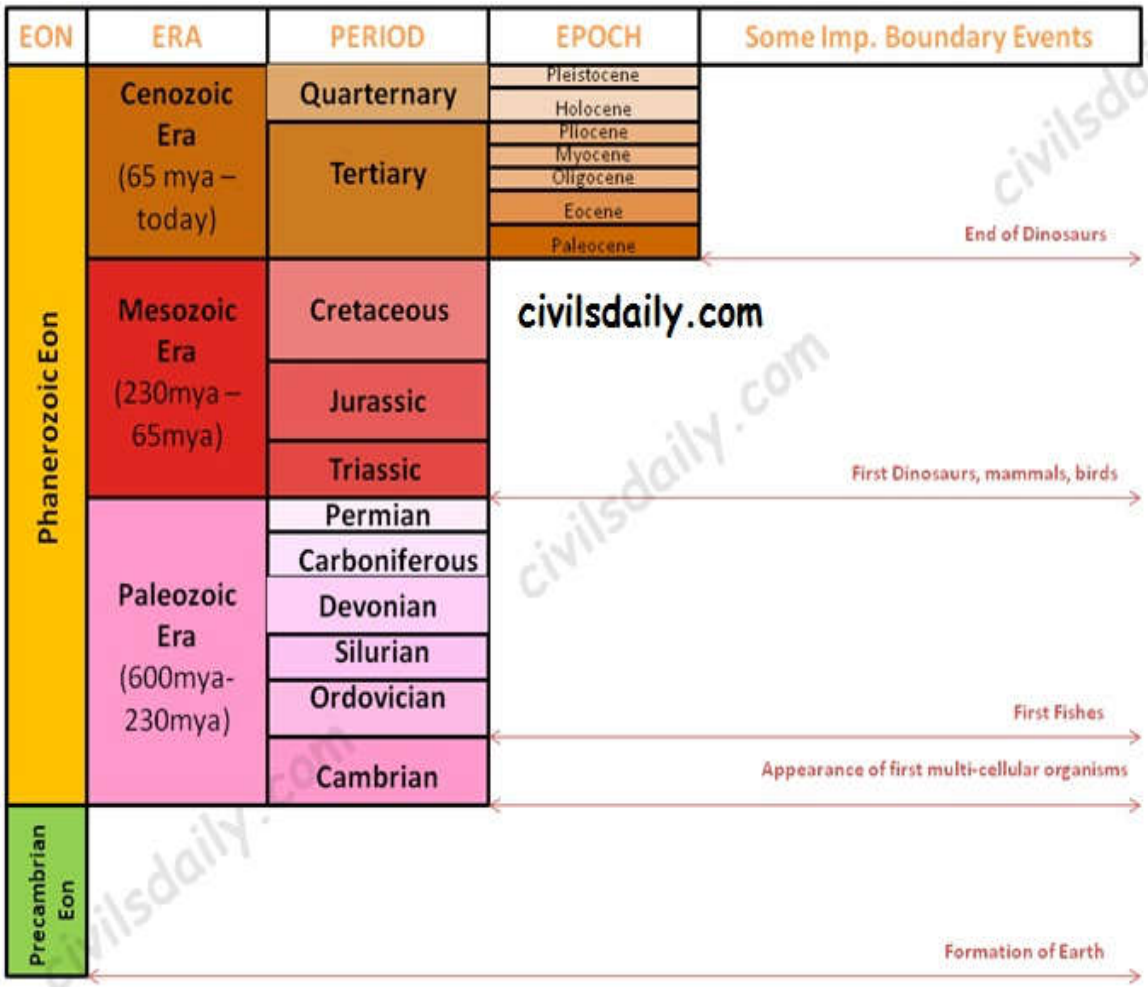
When did the dinosaurs get extinct? When did the birds first appear on earth? What about the beginning of life itself?

To answer these questions, geologists use a special timeline called **the Geological Time Scale**. It is a record of Earth's Geologic history based on radiometric dating and the record of ancient life preserved in layers of rocks.

The geological timescale is broken up into larger and smaller subdivisions which help us understand how the various historical events fit together. These time intervals are not equal in length like the hours in a day. Instead, the time intervals are variable in length because geologic time is divided using significant events in the history of the Earth. The various intervals are:



The geological timescale thus looks like:



Note: Due to lack of sufficient information about the Precambrian Eon, there is no subdivision into eras etc. At the same time, it is important to note that the Precambrian time constitutes about 86.7% of Earth's history.

The Indian Geological History:

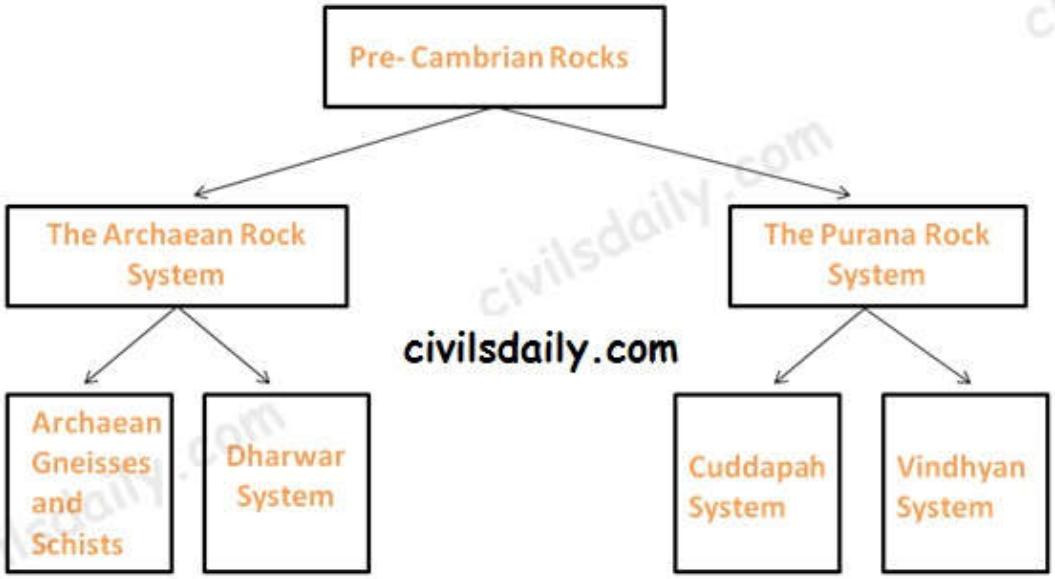
Major events in the geological history of India:

- Peninsular India was a part of the old landmass since the formation of the Earth's Crust
- The upheaval of Himalayas in the tertiary period.
- Aggradational formation of the Indo-Gangetic plain during the Pleistocene period. It continues till today through sedimentation in the floodplains of the rivers and the lower part of the Gangetic plain.

Based on this complex and varied geological history, the Geological Survey of India has classified rock systems of the country into 4 major divisions:

	The Indian Classification	Corresponding period on the Earth's Geological timescale:
1.	Archaean	Early Precambrian Eon
2.	Purana	Late Precambrian (or Proterozoic Eon)
3.	Dravidian	600-400mya (largely coinciding with the Palaeozoic era)
4.	Aryan	400mya – present

Let us study the basic features of each of these:



The Archaean rock system (Early Pre-Cambrian)

The Archaean group of rocks consists of two systems-(a) Achaean granites and gneisses, and (b) Dharwarian sedimentary:

- **Archaean Gneisses and Schists** (pre 2500 million years)

  - The Archean System contains the first formed rocks of the earth.
  - The rocks are primarily gneisses and granites, having no marks of fossils.
  - They often underlie the strata formed subsequently and the system is generally known as the **basement complex or fundamental gneisses**.
  - The Archaean rocks cover two-thirds of the peninsular India. They also occur in roots of the mountain peaks all along the Greater Himalayas, trans-Himalayan ranges of Zaskar, Ladakh and Karakoram

- **Dharwar System** (2500-1800 million years ago)

  - The weathering of the Archaean rocks yielded the earliest sediments and formed the oldest sedimentary strata, the Dharwar system.
  - These are found today in metamorphic forms and do not contain fossils.
  - These rocks occur in scattered patches in parts of Karnataka, Tamil Nadu, central and eastern parts of Chotanagpur plateau, Meghalaya plateau, Aravalis, Himalayan region etc as shown on the map.

The Archaean rocks are economically the most important rocks because they possess valuable minerals like high-grade iron ore, manganese, copper, lead, gold, quartzite, slates, mica, etc.

The Purana Rock System (Late Pre-Cambrian)

The Archaean gneiss and the Dharwar rocks underwent further erosion leading to the formation of the Purana Rock system.

The Purana rock system is further subdivided into (i) the Cuddapah and (ii) the Vindhyan

❖ **The Cuddapah**

- These rocks are generally without fossils
- These formations, named after the Cuddapah district in Andhra Pradesh are sedimentary metamorphic formations.
- These are found in Andhra Pradesh, southern Chhattisgarh, and Odisha and along the main axis of Aravallis.
- The metallic content in ores of Cuddapah rocks is low and at places uneconomical for extraction.

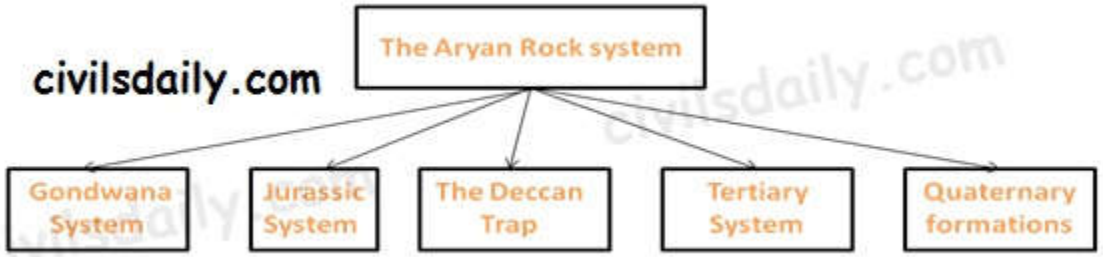
❖ **The Vindhyan**

- This system derives its name from the Vindhyan mountains
- Consists of enormous sedimentary deposits. In some tracts, Vindhyan rocks are buried under the Deccan lava.
- It stretches from Sasaram in Bihar to Chittorgarh in Rajasthan with the exception of the central tract of Bundelkhand gneiss.
- The well-known diamond mines of Panna and Golconda lie in the Vindhayan region.
- This rock system is well known for red sandstone, sandstone, durable stones, and ornamental stones, raw materials for lime, glass, cement and chemical industries.

The Dravidian Rock system (Cambrian to middle carboniferous)

❖ These formations do not occur in the peninsular plateau as it was above the sea level at that time but are found in continuous sequence in the Himalayas.
❖ They contain abundant fossils in them
❖ Coal formation started in the Carboniferous age. Carboniferous in geology means coal-bearing. [Most of the coal found in India is not of the Carboniferous period; High-quality coal of Great Lakes Region-USA, U.K and Ruhr region is Carboniferous coal].

The Aryan Rock system (Upper Carboniferous to recent)



- **The Gondwana System**:
  - The peninsula during the Upper Carboniferous period experienced crustal movements, which led to the formation of basin-shaped depressions. These depressions had countless terrestrial plants and animals, which were buried to from coal deposits in India known as the Gondwana Rocks.
  - These rocks have also marks of climatic changes from arctic cold to tropical and desert conditions.
  - These Rocks are found mainly in the Damodar, the Mahanadi and the Godavari valleys of the peninsula.
  - Gondwana rocks contain nearly 98 percent of India's coal reserves. Gondwana coal is much younger than the Carboniferous coal and hence its carbon content is low.

- **Jurassic System:**
  - The marine transgression in the latter part of the Jurassic gave rise to thick series of shallow water deposits in Rajasthan and in Kuchchh.
  - Coral limestone, sandstone, conglomerates and shales occur in Kuchchh.
  - Another transgression on the east coast of the Peninsula is found between Guntur and Rajahmundry.

- **The Deccan Trap:**
  - Towards the end of the Mesozoic era, intensive volcanic activity took place, which flooded with lava vast areas of Maharashtra and other parts of the Deccan known as the Deccan traps.
  - The volcanic rocks contain some thin fossiliferous sedimentary layers found between the lava flows. This indicates that the lava flows was not continuous. The volcanic activity led to two great events
    1. Breakup of the Gondwanaland masses
    2. Uplift of the Himalayas out of the Tethys Sea.
  - Present Deccan Trap covers about 5 lakh sq km mainly in parts of Kuchchh, Saurashtra, and Maharashtra, the Malwa plateau and northern Karnataka.
  - The weathering of these rocks for a long time has given birth to black cotton soil known as 'regur'.

- **Tertiary System**
  - Eocene to Pliocene about 60 to 7 million years ago.
  - The tertiary is the most significant period in India's geological history because the Himalayas were born and India's present form came into being in this period.

- **The Pleistocene and recent formations (The quaternary period)**
  - Quaternary is the name proposed for very recent deposits, which contains fossils of species with living representatives
  - These include Sutlej-Ganga-Brahmaputra plains and Karewa formations of the Kashmir valley.

Geological Divisions of India:

Geologic divisions are marked by geologists as regions of similar rocks, structures and geologic history [Recall the brief geological history of India discussed above]. Geologically, India is divided into 3 major regions (also called the Triple Tectonic division):

- **The Peninsular Plateau region** – It also includes the Shillong Plateau and the Kuchchh Kathiawar region (Outliers)
- **The Extra-peninsular region** – the mountainous region of Himalayas.

- The Himalayas are young, weak and flexible in their geological structure, unlike the rigid and stable Peninsular Block.
- Consequently, they are still subjected to the interplay of exogenic and endogenic forces, resulting in the development of faults, folds and thrust plains.
- These mountains are tectonic in origin, dissected by fast-flowing rivers which are in their youthful stage.
- Various landforms like gorges, V-shaped valleys, rapids, waterfalls, etc. are indicative of this stage.

❖ **The Indo-Gangetic Plain** between the above two.

In addition to these, there are 2 minor divisions:

❖ **The Coastal Plains** (Eastern and western)
❖ **The Islands** (Lakshadweep and Andaman and Nicobar)

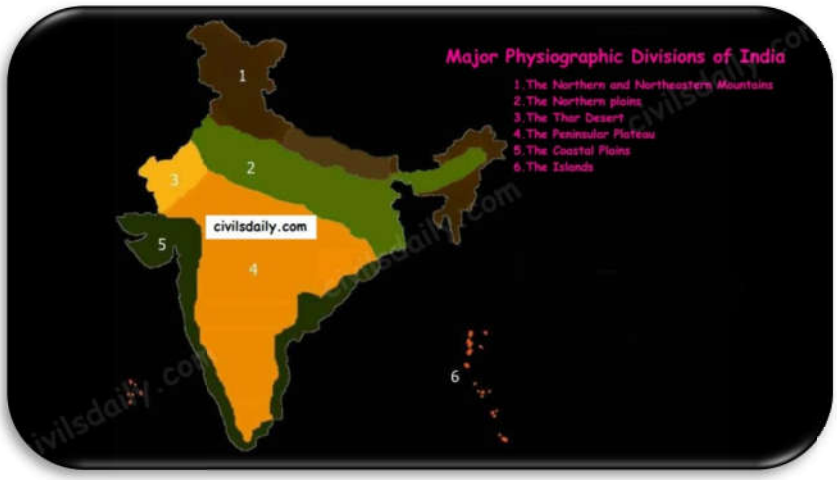
Physiographic divisions of India

Physiography deals with the study of surface features. This includes the landforms (mountains and valleys, their shape and steepness), the way rivers flow across the land, and the way in which the land erodes. Geographers recognize physiographic divisions based on the shape of the land.

There is a close relationship between India's physiographic and geologic divisions as geology affects the way the land erodes.

The Indian landmass can be divided into the following broad physiographic units:

1. The Northern and Northeastern Mountains
2. The Northern plains
3. The Thar Desert
4. The Peninsular Plateau
5. The Coastal Plains
6. The Islands



Prelims:

1997:

Question: Match List I with List II and select the correct answer using the codes given below the lists:

List I	List II
A) Deccan Traps	1) Late Cenozoic
B) Western Ghats	2) Pre-Cambrian
C) Aravali	3) Cretaceous Eocene
D) Narmada-Tapi alluvial deposits	4) Cambrian
	5) Pleistocene

a) A-3 B-5 C-1 D-4

b) A-3 B-1 C-2 D-5

c) A-2 B-1 C-3 D-4

d) A-1 B-4 C-2 D-5

Ans. b

3. Physiography

A. The Northern and Northeastern Mountains

Let's begin with the first physiographic division. It consists of:

- The Himalayas, and
- The Northeastern hills (Purvanchal).

A) ***The Himalayas:***

The name "Himalaya" means "the abode or house of snow" in Sanskrit (i.e. hima "snow", and ālaya "abode or house"). The Himalayas are the highest and longest of all young fold mountains of the world. The Pamir, known as the roof of the world, connects the Himalayas with the high ranges of Central Asia.

Let's begin by understanding how the Himalayas came into being:

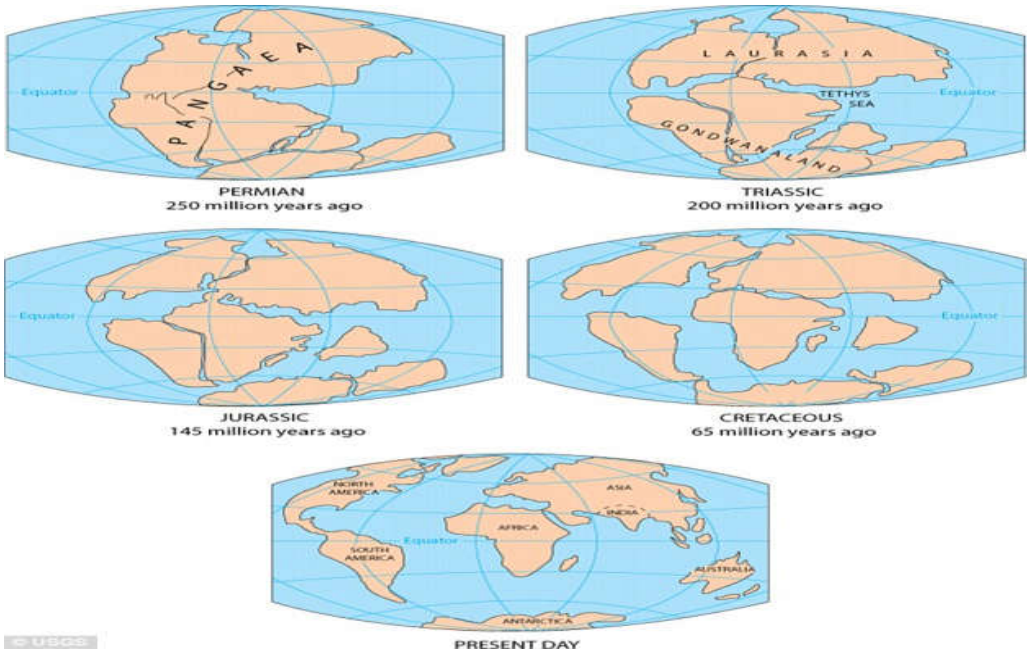
Origin and development:

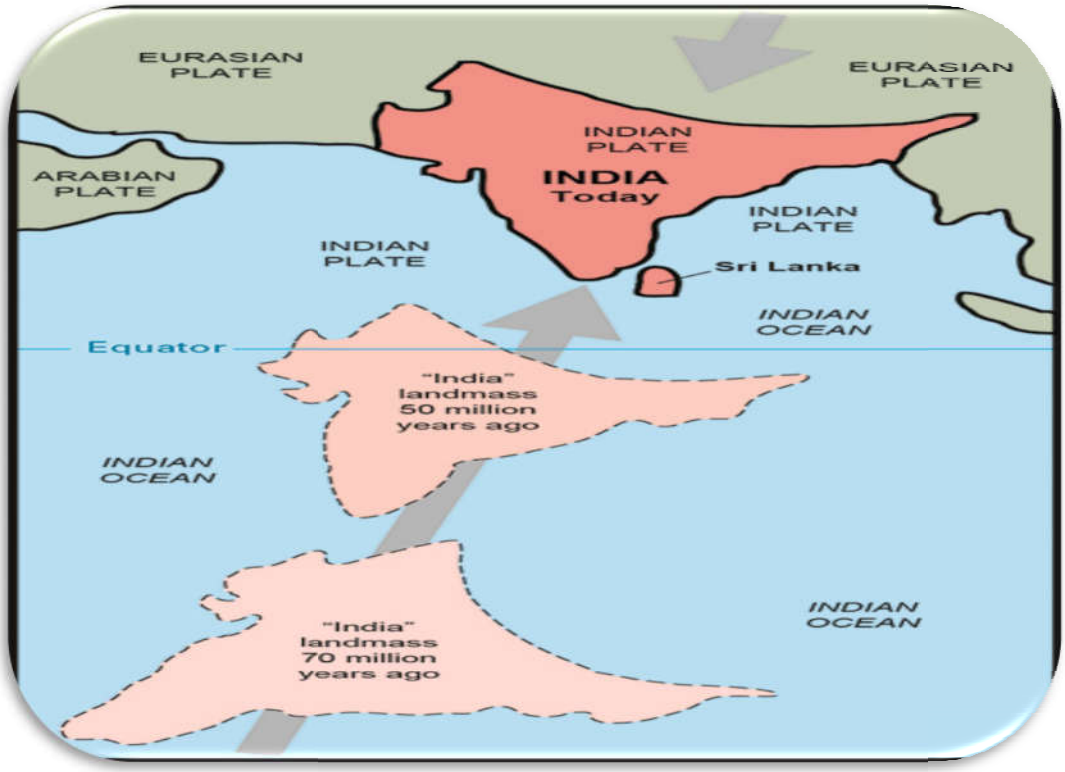
According to the theory of Continental Drift, the world was made up of a single continent through most of the geologic time. That continent eventually separated and drifted apart; forming the seven continents we have today.

About 200 million years ago: Pangaea broke apart leading to the formation of two landmasses – "Laurasia in North" and "Gondwanaland in South". Both the landmasses were separated by a shallow sea called "Tethys Sea". The size of Tethys Sea kept on decreasing due to movement of landmasses towards each other

About 40 to 50 million years ago: The two large landmasses, India and Eurasia, driven by plate movement, collided. As a result, the sediments accumulated in Tethys Sea (brought by rivers)

were compressed, squeezed and series of folds were formed, one behind the other, giving birth to folded mountains of the Himalayas.





Recent studies show that India is still moving northwards at the rate of 5cm/year and crashing into the rest of Asia, thereby constantly increasing the height of Himalayas.

Evidence to prove that the Himalayas are still rising:

1. Fossil formation found in Shivalik hills:

   - Similar fossils have also been found in the Tibet Plateau. This indicates that in the past, Tibetan plateau and Shivalik hills shared a common location, similar level and thus similar vegetation, life etc.; then Tibetan plateau got uplifted.

2. Desiccation of lakes of Tibet:

   - In the Tibet plateau, we find deposits which are generally found in lakes. This indicates that lakes once existed in Tibet but because of upliftment the water got discharged and deposits remained.

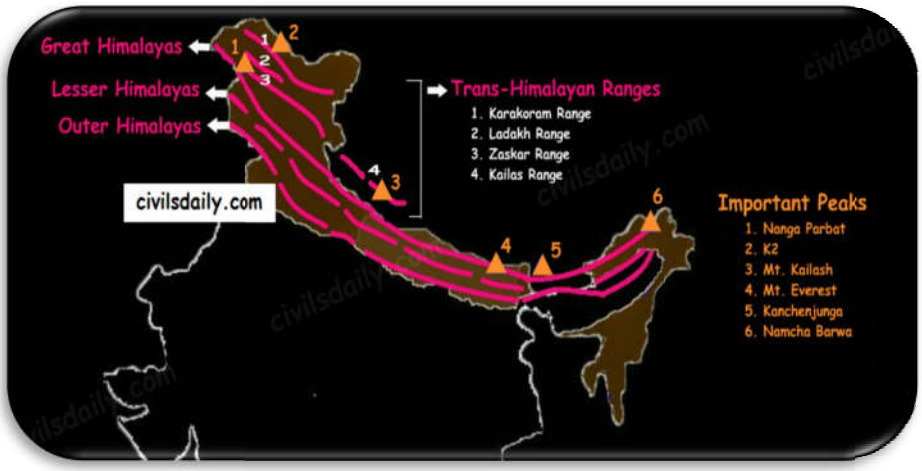
3. Frequent Earthquakes

4. Youthful nature of rivers (High erosion, v-shaped valleys etc.)

- **The North-South Division of the Himalayas**

The Himalayas consist of a series of parallel mountain ranges:

1. The Greater Himalayan range, which includes:
   - The Great Himalayas(Himadri), and
   - The Trans-Himalayan range
2. The Lesser Himalayas (or Himachal), and
3. The Outer Himalayas (or Shiwalik).

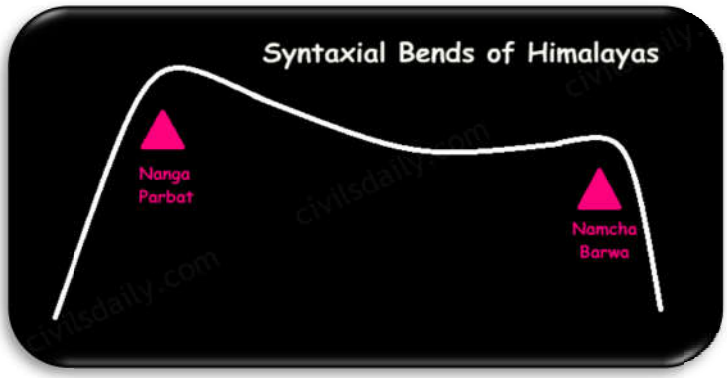


- **Formation** of these ranges: The Himadri and Himachal ranges of the Himalayas have been formed much before the formation of Siwalik range. The rivers rising in the Himadri and Himachal ranges brought gravel, sand and mud along with them, which was deposited in the rapidly shrinking Tethys Sea. In course of time, the earth movements caused folding of these relatively fresh deposits of sediments, giving rise to the least consolidated Shiwalik range.

- **Characteristic Features:**

  - Notice in the map shown above that the Himalayas form **an arcuate curve** which is convex to the south**.** This curved shape of the Himalayas is attributed to the maximum push offered at the two ends on the Indian peninsula during its northward drift. In the north-west, it was done by Aravalis and in the Northeast by the Assam ranges.

  - **Syntaxis/ Syntaxial bends**: The gently arching ranges of the Himalayan mountains on their Western and Eastern extremities are sharply bent southward in deep Knee-bend flexures that are called Syntaxial bends. On both the ends, the great mountains appear to bend around a pivotal point. The western point is situated south of the Pamir where the Karakoram meets the Hindu Kush. A similar sharp, almost hairpin bend occurs on the eastern limit of Arunachal Pradesh where the strike of the mountain changes sharply from the Easterly to Southerly trend. Besides these two major bends, there are a number of minor Syntaxial bends in other parts of Himalayas.

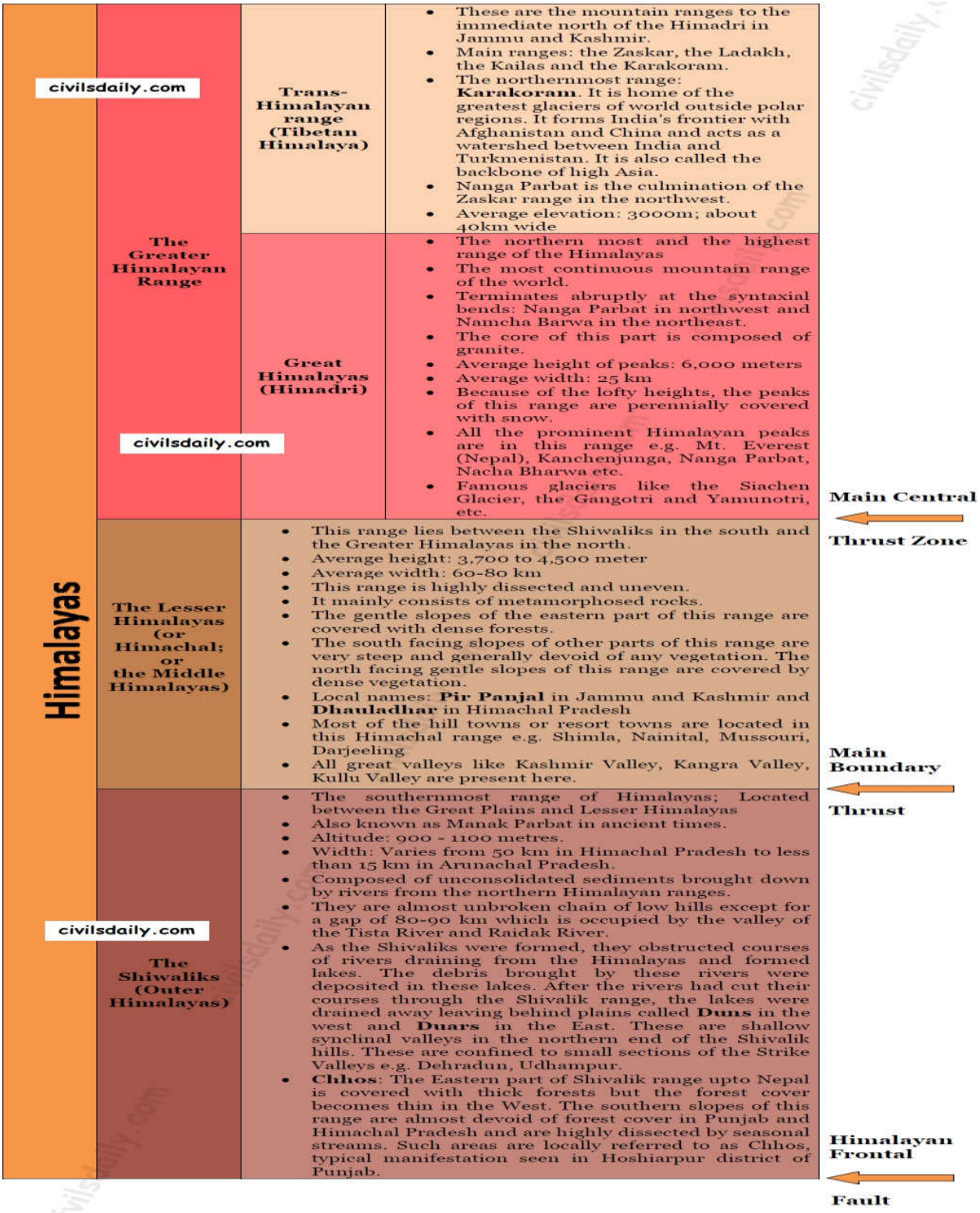


  - The Himalayas are **wider in the west than in the east**. The width varies from 400 km in Kashmir to 150 km in Arunachal Pradesh. The main reason behind this difference is that the compressive force was more in the east than in the west. That is why high mountain peaks like Mount Everest and Kanchenjunga are present in the Eastern Himalayas.

  - The ranges are separated by deep valleys creating a **highly dissected topography**.

  - The **southern slopes** of the Himalayas facing India are steeper and those facing the Tibetan side are generally gentler.

- Let's take up these Himalayan mountain ranges one by one:

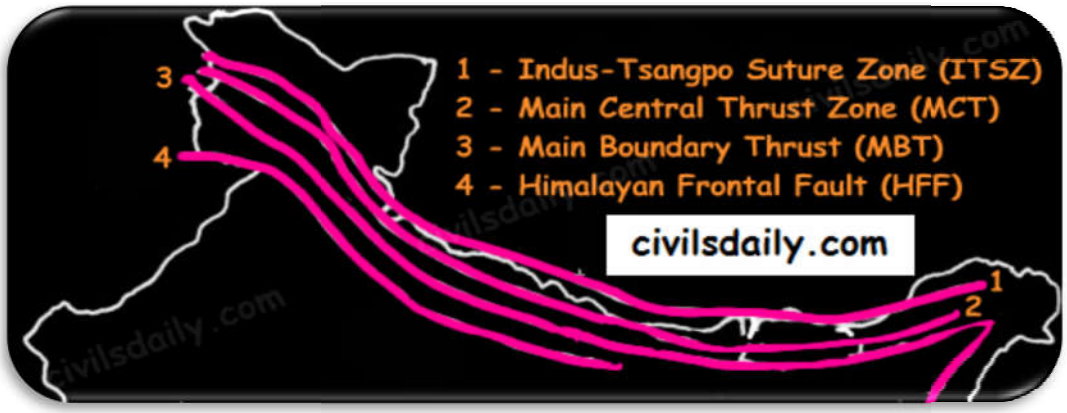


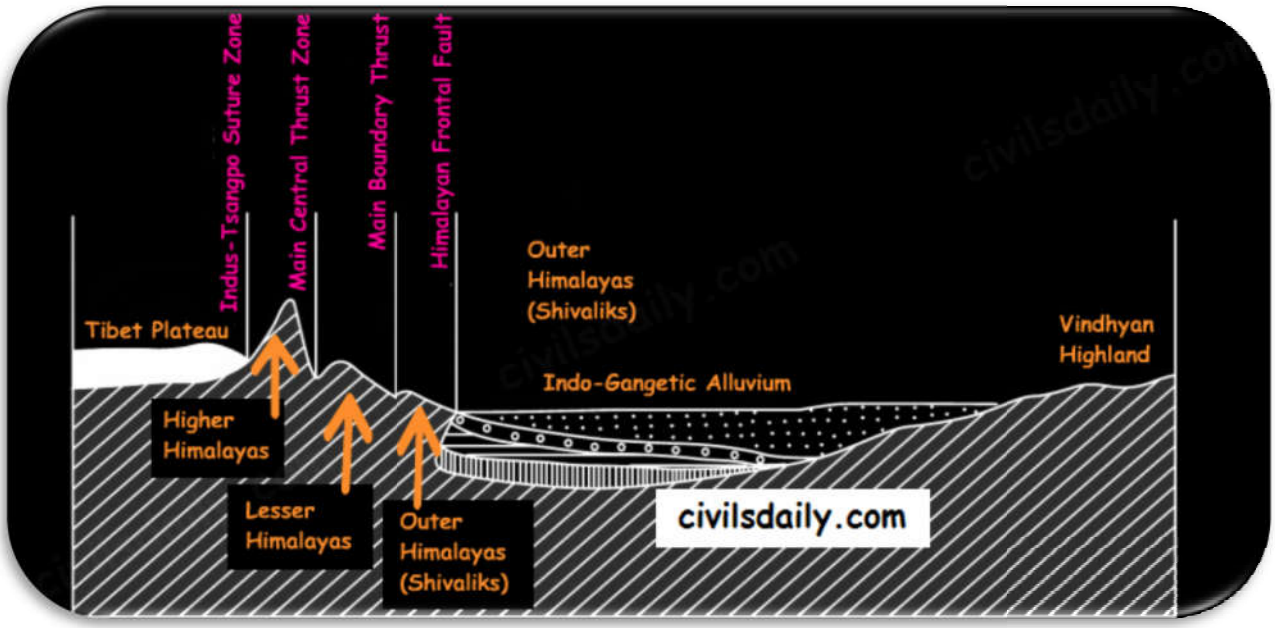
Indus-Tsangpo Suture Zone: It represents a belt of tectonic compression caused by the under thrusting of the Indian shield/ plate against the Tibetan mass. It marks the boundary between Indian and Eurasian plates. The suture zone stretches from the North Western Himalayan Syntaxis bordering the Nanga Parbat to the East as far as the Namche Barwa Mountain. The Karakoram Range and the Ladakh plateau lie to the north of ITSZ and originally formed a part of the European plate.

Main Central Thrust Zone: This separates the Higher Himalayas in the north from lesser Himalayas in the south. It has played an important role in the tectonic history of these mountains.

Main Boundary Thrust: It is a reverse fault of great dimensions which extends all the way from Assam to Punjab and serves to separate the outer Himalayas from the lesser Himalayas.

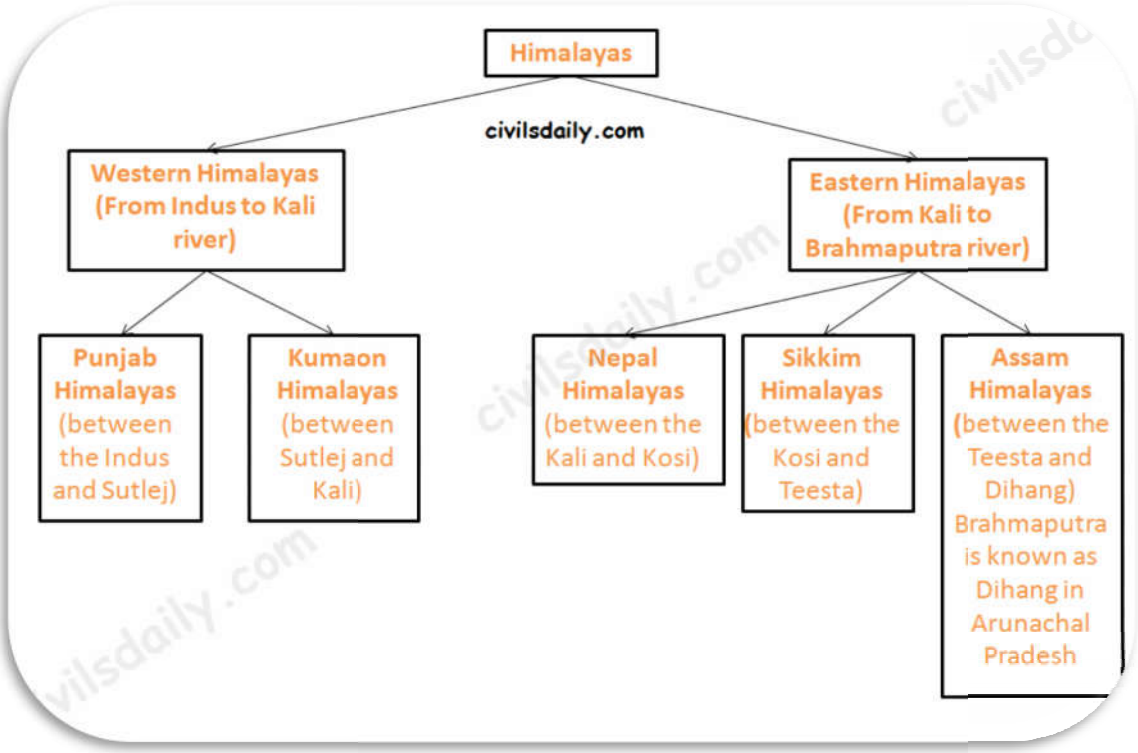
Himalayan Frontal Fault: It is a series of reverse faults that demarcates the boundary of the Shivalik from of the Himalayan province from the alluvial expanse of the Indo-Gangetic plains.





Besides the longitudinal divisions, the Himalayas have been divided on the basis of regions from west to east:

These divisions have been demarcated by river valleys:

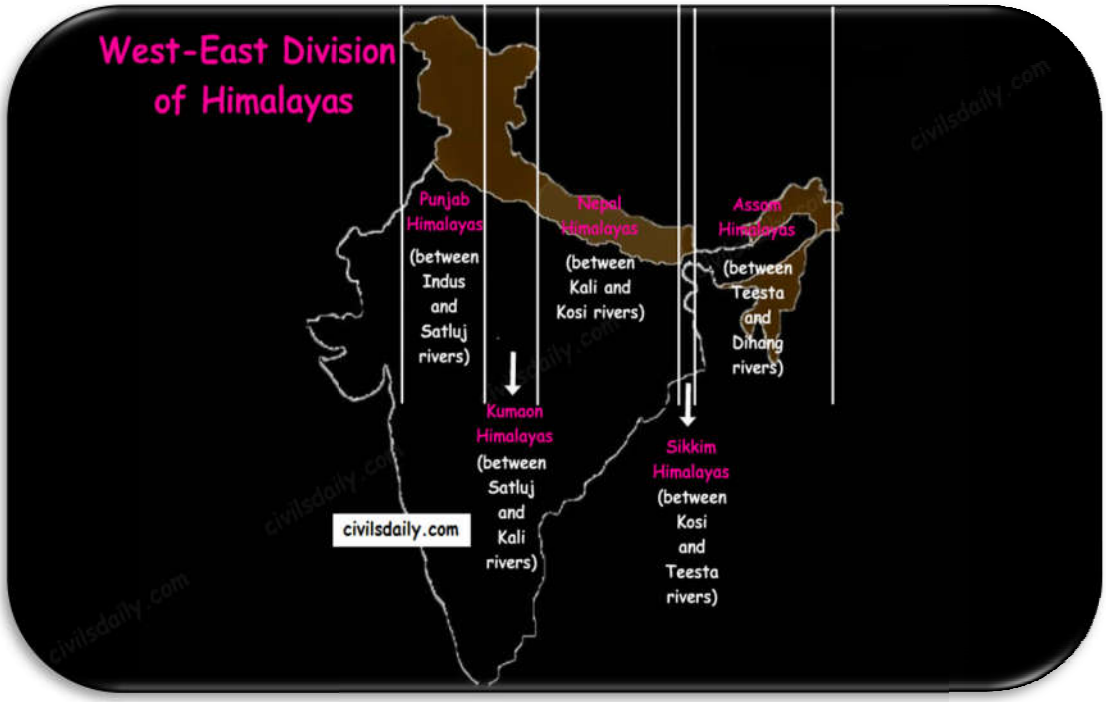


1. **Punjab Himalayas**:

   - A large portion of Punjab Himalayas is in Jammu and Kashmir and Himachal Pradesh. Hence they are also called the Kashmir and Himachal Himalaya.
   - Major ranges: Karakoram, Ladakh, Pir Panjal, Zaskar and Dhaola Dhar.
   - The general elevation falls westwards.
   - The Kashmir Himalayas are also famous for **Karewa formations**.
     - 'Karewas' in Kashmiri language refer to the lake deposits, found in the flat-topped terraces of the Kashmir valley and on the flanks of the Pir Panjal range.
     - These deposits consist of clays, silts and sands, these deposits also show evidence of glaciation.
     - The occurrence of tilted beds of Karewas at the altitudes of 1500-1800m on the flanks of the Pir Panjal strongly suggests that the Himalayas were in process of uplift as late as Pliocene and Pleistocene (1.8mya to 10kyears ago)

- Karewas are famous for the cultivation of **Zafran**, a local variety of saffron.

2. **Kumaon Himalayas**
3. **Nepal Himalayas**:
   - ❖ Tallest section of Himalayas
4. **Sikkim Himalayas:**
   - ❖ Teesta river originates near Kanchenjunga
   - ❖ Jelep la pass- tri-junction of India- China-Bhutan
5. **Assam Himalayas**:
   - ❖ Himalayas are narrower in this region and Lesser Himalayas lie close to Great Himalayas.
   - ❖ Peaks: Namcha Barwa, Kula Kangri
   - ❖ Bengal 'Duars'
   - ❖ Diphu pass- tri-junction of India- China-Myanmar
   - ❖ The Assam Himalayas show a marked dominance of fluvial erosion due to heavy rainfall.



Key differences between the Eastern and Western Himalayas:

Sr. No.	Western Himalayas	Eastern Himalayas
1.	From Indus to Kali river	From Kali river to Brahmaputra river
2.	Lower and gradual slope. Hence, the higher peaks in this part are farther from the plains and a number of ranges lie between the plains and high peak.	Higher and steep-sudden slope. That is why two of the highest peaks of Himalayas, Mt. Everest (in Nepal) and Kanchenjunga are not very far from the plains.
3.	Located on higher latitude, therefore colder. As a result, the snowline in the Western Himalaya is at a lower altitude than in the Eastern Himalaya.	Located on lower latitude, therefore warmer. Therefore, snowline is at a higher altitude.
4.	Peaks: Nanga Parbat, Nanda Devi, Badrinath	Peaks: Everest, Makalu, Annapurna, Dhaulagiri

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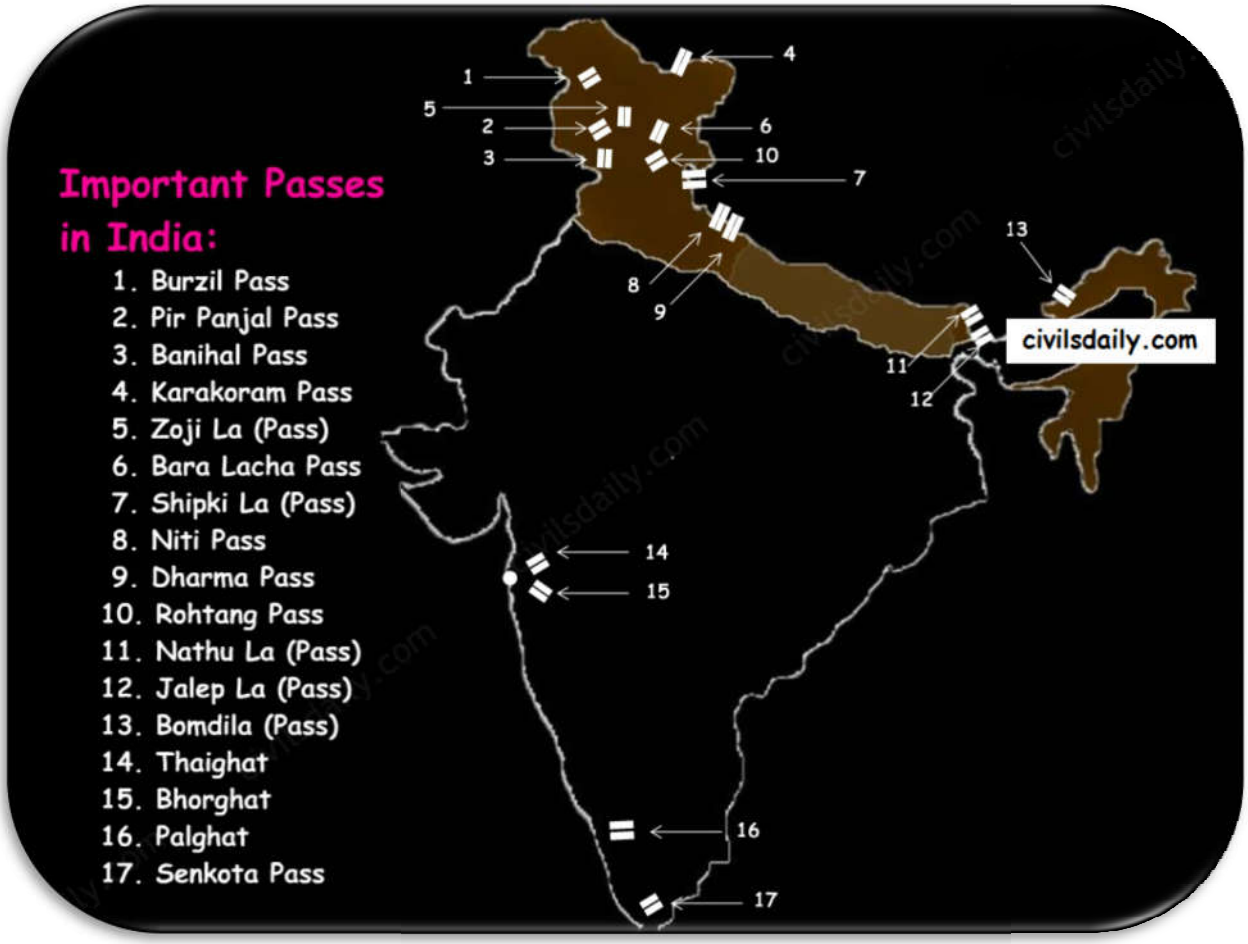
Important Passes in India:

A pass is a narrow gap in a mountain range which provides a passageway through the barrier.



1. **Pir Panjal Pass** – It provides the shortest and the easiest metal road between Jammu and the Kashmir Valley. But this route had to be closed down as a result of partition of the subcontinent.

2. **Banihal Pass** – It is in Jammu and Kashmir. The road from Jammu to Srinagar transversed Banihal Pass until 1956 when Jawahar Tunnel was constructed under the pass. The road now passes through the tunnel and the Banihal Pass is no longer used for road transport.

3. **Zoji La (Pass)** – It is in the Zaskar range of Jammu and Kashmir. The land route from Srinagar to Leh goes through this pass.

4. **Shipki La (Pass)** – It is in Himachal Pradesh. The road from Shimla to Tibet goes through this pass. The Satluj River flows through this pass.

5. **Bara Lacha Pass** – It is also in Himachal Pradesh. It links Mandi and Leh by road.

6. **Rohtang Pass** – It is also in Himachal Pradesh. It cuts through the Pir Panjal range. It links Manali and Leh by road.

7. **Niti Pass** – It is in Uttarakhand. The road to the Kailash and the Manasarovar passes through it.

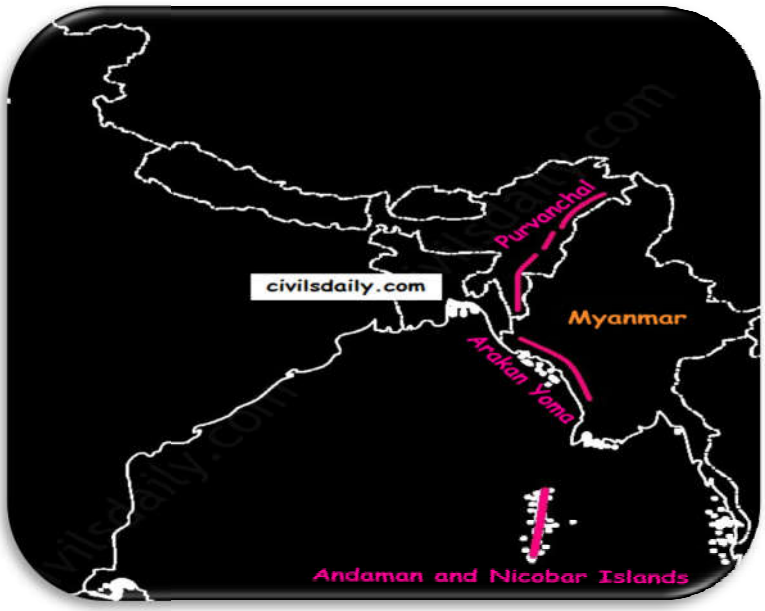
8. **Nathu La (Pass)** – It is in Sikkim. It gives way to Tibet from Darjeeling and Chumbi valley. The Chumbi River flows through this pass.

9. **Jalep La (Pass)** – At the tri-junction of India- China-Bhutan. The Teesta river has created this pass.

B) The North-Eastern Hills and Mountains

The Brahmaputra marks the eastern border of Himalayas. Beyond the Dihang gorge, the Himalayas bend sharply towards south and form the Eastern hills or **Purvanchal.**

- ✓ These hills run through the northeastern states of India.
- ✓ These hills differ in scale and relief but stem from the Himalayan orogeny.
- ✓ They are mostly composed of sandstones (i.e. Sedimentary rocks).
- ✓ These hills are covered with dense forests.
- ✓ Their elevation decreases from north to south. Although comparatively low, these hill ranges are rather forbidding because of the rough terrain, dense forests and swift streams.
- ✓ Purvanchal hills are convex to the west.
- ✓ These hills are composed of:
  - Patkai Bum – Border between Arunachal Pradesh and Myanmar
  - Naga Hills
  - Manipuri Hills – Border between Manipur and Myanmar
  - Mizo Hills.
- ✓ Patkai Bum and Naga Hills form the watershed between India and Myanmar.
- ✓ Extension of Purvanchal continues in Myanmar as Arakan Yoma –then Andaman and Nicobar Islands.



The importance of Himalayan Region:

- **Climatic Influence –** The altitude of the Himalayas, their sprawl and extension intercept the summer monsoon. They also prevent the cold Siberian air masses from entering into India. The climatic influence of the Himalayas will be dealt in detail in the next articles.
- **Defense**
- **Source of perennial rivers**
- **Source of fertile soils**
- **Generation of hydroelectricity**
- **Forest wealth**
- **Orchards**
- **Minerals –** The Himalayan region is rich in minerals e.g. gold, silver, copper, lead etc. are known to occur. Coal is found in Kashmir. But at present level of technological advancement, it is not possible to extract these minerals. Also, it is not economically viable.
- **Tourism**
- **Pilgrimage**

Now that we are done with this part, let's try to attempt some questions from the past UPSC examinations:

Prelims:

2012:

Question: When you travel in Himalayas, you will see the following:

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 evidences for Himalayas being young fold mountains?

1. 1 and 2 only

2. 1, 2 and 4 only
3. 3 and 4 only
4. 1, 2, 3 and 4

Ans. D

2003

Question: Nanda Devi peak forms part of:

A. Assam Himalayas

B. Kumaon Himalayas

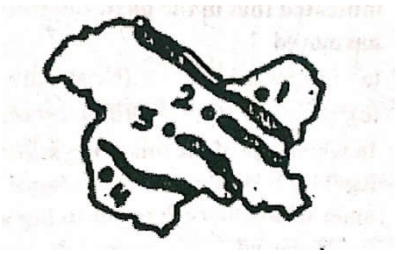
C. Nepal Himalayas

D. Punjab Himalayas

Ans. B [Nandadevi – Uttarakhand]

1997

Question: Examine the map of Jammu and Kashmir given below



The mountain ranges marked 1, 2, 3 and 4 are respectively:

a) Ladakh, Zaskar, Karakoram and Pir Panjal

b) Karakoram, Ladakh, Zaskar and Pir Panjal

c) Karakoram, Zaskar, Pir Panjal and Ladakh

d) Ladakh, Pir Panjal, Karakoram and Zaskar

Ans. B

1995

Question: The alpine vegetation in western Himalayas is found only upto a height of 3000m while in Eastern Himalayas it is found upto a height of 4000m. The reason for this variation in same mountain range is that:

A. Eastern Himalayas are higher than western Himalayas

B. Eastern Himalayas are nearer to equator and sea than Western Himalayas

C. Eastern Himalayas get more rainfall than western Himalayas

D. Eastern Himalayan rocks are more fertile than western Himalayas

Ans. C

Question: The Indian subcontinent was originally a part of a huge mass called

A. Jurassic landmass

B. Aryavarta

C. Indiana

D. Gondwana continent

Ans. D

Question: Arakan Yoma, the extension of the Himalayas is located in

A. Baluchistan

B. Myanmar

C. Nepal

D. Kashmir

Ans. B

Mains:

1. Write a short note on Karewas. (2marks 2005)
2. Bring out the causes for more frequent occurrence of landslides in the Himalayas than in the Western Ghats. (10 marks 2013)

B. The Northern Plains

Location and Extent:

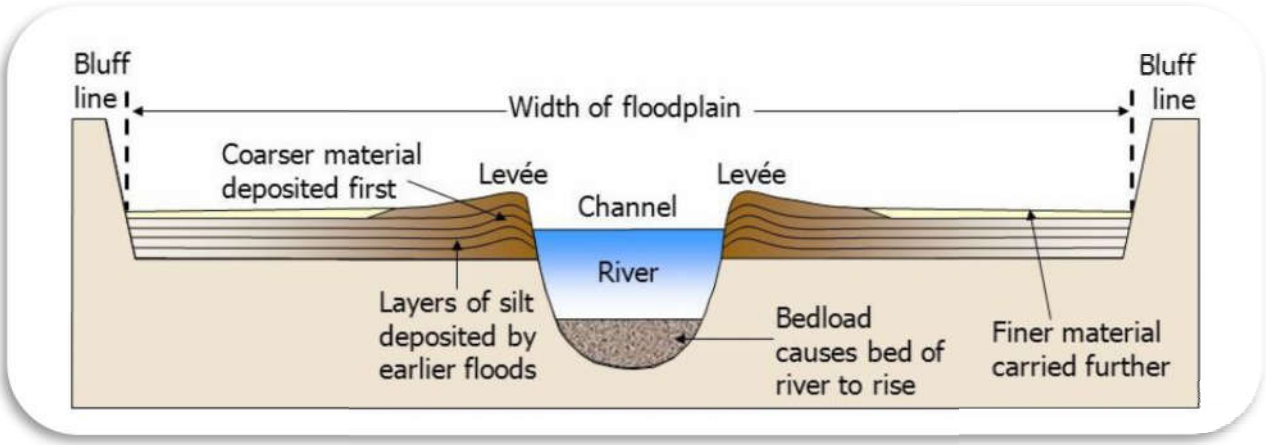
Northern plains are the youngest physiographic feature in India. They lie to the south of the Shivaliks, separated by the Himalayan Frontal Fault (HFF). The southern boundary is a wavy irregular line along the northern edge of the Peninsular India. On the eastern side, the plains are bordered by the Purvanchal hills.

Formation of Northern Plains:

Due to the uplift of the Himalayas in the Tethys Sea, the northern part of the Indian Peninsula got subsided and formed a large basin. That basin was filled with sediments from the rivers which came from the mountains in the north and from the peninsula in the south. These extensive alluvial deposits led to the formation of the northern plains of India.

Chief Characteristics:

- The northern plain of India is formed by three river systems, i.e. the Indus, the Ganga and the Brahmaputra; along with their tributaries.
- The northern plains are the **largest alluvial tract** of the world. These plains extend approximately 3200 km from west to east.
- The average **width** of these plains varies between 150 and 300 km. In general, the width of the northern plains increases from east to west (90-100km in Assam to about 500km in Punjab).
- The exact **depth of alluvium** has not yet been fully determined. According to recent estimates, the average depth of alluvium in the southern side of the plain varies between 1300-1400m, while towards the Shivaliks, the depth of alluvium increases. The maximum depth of over 8000m has been reached in parts of Haryana.
- **The extreme horizontality** of this monotonous plain is its chief characteristic (200m – 291m). The highest elevation of 291 m above mean sea level near Ambala forms a watershed between Indus system and Ganga system).
- The monotony of the physical landscape is broken at the micro level by the river bluffs, levees etc.
    - [**Floodplain** – That part of a river valley, adjacent to the channel, over which a river flows in times of a flood.
    - **Levee** – An elevated bank flanking the channel of the river and standing above the level of the flood plain.
    - **Bluff** – A river cut cliff or steep slope on the outside of a meander. A line of bluffs often marks the edge of a former floodplain.]

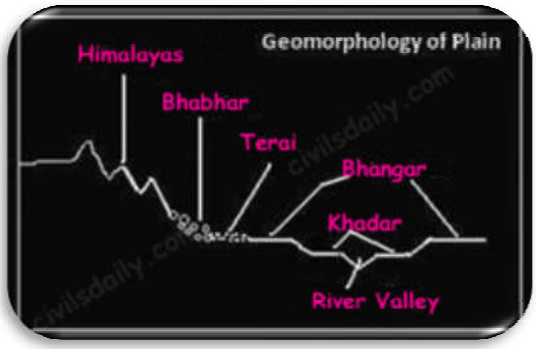


Physiographic Divisions of the Northern Plains:

From the north to the south, the northern plains can be divided into three major zones:

1. The Bhabar
2. The Tarai
3. The alluvial plains.

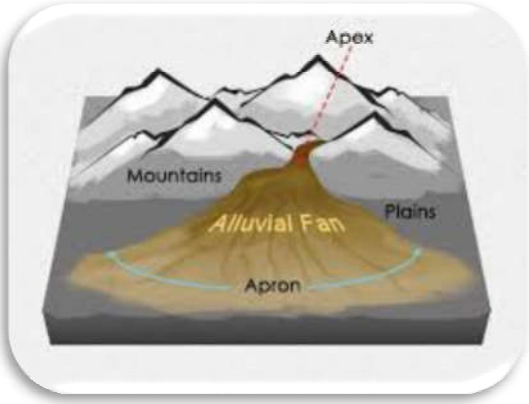
The alluvial plains can be further divided into the Khadar and the Bhangar as illustrated below:



Let's understand these divisions one by one:

Bhabar:

- Bhabar is a narrow belt (8-10km wide) which runs in the west-east direction along the foot of the Himalayas from the river Indus to Teesta.



- Rivers which descend from the Himalayas deposit their load along the foothills in the form of **alluvial fans**.
- These fans consisting of coarser sediments have merged together to build up **the piedmont plain/the Bhabar.**
- The porosity of the pebble-studded rock beds is very high and as a result, most of the streams sink and flow underground. Therefore, the area is characterized by dry river courses except in the rainy season.
- The Bhabar tract is not suitable for cultivation of crops. Only big trees with large roots thrive in this region.
- The Bhabar belt is comparatively narrow in the east and extensive in the western and north-western hilly region.

Tarai:

- It is a 10-20 km wide marshy region in the south of Bhabar and runs parallel to it.
- The Tarai is wider in the eastern parts of the Great Plains, especially in the Brahmaputra valley due to heavy rainfall.
- It is characterized by the re-emergence of the underground streams of the Bhabar belt.
- The reemerged water transforms large areas along the rivers into badly drained marshy lands.

- Once covered with dense forests, most of the Tarai land (especially in Punjab, Uttar Pradesh and Uttarakhand) has been reclaimed and turned into agricultural land over a period of time.

Bhangar:

- It is the older alluvium along the river beds forming terraces higher than the flood plain.
- Dark in colour, rich in humus content and productive.
- The soil is clayey in composition and has lime modules (called kankar)
- Found in doabs (inter-fluve areas)
- 'The **Barind plains**' in the deltaic region of Bengal and the '**bhur formations**' in the middle Ganga and Yamuna doab are regional variations of Bhangar. [Bhur denotes an elevated piece of land situated along the banks of the Ganga River especially in the upper Ganga-Yamuna Doab. This has been formed due to accumulation of wind-blown sands during the hot dry months of the year]
- In relatively drier areas, the Bhangar also exhibits small tracts of saline and alkaline efflorescence known as 'Reh', 'Kallar' or 'Bhur'. Reh areas have spread in recent times with increase in irrigation (capillary action brings salts to the surface).
- May have fossil remains of even those plants and animals which have become extinct.

Khadar:

- Composed of newer alluvium and forms the flood plains along the river banks.
- Light in colour, sandy in texture and more porous.
- Found near the riverbeds.
- A new layer of alluvium is deposited by river flood almost every year. This makes them the most fertile soils of Ganges.
- In Punjab, the Khadar rich flood plains are locally known as '**Betlands**' or '**Bets**'.
- The rivers in Punjab-Haryana plains have broad flood plains of Khadar flanked by bluffs, locally known as **Dhayas**. These bluffs are as high as 3metres.

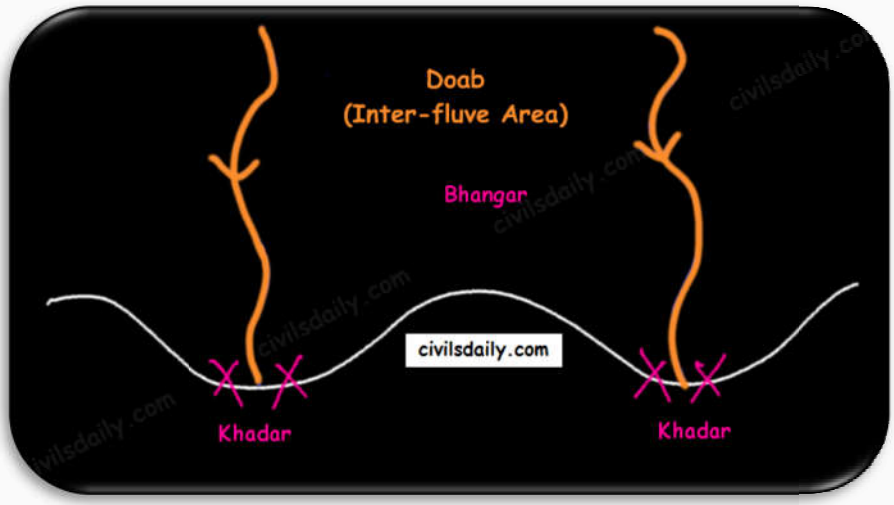
Regional Divisions of Northern Plains

Indian Geography

Source: Civils Daily

Punjab Plains:

- The Punjab plains form the western part of the northern plain.
- In the east, the Delhi-Aravali ridge separates it from the Ganga plains.
- This is formed by the Indus and its tributaries; like Jhelum, Chenab, Ravi, Beas and Sutlej. A major portion of these plains is in Pakistan.
- It is divided into many Doabs (do-"two" + ab- "water or river" = "a region or land lying between and reaching to the meeting of the two rivers").



- Important features:
  - ✓ Khadar rich flood plains known as 'Betlands' or '**Bets**'.
  - ✓ The rivers in Punjab-Haryana plains have broad flood plains of Khadar flanked by bluffs, locally known as **Dhayas.**
  - ✓ The northern part of this plane adjoining the Shivalik hills has been heavily eroded by numerous streams, which are called **Chhos**.
  - ✓ The southwestern parts, especially the Hisar district is sandy and characterized by shifting sand-dunes.

Ganga Plains:

- The Ganga plains lie between the Yamuna catchment in the west to the Bangladesh border in the East.
- The lower Ganga plain has been formed by the down warping of a part of the Peninsular India between Rajmahal hills and the Meghalaya plateau and subsequent sedimentation by the Ganga and Brahmaputra rivers.
- The main topographical variations in these plains include Bhabar, Tarai, Bhangar, Khadar, levees, abandoned courses etc.
- Almost all the rivers keep on shifting their courses making this area prone to **frequent floods**. The Kosi River is very notorious in this respect. It has long been called the 'Sorrow of Bihar'.

