ONLYIAS BY PHYSICS WALLAH

UDAAN

PRELIMS WALLAH (STATIC)

PRELIMS 2025

INDIAN GEOGRAPHY
HUMAN & ECONOMIC GEOGRAPHY

QUICK AND COMPREHENSIVE REVISION SERIES

ONLYIAS
BY PHYSICS WALLAH

UDAAN

PRELIMS WALLAH (STATIC)

INDIAN GEOGRAPHY
HUMAN & ECONOMIC GEOGRAPHY

QUICK AND COMPREHENSIVE REVISION SERIES FOR PRELIMS 2025

EDITION: Second

Published By: Physicswallah Private Limited

Physics Wallah Publication

ISBN: 978-93-6897-735-3

Mobile App: Physics Wallah (Available on Play Store)

Website: https://www.pw.live;https://pwonlyias.com/

Email: publication@pw.live

Disclaimer

A team of PW OnlyIAS experts and faculties with a deep understanding of the subject has worked hard for the creation and curation of this book.

While the content creators, editors and publisher have used their best efforts in preparing these books. The content has been checked for accuracy. As the book is intended for educational purposes, the author shall not be responsible for any errors contained in the book.

The publication has designed the content to provide accurate and authoritative information with regard to the subject matter covered.

(*This Book shall only be used for educational purposes.*)

PREFACE

A highly skilled professional team of PW ONLY IAS works arduously to ensure that the students receive the best content for the UPSC exam.

A plethora of UPSC study materials are available in the market, but PW ONLY IAS professionals continuously work to provide supreme-quality study material for our UPSC students.

From the beginning, the whole content team comprising Content Creators, Reviewers, DTP operators, Proofreaders and others are involved in shaping the material to their best knowledge and experience to produce powerful content for the students.

Faculties have adopted a new style of presenting the content in easy-to-understand language and have provided the team with guidance and supervision throughout the creation of this book.

PW ONLY IAS strongly believes in conceptual and fun-based learning and provide highly exam-oriented content to bring quality and clarity to the students.

This book adopts a multi-faceted approach to mastering and understanding the concepts and equipping the students with the knowledge for this competitive exam.

The main objective of the study material is to provide short, crisp, concise and high-quality content to our students.

BOOK FEATURES

- Holistic coverage of topics, strictly as per exam syllabus.
- One-stop solution for prelims based, subject-wise coverage.
- Diagrams and timelines for quick understanding and revision.
- Quick revision module for the UPSC prelims examination.
- Every topic is structured in headings and bullets for easy understanding of the students.

CONTENTS

1 India-Location, Structure and Physiography

INDIA'S GEOGRAPHICAL OVERVIEW

- **Land Area and Coastline**
  - India spans 3.28 million sq. km, covering **2.4% of the world's total area**.
  - With a **coastline of 6,100 km on the mainland and 7,517 km including island groups** (Andaman & Nicobar, Lakshadweep), India has the longest coastline among Indian Ocean littoral countries.
  - Territorial waters extend **12 nautical miles (22.2 km)** from the coast.