- The northern states, Haryana, Delhi, UP, Bihar, part of Jharkhand and West Bengal in the east lie in the Ganga plains.
- **The Ganga-Brahmaputra delta:** the largest delta in the world**.** A Large part of the coastal delta is covered tidal forests called Sunderbans. **Sunderbans**, the largest mangrove swamp in the world gets its name from the Sundari tree which grows well in marshland. It is home to the Royal Tiger and crocodiles.

Brahmaputra Plains:

- This plain forms the eastern part of the northern plain and lies in Assam.
- Its western boundary is formed by the Indo-Bangladesh border as well as the boundary of the lower Ganga Plain. Its eastern boundary is formed by **Purvanchal hills.**
- The region is surrounded by high mountains on all sides, except on the west.
- The whole length of the plain is traversed by the Brahmaputra.

- The Brahmaputra plains are known for their riverine islands (due to the low gradient of the region) and sand bars.
- The innumerable tributaries of the Brahmaputra River coming from the north form a number of **alluvial fans**. Consequently, the tributaries branch out in many channels giving birth to river meandering leading to the formation of **bill and ox-bow lakes**.
- There are large marshy tracts in this area. The alluvial fans formed by the coarse alluvial debris have led to the formation of terai or semi-terai conditions.

Significance of this region:

- The plains constitute less than one-third of the total area of the country but support over 40 percent of the total population of the country.
- Fertile alluvial soils, flat surface, slow moving perennial rivers and favourable climate facilitate an intense agricultural activity.
- The extensive use of irrigation has made Punjab, Haryana and western part of Uttar Pradesh the granary of India (Prairies are called the granaries of the world).
- Cultural tourism: Several sacred places and centres of pilgrimage are situated in these plains e.g. Haridwar, Amritsar, Varanasi, Allahabad, Bodh Gaya etc.
- The sedimentary rocks of plains have petroleum and natural gas deposits.
- The rivers here have very gentle gradients which make them navigable over long distances.

Prelims:

2000 Question:

Assertion (A): The frequency of floods in North Indian plains has increased during the last couple of decades.

Reason(R): There has been reduction in the depth of river valleys due to deposition of silt.

Ans. A (Both A and B are true and R is the correct explanation of A)

Question: Assertion (A): Ganga plain is the most densely populated part of India.

Reason(R): Ganga is the most harnessed river of India.

Ans. C (A is true but R is false)

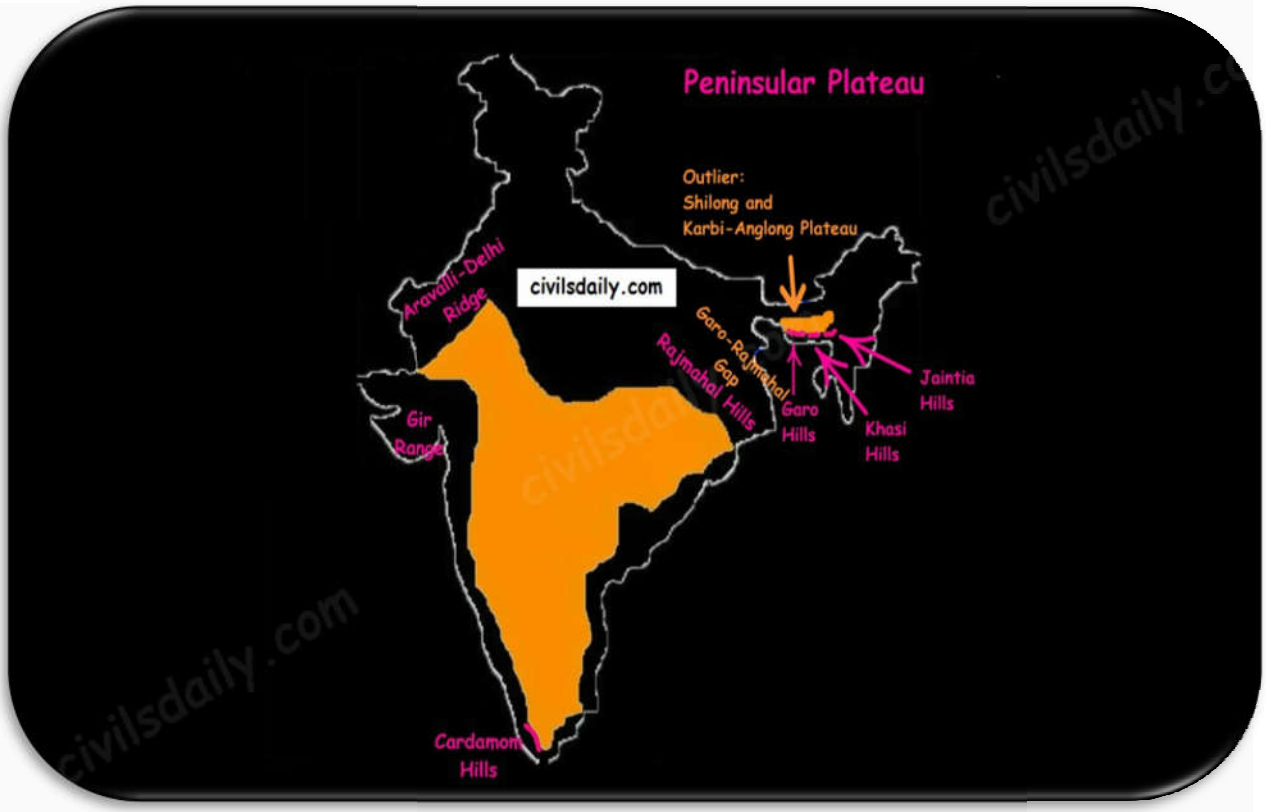
Mains Question: Write a short note on Tarai region. (2008/2marks)

C. The Peninsular Plateau

Peninsular Plateau is the oldest and largest Physiographic unit of India.

Location and Extent

- The Peninsular Plateau lies to the south of the Northern Plains of the India.
- It is bordered on all sides by the hill ranges:
- Delhi ridge in the north-west (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.



- Outlier:
  - **Shillong and Karbi-Anglong plateau.**

Note: **Kutchch Kathiawar region** – The region, though an extension of Peninsular plateau (because Kathiawar is made of the Deccan Lava and there are tertiary rocks in the Kutch area), they are now treated as integral part of the Western Coastal Plains as they are now leveled down.

- **The Garo-Rajmahal Gap:**
  - The two disconnected outlying segments of the plateau region are seen in the Rajmahal and Garo-Khasi Jaintia hills.
  - It is believed that due to the force exerted by the northeastward movement of the Indian plate at the time of the Himalayan origin, a huge fault was created between the Rajmahal hills and the Meghalaya plateau
  - Later, this depression got filled up by the deposition activity of the numerous rivers.
  - As a result, today the Meghalaya and Karbi Anglong plateau stand detached from the main Peninsular Block.

Geological History and Features:

The peninsular plateau is a tableland which contains igneous and metamorphic rocks. It is one of the oldest and the most stable landmass of India.

In its otherwise stable history, the peninsula has seen a few changes like:

1. Gondwana Coal Formation.
2. Narmada-Tapi rift valley formation.
3. Basalt Lava eruption on Deccan plateau:

During its journey northward after breaking off from the rest of Gondwana, the Indian Plate passed over a geologic hotspot, the Réunion hotspot, which caused extensive melting underneath the Indian Craton. The melting broke through the surface of the craton in a massive flood basalt event, creating what is known as the Deccan Traps.

Chief Characteristics:

The entire peninsular plateau region is an aggregation of several smaller plateaus and hill ranges interspersed with river basins and valleys. The Chhattisgarh plain occupied by the dense Dandakaranya forests is the only plain in the peninsula.

1. General elevation and flow of rivers:

- The average elevation is 600-900 meters.
- 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.
- Barring Narmada and Tapti all the major rivers lying to the south of the Vindhyas flow eastwards to fall into the Bay of Bengal.
- The westward flow of Narmada and Tapi is assigned to the fact that they have been flowing through faults or rifts which were probably caused when the Himalayas began to emerge from the Tethys Sea of the olden times.

2. Some of the important physiographic features of this region are:

- **Tors** – Prominent, isolated mass of jointed, weathered rock, usually granite.


- **Block Mountains and Rift Valleys:**
- Spurs: A marked projection of land from a mountain or a ridge

- Bare rocky structures,
- Series of hummocky hills and wall-like quartzite dykes offering natural sites for water storage.
- Broad and shallow valleys and rounded hills
- Ravines and gorges: 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.

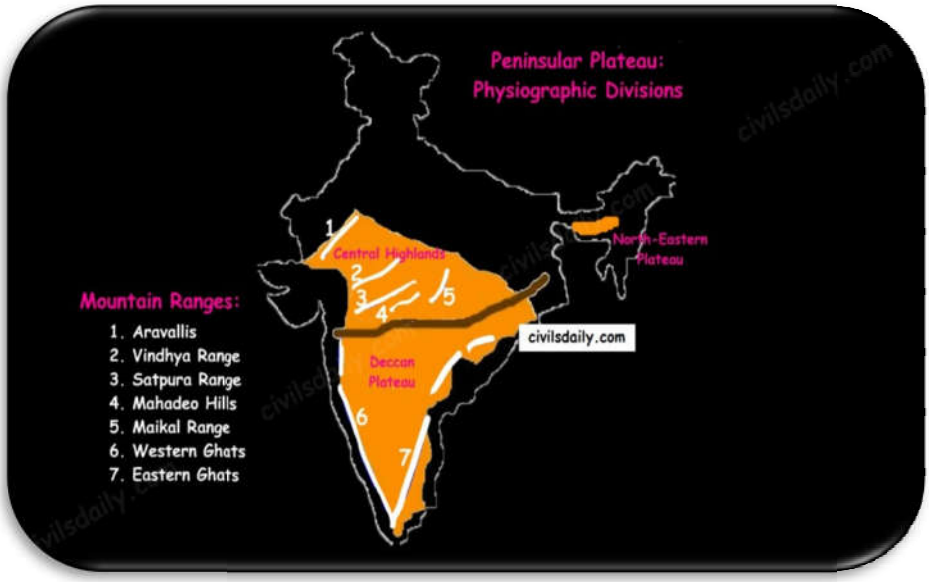
3. The Deccan Traps:

- One of the most important features of the peninsular plateau is the black soil area in the western and northwestern part of the plateau, which is known as the Deccan Trap.
- From the end of the Cretaceous until the beginning of the Eocene, numerous fissure-type eruptions took place in the north-western part of the Deccan plateau. It is believed that the lava outpourings were more than the mass comprising the present-day Himalayas.
- It covers a major portion of the Maharashtra plateau and parts of Gujarat, northern Karnataka and Malwa plateau. Some parts of Tamil Nadu, Andhra Pradesh, UP, and Jharkhand have some outliers of Deccan trap.
- Basalt is the main rock of the region.
- The region has black cotton soil as a result of weathering of this lava material and this soil is one of the finest examples of the parent material controlled soils.

Physiographic Divisions:

On the basis of prominent relief features, the peninsular plateau can be divided into three broad groups:

- The Central Highlands
- The Deccan Plateau
- The Northeastern Plateau.

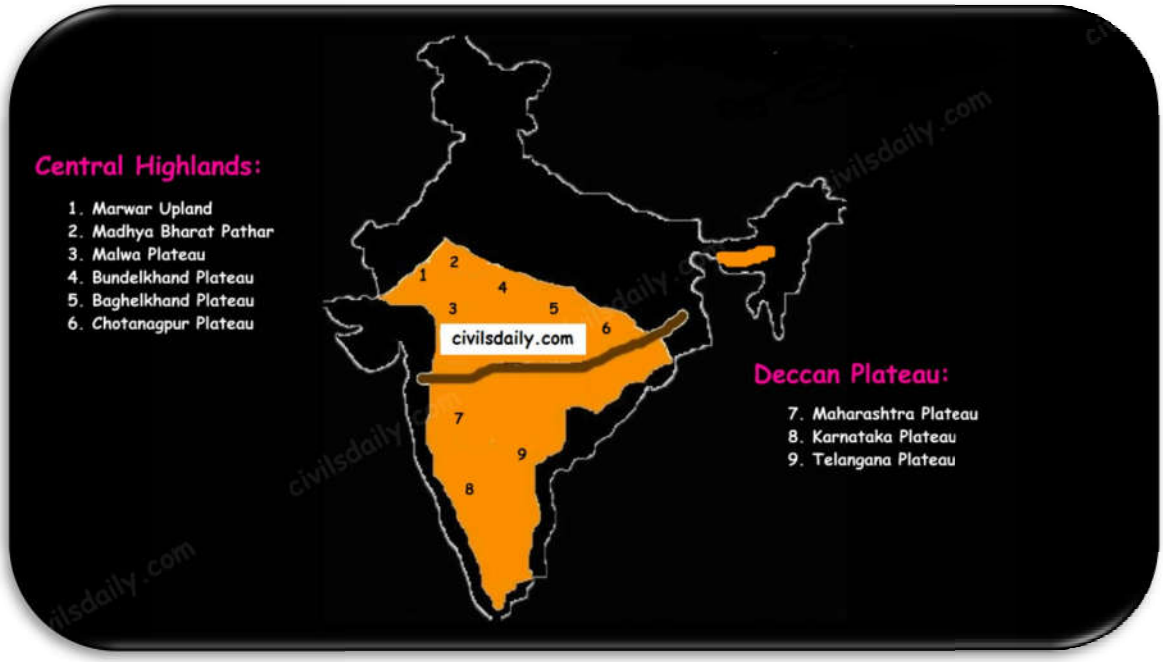


Let's take up these divisions one by one:

1. The Central Highlands

- The northern segment of the peninsular plateau is known as the Central Highlands.
- **Location**:
    1. North of Narmada River.
    2. They are bounded to the west by the Aravallis.
    3. Satpura ranges (formed by a series of scarped plateaus) lie in the South.
- **General Elevation**: 700-1,000 m above the mean sea level and it slopes towards the north and northeastern directions.
- These highlands consist of the:
    1. **Marwar upland** – to the east of Aravallis in Rajasthan
        - A rolling plain carved by Banas River. [Rolling plain: 'Rolling plains' are not completely flat; there are slight rises and fall in the land form. Ex: Prairies of USA]
        - Average elevation is 250-500 m above sea level.
    2. **Madhya Bharat Pathar** – to the east of Marwar upland.
    3. **Malwa plateau** – It lies in Madhya Pradesh between Aravali and Vindhyas. It is composed of extensive lava flow and is covered with black soils.
    4. **Bundelkhand plateau** – It lies along the borders of UP and MP. Because of intensive erosion, semi-arid climate and undulating area, it is unfit for cultivation.
    5. **Baghelkhand plateau** – It lies to the east of the Maikal range.
    6. **Chhotanagpur plateau** – the north–east part of Peninsular plateau.
        - It Includes Jharkhand, parts of Chhattisgarh and West Bengal.
        - This plateau consists of series of step like sub-plateaus (locally called patlands – high-level plateau). It is thus famous as the **Patland plateau** and known as **Ruhr of India**.

  - Rajmahal Hills are the northeastern projection of Chhota Nagpur Plateau.
  - It is a mineral rich plateau.
- 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**.
- This region has undergone metamorphic processes in its geological history, which can be corroborated by the presence of metamorphic rocks such as marble, slate, gneiss, etc.
- Most of the tributaries of the river Yamuna have their origin in the Vindhyan and Kaimur ranges. Banas is the only significant tributary of the river Chambal that originates from the Aravali in the west.



2. The Deccan Plateau

- The Deccan Plateau lies to the south of the Narmada River and is shaped as an inverted triangle.
- It is bordered by:
  1. The Western Ghats in the west,
  2. The Eastern Ghats in the east,
  3. The Satpura, Maikal range and Mahadeo hills in the north.
- It is volcanic in origin, made up of horizontal layers of solidified lava forming trap structure with step-like appearance. The sedimentary layers are also found in between the layers of solidified lava, making it inter–trapping in structure.
- Most of the rivers flow from west to east.
- The plateau is suitable for the cultivation of cotton; home to rich mineral resources and a source to generate hydroelectric power.
- The Deccan plateau can be subdivided as follows:

1. **The Maharashtra Plateau –** it has typical Deccan trap topography underlain by basaltic rock, the regur.
2. **The Karnataka Plateau (**also known as **Mysore plateau) –** divided into western hilly country region of 'Malnad' and plain 'Maidan'
3. **Telangana Plateau**

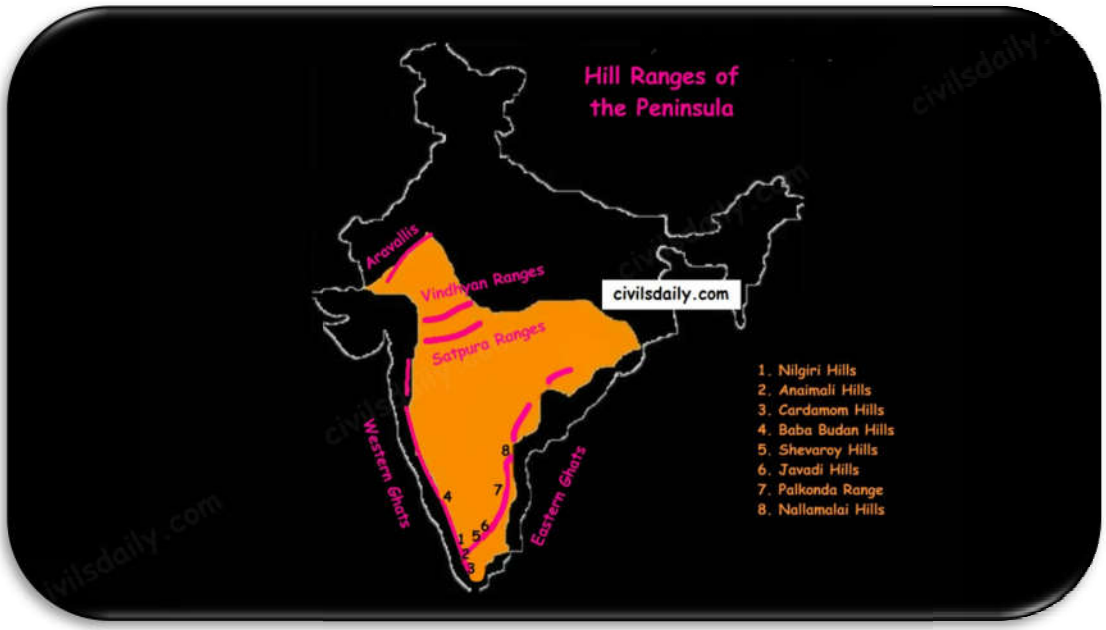
3. The Northeastern Plateau:

- The Meghalaya (or Shillong) plateau is separated from peninsular rock base by the Garo-Rajmahal gap.
- Shillong (1,961 m) is the highest point of the plateau.
- The region has the Garo, Khasi, Jaintia and Mikir (Rengma) hills.
- An extension of the Meghalaya plateau is also seen in the Karbi Anglong hills of Assam.
- 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. Cherrapunji displays a bare rocky surface devoid of any permanent vegetation cover.

Hill ranges of the peninsula:

Most of the hills in the peninsular region are of the **relict type (residual hills).** They are the remnants of the hills and horsts formed many million years ago (horst: uplifted block; graben: subsided block).

The plateaus of the peninsular region are separated from one another by these hill ranges and various river valleys.



1. The Aravali Mountain Range:

- It is a relic of one of the oldest fold mountains of the world.

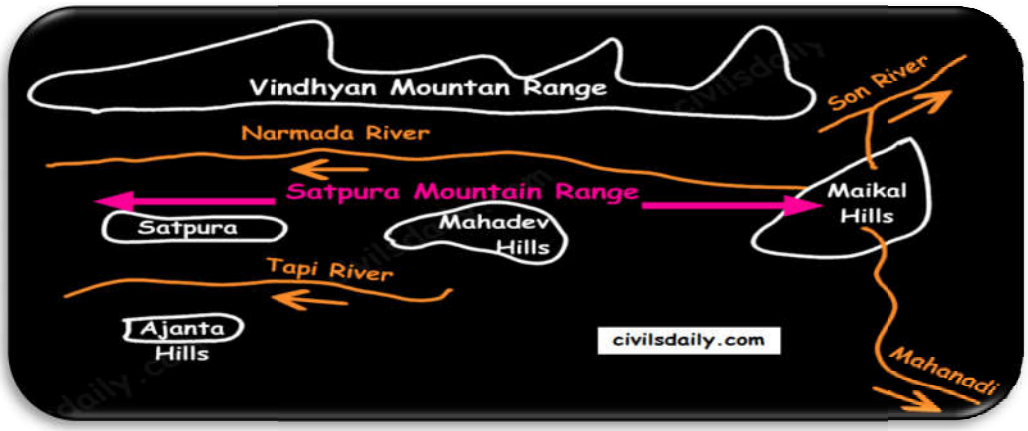
- Its general elevation is only 400-600 m, with few hills well above 1,000 m.
- At present, it is seen as a discontinuous ridge from Delhi to Ajmer and rising up to 1722m (Gurushikhar peak in Mount Abu) and thence southward.
- It is known as 'Jarga' near Udaipur and 'Delhi Ridge' near Delhi.
- Dilwara Jain Temple, the famous Jain temple is situated on Mt. Abu.

2. Vindhyan Ranges:

- They rise as an escarpment running parallel to the Narmada-Son valley.
- General elevation: 300 to 650 m.
- Most of them are made up of sedimentary rocks of ancient ages.
- They act as a watershed between Gangetic and peninsular river systems.

3. Satpura ranges:

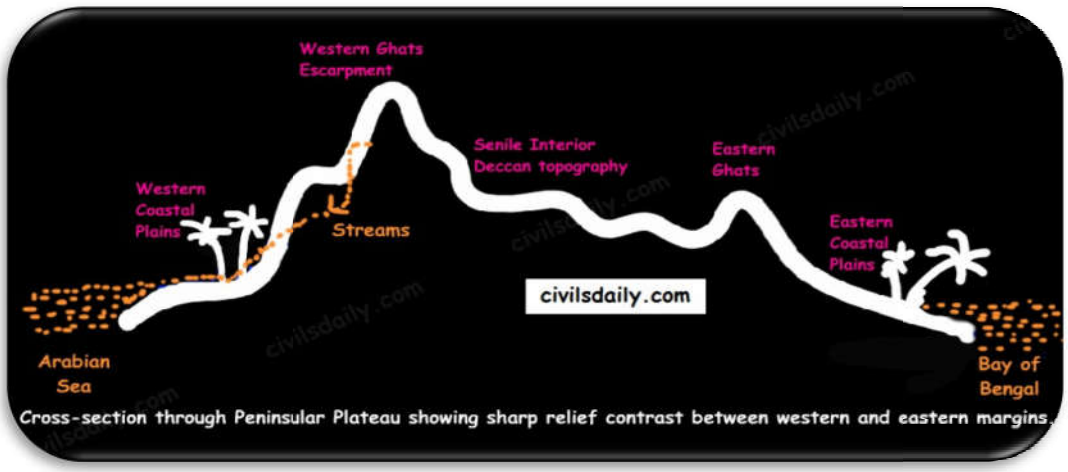
- Satpura range is a series of seven mountains ('Sat' = seven and 'pura' = mountains).
- The seven mountain ranges or folds of Satpura's are:
  - Maikal Hills
  - Mahadeo Hills near Pachmarhi
  - Kalibhit
  - Asirgarh
  - Bijagarh
  - Barwani
  - Arwani which extends to Rajpipla Hills in Eastern Gujarat.
- Satpura ranges run parallel between Narmada and Tapi, parallel to Maharashtra-MP border.
- Dhupgarh (1,350 m) near Pachmarhi on Mahadev Hills is the highest peak of the Satpura Range.
- Amarkantak (1,127 m) is another important peak. Amarkantak is the highest peak of the Maikal Hills from where two prominent rivers – the Narmada and the Son originate.
- Note that three rivers originate from the three sides of Maikal hills (as shown in the following map) but, from Amarkantak, only two rivers (the Narmada and the Son) originate (and not Mahanadi).



4. Western and Eastern Ghats:

- The Western Ghats are a faulted part of the Deccan plateau running parallel from the Tapi valley to a little north of Kanyakumari (1600km). Their western slope is like an escarpment while eastern slope merges gently with the plateau.
- The Eastern Ghats are in the form of residual mountains which are not regular but broken at intervals.
- The Eastern and the Western Ghats meet each other at the Nilgiri hills.
- A brief comparison between them:

Sr. No.	Western Ghats	Eastern Ghats
1.	Western Ghats stretch from the Tapi River to Kanayakumari.	But The Eastern Ghats stretch from Mahanadi Valley to the Nilgiris in the south.
2.	Average width: 50 to 80 km.	Average width: 100 to 200 km.
3.	Most of the Peninsular rivers have their origin in the Western Ghats.	No major river originates in the Eastern Ghats.
4.	Western Ghats are continuous and can be crossed through passes only.	Eastern Ghats comprise of discontinuous and low hills
5.	Average elevation: 900 to 1,600 meters.	Average elevation: About 600 metres above sea level.
6.	Highest Peak: Anai Mudi (2695 meters).	Highest Peak: Mahendragiri (1501 meters).
7.	Western Ghats receive orographic type of rainfall. Southwest monsoons coming from the Arabian Sea and causes heavy rainfall.	Eastern Ghats lie almost parallel to the monsoons coming from Bay of Bengal and does not cause much rainfall.
8.	Western Ghats are locally known by different names such as: • Sahyadri in Maharashtra, • Nilgiri hills in Karnataka and Tamil Nadu • Anaimalai hills and Cardamom hills in Kerala.	They are known as: • Maliya and Madugula Konda ranges in Odisha, • Nallamalai and Palkonda ranges in Andhra Pradesh. Southwards, they are present as detached low hills – Javdi, Shevroy, Panchaimalai, Sirumalai, Varushnad hills.

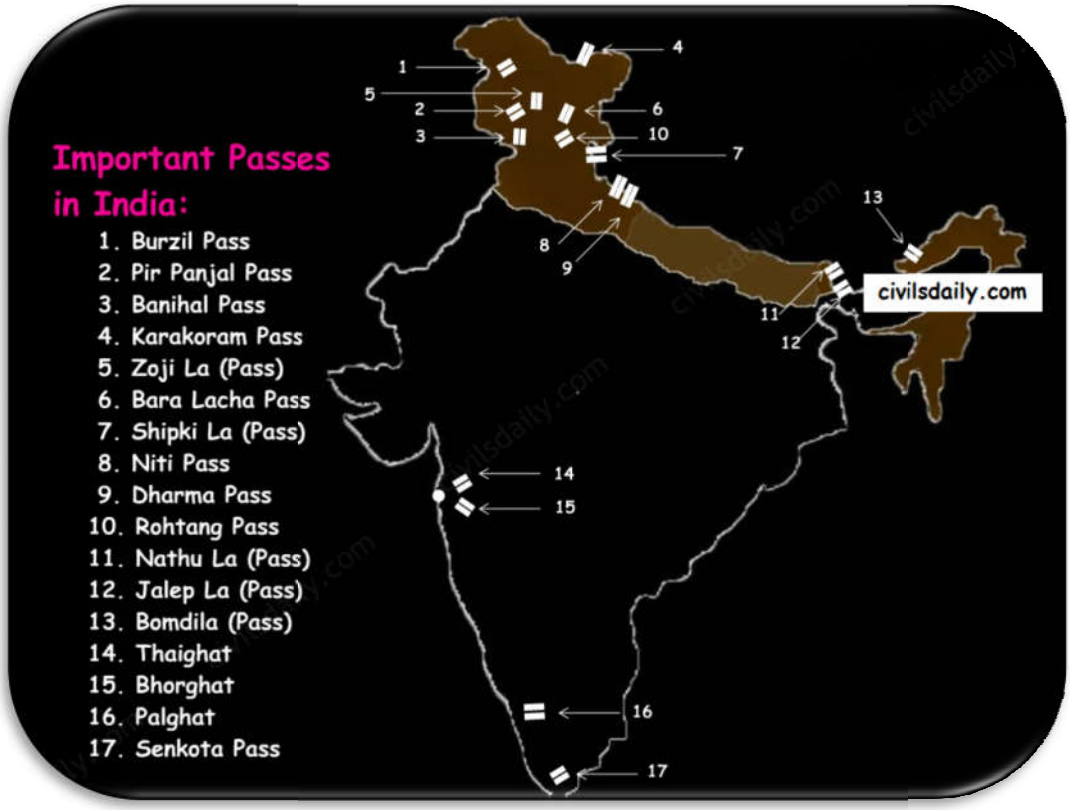


Cross-section through Peninsular Plateau showing sharp relief contrast between western and eastern margins.

Note: The Western Ghats are continuous and can be crossed through passes only. There are four main passes which have developed in the Western Ghats. These are:

1. Thal Ghat – It links Nasik to Mumbai.
2. Bhor Ghat – It links Mumbai to Pune.
3. Pal Ghat – This pass is located between the Nilgiris and the Annamalai mountains. It is in Kerala and connects Kochi and Chennai.
4. Senkota Pass – This pass located between the Nagercoil and the Cardamom hills links Thiruvananthapuram and Madurai.

For the geographical location of these passes, see the following map:



Significance of the Peninsular Region:

- **Rich in mineral resources**: The peninsular region of India is rich in both metallic and non-metallic minerals. About 98% of the Gondwana coal deposits of India are found in the peninsular region.
- **Agriculture**: Black soil found in a substantial part of the peninsula is conducive for the cultivation of cotton, maize, citrus fruits etc. Some areas are also suitable for the cultivation of tea, coffee, groundnut etc.
- **Forest Products**: Apart from teal, sal wood and other forest products, the forests of Western and Eastern Ghats are rich in medicinal plants and are home to many wild animals.

- **Hydel Power**: many rivers, which have waterfalls. They help in the generation of hydroelectric power.
- **Tourism**: There are numerous hill stations and hill resorts like Ooty, Mahabaleshwar, Khandala, etc.

Prelims:

1995

Question: Which one of the following mountain ranges is spread over only one state in India?

A) Aravali
B) Satpura
C) Ajanta
D) Sahyadri
Ans. C

1997

Question: Consider the map given below:

The places marked A, B, C, and D in the map are respectively
A) Rift valley region, Chhattisgarh plain, Rain shadow region, and Chotanagpur Plateau
B) Chhattisgarh plain, Chotanagpur Plateau, Rift valley region, Rain shadow region
C) Rift valley region, Chhattisgarh plain, Chotanagpur Plateau and Rain shadow region
D) Chhattisgarh plain, Rain shadow region, Chotanagpur Plateau, Rift valley region,
Ans. C

2005

Question: Which one of the following statements is not correct?

A) The Western Ghats are relatively higher in their northern regions.
B) The Anaimudi is the highest peak in the Western Ghats
C) Tapi River lies to the south of Satpura
D) The Narmada and the Tapi river valleys are said to be old rift valleys.
Ans. A

Question: Which one of the following is the correct sequence of the given hills starting from the north and going towards the south?

A) Nallamalai Hills – Nilgiri Hills – Javadi Hills – Anaimalai Hills
B) Anaimalai Hills – Javadi Hills – Nilgiri Hills – Nallamalai Hills
C) Nallamalai Hills – Javadi Hills – Nilgiri Hills – Anaimalai Hills
D) Anaimalai Hills – Nilgiri Hills – Javadi Hills – Nallamalai Hills
Ans. C

2007

Question: In which state is the Guru Shikhar peak located?

1. Rajasthan
2. Gujarat
3. Madhya Pradesh
4. Maharashtra

Ans. A

D. The Indian Desert

The Indian desert is also known as the Thar Desert or the Great Indian Desert.

Location and Extent:

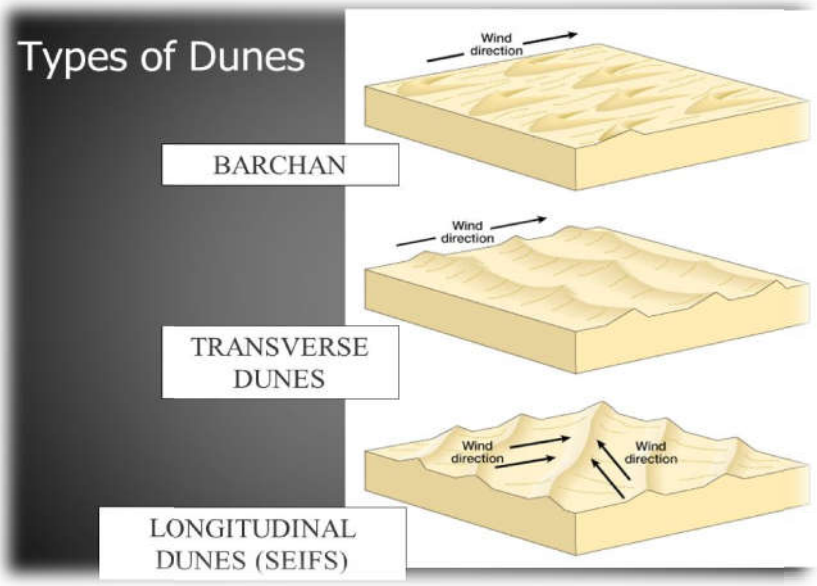
- Location – To the north-west of the Aravali hills.
- It covers Western Rajasthan and extends to the adjacent parts of Pakistan.

Geological History and Features

- Most of the arid plain was under the sea from Permo-Carboniferous period and later it was uplifted during the Pleistocene age. This can be corroborated by the evidence available at wood fossils park at Aakal and marine deposits around Brahmsar, near Jaisalmer (The approximate age of the wood fossils is estimated to be 180 million years).
- The presence of dry beds of rivers (e.g. Saraswati) indicates that the region was once fertile.
- Geologically, the desert area is a part of peninsular plateau region but on the surface it looks like an aggradational plain.

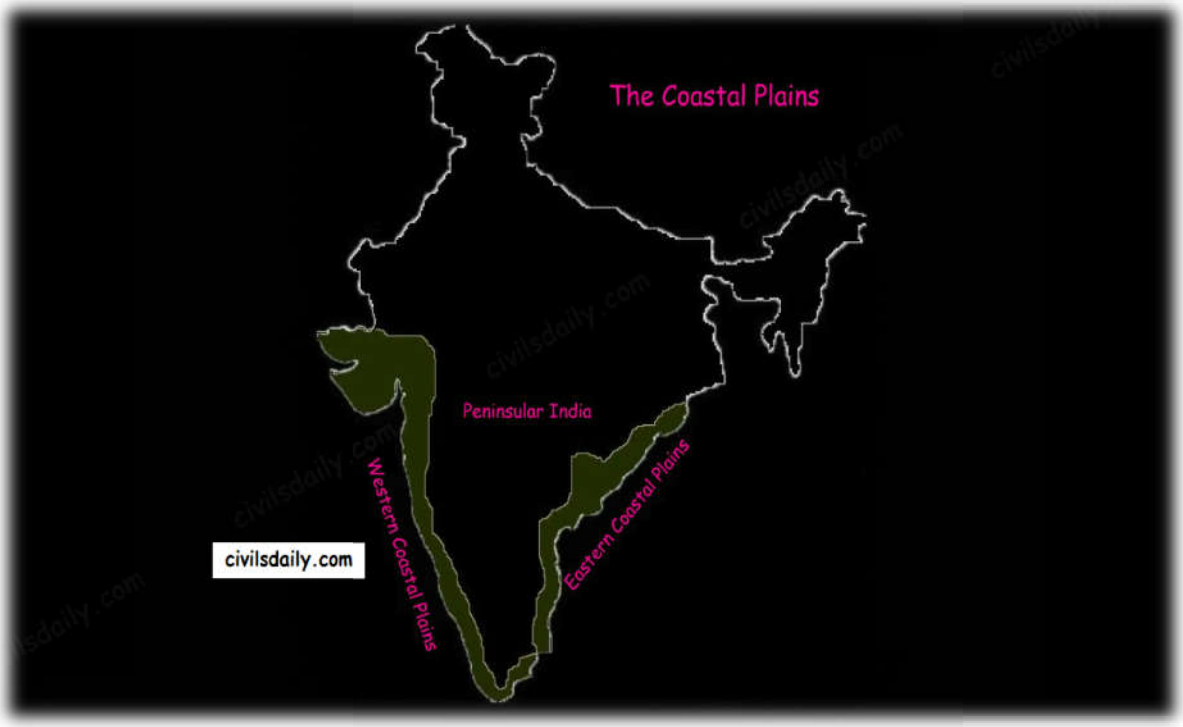
Chief Characteristics:

- The desert proper is called the **Marusthali** (dead land) as this region has an arid climate with low vegetation cover. In general, the Eastern part of the Marusthali is rocky, while its western part is covered by shifting sand dunes.
- **Bagar**: Bagar refers to the semi-desert area which is west of Aravallis. Bagar has a thin layer of sand. It is drained by Luni in the south whereas the northern section has a number of salt lakes.
- The Rajasthan Bagar region has a number of short seasonal streams which originate from the Aravallis. These streams support agriculture in some fertile patches called **Rohi**.
- Even the most important river '**Luni**' is a seasonal stream. The Luni originates in the Pushkar valley of the Aravalli Range, near Ajmer and flows towards the southwest into the Rann of Kutch.
- The region north of Luni is known as the **Thali or sandy plain**.
- There are some streams which disappear after flowing for some distance and present a typical case of inland drainage by joining a lake or **playa e.g. the Sambhar Lake**. The lakes and the playas have brackish water which is the main source of obtaining salt.
- **Well pronounced desert land features:**
    - **Sand dunes**: It is a land of undulating topography dotted with **longitudinal dunes, transverse dunes** and **barchans**. [Barchan – A crescent-shaped sand dune, the horns of which point away from the direction of the dominant wind; Longitudinal dune – A sand dune with its crest running parallel to the direction of prevailing wind]
- **Mushroom rocks**
- **Shifting dunes (**locally called **Dhrians)**
- **Oasis** (mostly in its southern part)



E. The Coastal Plains

Of the total coastline of India (7517 km), that of the peninsula is 6100 km between the peninsular plateau and the sea. The peninsular plateau of India is flanked by narrow coastal plains of varied width from north to south.



On the basis of the location and active geomorphologic processes, these can be broadly divided into two parts:

- The western coastal plains
- The eastern coastal plains.

We now take them up one by one:

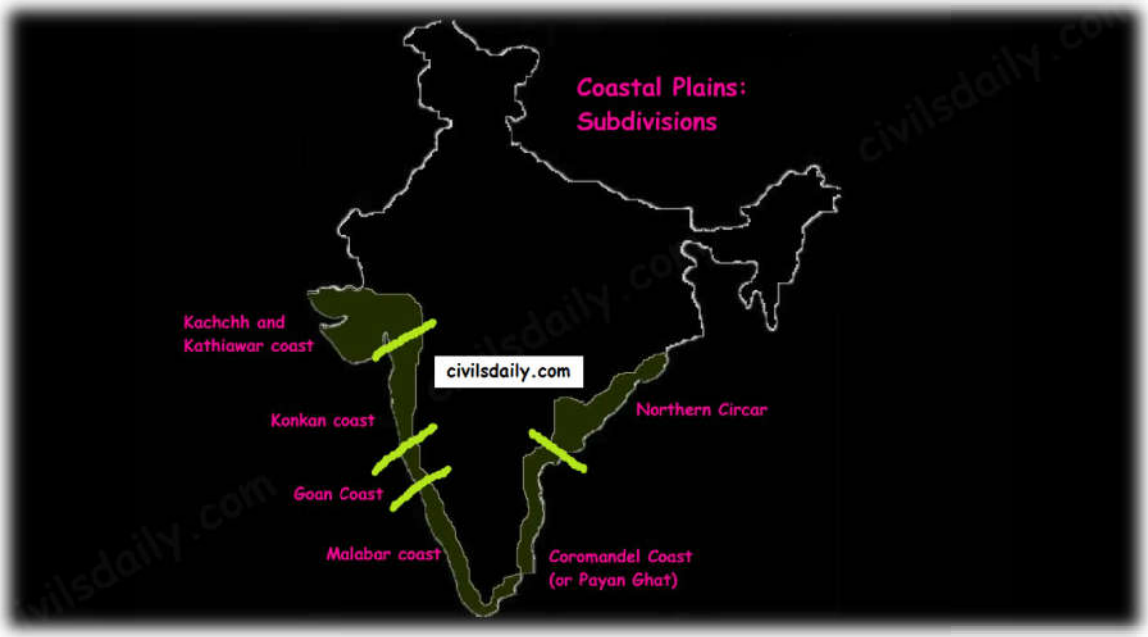
The Western Coastal Plain

1. Extent: The Western Coastal Plains are a thin strip of coastal plains with a width of 50 kms between the Arabian Sea and the Western Ghats.

2. Subdivisions: Extending from the Gujarat coast in the north to the Kerala coast in the south, the western coast may be divided into following divisions:

- Kuchchh and Kathiawar coast in Gujarat,
- Konkan coast in Maharashtra,
- Goan Coast in Karnataka, and
- Malabar coast in Kerala

Note: Kutch and Kathiawar, though an extension of Peninsular plateau (because Kathiawar is made of the Deccan Lava and there are tertiary rocks in the Kutch area), they are still treated as an integral part of the Western Coastal Plains as they are now leveled down.



3. A coastline of submergence: The western coastal plains are an example of submerged coastal plain. It is believed that the city of Dwaraka which was once a part of the Indian mainland situated along the west coast is submerged under water.

4. Characteristic Features:

- The western coastal plains are narrow in the middle and get broader towards north and south. Except for the Kuchchh and Kathiawar coastal region, these are **narrower** than their eastern counterpart.

- The coast is straight and affected by the South-West Monsoon winds over a period of six months. The western coastal plains are thus **wetter** than their eastern counterpart.
- The western coast being more indented than the eastern coast provides natural conditions for the development of **ports and harbours**. Kandla, Mazagaon, JLN port Navha Sheva, Marmagao, Mangalore, Cochin, etc. are some of the important natural ports located along the west coast.
- The western coastal plains are dotted with a large number of **coves** (a very small bay), **creeks** (a narrow, sheltered waterway such as an inlet in a shoreline or channel in a marsh) and a few **estuaries**. The estuaries, of the Narmada and the Tapi are the major ones.
- The rivers flowing through this coastal plain do not form any delta. Many small rivers descend from the Western Ghats making a chain of waterfalls.
- **The Kayals** – The Malabar Coast has a distinguishing feature in the form of 'Kayals' (backwaters). These backwaters are the shallow lagoons or the inlets of the sea and lie parallel to the coastline. These are used for fishing, inland navigation and are important tourist spots. The largest of these lagoons is the Vembanad Lake. Kochi is situated on its opening into the sea.

The Eastern Coastal Plain

1. Extent: The Eastern Coastal Plains is a strip of coastal plain with a width of 100 – 130 kms between the Bay of Bengal and the Eastern Ghats

2. Subdivisions: It can be divided into two parts:

- Northern Circar: The northern part between Mahanadi and Krishna rivers. Additionally, the coastal tract of Odisha is called the Utkal plains.
- Coromandel Coast (or Payan Ghat): The southern part between Krishna and Kaveri rivers.

3. A coastline of emergence: The eastern coastal plain is broader and is an example of an emergent coast.

4. Characteristic features:

- The eastern coastal plains are **wider** and **drier** resulting in shifting sand dunes on its plains.
- There are well-developed **deltas** here, formed by the rivers flowing eastward in to the Bay of Bengal. These include the deltas of the Mahanadi, the Godavari, the Krishna and the Kaveri.
- 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.
- **Chilika Lake** is an important feature along the eastern coast. It is the largest salt water lake in India.

Significance of the Coastal Plains region:

- These plains are agriculturally very productive. The western coast grows specialized tropical crops while eastern coasts witnessed a green revolution in rice.
- The delta regions of eastern coastal plains have a good network of canals across the river tributaries.
- Coastal plains are a source of salt, monazite (used for nuclear power) and mineral oil and gas as well as centres of fisheries.
- Although lacking in adequate natural harbours, with a number of major and minor ports, coastal plains are centres of commerce and have attracted dense human settlements.
- The coastal regions of India are noted for tourist centres, fishing and salt making.

Prelims:

Question: Assertion (A): The eastern coast of India produces more rice than the western coast.

Reason (R): The eastern coast receives more rainfall than the western coast.

Ans. C (Assertion is right but reason is wrong)

Mains:

Question: Assess the significance of coastal regions in the economic development of India. (2009/ 15 marks)

F. The Islands

There are two major island groups in India

1. The island groups of Bay of Bengal: Andaman & Nicobar Islands
2. The island groups of Arabian Sea: Lakshadweep and Minicoy Islands

Let's take these up one by one:

Andaman & Nicobar Islands:

- Also called the emerald islands.
- **Location and Extent**:
  - These are situated roughly between 6°N-14°N and 92°E -94°E.
  - The most visible feature of the alignment of these islands is their narrow longitudinal extent.
  - These islands extend from the Landfall Island in the north (in the Andamans) to the Indira Point (formerly known as Pygmalion Point and Parsons Point) in the south (In the Great Nicobar).
- **Origin:** The Andaman and Nicobar islands have a geological affinity with the tertiary formation of the Himalayas, and form a part of its southern loop continuing southward from the Arakan Yoma.
- The entire group of islands 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**.

- The Andaman islands are further divided into:
  - Great Andamans
    - North Andaman
    - Middle Andaman
    - South Andaman
  - Little Andaman

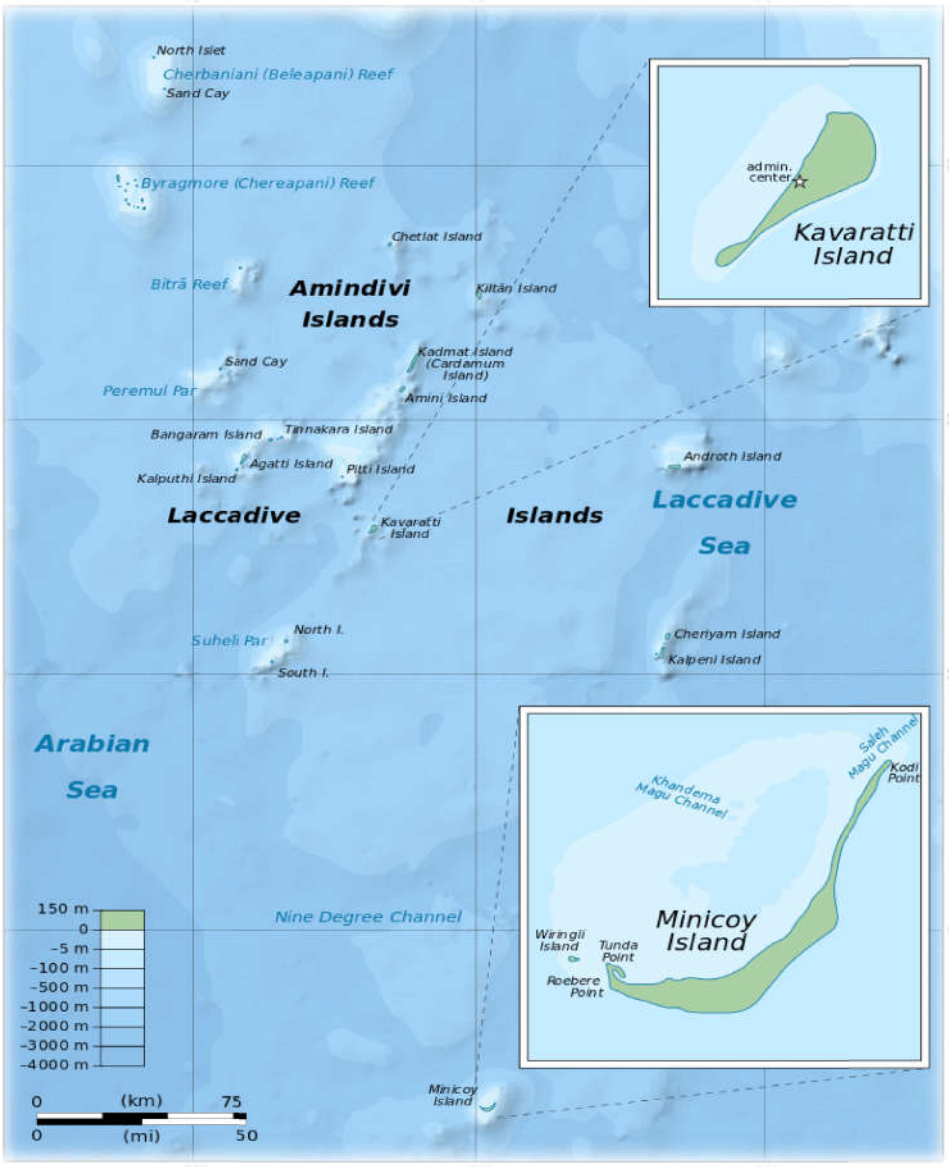
Little Andaman is separated from the Great Andamans by the **Duncan Passage**.

- **Chief Characteristics**:
  - These are actually a continuation of Arakan Yoma mountain range of Myanmar and are therefore characterized by hill ranges and valleys along with the development of some coral islands.
  - Some smaller islands are volcanic in origin e.g. the Barren Island and the Narcondam Island. Narcondam is supposed to be a dormant volcano but Barren perhaps is still active.
  - These islands make an arcuate curve, convex to the west.
  - These islands are formed of granitic rocks.
  - The coastal line has some coral deposits, and beautiful beaches.
  - These islands receive convectional rainfall and have an equatorial type of vegetation.
  - These islands have a warm tropical climate all year round with two monsoons.
  - The Saddle peak (North Andaman – 738 m) is the highest peak of these islands.
  - The Great Nicobar is the largest island in the Nicobar group and is the southernmost island. It is just 147 km away from the Sumatra island of Indonesia.

Lakshadweep Islands:

- These islands were earlier (before 1st November 1973) known as Laccadive, Minicoy and Amindivi Islands.
- **Location**:
  - These are scattered in the Arabian Sea between 8°N-12°N and 71°E -74°E longitude.
  - These islands are located at a distance of 280 km-480 km off the Kerala coast.
- **Origin**: The entire island group is built of coral deposits.
- **Important islands:**
  - Amindivi and Cannanore islands in the north.
  - Minicoy (lies to the south of the nine degree channel) is the largest island with an area of 453 sq. km.
- **Chief Characteristics**:
  - These consist of approximately 36 islands of which 11 are inhabited.
  - These islands, in general, have a north-south orientation (only Androth has an East-West orientation.
  - These islands are never more that 5 meters above sea level.
  - These islands have calcium rich soils- organic limestones and a scattered vegetation of palm species.
  - One typical feature of these islands is the formation of crescentic reef in the east and a lagoon in the west.
  - Their eastern seaboard is steeper.

- The Islands of this archipelago have storm beaches consisting of unconsolidated pebbles, shingles, cobbles and boulders on the eastern seaboard.
- The islands form the smallest Union Territory of India.



Other than the above mentioned two major groups, the important islands are:

1. **Majauli:** in Assam. It is:

1. The world's largest freshwater (Brahmaputra river) island.
2. India's first island district

2. **Salsette:** India's most populous island. Mumbai city is located on this island.
3. **Sriharikota:** A barrier island. On this island is located the satellite launching station of ISRO.

4. **Aliabet:** India's first off-shore oil well site (Gujarat); about 45 km from Bhavnagar, it is in the Gulf of Khambat.
5. **New Moore Island:** in the Ganga delta. It is also known as Purbasha Island. It is an island in the sunderban deltaic region and it was a bone of contention between India and Bangladesh. In 2010, it was reported to have been completely submerged by the rising sea water due to Global warming.
6. **Pamban Island**: lies between India and Sri Lanka.
7. **Wheeler Island**: near the Odisha coast; it is a missile launching station in Bay of Bengal.

Prelims:

1996

Question: 'Saddle Peak' the highest peak of Andaman and Nicobar Islands is located in

A. Great Nicobar

B. Middle Andaman

C. Little Andaman

D. North Andaman

Ans. D

Mains:

Question: Write a short note on New Moore Island. (2006/2M)

Question: Write a short note on Indira Point. (2007/2M)

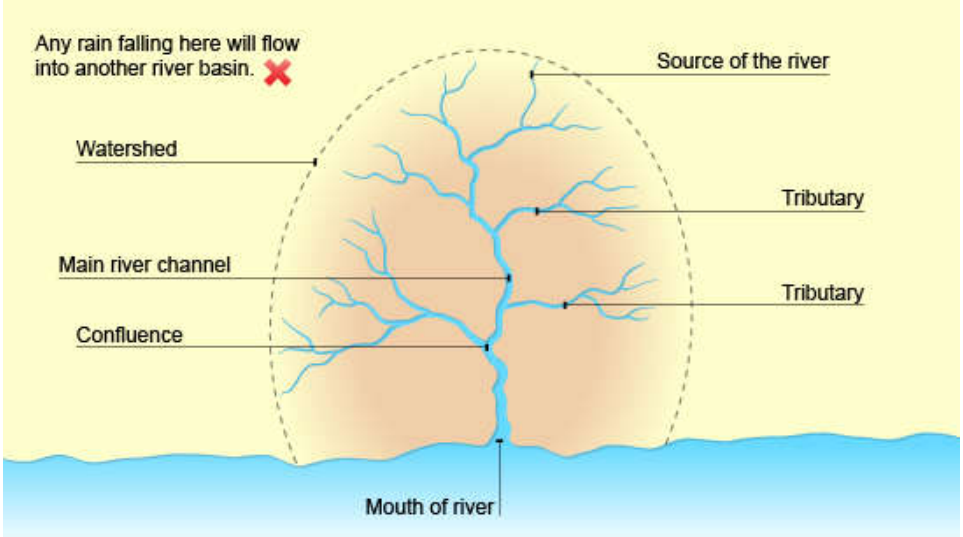
Question: Name the main physiographic divisions of India and give the salient features of each division. (2000/15M).

Question: How do the Andaman and Nicobar Islands and the Lakshadweep differ in the geological evolution and topographical conditions? (1998/15M)

Venkateswarlu Nagineni

4. Drainage System

Before we study India's Drainage system, it is imperative that we understand the basic terminology associated with a river and its drainage.



Some basic terms:

Source of a river: The beginning or start of a river.

Confluence: The point at which two rivers or streams join.

Distributary: The small river that branches out from the main river and then never meets again. It thus decreases the river's water volume. Distributaries are commonly found on deltas but are also important in the formation of alluvial fans and cones.

Tributary: A stream or smaller river which joins a larger stream or river and thus increases its water volume.

Mouth: The point where the river comes to the end, usually when entering a sea.

Determination of left/right bank of a river: Stand facing the mouth of the river in the direction of its course. Your left hand side will be the left bank and your right hand side, the right bank.

River basin, catchment area and watershed

Generally, the area drained by a river and its tributaries is called its river basin or catchment area or a watershed. But, there are subtle differences between them.

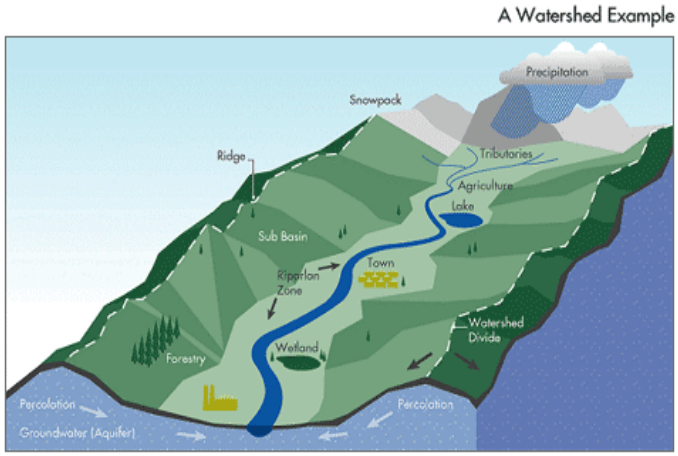
River Basin: All the area drained by a river and its tributaries.

Catchment area: It refers to all the area of land over which rain falls and is caught to serve a river basin.

The catchment area of large rivers or river system is called a river basin while those of small rivers, a lake, a tank is often referred to as a watershed. Watersheds are small in area, generally less than 1000 ha.

There are many smaller watersheds within a river basin. Example: watershed of Yamuna + water shed of Chambal + watershed of Gandak + …. = Drainage basin of Ganga.

Watershed:



1. As a catchment/drainage area: All the land with a common outlet for its surface water ie a geohydrological area from where the water drains to a common point.

Let's watch this video for a better understanding:

2. As a water divide: Watershed as a water divide refers to an elevated line from where the water flows in different directions into different river basins.

The 3 major watersheds which direct and control the flow of surface water in India are:

1. The Great Himalayan watershed with its important Karakoram branch
2. In Central India, the watershed is formed by Vindhyas, Satpura and Maikal ranges.
3. The Western Ghats.

A river basin or watershed is often taken as planning unit for macro/micro level developmental planning because:

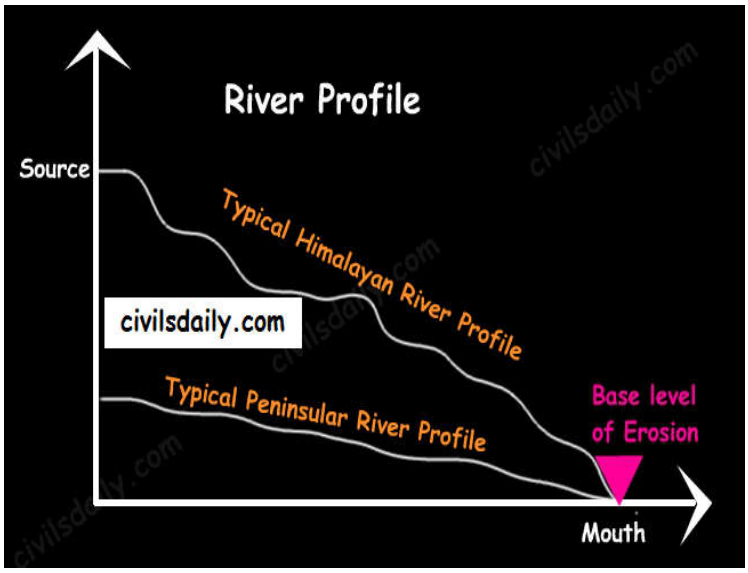
1. River basins and watersheds are marked by synergy and unity. What happens in one part of the basin or watershed (e.g. flood, drought etc.) directly affects the other parts and the unit as a whole.
2. The data about land and water characteristics is measurable and comparable.

Base level of erosion and River Profile:

Base level of erosion: – It is the lowest level to which down-cutting by a river is possible, often referred to as the 'mouth of the river'. The ultimate base level for any stream is the water body into which it flows – sea, lake, reservoir, dam etc. For large rivers, sea level is usually the base level, but a large river or lake is likewise the base level for tributary streams.

Under normal circumstances, the goal of a river is to do the work of erosion, initially up to its local and then permanent base level.

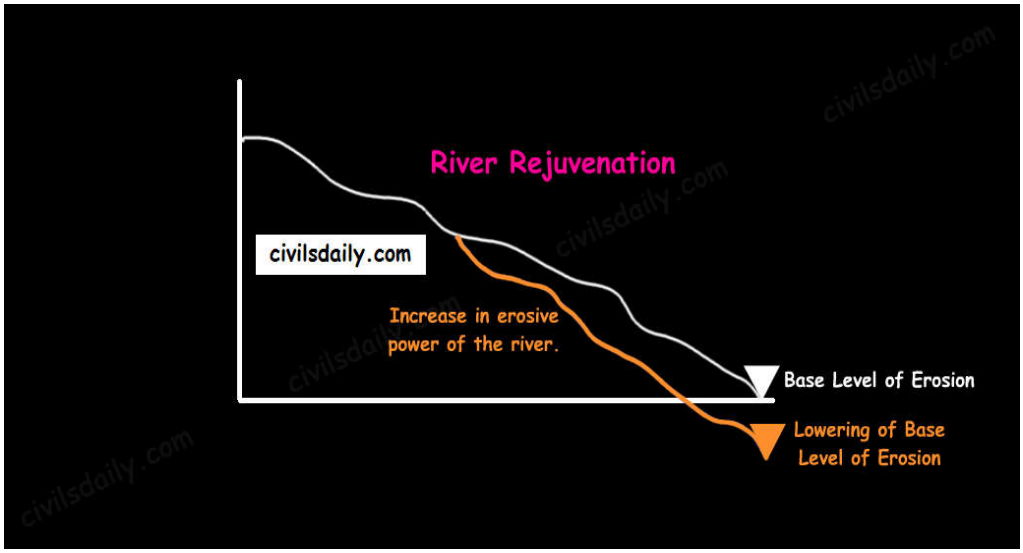
River Profile: It refers to the cross-section of a river from its source to mouth representing the height of the river at various points. The peninsular rivers have almost reached their base levels of erosion.



River Rejuvenation

River Rejuvenation refers to a significant enhancement in the erosive power of the rivers. It can happen because of the following reasons:

- Fall in the sea level (lowering of base level of erosion)
- Dynamic upliftment of the land
- For a given load, if there is a considerable increase in the volume of water.
- For a given volume of water, if there is a considerable decrease in the load.



River Regime and River Discharge:

Discharge: The volume of water flowing in a river measured over time. It is measured either in cusecs (cubic feet per second) or cumecs (cubic metres per second).

River regime: It refers to the seasonal fluctuation in respect of volume of water in the river.

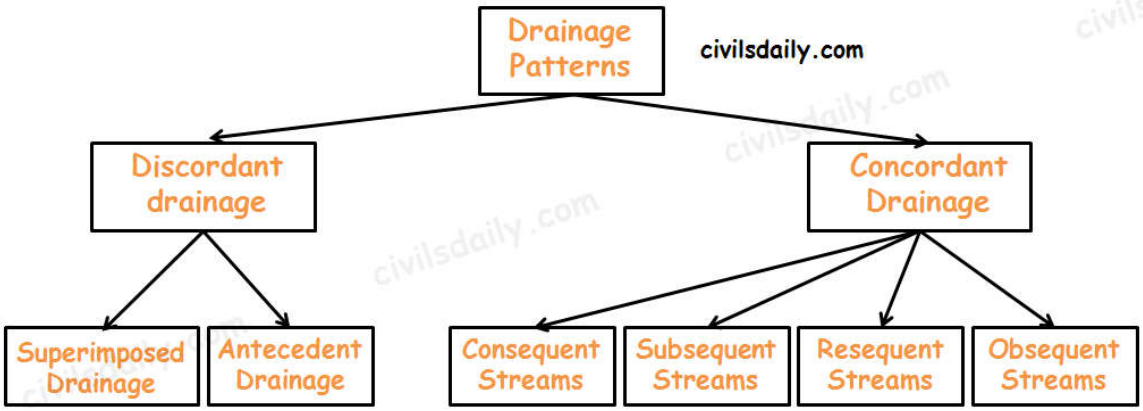
Let's consider the case of Himalayan and Peninsular rivers. The main differences in their flows are caused by the differences in climate. The main differences are:

- **The regimes of Himalayan Rivers are monsoonal as well as glacial**. This is because the Himalayan Rivers are perennial as they are fed by glaciers through snow melt and also receive rainfall water during rainy season. E.g. The river Ganga has its minimum flow during the January-June period, maximum flow is attained either in August or in September followed by a gradual steady fall afterwards.
- **The regimes of most of the peninsular rivers, on the other hand, are monsoonal** as they are fed by rainfall alone e.g. the river Narmada has a very low volume of discharge

from Jan-July and a sharp rise in August (the rise corresponding with the monsoon season). The fall in October is as spectacular as the rise in August (as the monsoon season ends). It also varies from one part of the peninsular plateau to the other.

Drainage

The flow of water through well-defined channels is known as 'drainage' and the network of such channels is called a 'drainage system'.



Discordant drainage

A pattern of drainage that bears no relation to the structure of the underlying rock. This may be because:

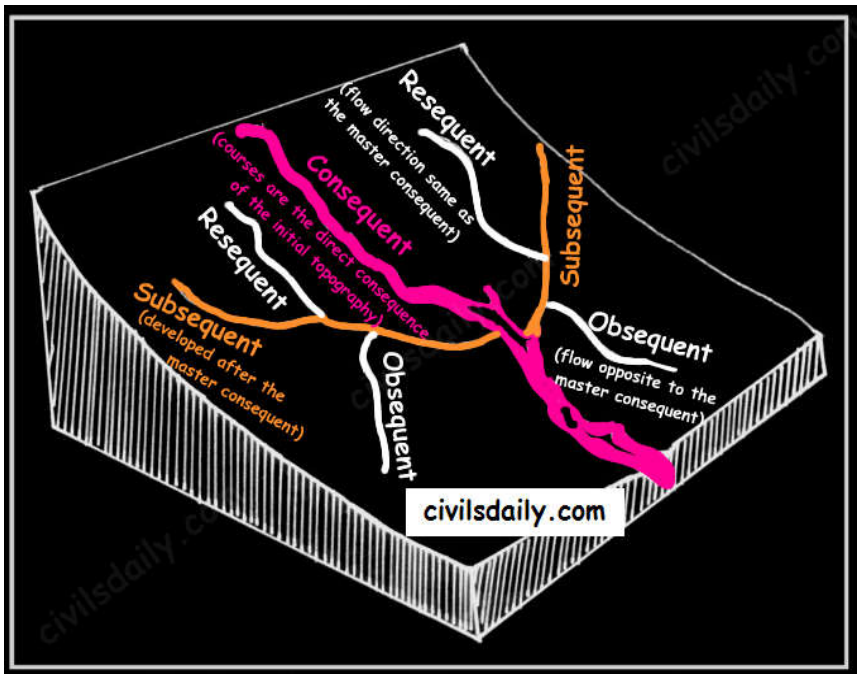
- The drainage pattern developed on rock strata that have since been removed by erosion; a process known as superimposition. The drainage pattern thus developed is called **superimposed drainage** (or Epigenetic or Super induced Drainage). Examples: The Damodar, the Subarnarekha, the Chambal, the Banas and the rivers flowing at the Rewa Plateau, rivers of eastern USA and southern France.
- The drainage pattern was already present before a period of uplift and folding that formed the present structure. As the uplift took place, the rivers were able to cut down at approximately the same rate and so maintain their courses. This process is called antecedence and the drainage system thus developed is called **antecedent drainage**.

Many of the Himalayan Rivers have antecedent origin i.e. these rivers existed even before the Himalayan ranges were uplifted. These rivers originate in the Tibetan side beyond the mountain ranges of Himalayas. The Indus, Satluj, Alaknanda, Gandak, Kosi, Brahmaputra all have an antecedent origin. Since these rivers are antecedent, they run transverse to the mountain ranges cutting deep V-shaped, steep-sided valleys (deep gorges).

Concordant Drainage (also called **accordant drainage)**

The pattern of drainage which arises from and closely follows the trends of the underlying strata is called concordant drainage.

1. **Consequent Streams**: Those streams whose courses are the direct consequence of the initial topography are called consequent streams.
2. **Subsequent Streams**: These are developed after the master consequent.
3. **Obsequent streams**: These flow in opposite direction to the master consequent.
4. **Resequent Streams**: A resequent stream flows in the same direction as that of the initial consequent stream, but which develops in response to a new base level formed due to inversion of relief.



Drainage pattern:

Drainage pattern refers to a design which a river and its tributaries form together from its source to its mouth. The drainage pattern of an area is the outcome of:

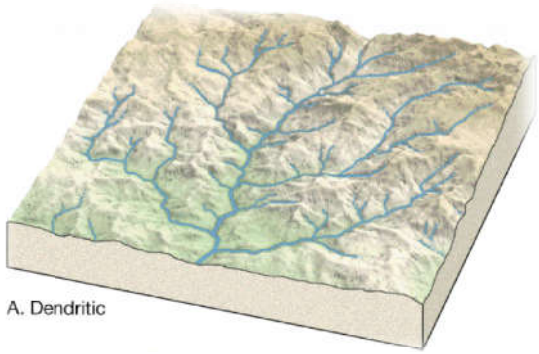
- The geological time period,
- Nature and structure of rocks,
- Topography,
- Slope,

- Amount of water flowing, and
- The periodicity of the flow.

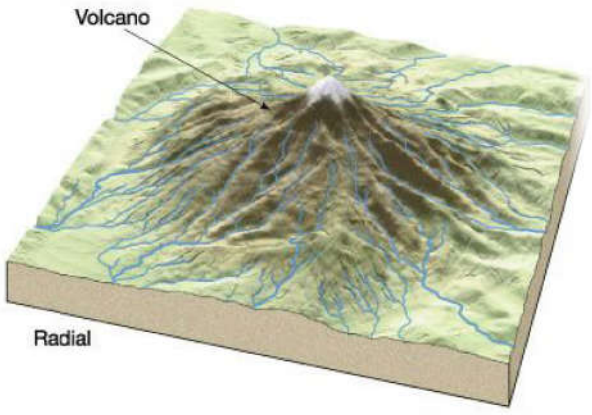
Some Important Drainage Patterns:

A combination of several patterns may be found in the same drainage basin.

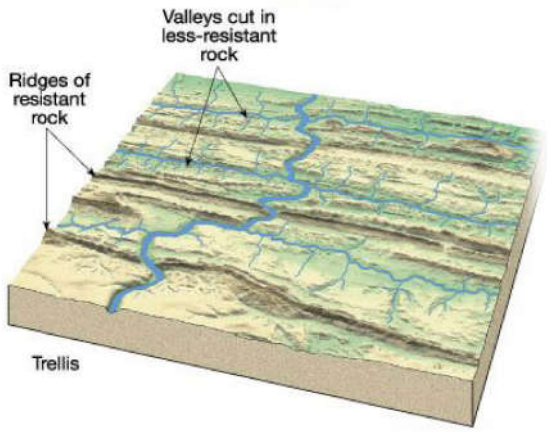
1. **Dendritic**: The dendritic pattern develops where the river channel follows the slope of the terrain. The drainage pattern resembling the branches of a tree is known as "dendritic" the examples of which are the rivers of northern plain. It is the most common stream pattern. A dendritic pattern develops in a terrain which has uniform lithology, and where faulting and jointing are insignificant.



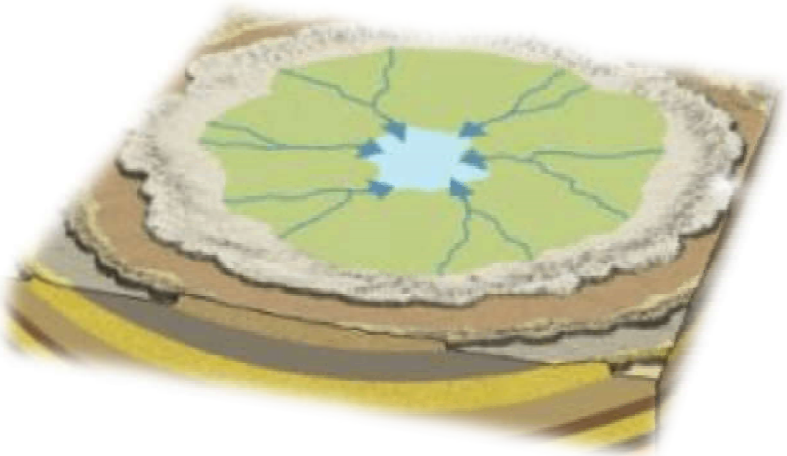
2. **Radial**: The radial pattern develops when streams flow in different directions from a central peak or a dome like structure. E.g. the rivers like Narmada, Son and Mahanadi originating from Amarkantak Hills flow in different directions and are good examples of radial pattern. Radial drainage patterns are also found/in the Girnar Hills (Kathiwar, Gujarat), and Mikir Hills of Assam.



3. **Trellis**: 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'. A trellis drainage pattern develops where hard and soft rocks lie parallel to each other. For example, rivers in the upper part of the Himalayan region and in the old folded mountains of the Singhbhum (Chotanagpur Plateau) have drainage of trellis pattern. The trellis drainage pattern can also be seen in the Appalachian region of the U.S.A., where hard and soft rocks occur in parallel bands.

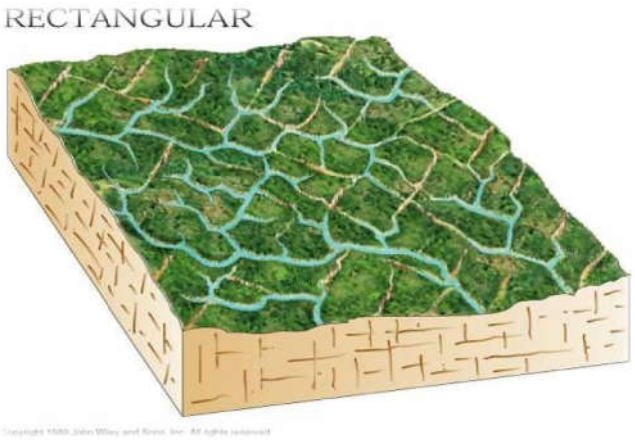


4. **Centripetal**: When the rivers discharge their waters from all directions in a lake or depression, the pattern is known as 'centripetal'. This drainage pattern is also called endorheic drainage. For example, Loktak lake in Manipur.



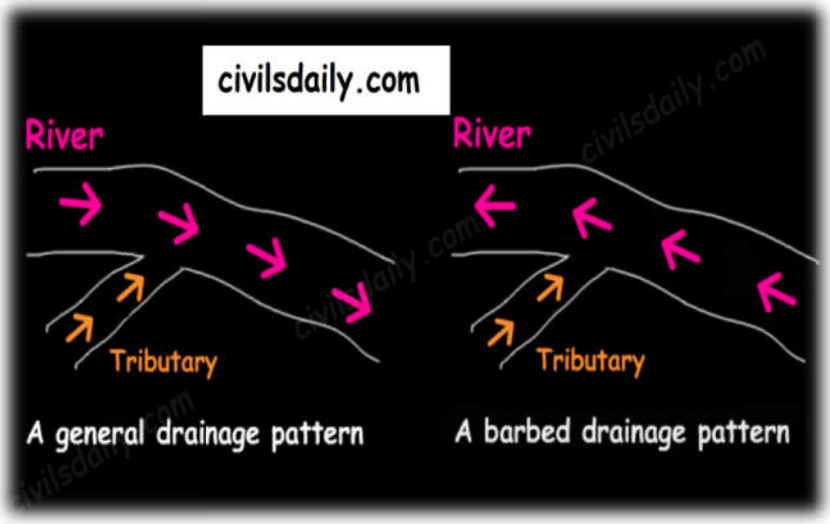
5. **Rectangular**: In this drainage, both the main stream and its tributaries show right-angled bends. A rectangular drainage pattern develops on a strongly jointed rocky terrain. It differs from trellis pattern drainage, since it is more irregular and its tributary streams are not as

long or as parallel as in trellis drainage. Example: Colorado River (USA), streams found is the Vindhyan Mountains of India.



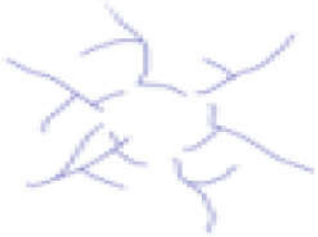
6. **Barbed:** If you look at the way that tributaries empty into larger rivers, you will notice that most of them flow in the same direction as the rivers they empty into. But quite a large number flow the other way. In fact, you will find stretches of some rivers where every tributary empties into the river in the "wrong" direction! Such an occurrence is known as a barbed drainage pattern.

   Most barbed drainage patterns are the result of river-capture which reverses the direction of flow. However, the tributary channels continue to flow in their original direction. The Arun River (Nepal), a tributary of the Kosi is an interesting example of barbed drainage pattern.

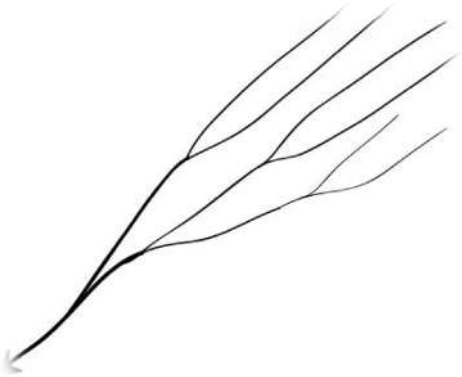


7. Annular: Annular pattern represents that part of a drainage pattern in which the subsequent streams follow the curving or arcuate courses before joining the consequent stream. These results from a partial adaptation to an underground circular structure i.e. batholiths. This is not a very

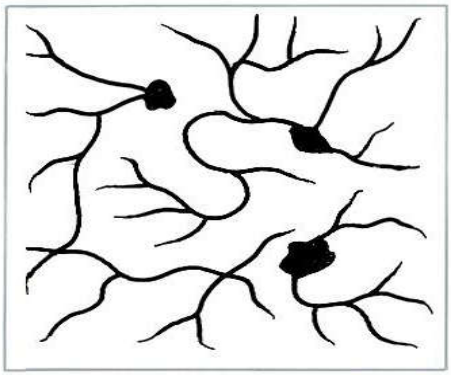
common drainage pattern in India. Some examples of this are however found in Pithoragarh (Uttarakhand), Nilgiri Hills in Tamil Nadu and Kerala.



8. Parallel drainage: The drainage pattern in which the rivers flow almost parallel to each other is known as parallel drainage. The small and swift rivers originating in the Western Ghats and discharging their water into the Arabian Sea provide a good example of parallel drainage pattern in India.



9. Deranged pattern: This is an uncoordinated pattern of drainage characteristic of a region recently vacated by an ice-sheet. The picture is one of numerous water courses, lakes and marshes; some inter-connected and some in local drainage basins of their own. This type of drainage is found in the glaciated valleys of Karakoram.

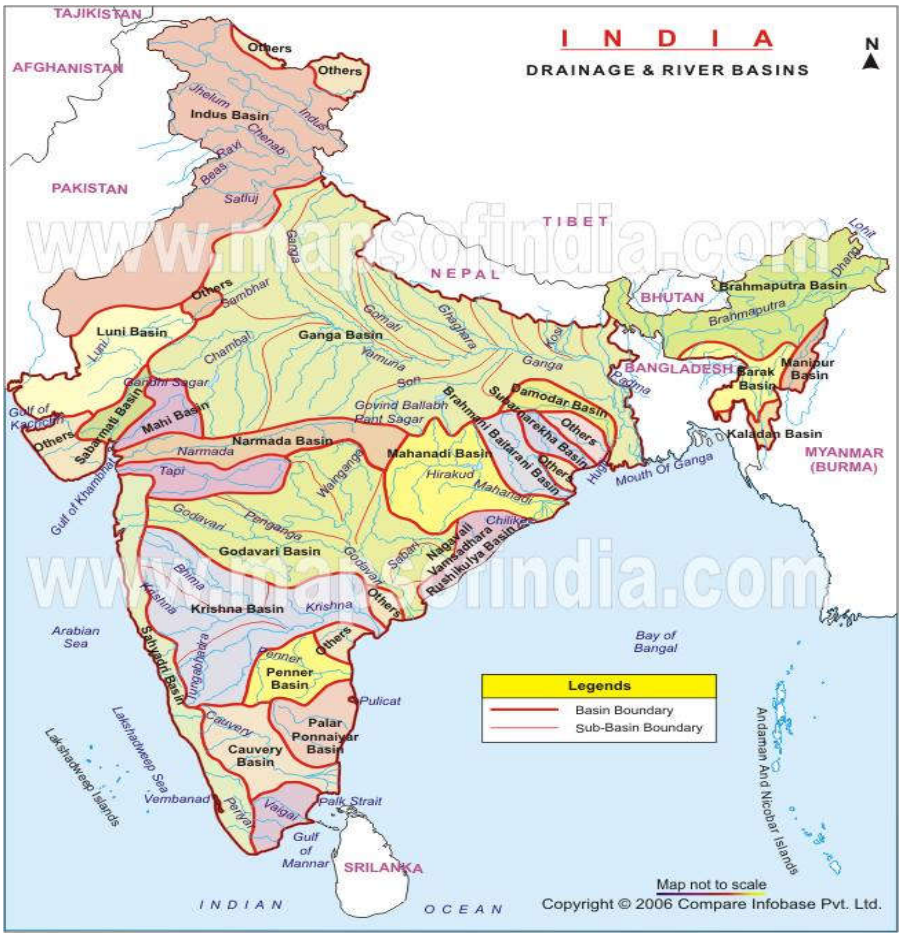


The Indian Drainage System

The Indian drainage system consists of a large number of small and big rivers.

It is an outcome of:

- The evolutionary process of the three major physiographic units
- The nature and characteristics of precipitation.

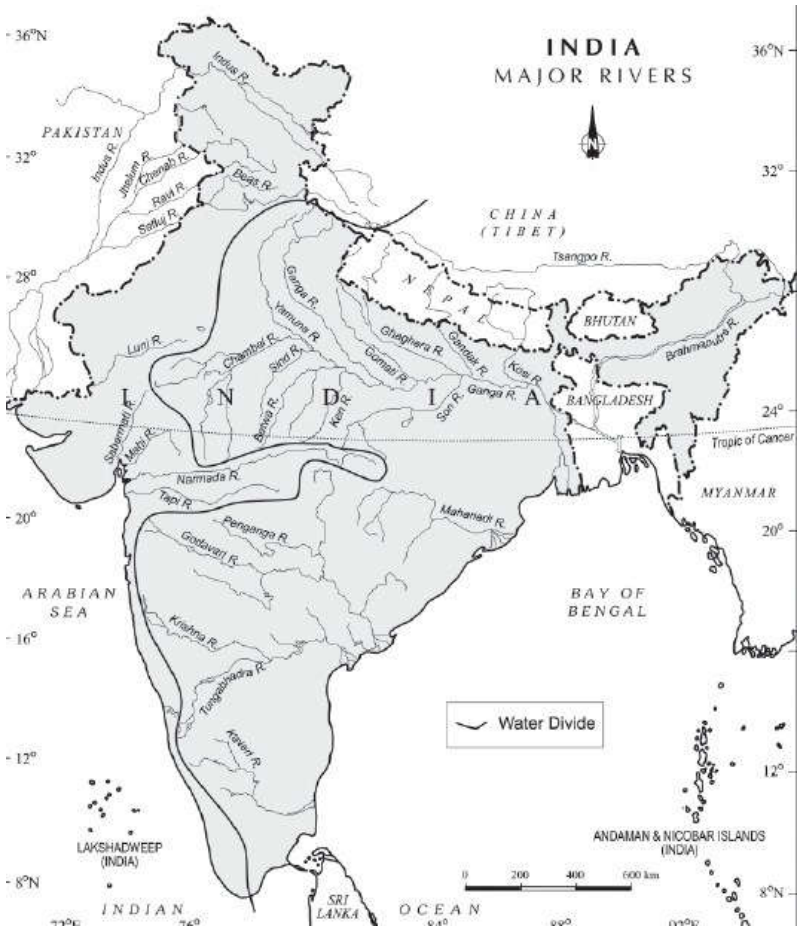


Classification of Drainage Systems in India:

1. On the basis of discharge of water – the Arabian Sea drainage and the Bay of Bengal drainage: On the basis of discharge of water (orientations to the sea), the drainage system of India may be grouped into:

- the Arabian Sea drainage
- the Bay of Bengal drainage

They are separated from each other by the Delhi ridge, the Aravalis and the Sahyadris (water divide is shown by a line in the following map).



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

Rivers of the inland drainage basin (endorheic basin):

When a river does not reach the sea but disappears into the sand, such a region is called an area of inland drainage. Inland drainage streams are ephemeral streams (short-lived). E.g.:

- The Ghaggar River in Haryana, which is supposed to be remnant of the proverbial ancient Saraswati River, gets lost in dry sands near Hanumangarh in Rajasthan.

- The Luni River in Rajasthan originates near Ajmer and after flowing through Thar Desert gets lost in the Rann of Kutch.
- The Aksai Chin region in Ladakh too has some inland drainage.

2. **On the basis of the size of the watershed:**

- **Major river basins –** with more than 20,000 sq. km of catchment area. It includes 14 drainage basins such as the Ganga, the Brahmaputra, the Krishna, the Tapi, the Narmada, the Mahi, the Pennar, the Sabarmati, the Barak, etc.
- **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.
- **Minor river basins –** with catchment area of less than 2,000 sq. Km, these include 55 river basins.

3. On the basis of the mode of origin, nature and characteristics:

- The Himalayan drainage, and
- The Peninsular drainage.

There is no clear-cut line of demarcation between these two drainage systems, as many of the peninsular rivers like the Chambal, Betwa, Sind, Ken and Son are much older in age and origin than the Himalayan rivers.

Let's follow this line of classification and look at the drainage system of India in detail. We begin with the Himalayan drainage.

The Himalayan Drainage system:

- It consists of the rivers originating in the Himalayan and trans-Himalayan region. It further consists of three river systems namely:
  - ✓ The Ganga,
  - ✓ The Indus, and
  - ✓ The Brahmaputra river systems.
- Since these are fed both by the melting of snow and precipitation, rivers of this system are perennial.
- The various geographical features made by the Himalayan rivers are:

- ✓ In upper reaches (Youthful stage): Gorges, V-shaped valleys, rapids, waterfalls, truncated spurs etc.
- ✓ In plain areas or middle part (Mature stage): While entering the plains, they form depositional features like flat valleys, ox-bow lakes, flood plains, braided channels, and deltas near the river mouth. Over the plains, they display a strong meandering tendency and shift their courses frequently.

Evolution of the Himalayan Drainage System:

There is a difference of opinion about the evolution of the Himalayan Rivers. However, geologists believe that:

1. A mighty river called Shiwalik or Indo-Brahma traversed the entire longitudinal extent of the Himalaya from Assam to Punjab and onwards to Sind, and finally discharged into the Gulf of Sind near lower Punjab during the Miocene period some 5-24 million years ago.

Evidences: The remarkable continuity of the Shiwalik and its lacustrine origin and alluvial deposits consisting of sands, silt, clay, boulders and conglomerates support this viewpoint.

2. It is opined that in due course of time Indo–Brahma river was dismembered into three main drainage systems:
   - the Indus and its five tributaries in the western part;
   - the Ganga and its Himalayan tributaries in the central part; and
   - The stretch of the Brahmaputra in Assam and its Himalayan tributaries in the eastern part.

The dismemberment was probably due to the Pleistocene upheaval in the western Himalayas, including the uplift of the Potwar Plateau (Delhi Ridge), which acted as the water divide between the Indus and Ganga drainage systems.

Likewise, the down thrusting of the Malda gap area between the Rajmahal hills and the Meghalaya plateau during the mid-pleistocene period diverted the Ganga and the Brahmaputra systems to flow towards the Bay of Bengal.

Let's take up the three major river systems of the Himalayan drainage individually:

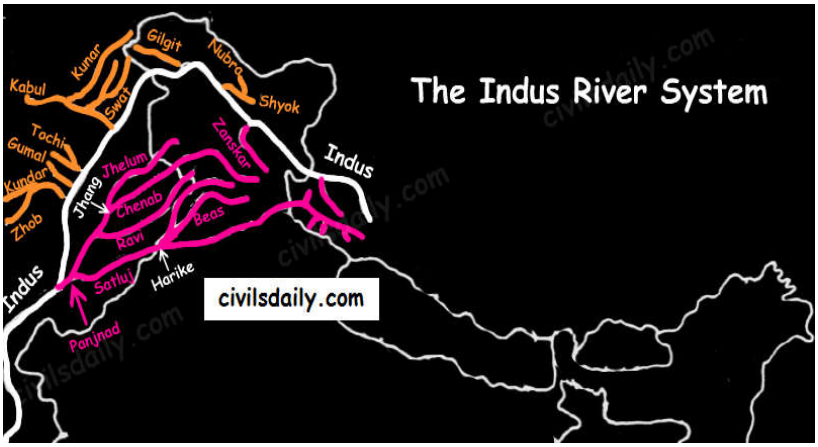
1. The Indus River System

- It is one of the largest river basins of the world. A little over one-third of the Indus basin is located in India; in the states of Jammu & Kashmir, Himachal Pradesh and Punjab. The rest of the portion is in Pakistan.

- The Indus also known as the Sindhu is the westernmost of the Himalayan rivers in India.
- **Origin**: It originates from a glacier near Bokhar Chu in the Kailash Mountain range (Tibetan region). In Tibet, it is known as 'Singi Khamban; or Lion's mouth.
- **The river-course**:
    - The Indus cuts through Himalayas and enters India near Damchok.
    - Flows in India only through the Leh district in Jammu and Kashmir.
    - It enters into Pakistan near Chillar in the Dardistan region through a deep gorge near the hair-pin bend of Nanga Parbat.
    - It finally discharges into the Arabian Sea, east of Karachi.
- The **right-bank tributaries** of Indus:

1. Shyok	5.Kabul	9. Sangar
2. Gilgit	6. Khurram	10. Kunar
3. Hunza	7. Tochi	
4. Nubra	8. Gomal	

- The **left-bank tributaries** of Indus:
    - Zaskar
    - 'Panjnad' joins Indus a little above Mithankot). The Panjnad is the name given to the five rivers of Punjab, namely:
        - *Satluj, Beas, Ravi, Chenab, Jhelum*
    - **Chief Characteristics**:
        - The Indus drains the largest number of glaciers of Himalayas, Ladakh, Zaskar, and Kailash.
        - The Indus plain has a very gentle slope.



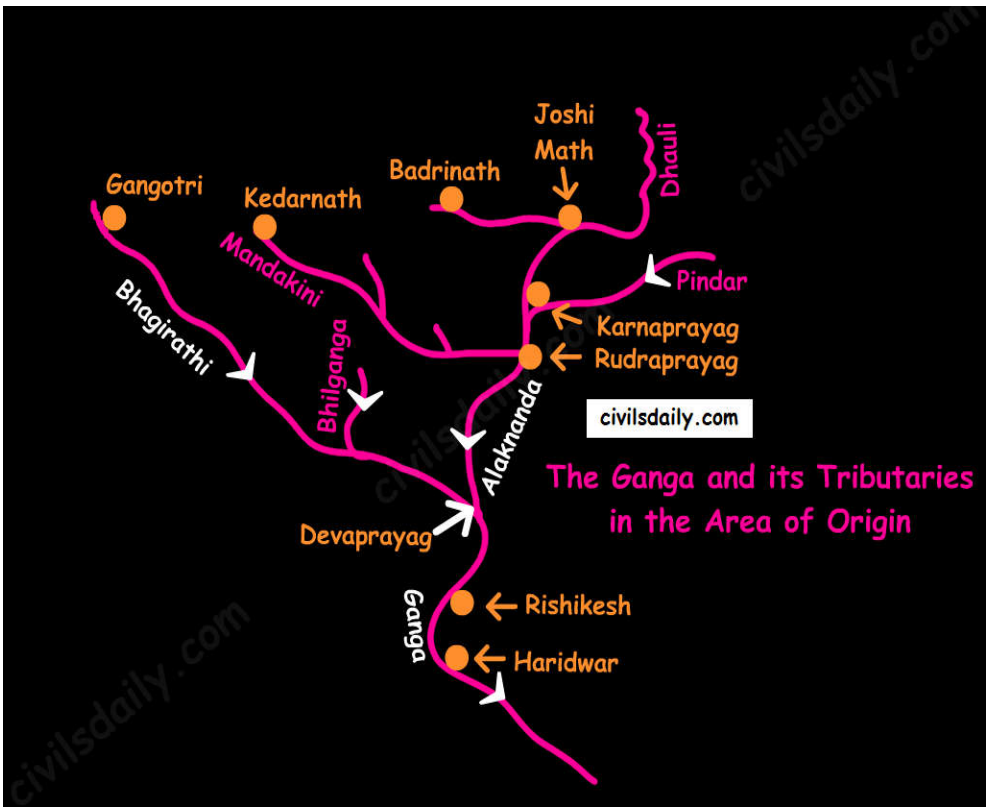
Let's look at some important tributaries of Indus:

	Tributary	Origin	Significance
1.	**Jhelum**	It rises from a spring at Verinag situated at the foot of the Pir Panjal in the south-eastern part of Kashmir	• It joins the Chenab near Jhang in Pakistan. • It is navigable between Anantnag and Baramulla and has Tulbul navigation project near Wular Lake.
2.	**Chenab**	The Chandra and the Bhaga, the two main source tributaries of river originate near Bara Lacha pass in Lahaul district of Himachal Pradesh. They join at Tandi near Keylong in Himachal Pradesh, and their combined flow is then called as Chenab. Hence, Chenab is also known as Chandrabhaga.	• It is the largest tributary of the Indus. • It flows between the Pir Panjal and the Greater Himalayas. • The important hydel projects installed across the Chenab are Selal, Dulhasti and Baglihar.
3.	**Ravi**	It rises west of the Rohtang pass in the Kullu hills of Himachal Pradesh and flows through the Chamba valley of the state.	• It drains the area between Pir Panjal and Dhauladhar. • It forms the boundary between India and Pakistan before entering into Pakistan.
4.	**Beas**	It originates from the Beas Kund near the Rohtang Pass.	• It drains Pir Panjal and Dhauladhar range and meets the Satluj river near Harike. • **It's the only river in the Indus system that lies entirely within the Indian Territory.**
5.	**Satluj**	It originates in the Rakas lake near Mansarovar in Tibet where it is known as Langchen Khambab.	• It flows almost parallel to the Indus for about 400 km before entering India, and comes out of a gorge at Rupar. • It passes through the Shipki La on the Himalayan ranges and enters the Punjab plains. • It is an antecedent river. • It is a very important tributary as it feeds the canal system of the Bhakra Nangal project. • The Nathpa-Jhakri is a runoff the river project on Satluj in Kinnaur district.

The Indus water treaty: The waters of the Indus river system are shared by India and Pakistan according to the Indus Water Treaty signed between the two countries on 19th September 1960. According to this treaty, India can utilize only 20 per cent of its total discharge of water. The Indus water treaty was recently in news.

2. The Ganga River System

- The Ganga river system is the largest in India having a number of perennial and non-perennial rivers originating in the Himalayas in the north and the Peninsula in the south, respectively. It accounts for 26.3% of the geographical area of the country and is shared by ten states.
- Ambala is located on the water divide between Indus and Ganga.
- **Origin**: It rises in the Gangotri glacier near Gaumukh in the Uttarkashi district of Uttaranchal. Here, it is known as the Bhagirathi. At Devprayag, the Bhagirathi meets the Alaknanda; hereafter, it is known as the Ganga.



- **The river-course**:
  - ❖ The Ganga enters the plains at Haridwar.
  - ❖ From here, it flows first to the south, then to the south-east direction to reach Allahabad. Here it is joined by the Yamuna.
  - ❖ Further, near Rajmahal hills, Ganga turns south-east and bifurcates at Farakka into Bhagirathi – Hugli in West Bengal and as the Padma in Bangladesh.
  - ❖ The river finally discharges itself into the Bay of Bengal near the Sagar Island.

- Important **left bank tributaries** of the Ganga:
  - *Ramganga,*
  - *Gomati,*
  - *Ghaghara,*
  - *Gandak,*
  - *Kosi,*
  - *Mahananda*
- Important **right bank tributaries** of the Ganga:
  - *Son,*
  - *Yamuna*

Some important tributaries and their characteristic features:

	Tributary	Origin	Significance

1.	**Yamuna**	It originates from Yamnotri glacier on the Banderpunch peak in Garhwal in Uttaranchal.	• It is the western most and the longest tributary of the Ganga.
			• It joins the Ganga at Prayag (Allahabad).
			• The Saraswati river of ancient past is supposed to have been captured by the present day Yamuna river.
			• Right-bank tributaries of Yamuna:
			  ○ Chambal
			  ○ Sind
			  ○ Betwa
			  ○ Ken
			• Left-bank tributaries of Yamuna:
			  ○ Hindan
			  ○ Rind
			  ○ Sengar
			  ○ Varuna

2.	**Chambal**	It rises near Mhow in the Malwa plateau of Madhya Pradesh.	The Chambal ravines: Recent geological uplift, poor rainfall and resulting severe erosion have given rise to numerous deep ravines and badland topography in the Chambal basin.
3.	**Gandak**	It rises in the Nepal Himalayas between the Dhaulagiri and Mt. Everest.	It comprises two streams, namely Kaligandak and Trishulganga. It enters the Ganga plain in Champaran district of Bihar and joins the Ganga at Sonpur near Patna.
4.	**Ghaghara**	It originates in the glaciers of Mapchachungo.	It meets the Ganga at Chhapra.
5.	**Kosi**	In the north of Mount Everest in Tibet.	• The Kosi is an antecedent river. • It consists of seven streams and is popularly called as Suptakoshi in Nepal. • Arun is its main stream which rises to the north of Gosainthan peak. • Soon after debouching on the plain, the river becomes sluggish and large scale deposition of eroded material takes place. The river is braided and shifts its course frequently. This has resulted in frequent devastating floods. Thus the river is often termed as "the Sorrow of Bihar". Totame the river, barragesin upstream course and embankments have been constructed as a joint venture of India and Nepal.
6.	**Ramganga**	Garhwal hills near Gairsain	It joins the Ganga near Kannauj.
7.	**Damodar**	It occupies the eastern margins of the Chotanagpur Plateau where it flows through a rift valley and finally joins the Hugli.	• River Barakar is its largest feeder. • Once known as the 'sorrow of Bengal', the Damodar has been now transformed into a life-line for industrial production by Damodar Valley Corporation's multipurpose projects.
8.	**Sarda or Saryu river**	It rises in the Milan glacier in the Nepal Himalayas.	• It forms the boundary between Nepal and Kumaon. • In the Nepal Himalayas, it is known as the Goriganga. Along the Indo-Nepal border, it is called Kali or Chauk, where it joins the Ghaghara.
9.	**Mahananda**	It rises in the Darjiling hills.	It joins the Ganga as its last left bank tributary in West Bengal.
10.	**Son**	It originates in the Amarkantak plateau.	After forming a series of waterfalls at the edge of the Amarkantak plateau, it reaches Arrah, west of Patna, to join the Ganga.

3. The Brahmaputra River System:

- **Origin**: The Brahmaputra has its origin in the Chemayungdung glacier of the Kailash range near the Mansarovar Lake. Mariam La separates the source of the Brahmaputra from the Manasarovar Lake.
- The **river-course**:
  - Most of the course of the Brahmaputra lies in Tibet, popularly known as Tsangpo. It flows eastwards parallel to the Himalayas. It receives a large number of tributaries in Tibet. The first major tributary is the Raga Tsangpo meeting the Tsangpo near Lhatse Dzong.
  - After reaching Namcha Barwa, it takes a "U" turn (also known as Hair Pin turn) and enters India west of Sadiya town in Arunachal Pradesh through the deep Dihang or Siang gorge of Himalayas. Here initially it is called as Siang and then as Dihang.
  - It is joined by Dibang, Lohit, Kenula and many other tributaries and finally forms the Brahmaputra in Assam.
  - It then 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 Jamuna. [Note: The Tista was a tributary of the Ganga prior to the floods of 1787 after which it diverted its course eastwards to join the Brahmaputra.]
  - The Jamuna and Ganga confluence at Goalundo and afterwards are called as the Padma. Further south, Padma is joined by Meghna (Barak River in India) and thence onward it is known as Meghna to finally merge in the Bay of Bengal.

- It is called:
  - The Tsangpo in Tibet (Tsangpo = 'the purifier.')
  - The Brahmaputra in India
  - The Jamuna in Bangladesh
- **Major left bank tributaries**:
  - Burhi Dihing,
  - Dhansari (South)
  - Kalang
- **Major right bank tributaries**:
  - Subansiri (It has its origin in Tibet and is an antecedent river.)
  - Kameng
  - Manas
  - Sankosh
- **Characteristic Features**:
  - River Brahmaputra is a little longer than the river Indus.
  - It forms a spectacular Grand Canyon – like canyon in Tibet.
  - The river is nearly 16 km wide at Dibrugarh and forms many islands, the most important of which is Majauli. Majauli is the world's largest riverine island and India's first island district.
  - The Brahmaputra has a braided channel. It carries a lot of silt and there is excessive meandering.
  - 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 its catchment area.

The Peninsular Drainage:

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.

Evolution: Three major geological events in the distant past have shaped the present drainage systems of Peninsular India:

- **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 and left just the upper parts of west flowing rivers above the sea level.
- **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.
- **Slight tilting of the Peninsular block** from north-west to the southeastern direction gave orientation to the entire drainage system towards the Bay of Bengal during the same period.

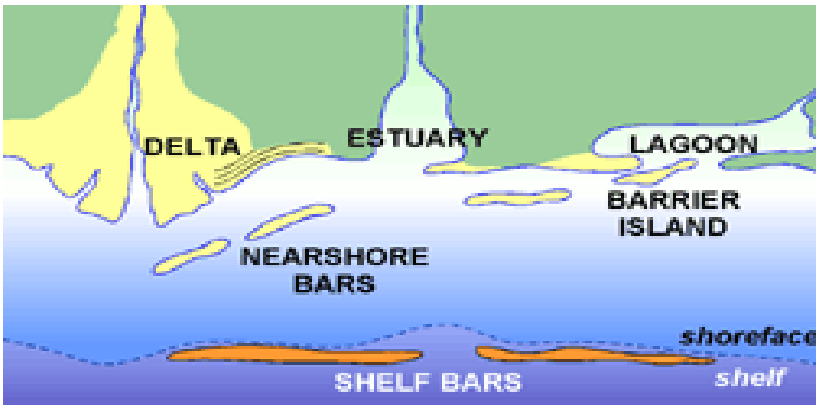
River-Systems:

The peninsular river system can be categorised into the following sections:

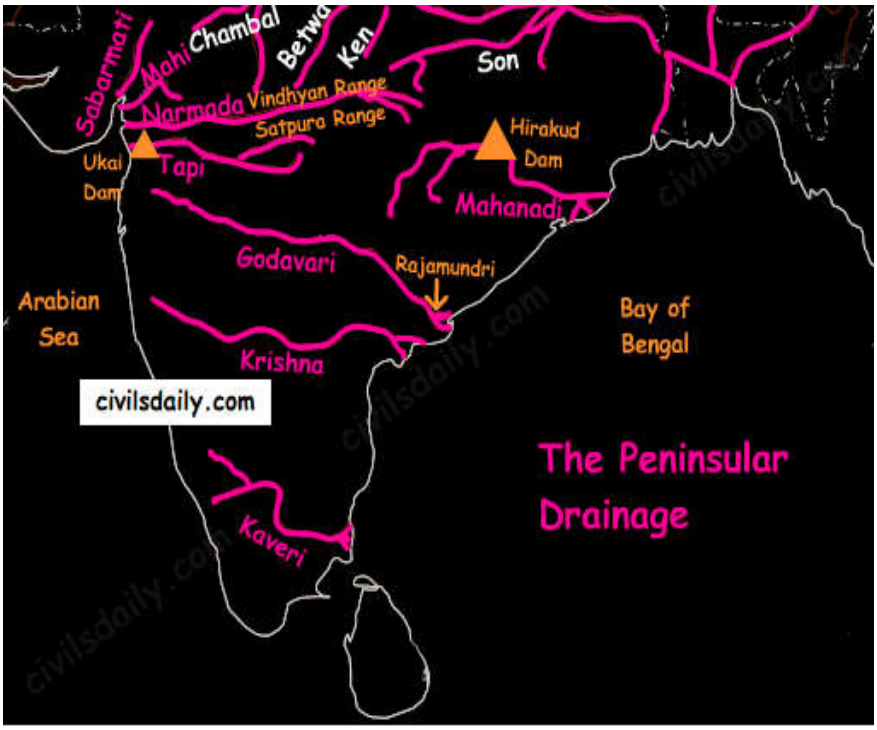
- The **East flowing rivers** – the Mahanadi, the Godavari, the Krishna and the Cauvery flow eastwards and drain into the Bay of Bengal. These rivers make **deltas** at their mouths.
- The **West flowing rivers**:
  - Narmada and Tap along with other small rivers originating from the Western Ghats and falling in the Arabian Sea form **estuaries** in place of deltas. This is due to the fact that these rivers, especially Narmada and Tapi, flow through hard rocks and are not able to form distributaries before they enter the sea.
  - Although these west flowing rivers of Sahyadri form only about 3% of the areal extent of basins of India, they contain about 18% of the country's water resources.

Wondering what is the difference between a delta and an estuary? Let's see:

Delta	Estuary
1. The triangular deposits made by the rivers at their mouth form Delta.	1. The sharp edged mouth of rivers, devoid of any deposits is known as Estuary.
2. Deltas are formed in the regions of low tides and coastal plains.	2. Regions of high tides and rift valleys witness Estuaries.
3. Deltas are fertile lands.	3. Estuary does not have fertile lands.
4. Ganga and Brahmaputra, Krishna, Kaveri and Mahanadi form delta.	4. Narmada and Tapi rivers form Estuaries.



- The Western Ghats running close to the western coast act as water divide between the major Peninsular Rivers discharging their water in the Bay of Bengal and the small rivulets joining the Arabian Sea.
- The Chambal, the Sind, the Betwa, the Ken, the Son, originating in the northern part of the Peninsula belong to the Ganga river system.
- The Peninsular rivers are characterized by fixed courses, absence of meanders and non-perennial flow of water. The Narmada and the Tapi which flow through the rift valley are, however, exceptions.



A brief account of the major Peninsular river systems is given below:

	River System	Origin	Characteristic Features civilsdaily.com
			East Flowing Rivers
1.	**Mahanadi**	It originates in the northern hills of Dandakaranya in Raipur district of Chhattisgarh.	• It is 851 km long • Its upper course lies in the saucer-shaped basin called the 'Chhattisgarh Plain'. • Some navigation is carried on in the lower course of this river. • Its drainage basin encompasses Madhya Pradesh, Chhattisgarh and Orissa. • The basin is subject to severe flooding occasionally in the delta area due to inadequate carrying capacity of the channels. The multi-purpose Hirakud dam provides some amount of flood relief by storing part of flood water. • It is one of the most-active silt-depositing streams in the Indian subcontinent.

2.	**Godavari**	It rises in the Nasik district of Maharashtra and discharges its water into the Bay of Bengal.	• It is 1,465 km long.
			• It is the largest Peninsular river system.
			• It is also called the **Dakshin Ganga**.
			• Its drainage basin encompasses Maharashtra, Madhya Pradesh, Chhattisgarh, Orissa and Andhra Pradesh.
			• Principal Tributaries:
			  ○ Penganga
			  ○ Indravati
			  ○ Pranhita
			  ○ Manjra
			• The Godavari is subjected to heavy floods in its lower reaches to the south of Polavaram, where it forms a picturesque gorge.
			• It is navigable only in the deltaic stretch.
			• The river after Rajamundri splits into several branches forming a large delta.

3.	**Krishna**	civilsdaily.com
		It rises near Mahabaleshwar in Sahyadris
			• It is the second largest eastflowing Peninsular river.
			• Total length - 1,401 km.
			• Major Tributaries –
			  ○ Koyna
			  ○ Tungabhadra
			  ○ Ghataprabha
			  ○ Malprabha
			  ○ Bhima
			  ○ Musi
			  ○ Muneru
			• Its drainage basin encompasses Maharashtra, Karnataka and Andhra Pradesh.
			• The large delta of Krishna appears to merge with that formed by Godavari.

4.	**Kaveri**	It rises in Brahmagiri hills in Karnataka.	• **Length**: 800 km.
			• **Important tributaries**
			  ○ Kabini
			  ○ Bhavani
			  ○ Amravati.
			• 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 with comparatively **less fluctuation** than the other Peninsular Rivers.
			• Its drainage basin encompasses Kerala, Karnataka Tamil Nadu.

West Flowing Rivers			civilsdaily.com
5.	**Narmada**	It originates on the western flank of the Amarkantak plateau (Maikal Range) in Madhya Pradesh.	• It is the largest of all the west flowing rivers of Peninsula. • It flows in a rift valley between the Satpura in the south and the Vindhyan range in the north. • It forms spectacular Dhuandhar falls near Jabalpur. • The Narmada basin covers parts of Madhya Pradesh and Gujarat. • The Sardar Sarovar Project has been constructed on this river. • Since the river flows through a narrow valley confined by precipitous hills, it does not have major tributaries with the exception of Hiran river on its right bank. • All the tributaries of the Narmada are very short. Most of the tributaries join the Narmada at right angles. • It meets the Arabian sea south of Bharuch, forming a broad 27 km long estuary. There are several small islands in the estuary of Narmada, of which Aliabet is the largest.
6.	**Tapi**	The Tapi rises in the Satpura ranges, in Betul district of Madhya Pradesh.	• Length: 724 km • Its drainage basin encompasses Maharashtra, Madhya Pradesh and Gujarat. • The river flows towards the west through rift valleys parallel to river Narmada. • The Ukai dam on Tapi river provides water for urban and agricultural uses to area around Surat.
7.	**Luni**	It originates near Pushkar in two branches, i.e. the Saraswati and the Sabarmati, which join with each other at Govindgarh. From here, the river comes out of Aravali and is known as Luni.	civilsdaily.com • It is the largest river system of Rajasthan, west of Aravali. • The entire river system is ephemeral.

Smaller rivers flowing Towards the West:

The rivers flowing towards the Arabian Sea have short courses (Because their origins lie closer to the sea, and the Western Ghats act as a water divide). Several of these small rivers are important for the production of hydroelectricity because of steep slopes and waterfalls.

Gujarat:

- The Shetruniji – It rises near Dalkahwa in Amreli district.
- The Bhadra – It originates near Aniali village in Rajkot district.
- The Dhadhar rises near Ghantar village in Panchmahal district.
- Sabarmati
- Mahi

Maharashtra:

- The Vaitarna rises from the Trimbak hills in Nasik district
- The Kalinadi rises from Belgaum district and falls in the Karwar Bay.
- The source of Bedti river lies in Hubli Dharwar and traverses a course of 161 km.
- The Sharavati is another important river in Karnataka flowing towards the west. The Sharavati originates in Shimoga district of Karnataka and drains a catchment area of 2,209 sq. km. The famous Jog or Gersoppa Falls (289m) made by Sharavati river is the highest in India.

Goa:

- Mandovi
- Juari

Kerala:

- Bharathapuzha – It is the longest river of Kerala. It rises near Annamalai hills. It is also known as Ponnani.
- The Periyar – It is the second largest river of Kerala.
- The Pamba river – It falls in the Vemobanad lake.

Small Rivers Flowing towards the East:

There are small rivers which join the Bay of Bengal, though small, these are important in their own right.

- The Subarnrekha
- the Baitarni
- the Brahmani
- the Vamsadhara
- the Penner
- the Palar
- the Vaigai

Differences between Himalayan and Peninsular river systems:

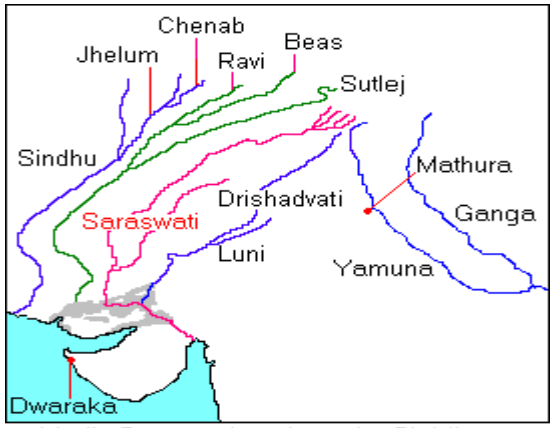
Criterion	Himalayan Rivers	Peninsular rivers
1. **Place of origin**	Himalayan mountain covered with glaciers	Peninsular plateau and central highland
2. **Basin Size**	These rivers have very large basins and catchment areas.	Small basins and catchment areas.
3. **Type of drainage**	Antecedent and consequent leading to dendritic pattern in plains	Super imposed, rejuvenated resulting in trellis, radial and rectangular patterns
4. **Valleys**	The Himalayan rivers flow through steep sided V-shaped valleys .	These flow in comparitively shallow valleys. These are more or less graded valleys i.e. the rivers have little erosional activities to perform.
5. **Water flow**	Perennial; receive water from glacier and rainfall	Seasonal; dependent on monsoon rainfall
6. **Stage**	These rivers flow across the young fold mountains and are still in a youthful stage.	These rivers have been flowing in one of the oldest plateaus/shields and have almost reached their base levels of erosion.
7. **Meanders**	When these rivers enter the plains, there is a sudden reduction in the speed of the flow of water. Under these circumstances, these rivers form meanders and often shift their beds.	The hard rock surfaces and non-alluvial character of the plateau permits little scope for the formation of meanders. The rivers of the peninsular plateau have more or less straight courses.
8. **Delta formation and Estuaries**	These rivers make only deltas. The Sundarbans delta is the largest in the world.	These rivers make deltas (Krishna, Kaveri and Godavari) and estuaries like Narmada and Tapi.

The Shifting Courses of Rivers:

An interesting phenomenon observed in the case of most of the peninsular and extra-peninsular rivers is that they have shifting courses, especially in their lower reaches. In the upper reaches, the Himalayan rivers have the tendencies of river capturing.

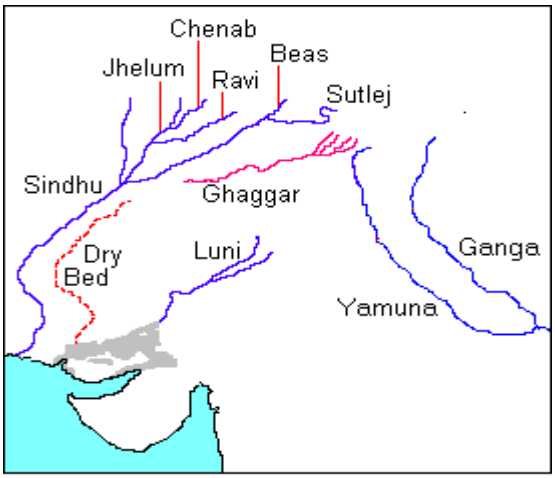
Wondering **why a river shifts its course**? There can be numerous reasons as to why a river shifts its course. It could be a response to physiographic changes or it could be a part of its natural evolution e.g. fast-flowing rivers are prone to silting up as they surge down the hills and spread out on the plains, allowing sand and suspended matter to deposit in their slower, wider depths. Over time, the deposits create resistance, forcing the river to move to an area of lower resistance. This leads to a shift in its course.

The ancient **Saraswati river**, which provided an abode for the early Aryan settlers, presents a typical example of shifting courses and river capturing. Descending from the Himalayan ranges, its initial course during the prehistoric period was passing near Churu (about 2000 to 3000 BC) and the Luni river was one of its tributaries.



Vedic Saraswati as drawn by Shridhar.

It gradually shifted towards west till it joined the Satluj near Ahmadpur. Later on, the water of its upper course was captured by a tributary of the Ganga river, as a result of which, its lower course became dry. This gave birth to the Yamuna river, an important tributary of the Ganga river system. Even today, the dry valley of the Saraswati river is found in the Rajasthan area in the form of Ghaggar valley.



The river courses today. 2000 AD

Similar shifting has also been observed in the rivers of Punjab during historical past. The records of 3rd century BC show that the **Indus** flowed more than 130 km east of its present course, through the now practically dry beds of the deserted channel, to the Rann of Kachchh which was then a gulf of the Arabian Sea. Later on it gradually shifted west and occupied its present position.

Even the entry of **Brahmaputra** into the plains of Assam is an outcome of the process of river capturing. According to geologists, during early days, the Tsangpo river of Tibet taking an easterly course used to join the Irrawaddy river (Myanmar) through the Chindwin, which was then a large river, transporting huge quantity of water. Later on, a small river flowing along the southern slopes of the Himalayas through its headward erosion captured the water of the Tsangpo river, and thus helped in the evolution of the stream of Brahmaputra.

Kosi and **Gandak** are notorious for changing their courses during floods.

some related questions from the past UPSC examinations:

Prelims

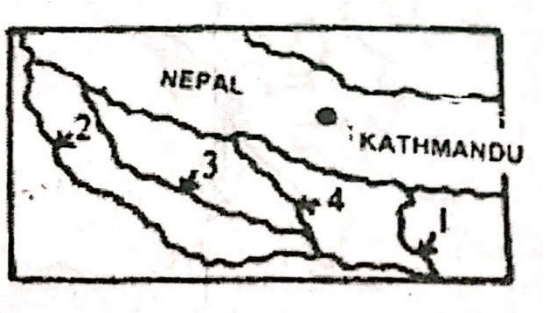
(1997)

Question: The Alamatti is on the river:

A. Godavari
B. Cauveri
C. Krishna
D. Mahanadi

Ans. C

Question: In the map shown in the given figure, river labelled as 1, 2, 3 and 4 respectively:



A. Kosi, Gomati, Ghaghara and Gandak
B. Kosi, Ganga, Gomati and Ghaghara
C. Gandak, Ganga, Gomati and Ghaghara
D. Teesta, Gomati, Ghaghara and Kosi

Ans. A

(1998)

Question: Which of the following east-flowing rivers of India has rift valley due to down warping?

A. Damodar
B. Mahanadi
C. Son
D. Yamuna

Ans. B

(2000)

Question: Which one of the following statements is not true?
A. Ghaggar's water is utilised in the Indira Gandhi canal
B. Narmada rises from the Amarkantak region
C. Nizam Sagar is situated on the Manjira river
D. Penganga is a tributary of the Godavari.
Ans. A

(2002)
Question: The correct sequence of the eastward flowing rivers of the Peninsular India from north to south is
A. Subarnarekha, Mahanadi, Godavari, Krishna, Pennar, Cauvery and Vaigai
B. Subarnarekha, Mahanadi, Krishna, Godavari, Cauvery, Vaigai, and Pennar
C. Mahanadi, Subarnarekha, Godavari, Krishna, Cauvery, Pennar and Vaigai
D. Mahanadi, Subarnarekha, Krishna, Godavari, Cauveri, Vaigai and Pennar
Ans. A

(2003)
Question: What is the correct sequence of the rivers – Godavari, Mahanadi, Narmada and Tapi in the descending order of their lengths?
A. Godavari – Mahanadi – Narmada – Tapi
B. Godavari – Narmada – Mahanadi – Tapi
C. Narmada – Godavari – Tapi – Mahanadi
D. Narmada – Tapi – Godavari – Mahanadi
Ans. B

(2006)
Question: Which one of the following statements is not correct?
A. Mahanadi river rises in Chhattisgarh.
B. Godavari river rises in Maharashtra.
C. Cauvery river rises in Andhra Pradesh.
D. Tapti River rises in Madhya Pradesh.
Ans. C

Question: Between which of the following was the ancient town of Takshasila located?
A. Indus and Jhelum.
B. Jhelum and Chenab.
C. Chenab and Ravi.
D. Ravi and Beas.
Ans. A

Question: From north towards south, which one of the following is the correct sequence of the given rivers in India?
A. Shyok – Spiti – Zaskar – Satluj
B. Shyok – Zaskar – Spiti – Satluj
C. Zaskar – Shyok – Satluj – Spiti

D. Zaskar – Satluj – Shyok – Spiti
Ans. B

(2007)

Question: Match List-I with List-II and select the correct answer using the code given below the lists:

List-I	List-II
A. Betul	1. Indravati
B. Jagdalpur	2. Narmada
C. Jabalpur	3. Shipra
D. Ujjain	4. Tapti

A) A1 B4 C2 D3
B) A4 B1 C2 D3
C) A4 B1 C3 D2
D) A1 B4 C3 D2
Ans. B

Question: Which of the following rivers originates at Amarkantak?

A. Damodar
B. Mahanadi
C. Narmada
D. Tapti
Ans. C

Question: Assertion (A): River Kalinadi is an east-flowing river in the southern part of India.
Reason (R): The Deccan plateau is higher along its western edge and gently slopes towards the Bay of Bengal in the east.
Ans. D (A is false but R is true)

Mains:

1. Question: There is no formation of deltas by rivers of the Western Ghat. Why? (2013/10 marks)
2. Question: What are the causes for dominant dendritic pattern of drainage in the Gangetic plains? (2010/5M)
3. Question: Why do the rivers of west coast not form a delta? (2006/2M)
4. Question: Describe the major characteristics of rivers of peninsular India. (2003/10M)
5. Question: Write a short note on two prominent left bank tributaries of river Ganges. (2001/2M)
6. Question: Why do the rivers of the peninsular India have well defined rigid channels in sharp contrast to the Himalayan rivers? (1995/2M)
7. Question: Name the major international rivers flowing through India. What countries/States are covered by the Ganga and Godavari rivers on their course from their source to the sea? (1980/2M)

5. The Climate

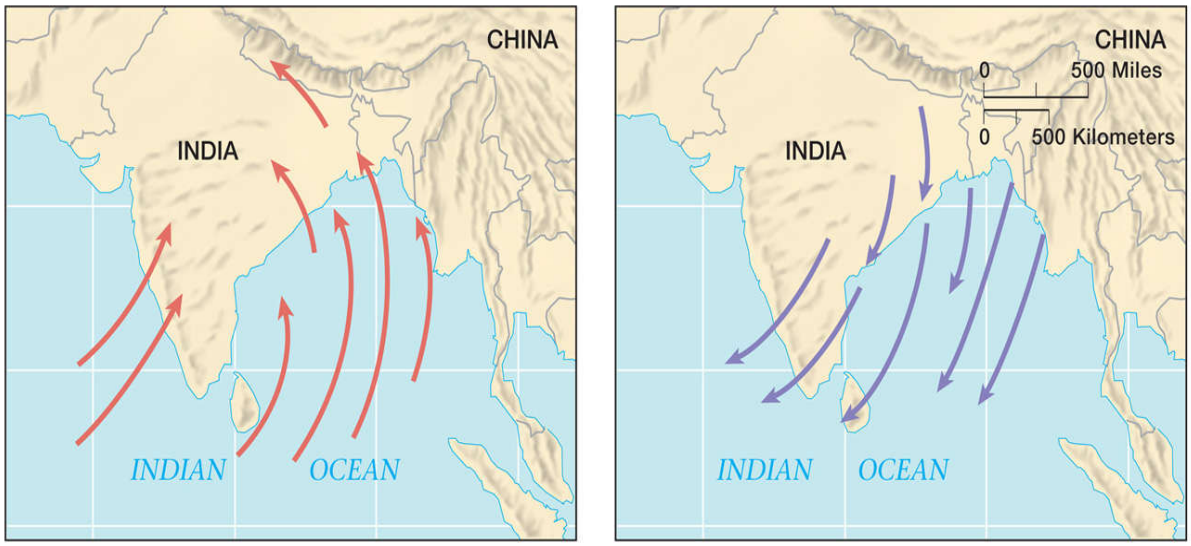
Indian Climate – An Introduction

India's climate can be described as hot monsoonal type. The word monsoon comes from the Arabic word 'Mausim' which means 'season'. Monsoon, by definition, is a wind system that changes wind direction seasonally. The four principal monsoon regions in the world are:

- South Asia
- East Asia
- Northern Australia
- West Africa

Let's take the case of South Asia:

During winter, the large continent of Asia gets extremely cold and the Siberian high pressure develops. Air flow is offshore and dry. During the summer, the continent develops low pressure in response to heating and the airflow reverses. Moisture-laden air from the ocean is brought inland where it rises over the terrain and produces extremely large amounts of rainfall. See the following diagram and observed the marked shift in the wind direction.



Summer Winter

But at the same time, we know that there are great regional differences and variations experienced in India with respect to temperature rainfall etc. Let's look at some of these regional variations:

- **Variations in temperature**: 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. On a December night, the temperature in Drass (Jammu and Kashmir) may drop down to minus 45°C while Thiruvananthapuram or Chennai on the same night record 20°C or 22°C.
- **Daily temperature range**: In Kerala and in the Andaman Islands, the difference between day and night temperatures may be hardly seven or eight degree Celsius. But in the Thar desert, if the day temperature is around 50°C, at night, it may drop down considerably up to 15°-20°C.
- **Regional variations in type and amount of precipitation**: While snowfall occurs in the Himalayas, it only rains over the rest of the country. Similarly, while Cherrapunji and Mawsynram in the Khasi Hills of Meghalaya receive rainfall over 1,080 cm in a year, Jaisalmer in Rajasthan rarely gets more than 9 cm of rainfall during the same period. Most parts of the country get rainfall during June-September, but in the coastal areas of Tamil Nadu, it rains in the beginning of the winter season.

These regional variations differentiate the weather and climate of different regions of India.

This brings us to the difference between weather and climate:

Weather is the momentary state of the atmosphere while climate refers to the average of the weather conditions over a longer period of time. Weather changes quickly, maybe within a day or week but climate changes imperceptivity and may be noted after 50 years or even more.

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, and factors related to air pressure and winds.

Factors related to Location and Relief

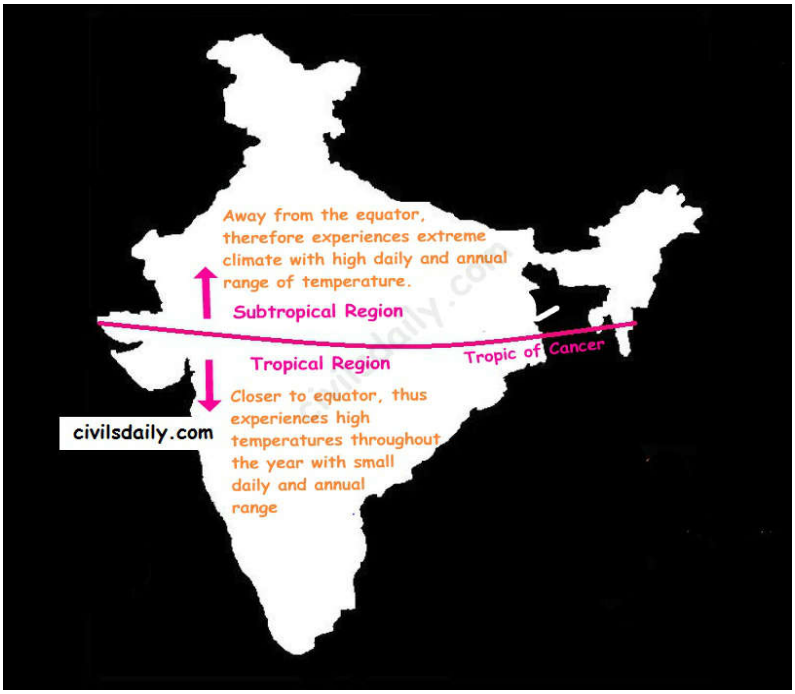
1. **Latitude:** The Tropic of Cancer passes through the central part of India in the east-west direction. Thus, the northern part of the India lies in the sub-tropical and temperate zone and the part lying south of the Tropic of Cancer falls in the tropical zone. The tropical zone being nearer to the equator experiences high temperatures throughout the year with small daily and annual range. Areas north of the Tropic of Cancer being away from the equator, experience extreme climate with high daily and annual range of temperature.

2. The Himalayan Mountains:

The lofty Himalayas in the north along with its extensions act as an effective climatic divide.

- The Himalayas act as an invincible shield to protect the subcontinent from the cold northern winds. These cold and chilly winds originate near the Arctic circle and blow across central and eastern Asia.

- The Himalayas also trap the monsoon winds, forcing them to shed their moisture within the subcontinent.



3. 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. The difference in air pressure causes a reversal in the direction of monsoon winds.

4. Distance 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 Mumbai and 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 Delhi, Kanpur and Amritsar affect the entire sphere of life.

5. Altitude: Temperature decreases with height. Due to thin air, places in the mountains are cooler than places on the plains. For example, Agra and Darjeeling are located on the same latitude, but the temperature of January in Agra is 16°C whereas it is only 4°C in Darjeeling.

6. Relief: The physiography or relief of India also affects the temperature, air pressure, direction and speed of the 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.

Factors Related to Air Pressure and Wind

The following three factors are responsible for the differences in local climates of India:

1. Distribution of air pressure and winds on the surface of the earth.
2. Upper air circulation caused by factors controlling the global weather and the inflow of different air masses and jet streams.
3. The inflow of western cyclones generally known as disturbances during the winter season and tropical depressions during the south-west monsoon period into India.

Note: The variations in the atmospheric pressure closer to the surface of the earth have no role to play in the making of upper air circulation.

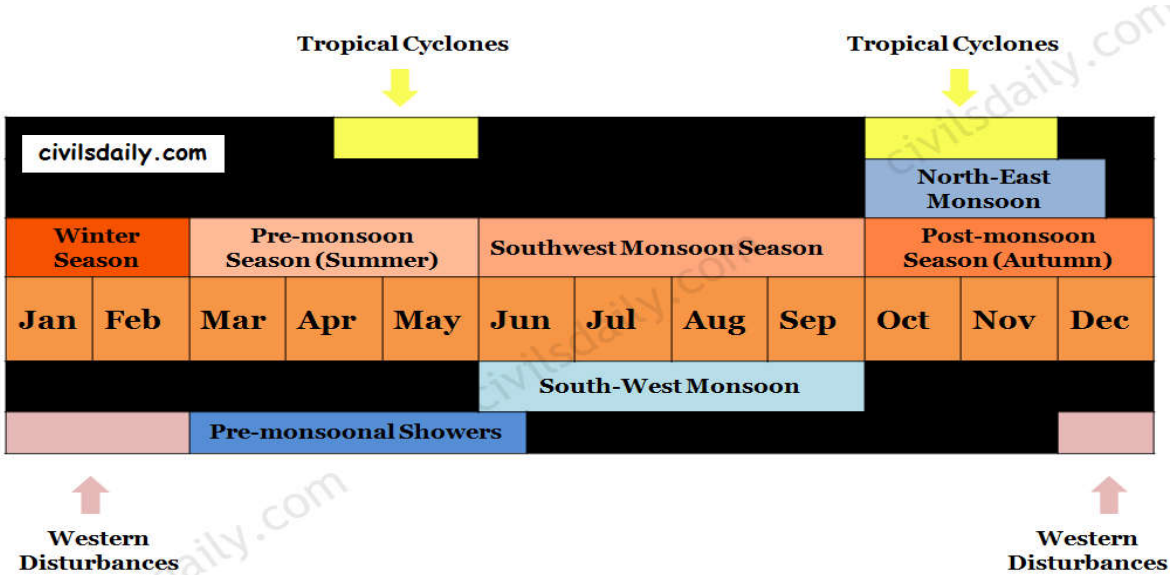
The mechanism of these three factors and their impact on the Indian climate will be understood with reference to specific seasons of the year in the following sections.

India's Climatic Calendar

The climatic conditions of India can best be described in terms of an annual cycle of seasons.

The India Meteorological Department (IMD) recognises the following four seasons:

- **The Winter Season** (January – February)
- **The Pre-monsoon Season or summer season** (March – May)
- **The Southwest Monsoon Season or rainy season** (June – September)
- **The Post Monsoon Season or autumn season** (October – December)

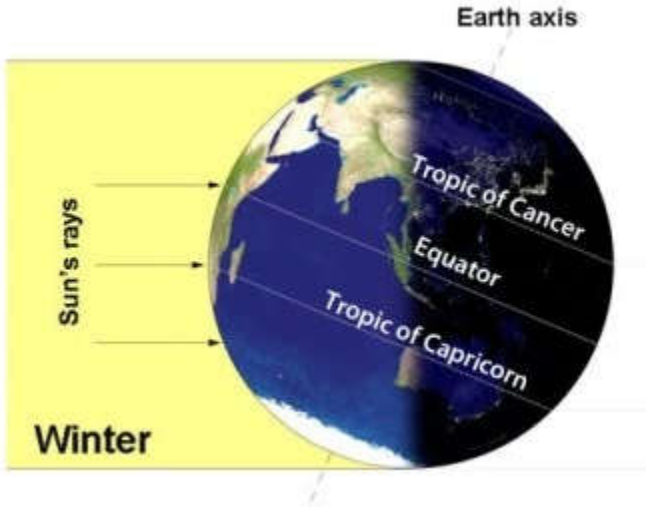


India's Climatic Calendar

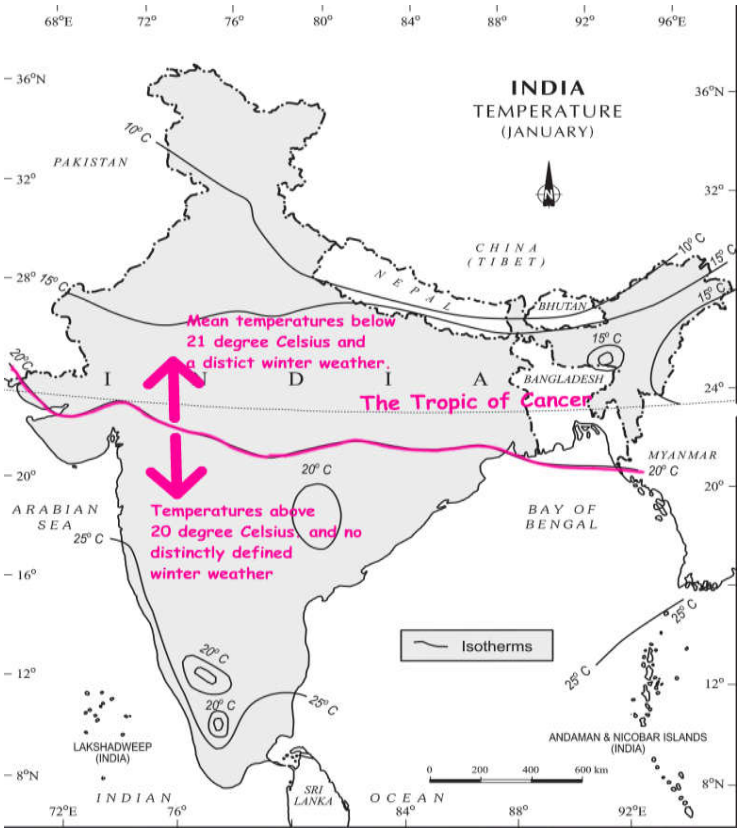
1. The Winter Season (January – February)

Temperature Conditions during this season:

By the end of December (22nd December), the sun shines vertically over the Tropic of Capricorn in the southern hemisphere. So, India which is located in the northern hemisphere experiences low temperatures. January and February are the coldest months over most parts of the country.



The isotherm of 20°C runs roughly parallel to the Tropic of Cancer.



The northern region:

This season usually begins in late-November in northern India. Lowest temperatures are observed in Punjab and Rajasthan. December and January are the coldest months in the northern plain. The night temperature may be quite low, sometimes going below freezing point in Punjab and Rajasthan.

There are three main reasons for the excessive cold in north India during this season:

1. States like Punjab, Haryana and Rajasthan being far away from the moderating influence of sea experience continental climate.
2. The snowfall in the nearby Himalayan ranges creates cold wave situation; and
3. Around February, the cold winds coming from the Caspian Sea and Turkmenistan bring cold wave along with frost and fog over the northwestern parts of India.

The peninsular region:

The Peninsular region of India, however, does not have any well-defined cold weather season. There is hardly any seasonal change in the distribution pattern of the temperature in coastal areas because of:

- Moderating influence of the sea, and
- Proximity to the equator.

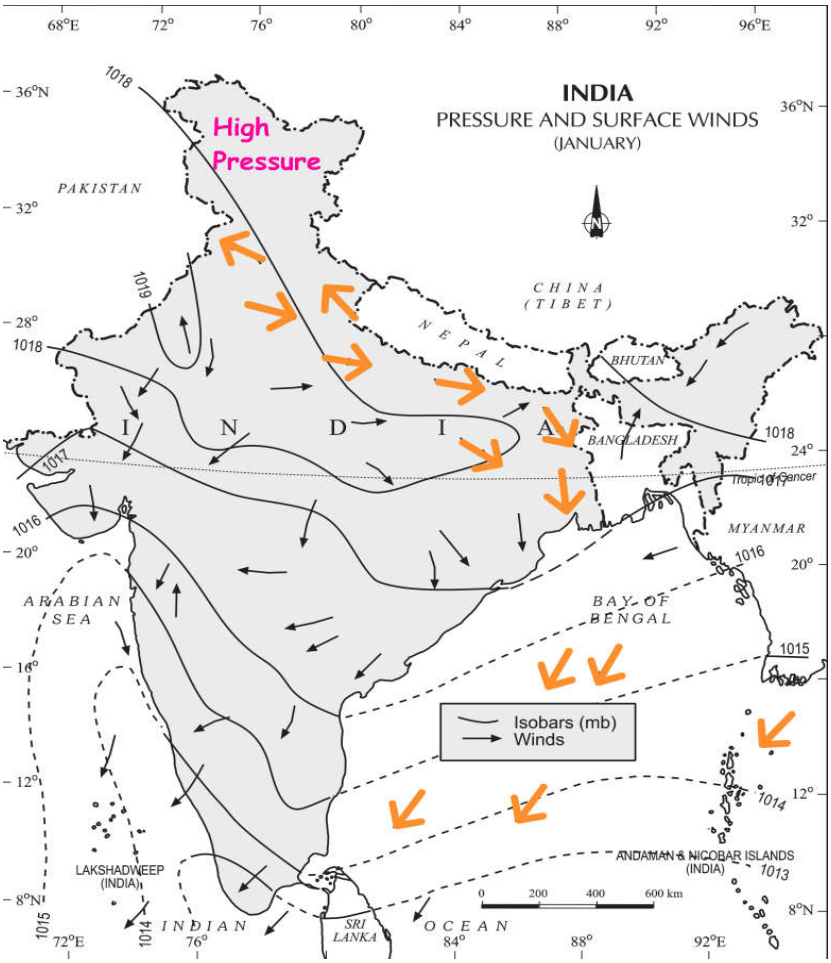
Distribution of air pressure and winds on the surface of the earth:

In winter months, the weather conditions over India are generally influenced by the distribution of pressure in the Central and Western Asia.

- A high-pressure centre in the region lying to the north of the Himalayas develops during winter.
- This centre of high pressure gives rise to the flow of air from the north towards the Indian subcontinent, south of the mountain range.
- These surface winds blowing out of the high-pressure centre over Central Asia reach India in the form of a dry continental air mass.
- These continental winds come in contact with trade winds over northwestern India. The position of this contact zone is not, however, stable. Occasionally, it may shift its position as far east as the middle Ganga valley with the result that the whole of the northwestern and northern India up to the middle Ganga valley comes under the influence of dry northwestern winds.
- In south India, the air pressure is slightly lower (due to higher temperatures). As a result, winds start blowing from northwestern high-pressure zone to the low air pressure zone over the Indian Ocean in the south. Due to a low pressure gradient, the light winds blow outwards with a low velocity of about 3-5 km per hour.
- By and large, the topography of the region influences the wind direction (See the following map):
  - They are westerly or northwesterly down the Ganga Valley.
  - They become northerly in the Ganga-Brahmaputra delta.

- Free from the influence of topography, they are clearly north-easterly over the Bay of Bengal.

- These land bearing winds being cold and dry don't give rain over most parts of the country. However, these winds cause rain along the Coromandel Coast since they collect moisture on their way over the Bay of Bengal.

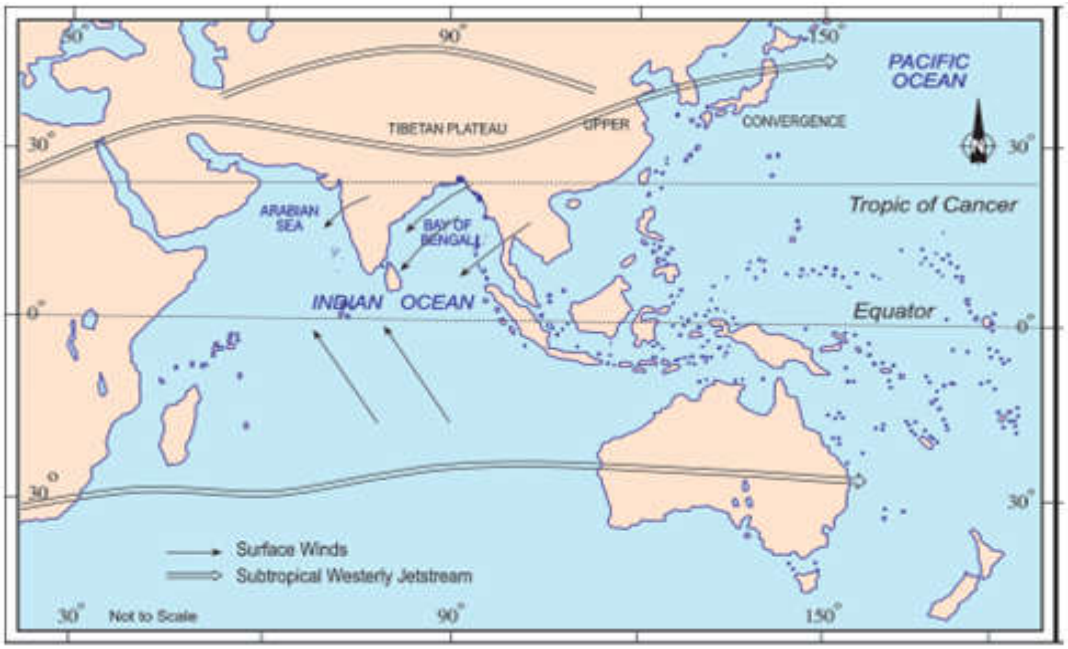


Jet Stream and Upper Air Circulation:

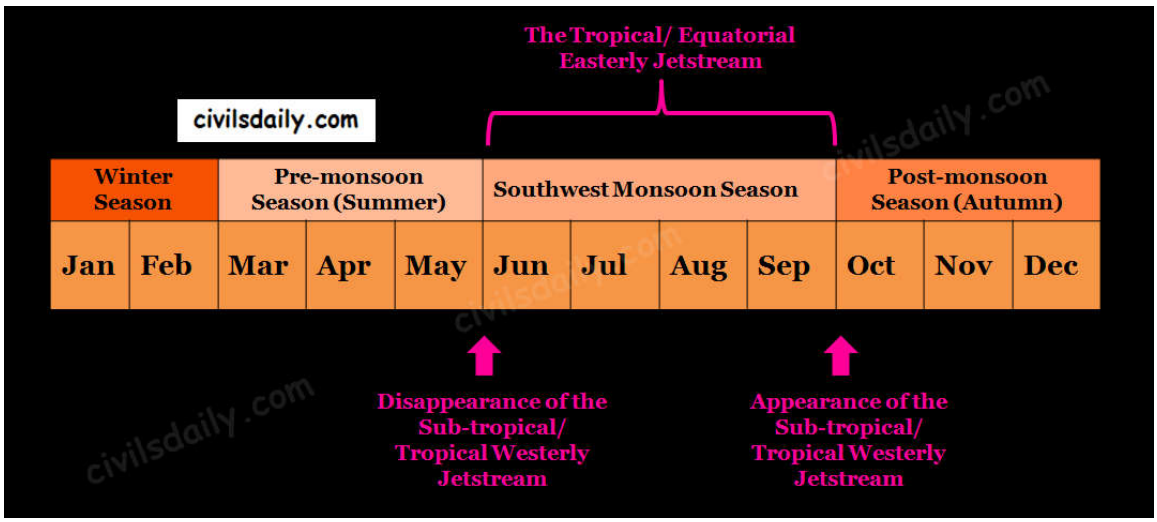
Higher up in the atmosphere, a different pattern of air circulation is observed during the winter months:

- All of Western and Central Asia remains under the influence of **westerly** winds along the altitude of 9-13 km from west to east. These winds blow across the Asian continent at latitudes north of the Himalayas roughly parallel to the Tibetan highlands. These are known as the **sub-tropical/tropical westerly jet stream**.
- Tibetan highlands act as a barrier in the path of these jet streams. As a result, jet streams get bifurcated. One of its branches blows to the north of the Tibetan highlands, while the southern branch blows in an eastward direction, south of the Himalayas, later recombining into a single stream over China.

- It is believed that this southern branch of the jet stream exercises an important influence on the winter weather in India.
- The mean position of this jet stream is about 25°N.



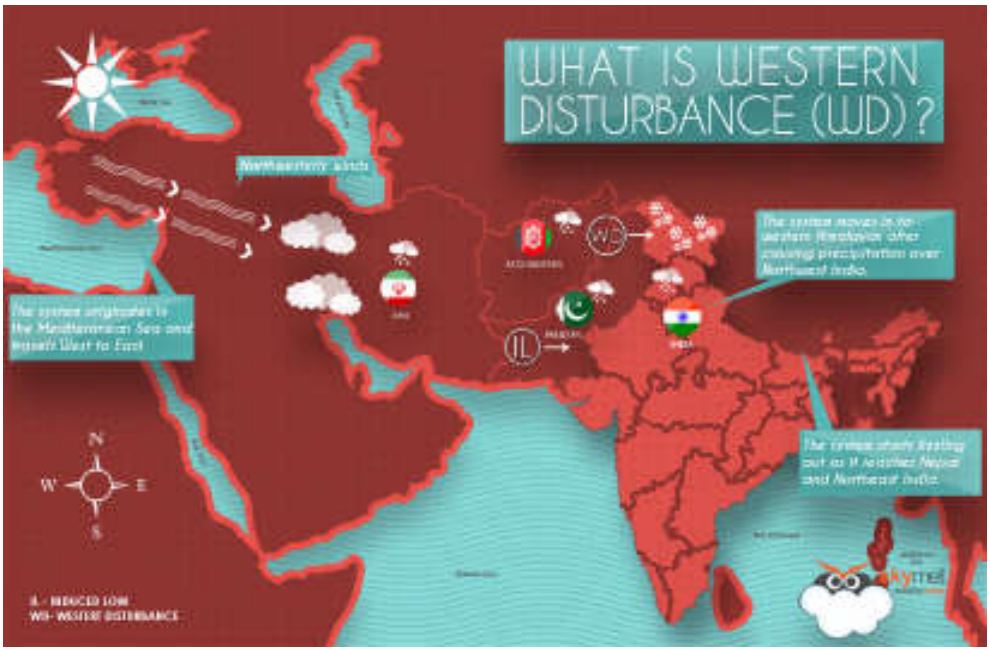
- This jet stream first appears over the northern parts of the Indian subcontinent in the month of October after the withdrawal of the summer monsoon and shifts progressively southwards with the advance of the winter season. Thereafter, it shifts back towards the north, weakens and disappears from the South Asian region with the establishment of the South-West monsoon in June. According to Dr.Koteshwaram, the disappearance of this jet from the south of the Himalayas paves the way for the burst of South-West Monsoon along the coast of Kerala.



Western Disturbances:

During the winters, the weather in India is pleasant. The pleasant weather conditions, however, at intervals, get disturbed by shallow **cyclonic depressions** originating over the east Mediterranean Sea.

- These temperate cyclones travel eastwards across West Asia, Iran, Afghanistan and Pakistan and enter the north-western parts of India with the help of the westerly jet stream (discussed above).
- On their way, the moisture content gets augmented from the Caspian Sea in the north and the Persian Gulf in the south. Since these extra tropical cyclones reach India from the West, they are usually referred to as the **western disturbances** over the Indian region.



- Because of the high terrain, mountain ranges, most of these disturbances are in the mature stage and hence weak or irregular by the time they reach India.
- Reaching Rajasthan, Haryana and Punjab, these disturbances slow down and stagnate due the nearly closed in nature of the region with high hills.
- With moisture feed from the Arabian Sea, these disturbances may intensify and move north-east. The tracks of these disturbances come farthest south to latitudes 22/23°N in the month of February.
- An increase in the prevailing night temperature generally indicates an advance in the arrival of these disturbances.

The western disturbances result in:

1. Cold spells in north-western India as these depressions are followed by cold waves.
2. Rainfall in Punjab, Haryana, Delhi and western Uttar Pradesh. Although the amount is meagre, it is highly beneficial for Rabi crops.

3. Snowfall in the higher altitudes of Kashmir and Himachal Pradesh and sometimes hail too. It is this snow that sustains the flow of water in the Himalayan rivers during the summer months.

The precipitation goes on decreasing from west to east in the plains and from north to south in the mountains.

Note: The term western disturbance is generally applied to all disturbances which come from the West, even when a "low" may not be seen on the synoptic charts.

2. The Pre-Monsoon Season/ Summer Season (Mar – May)

Temperature Conditions during this season:

- As the sun shifts northward towards the Tropic of Cancer after the vernal Equinox, the whole India experiences an **increase in temperature**.
- In most parts of India, temperatures recorded are between 30°-32°C.

North India:

- April, May and June are the months of summer in north India.
- In May, the heat belt moves further north, and in the north-western part of India, temperatures around 48°C are not uncommon.

South India:

- The Peninsular situation of south India with **moderating effect of the oceans** keeps the temperatures lower than that prevailing in north India. So, temperatures remain between 26°C and 32°C.
- **Western Ghats** – Due to altitude, the temperatures in the hills of Western Ghats remain below 25°C.
- The temperature increases from the coast towards the interior areas.

Surface Pressure and Winds:

- The **atmospheric pressure is low** all over the country due to high temperatures.
- Since the sun goes gradually towards the north (summer solstice), the Inter Tropical Convergence Zone (ITCZ) begins to move towards the north (Eventually reaching up to 25° latitude in July).
- The general direction of winds is from the north-west and west in north-western India, and from the south-west in the Arabian Sea and adjoining coasts.
- In the months of May and June, the high temperature in north-western India builds steep pressure gradient.
- Under such conditions, hot dust-laden strong winds known as '**loo**' blow.
    - These strong dust storms result from the convective phenomenon and their intensity increases in the afternoon. These are locally known as **Andhis**.
    - These are essentially short-lived thunderstorms, which move like a solid wall of sand and dust.
    - These bring little rainfall and give much needed relief from heat.
    - Dust storms in the evening are very common during May in Punjab, Haryana, Eastern Rajasthan and Uttar Pradesh.


A Dust Storm in Delhi this May.

Pre monsoonal showers:

- Occasionally, the moisture-laden winds are attracted towards the periphery of the trough. A sudden contact between dry and moist air masses gives rise to local storms of great intensity. These local storms are associated with violent winds, torrential rains and even hailstorms.
- The thunderstorms which originate over Chotanagpur plateau are carried eastwards by westerly winds. The areas with the highest incidence of thunderstorms are the north-eastern states, West Bengal, and the adjoining areas of Orissa and Jharkhand.
- In West Bengal and the adjoining areas of Assam, Orissa and Jharkhand, the direction of squalls is mainly from the northwest and they are called **Norwesters** (Squall – a sudden, violent gusty wind).
    - ✓ The rainfall brought by norwesters is called spring storm showers.
    - ✓ These are often very violent with squall speeds of 60-80km/hour.
    - ✓ Large sized hailstones sometimes accompany these showers and harm the animals and standing crops.
    - ✓ The period of maximum occurrence of these storms is the month of Baisakh. These are thus locally called '**Kal Baisakh** (a calamity of the month of Baisakh)'.
    - ✓ In Assam, these storms are known as "**Bardoli Chheerha or Bordochila**".
- In the south, thunderstorms occur in Kerala and adjoining parts of Karnataka and Tamil Nadu particularly in the evenings and nights. These pre-monsoonal showers are called by various names:
    - ✓ **Tea showers** in Assam (they are good for tea, jute and rice)
    - ✓ **Mango showers** in Kerala and coastal areas of Karnataka as they help in the early ripening of mangoes.

- ✓ **Cherry Blossoms/ Coffee showers** in Kerala and nearby areas (good for coffee plantations)

Tropical Cyclones:

Tropical Cyclones (TC) are intense low-pressure systems that develop over the seas or oceans in the tropical and subtropical regions. Tropical cyclones cause destruction in the coastal areas because of:

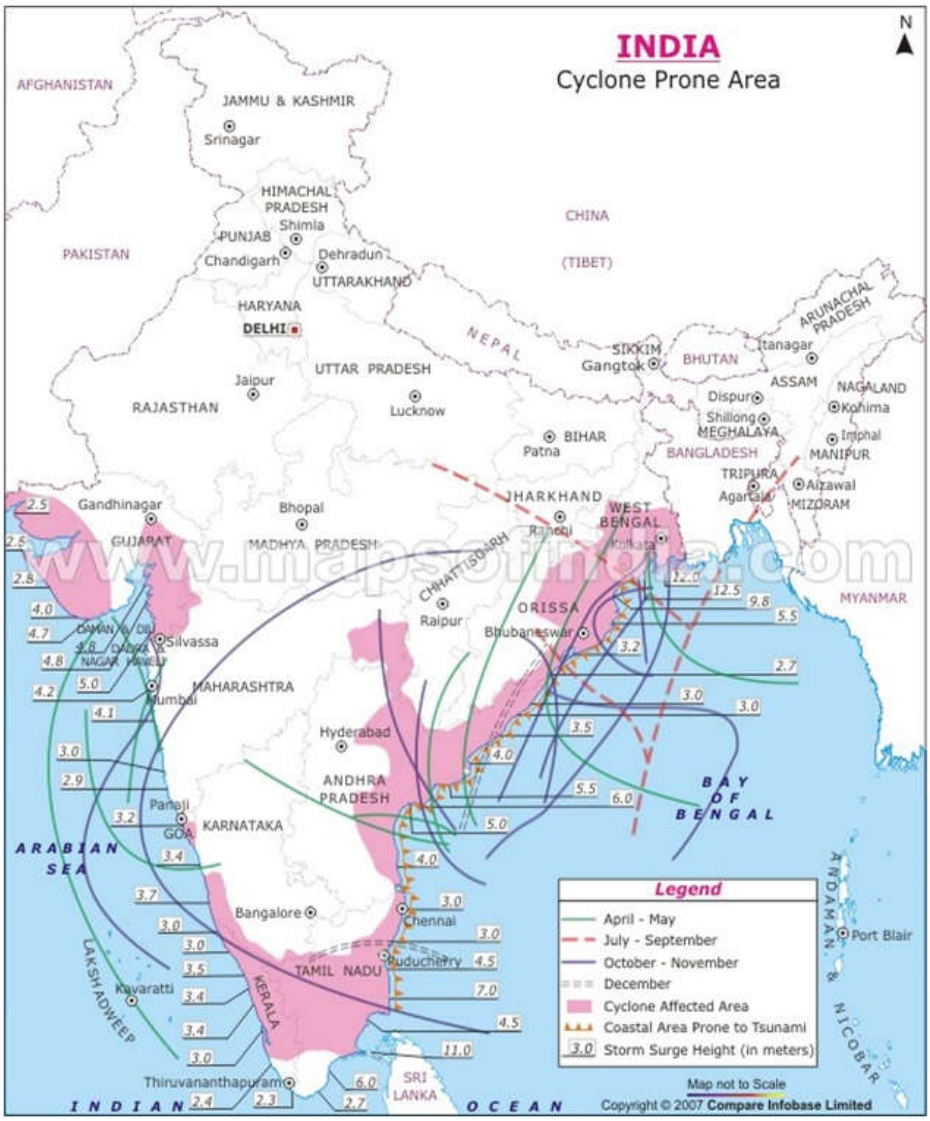
1. High wind velocities.
2. Storm Surge (i.e. rise of coastal waters due to approaching cyclone)
3. Torrential rainfall which often lead to floods in the coastal areas.

Note: The interior regions do benefit from the torrential rain associated with a tropical cyclone for agriculture and other applications of water.

The Indian sub-continent having a coast line of 7516 km is the worst affected region of the world. It is exposed to nearly 10% of the world's Tropical Cyclones.

- ❖ Many low-pressure systems of varying stages of development form in the Bay of Bengal and in the Arabian Sea and move west or north-westwards, sometimes re-curving north or north-east at a later stage (See the following map). Re-curvature usually occurs when these systems are between 16° and 18°N.
- ❖ Only a few of them develop fully into the mature stage and the majority remain as depressions.

- The fully developed low-pressure systems called cyclones generally form in the lower latitude belt (10° N – 14°N) before and after the SW monsoon. They are very intense systems and are responsible for the major portion of rainfall over the peninsula.
- **These systems reach their maximum intensity before/after the monsoon period.**
- During the SW monsoon season, these systems form in the Bay of Bengal and generally travel west or north-west along the monsoon trough. The rainfall over northern India is to a large extent dependent on the frequency, track and intensity of these depressions (called monsoon depressions). The frequency and direction of these cyclones also influence weather conditions along the eastern coast during retreating monsoon season i.e. in October and November.
- An analysis of the frequencies of cyclones on the East and West coasts of India shows that the East Coast is more prone to tropical cyclones as compared to the West Coast.



3. The South-West Monsoon Season (Jun – Sep)

Temperature Conditions during this season:

As the sun shifts northwards, the temperature rapidly increases especially in the northern India.

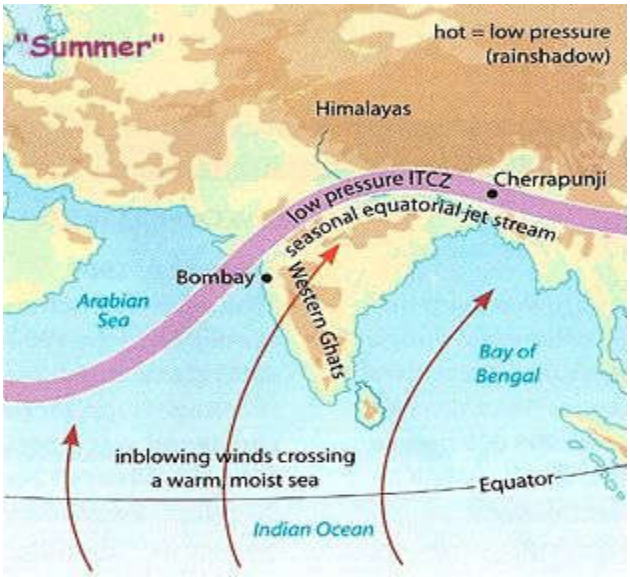
The wind circulation over the subcontinent undergoes a complete reversal at both, the lower as well as the upper levels. Let's see how:

Distribution of air pressure and winds on the surface of the earth:

- As a result of rapid increase in temperature in May over the north-western plains, the low-pressure conditions over there get further intensified.
- Because of the heating of the subcontinent, by the middle of July, the low-pressure belt near the surface [termed as Inter Tropical Convergence Zone (ITCZ)] shifts northwards, roughly parallel to the Himalayas between 20° N and 25° N. The ITCZ in this position is sometimes called the **monsoon trough**.

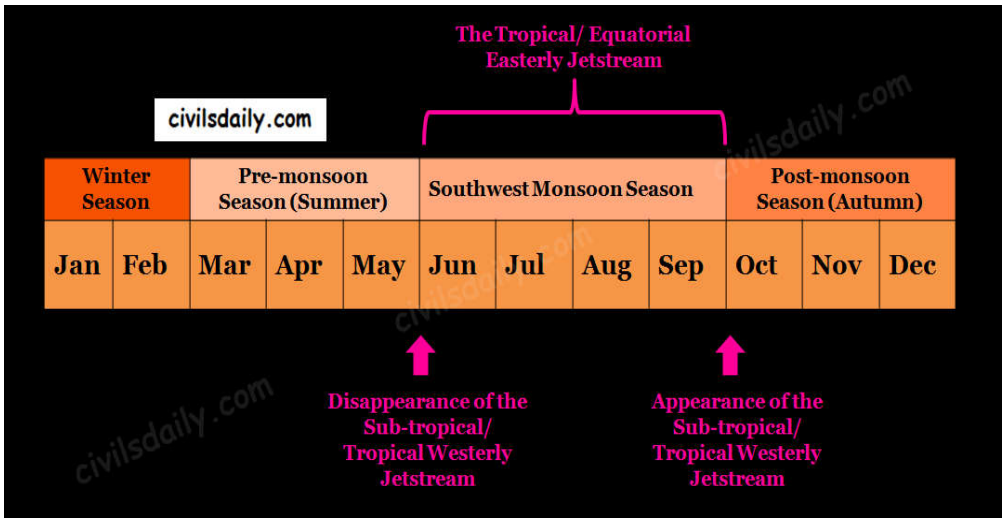
[**Revision Note**: ITCZ is the low-pressure zone located at the equator where the trade winds converge. It is also referred to as the thermal equator. It is a zone of generally calm, hot, rising air and low pressure.]

- Roughly, this elongated low-pressure monsoon trough extends over the Thar desert in the north-west to Patna and Chotanagpur plateau in the east-southeast.
- Meanwhile, the sea surrounding India heats up slowly, creating a zone of relatively high pressure off India's Southern Coastline.
- Next, because winds blow from high to low pressure, warm moisture-laden air moves south-westerly direction from the sea over to India in the north and North East and is deflected by the Coriolis force as the Earth spins. It is this moist air current which is popularly known as the south-west monsoon.

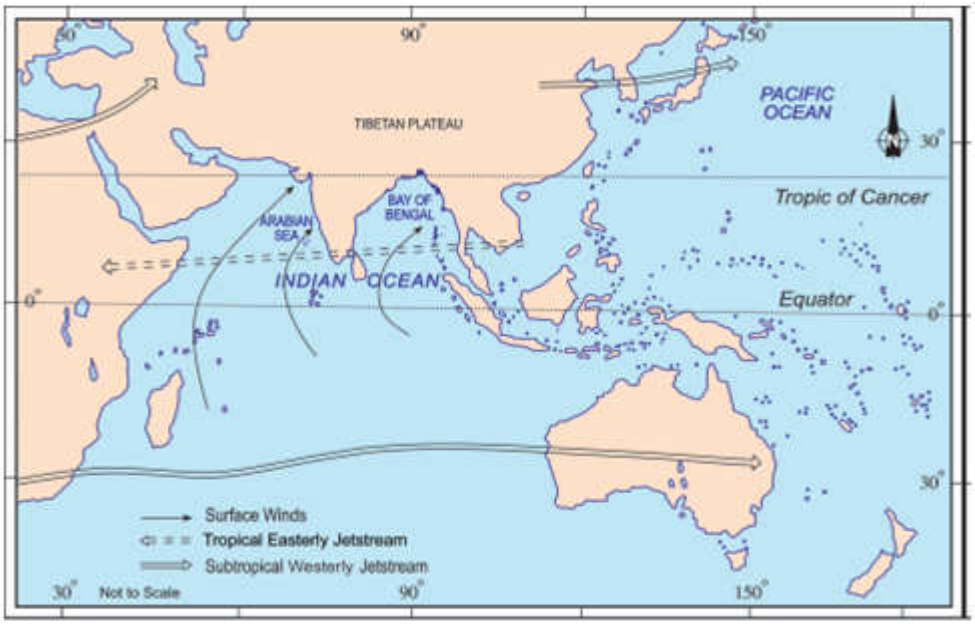


Jet Stream and Upper Air Circulation:

- By this time, the westerly jet stream withdraws from the Indian region. In fact, meteorologists have found an interrelationship between the northward shift of the equatorial trough (ITCZ) and the **withdrawal of the westerly jet stream** from over the North Indian Plain. It is generally believed that there is a cause and effect relationship between the two.



- An **easterly jet stream flows** over the southern part of the Peninsula in June and has a maximum speed of 90 km per hour. In August, it is confined to 15°N latitude, and in September up to 22° N latitudes. The easterlies normally do not extend to the north of 30° N latitude in the upper atmosphere.



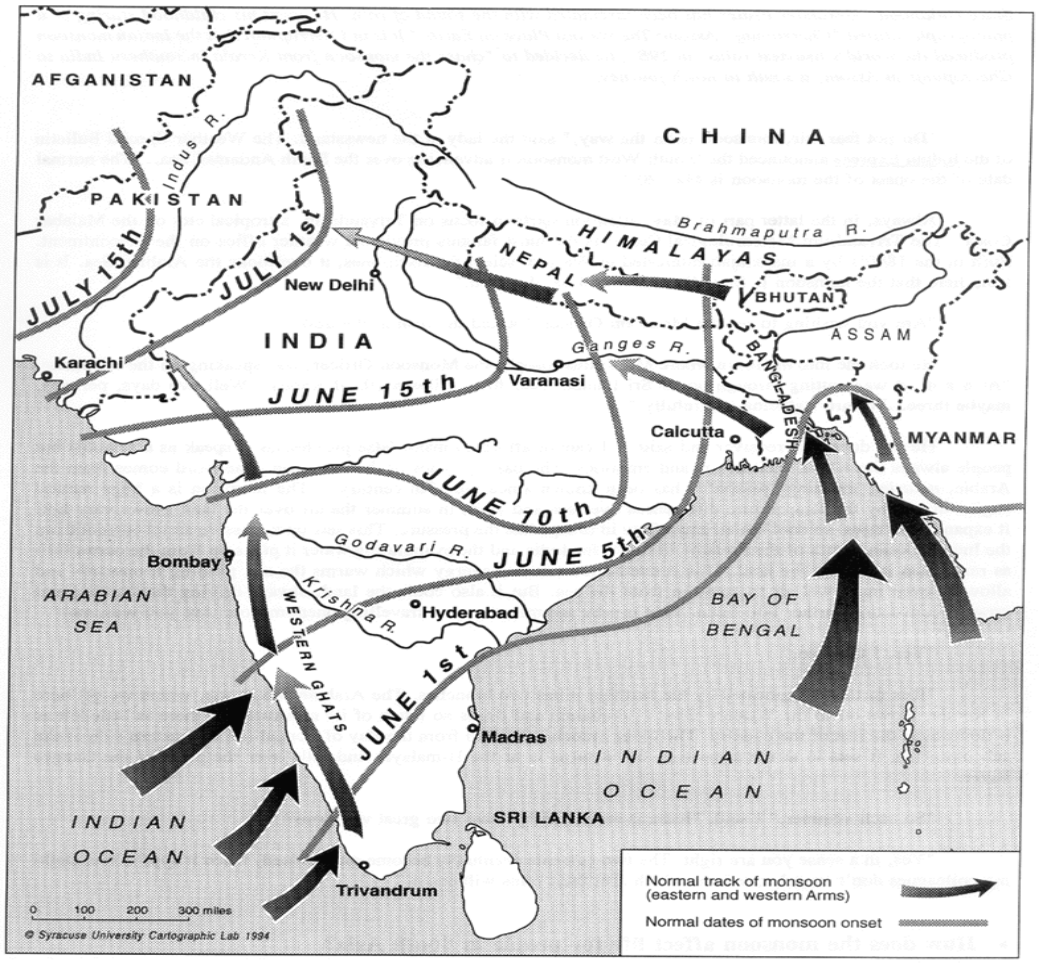
Easterly Jet Stream and Tropical Cyclones: [The tropical cyclones were discussed in detail in the discussion on summer season. Remember? Revise here before moving forward!]

- 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.
- The frequency at which these depressions visit India, their direction and intensity, all go a long way in determining the rainfall pattern during the south-west monsoon period.

The onset and progress of South-West Monsoon in India:

1. Entry of Monsoon into India:

- The rain in the south-west monsoon season begins rather abruptly. 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.
- The mean date for the burst of monsoon along the coast of Kerala is 1 first June with a coefficient of variation of a week. It reaches the interior parts of the country by the first week of July. By mid-July, south-west monsoon engulfs the entire subcontinent.



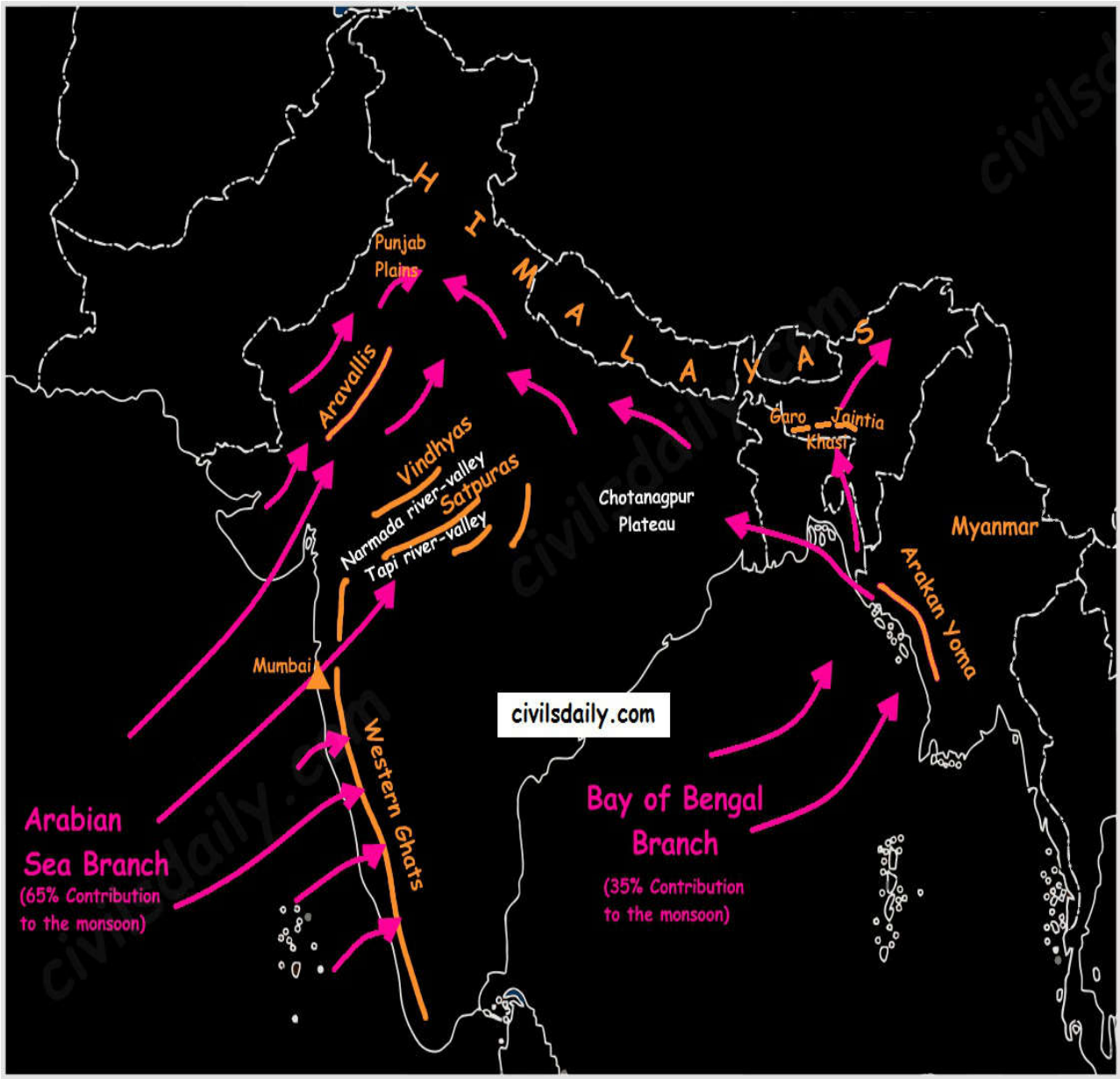
- **Impact** of this rainfall: One result of the first rain is that it brings down the temperature substantially. The day temperature registers a decline of 5°C to 8°C between mid-June and mid-July.

2. The progress of monsoons: As these winds approach the land, their south-westerly direction is modified by:

- ✓ The relief, and
- ✓ The thermal low pressure over the north-west India.

The monsoon approaches the landmass in two branches:

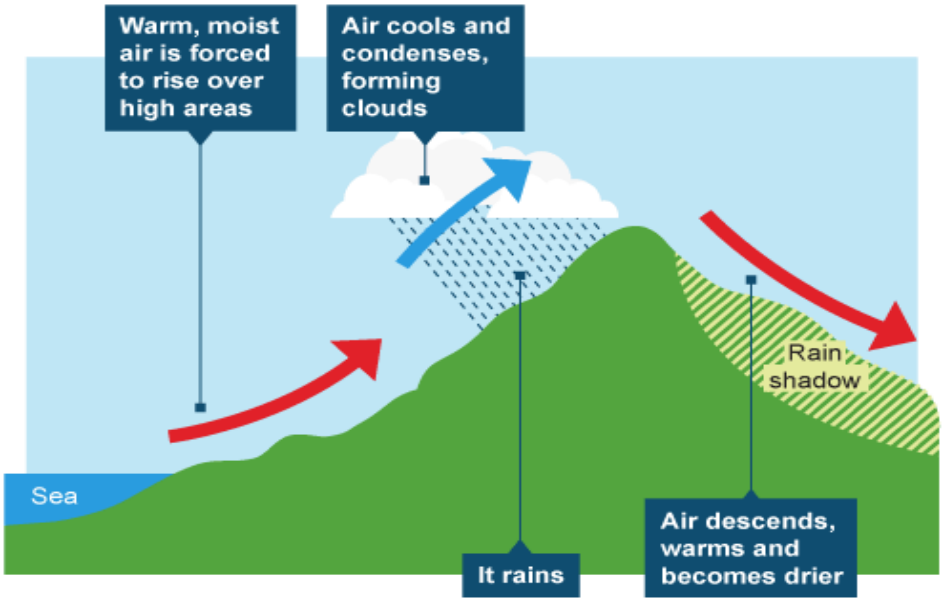
1. The Arabian Sea branch
2. The Bay of Bengal branch.



The Arabian Sea branch:

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

1. One branch is obstructed by the **Western Ghats**.
    - As these winds climb the slopes of the Western Ghats, they become cooler, their moisture retention capacity reduces and as a result, the windward side of the Sahyadris and Western Coastal Plain receive very heavy rainfall ranging between 250 cm and 400 cm.
    - Much of the rainfall along the Western Ghats is thus orographic, as the moist air is obstructed and forced to rise along the Ghats.
    - 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.



2. 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.
3. The third branch of this monsoon wind strikes the **Saurashtra Peninsula** and **the Kachchh**. 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.

Note: Though this branch passes through Rajasthan, it does not cause rainfall there. This is because:

- ✓ The direction of Aravallis is parallel to these monsoon winds.

- ✓ The dry and hot winds from the Sindh region of Pakistan lessen the relative humidity of these monsoon winds and do not allow them to get saturated.

The Bay of Bengal branch:

- The Bay of Bengal branch strikes the coast of Myanmar and parts of south-east 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 the south and south-east instead of from the south-westerly direction.
- From here, this branch splits into two under the influence of the Himalayas and the thermal low in north-west 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. The hills of Garo, Khasi and Jaintia are expanded in a **funnel shape** with an opening towards the sea. So the moist winds coming from the Bay of Bengal undergo a sudden rise here and cause excessive rainfall. Mawsynram, located on the crest of Khasi hills, receives the highest average annual rainfall in the world (1141cm).
    - There is relatively less rainfall on the leeward slope of the Meghalaya Plateau e.g. 143 cm in Shillong and 161 cm in Guwahati which is very less in comparison to that in Mawsynram.
    - The Brahmaputra valley to the north also experiences a rain-shadow effect; the problem is mitigated, however, by the adjacent Himalayas, which cause the winds to rise again, thereby establishing a parallel belt of heavy precipitation.

Note:

- ✓ The Arabian Sea branch is stronger than the Bay of Bengal branch. 65% of the humidity brought by the monsoon comes from the Arabian Sea whereas the monsoon coming from the Bay of Bengal contributes only 35% to the humidity.
- ✓ In the Gangetic Plains, the two branches merge into one. By the time they reach the Punjab their moisture is largely spent. The gradual reduction in the amount of rainfall toward the west is evidenced by the decline from 162 cm at Kolkata to 66 cm at Delhi and to desert conditions still farther west.
- ✓ Over the north-eastern portion of peninsular India, the two branches also intermittently collide, creating weak weather fronts with sufficient rainfall to produce patches of fairly high precipitation (more than 152 cm) in the Chotanagpur plateau.

Here it is important to know why the Tamil Nadu coast remains dry during this season.
It is because:

1. The Tamil Nadu coast is situated parallel to the Bay of Bengal branch of south-west monsoon.
2. It lies in the rain-shadow area of the Arabian Sea branch of the south-west monsoon.

3. 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.

Reasons:

- These breaks 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.
- 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.
- Over the west coast, the dry spells are associated with days when winds blow parallel to the coast.

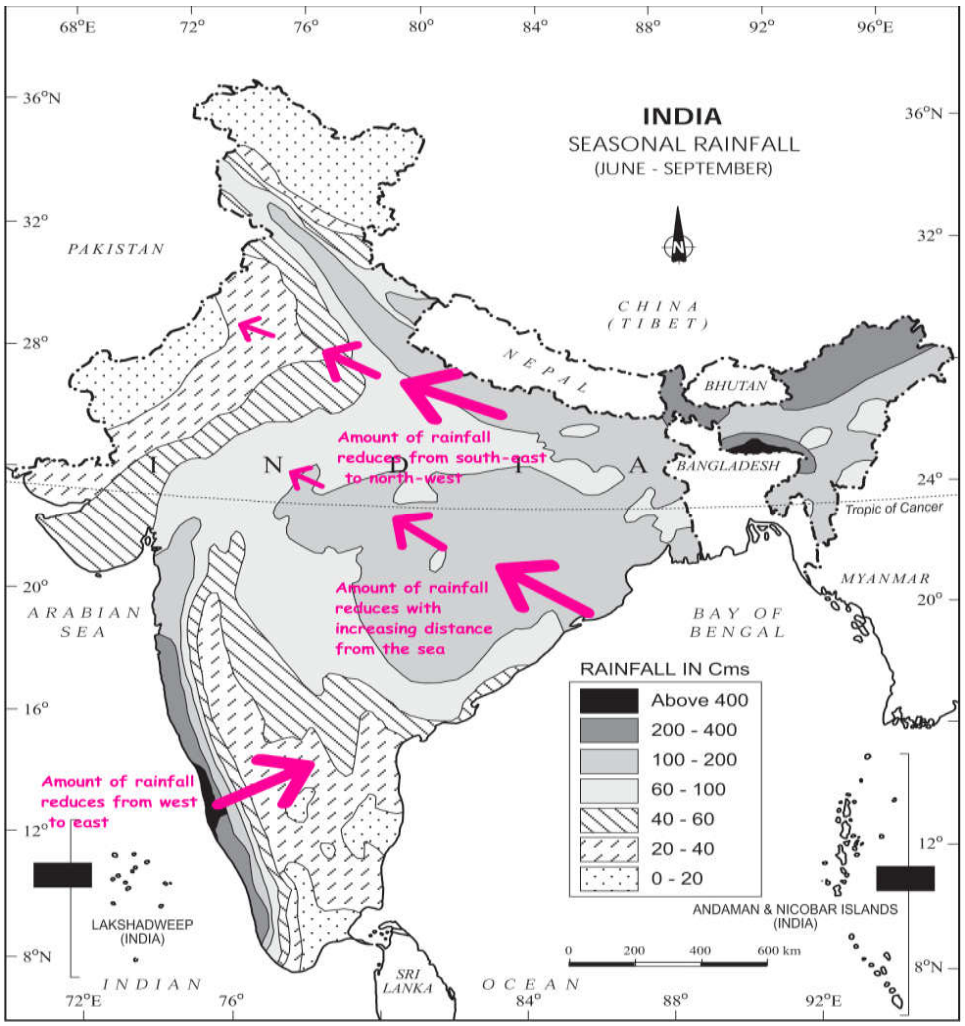
4. The Withdrawal of the SW monsoon:

The withdrawal of the SW monsoon and the onset of the NE monsoon in the end of September are a gradual phenomenon. They take place almost at the same time and tend to merge. This explains the popularity of the phrase "Retreating Monsoon".

Chief Characteristics of Monsoonal Rainfall:

- Monsoonal rainfall is largely governed by relief or topography. For example:
  - The windward side of the Western Ghats registers a rainfall of over 250 cm.
  - The heavy rainfall in the north-eastern states can be attributed to their hill ranges and the Eastern Himalayas.
- The monsoon rainfall has a declining trend with increasing distance from the sea. E.g. consider the amount of rainfall received during the south-west monsoon period at the following places:

  Kolkata (119 cm) –> Patna (105 cm) –> Allahabad (76 cm) –> Delhi (56 cm)
- The rain comes in spells and displays a declining trend from west to east over the west coast and from the south-east towards the north-west over the North Indian Plain and the northern part of the Peninsula.
- Its spatial distribution is also uneven which ranges from 12 cm to more than 250 cm.



What causes monsoons?

Monsoon is a familiar though a little known climatic phenomenon. Despite the observations spread over centuries, the monsoon continues to puzzle the scientists. Many attempts have been made to discover the exact nature and causation of monsoon, but so far, no single theory has been able to explain the monsoon fully.

Let's look at some of the important concepts about the **origin of monsoons.** We will study these along the following lines:

1. The Classical Hypothesis
    1. Halley(1690's)
    2. Hadley (1730's)
2. The role of moisture.
3. The shifting of ITCZ – Flohn

Recent theories:

1. The role of Tibetan plateau

1. As a mechanical barrier
2. As a high-level heat source

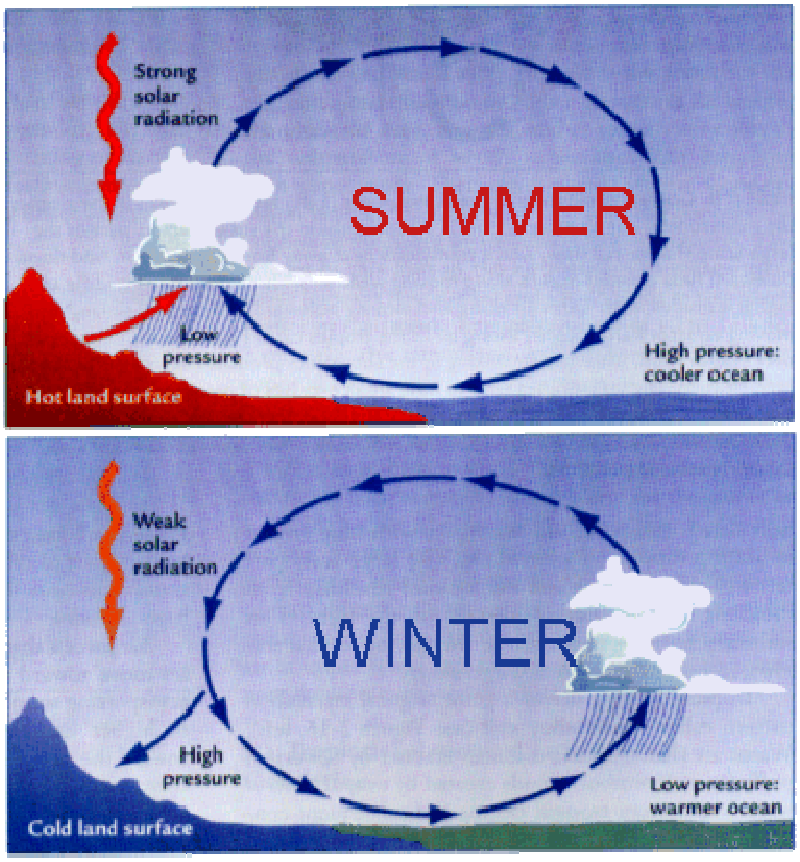
2. The role of jetstreams
    1. The Sub-tropical/ tropical westerly jet stream
    2. The tropical/ equatorial easterly jet stream

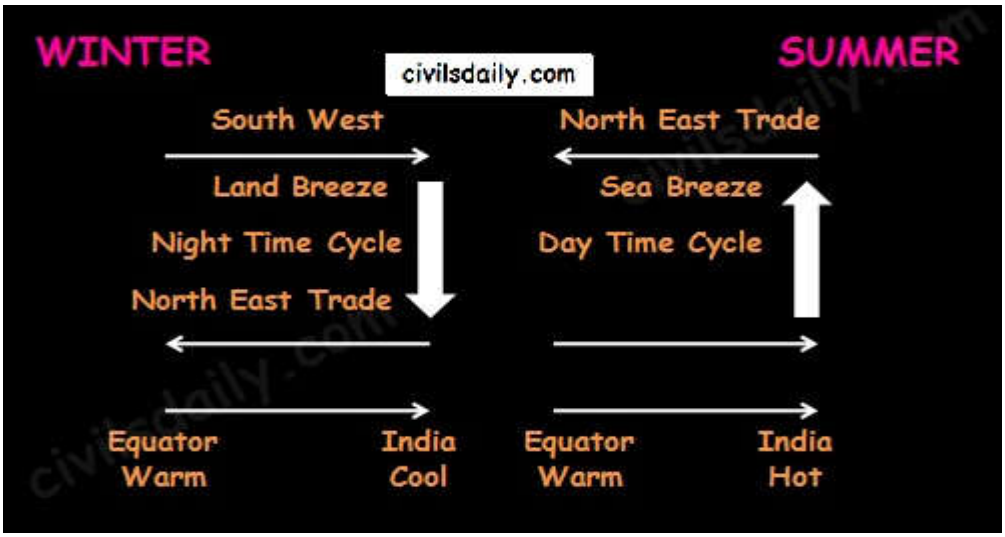
1. The Classical Hypothesis

Halley hypothesized that the primary cause of the annual cycle of Indian monsoon circulation was a differential heating effect between the ocean and land in South Asia.

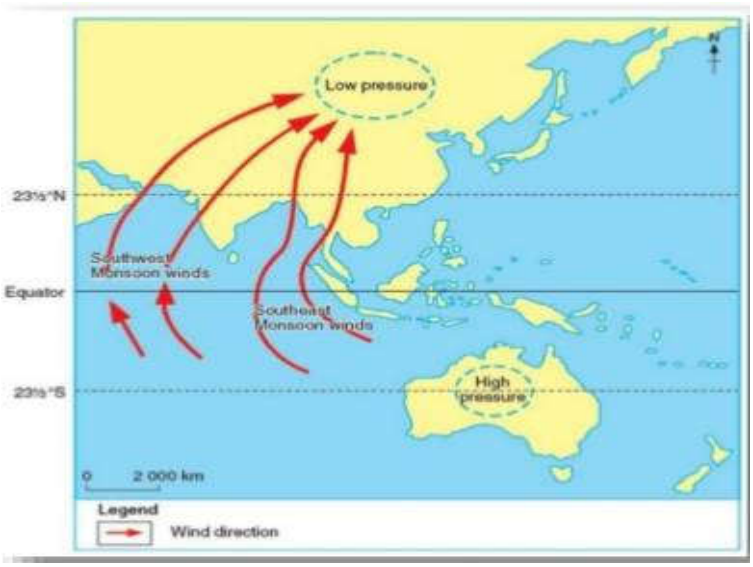
- ✓ During April and May when the sun shines vertically over the Tropic of Cancer, the large landmass in the north of Indian ocean gets intensely heated. This causes the formation of an intense low pressure in the northwestern part of the subcontinent.
- ✓ The pressure in the Indian Ocean in the south of the landmass is high as water gets heated slowly.
- ✓ This pressure differences causes the flow of winds from the high pressure to low pressure areas

Thus the first model ever proposed about the mechanism of the Indian monsoon was Haley's planetary scale sea-breeze – land breeze system in 1690's.





Hadley later argued that Haley's model was lacking in the physical ingredient of the effect of rotation of earth about its axis. Hadley reasoned that the monsoon originates in the SE trades of the southern hemisphere and as it flows across the equator towards the heated landmass, the Coriolis force causes it to turn to right, thereby forming the summer monsoon or the SW monsoon.

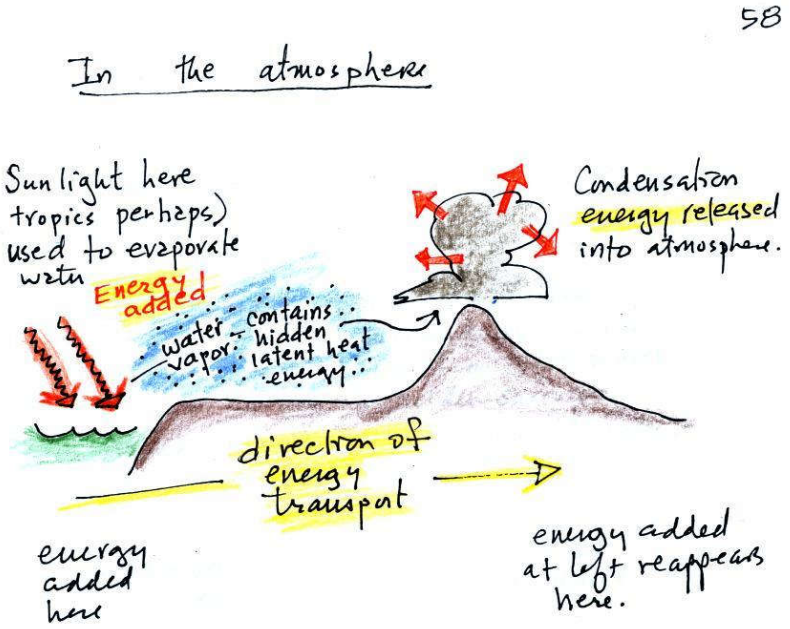


2. The role of moisture:

Moisture plays an important role in the atmospheric circulation which was not appreciated by either Halley or Hadley.

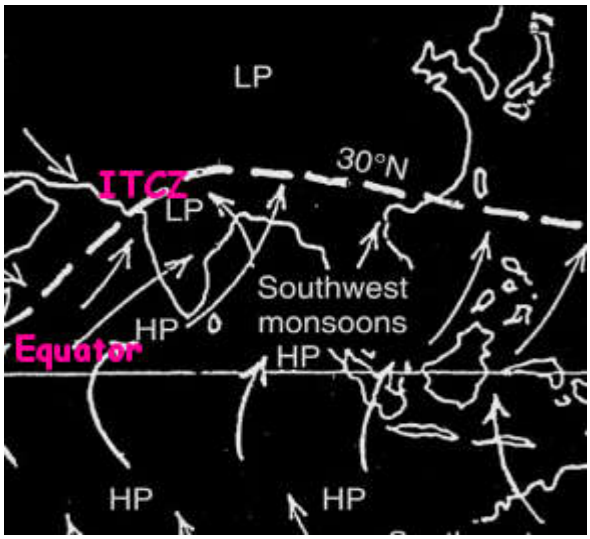
In this respect, the release of latent heat augments the differential heating produced by the land-sea contrast by providing a mechanism for the solar energy received over the vast stretches of the Indian Ocean to be collected, stored, concentrated and later released over the parched landscape of India by a massive atmospheric motion (See the following image to

understand this transfer of solar energy). As the moisture laden air comes over India, with its upliftment there takes place condensation releasing latent heat – augmenting the low pressure conditions i.e. **the cause getting augmented by its effect.**



3. The shifting of ITCZ – Dr. Flohn

The existence of Asian monsoon according to Dr. Flohn is not due to the temperature contrast between land and sea but primarily due to the annual migration of thermally induced planetary winds and pressure belts. **For Flohn, the winter monsoon is nothing but the tropical easterlies or the northern trade winds**. According to Flohn, the SW monsoon is constituted by the equatorial westerlies which have been displaced northward (because of shift of ITCZ by 20° or more).



Recent Theories:

1. The role of Tibetan Plateau:

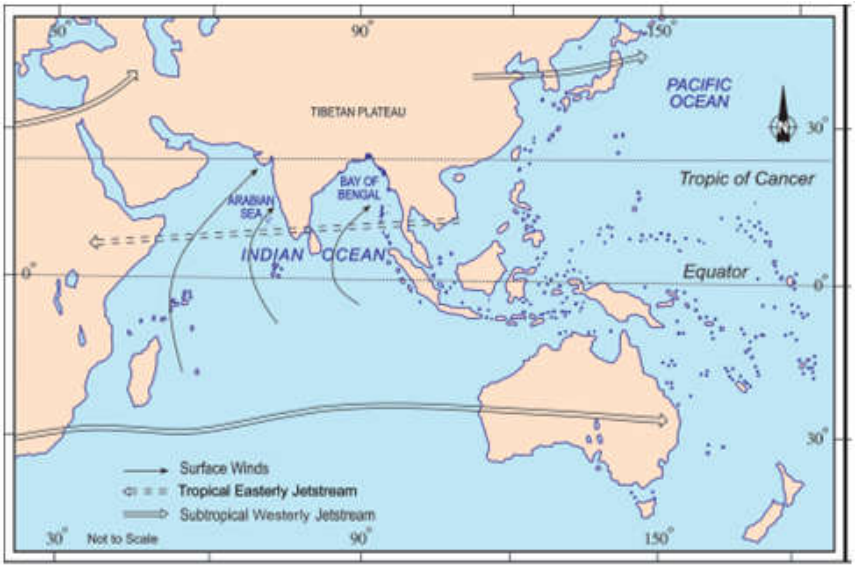
A remarkable aspect of the large scale circulation during the summer monsoon season over south-Asia is the upper tropospheric anti-cyclone situated over the Tibetan Plateau.

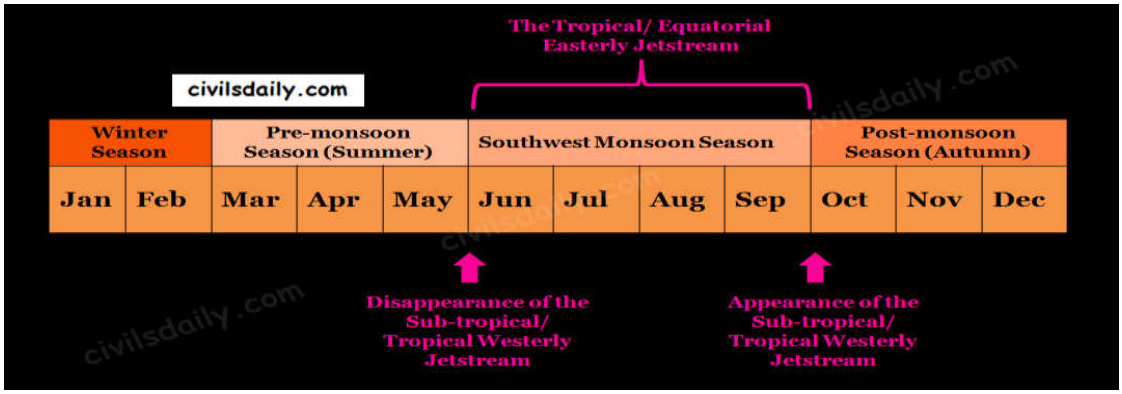
- The Tibetan Plateau located more than 4500m above mean sea-level with a length of 2000km and width of 600km in the west and 1000km in the east, is considered to be one of the key factors in the development of monsoon circulation in the region.
- **The Tibetan plateau exerts its influence both as a mechanical barrier in the atmospheric flow as well as a high level heat source.**
- An anti-cyclone appears in the upper troposphere over Tibet during the Indian monsoon season primarily due to latent and sensible heating over the plateau.
- This anti cyclone appears over south-east Asia in the month of May and then moves north-westwards, reaching Tibetan plateau around the height of the summer monsoon season.
- From about September, the anticyclone migrates south-eastward towards Indonesia and loses definition after October.
- Variations in the intensity and position of this High and its orientation have been found to be closely related to the monsoon circulation over South Asia.

2. The role of Jet streams:

Jet streams which affect India's monsoon:

1. **Sub tropical/ Tropical Westerly Jet stream (TWJS) ~27°N**
   - ✓ (Covered in detail in the discussion on winter season. Need to revise!)
   - ✓ According to Dr. Koteshwaram, the disappearance of this jet from the south of the Himalayas paves the way for the burst of South-West Monsoon along the coast of Kerala.
2. **Tropical/ Equatorial Easterly Jet stream (TEJS) ~14°N**
   - ❖ This jet is a prominent feature of the upper air circulation during the Indian summer monsoon season (June – September). It appears as a band of strong easterlies extending from SE Asia across the Indian Ocean and Africa to the Atlantic, generally at a height of about 14 kms. It is present over south Indian peninsula between 12° and 15°N with a mean position of 14°N. This easterly jet stream is held responsible for the burst of the monsoon in India.
   - ❖ The position and speed of this jet have been found to have significant spatial and temporal fluctuations, which in turn correlate with monsoon rainfall distribution over peninsular India.

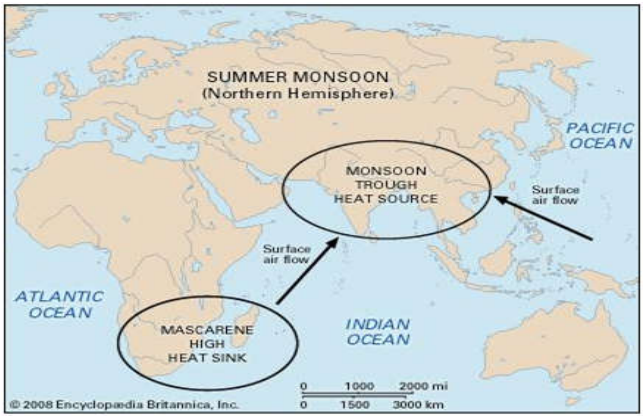




Factors which influence the South-West monsoon intensity and rainfall distribution:

1. Mascarene High and the Somali Jetstream: It is the high pressure area at sea level south of the equator in the Indian Ocean near Mascarene Islands. The position and intensity of this high are considered to be closely linked to the south summer monsoon activity.

According to scientists, the broad belt of high pressure around the Mascarene Islands generates a cross-equatorial flow known as the **Somali Jet** which brings heavy rain to India's west coast. A strong, low level jet usually means a strong monsoon over peninsular India.



2. Variation in the axis of the monsoon trough: The monsoon trough axis experiences considerable day to day variation in its position, which has a vital bearing on the monsoon rainfall distribution in the region. During the break monsoon periods, when there is a temporary lull in monsoon activity, the trough line shifts to the foothills of the Himalayas. Rainfall over the central parts of India decreases considerably and there is an increase in rainfall over northern India along the Himalayan foothills.

3. Teleconnections (ENSO – El–Nino and Southern Oscillation Index):

A. Southern Oscillation Index (SOI)

- ✓ A curious see-saw pattern of meteorological changes has been observed b/w Indian Ocean & Pacific ocean. Whenever pressure is higher over Indian Ocean, low pressure prevails over Pacific Ocean & vice versa. This see-saw relationship is referred to as the Southern Oscillations.
- ✓ To measure this pressure difference, a SOI has been developed based on the pressure data at certain representative stations (e.g. the SOI between Tahiti island and Darwin is the most widely used)

SOI (Southern Oscillation Index) = (Atm. Pressure @Tahiti) – (Atm. Pressure @Darwin)
Tahiti = Pacific Ocean, Darwin = Indian Ocean

B. El-Nino (Spanish for male child)

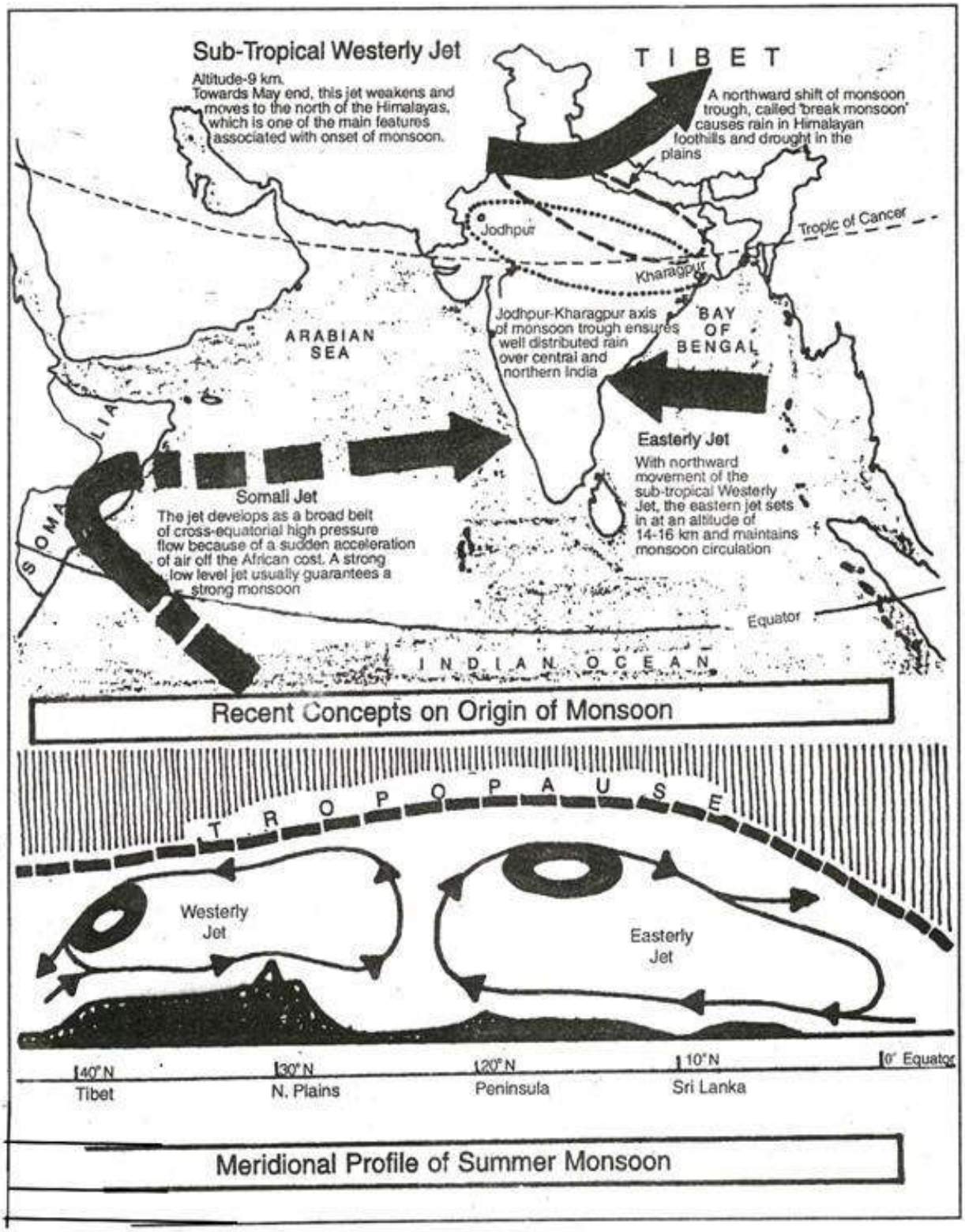
- ✓ It is an anomalous warming of the Eastern Tropical Pacific Ocean that occurs at 2 – 10 years intervals and is frequently associated with far reaching climatic and oceanic impacts around the world.

These two are believed to be inter-connected – the southern oscillation has been identified as the atmospheric counterpart to El-Nino. Both are together referred to as ENSO.

During **the high southern oscillation phase** (**Normal situation**), precipitation tends to be abundant in the Indonesian – Australian region, most of the south Asian region, SE Africa and northern coast of South America. Relatively dry conditions prevail over the equatorial pacific, east central Africa and northern Mexico.

During **the low phase of the southern oscillation (El-Nino)**, the rainfall anomalies are approximately opposite. The El-Nino is found to be adversely correlated with the SW monsoon rain.

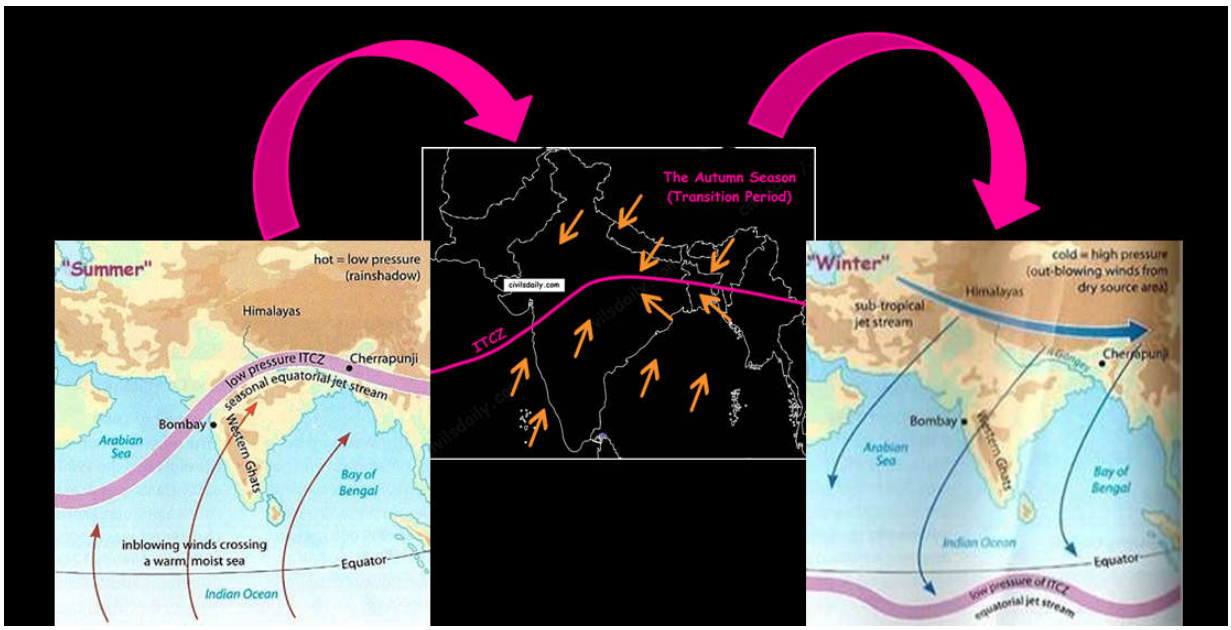
La-Nina (Spanish for girl child) refers to the reinforced normal situation and is found to be positively correlated with the SW monsoon rain.



3.23 Role of the Tibet Plateau and Jet Streams in the origin and mechanism of Indian Monsoon, according to some recent theories.

4. The Post Monsoon Season (Oct – Dec)/ Autumn (North-East Monsoon Season)

The months of October-November form a period of transition from the hot rainy season to the dry winter conditions.



The withdrawal of the south-west monsoon and the onset of north-east monsoon are both gradual phenomenon. They take place almost at the same time and tend to merge. This explains the popularity of the phrase "**Retreating Monsoon**".

A Season of Retreating Monsoon

The retreat takes place due to the weakening of the low-pressure area over the north-western parts of India (and thus a gradual transition of ITCZ towards the south). This happens due to:

- The apparent shift of sun towards the equator
- Reduction in temperature due to widespread rains.

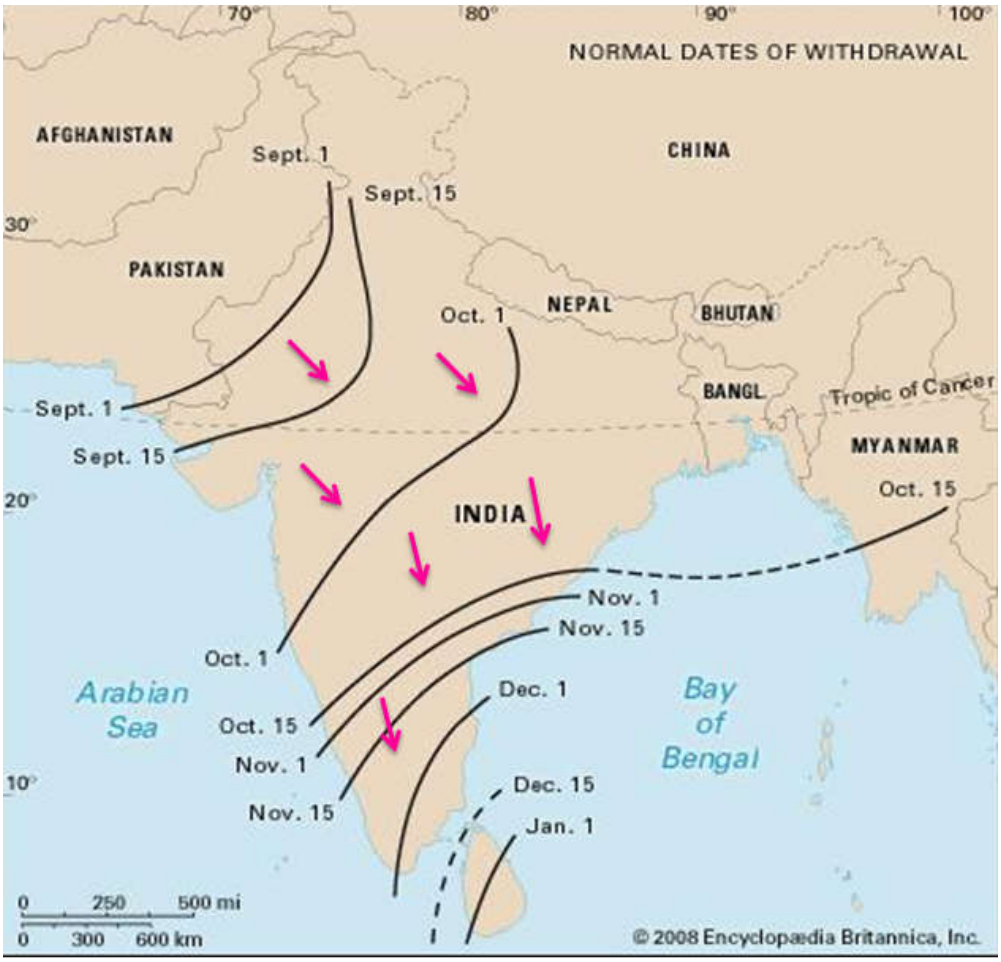
Consequently, the air pressure starts decreasing. Such changes in the atmospheric pressure cause the south-west monsoons to withdraw.

The Retreat of Monsoons is a process much slower than its arrival. It does not imply a right about turn but a gradual change of comparative pressure positions, thus gradually weakening and reducing the area of coverage and influence.

The retreat:

The south-west monsoons start retreating in the first week of September from Pakistan's border in North-West India. Thus these winds withdraw earlier from the regions they reached the last.

The monsoon retreats from the western Rajasthan by the first week of September. It withdraws from Rajasthan, Gujarat, Western Ganga plain and the Central Highlands by the end of the month. By the beginning of October, the low pressure covers northern parts of the Bay of Bengal and by early November, it moves over Karnataka and Tamil Nadu. By the middle of December, the centre of low pressure is completely removed from the Peninsula.



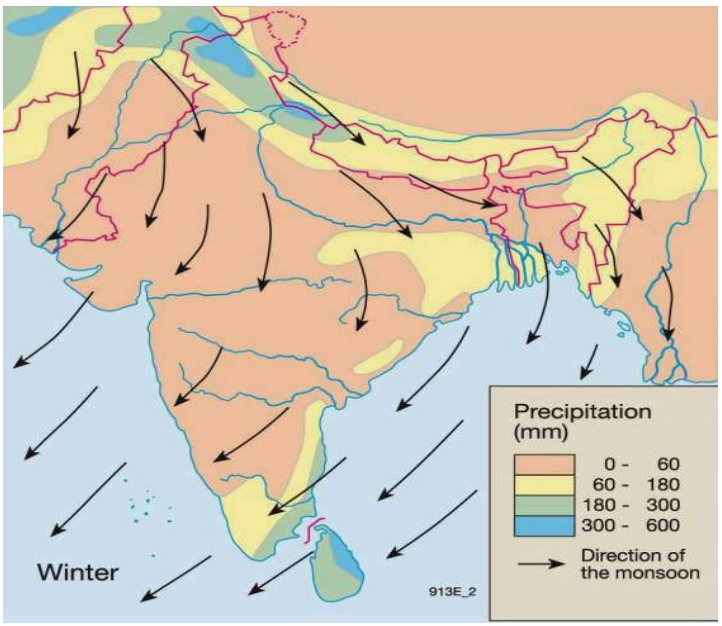
Temperature Conditions during this season:

- This season is marked by clear skies and a rise in temperature. The land is still moist. Owing to the conditions of high temperatures (around 25°C) and humidity, the weather becomes rather oppressive and unbearable. This is commonly known as the '**October heat' or 'Kwar ki Umas'**.

- In the second half of October, the mercury begins to fall rapidly, particularly in northern India. This continuous decrease in temperature after mid-October helps winter to set in by November or Early December.

Surface Winds and Precipitation:

- By and large, the topography of the region influences the wind direction:
  - ✓ The winds are westerly or northwesterly down the Ganga Valley.
  - ✓ They become northerly in the Ganga-Brahmaputra delta.
  - ✓ Free from the influence of topography, they are clearly north-easterly over the Bay of Bengal (thus the name North-East monsoon).
- **Precipitation:**
  - ✓ Winter monsoons do not cause rainfall as they move from land to the sea. It is because:
    - They have little humidity; and
    - Due to anti-cyclonic circulation on land, the possibility of rainfall from them reduces.
  - ✓ However, there are some exceptions:
    - These months are the rainiest months of the year in coastal areas of Tamil Nadu. This is because the large indentation made by the Bay of Bengal into India's eastern coast means that the flows are humidified before reaching Cape Comorin and rest of Tamil Nadu. Parts of West Bengal, Orissa, Andhra Pradesh, Karnataka and North-East India also receive minor precipitation from the northeast monsoons.
    - Central parts of India and northern parts of southern Peninsula also get winter rainfall occasionally.
    - Arunachal Pradesh and Assam in the northeastern parts of India also have rains between 25 mm and 50 mm during these winter months.



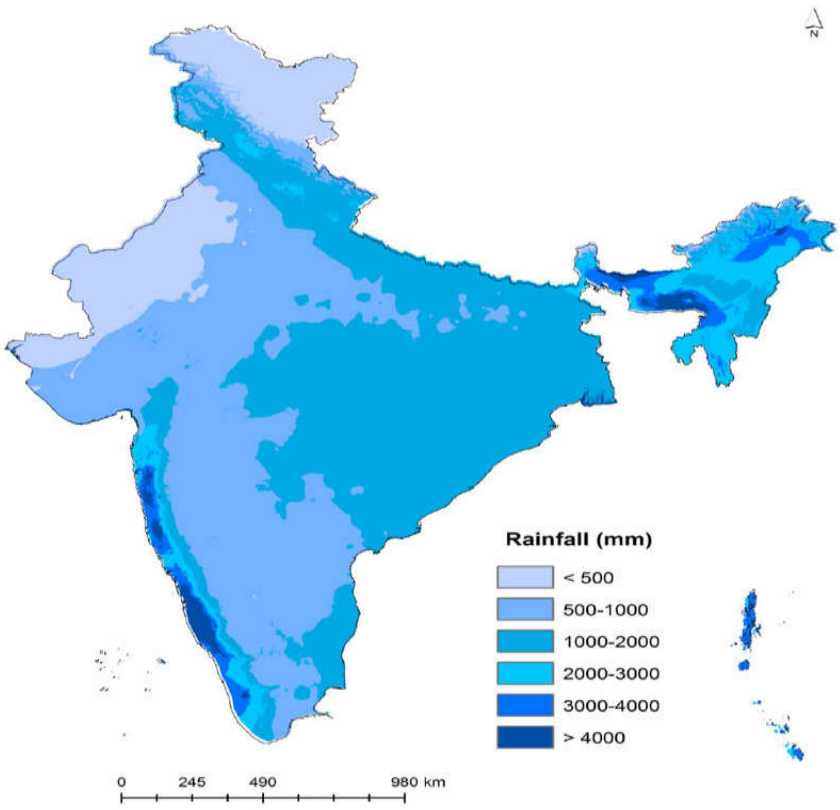
Tropical Cyclones:

- The low-pressure area lying over north-west India is transferred to the middle of Bay of Bengal by the end of October. As a result of these unstable conditions, severe cyclonic storms originate in this region.
- These cyclonic storms strike along the eastern coast of India causing widespread rain in the coastal regions.
- These tropical cyclones are very destructive. The thickly populated deltas of the Godavari, Krishna and Kaveri are their preferred targets. Every year cyclones bring disaster here. A few cyclonic storms also strike the coast of West Bengal, Bangladesh and Myanmar.
- A bulk of the rainfall of the Coromondal coast is derived from these depressions and cyclones. Such cyclonic storms are less frequent in the Arabian Sea.

Now that we have studied all the seasons in detail, let's have a look at the annual distribution and variability of rainfall in India:

Rainfall Distribution:

The distribution of rainfall in India is highly uneven. Its distribution is largely controlled by the nearness of the sea and orographic features. The average annual rainfall in India is shown in the following map. Notice that the regional variations in the distribution of rainfall over India are quite pronounced.



Variability:

The rainfall in India is highly variable. The actual rainfall of a place in a year deviates from the average rainfall by 10-60%.The variability of rainfall is computed with the help of the following formula:

The variability of rainfall is computed with the help of the following formula:

C.V. = (Standard Deviation÷ Mean) × 100

where C.V. is the coefficient of variation.

Annual Rainfall	Areas	Variability of rainfall
More than 100 cm	**Areas of High Rainfall (>200cm)** • The west coast • The Western Ghats • The sub-Himalayan areas in the northeast • The hills of Meghalaya. • In some parts of Khasi and Jaintia hills, the rainfall even exceeds 1,000 cm.	Less than 25%
	Areas of Medium Rainfall (100-200 cm): • Southern parts of Gujarat • East Tamil Nadu • Northeastern Peninsula covering Orissa, Jharkhand, Bihar, eastern Madhya Pradesh • Northern Ganga plain along the sub-Himalayas • Cachar Valley • Manipur.	
Between 50 -100 cm	**Areas of Low Rainfall (50-100cm)**: • Western Uttar Pradesh • Delhi • Haryana • Punjab • Jammu and Kashmir • Eastern Rajasthan • Gujarat • Deccan Plateau	25-50 %

Less than 50 cm	**Areas of Inadequate Rainfall (<50cm)**:
	• Parts of the Peninsula, especially in:
	  ○ Andhra Pradesh
	  ○ Karnataka
	  ○ Maharashtra
	• Ladakh
	• Western Rajasthan
		More than 50%

Notice that the regions of inadequate rainfall are also the regions with the highest variability of rainfall. The variability of rainfall has a significant role in the agricultural operations and other economic activities of a country. The areas showing high variability of rainfall have a chronic deficiency of water.

Climatic Regions of India

As discussed in the beginning, India has a monsoon type of climate with many regional variations. These variations represent the subtypes of the monsoon climate. It is on this basis that the climatic regions can be identified.

A climatic region has a homogeneous climatic condition which is the result of a combination of factors. Temperature and rainfall are two important elements which are considered to be decisive in all the schemes of climatic classification.

The classification of climate, however, is a complex exercise. There are different schemes of classification of climate. Two important ones are discussed here:

A) Koeppen's scheme of Climatic classification

It is based on monthly values of temperature and precipitation.

He identified five major climatic types and used letter symbols A, B, C, D and E to denote them:

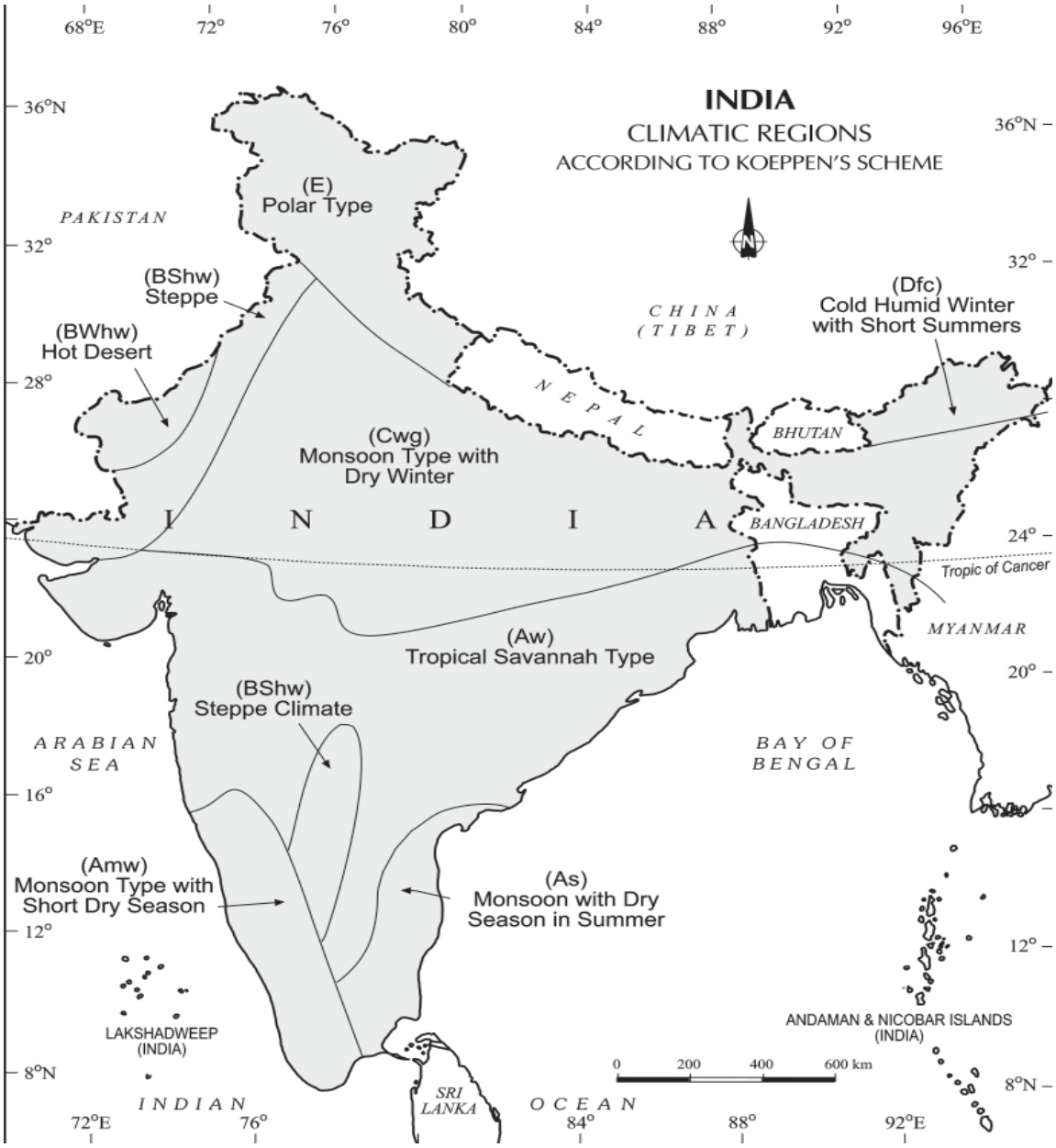
1. **Tropical climates (A)**: [where mean monthly temperature throughout the year >18°C]
2. **Dry climates (B)**: where precipitation is very low in comparison to temperature.
    - If dryness is less, it is semiarid (S);
    - If it is more, the climate is arid (W).
3. **Warm temperate climates (C):** where mean temperature of the coldest month is between 18°C and minus 3°C.
4. **Cool temperate climates (D)**: where mean temperature of the warmest month is over 10°C, and mean temperature of the coldest month is under minus 3°C.
5. **Ice climates (E)**, where mean temperature of the warmest month is less than 10°C.

These five types can be further subdivided into sub-types on the basis of seasonal variations in the distribution pattern of rainfall and temperature. Koppen used small letters such as m, w or h to define these sub-types:

- f (sufficient precipitation)
- m (rain forest despite a dry monsoon season),
- w (dry season in winter)
- h (dry and hot)
- c (less than four months with mean temperature over 10°C)
- g (Gangetic plain)

Accordingly, India can be divided into the following eight climatic regions:

Climatic Regions According to Koppen's Scheme	
Type of Climate	**Areas**
Amw - Monsoon with short dry season	West Coast of India, South of Goa
As - Monsoon with dry summer	Coromandel coast of Tamil Nadu
Aw - Tropical Savannah	Most of the Peninsular Plateaus, south of the Tropic of Cancer
BShw - Semi arid steppe climate	North western Gujarat, Some parts of West Rajasthan & Punjab
BWhw - Hot Desert	Extreme Western Rajasthan
Cwg - Monsoon with dry winter	Ganga plain, Eastern Rajasthan, northern M.P., most of NE India.
Dfc - Cold humid winter with short summer	Arunachal Pradesh
E - Polar type	Jammu and Kashmir, H.P. and Uttarakhand



Source: Civils Daily

B) Climatic Divisions by Stamp and Kendrew:

Kendrew and Stamp on the basis of the 18°C isotherm for the month of January (which almost follows the Tropic of Cancer) divided India into two major climatic regions:

1. Subtropical India (Continental)
2. Tropical

These two major climatic regions have been further divided into eleven regions as follows:

1. Subtropical India (Continental)
   - The Himalayan region (heavy rainfall)
   - The north-western region (moderate rainfall)
   - The arid low land (dry plains)
   - The region of moderate rainfall
   - The transitional zone
2. Tropical India
   - Region of very heavy rainfall
   - Region of heavy rainfall
   - Region of moderate rainfall
   - The Konkan Coast
   - The Malabar Coast
   - Tamil Nadu

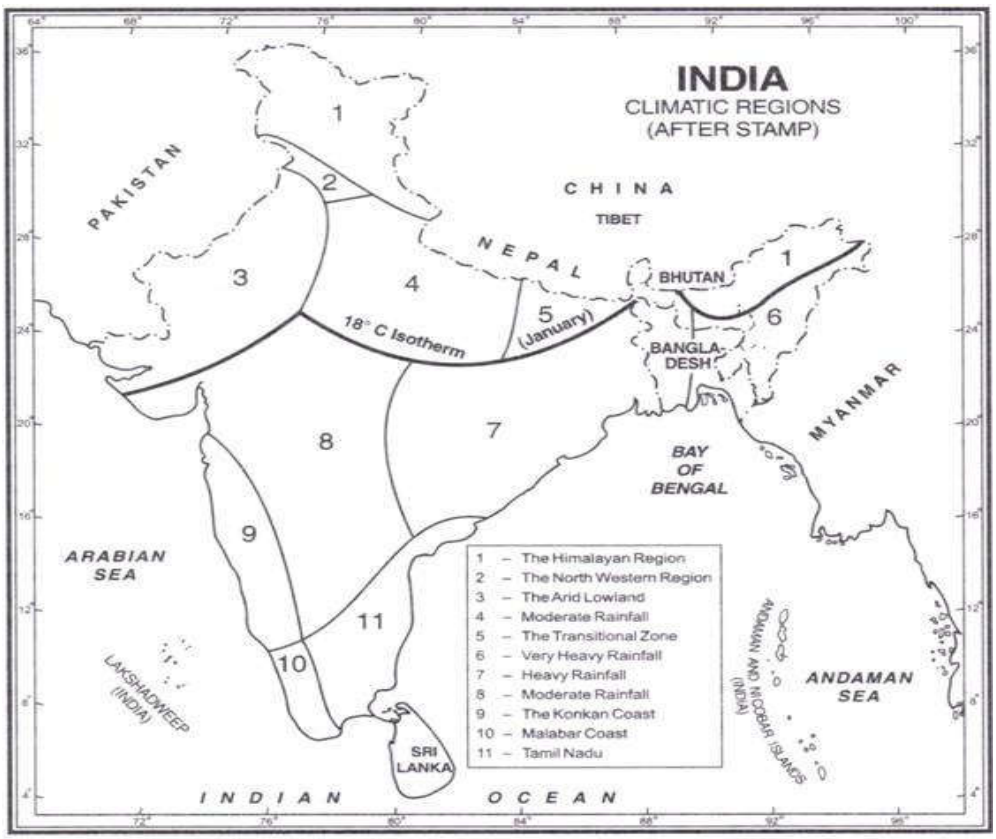


FIG. 5.26. Climatic Regions of India (After Stamp)

6. Natural Vegetation

Before we discuss the natural vegetation types found in India, let's get acquainted with some basic terms:

Flora, Vegetation and Forests:

Flora refers to plants of a particular region or period, listed as a species and considered as a group. Likewise, **fauna** refers to the animal life, considered collectively, of any given period, environment or region.

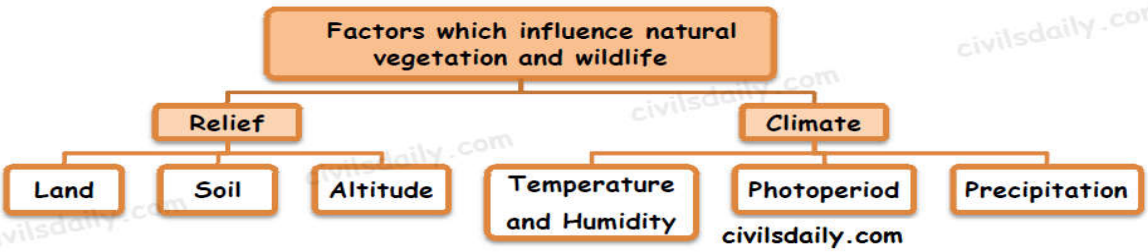
Vegetation, on the other hand, refers to the assemblage of plant species in a given environmental frame or ecological frame. It is broader than the term flora which refers to species composition. Further:

- **Natural vegetation** includes that part of the plant life which grows in wild without human aid and adapts to constraints of the natural environment in size, structure and requirements. Thus cultivated crops and fruit orchards form a part of the vegetation but not natural vegetation.
- That part of natural vegetation which has remained undisturbed by humans is referred to as **virgin vegetation**. It can be found in India in the inaccessible parts of the Himalayas, the Thar Desert and the Sunderbans. Elsewhere, human occupation has either transformed natural vegetation into cultivated vegetation or degraded the natural vegetation.
  - →The virgin vegetation, which is purely Indian, is known as **endemic** or indigenous species but that which has come from outside India is termed as **exotic.**

Forest: The term forest implies 'natural vegetation' of the area, existing from thousands of years and supporting a variety of biodiversity, forming a complex ecosystem.

Depending on the physical, geographical, climatic and ecological factors, there are different types of forests like evergreen forest (mainly composed of evergreen tree species i.e. species having leaves all throughout the year) and deciduous forest (mainly composed of deciduous tree species i.e. species which lose their leaves during particular months of the year). Each forest type forms a habitat for a specific community of animals that are adapted to live in it.

Various factors which influence the type and distribution of natural vegetation and wildlife:



- **Land**

The nature of land affects the natural vegetation directly and indirectly. E.g. the type of vegetation in the mountainous regions is different than that in the plateau and plain areas. The fertile land is generally devoted to agriculture, while the undulating and rough terrains are areas where grassland and woodlands develop and give shelter to a variety of wildlife.

- **Soil**

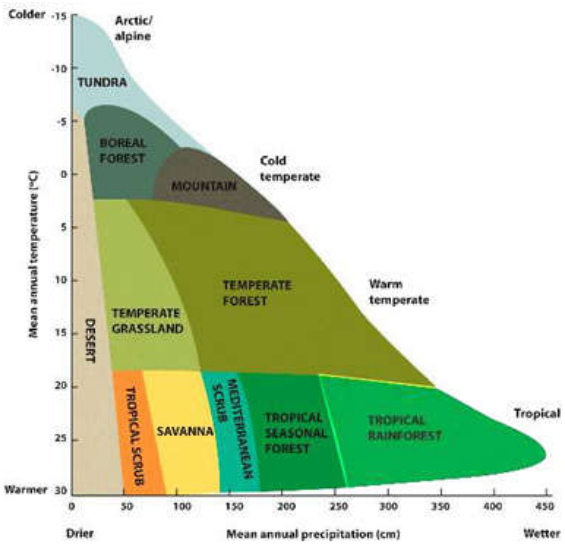
Different types of soils provide basis for different types of vegetation. The sandy soils of the desert support cactus and thorny bushes while wet, marshy, deltaic soils support mangroves and deltaic vegetation. The hill slopes with some depth of soil have conical trees.

- **Temperature and Humidity**

Temperature and humidity are the main factors which determine the character and extent of vegetation. E.g. an area with high temperature and high humidity supports evergreen forest, while an area with high temperature and low humidity supports thorny bushes (desert).

- **Precipitation**

Areas of heavy rainfall have more dense vegetation as compared to other areas of less rainfall. See the following diagram to understand the combined effect of temperature and annual precipitation on the vegetation type of an area:



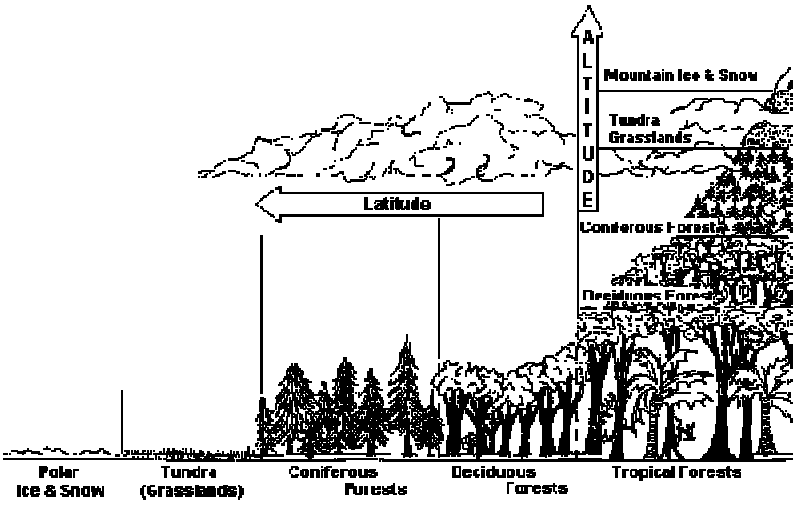
- **Photoperiod (Sunlight)**

Photoperiod, also called the light duration or day length, refers to the length of the light period as compared to the darkness within a day. The variation in photoperiod at different places is due to the differences in latitude, altitude, season and duration of the day. Due to longer duration of sunlight, trees grow faster in summer.

- **Altitude**

Increasing elevation causes a distribution of vegetation similar to that of increasing latitude. In general, 'altitude mimics latitude' and there occurs a close parallel between latitudinal and altitudinal zonation of climate and thus natural vegetation too. E.g. Mount Kenya in east Africa and Mount Chimborazo in Ecuador have their feet on the equator but their peaks are snow covered.

It was Alexander Von Humboldt who first recognised the relationship between vegetation and altitude.

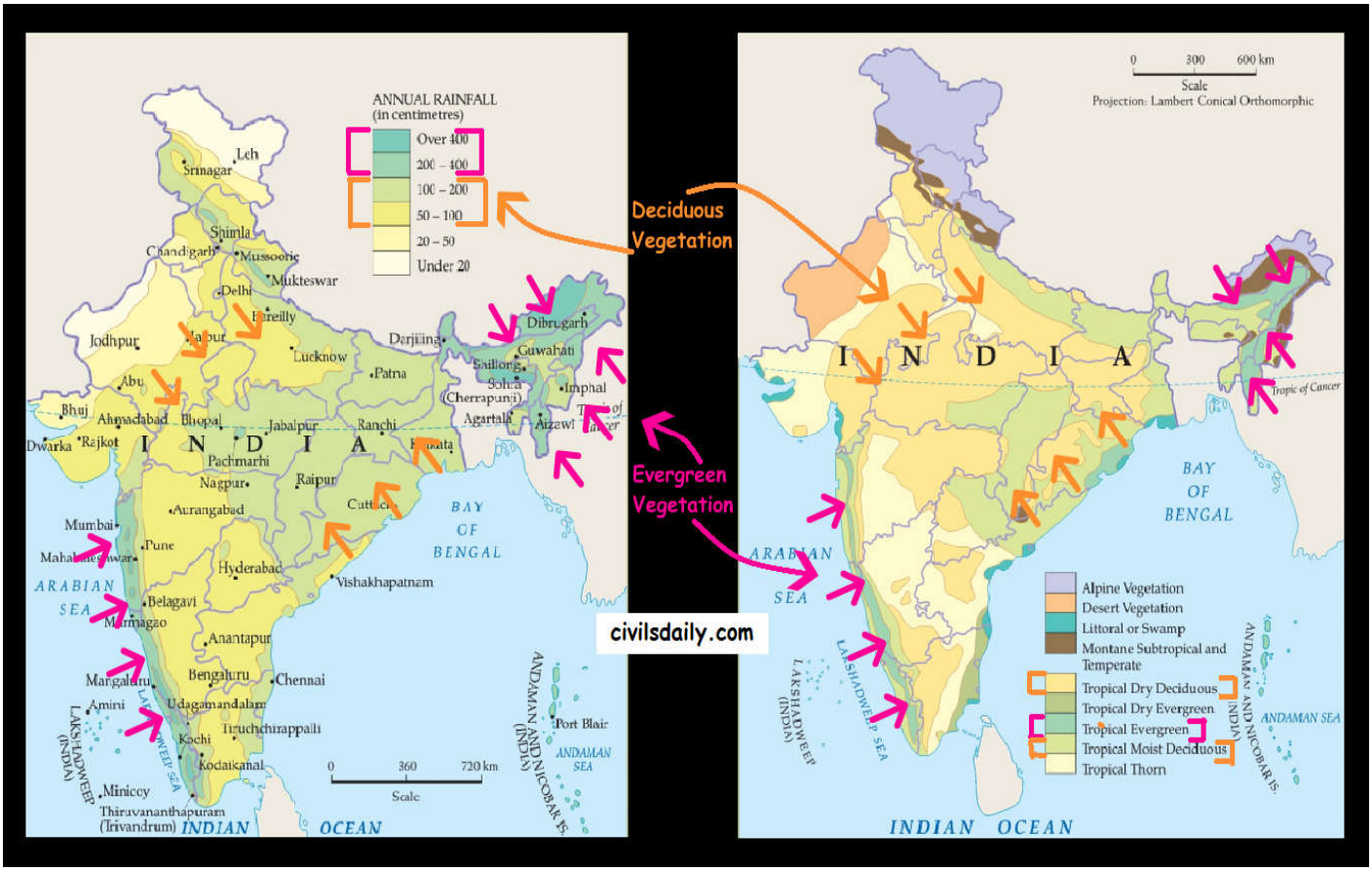


The Forest Types of India:

Since India is a land of various climatic regions, varied kinds of natural vegetation have developed here. Having said that, rainfall is more important than temperature (except in the Himalayas) in determining the vegetation distribution in India. The seasonal rainfall distribution/the length of the dry season also affect the vegetation distribution in an important way. In general, the following inter-relationship is observed in India:

Annual Rainfall	Vegetation Type
>200cm	Evergreen Rainforest
100-200 cm	Monsoon Forest/Deciduous civilsdaily.com
70-100 cm	Dry Deciduous/Tropical Savanna grading into open thorny scrub
<70 cm	Dry thorny scrub and low open bush merging into semi-desert/desert.

Observe this broad relationship as highlighted in the following map:



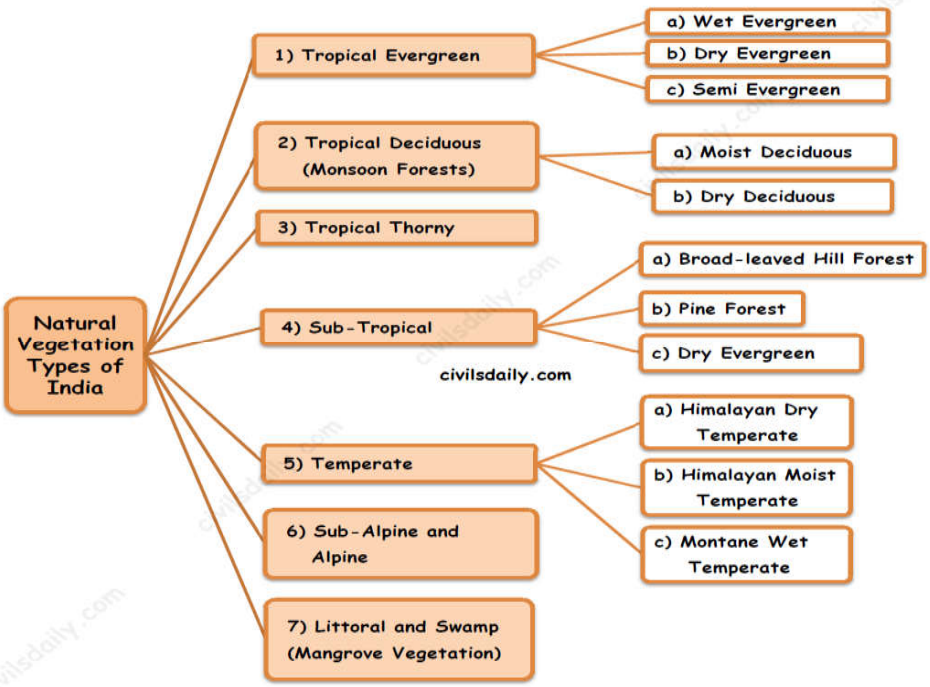
High rainfall areas (>200cm) —> **Evergreen forests** grow in the high rainfall areas of the Western Ghats, North –eastern India and the Andaman and Nicobar Islands. These forests grow in areas where the monsoon period lasts for several months. There is no definite time for trees to shed their leaves, flowering and fruition. As such these forests appear green all the year round, hence the name evergreen.

Moderate Rainfall Areas (70-200cm) —>**Deciduous forests** are found in regions with a moderate amount of seasonal rainfall that lasts for only a few months. Most of the forests in which Teak trees grow are of this type. The deciduous trees shed their leaves during the winter and hot summer months.

Low Rainfall areas/ Semi-arid areas (<70cm) —> **Thorn forests** are found in the semi-arid regions of India. The trees, which are sparsely distributed, are surrounded by open grassy areas.

Apart from these, mangroves forests grow along the coast, especially in the river deltas. These plants are uniquely adapted to be able to grow in a mix of saline and freshwater (will be taken up in detail in the following sections.)

Moving on, let's discuss the various natural vegetation types of India in detail:

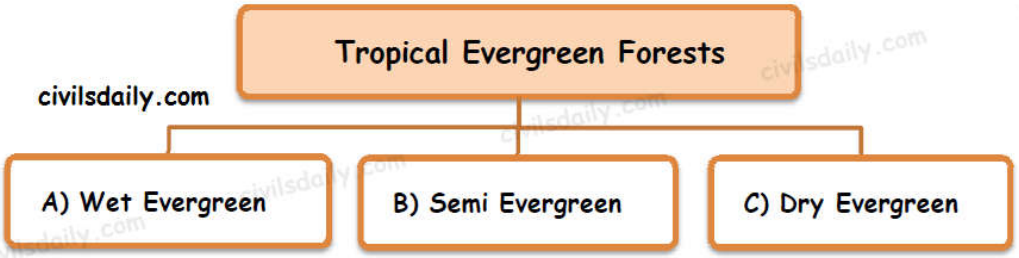


Natural Vegetation Types of India

1. Tropical Evergreen Forests

'Evergreen' because there is no definite time for trees to shed their leaves, flowering and fruition. As such these forests appear green all the year round.

The common animals found in these forests are elephants, monkey, lemur and deer. The one-horned rhinoceros are found in the jungles of Assam and West Bengal. Besides these animals, plenty of birds, bats, sloth, scorpions and snails are also found in these jungles.



A. Tropical Wet Evergreen Vegetation:

- **Distribution**: These forests are found on the western slope of the Western Ghats, upper Assam through Cachar and the Andaman and Nicobar Islands.
- **Climatic Conditions**: They are found in warm and humid areas with an annual precipitation of over 250 cm and a short dry season. The mean annual temperature here is above 22°C.
- **Characteristic Features**:
    1. Tropical evergreen forests are well stratified, with layers closer to the ground covered with shrubs and creepers, followed by short structured trees, further followed by tall variety of trees.
    2. In these forests, trees reach great heights up to 60 m or above.

Stratification a Trophical Forest

3. Bounded by semi-evergreen forests on drier margins.
4. Very rich biodiversity.

5. Timber produced in these forests is fine-grained and durable.

- **Important Species** found in these forests: Rosewood, Mahogony, Aini, Ebony, etc. Important species in Kerala are Mesa, White cedar, Jamun, Canes etc. Common species found in Assam forests are Gurjan, Jamun, Agar, Bamboo etc.

B. Tropical Semi-Evergreen Vegetation:

- **Distribution**: These forests occur in areas adjoining tropical wet evergreen, and form a transition between evergreen and moist deciduous forests. These forests occur on the western coast, in Assam, on the lower slopes of the eastern Himalayas and in the Andamans in the areas where precipitation and atmospheric humidity is slightly less than that in tropical evergreen vegetation area.
- **Characteristic Features**:
  1. Such forests have a mixture of evergreen and moist deciduous trees. The undergrowing climbers provide an evergreen character to these forests.
  2. The climbers are heavy, bamboos are less prevalent and epiphytes are abundant. [Epiphytes – The plants which depend on other plants for mechanical support (and not for nutrients). e.g. lichens, mosses, orchids etc.]
  3. The forest is dominated by a variety of large trees with a tendency to gregariousness (i.e. growing in groups that are close together)
  4. **Plant Adaptations in these areas:**
     1. Buttresses – Many large trees have huge ridges called buttresses near the base that can rise 30 feet high before blending into the trunk. Buttress roots provide extra stability and increase the surface area of a tree so that it can 'breathe in' more carbon dioxide and 'breathe out' more oxygen. Typically, they are found in nutrient-poor rainforest soils and do not penetrate to deeper layers. A buttress root system provides structural support.

Big trees with buttress roots in tropical evergreen forest, India, Andaman Islands, Havelock Island.

2. The bark is thicker and rougher, and the canopy is less dense than that in the previous type. Also, the canopies are not continuous and species richness is lower

- **Main species** are white cedar, hollock and kail. Important Species in Kerala are Aini, Laurel, Rosewood, thorny bamboo, etc. Important species of northeastern India are White Cedar, Indian Chestnut, Champa and Mango.

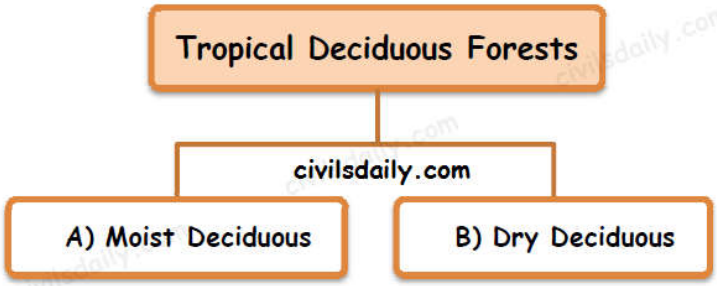
C. Tropical Dry Evergreen Vegetation:

- **Distribution**: This type is confined to the Tamil Nadu coast and the areas which receive rainfall of about 100cm mostly from the north-east monsoon/winter monsoon (October-December).
- The growth of evergreen forests in areas of such low rainfall arouses great botanical interest. This vegetation may be due to the seasonal distribution of rainfall (winter rainfall).
- **Characteristic Features of this vegetation**:
  1. Short height trees (<12m)
  2. A closed but low canopy of grasses and shrubs.
  3. No canopy layer differentiation.
  4. Bamboos are rare /absent.
- **Important Species** found in these forests: Neem, Jamun, Tamarind, Machkund, Khirni, Kokko, Ritha, Gamari Canes.
- Most of the land under these forests has been cleared for agriculture or casuarinas plantations (Eucalyptus tree plantations)

2. Tropical Deciduous Vegetation

Also called the monsoon forests, these are the most widespread forests in India. The term 'Deciduous' refers to the ability of some plants to lose their leaves annually. They are spread over regions which receive rainfall between 70 and 200 cm.

In these forests, the common animals found are lion, tiger, pig, deer and elephant. A huge variety of birds, lizards, snakes, and tortoises are also found here. [Currently, India is the only country on Earth confirmed to have both lions and tigers in its wilderness.]



On the basis of the availability of water, these forests are further divided into:

A. Tropical Moist Deciduous Vegetation

- **Climatic Conditions:** It thrives in areas having of moderate rainfall of 150-200 cm with a dry season of 4 to 6 months, a mean annual temperature of 26°C to 27°C and an average relative humidity of 60-80%. On the wetter margins, it has a transition to the tropical Semi-Evergreen Vegetation, while on the drier margins to the Tropical Dry Deciduous.
- **Distribution:** It is found on the eastern slopes of the Western Ghats, eastern coastal plains, eastern plateaus, Himalayan foothills and in some parts of the Satluj-Ganga plains.
- **Characteristic Features:**
    1. The trees shed their leaves during the dry season.
    2. These forests are usually 2 to 3 layered.
    3. Dense undergrowth

- **Important Species:** The common trees are Sal, Teak, Sandalwood, Ajun, Ebony, Shisham, Hurra, Mahua, Amla, Semul, Mulberry and Kusum.

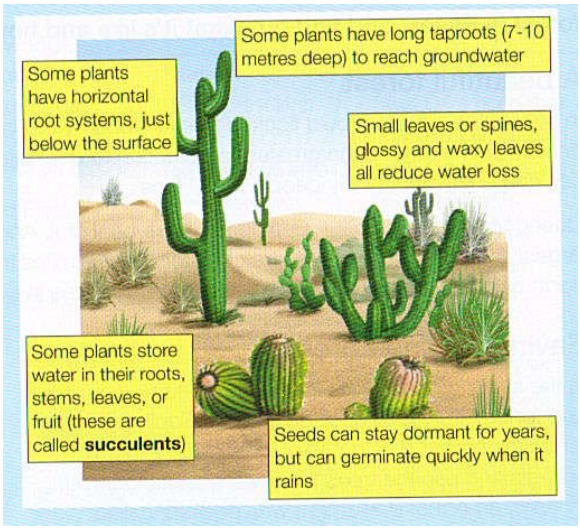
B. Tropical Dry Deciduous Vegetation

- **Climatic Conditions:** The dry deciduous trees grow in areas where rainfall is less than 150cm and the dry period is relatively long. On the wetter margins, it has a transition to the moist deciduous, while on the drier margins to thorn forests.
- **Distribution:** It is found in Eastern Rajasthan, Kathiawar, rain-shadow areas of the Deccan plateau, central India and Punjab.

- **Characteristic Features:**
    1. These forests consist of trees less than 25m high, with a light canopy consisting of deciduous trees. The undergrowth is shrubby and grassy.
    2. As the hot dry season begins (March-May), the trees shed their leaves completely and the forest appears like vast grassland with naked trees all around.
    3. In the higher rainfall regions of the Peninsular plateau and the northern Indian plain, these forests have a parkland landscape i.e. trees are more stunted and widely spaced and are interspersed with patches of grass.
    4. In the western and southern part of Rajasthan, vegetation cover is very scanty due to low rainfall and overgrazing.
- **Important Species:** Common plants are Teak, Sal, Laurel, Palas, Khair, Tendu, Amaltas, Bel, Axlewood etc.

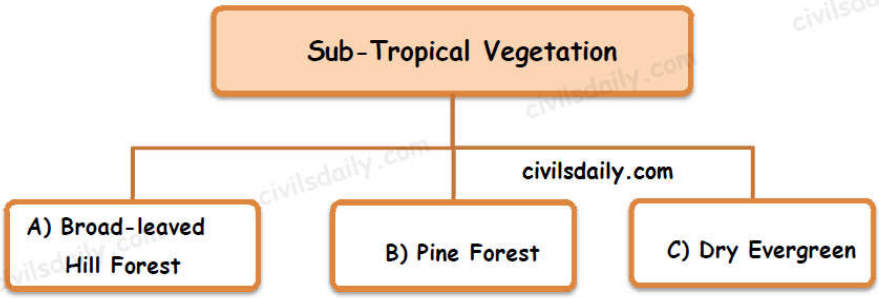
3. Tropical Thorny Vegetation

- **Climatic Conditions:** In areas with 50-70cm of rainfall
- **Distribution:** It is found in south-western Punjab, western Haryana, western Uttar Pradesh, central and eastern Rajasthan, western Madhya Pradesh, and Kachchh and, neighbouring parts of Saurashtra, leeward areas of Sahyadris.
- **Characteristic Features:**
    1. Plant life is highly specialized to adapt to the coarse and dry conditions in this area, with long roots, small leaves, stems that store water, and prickly spines that discourage animals from touching or eating them.
    2. The natural vegetation consists of open stunted (trees with 6-9m height) forest breaking down into xerophytic bush and western Rajasthan grading into deserts.
    3. In these forests, plants remain leafless for the most part of the year and give an expression of scrub vegetation.
    4. Plant adaptations:
        - ❖ These xerophytic plants combat drought with certain devices of water preservation like partial or complete replacement of leaves by thorns, waxy leaves, water storing cells, hair on the stalk etc.
        - ❖ Tussocky grass grows up to a height of 2 m as the undergrowth.
        - ❖ Trees are scattered and have long roots penetrating deep into the soil in order to get moisture.
        - ❖ The stems are succulent to conserve water.
        - ❖ Leaves are mostly thick and small to minimize evaporation.



- **Important Species:** Common species are Babul, Acacia, Kokko, Khair, Khajuri, Ber, Neem, Khejri, Palas, etc.
- In these forests, the **common animals** are rats, mice, rabbits, fox, wolf, tiger, lion, wild ass, horses and camels.

4. Subtropical Vegetation



A. Sub-tropical Broad-leaved Hill Forests:

- **Distribution:** These forests occur on the lower slopes of the Himalaya in Bengal and Assam and on other hill ranges such as Khasi, Nilgiri, Mahabaleshwar, Pachmarhi, Amarkantak and Parasnath.
- **Important Species:** In the eastern Himalayas, Oak, Chestnut, Ash, Birch, Pine are common species.

B. Sub-tropical Pine Forest

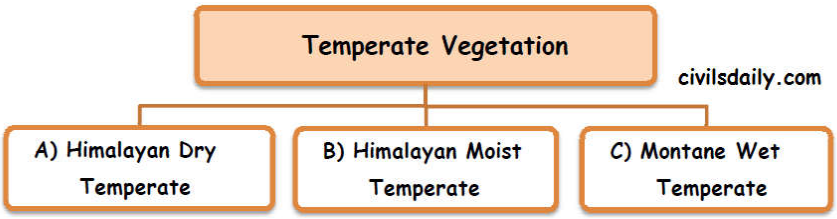
- **Distribution:** Subtropical Chir pine forest occurs throughout the central and western Himalaya, and Khasi pine forest occurs in Khasi hills.

- **Important Species:** In the western Himalayas Chir Pine is the most important tree while Oak occurs in the wetter areas. In drier areas of Kashmir (rainfall 50-100cm) wild Olives are common with varieties of scrub.
- **Chief Characteristics**:
    1. These forests are almost pure throughout their zone of distribution.
    2. The under storey is also not pronounced.

C. Sub-tropical Dry Evergreen Forest

- **Distribution:** These forests occur in areas with low rainfall and consist of xerophytic, thorny and small-leaved evergreen species. Such forests are localized in the north-west corner of the country.

5. Temperate Vegetation



A. Himalayan Dry Temperate Vegetation

- **Distribution:** It is found in the inner dry ranges of the western Himalayas.
- **Characteristic Features:** It is predominantly a coniferous forest with xerophytic scrubs. Epiphytes and climbers are rare. [Coniferous trees are tall, straight with narrow needle like leaves. Most of the coniferous trees are evergreen but some like Larch are deciduous in nature]
- **Important Species** are Chilgoza, Deodar, Oak, Maple, Ash, Olive etc.

B. Himalayan Moist Temperate Vegetation

- **Distribution:** In the western Himalayas between 1500m and 3000m.
- **Characteristic Features:** The trees are 30 to 50m tall and undergrowth is mostly evergreen. Mosses and ferns grow freely on trees.
- **Important Species:** Deodar, Spruce, Maple, Walnut, Poplar, Cedar, Chestnut, Birch, Oak etc.

C. Montane Wet Temperate Vegetation

- **Distribution:** In the eastern Himalayas, evergreen wet temperate forests occur between 1800m and 2700m of altitude. Nilgiris, the Annamalai and the Palni hills of south India also have this kind of forests above 1500m of altitude. The trees there are shorter, and the undergrowth is denser with abundance of epiphytes, mosses and ferns.

- **Characteristic Features:** Rainfall is high, temperature is moderate in summer, and winter is cold. Rate of evaporation is not high. So trees do not shed their leaves annually, at least not at the same time.
- **Important Species:** Oak, Poplar, Elm, Laurel, Maple, Birch, Alder, Magnolia

6. Sub-Alpine and Alpine Vegetation

- **Distribution:** It occurs above 2700m of altitude in the eastern Himalayas and above 3000m in the western Himalayas.
- **Important Species:** It is a dense scrubby forest of Silver Fur, Juniper, Pine, Birch and Rhododendron.
- **Characteristic Features:**
    1. The alpine forests give way to alpine grasslands through shrubs and scrub. These extend upwards up to the snowline.
    2. **Bugyals**: Bugyals are high altitude alpine grasslands or meadows in Uttaranchal (at an elevation between 3400m and 4000m). These are referred to as 'nature's own gardens'. The topography of the terrain is either flat or sloped. The surface of these bugyals is covered with natural green grass and seasonal flowers. They are used by tribal herdsmen to graze their cattle. During the winter season the alpine meadows remain snow-covered. During summer months, the Bugyals present a riot of beautiful flowers and grass. Bugyals have a very fragile ecosystem. Some examples of Bugyals:
        - Auli (near Joshimath) – A premier ski range is located here.
        - Gorso
        - Kwanri Bugyal
        - Bedni
        - Panwali and Kush Kalyan
        - Dayara
        - Munsiyari Bugyal


Auli Bugyal during summers

Auli Bugyal during winters

7. Littoral and Swamp Vegetation (Mangrove Vegetation/ Tidal Forests)

- **Distribution:** In the tidal deltas of Ganga, Mahanadi, Godavari and Krishna rivers, evergreen mangrove vegetation thrives. These areas have rainfall of more than 200cm.
- **Important Tree Species:** Sundari, Agar, Bhendi, Keora, Nipa
- **Important Animal Species**: Turtles, crocodiles, gharials and snakes are the common animals found in these forests. Royal Bengal Tiger is found in the tidal forests of Ganga delta.
- **Characteristic Features:**
  1. The trees are mainly evergreen. Typically they produce tangled webs of arching roots that are exposed during low tides.
  2. This vegetation is an adaptation to two conditions:
     - High water salinity
     - Flooded at regular intervals
  3. Prominent among these adaptations are the presence of stilt roots, buttress, pneumatophores etc.
     - **Stilt roots (also called prop roots) -** Stilt roots outgrow the trunk of the mangrove, branches or already existing stilt roots. As soon as stilt roots reach the ground the tip of the stilt root develops an underground root system with which it connects the stilt root into the ground and then develops one or more further stilt roots which grow arcuately into the air to again run into the ground to develop an underground root system, this process repeats several times.

- **Buttress Roots** – Buttress roots, developed by many trees concerning mangroves, provide stability to huge trees. The buttress roots can grow up to 10 meters in height. Buttress roots, also called buttresses do not continue their growth underground as they do above; underground buttresses develop a huge amount of small roots that grow in the soil under the buttress root.

- **Pneumatophores** – Because of waterlogged conditions, the roots are deprived of oxygen during high tides. Some mangrove roots extend vertically above the ground. These specialised roots are known as pneumatophores. These have pores which enable the trees to breathe when other roots are submerged under water during high tide.

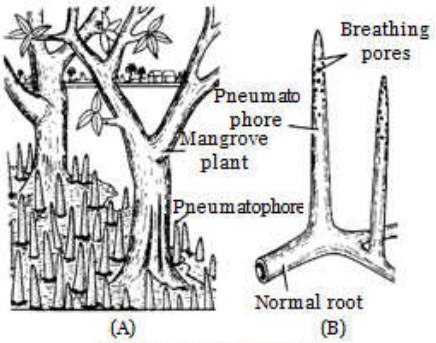
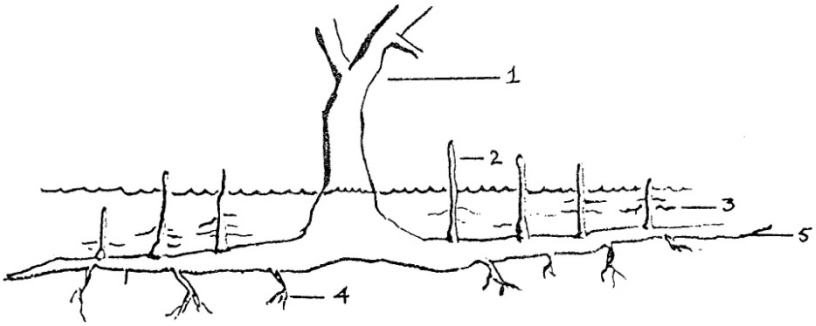


Fig : Pneumatophores :
(A) Plants showing pneumatophores
(B) Part of pneumatophores showing breathing pores

Sunderbans breathing roots

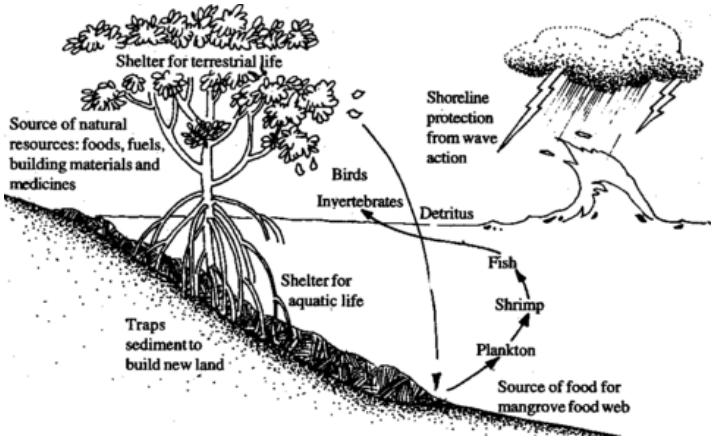


Simplified diagram of the mature mangrove root system.

1. Main trunk
2. Pneumatophors
3. Nutritive roots
4. Support roots
5. Cable roots

Fig. 5

4. Mangrove shrubs, known best for a thriving aquatic life nurtured within their mesh of stilt-roots also serve a vital socio-economic function. They act as "green shields" buffering the coastline against sea erosion, and the potentially devastating impacts of cyclones and tsunami.
5. Mangroves support livelihood, essentially aquaculture, they supply medicinal plants, and fuel wood and construction materials. And in terms of ecological services, they stabilise shorelines, are nurseries for fish breeding and filter heavy metals.



Note:

A study in November 2014 found mangrove patches in Karnataka. The Forest Survey of India missed recording these mangrove patches earlier as they were not large. According to the study, Karnataka has 300 hectares of mangrove forests spread over 3 coastal districts and a vibrant saline water ecosystem generally associated with India's east coast. At the confluence of 4 rivers – Aghanashini, Gangavali, Sharavati and Venkatpura; and the Arabian Sea, is a long stretch of dense and tall mangrove vegetation locally known as Kandla or Sundar (Sundar is a well-known species of trees in mangrove forests after which the Sunderbans have been named). The study notes that while mangroves have been declining in several parts of the world from timber harvesting and pollution, these forests in Karnataka have in fact grown spatially over the last two decades.

Grasslands in India:

Owing to a short monsoon season followed by a long hot dry season, grasslands equivalent to Steppe/Pampas/Savanna are absent in India. The closed deciduous forest grades into thorny forest without an intermediate park like stage, and there is no steppe type of Grassland between the woodland and the desert.

But locally available types of grassland are:

1. Hilly/Upland Grassland:
    1. Himalayas (generally above 1000m height)
    2. Deccan Plateau Hills (Western Ghats in Karnataka where forests have been cleared)
    3. Nilgiris have extensive grassy slopes (grass is often found interspersed with small isolated 'shola' forests*).
2. Low Lands: in the plains of Punjab, Haryana, UP, Assam and Bihar.
3. Riverine Grasses: These are found along the banks of the rivers which provide grazing facilities to cattle especially the bhabar pastures in northern India.

***'Sholas' are the mixed dense forests of tropical evergreen and temperate evergreen rainforest species in the Nilgiri Hills. The patches of shola forests are found mainly in valleys and are usually separated from one another by undulating montane grassland. The shola and grassland together form the shola-grassland complex or mosaic.**

Now that we are done with the vegetation types of India, expand the following image for a quick revision!

Venkateswarlu Nagineni

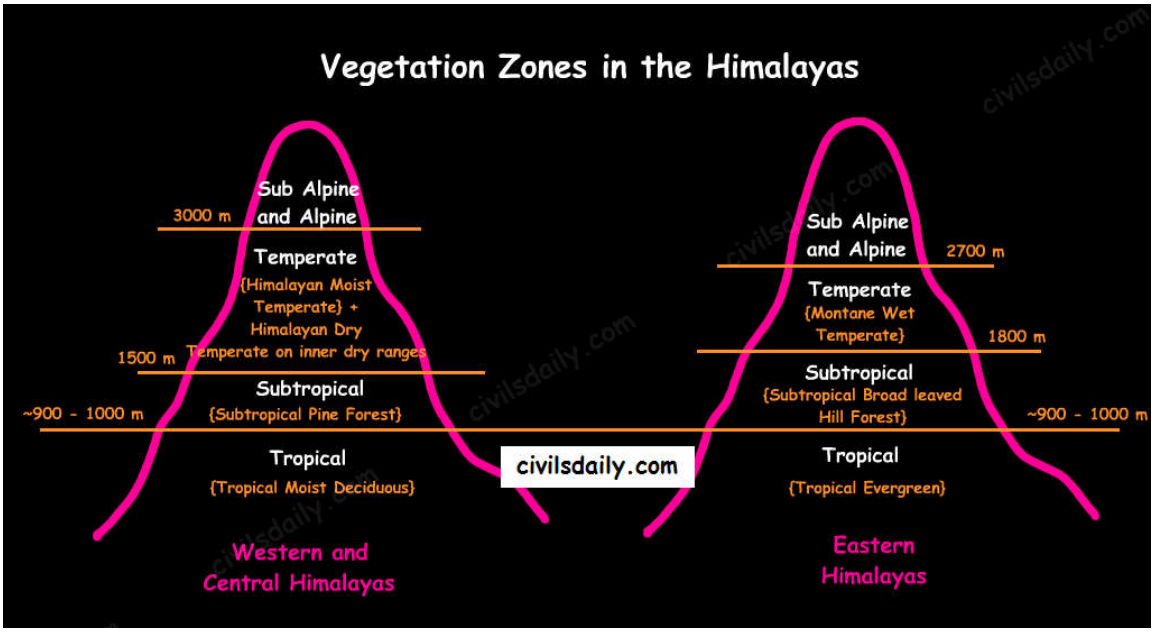
Vegetation Type		Climatic Conditions	Distribution	Characteristic Features	Important Plants/Trees	Important Animals
Tropical Evergreen	Wet Evergreen	Precipitation > 250 cm Mean annual temp. > 22°C Short Dry Season	The western slope of the Western Ghats, upper Assam and the Andaman and Nicobar Islands	i. Well stratified with trees reaching great heights ii. Very rich biodiversity iii. Fine-grained and durable timber	Rosewood, Mahogony, Aini, Ebony, etc. Kerala - Mesa, White cedar, Jamun, Canes etc. Assam - Gurjan, Jamun, Agar, Bamboo etc	Elephants, Monkeys, Lemur, Deer, One horned rhinoceros (in the jungles of Assam and West Bengal), plenty of birds, bats, sloth, scorpions and snails.
	Dry Evergreen	Atmospheric Humidity slightly less than the above category.	Adjoining tropical wet evergreen - the western coast, Assom, the lower slopes of the eastern Himalayas and the Andamans	i. Mixture of evergreen and moist deciduous trees. ii. Heavy climbers, abundant epiphytes iii. Trees with buttress roots iv. Thicker and rougher bark, less dense canopy, lower species richness than the category above.	Hollock and Kail. Kerala - Aini, Laurel, Rosewood, thorny bamboo. Assam - White Cedar, Indian Chestnut, Champa and Mango	
	Semi Evergreen	Areas which receive rainfall of about 100cm mostly from the north-east monsoon/winter monsoon.	Tamil Nadu coast and adjoining areas	i. Short height trees (<12m) ii. Closed but low canopy of grasses and shrubs, no canopy layer differentiation iii. Bamboos are rare /absent.	Neem, Jamun, Tamarind, Mochkund, Khirni, Kokko, Ritha, Gamari Canes.	
Tropical Deciduous	Moist Deciduous	Rainfall - 150 to 200 cm with a dry season of 4 to 6 months Temp. - 26°C to 27°C Average relative humidity of 60-80%.	The eastern slopes of the Western Ghats, eastern coastal plains, eastern plateaus, Himalayan foothills and some parts of the Satluj-Ganga plains.	i. Trees shed their leaves during the dry season. ii. Forests are usually 2 to 3 layered. iii. Dense undergrowth	Sal, Teak, Sandalwood, Ajun, Ebony, Shisham, Hurra, Mahua, Amla, Semul, Mulberry and Kusum.	Lions, Tigers, Pigs, Deers and Elephants. + a huge variety of birds, lizards, snakes, and tortoises
	Dry Deciduous	Rainfall - < 150cm A relatively long dry period	Eastern Rajasthan, Kathiawar, rain-shadow areas of the Deccan plateau, central India and Punjab.	i. Deciduous trees - less than 25m high trees with a light canopy ii. Shrubby and grassy undergrowth. iii. Trees shed their leaves completely in the dry season iv. Parkland landscape in peninsular plateau and the northern Indian plain, v. Scant vegetation cover in the western and southern part of Rajasthan	Teak, Sal, Laurel, Palas, Khair, Tendu, Amaltas, Bel, Axlewood etc.	
Tropical Thorny		Rainfall - 50 to 70cm	South-western Punjab, western Haryana, western Uttar Pradesh, central and eastern Rajasthan, western Madhya Pradesh, Kachchhand, neighbouring parts of Saurashtra, leeward areas of Sahyadris.	i. Plant adaptations - long roots, small leaves, stems that store water, and prickly spines that discourage animals from touching or eating them, , waxy leaves, water storing cells, hair on the stalk etc. ii. Open stunted (trees with 6-9m height) forest breaking down into xerophytic bush and western Rajasthan grading into deserts. iii. Tussocky grass	Babul, Acacia, Kokko, Khair, Khajuri, Ber, Neem, Khejri, Palas, etc.	Rats, Mice, Rabbits, Fox, Wolf, Tiger, Lion, Wild Ass, Horses and Camels.
Sub-Tropical	Broad-leaved Hill Forest		Lower slopes of the Himalayas in Bengal and Assam Hill ranges of Khasi, Nilgiri, Mahabaleshwar, Pachmarhi, Amarkantak and Parasnath.		Oak, Chestnut, Ash, Birch, Pine	
	Pine Forest		Central and western Himalayas Khasi hills.	i. Almost pure forests. ii. The understorey is not pronounced.	Western Himalayas - Chir Pine, Oak occurs in the wetter areas. Wild Olives & varieties of scrub in drier areas of Kashmir (rainfall 50-100cm)	
	Dry Evergreen	Rainfall < less than 70cm	Northwest corner of India	xerophytic, thorny and small-leaved evergreen species		
Temperate	Himalayan Dry Temperate		The inner dry ranges of the western Himalayas	i. Predominantly a coniferous forest with xerophytic scrubs. ii. Epiphytes and climbers are rare.	Chilgoza, Deodar, Oak, Maple, Ash, Olive etc.	
	Himalayan Moist Temperate		In the western Himalayas between 1500m and 3000m	i. Trees - 30 to 50m tall ii. Undergrowth - mostly evergreen. iii. Mosses and ferns grow freely on trees.	Deodar, Spruce, Maple, Walnut, Poplar, Cedar, Chestnut, Birch, Oak	
	Montane Wet Temperate		The eastern Himalayas - between 1800m and 2700m of altitude. Nilgiris, Annamalai and Palni hills - above 1500m of altitude.	i. Trees do not shed their leaves annually, at least not at the same time.	: Oak, Poplar, Elm, Laurel, Maple, Birch, Alder, Magnolia	Red Panda, Kashmir Stag, Yak,
Sub-Alpine and Alpine			Above 2700m of altitude in the eastern Himalayas Above 3000m in the western Himalayas.	i. The alpine forests give way to alpine grasslands through shrubs and scrub. These extend upwards up to the snowline. ii. Bugyals	Silver Fur, Juniper, Pine, Birch and Rhododendron.	Snow Leopard etc.
Littoral and Swamp			Tidal deltas of Ganga, Mahanadi, Godavari and Krishna rivers	i. The trees are mainly evergreen ii. Plant adaptations - stilt roots, buttresses, pneumatophores	Sundari, Agar, Bhendi, Keora, Nipa	Turtles, Crocodiles, Gharials and Snakes. Royal Bengal Tiger in the Ganga delta region.

Indian Geography

Source: Civils Daily

Vegetation in the Himalayas:

In the preceding discussion, Himalayas were mentioned in a number of vegetation types. In case you are finding it difficult to piece all those together, look at the following diagram. It would help in getting a clearer picture:



Vegetation Zones in the Himalayas.

The Himalayan ranges show a succession of vegetation from the tropical to the tundra, which changes with altitude. When we look at the vegetational zones, the eastern Himalayas are similar to the western Himalayas.

But on the whole, the eastern Himalayas have more tropical elements, a greater variety of Oaks and Rhododendrons and less of conifers than the western Himalayas.

Some other differences are:

- The higher rainfall and warmer conditions in this part of the Himalayas.
- Also, the tree line and the snow line are higher in the eastern Himalayas than the corresponding lines in the western Himalayas.
- Species diversity and vegetation density are also higher in the East.

Also, the southern slopes of the Himalayas carry a thicker vegetation cover because of relatively higher precipitation than the drier north-facing slopes.

Some other ways of classifying forests:

1. Classification according to composition:

- **Coniferous** Forests: These are temperate forests occupying about 6.50% of the total forest area of the country. These are confined to the Himalayan ranges and provide soft wood timber.
- **Broad-Leaved** Forests: These are tropical and subtropical monsoon forests. These are widely spread and cover 94% of the total forest area of the country. These are found in the plains, plateaus and mountainous areas of the country. Sal, Teak and Bamboo are important varieties.

2. Legal or Administrative Classification:

Broadly speaking, reserved, protected and unclassed are the three major legal classes of forest in India. A legal notification in a government gazette under Indian Forest Act creates or defines the boundaries of "reserved and "protected" forests in India. These forests by definition are owned by government. The rest of forests areas or waste land or any other land "recorded" in land records as "forest" but not notified in government gazette as "reserved" or "protected" forests under Indian Forest Act, are called unclassed forests. The status of their ownership and control varies among various States in India.

- **Reserved Forests:**
    - These forests are under the direct supervision of the government and no public entry is allowed for the collection of timber or grazing of cattle.
    - About 53 % of total forest area falls in this category.
    - Reserved forests are regarded as the most valuable as far as the conservation of forests and wildlife is concerned.
    - In such forests, most of the activities are prohibited unless allowed.
- **Protected Forests:**
    - These forests are looked after by the government but the local people are allowed to collect fuel wood/timber and graze their cattle without causing serious damage to the forests.
    - These occupy 29% of the total forest area of the country.
    - In such forests, most of the activities are allowed unless prohibited.

- **Unclassed/Unclassified Forests:**
    - There is no restriction on cutting of trees and cattle grazing.
    - These occupy 18% of the total forest area of the country.
    - These are the other forests and wastelands belonging to both government and private individuals and communities.
    - All north-eastern states and parts of Gujarat have a very high percentage of their forests as unclassed forests managed by local communities.

Reserved and protected forests are referred to as **permanent forest estates** because they are maintained for the purpose of producing timber and other forest produce, and for protective reasons

3. The **Forest Survey of India** classifies forest cover in 4 classes:

1. **Very Dense forest**: All lands with tree cover (including mangrove cover) of canopy density of 70% and above.
2. **Moderately dense forest**: All lands with tree cover (including mangrove cover) of canopy density between 40% and 70%.
3. **Open forests**: All lands with tree cover (including mangrove cover) of canopy density between 10% and 40%.
4. **Scrubs**: All forest lands with poor tree growth mainly of small or stunted trees having canopy density less than 10%

The moderately dense and very dense forests are called **Prime forests**. Non-Forests are the lands not included in any of the above classes.

Source – India State of Forest Report (ISFR) 2015

Forest Cover in India:

According to the India State of Forest Report 2015, forests cover 21.34% of the total geographical area of the country .

Some other facts:

- Out of the total forest cover, the maximum share is of Moderate Dense Forests, followed by Open Forests.
- Also, Madhya Pradesh has the largest total forest cover, followed by Arunachal Pradesh and Chhattisgarh.
- Mizoram, with 88.93 % of forest cover has the highest forest cover in percentage terms, followed by Lakshadweep.

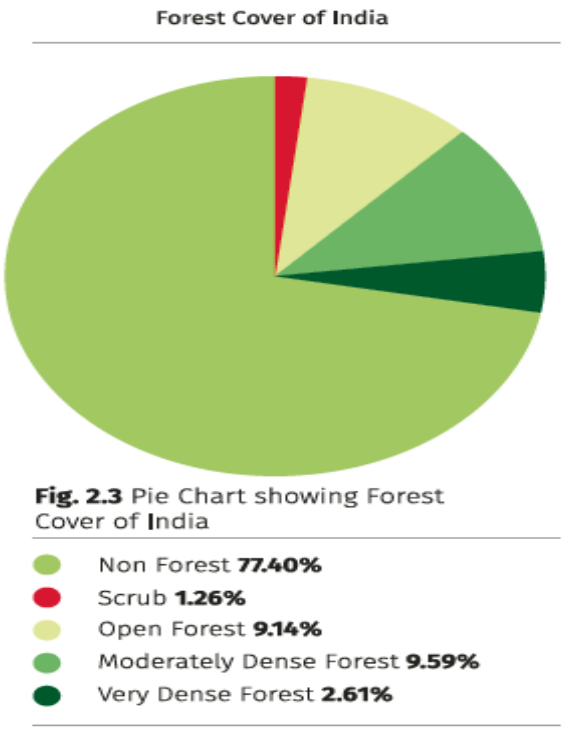
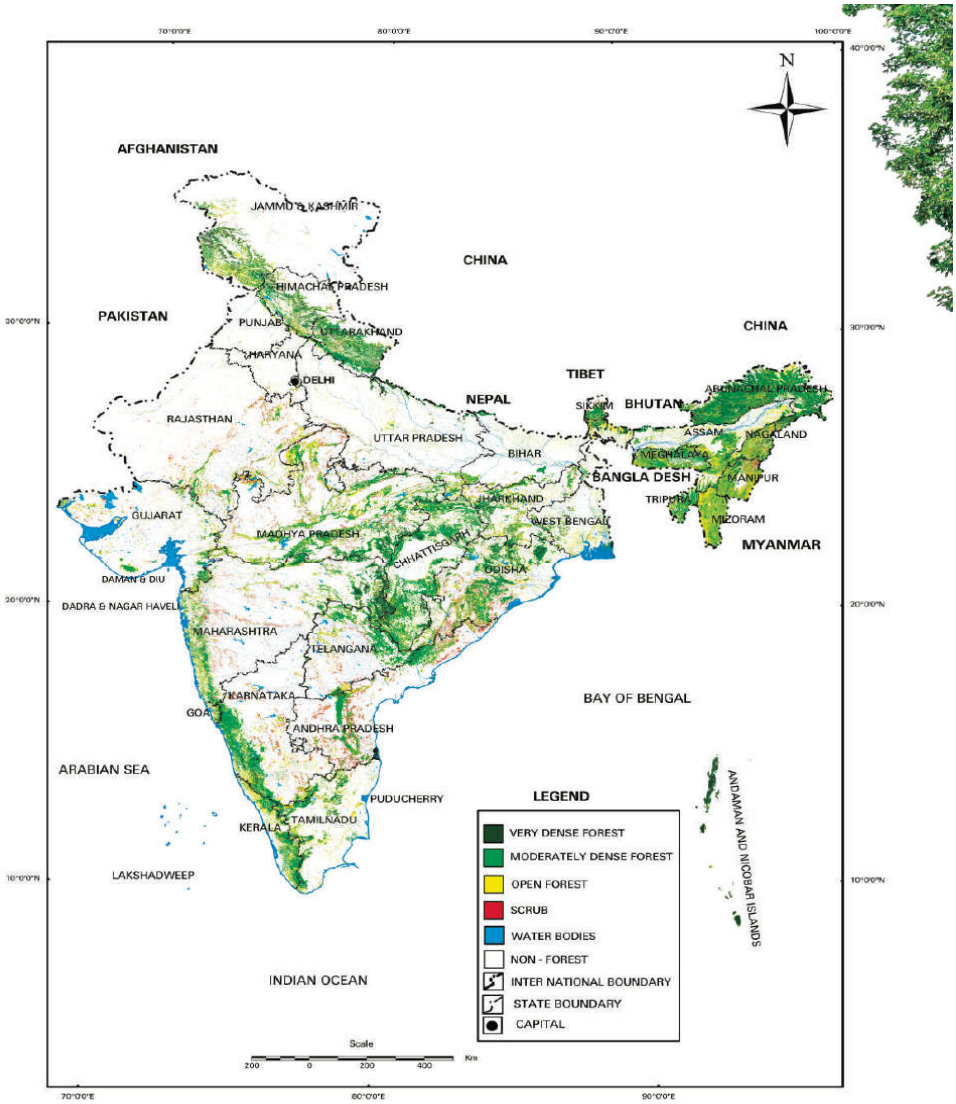


Fig. 2.3 Pie Chart showing Forest Cover of India

Source – India State of Forest Report (ISFR) 2015



The Forest Cover map of India. Source: India State of Forest Report (ISFR) 2015

The Problems of Indian Forestry:

The specific problems of the Indian Forestry are the following:

1. Low Forest Cover

The forest cover in India is only 21.34% against the world average of about 35% and the stipulated 33% under the National Forest Policy 1952. The states of Punjab, Haryana and Rajasthan have less than 5% of their areas under forests. Forest area is decreasing due to deforestation on account of:

- Growing demand for agricultural land.
- Urbanisation and industrialisation
- Construction of multipurpose projects
- Commercial activities like mining, quarrying, oil extraction, orchard development etc.
- Shifting cultivation – Increasing pressure of population has reduced the jhum cycle to only 5 years in many parts of Nagaland, Meghalaya, Mizoram, Tripura and Manipur. Consequently, the forests do not have sufficient time to regenerate.
- Overgrazing by cattle
- Transhumance i.e. seasonal migration by nomadic tribes up and down the mountains.

2. Uneconomic utilisation of forests:

- Most of the forests are not gregarious i.e. usable plants not growing close enough. This creates a problem in their exploitation.
- 40% of the total forest area is inaccessible.
- Lumbering, transport and sawing of timber is still done by primitive techniques.
- Lack of scientific techniques of growing forests as in Canada, Russia. Only natural growth of forests takes place in India

3. Forest Fires – Natural and manmade.

4. Plant diseases, pests, insects

Conservation of Forests – Afforestation Schemes and Other Initiatives

Conservation of Forests:

1. The National Forest Policy:

- **The National Forest Policy 1952** aimed at bringing one-third of the total land area with 65% in hilly and 25% in plains under the forest cover. It suggested the extension of tree lands on river/canal banks, roads, railways, cultivable waste and degraded lands.

- A new forest policy was adopted in **1988** the main emphasis of which was on the protection, conservation, regeneration, and development of forests.

2. Social Forestry:

- The term, social forestry, was first used in India in 1976 by The National Commission on Agriculture. It was then that India embarked upon a social forestry project with the **objective** of taking the pressure off the traditional forests by the plantation of fuel wood, fodder, timber and grasses on unused and fallow land.
- What social forestry **means** – Social Forestry refers to the forests (trees) planted by the people of a society. It has been defined as 'the forestry of the people, for the people, by the people'.

Although a wide range of activities are included in social forestry, these mainly have the following components:

1. **Agro Forestry** – Encouraging Farmers to plant trees on their farms.
2. **Extension Forestry** – Woodlots planted by forest departments for the needs of the community especially along roads, canals, railways, and other public lands
3. **Community Forestry** – Trees planted by the community themselves, on community lands, to be shared equally by them.
4. **Reforestation or rehabilitation of degraded forest areas**.

The social forestry projects, however, failed because:

- They did not involve women who were the main beneficiaries.
- Market-oriented trees were planted. Thus communities and farmers saw it as a cash generating rather than basic need generating exercise. The wood ended up for urban and industrial use rather than fuel and fodder needs of the rural people.
- Agro-forestry reduced land employment while absentee landlordism increased.

3. **Several laws** have been passed by legislatures to regulate the use of forests, ban on cutting of trees and encroachment on forest lands:

- **Forest Conservation Act, 1980** was passed for reserved forest areas.
- **Environmental Protection Act** gave the Central Government powers to protect and improve the quality of the environment and preventing pollution.

- **The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006,** recognises the rights of forest-dwelling Scheduled Tribes and other traditional forest dwellers over the forest areas inhabited by them and provides a framework for according the same.

Besides, **international conventions** like Reducing Emissions through Deforestation and Degradation plus (REDD+) help to set guidelines.

4. **At present there are two major afforestation schemes namely**:

- **National Afforestation Programme – NAP** (Aimed at afforestation and eco-restoration of degraded forests and adjoining areas with emphasis on community participation)
- **National Mission for a Green India** (Aimed at increasing the forest cover of country along with improving its quality)
    - Commonly called the Green India Mission (GIM)
    - Launched in February 2014
    - It is one of the eight Missions outlined under India's action plan for addressing the challenge of climate change -the National Action Plan on Climate Change (NAPCC). GIM.
    - There is a component under GIM to support forestry on farm lands for taking up Agro-forestry and Social forestry.

[Note: Generally a "mission mode" project implies a project that has clearly defined objectives, scopes, implementation timelines and milestones, as well as measurable outcomes and service levels.]

5. Other Government Initiatives:

- **National Green Highways Mission**
    - Launched in July 2016
    - The mission aims to provide a green canopy along 100,000km of highways and create jobs for 1 million youth.
    - Under the mission, the government has made it mandatory to set aside 1% of the total project cost of any national highway contract to a Green Fund for plantation.
- **Nagar Van-udyan Yojana**

- A programme for climate smart green cities.
- It is a Pilot scheme recently launched for implementation for a period of five Years.
- The scheme aims at developing 200 Nagar Van (City Forests) across the country in cities having Municipal Corporation or Municipalities.
- A Nagar Van-Udyan is a forested area in the vicinity of a city accessible to the city dwellers suitably managed for providing a wholesome natural environment for recreation, conservation education, biodiversity conservation etc.

- **School Nursery Yojana**
  - It seeks to bring students closer to nature and inculcate in them a sense of urgency to protect the environment.
  - Under the scheme, students will sow seeds and grow saplings in the school nursery as part of their practical exercise for Biology classes or as their extra-curricular activities.
  - The students will also carry out a tree census in their school and the locality.

6. The Role of communities: Communities have played a vital role in the conservation and protection of forests in India. E.g.

- **Chipko movement**: – Chipko Movement, started in 1970's, was a non-violent movement aimed at protection and conservation of trees and forests from being destroyed. The name of the Chipko moment originated from the word 'embrace' as the villagers used to hug the trees and protect them from wood cutters from cutting them. This movement headed by Shri Sunderlal Bahaguna in the Himalayas not only successfully resisted deforestation in several areas but also showed that community afforestation with indigenous species can be enormously successful.
- **Appiko Movement –** On the lines of Chipko movement, Pandurang Hegde launched the Appiko Movement in Karnataka in 1983 (Appiko – to express one's affection for a tree by embracing it). Its objectives were afforestation as well as development, conservation and proper utilization of forests in the best manner.
- **Silent Valley Movement –** The silent valley is an area of tropical evergreen forests in Kerala. It is among the last tracts of virgin tropical evergreen forest in India and is very rich in bio-diversity. The environmentalists and the local people strongly objected to the Hydel power project being set up here in 1973. Under pressure, the government had to declare it a national reserve forest in 1985.

- **Joint forest management**: – this programme furnishes a good example for involving local communities in the management and restoration of degraded forests. The programme has been in formal existence since 1988 when the state of Orissa passed the first resolution for joint forest management. JFM depends on the formation of local (village) institutions that undertake protection activities mostly on degrade forest land managed by the forest department. In return, the members of these communities are entitled to intermediary benefits like non – timber forests produce and share in the timber harvested by successful protection.

- Certain **societies** revere a particular tree which they have preserved from time immemorial. E.g. the Mundas and the Santhals of Chhotanagpur region worship Mahua and Kadamba trees and the tubes of Orissa and Bihar worship the Tamarind and many trees during weddings.

Conservation of Wildlife

India is one of the 17 mega diverse countries of the world. With only 2.4% of the world's land area, 16.7% of the world's human population and 18% livestock, it contributes about 8% of the known global biodiversity, however, putting enormous demands on our natural resources. India is home to world's largest wild tigers population and has a unique assemblage of globally important endangered species like Asiatic lion, Asian Elephant, One-horned Rhinoceros, Gangetic River Dolphin, Snow Leopard, Kashmir Stag, Dugong, Gharials, Great Indian Bustard, Lion Tailed Macaque etc. The following steps have thus been taken to protect and manage the wildlife of the country:

Conservation of Wildlife:

1. The Government of India enacted **Wild Life (Protection) Act 1972** with the objective of effectively protecting the wild life of this country and to control poaching, smuggling and illegal trade in wildlife and its derivatives.

- The act extends to the whole of India except J&K which has its own wildlife act.
- It has 6 schedules which give varying degrees of protection.
    - Schedule I and part II of Schedule II provide absolute protection and offences under these are prescribed the highest penalties.
    - The penalties for Schedule III and Schedule IV are less and these animals are protected.

- Schedule V includes the animals which may be hunted. These are the Common crow, Fruit bats, Mice & Rats only.
- Schedule VI contains the plants, which are prohibited from cultivation and planting.

2. A **National Board for Wildlife (NBWL),** chaired by the Prime Minister of India provides for policy framework for wildlife conservation in the country.

3. The **National Wildlife Action Plan (2002-2016)** was adopted in 2002, emphasizing the people's participation and their support for wildlife conservation. The Draft National Wildlife Action Plan (NWAP) 2017-31 envisages 17 focus areas, including a new area linking wildlife planning to climate change.

4. The Indian Constitution entails the subject of forests and wildlife in the **Concurrent** list thus laying the responsibility of wildlife conservation on both the Centre and the State. The Federal Ministry acts as a guiding torch dealing with the policies and planning on wildlife conservation, while the provincial Forest Departments are vested with the responsibility of implementation of national policies and plans.

5. Specialized projects: To save the endangered species of animals, specialised projects are being implemented with international cooperation (WWF, UNDP, UNEP, and IUCN) as well as on a stand-alone basis e.g.

1. Project Tiger 1973
2. Operation Crocodile 1975
3. Project Rhinoceros 1987
4. Project Snow Leopard
5. Project Elephant 1988

More recently, the Black Buck (chinkara), the Great Indian Bustard (godawan) and the snow leopard etc. have been given full or partial legal protection against hunting and trade throughout India.

6. The Protected Areas of India:

Protected areas are those in which human occupation or at least the exploitation of resources is limited. These are defined according to the categorization guidelines for protected areas by the International Union for Conservation of Nature (IUCN). There are several kinds of protected areas, which vary by level of protection depending on the enabling laws of each country or the regulations of the international organizations involved.

There are 4 categories of the Protected Areas in India viz,

- National Parks,
- Sanctuaries,
- Conservation Reserves, and
- Community Reserves.

Protected Areas of India (as on January, 2017)

	No.	Total Area (km^2)	Coverage % of Country
National Parks (NPs)	103	40500.13	1.23
Wildlife Sanctuaries (WLSs)	537	118005.33	3.59
Conservation Reserves (CRs)	67	2349.38	0.07
Community Reserves	26	46.93	0.001
Protected Areas (PAs)	**733**	**160901.77**	**4.89**

Let's look at these in detail:

- **National Park**:
  - → A National park is an area with enough ecological, geo-morphological and natural significance with rich fauna and flora, which is designed to protect and to develop wildlife or its environment.
  - → National parks in India are IUCN category II protected areas.
  - → Activities like grazing, hunting, forestry or cultivation etc. are strictly prohibited. No human activity is permitted inside the national park except for the ones permitted by the Chief Wildlife Warden of the state.
  - → India's first national park was established in 1936 as Hailey National Park, now known as Jim Corbett National Park, Uttarakhand.
  - → There are 103 existing national parks in India covering an area of 40,500 km2, which is 1.23% of the geographical area of the country (National Wildlife Database, April 2015).

- **Wildlife Sanctuary**:

- → Any area other than area comprised with any reserve forest or the territorial waters can be notified by the State Government to constitute as a sanctuary if such area is of adequate ecological, faunal, floral, geomorphological, natural. or zoological significance, for the purpose of protecting, propagating or developing wildlife or its environment.

- → The difference between a Sanctuary and a National Park mainly lies in the vesting of rights of people living inside. Unlike a Sanctuary, where certain rights can be allowed, in a National Park, no rights are allowed. No grazing of any livestock is permitted inside a National Park while in a Sanctuary; the Chief Wildlife Warden may regulate, control or prohibit it.

- → There are a total of 537 wildlife sanctuaries in India.

- **Conservation reserves and community reserves** in India:

  - → These terms denote the protected areas of India which typically act as buffer zones to or connectors and migration corridors between established national parks, wildlife sanctuaries and reserved and protected forests of India.

  - → Such areas are designated as Conservation Reserves if they are uninhabited and completely owned by the Government of India but used for subsistence by communities and Community Reserves if a part of the lands is privately owned.

  - → These protected area categories were first introduced in the Wildlife (Protection) Amendment Act of 2002 − the amendment to the Wildlife Protection Act of 1972.

  - → These categories were added because of reduced protection in and around existing or proposed protected areas due to private ownership of land, and land use.

7. Biosphere Reserves: A biosphere reserve is an area of land or water that is protected by law in order to support the conservation of ecosystems, as well as the sustainability of mankind's impact on the environment.

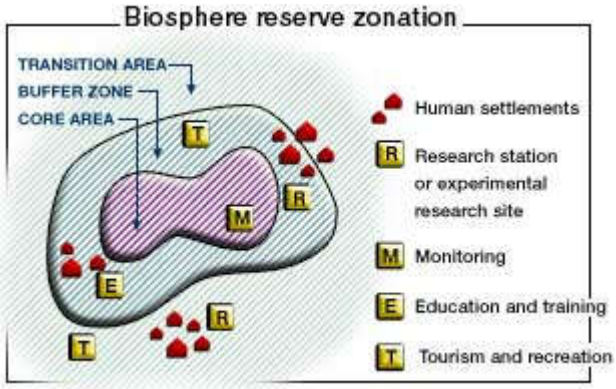
- Each reserve aims to help scientists and the environmental community figure out how to protect the world's plant and animal species while dealing with a growing population and its resource needs.

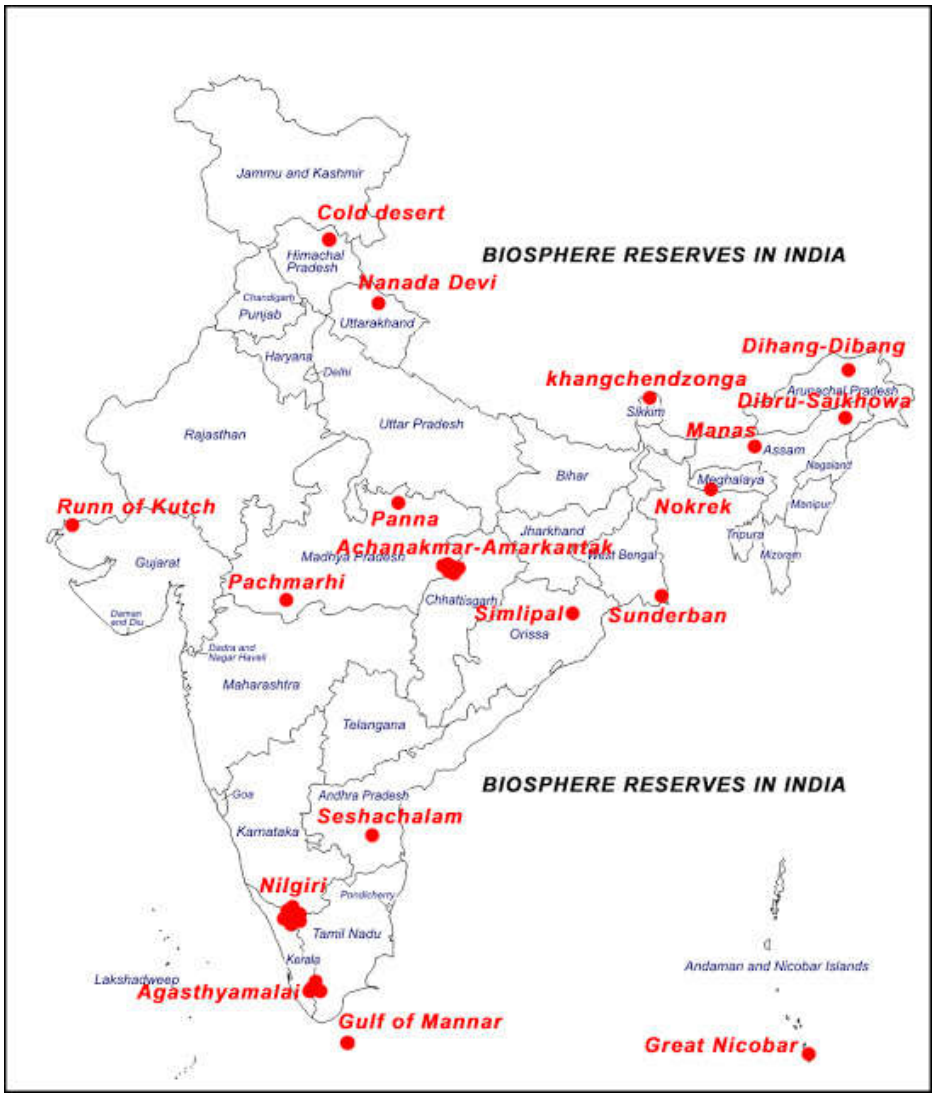
- To carry out the complementary activities of biodiversity conservation and sustainable use of natural resources, biosphere reserves are traditionally organized into 3 interrelated zones, known as:

  - ✓ the core area,

  - ✓ the buffer zone, and

- ✓ A transition zone or 'area of cooperation.





- The purpose of the formation of the biosphere reserve is to conserve in situ all forms of life, along with its support system, in its totality, so that it could serve as a referral system for monitoring and evaluating changes in natural ecosystems.
- Presently, there are 18 notified biosphere reserves in India. Ten out of the eighteen biosphere reserves are a part of the World Network of Biosphere Reserves, based on the UNESCO Man and the Biosphere (MAB) Programme list.

How is a biosphere reserve different from a national park/ wildlife sanctuary?

Biosphere Reserves of India protect larger areas of natural habitat (than a National Park or Wildlife Sanctuary). Biosphere Reserves may cover multiple National Parks, Sanctuaries and reserves as well.

Ex. the Nilgiri Biosphere covers: Bandipur National park, Mudumalai Tiger Reserve, Silent Valley National Park, Nagarhole National Park, Mukurthi National Park and is usually a contiguous area.

Some of the other differences are listed in the image below:

Distinction Between National Park, Sanctuary and Biosphere Reserve

National Park	Sanctuary	Biosphere Reserve
(i) Habitat for particular wild animal species.	Generally species-oriented such as citrus, pitcher plant, etc.	Hitched to the whole ecosystem, i.e., totality of all forms of life, i.e., ecosystem-oriented.
(ii) In India, most common average size is 100-500 sq km (in about 40 per cent cases) and 500-1000 sq km (about 15 per cent cases). The general size range is 0.04 to 3162 sq km.	Size range is 0.61 to 7818 sq km. Most common (in about 40 per cent) is 100-500 sq km. In 25 per cent, the size varies between 500 and 1000 sq km.	Size range over 5670 sq km.
(iii) Boundaries fixed by legislation.	Boundaries are not sacrosanct.	Fixed by legislation.
(iv) Except the buffer zone, no biotic interference.	Limited biotic interference.	Except the buffer zone, no biotic interference.
(v) Tourism permissible.	Permissible.	Normally not permissible.
(vi) Research and scientific management lacking.	Lacking.	Managed.
(vii) So far no attention to genepools and conservation.	So far no such attention.	Attention given.

8. Some other important Conservation Sites:

- **Tiger reserves** – Project Tiger was launched by the Government of India in the year 1973 to save the endangered species of tiger in the country. Starting from nine (9) reserves in 1973 the number has now grown up to fifty (50) in 2016.
- **Elephant reserves**
- **RAMSAR Wetland Sites**
- **UNESCO World Heritage Sites (Natural, Cultural and Mixed) –** Places listed by the United Nations Educational, Scientific and Cultural Organization as of special cultural or physical significance.
- **Marine Protected Areas**
- **Important Bird Areas**

Important Conservation Sites in India (as on December, 2016)

Reserves/ Sites	Numbers	Total area (in Sq.Kms.)
Tiger Reserves	50	71027.10
Elephant Reserves	32	69,582.80
Biosphere Reserves	18	87491.6
RAMSAR Wetland Sites	26	12119.03
Natural World Heritage Sites	07	11755.84
Cultural World Heritage Sites	27	--
Mixed World Heritage Sites	01	1784.00
Important Coastal and Marine Biodiversity Areas	107	10773.07
Marine Protected Areas	131	9801.13
Important Bird Areas	467	--
Potential Important Bird Areas	96	--

9. Role of communities: Communities have played a vital role in the conservation and protection of wildlife in India. E.g.

- **Sariska Tiger Reserve**: In Sariska tiger reserve Rajasthan villagers have fought against mining by citing the wildlife protection act. In many areas, villagers themselves are protecting habitats and explicitly rejecting government involvement.

- **Bhairodev Dakav Sonchuri**: The inhabitants of five villages in the Alwar district of Rajasthan have declared 1200 hectares of forests as the Bhairodev Dakav Sonchuri declaring their own set of riles and regulation which do not allow hunting, and are protecting the wildlife against any outside encroachments.

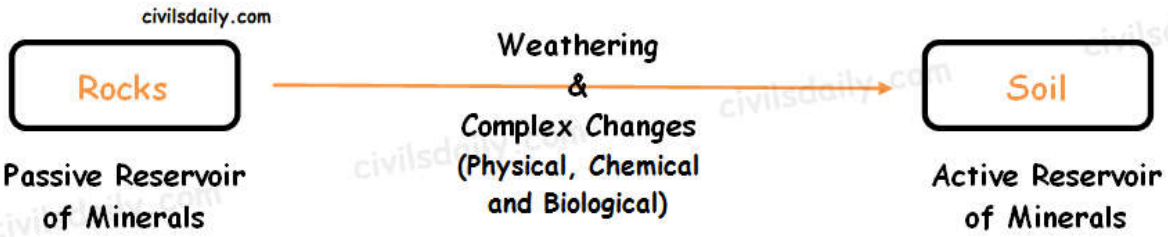
- **Bishnoi villages**: In and around Bishnoi villages in Rajasthan, herds of blackbuck, Nilgai and peacocks can be seen as an integral part of the community and nobody harms them.

7. Soils

Before we discuss the various soil types and their distribution in India, it is imperative that we first go through the basics. Let's begin with what soil is and how it is formed:

What is soil?

Soil is the loose material of the earth's surface in which the terrestrial plants grow. It is usually formed from weathered rock or regolith changed by chemical, physical and biological process.



Thus the soil may be considered as an entity, quite apart from the rocks below it. It consists partly of mineral particles and partly, to a varying extent, of organic matter. Let's look at the composition in detail:

Composition of soils:

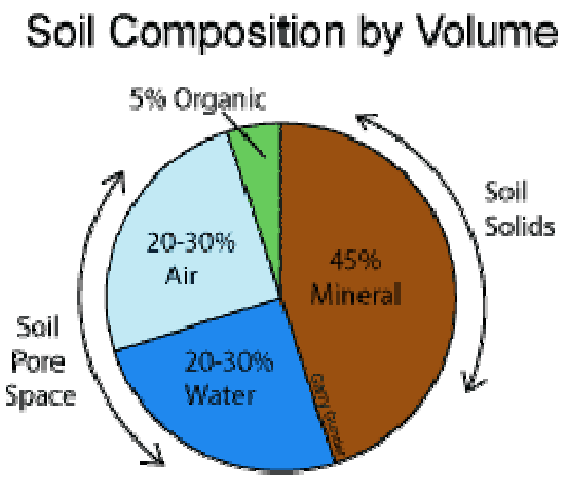
Soils have four main constituents:

- Mineral matter – It includes all minerals inherited from the parent material as well as those formed by recombination from substances in the soil solution.
- Organic matter – It is derived mostly from decaying plant material broken down and decomposed by the actions of animals and microorganisms living in the soil. It is this organic portion that differentiates soil from geological material occurring below the earth's surface which otherwise may have many of the properties of a soil. (Note: The end product of breakdown of dead organic material is called humus.)
- Air
- Water

Normally, both air and water fill the voids in soil. Air and water in the soil have a reciprocal relationship since both compete for the same pore spaces.

For example, after a rain or if the soil is poorly drained, the pores are filled with water and air is excluded. Conversely, as water moves out of a moist soil, the pore space is filled with air. Thus the relationship between air and water in soils is continually changing.

The ratio of the components by volume is generically indicated as:



Note: The exact ratio depends on various factors like geographical location and the historical treatment of soil – by humans, by climate, by time.

Why is soil so important?

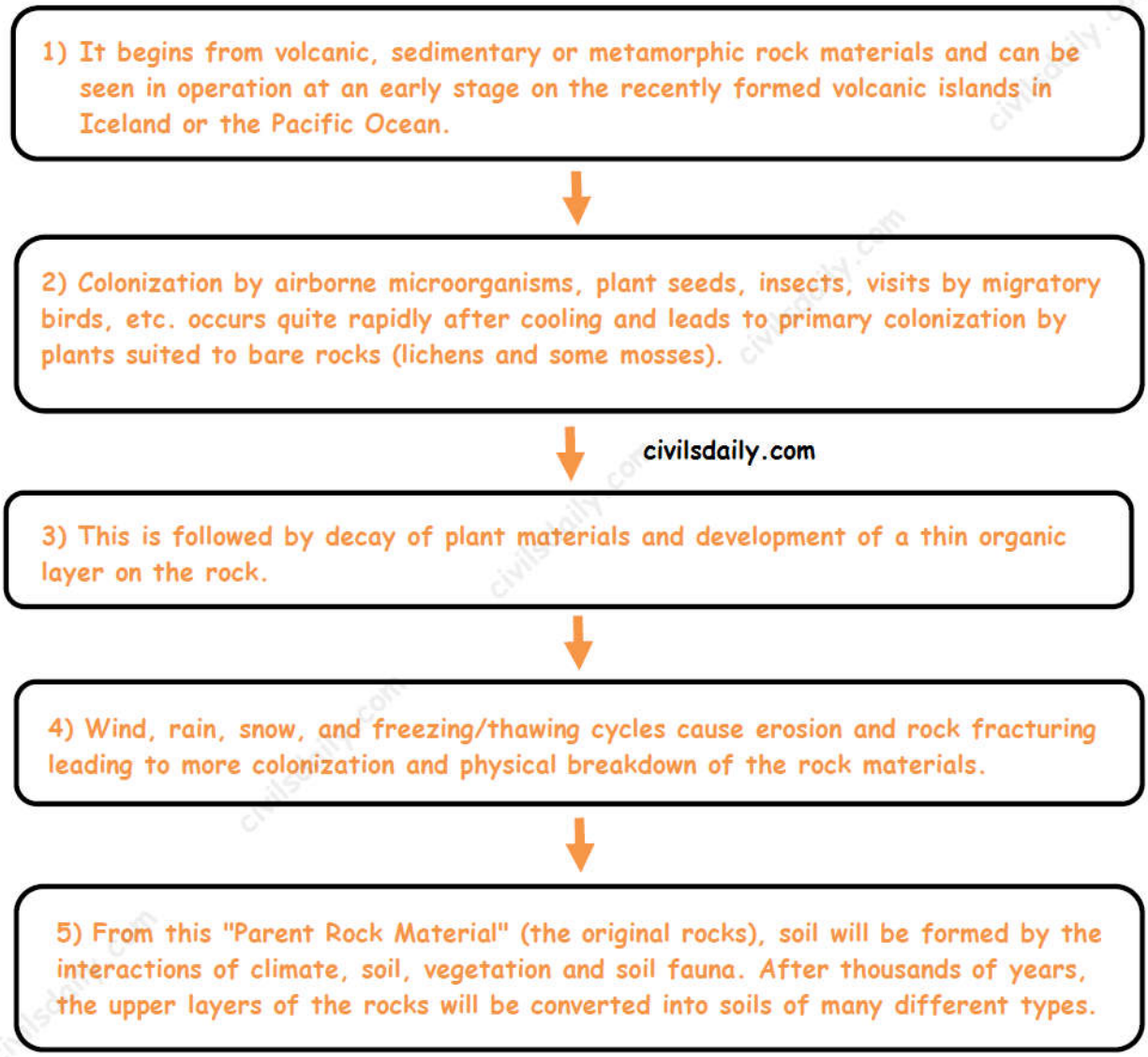
Soils are essential for life, in the sense that they provide the medium for plant growth, habitat for many insects and other organisms, act as a filtration system for surface water, carbon store and maintenance of atmospheric gases. They also support buildings and highways and contribute to the economies of our cities.

E.g. the rich, deep fertile soils of the Ganga plain especially its delta and the coastal plains of Kerala support a high density of population through agricultural prosperity. On the other hand, the shallow and coarse-grained soils of Telangana and Rajasthan do not provide a base for prosperous agriculture and thus support only a small population.

At the same time, the soil must not be regarded as a passive and inert body on the earth's surface. **It is a continually changing system within the total environment**. The nature of a soil reflects the ancient environments under which it formed as well as current environmental conditions. The soil forming process, also known as pedogenesis, is described below:

How is soil formed?

Soil formation is a process taking many thousands of years.



Formation of soil from rocks.

The Pedogenic Processes:

The above-explained conversion from rocks to soils happens via four basic processes:

1. Additions
2. Losses
3. Translocations
4. Transformations

Let's look at these soil forming processes in detail:

1. **Additions:** Most additions occur at the surface. The most obvious ones include solar energy, water controlled by climate, and organic material derived principally from the vegetation.

2. **Losses**: Losses occur both from the surface and from the deep subsoil. For instance, water is lost by evapotranspiration and carbon dioxide by diffusion at the surface and, on a more catastrophic level, large masses of soil can be stripped by erosion. Materials suspended or dissolved in water are the main forms of losses from the subsoil e.g. leaching.

3. **Translocation**: It refers to the physical movement of material within the soil. The material can be in the solid, liquid or gaseous form, the movement can be in any direction from and to any horizon. For instance clay, organic matter and iron and aluminium hydrous oxides are commonly moved from the surface horizon to a subsurface horizon. Conversely, in very dry climates salts are moved upwards in solution by capillarity, and in very cold climates solid mineral fragments are moved upwards by frost action.

4. **Transformation**: Additions, losses and translocations all involve movement as shown in the above figure. Transformations, on the other hand, involve the change of some soil constituent without any physical displacement. Chemical and physical weathering and the decomposition of organic matter are included here.

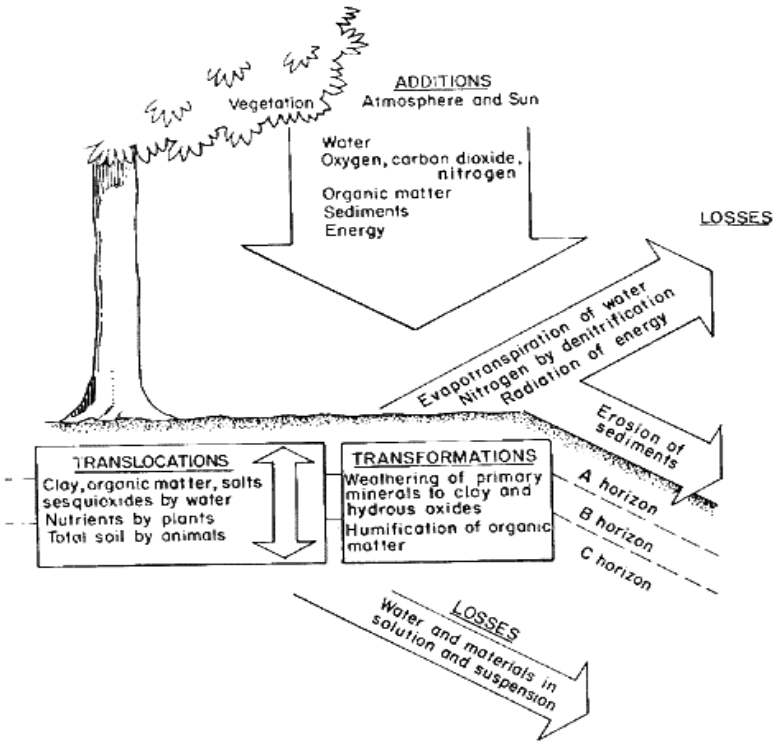


FIGURE 2.2.1 Diagrammatic representation of additions, losses, translocations and transformations involved in soil formation (after Millar, Turk and Foth 1965).

All these processes occur to a greater or lesser extent in all soils. The properties that characterise one soil are the result of a particular balance among all the processes. Other soils will be different because they have been formed by groups of processes having different balances.

- The two driving forces for these processes are:
    - climate (temperature and precipitation), and
    - Organisms, (plants and animals).
- Passive factors:
    - Parent material is usually a rather passive factor in affecting soil processes because parent materials are inherited from the geologic world.
    - Topography (or relief) is also rather passive in affecting soil processes, mainly modifying the climatic influences of temperature and precipitation.

The major factors responsible for the formation of soil:

The major factors affecting the formation of soil are relief, parent material, climate, vegetation and other life-forms and time. Besides these, human activities also influence it to a large extent.

1. Parent Material

The parent material of soil may be deposited by streams or derived from in-situ weathering. Soil inherits many properties from the parent material from which it forms, for example, the mineral composition, the colour, the particle size and the chemical elements.

For Example,

- The peninsular soils reflect the parent rock very much.
- The ancient crystalline and metamorphic rocks which are basically granite, gneiss and schist form red soils on weathering because they contain iron oxide.
- Soils derived from lava rocks are black coloured.
- Sandy soils are derived from sandstone.
- At the same time, the soils of the northern plains are transported and deposited from Himalayan and peninsular blocks, so they have little relation to rock material in-situ.

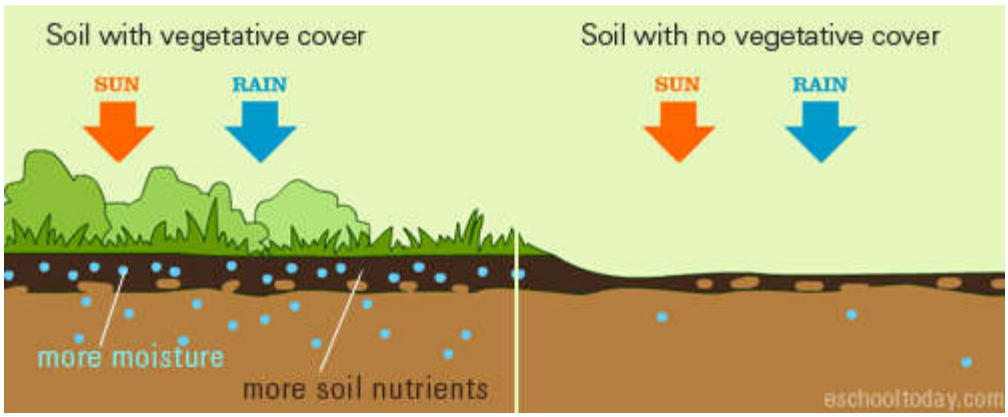
2. **Climate**

The role of climate is to vary the inputs of heat and moisture. It affects the rate of weathering of the parent rock. Hot and humid environments, in general, witness the most rapid weathering of parent materials.

- **Role of precipitation**: In areas that experience a lot of rainfall, water percolating down through soil tends to leach nutrients and organic matter out of the upper layers, unless modified by other soil components like plant roots.
    - E.g. the soils underlying tropical rain forests tend to be nutrient-poor because of intensive leaching due to heavy rains; most of the nutrients are stored in the lush vegetation itself.
    - Conversely, in arid regions with little annual precipitation, high rates of evaporation encourage the accumulation of salts in the soil.
- **Role of temperature**: Solar energy, usually expressed as temperature, controls the form of water falling onto the soil surface as well as in the soil. Also, it increases the rate of reactions, such as chemical reactions, evapotranspiration and biological processes. Wide fluctuations in temperature, especially in the presence of water cause shrinking and swelling, frost action and general weathering in soils.
    - E.g. Laterite soils are found in alternate wet and dry climate.
    - In Rajasthan, both granite and sandstone give birth to sandy soil irrespective of parent rock because of high temperature and wind erosion.

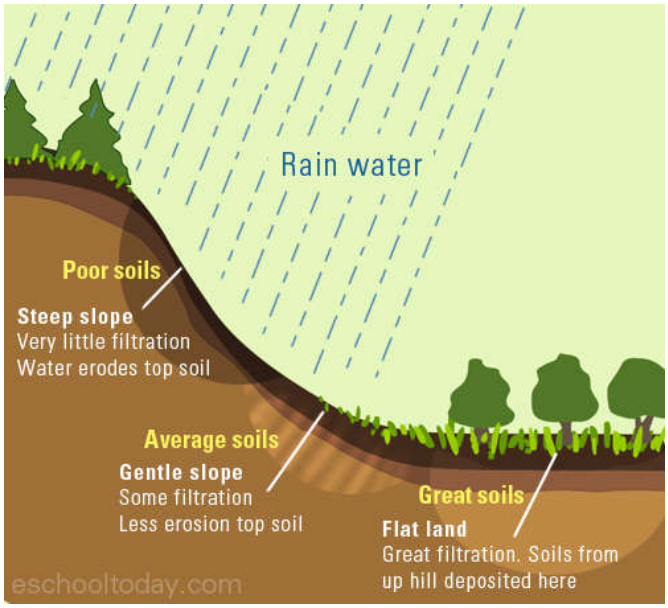
3. Biota (Flora, Fauna and Microorganisms): Biota, in conjunction with climate, modifies parent material to produce soil.

- The kind and amount of plants and animals that exist bring organic matter into the soil system as well as nutrient elements. This has a great effect on the kind of soil that will form.
    - E.g. Soils formed under trees are greatly different from soils formed under grass even though other soil-forming factors are similar.
- The roots of plants also hold the soils and protect them from wind and water erosion. They shelter the soils from the sun and other environmental conditions, helping the soils to retain the needed moisture for chemical and biological reactions.



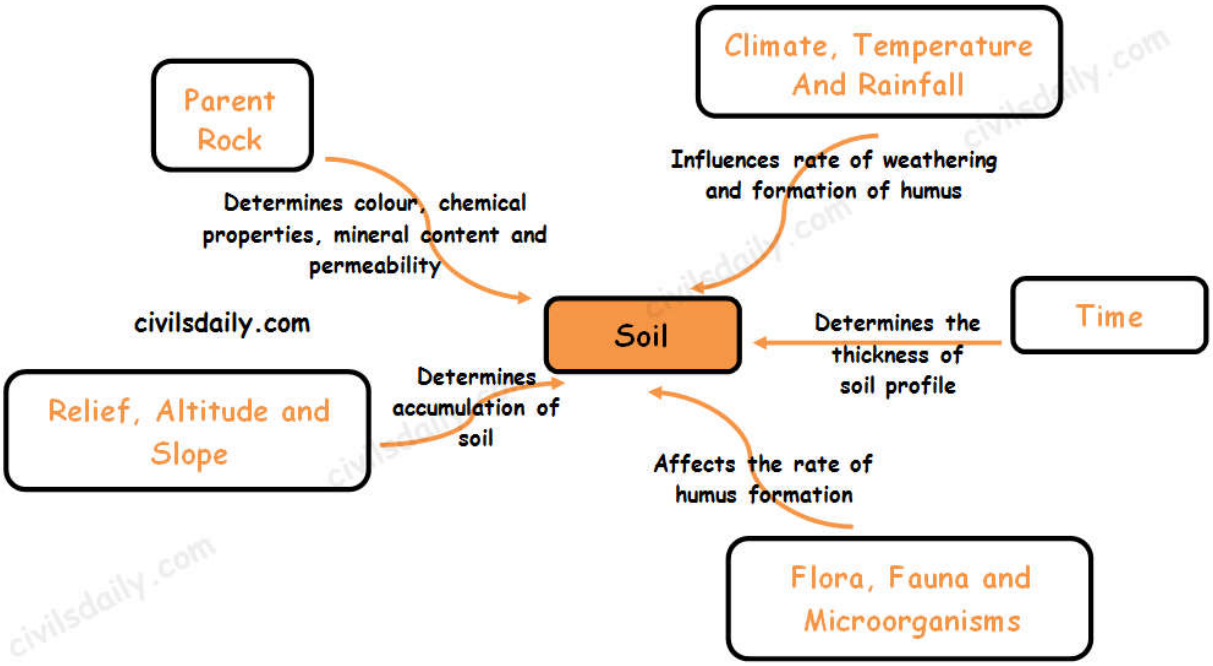
4. Topography (Relief, Altitude and Slope): Topography is often considered a passive factor modifying the effects of climate.

Topography redistributes the water reaching the soil surface. Runoff from uplands creates wetter conditions on the lowlands, in some cases saline sloughs or organic soils. Thus, as a redistributor of the climate features, topography affects soil processes, soil distribution and the type of vegetation at the site.



5. Time: Soils can take many years to form. Younger soils have some characteristics from their parent material, but as they age, the addition of organic matter, exposure to moisture and other environmental factors may change its features. With time, they settle and are buried deeper below the surface, taking time to transform. Eventually, they may change from one soil type to another.

Look at the following diagram for a quick revision of the above-discussed facts:



Note: The above factors are not mutually exclusive but interdependent. For example, the kind of vegetation found at any one location on the earth's surface is dependent on climate, parent material, topography, time and, in fact, soil. It is obvious that numerous combinations of the factors are possible. This leads to many different kinds of soils, each representing a certain combination of the factors of soil formation.

Soil Profile

As we discussed earlier, soil development begins when plants and animals colonize rocks or deposits of rock fragments. Once organic processes start among mineral particles or rock fragments, chemical and physical differences begin to develop from the surface down through the parent material.

Initially, vertical differences result from surface accumulations of organic litter and the removal of fine particles and dissolved minerals by percolating water that deposits these materials at a lower level.

Over time, as climate, vegetation, animal life, and the land surface affect soil development, this vertical differentiation becomes increasingly apparent.

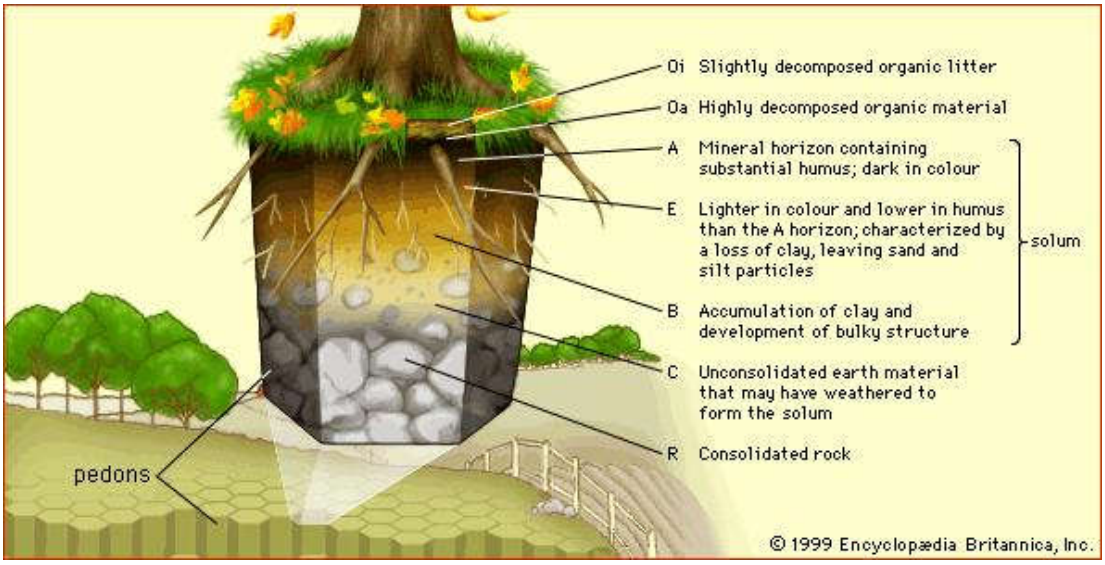
If you could dig a massive trench, about 50-100ft vertically downwards into the ground, you will notice that you would have cut through various layers of soil types. A look at the layers from a distance gives one a cross-section view of the ground (beneath the surface) and the kind

of soils and rocks it is made up of. This cross section view of soil from the surface down to the parent material is called a **Soil Profile**.

The Soil Profile is a product of the balance between the soil system inputs (i.e. additions) and outputs (i.e. losses) and the redistribution of (i.e. translocations), and chemical changes (transformations) in the various soil constituents.

The soil profile is made up of layers, running parallel to the surface, called **Soil Horizons**. These layers are distinguished by their physical and chemical properties.

Most soils have three major horizons. These are A Horizon, B Horizon and C Horizon. Aside these three, there are also the O, E and R horizons. How are they different? Let's see!



1. O-Horizon: The **O-horizon** is very common to surfaces with lots of vegetative cover. It is the layer made up of organic materials such as dead leaves and surface organisms, twigs and fallen trees. In fact, the **'O'** designation refers to this horizon's high content of organic debris and humus. It is often black or dark brown in colour, because of its organic content. It is the layer in which the roots of small grass are found.

2. The A-Horizon: The **A horizon**, immediately below the **O** horizon, is usually known as the topsoil. It is the top layer soil for many grasslands and agricultural lands. In general, **A** horizons are dark because they contain decomposed organic matter.

3. The E-Horizon: The **E horizon** is usually lighter in colour, often below the **O** and **A horizons**. It is often rich in nutrients that are leached from the top **A** and **O horizons**. It has lower clay content and is common in forested lands or areas with high-quality **O** and **A horizons.**

4. The B-Horizon: Below the **E-horizon** is the **B-horizon**, a zone of accumulation, where much of the nutrients removed from the **A** and **E horizons** are deposited. It is the layer in which the roots of big trees end. There is a close relationship between the **A** and **B horizons**. Translocations, as well as, many biological and chemical reactions take place between them. The **B horizon**, however, tends to be more stable than the **A** for short term differences.

5. The C-Horizon: The **C horizon** is the weathered parent material from which the soil has developed. This layer is the first stage in the soil formation process and eventually forms the above two layers. The **C horizon** is also known as saprolite.

6. The R-Horizon: It is the unweathered parent material.

Soil Characteristics

Knowing a soil's water, mineral, and organic components and their proportions can help us determine its productivity and what the best use for that soil may be. Several soil properties that can be readily tested or examined are used to describe and differentiate soil types. The most important properties are discussed below:

1. Colour:

A soil's colour is generally related to its physical and chemical characteristics. E.g.

- Soils rich in humus tend to be dark because decomposed organic matter is black or brown. Soils with high humus content are usually very fertile, so dark brown or black soils are often referred to as 'rich'. [Note – Some dark soils may be dark because of other soil forming factors and may have little or no humus]
- Red or yellow soils typically indicate the presence of iron.

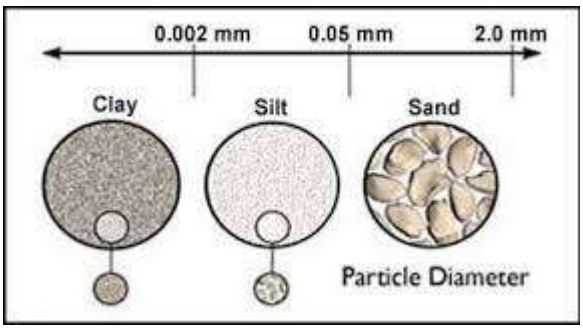
2. Texture:

The soil texture refers to the coarseness/fineness of the mineral matter in the soil. It is determined by the proportion of the sand, silt and clay particles:

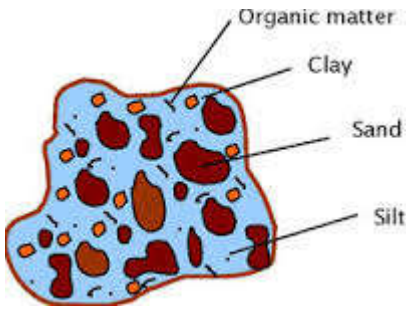
1. Clay: Particle Size – diameters less than 0.002 millimeter
2. Silt: Particle Size – diameters between 0.002 millimeters to 0.05 millimeters.
3. Sand: Particle Size – diameters between 0.05 and 2 millimeters.

[Rocks larger than 2 millimeters are regarded as pebbles, gravel, or rock fragments and technically are not soil particles.]

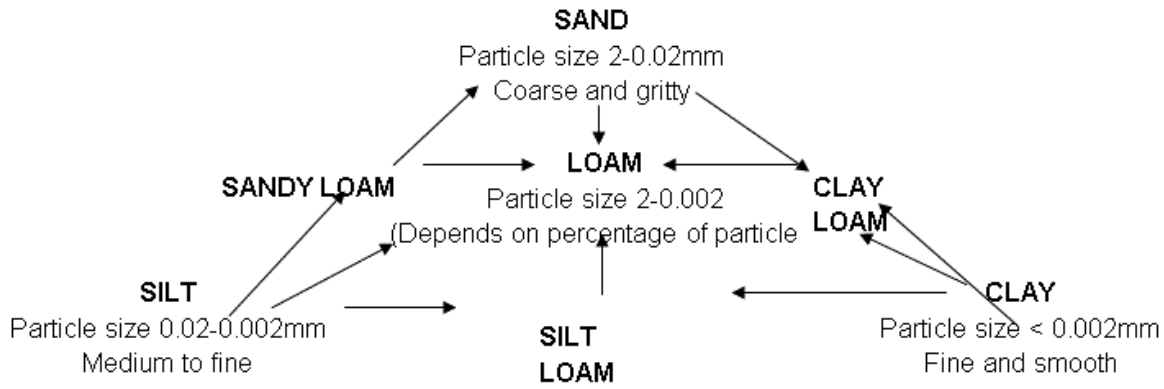
Note: Clay being the finest of all plays the most important role in soil chemistry (offers more surface area).



The proportions of each of these soil fractions determine soil texture and its properties.



The Soil Triangle



The soil texture directly affects:

- The soil water content
- Water flow
- Retention of nutrients
- Extent of aeration

Loamy Soil: Loamy soil is the one in which none of the three (sand/silt/clay) dominates the other two. In particular, loamy soil has about 40% sand, 40%silt, and 20% clay.

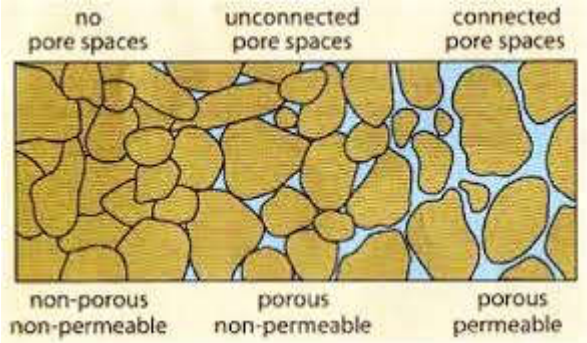
Note: Generally speaking, Good Soils = Clay + Humus. The clay-humus complex is essential for a fertile soil as it provides it with a high water and nutrient holding capacity. Humus acts as cement binding the soil particles together and thus reducing the risk of erosion.

3. Structure:

While the soil texture describes the size of soil particles, soil structure refers to the arrangement of the soil particles. The way in which sand, silt, clay and humus bond together is called soil structure. Structure can partially modify the effects of soil texture.

Some structural characteristics of soil:

- Permeability – The ease with which liquids/gases can pass through rocks or a layer of soil is called permeability. It depends on the size, shape and packing of particles. It is usually greatest in sandy soils and poor in clayey soils.
- Porosity – The volume of water which can be held within a soil is called its porosity. It is expressed as a ratio of volume of voids (pores) to the total volume of the material.



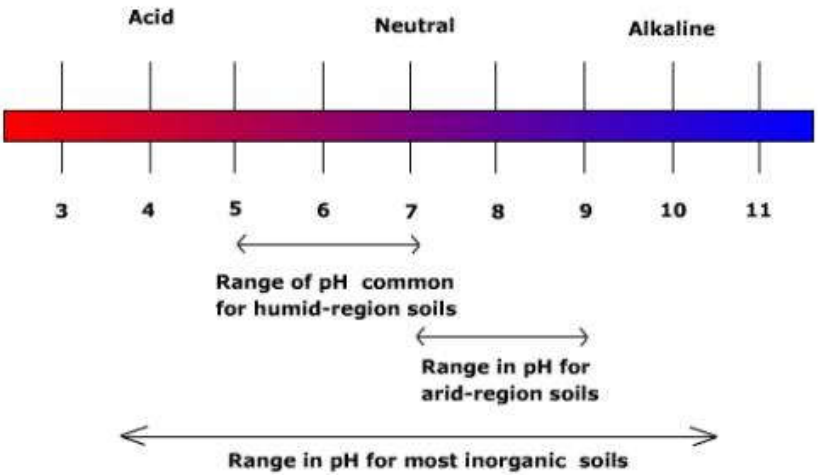
- Note: Most porous rocks are permeable with the exception of clay in which pore spaces are so small that they are often sealed with groundwater held by surface tension. Another exception – granite is non-porous but permeable. It is a crystalline rock and hence non-porous. Its individual crystals absorb little or no water but the rock may have numerous joints/ cracks through which the water can pass rendering it permeable.

- A soil with high organic content also tends to have high porosity.

4. Soil Chemistry – Acidity or Alkalinity:

An important aspect of soil chemistry is acidity, alkalinity (baseness), or neutrality.

Low pH values indicate an acidic soil, and a high pH indicates alkaline conditions. Most complex plants grow only in the soils with levels between pH 4 and pH 10 but optimum pH varies with the plant species.



- In arid and semi-arid regions, soils tend to be alkaline and soils in humid regions tend to be acidic.

- To correct soil alkalinity and to make the soil more productive, the soil can be flushed with irrigation water.

- Strongly acidic soils are also detrimental to plant growth, but soil acidity can generally be corrected by adding lime to the soil.

Now that we are done with the basics, let's move on to the soils of India!

Soils of India

India has varied relief features, landforms, climatic realms and vegetation types. These have contributed to the development of various types of soils in India.

Various classifications adopted to study the Indian Soils:

1. In ancient times, soils used to be classified into two main groups:

- **Urvara** (i.e. fertile), and
- **Usara** (i.e. sterile)

2. In the 16th century A.D., soils were classified on the basis of their inherent characteristics and external features such as texture, colour, the slope of land and moisture content in the soil.

- Based on **texture**, main soil types were identified as sandy, clayey, silty and loam, etc.
- On the basis of **colour**, they were red, yellow, black, etc.

3. 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. In their effort to study soil and to make it comparable at the international level, the ICAR has classified the Indian soils on the basis of their nature and character as per the **United States Department of Agriculture (USDA) Soil Taxonomy**.

ICAR has classified the soils of India into the following order as per the USDA soil taxonomy

Sl. No.	*Order*	*Area (in Thousand Hectares)*	*Percentage*
(i)	Inceptisols	130372.90	39.74
(ii)	Entisols	92131.71	28.08
(iii)	Alfisols	44448.68	13.55
(iv)	Vertisols	27960.00	8.52
(v)	Aridisols	14069.00	4.28
(vi)	Ultisols	8250.00	2.51
(vi)	Mollisols	1320.00	0.40
(viii)	Others	9503.10	2.92
	Total		**100**

Source : Soils of India, National Bureau of Soil Survey and Land Use Planning, Publication Number 94

Chief characteristics of these are:

- **Entisols** – Immature soils that lack the vertical development of horizons. These soils are often associated with recently deposited sediments from wind, water, or ice erosion. Given more time, these soils will develop into another soil type.
- **Inceptisols** – young soils that are more developed than Entisols.
- **Vertisols** – heavy clay soils that show significant expansion and contraction due to the presence or absence of moisture. These are common in areas that have shale parent material and heavy precipitation.
- **Aridisols** – soils that develop in very dry environments.
- **Ultisols** – associated with humid temperate to tropical climates. Warm temperatures and the abundant variability of moisture enhance the weathering process and increase the rate of leaching in these soils.
- **Mollisols** – soils common to grassland environments

4. On the basis of genesis, colour, composition and location, the soils of India have been classified into:

- ✓ Alluvial soils
- ✓ Black soils
- ✓ Red and Yellow soils
- ✓ Laterite soils
- ✓ Arid soils
- ✓ Saline soils
- ✓ Peaty soils
- ✓ Forest soils.

5. Another way of classifying rocks is on the basis of dominant soil forming factors:

- **Zonal Soil** – These soils occur in broad geographical areas or zones.
    - They are influenced more by the climate and vegetation of the area rather than the rock-type.
    - They are mature, as a result of stable conditions over a long period of time.
    - For example – red soils, black soils, laterite soils, desert soils etc.
- **Azonal Soil** – It is that soil which has been developed by the process of deposition by the agents of erosion.

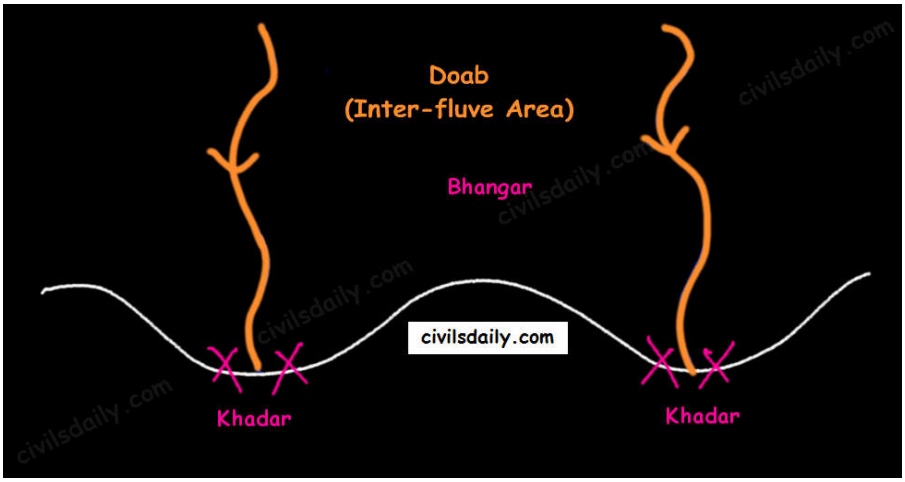
- It means that it has been made by the fine rocky particles transported from the far-off regions.
- These are immature soils and lack well-developed soil profiles. This may be due to the non-availability of sufficient time for them to develop fully or due to the location on very steep slopes which prohibits profile development.
- For Example – alluvial and loess soils.

- **Intrazonal Soil** – These soils occur within other zonal soils.
  - It is a well-developed soil reflecting the influence of some local factor of relief, parent material, or age rather than of climate and vegetation.
  - For example, calcerous soil (soils which develop from limestone), peat soil.

we will look at the various types of Indian soils in detail (According to ICAR's classification). Let's begin!

1. Alluvial Soils

- **Formation:** They are mainly derived from the debris brought down from the Himalayas or the silt left out by the retreating sea. Thus they are azonal soils.
- **Areas:** Alluvial soils are widespread in the northern plains and the river valleys. 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.
- **Soil texture**: The alluvial soils vary in nature from sandy loam to clay. These soils are more loamy and clayey in the lower and middle Ganga plain and the Brahmaputra valley. The sand content decreases from the west to east.
- **Soil Colour**: The colour of the alluvial soils varies from the light grey to ash grey depending on the depth of the deposition, the texture of the materials, and the time taken for attaining maturity.
- **Other Characteristic Features**:
  - In the Upper and Middle Ganga plain, two different types of alluvial soils have developed, viz. Khadar and Bhangar.



Khadar and Bhangar

  - **Khadar**: the newer alluvium deposited by floods annually, enriches the soil by depositing fine silts, light colour, found near river beds, porous in nature. **Bhangar**: older alluvium, clayey, darker, has lime nodules called Kankars, found in doabs (inter-fluve areas).
  - Alluvial soils of the northern plains —> transported soils —> therefore lack humus —> lack nitrogen [That is why we need to use nitrogenous fertilisers in the

northern plains!]. Exception: the Ganga-Brahmaputra delta region is rich in humus.

- These soils lack in nitrogen, phosphorus and humus. However, they are generally rich in potash and lime.
- The soil profile has no stratification.
- Alluvial soils are intensively cultivated.
- In certain areas, these soils are covered with unproductive wind-borne soil called Loess.

- **Limitations:**
  - Allow water to sink into lower strata, and
  - Lack nitrogen (But these soils are capable of fixing nitrogen very rapidly through leguminous crops (peas, beans, cloves etc.)
- **Suitable Crops:** Wheat, rice, maize, sugarcane, pulses, oilseeds, fruits and vegetables, leguminous crops.

2. Black Soil

- These soils are locally known as the 'Regur Soil' or the 'Black Cotton Soil'. Internationally, these are known as 'tropical chernozems'. These soils are famous for the cultivation of cotton.
- **Formation**: These have mainly formed from the Deccan Trap rocks —> Zonal Soils
- **Areas:** These are found in the Deccan trap region. Black soil covers most of the Deccan Plateau which includes parts of:
  - ✓ Maharashtra,
  - ✓ Madhya Pradesh,
  - ✓ Gujarat,
  - ✓ Andhra Pradesh and some parts of
  - ✓ Tamil Nadu.
- **Soil Texture:** Black cotton soil (regur soil) is highly argillaceous i.e. clayey. It is deep and impermeable and thus has high water retention capacity.

- **Soil Colour:** These soils are black in colour due to the presence of iron, aluminium compounds and humus.
- **Other Characteristic Features:**
  - ✓ These soils are rich in minerals and known for their fertility.
  - ✓ The soil depth varies from place to place. It is very thick in lowlands but very thin on highlands. Also, in the upper reaches of the Godavari and the Krishna, and the northwestern part of the Deccan Plateau, the black soil is very deep.
  - ✓ These soils swell and become sticky when wet and develop deep wide cracks when dry. This helps in self-aeration, which leads to absorption of nitrogen from atmosphere. Thus, there occurs a kind of 'self ploughing'. This aeration and oxidisation to deep levels contributes to maintenance of fertility of these soils. This continued fertility is favourable in the area of low rainfall for cotton cultivation even without irrigation.
  - ✓ Due to slow absorption and loss of moisture, 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.
  - ✓ Chemically, the black soils are rich in lime, iron, magnesia and alumina. They also contain potash. But they lack in phosphorous, nitrogen and organic matter.
- **Suitable Crops:** These soils are highly productive and well suited to the cultivation of cotton, pulses, millets, linseed, tobacco, sugarcane, vegetables and citrus fruits.

Note: In the southern and eastern parts of the country where rainfall is heavy, black soils often occur in close proximity to red soils. Black soils occupy valleys and low-level areas whereas the red soils occur on higher slopes and hill tops. Mixed black and red soils occur in Coimbatore, Madurai, Tirunelveli (Tamil Nadu) and Bundelkhand region.

3. Red and Yellow Soils

- Locally called 'Chalka' in Andhra Pradesh.
- **Formation**: These are derived from granites, gneisses and other metamorphic rocks —> Zonal Soils. These are formed under well-drained conditions.
- **Areas:** Along the piedmont zone of the Western Ghat, a long stretch of area is occupied by red loamy soil. Yellow and red soils are also found in parts of Orissa and Chhattisgarh and in the southern parts of the middle Ganga plain. They encircle the black cotton soil zone.

- **Soil Colour:** 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. Often, their upper layer is red and the lower layer is yellow.
- **Soil Texture**: Varies from sand to clay and loam.
- **Other Characteristic Features:**
  - → The fine-grained red and yellow soils are normally fertile, whereas coarse-grained soils found in dry upland areas are poor in fertility.
  - → Have a porous and friable structure.
  - → They are generally poor in nitrogen, phosphorous and humus.
  - → These soils are airy and need irrigation for cultivation.
  - → Intense leaching is a menace in these soil areas.
- **Suitable Crops**: In places where irrigation facilities are available, the crops cultivated are wheat, cotton, pulses, tobacco, millets, oilseeds, potato, maize, groundnut and orchards.

4. Laterite Soil

- The word laterite has been derived from the Latin word 'Later' which means brick. These soils when wet are as soft as butter but become hard and cloddy on drying. Therefore, these are widely cut as bricks for use in house construction.
- **Formation:** The lateritic soils are particularly found on high flat erosion surfaces in areas of high (>200cm) and seasonal rainfall. The alternating wet and dry seasons lead to the leaching away of the siliceous matter of the rocks leaving behind the compounds of iron and aluminium. These are zonal soils.
- **Areas**: These soils have mainly developed in the higher areas of the Peninsular plateau. The laterite soils are commonly found in Karnataka, Kerala, Tamil Nadu, Madhya Pradesh and the hilly areas of Orissa and Assam.
- **Soil Colour**: Reddish brown in colour due to the presence of iron oxide.
- **Other characteristic features**:
  - → With rain, lime and silica are leached away, and soils rich in iron oxide and aluminium compound are left behind (thus the reddish brown colour). Also, humus content of the soil is removed fast by bacteria that thrive well in high temperature.

- These soils represent the end product of decomposition and are generally low in fertility.
- The pebbly crust is the important feature of laterites which is formed due to alteration of wet and dry periods.
- These soils are acidic in character due to leaching. Application of manures and fertilisers is required for making these soils fertile for cultivation.
- These soils are poor in organic matter, nitrogen, phosphate and calcium, while iron oxide and potash are in excess.

- **Suitable crops**: Red laterite soils in Tamil Nadu, Andhra Pradesh and Kerala are more suitable for tree crops like cashew nut. These soils are also suitable for tea plantations.

5. Arid Soils

- **Formation:** These are derived from the disintegration of adjacent rocks and are largely blown from coastal regions and Indus valley.
- **Areas:** Arid soils are characteristically developed in western Rajasthan, which exhibit characteristic arid topography.
- **Soil Colour:** Arid soils range from red to brown in colour.
- **Soil Texture:** They are generally sandy to gravelly in texture and have a high percentage of soluble salts.
- **Other characteristic features:**
  - These are saline in nature. In some areas, the salt content is so high that common salt is obtained by evaporating the saline water.
  - Due to the dry climate, high temperature and accelerated evaporation, they lack moisture and humus.
  - These soils are deficient in nitrogen and humus. The phosphate and iron content is normal. These soils are rich in minerals but the main limitation is the lack of water.
  - The soils exhibit poorly developed horizons.
  - Plants are widely spaced.
  - Chemical weathering is limited.

→ Lower horizons of the soil are occupied by 'kankar' layers because of the increasing calcium content downwards. The 'Kankar' layer formation in the bottom horizons restricts the infiltration of water, and as such when irrigation is made available, the soil moisture is readily available for a sustainable plant growth.

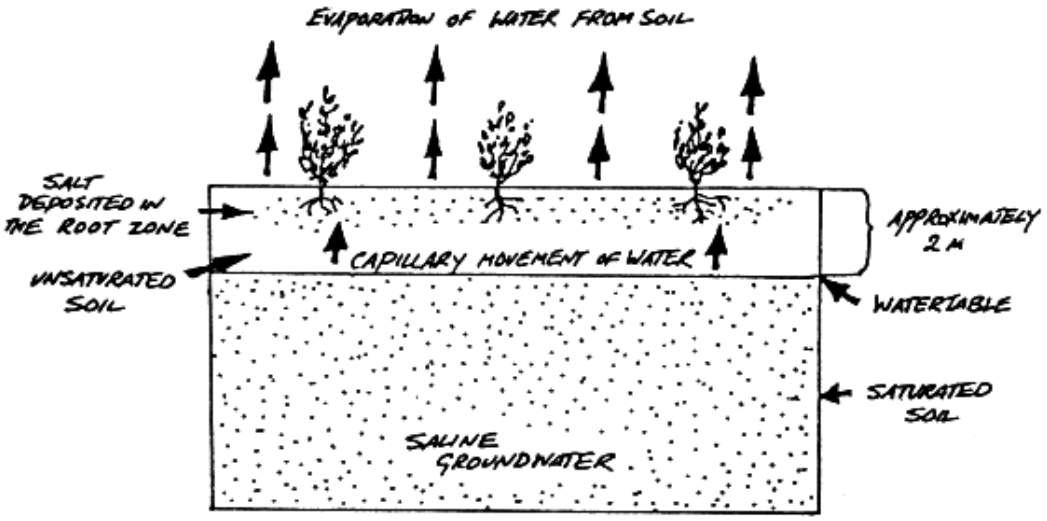
- **Suitable crops:** If irrigated these soils give high agricultural returns. The availability of water from the Indira Gandhi canal has transformed the agricultural landscape of desert soils of western Rajasthan. These soils are mainly devoted to bajra, pulses, guar, fodder and less water requiring crops.

6. Saline and Alkaline Soils

- They are also known as Usara soils. Various local names for saline soils are Reh, Kallar, and Chopan, Rakar, Thur, Karl etc.

- **Formation:**

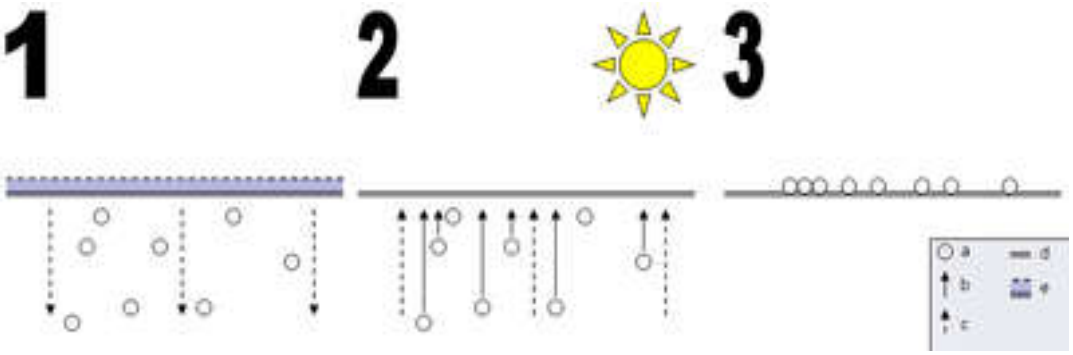
  - These soils have developed in areas with dry climatic conditions (in areas having a little more rainfall than the areas of desert soils) accompanied by lack of proper drainage. In this situation, salts of sodium, calcium and magnesium are deposited on the upper layer of the soil by capillary action.



  - In the Rann of Kuchchh, the Southwest Monsoon brings salt particles and deposits there as a crust.

  - These soils are also formed when saline water spreads on the land at the time of high tide in coastal areas. Also, seawater intrusions in the deltas promote the occurrence of saline soils.

- Salinization also occurs because of over-irrigation (canal irrigation/groundwater use) and in areas of high water table (as in the coastal areas of Maharashtra and Tamil Nadu).Salinity from irrigation can occur over time wherever irrigation occurs. This is because almost all water (even natural rainfall) contains some dissolved salts. When the plants use the water, the salts are left behind in the soil and eventually begin to accumulate. Also, excessive irrigation with dry climatic conditions promotes capillary action, which results in the deposition of salt on the top layer of the soil (See the following figure).



- These are thus, Intrazonal soils.

- **Areas**: They occur in arid and semi-arid regions, and in waterlogged and swampy areas. These are more widespread in western Gujarat, deltas of the eastern coast and in Sunderban areas of West Bengal.

- **Soil Texture**: Their texture ranges from sandy to loamy.

- **Other characteristic features**:

  - Because of capillary action, the salts are sucked up in solution to the surface and form white encrustations on the surface (See the picture below).

  - The salt efflorescence of calcium, magnesium and sodium makes these soils infertile.

- Saline soils contain an excess of neutral soluble salts of chlorides and sulphates whereas sodic or alkali soils contain sodium carbonates/ sodium bicarbonates.
- They lack in nitrogen and calcium and have low water bearing capacity.
- These soils can be reclaimed by improving drainage, by applying gypsum and/or lime, and by cultivating salt resistant crops like barseem, dhaincha and other leguminous crops.
- The saline and alkaline soils may occur in any group of soils.

- **Crops grown**: In coastal areas, coconut trees are found in plenty in these soils. As discussed above, cultivating salt resistant crops like barseem, dhaincha and other leguminous crops can help in reclaiming these soils.
- **Note:** 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.

7. Peaty Soils

- These soils are locally called Kari in Kottayam and Alleppey districts of Kerala.
- **Formation**: These are marshy soils and are a result of water logging and anaerobic conditions (which leads to partial decomposition of organic matter).
- **Areas:** They are found in the areas of heavy rainfall and high humidity, where there is a good growth of vegetation. It occurs widely in the northern part of Bihar, the southern part of Uttaranchal and the coastal areas of West Bengal, Orissa and Tamil Nadu.
- **Soil Colour and Texture**: These soils are normally heavy and black in colour
- **Other characteristic features**:
  - → These soils are characterised by a rich humus and organic content.
  - → There is a presence of iron and varying amounts of organic matter (10-40%). The organic matter in these soils may go even up to 40-50 per cent.
  - → These soils are generally acidic in nature. But at many places, they are alkaline also.
- **Suitable crops**: These are generally submerged during the rainy season and utilised for the cultivation of rice.

8. Forest Soils

- **Formation:** As the name suggests, forest soils are formed in the forest areas where sufficient rainfall is available.
- **Areas**: These are found in the forest areas of Himalayas, Sahyadris, Eastern Ghats and terai region.
- **Soil colour and texture:** The soils vary in structure and texture depending on the mountain environment where they are formed. They are loamy and silty on valley sides and coarse-grained in the upper slopes. Their colour is dark brown.
- **Other Characteristics:**
    - In the snow-bound areas of the Himalayas, they are acidic with low humus content. This is because humus is rawer at higher levels. Also, these soils are subjected to denudation due to landslides and snowfall.
    - The soils found in the lower valleys are fertile and rich in organic content.
    - Owing to sharp differences of hill slopes and climates, these soils may differ greatly even when in proximity. [Recall here the discussion on the impact of topography on soils!]
    - Also, these soils exist in thin layers because of their development on the mountain slopes.
    - These soils are poor in potash, phosphorus and lime.
    - Soil erosion is a major problem in these areas.
- **Crops grown:** The slopes are used for horticulture and plantations crops like tea, coffee, spices, apple, peach etc. Rice and wheat are grown in valleys. Potatoes are grown in mostly all areas.

Now that we are done with all the soil types, expand the following image for a quick revision!

Venkateswarlu Nagineni

Soil Type	Other Names	Formation	Type	Distribution	Soil Texture	Soil Colour	Mineral Content		Other Characteristic Features	Suitable Crops
							Rich in	Deficient in		
Alluvial Soil		Derived from the debris brought down from the Himalayas or the silt left out by the retreating sea	Azonal	• Northern Plains and the River Valleys. • Parts of Rajasthan and Gujarat. • In the deltas of the east coast and in the river valleys in the peninsular region.	Sandy loam to clay	Light grey to ash grey	Potash and lime	Nitrogen, phosphorous and humus	• Soil profile has no stratification • Khadar and Bhangar in the upper and middle Ganga plain • Loess • These soils allow water to sink into lower strata • Lack nitrogen but capable of fixing nitrogen very rapidly through leguminous crops	Wheat, rice, maize, sugarcane, pulses, oilseeds, fruits and vegetables.
Black Soil	Regur Soil, Black Cotton Soil, Tropical Chernozems	Formed from the Deccan Trap rocks	Zonal	Parts of: • Maharashtra • Madhya Pradesh • Gujarat • Andhra Pradesh • Tamil Nadu	Clayey	Black	Lime, iron, magnesia and alumina	Phosphorous, nitrogen and organic matter	• Maintenance of fertility via 'self-aeration' and 'self ploughing' • Ability to retain moisture for a long time • Highly productive	Cotton, pulses, millets, linseed, tobacco, sugarcane, vegetables and citrus fruits
Red and Yellow Soil	Chalka	Derived from granites, gneisses and other metamorphic rocks under well drained conditions	Zonal	They encircle the black cotton soil zone. Specific Areas: • Along the piedmont zone of the Western Ghats • Parts of Orissa and Chhattisgarh • Southern parts of the middle Ganga plain	Varies from sand to clay and loam	Reddish; Yellow in hydrated form		Nitrogen, phosphorous and humus	• Fertile when fine-grained; coarse-grained soils found in dry upland areas are poor in fertility. • Have a porous and friable structure. • These soils are airy and need irrigation for cultivation. • Intense leaching	With irrigation: wheat, cotton, pulses, tobacco, millets, oilseeds, potato, maize, groundnut and orchards.
Laterite Soil		Formed in-situ under conditions of high rainfall with alternation dry and wet periods	Zonal	Found in higher areas of the Peninsular plateau. Specific Areas: Karnataka, Kerala, Tamil Nadu, Madhya Pradesh and the hilly areas of Orissa and Assam.		Reddish brown	Iron oxide and potash	Organic matter, nitrogen, phosphate and calcium	• With rain, lime and silica are leached away, and soils rich in iron oxide and aluminium compound are left behind • Generally low in fertility and acidic in character due to leaching • Soft when wet, hard and cloddy on drying; thus widely cut as bricks for use in house construction. • Represent the end product of decomposition • On account of excessive leaching, these soils are porous	Tree crops like cashewnut, also suitable for tea plantations.
Arid Soil		Derived from the disintegration of adjacent rocks and are largely blown from coastal regions and Indus valley.	Zonal	Western Rajasthan	Sandy to gravelly	Red to brown	Normal phosphate and iron content	Humus and Nitrogen	• saline in nature. • Lack moisture and humus. • Exhibit poorly developed horizons. • Plants are widely spaced. • Chemical weathering is limited. • 'Kankar' layer formation in the bottom horizons	Bajra, pulses, guar, fodder and less water requiring crops
Saline and Alkaline Soils	Usara, Reh, Kallar, and Chopan, Rakar, Thur, Karl	• Develop in areas with dry climatic conditions accompanied by lack of proper drainage • Develop because of over-irrigation (canal irrigation/groundwater use) and in areas of high water table. • Also develop in coastal areas	Intrazonal	Western Gujarat, deltas of the eastern coast and in Sunderban areas of West Bengal. Due to excessive irrigation, fertile alluvial soils in Punjab and Haryana are increasingly becoming saline.	Sandy to loamy		Saline soils: neutral soluble salts of chlorides and sulphates Alkaline soils: sodium carbonates/sodium bicarbonates	Nitrogen and calcium	• Because of capillary action, the salts are sucked up in solution to the surface and form white encrustations on the surface • Infertile but can be reclaimed by improving drainage, by applying gypsum and/or lime, and by cultivating salt resistant and leguminous crops. • Low water bearing capacity • May occur in any group of soils	Coconut trees found in coastal areas. Suitable crops: salt resistant crops like barseem, dhaincha and other leguminous crops can help in reclaiming these soils.
Peaty Soils	Kari	A result of water logging and anaerobic conditions.	Intrazonal	Found in the areas of heavy rainfall and high humidity. Specific Areas: The northern part of Bihar, southern part of Uttaranchal and the coastal areas of West Bengal, Orissa and Tamil Nadu.		Black	Rich humus and organic content, a presence of iron.		• Generally acidic in nature. But at many places, they are alkaline too. • Generally submerged during the rainy season	Rice
Forest Soils		Formed in the forest areas where sufficient rainfall is available.	Zonal	Forest areas of Himalayas, Sahyadris, Eastern Ghats and Terai region.	Loamy and silty on valley sides and coarse-grained in the upper slopes.	Dark brown		Potash, phosphorus and lime	• Acidic with low humus content in the snow-bound areas of the Himalayas. • Soils found in the lower valleys are fertile and rich in organic content. • Exist in thin layers	On the slopes: horticulture and plantations crops like tea, coffee, spices, apple, peach etc. In the valleys: Rice and wheat. Potatoes are grown in mostly all areas.

Major Soil Types of India (Classification by ICAR)

Indian Geography

Source: Civils Daily

8. Irrigation

Sources and Methods of Irrigation

The monsoonal rainfall in India is concentrated only in four months and more than 50% of the net sown area is rainfed only. Irrigation is thus essential to overcome spatial and temporal variation of rainfall.

Archaeological and historical records show that from ancient times we have been constructing sophisticated hydraulic structures like dams built of stone rubble, reservoirs or lakes, embankments and canals for irrigation. Not surprisingly, we have continued this tradition in modern India by building dams in most of our river basins. Before we look at these methods of irrigation in detail, let's have a look at some of the hydraulic structures used in ancient India!

Some Hydraulic Structures used in Ancient India:

- In the first century BC, Sringaverapura near Allahabad had sophisticated water harvesting system channeling the flood water of the river Ganga.
- During the time of Chandragupta Maurya, dams, lakes and irrigation systems were extensively built.
- Evidences of sophisticated irrigation works have also been found in Kalinga (Orissa), Nagarjunakonda (Andhra Pradesh), Bennur (Karnataka), Kolhapur (Maharashtra), etc.
- In the eleventh century, Bhopal Lake, one of the largest artificial lakes of its time was built.
- In the 14th century, the tank in Hauz Khas, Delhi was constructed by Iltutmish for supplying water to the Siri Fort Area.

Coming back to irrigation in the present day India, let's look at some important facts and figures before we move forward:

Some important facts and figures:

- The net irrigated area = 66.1 million hectares.
- Total/Gross Irrigated Area = 92.6 million hectares.
- Irrigation Intensity in India = (Gross Irrigated Area ÷Gross Sown Area) * 100

  = (92.6 ÷ 194.4) *100 = 47.6%

More than 50% of the country's cropped area depends exclusively on rainfall, most of which is concentrated in a few months of the year. Even where the annual overall precipitation is high, the available moisture is not adequate to support multiple cropping.

Ultimate Irrigation Potential:

As seen in the above figures, only about 66mha i.e. 47.6% of the net sown area is estimated to be irrigated. There is a need to bring more cropped area under assured irrigation so as to increase agricultural productivity and production.

The total ultimate irrigation potential of the country has been estimated as 140mha, with about 76 mha from surface water sources and about 64mha from groundwater sources.

Irrigation – Sources and Methods

The main sources of irrigation in India are:

1. Canals
2. Wells (and tube wells)
3. Tanks

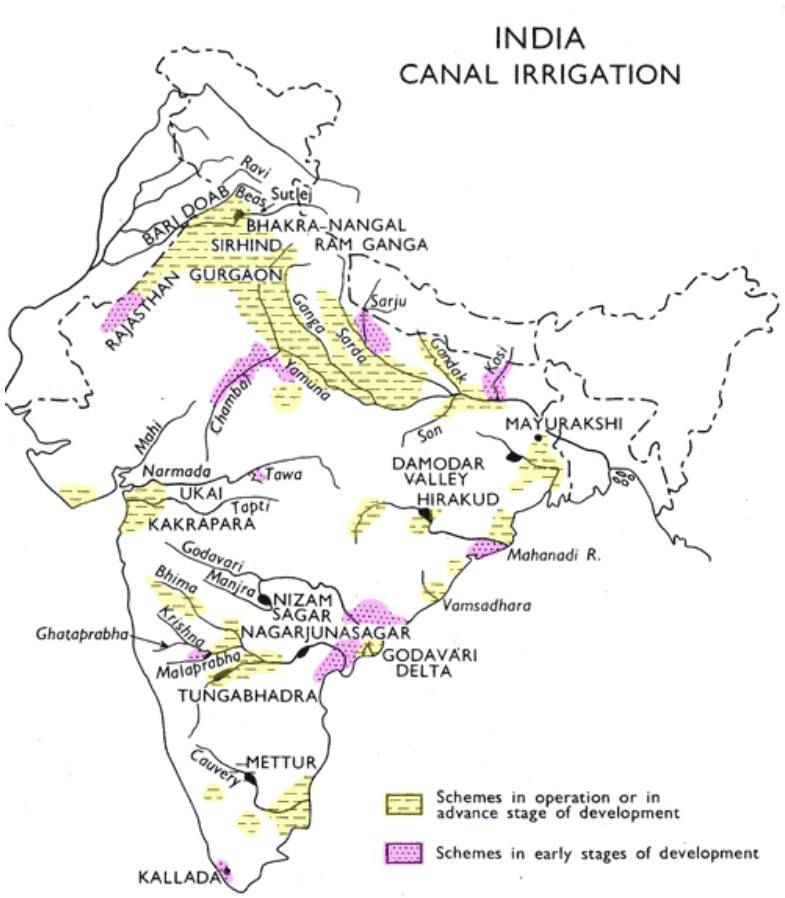
The relative importance of these has been changing from time to time. Let's look at these in detail:

1. Canal Irrigation:

- A canal is an artificial watercourse constructed for water supply and irrigation.

Sardar Sarovar Canal in Gujarat

- There are two types of canals:
    1. *Inundation Canals* – These are taken out from the rivers without any regulating system like weirs etc at their head. Such canals are useful only during the rainy season
    2. *Perennial Canals* – These are those which are taken off from perennial rivers by constructing a barrage across the river. Most of the canals at present in India are perennial.
- Canals can be an effective source of irrigation in areas of low relief, deep fertile soils, perennial source of water and an extensive command area. Therefore the main concentration of canal irrigation is in the northern plains.
- The canals are practically absent from the peninsular plateau region because of rocky terrain. However, the coastal and the delta regions in South India have some canals for irrigation.



Canal Irrigation in India

- The percentage of canal irrigation area to total irrigated area in the country has fallen from about 40% in 1950-51 to less than 25% at present.
- The states UP, Punjab, Haryana, Rajasthan and Bihar account for about 60% of the canal irrigated area in the country.
- *Merits of canal irrigation*:
  - → Perennial Source
  - → Provides safety from droughts
  - → Brings fertile sediments to the fields
  - → Economical to serve a large area
- *Demerits*:
  - → Canal water soaks into the ground and leads to water logging, increases salinization, and leads to marshy conditions leading to malaria and flooding
  - → Wastage of water.

2. Wells (and Tube Wells)

- A well is a hole dug in the ground to obtain the subsoil water. An ordinary well is about 3-5 metres deep but deeper wells up to 15 metres are also dug.
- This method of irrigation has been used in India from time immemorial. Various methods are used to lift the ground water from the well. Some of the widely used methods are the Persian wheel, reht, charas or mot, and dhinghly (lever) etc.
- A tube well is a deeper well (generally over 15 metres deep) from which water is lifted with the help of a pumping set operated by an electric motor or a diesel engine.

A Tube well

- Well irrigation is gradually giving way to energized tube wells. But there are many wells still in use where electricity is not available or the farmers are too poor t0 afford diesel oil.
- This method of irrigation is popular in those areas where sufficient sweet ground water is available.
- It is particularly suitable in areas with permeable rock structure which allows accumulation of ground water through percolation. Therefore wells are seen more in areas with alluvial soil, regur soil, etc. and less seen in rocky terrain or mountainous regions.
- These areas include a large part of the great northern plains, the deltaic regions of the Mahanadi, the Godavari, the Krishna and the Cauvery, parts of the Narmada and the Tapi valleys and the weathered layers of the Deccan trap and crystalline rocks and the sedimentary zones of the peninsula
- However, the greater part of peninsular India is not suitable for well irrigation due to rocky structure, uneven surface and lack of underground water.
- Large dry tracts of Rajasthan, the adjoining parts of Punjab, Haryana and Gujarat and some parts of Up have brackish ground water which is not fit for irrigation and human consumption and hence unsuitable for well irrigation
- At present irrigation from wells and tube wells accounts for more than 60% of the net irrigated area in the country.
- UP has the largest area under well irrigation which accounts for 28% of the well irrigated area of the country. U.P., Rajasthan, Punjab, Madhya Pradesh, Gujarat, Bihar and Andhra Pradesh account for about three-fourths of the total well-irrigated area
- *Merits of well irrigation*
    - ✓ Simplest and Cheapest
    - ✓ Well is an independent source of irrigation and can be used as and when the necessity arises. Canal irrigation, on the other hand, is controlled by other agencies and cannot be used at will.
    - ✓ Some ground water salts are useful for crops
    - ✓ Does not lead to salinization and flooding problems
    - ✓ There is a limit to the extent of canal irrigation beyond the tail end of the canal while a well can be dug at any convenient place.

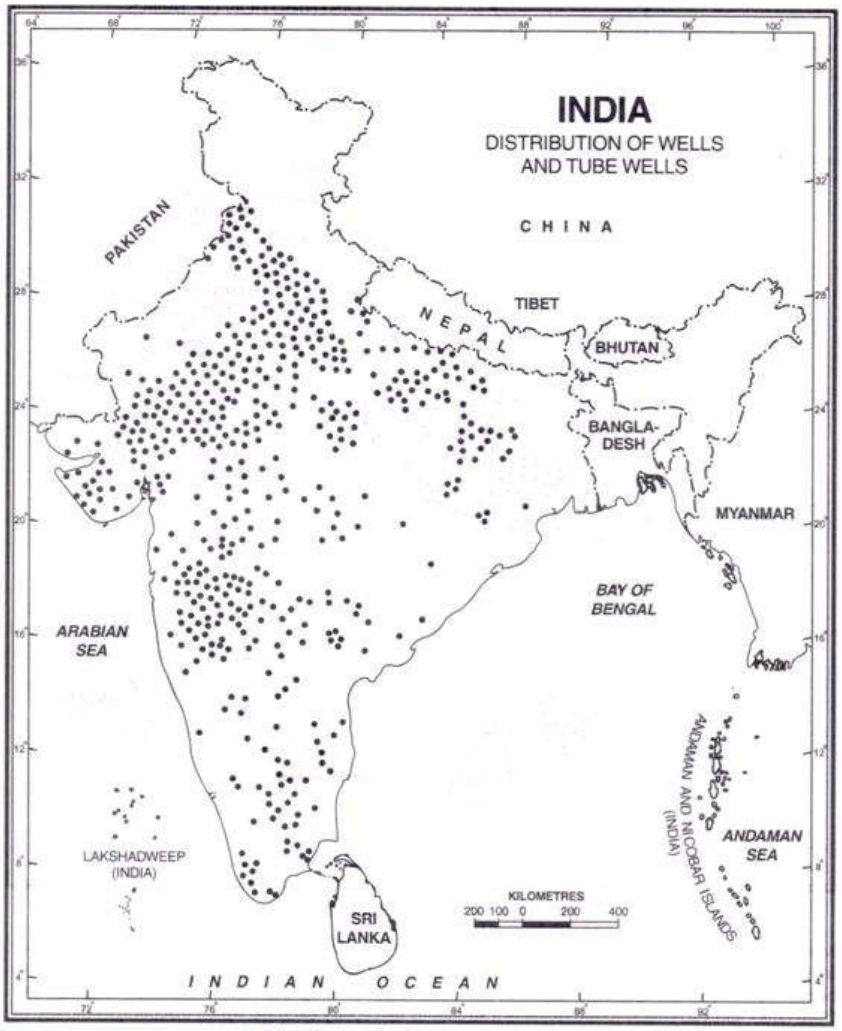


FIG. 17.3. India : Distribution of Wells

- *Demerits*
  - ✓ Only limited area can be irrigated. Normally, a well can irrigate 1 to 8 hectares of land.
  - ✓ Not suitable for dry regions
  - ✓ Overuse may lead to lowering of water table

3. Tank irrigation

- A tank is a reservoir for irrigation, a small lake or pool made by damming the valley of a stream to retain the monsoon rain for later use.

A Tank in Tamil Nadu

- It accounts for approximately 3% of the net irrigated area in India.
- Tank Irrigation is popular in the peninsular plateau area where Andhra Pradesh and Tamil Nadu are the leading states.
- Andhra Pradesh has the largest area (29%) of tank irrigation in India followed by Tamil nadu (23%).
- It is practiced mainly in the peninsular region due to the following reasons:
  - → The undulating relief and hard rock's make it difficult to dig canals and wells
  - → There is little percolation of water due to hard rock structure and ground water is not available in large quantities.
  - → Most of the rivers are seasonal; there are many streams which become torrential during the rainy season – so the only way to use this water is to impound it by constructing bunds and building tanks. Also, it is easy to collect rainwater in natural or artificial pits because of impermeable rocks.
  - → Scattered nature of agricultural fields
- *Merits*
  - → Most of the tanks are natural and do not involve cost for their construction
  - → Independent source for an individual farmer or a small group of farmers
  - → longer life span
  - → can be used for fishing also

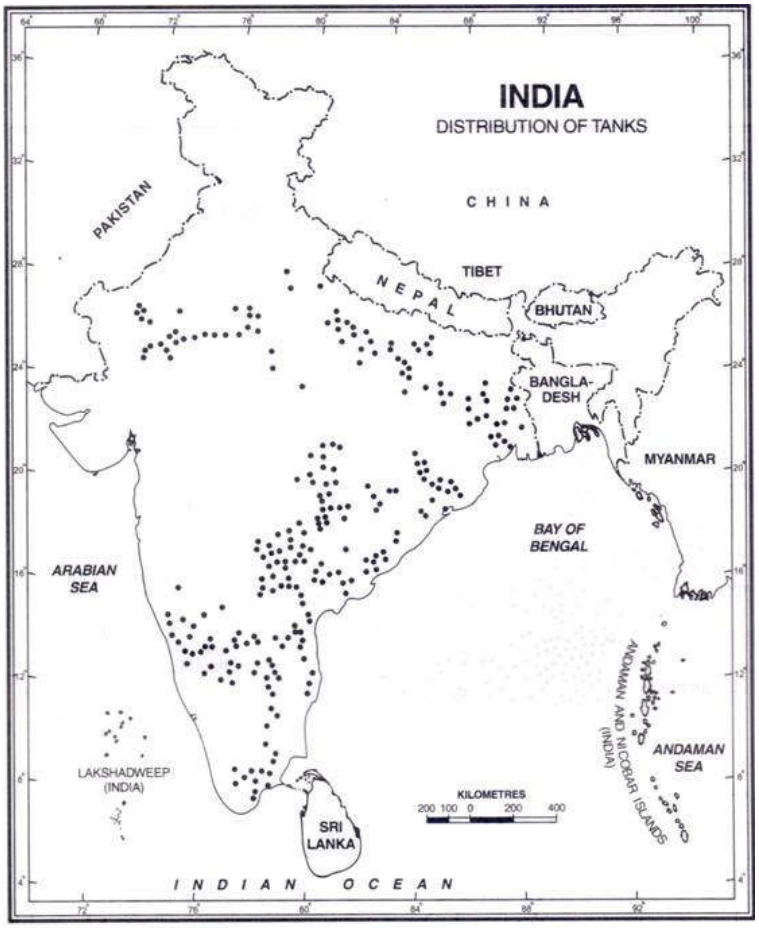


FIG. 17.2. India : Distribution of Tanks

Tank Irrigation in India

- *Demerits*
  - → Depends on rain and these tanks may dry up during the dry season
  - → Silting of their beds
  - → Require large areas
  - → Evaporation losses
  - → Sometimes there might be a need to lift the water to take it to the field

Venkateswarlu Nagineni

Multipurpose River Valley Projects

Dams were traditionally built to impound rivers and rainwater that could be used later to irrigate agricultural fields. Today, dams are built not just for irrigation but for:

- electricity generation,
- water supply for domestic and industrial uses,
- flood control,
- recreation,
- inland navigation,
- Fish breeding etc.

Hence dams are now referred to as multipurpose projects where the many uses of the impounded water are integrated with one another. For example, in the Satluj-Beas river basin, the Bhakra Nangal project water is being used both for Hydel power production and irrigation. Similarly, the Hirakud project in the Mahanadi basin integrates conservation of water with flood control.

Multipurpose projects, launched after independence with their integrated water resources management approach, were thought of as the vehicle that would lead the nation to development and progress. But in the recent years, multipurpose projects and large dams have come under great scrutiny for a variety of reasons:

- Regulating and damming of rivers affects their natural flow causing poor sediment flow and excessive sedimentation at the bottom of the reservoir, resulting in rockier stream beds and poorer habitats for the rivers' aquatic life.
- Dams also fragment rivers making it difficult for the aquatic fauna to migrate, especially for spawning.
- The reservoirs that are created on floodplains also submerge the existing vegetation and soil leading to its decomposition over a period of time.
- In geologically unstable areas, development of large dams can destabilize the land. The 2013 Uttarakhand Floods triggered a debate on whether the hydropower projects operational in Uttarakhand were responsible for the floods that killed more than 1000 people.
- Inter-state water disputes are also becoming common with regard to sharing the costs and benefits of the multipurpose projects.

A List of Important River Water Projects in India:

Project	River	Related State
Bansagar Project	Son	Bihar Uttar Pradesh Madhya Pradesh
Bargi Project	Bargi	Madhya Pradesh
Beas Project	Beas	Haryana

		Punjab Rajasthan
Bhadra Project	Bhadra	Karnataka
Bhakhra Nangal Project	Sutlej	Punjab, Himachal Pradesh , Haryana, Rajasthan
Bheema Project	Pawana	Maharashtra
Chambal Project	Chambal	Rajasthan Madhya Pradesh
Damodar Ghati Project	Damodar	Jharkhand West Bengal
Dulhasti Project	Chenab	Jammu & Kashmir
Durga Barrage Project	Damodar	West Bengal Jharkhand
Farakka Project	Ganga, Bhagirathi	West Bengal
Gandak Project	Gandaki	Bihar, Uttar Pradesh
Ganga Sagar Project	Chambal	Madhya Pradesh
Ghatprabha Project	Ghatprabha	Karnataka
Girna Project	Girna	Maharashtra
Hansdev Bango Project	Hansdev	Madhya Pradesh
Hidkal Project	Ghatprabha	Karnataka
Hirakud Project	Mahanadi	Orissa
Idduki Project	Periyar	Kerala

Indira Gandhi Canal Project	Satlaj	Rajasthan Punjab Haryana
Jawahar Sagar Project	Chambal	Rajasthan
Jayakwadi Project	Godawari	Maharashtra
Kakrapara Project	Tapti	Gujarat
Kangsawati Project	Kangsawati	West Bengal
Kol Dam Project	Sutlaj	Himachal Pradesh
Kosi Project	Kosi	Bihar & Nepal
Koyana Project	Koyana	Maharashtra
Krishna Project	Krishna	Karnataka
Kunda Project	Kunda	Tamilnadu
Let Bank Ghaghra Canal	Ganaga	Uttar Pradesh
Madhya Ganaga Canal	Ganaga	Uttar Pradesh
Mahanadi Delta Project	Mahanadi	Odisha
Malprabha Project	Malprabha	Karnataka
Mandi Project	Vyas	Himachal Pradesh
Matatilla Project	Betwa	Uttar Pradesh Madhya Pradesh
Mayurakshi Project	Mayurakshi	West Bengal
Minimato Bango Hasdeo Project	Hasdeo Bango river	Madhya Pradesh
Muchkund Project	Muchkund	Odisha Andhra Pradesh
Nagarjunsagar Project	Krishna	Andhra Pradesh

Nagpur Power Project	Koradi	Maharashtra
Narmada Sagar Project	Narmada	Madhya Pradesh Gujarat
Nathpa Jhakri Project	Sutlaj	Himachal Pradesh
Panam Project	Panam	Gujarat
Panama Project	Panama	Gujarat
Panchet Project	Damodar	Jharkhand West Bengal
Pong Project	Beas	Punjab
Poochampad Project	Godawari	Andhra Pradesh
Purna Project	Purna	Maharashtra
Rajasthan Canal Project	Sutlej, Vyas, Ravi	Rajasthan Punjab Haryana
Ramganga Project	Ramganga	Uttar Pradesh
Rana Pratap Sagar Project	Chambal	Rajasthan
Ranjeet Sagar Project	Ravi	Punjab
Rihand Project	Rihand	Uttar Pradesh
Salal Project	Chenab	Jammu & Kashmir
Sardar Sarovar Project	Narmada	Madhya Pradesh Maharashtra Rajasthan
Sarhind Project	Sutlaj	Haryana
Sharawati Project	Sharawati	Karnataka

Sharda Project	Sharda, Gomti	Uttar Pradesh
Shivsamundram Project	Kaveri	Karnataka
Sutlaj Project	Chenab	Jammu & Kashmir
Tawa Project	Tawa	Madhya Pradesh
Tehri Dam Project	Bhagirathi	Uttarakhand
Tilaiya Project	Barakar	Jharkhand
Tulbul Project	Chenab	Jammu & Kashmir
Tungabhadra Project	Tungabhadra	Andhra Pradesh. Karnataka
Ukai Project	Tapti	Gujarat
Upper Penganga Project	Penanga	Maharashtra
Uri Power Project	Jhelum	Jammu & Kashmir
Vyas Project	Vyas	Rajasthan Punjab Haryana Himachal Pradesh

Irrigation Application Methods

Irrigation water is generally applied to crops by:

- → Flooding on the field surface
- → Applying beneath the soil surface
- → Spraying under pressure
- → Applying in drops in the crop root zone

The application method must ensure a uniform distribution of water along the cropped field as well as in the root zone of the crop with high application efficiency. The ratio of water stored in the root zone to that delivered to the field should be maximum. There should be minimum or no wastage of water either through surface run-off or deep percolation below the root zone of a crop.

Several water application methods are practiced to suit different soil types, water supply and its quantity, the topography of the land, crops to be irrigated and costs.

Surface Application Methods:

- In this method, water is applied to the crop by flooding it on the soil surface.
- This method requires proper land grading for the flow of water over the land surface.
- More than 95% of the irrigated area in India is under surface irrigation.
- ***Merits***:
  - ✓ It is simple in layout and operation.
  - ✓ The amount of manual labour required is minimum.
  - ✓ It does not obstruct the use of machinery for land preparation, cultivation, harvesting, etc.
- ***Demerits***:
  - ✓ The overall irrigation efficiency is low. The worldwide average irrigation in canal command areas shows an overall efficiency of as low as 28%.
  - ✓ It may result in water=logging and soil salinization besides the huge amount of water losses.
- Surface Irrigation methods may be broadly classified as:

Border Method:

- Borders are formed by dividing the field into a number of strips which are separated by ridges.
- The strips are generally levelled along the width but may or may not have slope along the length.
- An irrigation channel runs along the upper end of the borders.

- The water is diverted from the channel into the strips. The water flows slowly towards the lower end, wetting the soil as it advances. Extra water is generally removed from the strip by means of a collecting drain. It is provided at the other end.
- This method is suitable in the fields where the soil is sufficiently capable of absorbing the water.

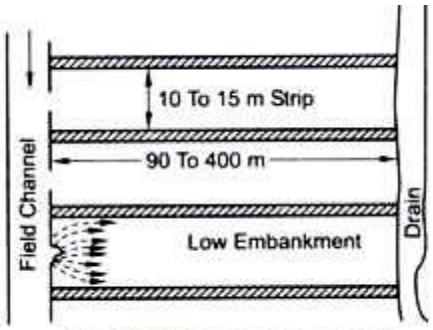


Fig. 6.2. Border strip method

Furrow Method:

- Furrow irrigation is adaptable to a great variation in slope, crops and topography.
- When the crops are grown and planted in rows this method is the best suited. In this method, unlike flooding, only a part of the field is wetted. The area wetted varies from 1/2 to 1/5 of total area over which crops are grown.
- Close growing crops, on slopes and soils that develop crust after being wet, may be irrigated with small furrows which are called corrugations or rills.

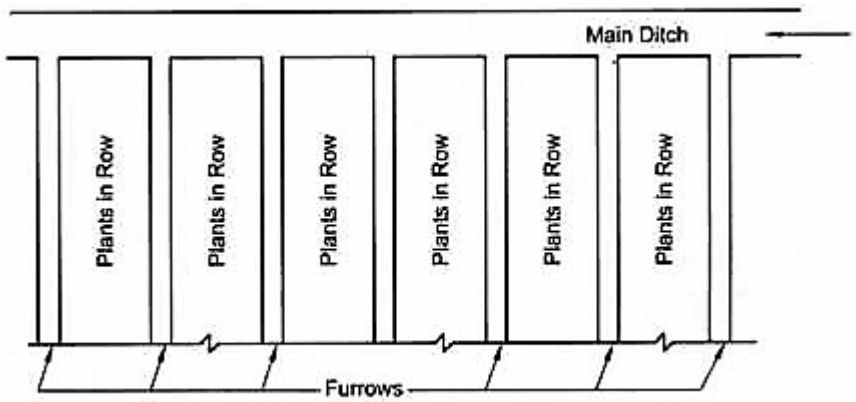
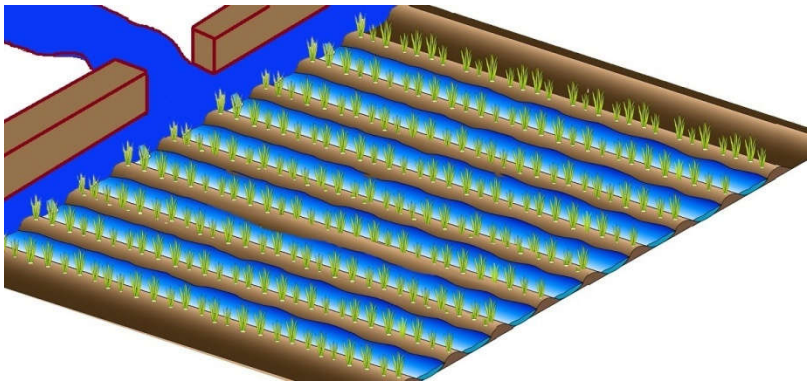


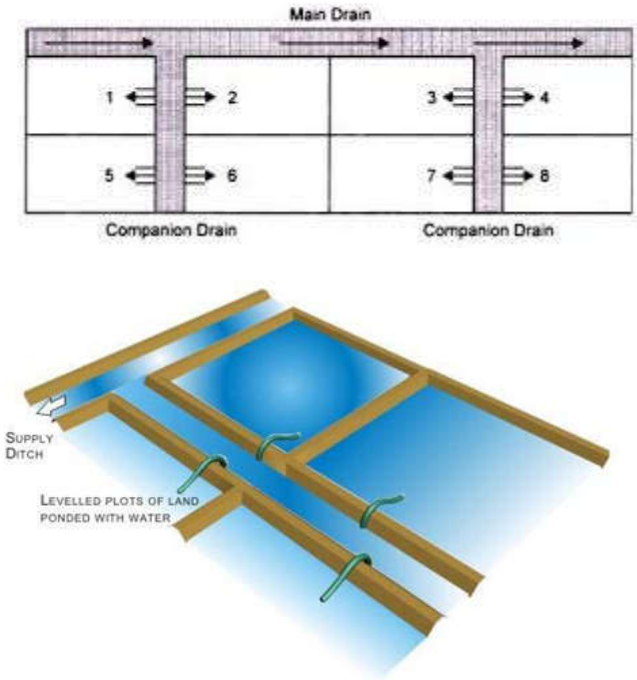
Fig. 6.5 Furrow Irrigation



- The main design parameters of furrows are
  - Longitudinal slope
  - Inflow stream design
  - Furrow spacing:
    - ✓ Furrow spacing should be such that the lateral water movement of the moisture wets the ridges by the time irrigation is complete. The lateral movement from the furrows depends on the soil type.
    - ✓ Furrow spacing is determined by agronomic requirements of row-to-row spacing and machinery to be used for planting and cultivation.
    - ✓ Furrow length: Longer furrows = more percolation and less run-off
  - **Benefits of this method**:
    - ✓ In this method plants in their early tender age are not damaged by the flow of water.
    - ✓ The land between the rows of plants is utilised to construct furrows, therefore useful irrigable land is not wasted.
    - ✓ As the area wetted is just 1/2 to 1/5 of the cropped area of the field, puddling and crusting of the soil is minimum.
  - **Check basin**:
    - ✓ It consists of running water into relatively level plots surrounded by small ridges.
    - ✓ The length of the plot is generally less than 3 times the width.

- ✓ The main and lateral channels irrigate The main channel is aligned along the upper end of the field and checks are made on the either side of the lateral channels.

Figure 8.1
Check Basin Method



- ✓ The check basins are especially suitable for heavy soils with low infiltration rate or highly permeable sandy soils.
- ✓ The key to attaining high irrigation efficiency in the design of the check basin is to spread water over the entire basin as rapidly as possible.
- ✓ Therefore, the use of large inflow stream reduces water spread time over the basin.

Sprinkler and Micro-Sprinkler Application:

- ***Sprinklers:***
  - This system sprinkles water in a manner similar to rainfall so that run-off and deep percolation losses are avoided and the uniformity of application is quite high.
  - The system consists of sprinkler heads or nozzles, which are mounted on risers in lateral lines taken from the main line, which is further connected to a pumping unit.

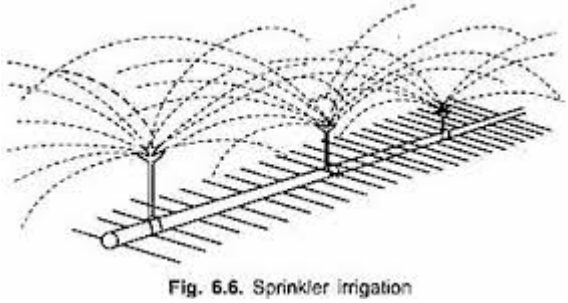


Fig. 6.6. Sprinkler Irrigation

- This system of irrigation is suitable when:
  - The soil is too porous for good distribution by surface irrigation.
  - The fields have an uneven surface.
  - The soil is easily erodable.
  - The water supply is just sufficient for crop growth.
- ***Merits:***
  - Sprinklers can be used on all soil types of any topography.
  - It entails increased irrigation frequency which has a positive effect on crop yield.
  - In this method, a water saving of 30% to 50% is reported in comparison to the surface method of irrigation
  - Thus by introducing sprinklers, an additional area ~ up to 50% can be brought under irrigation besides increased crop yields
  - The overall efficiency of the system is above 80% and no land is wasted on making bunds and channels, and about 40-50% of saving in labour as compared to surface irrigation.
  - Only 2 to 5% water is lost through evaporation.

- ***Demerits:***
  - Expensive
  - Requires continuous maintenance and skill for installation and operation
  - The high energy requirement for operation as sprinklers operates at water pressure ranging from 1 to 10 kg/sq cm.
  - Wind interferes with the distribution pattern. It reduces the spreading rate and in turn the efficiency. Under high temperatures and strong winds heavy evaporation loss takes place thereby offsetting the saving in water.
- **Micro-sprinklers**:
  - It sprinkles around the root zone with small sprinklers that work under low pressure.
  - In this method, water is applied only to the root zone area unlike to the entire field as in the case of sprinkler irrigation method.
  - This method is highly suitable for orchard crops and vegetable crops.

- ***Drip Application***
  - In this method, the application of water is precise but slow as discrete drops, continuous drops, tiny streams or miniature sprays through mechanical devices, called emitters or applicators located at selected points along water delivery lines.
  - This is useful in areas with water scarcity and salt problems.
  - Drip irrigation system consists of main pipe, sub-mains, lateral valves, drippers or emitters, a riser valve, vacuum breakers, pressure gauges, water metres, filters, fertiliser tanks etc.
  - These are designed to supply water at desired rates (1 to 10 liters/hour) directly to the soil.
  - Low pressures ranging from 0.35 to kg/sq cm are sufficient for drip system

- ***Merits***:
  - Water saving
  - Enhanced plant growth and yield
  - Saving of labour and energy
  - More suited to poor soils
  - Controls weed growth
  - Easy operations
  - Fertilisers or other chemical amendments can be efficiently applied to individual or separate plants using drip irrigation.
  - Flexibility in operation
  - No soil erosion
  - Requires less land preparation
  - Minimum disease and pest problems
  - This method has been found to be of great value in reclaiming and developing desert and arid areas.
- ***Demerits***:
  - Expensive
  - Technical Limitations
  - Requirement of high skills for design, installation and operation

9. Agriculture

Agriculture and the Indian Economy:

Agriculture plays a vital role in India's economy. 54.6% of the population is engaged in agriculture and allied activities (census 2011) and it contributes 17.4% to the country's Gross Value Added. Besides, agriculture is an important source of raw material for industrial production and serves as a huge market for industrial products.

"It is in the agriculture sector that the battle for long term economic development will be won or lost."- Gunnar Myrdal

Before we study this important sector, let's look at some basic terms and statistics:

Some Important Terms and Statistics:

1. ***Total Geographical Area of India:***

As per the land use statistics 2012-13, the total geographical area of the country is 328.7 million hectares. The latest figures of geographical area of the State/Union Territories are as provided by the Office of the Surveyor General of India.

2. ***Total Reporting Area for Land Utilisation Statistics:***

The Reporting area stands for the area for which data on land use classification are available. As per the land use statistics 2012-13, the total reporting area is 305.9 million hectares. [*Difference between the total geographical area and reporting area is on account of mapping issues due to difficult terrain + disputed land between India-Pak & India- China]*

3. ***Net Sown Area:***

This represents the total area sown with crops and orchards. The area sown more than once in the same year is counted only once.

Net Sown Area in India: 139.9 million hectares (42.57% of the total geographical area)

4. ***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.

Gross Cropped Area in India: 194.4 million hectares (59.14% of the total geographical area)

5. *Cropping Intensity*

It is the ratio of the Total Cropped Area (or the gross cropped area) to the Net Area Sown.

Cropping Intensity in India = (Gross Cropped Area ÷Net Area Sown) * 100

= (194.4 ÷ 139.9) * 100

= 138.9%.

Therefore, more the use of arable land during a year more is the cropping intensity. Cropping Intensity depends on a number of factors:

- *Natural factors* – More in areas with high temperatures and rainfall, cultivation is not possible in areas of cold climates/frost etc.
- *Socio-economic factors* – Often the lands near towns have more cropping intensity because of higher demand of fruits, vegetables, flowers etc in urban areas.
- *Institutional Factors* – Availability of irrigation facilities, good quality seeds, fertilizers etc also impacts the cropping intensity of a region. Eg. Higher cropping intensity in Punjab because of better infrastructural and institutional facilities.

6. *Fallow land*

Fallow land includes the land out of cultivation for one to five years.

7. *Culturable Waste:*

It includes the areas which can be brought under cultivation by efforts.

Box 2.1: Land Use in India

- Forest area: 70 mha (21.30per cent)
- Non-agricultural uses: 26.5 mha (8.05per cent)
- Barren & uncultivable: 17.3 mha (5.26per cent)
- Culturable waste:12.6 mha (3.83per cent),
- Permanent pastures:10.2 mha (3.12per cent)
- Miscellaneous tree crops: 3.2 mha (0.96per cent)
- Fallow land: 26.3 mha (8per cent),
- Agricultural land: 181.95 mha (55.3per cent)
- Net Sown Area: 139.9 mha (42.57per cent)

Source: Land Use Statistics (2012-13), Ministry of Agriculture & Farmers Welfare

Determinants of Agriculture

The following factors determine the cropping pattern, yield of crops and overall agricultural development:

1. Physical factors – Topography, Climate and Soil
2. Institutional factors – Land holding size, land tenure
3. Infrastructural factors – Irrigation, Electricity, Credit, Roads, Storage, Marketing
4. Technological factors – High Yielding Variety (HYV) seeds, fertilisers, insecticides, pesticides, farm machinery.

Types of Farming:

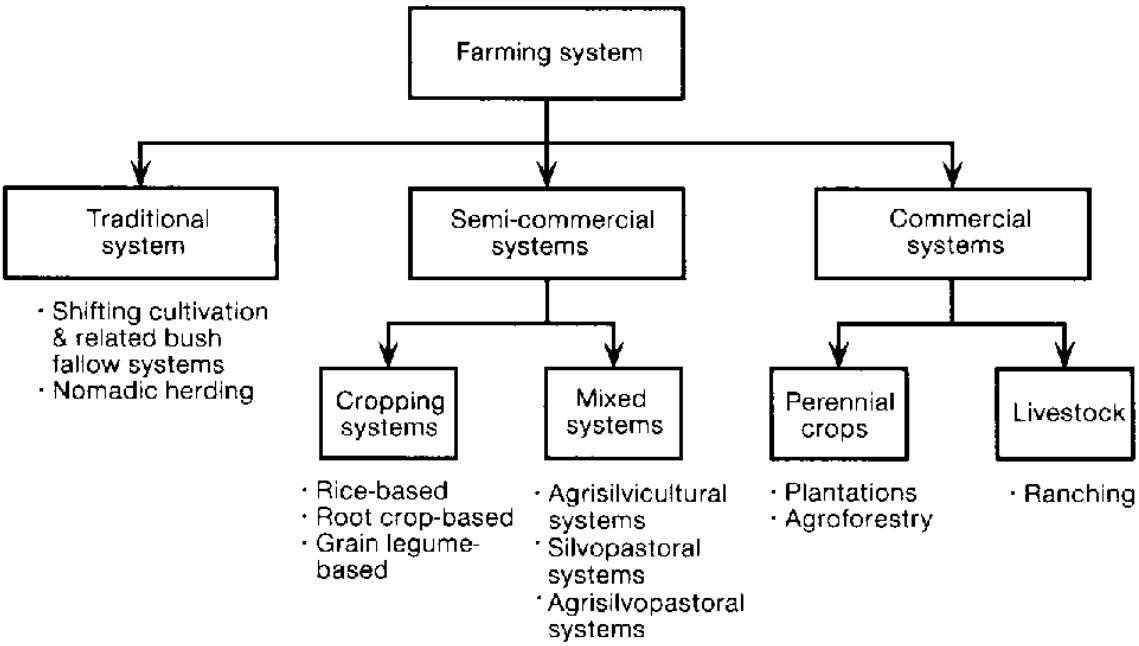
Agriculture is an age-old economic activity in our country. Over the years, cultivation methods have changed quite significantly depending on the above-mentioned factors. Farming varies from subsistence to commercial type.

Following are the 8 major farming systems practiced in India:

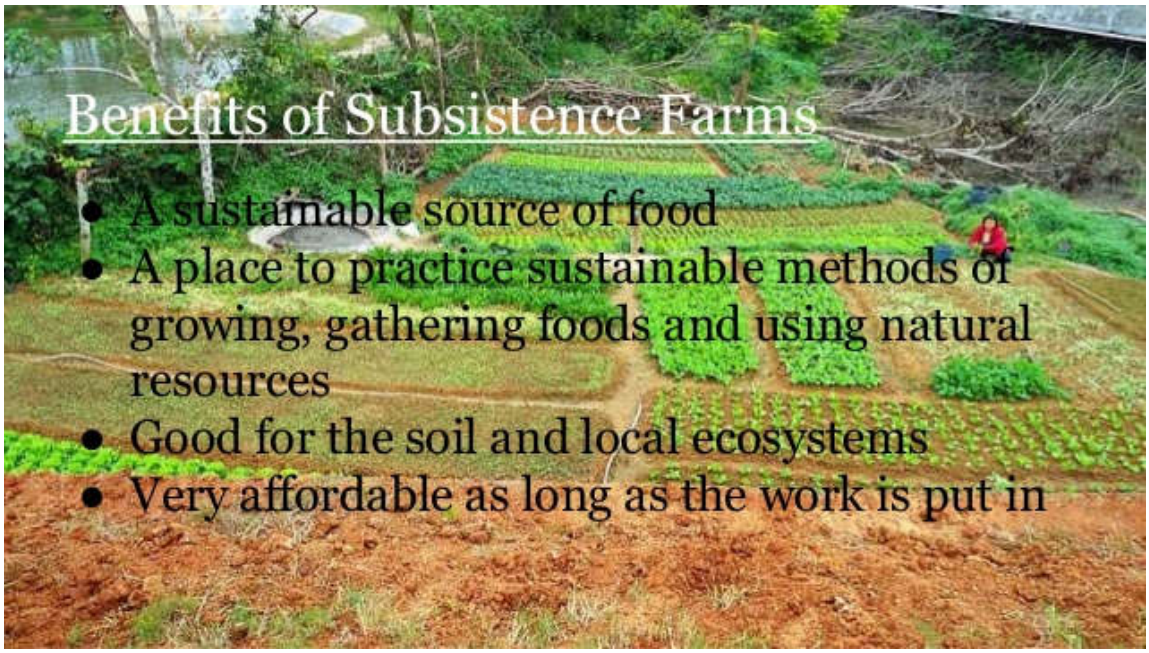
1. Subsistence Farming
2. Shifting Agriculture
3. Plantation Agriculture
4. Intensive Farming
5. Dry Agriculture
6. Mixed and Multiple Agriculture
7. Crop-Rotation
8. Terrace Cultivation

The 8 Major Types of Farming Systems in India

Based primarily on nature of land, climatic characteristics and available irrigational facilities, the farmers in India practice different types of farming.



1. Subsistence Farming:

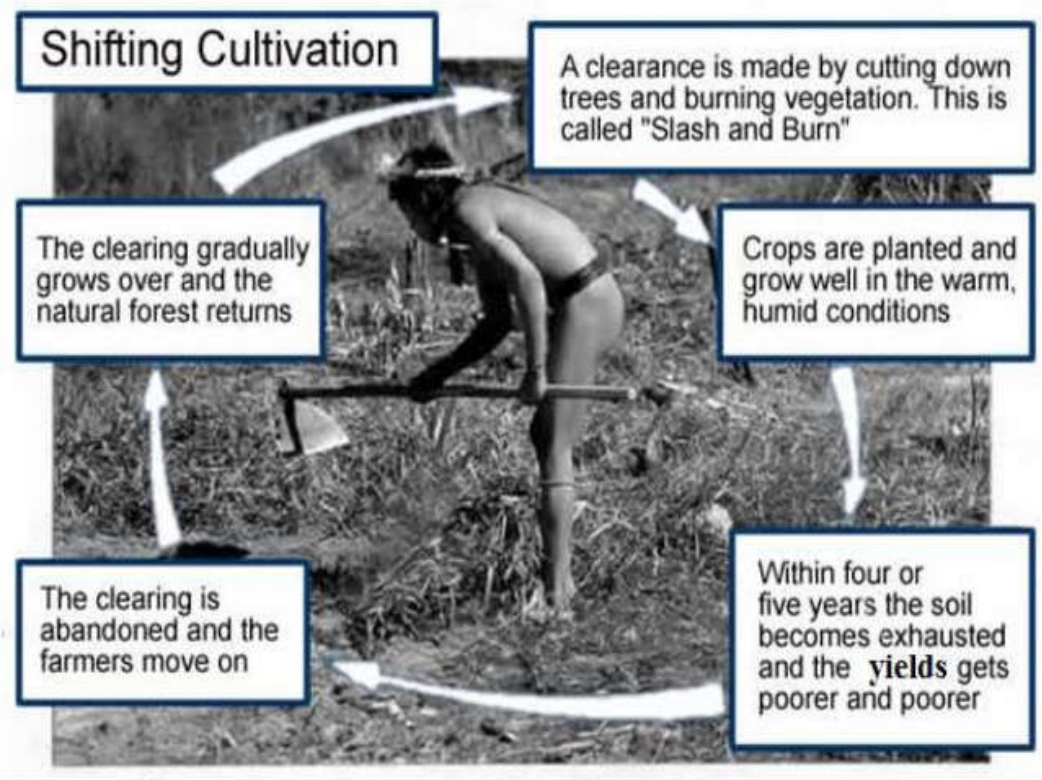


- Majority of farmers in the country practice subsistence farming.
- It is characterised by small and scattered land holdings and use of primitive tools.
- As the farmers are poor, they do not use fertilisers and high yielding variety of seeds in their fields to the extent they should do.
- Facilities like electricity and irrigation are generally not available to them.

Features of Subsistence Farming:

- → The whole family works on the farm
- → Most of the work is done manually
- → The farms are small
- → Tradition methods of farming are followed
- → Yield is not very high
- → Most of the yield is consumed by the family with very little surplus for the family

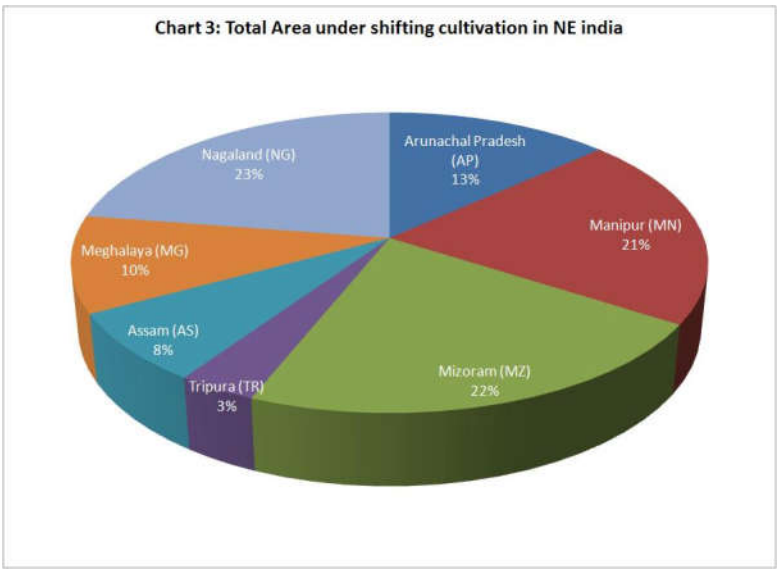
2. Shifting Agriculture:



- In this type of agriculture, first of all a piece of forest land is cleared by felling trees and burning of trunks and branches.
- After the land is cleared, crops are grown for two to three years and then the land is abandoned as the fertility of the soil decreases.
- The farmers then move to new areas and the process is repeated.
- *Dry paddy, maize, millets and vegetables are the crops commonly grown in this type of farming.*

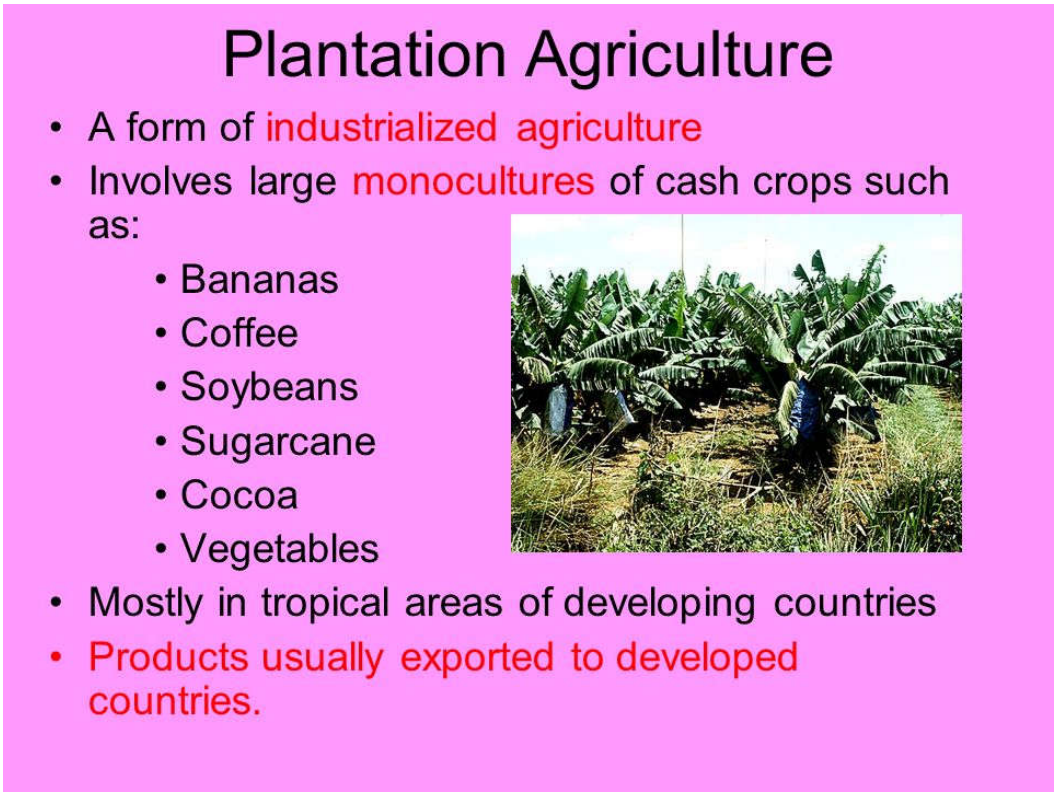
This practice is known by different name in different regions of India like:

1. Jhum in Assam,
2. Ponam in Kerala,
3. Podu in Andhra Pradesh and Odisha and
4. Bewar masha penda and Bera in various parts of Madhya Pradesh.



As far as possible governments have tried to discourage this practice of cultivation by tribals due to wasteful nature such as soil erosion caused by it, when soil erosion caused by it, when soils are not under cultivation.

3. Plantation Agriculture:



- Plantation farming is bush or tree farming. It was introduced by the British in the 19th century.
- **It is a single crop farming** of rubber, tea, coffee, cocoa, spices, coconut and fruit crops like apples, grapes, oranges, etc.
- It is capital intensive and demands good managerial ability, technical know-how, sophisticated machinery, fertilisers, irrigation, and transport facilities.
- Plantation agriculture is an **export-oriented agriculture.** Most of the crops grown in plantation agriculture have a life cycle of more than two years.
- Natural rubber, coconuts, oil palm, tea, cocoa, and coffee are all tree crops and take years to mature, but afterwards they are productive for long periods.
- Plantation agriculture **is confined within tropical areas, i.e., both sides of the equator.** Plantations exist on every continent possessing a tropical climate.

Some of the plantations like tea, coffee and rubber have a processing factory within the farm itself or close to it.

This type of agriculture has developed in hilly areas of north-eastern India, sub-Himalayan West Bengal and in Nilgiri, Anamalai and Cardamom hills in peninsular India.

4. Intensive Farming:

In areas where irrigation has been possible, the farmers use fertilisers and pesticides on large scale. They have also brought their land under high yielding variety of seeds. They have mechanised agriculture by introducing machines in various processes of farming.

Also known as industrial agriculture, it is characterized by a low fallow ratio and higher use of inputs such as capital and labour per unit land area. This is in contrast to traditional agriculture in which the inputs per unit land are lower.

Remember Intensive Agriculture Development program?

Intensive Agriculture Development program (IADP) was the first major experiment of Indian government in the field of agriculture and it was also known as a "package programme" as it was based upon the package approach.

The programme was launched in 1961 after the Community Development Programme lost sheen. The core philosophy was to provide loan for seeds and fertilizers to farmers. Intensive Agriculture Development program was started with the assistance of Ford Foundation.

The IADP was expanded and later a new Intensive Agriculture Area programme (IAAP) was launched to develop special harvest in agriculture area.

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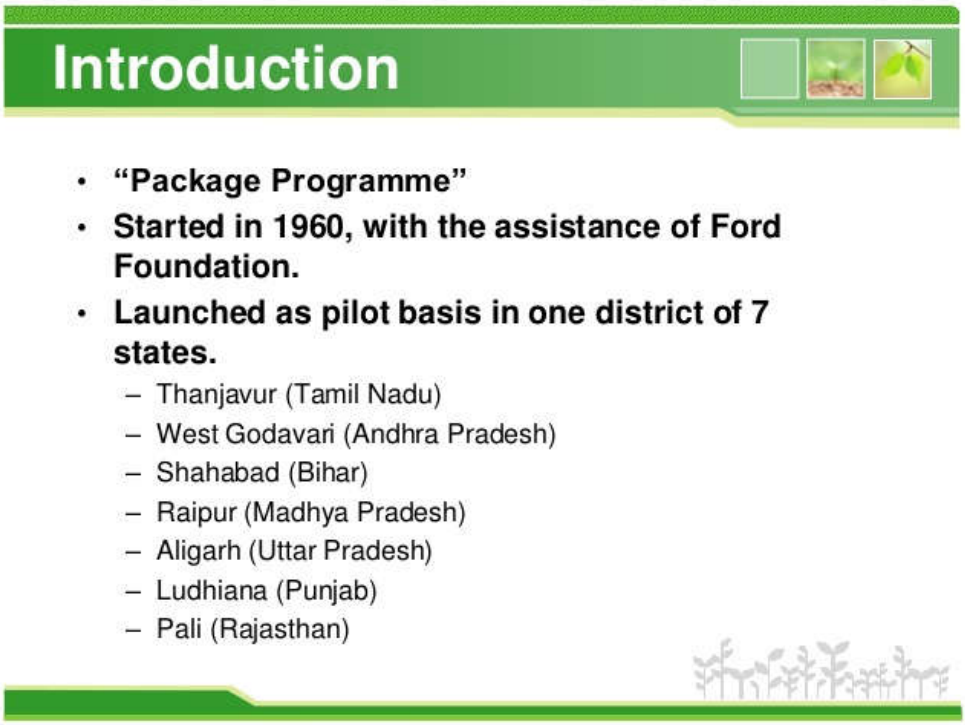


5. Dry Agriculture:

Dry farming or dry-land farming may be defined as a practice of growing crops without irrigation in areas which receive an annual rainfall of 750 mm – 500 mm or even less.

DRYLAND VS. RAINFED FARMING

Constituent	Dryland farming	Rainfed farming
Rainfall (mm)	750 to 1150	>1150
Moisture availability to the crop	Shortage	Enough
Growing season (days)	75-120	>120
Growing regions	Arid and semiarid as well as uplands of sub-humid and humid regions	Humid and subhumid Regions
Cropping system	Single crop or intercropping	Intercropping or double cropping
Constraints	Wind and water erosion	Water erosion

Key elements of effective combat with perils of Dryland agriculture

- Capturing and Conservation of Moisture
- Effective Use of Available Moisture
- Soil Conservation
- Control of Input Costs

Dryland agriculture is subject to high variability in areas sown, yields and output. These variations are the results of aberrations in weather conditions, especially rainfall. **Alternate crop strategies have been worked out for important regions of the country:**

Table 1. Traditional and Alternate Efficient crops in Different Dryland Regions of India

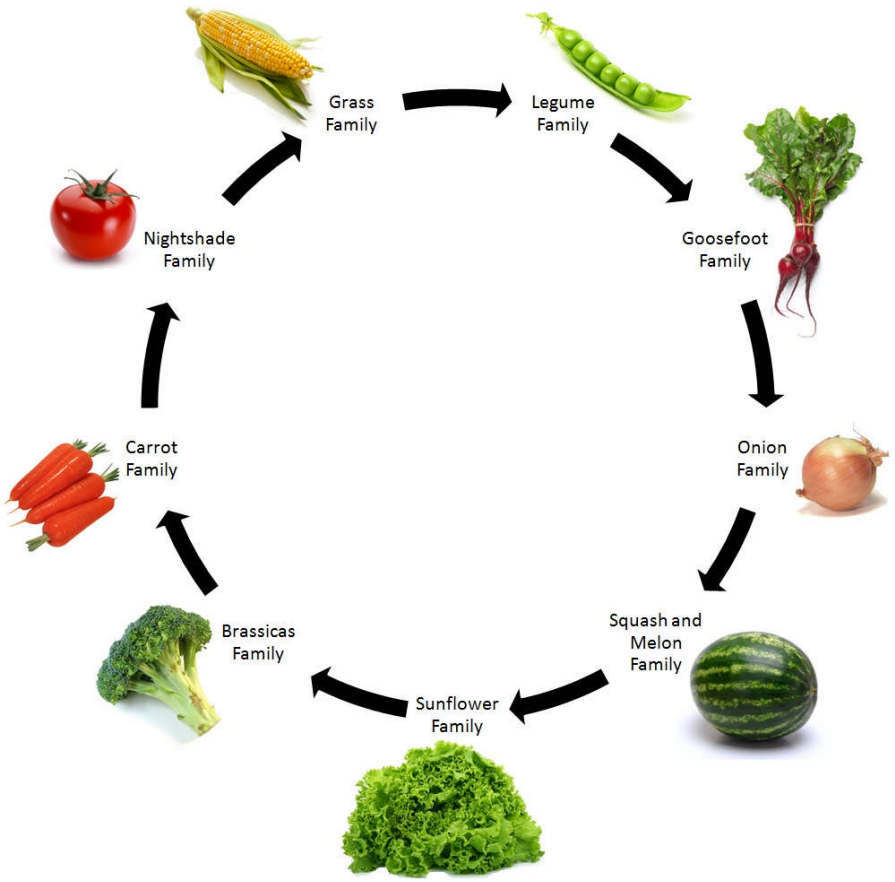
S. no	Region	Traditional crop	Alternate efficient crop
1.	Deccan Rabi season	Cotton, wheat	safflower
2.	Malwa Plateau	wheat	Safflower, Chick pea
3.	Uplands of Bihar Plateau and Orissa	Rice	Ragi, Black gram, Groundnut
4.	South-easy Rajasthan	Maize	Sorghum
5.	North Madhya Pradesh	Maize	Soybean
6.	Eastern UP	Kalitur	Chick pea
7.	Sierozems of North-west India	Wheat	Mustard, Taramira (Eruca sativa)

6. Mixed and Multiple Agriculture:

- Mixed farming is referred to cultivation of crops and rising of animals simultaneously.
- The multiple farming is used to denote the practice of growing two or more crops together.
- In such case a number of **crops having varying maturing periods** are sown at the same time.
- *This practice is followed is areas having good rainfall or facilities of irrigation.*

Inter cropping	Mixed cropping
1. The main object is to utilize the space left between two rows of main crop.	1. To get at least one crop under favorable conditions
2. More emphasis is given to the main crop	2. All crops are cared equally
3. There is no competition between both crops	3. There is competition between all crops growing
4. Inter crops are of short duration & are harvested much earlier than main	4. The crops are almost of the same duration
5. Sowing time may be same or different	5. It is same for all crops
6. Crops are sown in different rows without affecting the population of main crop when sown as sole crop	6. Either sown in rows or mixed without considering the population of either.

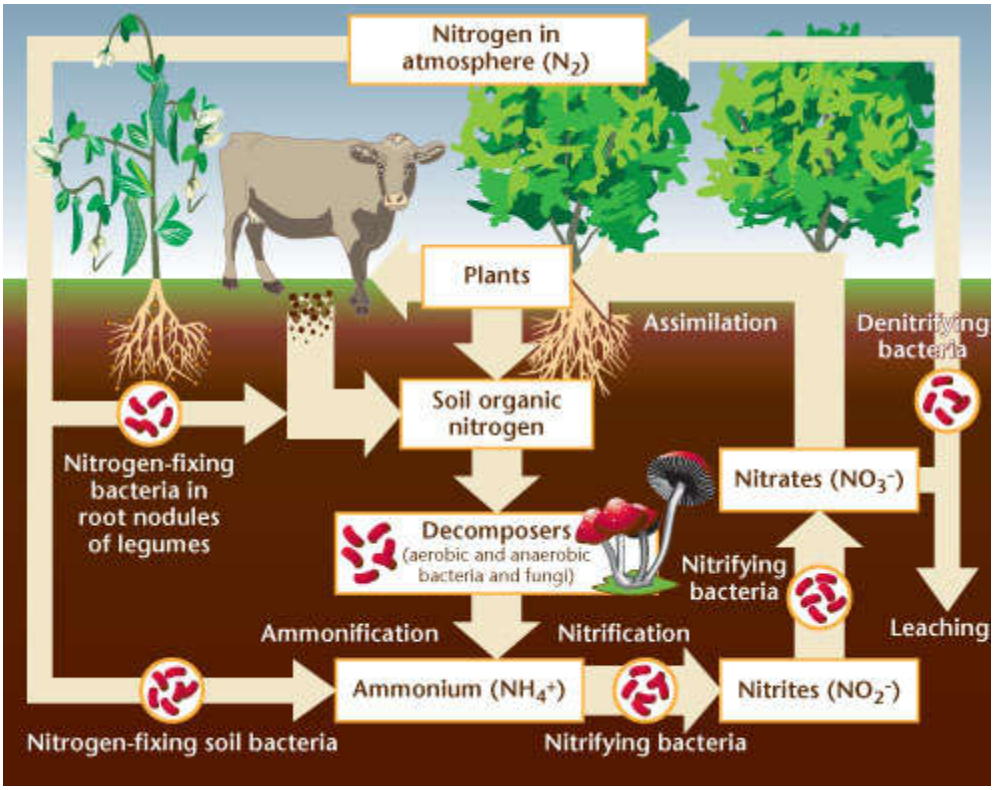
7. Crop Rotation:



This refers to growing of number of Crops one after the other in a fixed rotation to maintain the fertility of the soil. The rotation of crops may be complete in a year in some of the areas while it may involve more than one year's time is others.

- Pulses or any leguminous crop is grown after the cereal crops.
- Legumes have the ability of fixing nitrogen to the soil.
- Highly fertilizer intensive crops like sugarcane or tobacco are rotated with cereal crops.
- The selection of crops for rotation depends upon the local soil conditions and the experience and the understanding of the farmers.

Good time to re-visit the nitrogen cycle again!



8. Terrace Cultivation:

- The hill and mountain slopes are cut to form terraces and the land is used in the same way as in permanent agriculture.
- Since the availability of flat land is limited terraces are made to provide small patch of level land.
- Soil erosion is also checked due to terrace formation on hill slopes.

Cropping Seasons in India:

India has the following three cropping seasons:

1. Rabi:

- Rabi crops are sown in winter (from October to December) and harvested in summer (from April to June).
- Major Rabi crops are wheat, barley, gram, peas, mustard etc.
- Though these crops are grown in large parts of India, states from the north and north-western parts such as Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, and Haryana, Jammu and Kashmir are important for the production of wheat and other Rabi crops. This can be attributed to:
    1. The availability of precipitation in the winter months due to the western temperate cyclones.
    2. The success of green revolution in these areas.

2. Kharif:

- Kharif crops are sown with the onset of monsoon in different parts of the country and are harvested in September to October.
- The major Kharif crops are rice, jowar, bajra, maize, jute, groundnut, cotton, arhar, moong, urad, soyabean etc.

3. Zaid:

- In between the Rabi and Kharif seasons, there is a short season during the summer months known as the Zaid season.
- Vegetables, watermelon, musk melon, cucumber, fodder crops etc. which are grown with the help of irrigation fall under this category.

Important Crops:

Variations in the physical environment and preferences for various types of food in India have resulted in a large number of crops being grown. In the next article, we will look at the chief crops grown in India, the geographical conditions required for their growth and their important producing areas.

Important Food Crops

1. Rice:

- Geographical Conditions of Growth:
  - Rice grows best in areas of warm, humid climate; rice requires temperatures between 20°C and 35°C and a well-distributed rainfall of about 100 cm or irrigation facilities.
  - Fertile soil. Delta and valley soils are the most suitable. Soils with higher clay content are preferred for its cultivation due to their better moisture retention capacity.
- Important Producing Areas:
  - West Bengal (highest producer), Uttar Pradesh, Andhra Pradesh, Punjab (highest per hectare yield), Bihar, Orissa, Chhattisgarh, Assam, Tamil Nadu, Haryana.
  - About 25% of the arable land is used for the cultivation of rice.
- On the basis of climatic conditions, three varieties of rice are found in India:
  - Winter/ Agahani/ Aman – Planted in July-August and harvested in October-December. 86% of the total rice cultivation comes under this variety.
  - Autumnal/ Kuari/Aus – Sown in May-June and harvested in September – October.
  - Summer/Boro – It is sown in November – December and harvested in March-April. It is grown on 1% of the total rice area.

Note: All the above mentioned 3 varieties (aman, aus, and boro) are grown in West Bengal and Assam.

- Important varieties: IR-8, Jaya, Padma, Hamsa, Krishna, Sabarmati, and IET 1039.
- India is the 2nd largest producer in the world after China.

2. Wheat

- Geographical Conditions of Growth:
  - It is a crop of temperate climate. The ideal temperature for its cultivation is about 15°-20°C and requires a moderate amount of rainfall of 25-75 cms. It can be grown in the drier areas with the help of irrigation.
  - Well drained loamy and clayey soils are ideal.

- Important Producing Areas:
  - Wheat is cultivated on about 14% of the total arable area of the country.
  - There are two important wheat producing zones in the country – the Ganga-Satluj plains in the north-west and the black soil region in the Deccan.
  - In north India, wheat is sown in October – November and harvested in March – April. In south India, it is sown in September-October and harvested in December – January. Wheat takes lesser time in ripening in south India than that in the north because of hotter climatic conditions in the south.
  - Uttar Pradesh (highest producer), Punjab (highest yield per hectare), Madhya Pradesh, Haryana, Rajasthan, Bihar, Gujarat, Maharashtra, West Bengal, Uttarakhand.
- Important varieties: Sonalika, Kalyan, Sona, Sabarmati, Lerma, Roso, Heera, Shera, Sonara-64.

3. Maize

- Geographical Conditions of Growth:
  - It is a crop of semi-arid climate and is used both as food and fodder.
  - A temperature of 21°C- 27°C and 50-100cm rainfall is suitable for its cultivation.
  - Alternate spells of rains and sunny weather are ideal for maize.
  - It is a Kharif Crop but in some states like Bihar, it is grown in the Rabi season also.
  - It grows well in alluvial and red soils with good drainage. It can also be grown in mountainous soils.
- Important Producing Areas:
  - It is grown on 3.6% of the total sown area in the country.
  - Karnataka, Uttar Pradesh, Bihar, Rajasthan and Andhra Pradesh are important maize producing states.
- Important Varieties: Sartaz, Ganga, Deccan-103, Deccan-105, Dhawal, Prabhat, Arun, Kiran etc.

4. Millets:

Jowar, Bajra and Ragi are the important millets grown in India. Though these are known as coarse grains, these have high nutritional value. These are grown on 16.5% of the total sown area in the country.

1. *Bajra*

- Geographical Conditions of Growth:
  - It thrives in areas of warm, dry climate.
  - It requires an annual rainfall of 45cm and temperature ranging between 25 to 30°C.
  - It grows well on sandy soils and shallow black soil.
- Important Producing Areas:
  - Rajasthan is the largest producer of bajra followed by Uttar Pradesh, Maharashtra, Gujarat and Haryana.

2. *Jowar*

- Geographical Conditions of Growth:
  - It is a rainfed crop mostly grown in moist areas which hardly needs irrigation.
  - This crop requires moderate rainfall of 30-100cms and high temperatures ranging from 20 to 32°C.
  - Both excessive moisture and prolonged drought are harmful.
  - Well drained light soils are ideal.
- Important Producing Areas:
  - It is the third most important food crop with respect to area and production.
  - It is cultivated as the major food crop in semi-arid areas of the central and south India.
  - In north India, Jowar is mainly a Kharif crop whereas it is sown as both Kharif and Rabi in the southern states.
  - Maharashtra is the largest producer of jowar followed by Karnataka, Andhra Pradesh and Madhya Pradesh.

- India is the largest producer of jowar in the world.

3. *Ragi*

- Ragi is very rich in iron, calcium, other micro-nutrients and roughage.
- Geographical Conditions of Growth: It is a crop of dry regions and grows well on red, black, sandy, loamy and shallow black soils.
- Important Producing Areas: Karnataka is the largest producer of Ragi followed by Tamil Nadu. Other states important for the production of ragi are Himachal Pradesh, Uttaranchal, Sikkim, Jharkhand and Arunachal Pradesh.

5. Pulses

- Major pulses that are grown in India: tur, urad, moong, masur, peas and gram.
- Chief Characteristics:
  - India is the largest producer as well as consumer of pulses in the world. About 20% of the pulses of the world are produced here.
  - These are the major sources of protein in a vegetarian diet.
  - Being leguminous crops, all the above-mentioned pulses (except tur) help in restoring soil fertility by fixing nitrogen from the air. Therefore these crops are mostly grown in rotation with other crops.
- Geographical Conditions of Growth:
  1. Pulses need less moisture and survive even in dry conditions
- Important Producing Areas: The major pulse producing areas are Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra and Karnataka. It is grown on about 11% of the total sown area in India.

6. Barley

- Geographical Conditions of Growth:
  - This is grown mainly as a dry crop.
  - This is the crop grown in the wheat producing area on the poor soil and in area of lower precipitation.
  - Although the geographical conditions required for its cultivation are similar to those for wheat, it has more tolerance for adverse environmental conditions.

- Important Producing Areas: The major producers are Uttar Pradesh, Bihar and Madhya Pradesh.

Horticultural Crops (Fruits, Vegetables, Flowers etc.)

- The contribution of horticulture in the total agricultural produce of the country is 30.4% (Year 2012-13)
- **Fruits:**
  - India produces 10% of the total fruit production in the world and is the second largest producer of fruits in the world.
  - India is the largest producer of mango, banana, cashew, cheekoo, and lemon in the word.
  - India produces both tropical and temperate fruits.
- **Vegetables:**
  - India is the second largest producer of vegetables in the world and produces about 13% of the world's vegetables.
  - India is an important producer of potato, pea, cauliflower, onion, cabbage, tomoato and brinjal.

Important Cash Crops

Under cash crops, those commercial crops are included which are produced by farmers mainly to earn money. The cash crop is often not consumed by the farmer himself. Some important cash crops have been discussed below in detail:

1. Sugarcane

- Geographical Conditions of Growth:
  - It is a tropical as well as sub-tropical crop.
    - Sugarcane in North India is of the sub-tropical variety and has low sugar content. Also sugar factories have to remain shut in winter seasons in North India. Also, sugarcane juice begins to dry up because of the long dry season in north India.

        - Sugarcane in South India is of the tropical variety and high sugar content and high yield.
    - It grows well in hot and humid climate with a temperature of 21°C to 27°C and an annual rainfall of 75-100cm.
    - Medium and heavy soils where irrigation facilities are available are ideal for its cultivation.
    - It can be grown on a variety of soils and needs manual labour from the time of sowing to harvesting.
    - It is a long maturing crop planted between February and April. Harvesting begins in October and November.
    - It is a soil-exhausting crop and thus needs regular application of manure or fertilisers.
- Important Producing Areas:
    - India is considered the original homeland of sugarcane and has the largest area under sugarcane in the world.
    - India is the second largest producer of sugarcane only after Brazil.
    - The major sugarcane producing states are Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Bihar, Punjab and Haryana.

2. Cotton

- India is believed to be the original home of the cotton plant.
- It is also one of the most important industrial crops of India.
- Geographical Conditions of Growth:
    - Cotton grows well in the drier parts of the black cotton soil of the Deccan plateau. It can also be grown on alluvial and red soils.
    - It requires high temperature (20-35°C), light rainfall (50 to 80cm) or irrigation, 210 frost free days and bright sunshine for its growth. Clear sky during the picking season is ideal.
    - It is a Kharif crop and requires 6-8 months to mature.

- Important Producing Areas:
  - India is the fourth largest producer of cotton in the world. China, USA and Pakistan grow more cotton than India.
  - Cotton is cultivated in about 45% of the total sown area in the country.
  - The major cotton producing states are Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu, Punjab, Haryana and Uttar Pradesh.
- Important Varieties: India produces both short staple (Indian) cotton and long staple (American) cotton. American Cotton is called 'Narma' in the north-western part of the country.

3. Jute

- It is also known as the golden fibre and is India's major cash crop.
- Jute fibre is obtained from the inner bark of the jute plant.
- It is used in making gunny bags, mats, ropes, yarn, carpets and other artifacts. Jute cultivation in India has recently suffered due to reduced demand as a result of increasing competition with artificial fibre and packaging material.
- Geographical Conditions of Growth:
  - It is a soil-exhausting crop like sugarcane and lowers soil fertility rapidly. It thus grows well on the well drained fertile soils in the flood plains where the soils are renewed every year.
  - High temperatures (24°C to 35°C), heavy rain (125 – 200cm) and low plain land are favourable conditions for the cultivation of jute.
- Important Producing Areas:
  - West Bengal (largest producer in India), Bihar, Assam, Orissa and Meghalaya.
  - India is the largest producer of jute in the world.
- Important Varieties: Mesta

4. Tobacco

- Tobacco was brought to India by the Portuguese.
- Uses: Its leaves are used in making cigarettes, cigar, beedi etc. Its stem is used as potash fertilizer and its powder as an insecticide.

- Geographical Conditions of Growth:
  - It requires temperatures of 15°C to 40°C and rainfall of about 50cm or irrigation facilities. More than 100cm of annual rainfall and frost is harmful for the crop.
  - Fertile soils with good drainage are ideal as it is an exhaustive crop
- Important Producing Areas:
  - Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Bihar.
  - More than 1/3rd tobacco of the country is produced by Andhra Pradesh alone.
- Important Varieties: Nicotina Tabacum and Nicotina Rustics. Virginia tobacco used for making cigarettes and Dale Crest varieties are grown in Andhra Pradesh.

5. Oilseeds

- Main oilseeds produced in India include groundnut, mustard, and coconut, sesasmum (til), soyabean, castor seeds, linseed, and sunflower.
- Uses – Most of these are edible and used as cooking mediums. Some of these are also used as a raw material in the production of soaps, ointments and cosmetics.
- Geographical Conditions of Growth:
  - Most oilseeds are grown as dry crops or in association with other crops e.g. mustard is grown with wheat.
- Important Producing Areas:
  - India is the largest producer of oilseeds in the world. About 20% of the world's oilseed producing area is in India.
  - Different oilseeds are grown covering approximately 14% of the total cropped area of the country.
  - Major oilseed producing areas are the plateau of Malwa, Marathwara, Gujarat, dry areas of Rajasthan, Telangana and Rayalseema regions of Andhra Pradesh.
  - Madhya Pradesh ranks first (31%) in the total oilseeds production and is followed by Rajasthan and Gujarat.
  - The smaller oilseeds are grown mainly in the north (Gujarat, MP, Rajasthan, Punjab and Haryana) and the larger seeds in the south mainly Kerala, Tamil Nadu, Andhra Pradesh and Karnataka. A list of particular oilseeds and their producing states:

- Coconuts – The southern coastal region in the states of Kerala, Tamil Nadu and Andhra Pradesh.
- Castor seed – Gujarat
- Linseed – Chhattisgarh
- Soya beans – Madhya Pradesh
- Mustard and rapeseeds – Rajasthan
- Sunflower – Karnataka, Maharashtra and Andhra Pradesh

Important Plantation Crops

1. Tea

- It is an important beverage crop introduced in India initially by the British.
- Geographical Conditions of Growth and Production:
  - The tea plant grows well in tropical humid and subtropical humid climates endowed with deep and fertile well-drained soils, rich in humus and organic matter.
  - 150cm summer rain and 21°C to 27°C daily temperature are needed for its cultivation.
  - Tea bushes require warm and frost-free climate all through the year.
  - Frequent showers evenly distributed over the year ensure continuous growth of the tender leaves.
  - Tea is often cultivated on the hill slopes so that there is no waterlogging in its roots.
  - Its leaves are to be plucked several times in a year, so availability of abundant and cheap labour is essential for its cultivation.
- Important Producing Areas:
  - Assam, hills of Darjeeling and Jalpaiguri districts, West Bengal, Tamil Nadu and Kerala. Apart from these, Himachal Pradesh, Uttaranchal, Meghalaya, Andhra Pradesh and Tripura are also tea producing states in the country.

- India is the leading producer as well as exporter of tea in the world. 28% tea of the world is produced here.

2. Coffee

- Geographical Conditions of Growth:
  - Coffee is a tropical plantation crop.
  - 16° – 28°C temperature, 150-250cm rainfall and well-drained slopes are essential for its growth.
  - It grows on hilly slopes at the height of 900-1800m.
  - Low temperature, frost, dry weather for a long time and harsh sunshine are harmful for its plants.
  - Coffee plants grow better in the laterite soils of Karnataka in India.
- Important Producing Areas:
  - India contributes about 4% of the world's total coffee production. It ranks 6th in the world in coffee production.
  - The coffee plant was grown for the first time on the Baba Budan Hills (Karnataka) in India.
  - At present, more than half of the total coffee production in India is produced by Karnataka alone, followed by Kerala and Tamil Nadu.
- Important Varieties: The Arabica variety initially brought from Yemen is produced in the country.

Cropping Patterns and Systems in India

Cropping Pattern refers to a yearly sequence and spatial arrangement of crops and fallow in a given area

Cropping pattern used on a farm and its interaction with farm resources, other farm enterprises and available technology that determines its makeup, is called a cropping system.

A farmer's choice of crops is governed by several sets of factors: Physical, Social and Economic. But, by and large, most of the Indian farmers go for cultivation of a number of crops at their farms and rotate a particular crop combination over a period of 3-4 years. It results in a multiplicity of cropping systems, which remains dynamic in time and space making it difficult to precisely determine the spread of different cropping systems.

Scientists have identified more than 250 cropping systems being followed throughout the country but it is estimated that only 30 major cropping systems are prevalent (except the areas under monocropping due to moisture or heat conditions)

A large diversity of cropping systems exists under rainfed and dryland areas with an overriding practice of intercropping. This is because of greater risks involved in cultivating a large area under a particular crop. While in areas with assured irrigation only a few cropping systems are followed and they have a considerable coverage across the region and contribute significantly to food grains production at the national level.

Types of Cropping Systems in India:

Broadly speaking there are 3 types of cropping systems in India:

1. Sequential – In sequential multiple cropping, farmers use short duration crops and intensive input management practices. E.g.

- In Maharashtra:- Rice-Frenchbean-Groundnut
- In Rainfed Areas:- Pigeon Pea – Wheat

2. Inter-Cropping – Growing two or more crops simultaneously on the same field is called intercropping. In this case, crop intensification is in both temporal and spatial dimension. There is an inter-crop competition during all or in part of crop growth. E.g.

- Maize and Groundnut in Ranchi
- Cotton and Groundnut in Junagarh

3. Alley Cropping System – Growing of annual crops with multipurpose perennial shrubs/trees is called alley cropping. It is a way of increasing production potential under fragile environments. It is recommended to meet food, fodder and fuel needs besides improving soil fertility e.g. In the salt affected alluvial soil areas of Modipuram, alley cropping of rice-wheat sequence is done with trees like babool.

Major Cropping Systems in India:

The crop occupying the highest percentage of sown area of the region is taken as the base crop and all the other possible alternative crops sown in the region as substitutes (i.e. spatial variation) for the base crop in the same season or as the crops that fit in with the rotation in the subsequent seasons (i.e. temporal variations) are considered in the pattern.

1. Rainy Season Cropping Systems:

Among the Kharif Crops – Rice, Sorghum, Pearl Millet (Bajra), Maize, Groundnut and Cotton are the prominent crops to be considered as the base crops for describing the Kharif Cropping Patterns.

1. **Rice Based Cropping Patterns**: Rice is grown in the high rainfall area or in the areas where supplemental irrigation is available to ensure good yields. At an all India Basis, nearly 80% of rice is sown during June to September and the rest during the remaining season. E.g.

    - With rice, other crops being cotton, vegetables and fruits (in Meghalaya)
    - Jute as an alternative to rice (in Orissa, coastal Andhra Pradesh, Bihar, Jharkhand, Assam etc.)
    - In Bihar, the alternative crops being pulses, wheat, maize, jute, sugarcane and oilseeds

2. **Kharif Cereals other than rice:**

    - Maize-based cropping systems: Maize is grown in high rainfall areas or on soil with a better capacity for retaining moisture, but with a good drainage.
    - Sorghum based cropping system: Grown in medium rainfall regions. These systems are popular in Maharashtra and Madhya Pradesh. The alternative crops being cotton, pulses, groundnut, and small millets in Maharashtra.
    - Pearl-Millet based cropping system –Pearl millet is a more drought resistant crop than several other cereal crops and is generally preferred in low or less dependable rainfall and on light textured soils. These are popular in Rajasthan, Maharashtra, Gujarat and Uttar Pradesh. E.g. in Rajasthan with pulses, groundnut, oilseeds, etc.

3. **Groundnut based cropping systems:** These are popular in Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu and Maharashtra. E.g. in Andhra Pradesh and Tamil Nadu, rice forms an alternative; in Karnataka, Sorghum is the main alternative crop, whereas cotton, tobacco, sugarcane and wheat are also grown here.

4. **Cotton based cropping systems:** These are popular in Maharashtra, Gujarat, Andhra Pradesh and Punjab. E.g. Cotton with other crops:

    - Sorghum (Kharif and rabi), groundnut, pulses and wheat etc;
    - With irrigation in some places sugarcane and rice are also grown with cotton.

2. ***Winter Cropping Systems:***

Among the Rabi Crops, wheat together with barley and oats, sorghum and chickpea are the main base crops. Generally, wheat and chickpea are concentrated in the subtropical region in northern India, whereas Rabi sorghum is grown mostly in the Deccan.

1. **Wheat and Chickpea based cropping systems**: Wheat and Chickpea are grown under identical climate and can be substituted for each other. E.g. alternative crops in Madhya Pradesh being Kharif sorghum groundnut, oilseeds, cotton, small millets etc. In Punjab, the alternative crops are rice, maize, cotton, pearl-millet etc.

2. **Rabi Sorghum based cropping systems**: These are popular in Maharashtra, Karnataka and Andhra Pradesh. E.g. in Maharashtra, the alternative crops are pearl millet, pulses, oilseeds and tobacco etc.

3. Plantation and other commercial crops:

- Sugarcane, Tobacco, Potato, Jute, Tea, Coffee, Coconut, Rubber, Spices and condiments are important crops. Some of these are seasonal, some annual, some perennial.
- Generally, the areas occupied by these crops are very limited compared with those of food and other crops. Nevertheless, they are important from commerce point of view.
- Besides the above-mentioned crops, there are certain horticultural crops like apple, mango and citrus fruits.
- E.g. in the jute growing areas, rice is the usual alternative crop; in Punjab, Bihar, Haryana and Uttar Pradesh, wheat and maize are rotation crops with sugarcane.

4. Mixed Cropping:

- Crop Mixtures, for example, pulses and some oilseeds are grown with maize, sorghum and pearl millet.
- Lowland Rice is invariably grown unmixed, but in upland rice, several mixtures are prevalent. E.g. In un-irrigated areas of the north, during Rabi season, wheat, barley and chickpea are the mixtures of grain crops.
- Note: Mixed Cropping was considered by some researchers a primitive practice, but now many researchers regard it as a more efficient way of using the land. [Mixed cropping ≠Mixed Farming; Mixed Farming = Farming + Animal Rearing. Note the difference!]

Questions from Previous Year's Prelims

1. Which of the following is the chief characteristic of 'mixed farming'? [UPSC 2012]

A. Cultivation of both cash crops and food crops

B. Cultivation of two or more crops in the same field

C. Rearing of animals and cultivation of crops together

D. None of the above.

Ans: C

2. With reference to Indian agriculture, which one of the following statements is correct? [UPSC 2002]

A. About 90 per cent of the area under pulses in India is rainfed.

B. The share of pulses in the gross cropped area at the national level has double in the last two decades

C. India accounts for about 15 per cent of the total area under rice in the world

D. Rice occupies about 34 per cent of the gross cropped area of India

Ans: A

3. Which one of the following agricultural practices is eco-friendly? [UPSC 1999]

A. Organic farming

B. Shifting cultivation

C. Cultivation of high-yielding varieties

D. Growing plants in glass-houses

Ans: A

4. What can be the impact of excessive/ inappropriate use of nitrogenous fertilizers in agriculture? [UPSC 2015]

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 groundwater can occur.

Select the correct answer using the code given below.

A. 1 and 3 only

B. 2 only

C. 2 and 3 only

D. 1, 2 and 3

Ans: C

5. in India, the problem of soil erosion is associated with which of the following? [UPSC 2015]

1. Terrace cultivation
2. Deforestation
3. Tropical climate

Select the correct answer using the code given below.

A. I and 2 only

B. 2 only

C. 1 and 3 only

D. 1, 2 and 3

Ans: B

Venkateswarlu Nagineni

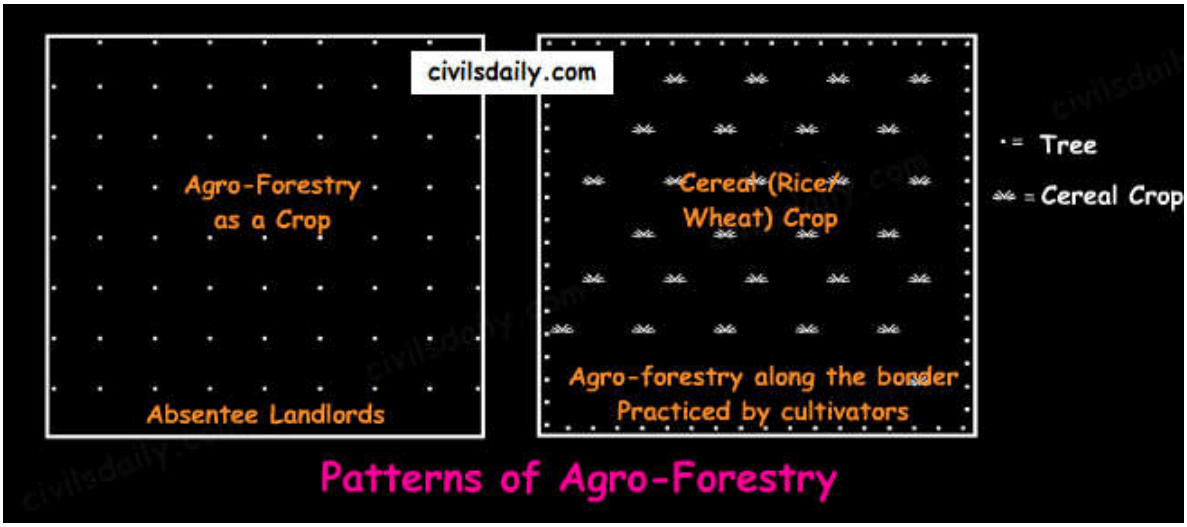
Agroforestry

What is Agroforestry?

Agroforestry is a sustainable management mechanism for land that:

- increases overall production,
- combines agricultural crops, tree crops, forest plants and animals simultaneously, and
- applies management practices that are compatible with cultural practices of the local population.

It is a type of social forestry in which an individual farmer undertakes tree farming and grows fodder plants, grasses and legumes on his own land. In Agroforestry trees are considered a crop and become a part of crop combinations.



Some Patterns of Agroforestry

There is an increasing number of farmers who plant trees either along the boundaries or in the whole field/farm as a crop. In fact, in the northern plains of India, trees are planted by most of the farmers irrespective of the size of their holdings. The large farmers and absentee landlords generally put a part of their holdings or total agricultural area under tree crops.

The main advantage of Agroforestry is considered to be its positive impact on the soil. Let's understand the impact of trees on the soil.

How trees improve soils:

1. Litter or Mulch:

During the lifetime of a tree, leaves, twigs and branches die and fall to the ground as litter. Litter contributes to the **organic-matter content** of the soil after it decomposes. A soil that is rich in organic matter has a better capacity to absorb and retain water and thus is also more **resistant to erosion**. A good cover of litter or mulch can also be very effective in **suppressing weeds**.

2. Increase nutrient content of soil:

- Nutrient Uptake from deeper layers of soil: Tree roots normally penetrate deeper into the soil than the roots of crops. Though not experimentally verified, trees are generally considered more efficient than crops in taking up nutrients released by weathering deep in the soil.
- Nutrients from the atmosphere: The presence of a tree reduces the wind speed and creates good conditions for the deposition of dust. Nutrients in the atmosphere are conveyed to the soil when they are dissolved in rain or settle with dust. Rain water dripping from leaves and flowing along the branches carries the nutrients to the ground, together with those released from the tree itself and associated plants growing on it. It is known that the amounts of nutrients reaching the ground in this way are substantial.
- Nitrogen Fixation: Many leguminous trees and a few non-leguminous ones have the ability to fix atmospheric nitrogen through symbiosis with bacteria or fungi in root nodules. The fixation of nitrogen has been proven and found to be a significant factor in soil fertility. Also, the litter from nitrogen-fixing plants is often rich in nitrogen which is added to the soil when the litter or mulch decomposes.

3. Protection from soil erosion

Tree roots and stems reduce surface run-off, nutrient leaching and soil erosion.

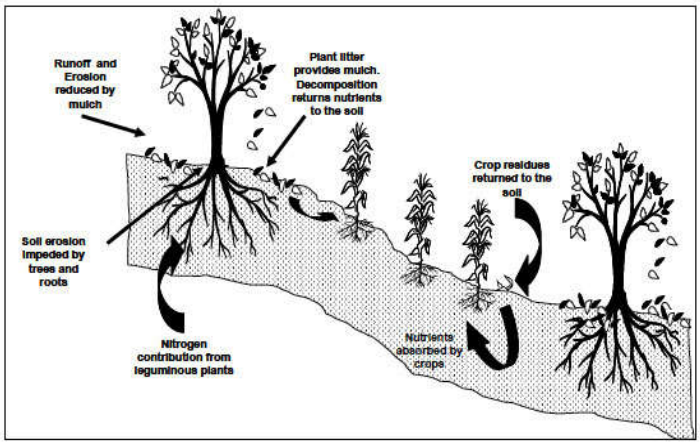


Figure 2 A schematic representation of the potential benefits of introducing an agroforestry system on ecosystem functioning

Some Other Benefits of Agroforestry:

1. Environmental Benefits:

- Reduction of pressure on natural forests. It is also recognized that Agroforestry is perhaps the only alternative to meeting the target of increasing forest or tree cover to 33 percent from the present level of less than 25 per cent, as envisaged in the National Forest Policy (1988).
- Agroforestry is known to have the potential to mitigate the climate change effects through:
    - ❖ microclimate moderation and natural resources conservation in the short run, and
    - ❖ Carbon sequestration in the long run. Agroforestry species are known to sequester as much carbon in below-ground biomass as the primary forests, and far greater than the crop and grass systems.
- When strategically applied on a large scale, with an appropriate mix of species, agro-forestry enables agricultural land to withstand extreme weather events, such as floods and droughts, and climate change.

2. Economic benefits:

- A greater output of food, fuel wood, fodder and timber.
- Increase in levels of farm income due to improved and sustained productivity.
- Agroforestry leads to a reduction in the incidence of total crop failure, which is common to single cropping or monoculture systems. This is because such systems are structurally and functionally more complex than monoculture.
- The absentee landlords go for Agroforestry to retain the title of the land and to increase their income. It provides an alternative to land owners to manage their agricultural land in absence of family labour.
- Agroforestry has significant potential to provide employment to the rural and urban population through production, industrial application and value addition ventures. Current estimates show that about 65 % of the country's timber requirement is met from the trees grown on farms.

3. Social benefits:

- Improvement in rural living standards from sustained employment and higher income.
- Makes the villagers self-dependent at the village-level.

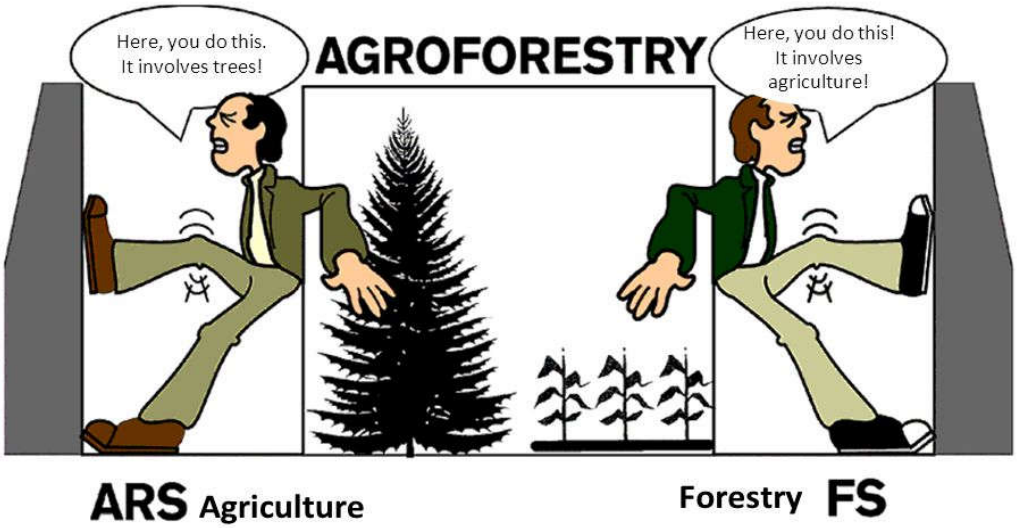
Despite the numerous material and geo-climatic benefits, Agroforestry if not carefully planned can have some adverse effects on agricultural land. Some of these are:

1. In the fields along which trees have been planted, the productivity per unit area decreases, as in at least about two meters from the trees the moisture content in the soil is significantly reduced. Also, the combination of trees and crops must be so chosen so as to minimise the competition between their roots for moisture.

2. Unscientific planning can also negatively impact the agricultural productivity of the land. E.g. growing trees with photophilic i.e. light-loving plants.

3. Pests and Diseases: Mixtures of trees and crops make a more diverse environment than monocropping. A diverse environment enables a greater variety of species of all kinds of organisms — both desirable and less desirable — to thrive. With increased diversity, the risks of pests and diseases may also increase. On the other hand, a greater diversity of species also allows for better regulatory mechanisms which may reduce the seriousness of the pests and diseases. Careful planning is necessary so that the organisms promoted by one component in the system and are not harmful to the other component or components.

Thus, for an Agroforestry system to be successful, a careful and scientific approach is required which incorporates knowledge from both agriculture and forestry.



Agroforestry incorporates technology from agriculture and forestry. Both areas of expertise are needed, neither can be ignored if an agroforestry system is to provide the desired benefits.

Apart from these, certain shortcomings have been observed in the case of Agroforestry programs in India:

1. The tendency of farmers to opt for market-oriented trees rather than the trees which are more ecologically suited or are locally needed (fuel wood/fodder).
2. Agroforestry has benefitted the big farmers more than the marginal and small farmers. Many of the absentee landlords plant commercial trees in their agricultural landholdings to save their land from dispossession. This programme is said to have encouraged absentee land lordship.
3. The diversion of good agricultural land from cereal and commercial crops may create the scarcity of food and industrial raw material.
4. Possible negative impact on crop production because of planting trees on fertile lands.

Thus, while the potential benefits of Agroforestry are well documented, particular aspects of these systems need to be adapted to suit the areas where they are introduced. These adaptations primarily involve the selection of the ideal combinations of trees, shrubs and crops that will benefit each other, the environment and the income of the small-scale farmers.

National Agroforestry Policy 2014:

In February 2014, India became the first nation in the world to adopt an Agroforestry policy. Agroforestry was earlier covered as a part of other policies e.g. the National Forest Policy, the Green India Mission etc.

The Policy aims to improve coordination, convergence and synergy between various elements of Agroforestry, scattered across various existing missions, programme and schemes under different ministries—agriculture, rural development and environment.

Objectives of the **National Agroforestry Policy 2014**:

1. Promote Agroforestry to increase farm income and livelihoods of rural households, especially the small and marginal farmers.
2. Protect and stabilise ecosystems, and promote resilient cropping and farming systems to minimise the risk during extreme climatic events.
3. Simultaneously provide raw material to wood based industries. Thus create new avenues for rural employment, and reduce pressure on the forests.
4. To develop capacity and strengthen research in Agroforestry and create a massive people's movement for achieving these objectives.