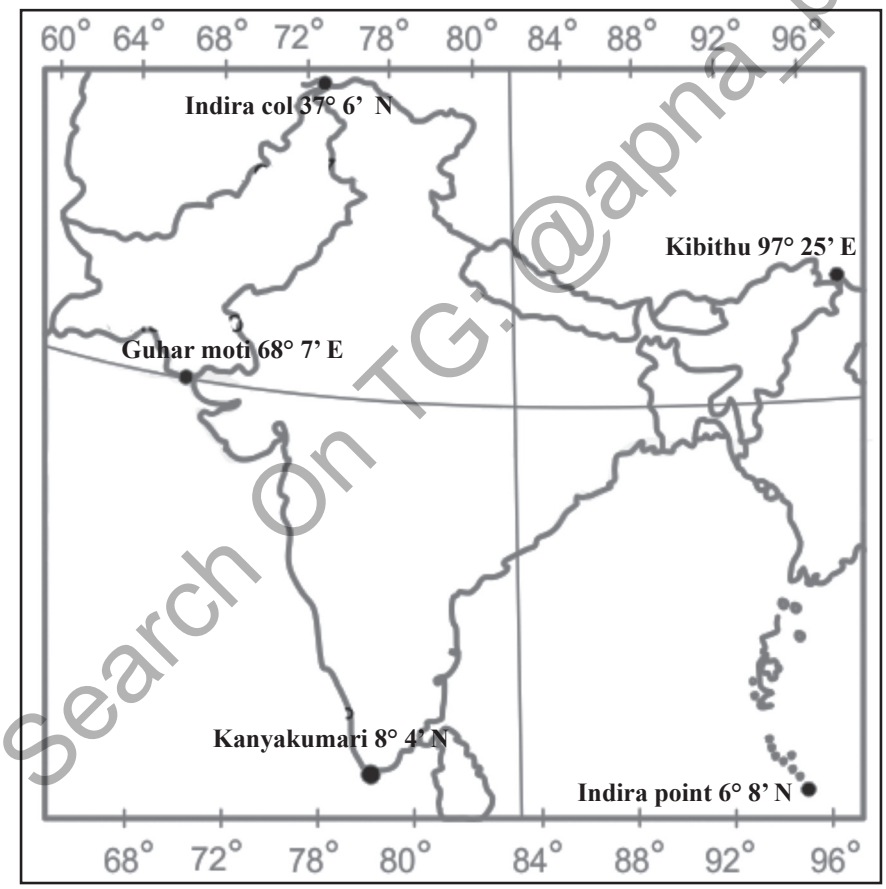


Fig. Geographical Extent

- **Geographical Extent**
  - **Latitudinal Extent**: From 6°8'N (Kanyakumari) to 37°6'N (Ladakh), spanning approximately 3,200 km.
  - **Longitudinal Extent**: From 68°7'E (Gujarat) to 97°25'E (Arunachal Pradesh), covering about 2,900 km. **[UPSC 2015]**
- **Key Geographic Points**:
  - **Southernmost Mainland Point**: Kanyakumari
  - **Northernmost Point**: Indira Col (Karakoram Range)
  - **Southernmost Point (Indian Union)**: Indira Point, submerged during the 2004 tsunami, lies in the Great Nicobar Islands, separated from Indonesia by the Six Degree Channel.

- **Neighbouring Countries**
  - **Land Neighbours**: India shares land borders with Pakistan and Afghanistan (through the **Wakhan Corridor**) in the northwest; China, Nepal, and Bhutan in the north; and Myanmar and Bangladesh in the east.
    - India shares its longest land border with Bangladesh, followed by China and Pakistan.
- **Island Neighbors**:
  - **Sri Lanka**: Separated by the Gulf of Mannar and the Palk Strait.
  - **Maldives**: Separated from the Lakshadweep Islands by the Eight Degree Channel.
- **Significant Latitudes and Longitudes**
  - **Tropic of Cancer (23°27'N)**: Passes through **eight Indian states:** Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, West Bengal, Tripura, and Mizoram.
    - Maximum passage is through Madhya Pradesh, with Rajasthan having the shortest section.
    - The Mahi River crosses the Tropic of Cancer twice.
    - Capital cities close to this latitude include **Ranchi** (Jharkhand) in the south and **Jaipur** (Rajasthan), **Agartala** (Tripura), and **Aizawl** (Mizoram) in the north Agartala is the closest city to Tropic of Cancer.
- **Standard Meridian of India (82°30'E)**
  - This longitude defines the Indian Standard Time (IST), ensuring uniform time across the country.
  - It crosses the states of Uttar Pradesh (Mirzapur), Chhattisgarh, Odisha, Madhya Pradesh and Andhra Pradesh, with Raipur (Chhattisgarh) being the closest capital city to this meridian.
- **Climatic Zones**
  - The Tropic of Cancer divides India into two main climatic zones:
    - **Tropical Zone**: Located south of the Tropic of Cancer, this area experiences a generally warmer climate.
    - **Subtropical Zone**: Northern India lies in this zone, experiencing more varied seasonal temperature changes than the tropical zone.

STRUCTURE AND PHYSIOGRAPHY

The Indian plate, once located south of the equator and part of a larger entity including the Australian plate, fragmented and shifted northwards, leading to the development of the following geological divisions of India.

Major Geological Divisions of India

The Himalayas

- The Himalayas, a majestic mountain range, were formed due to the collision of the Indian and Eurasian tectonic plates.
- The Himalayas comprise **three parallel ranges:** the **Outer Himalayas (Siwaliks),** characterized by low hills and valleys; the **Lesser Himalayas (Himachal),** composed of sedimentary and metamorphic rocks and housing hill stations like **Shimla and Mussoorie;** and the **Greater Himalayas (Himadri),** the highest range with peaks like Mount Everest, formed of granite and crystalline rocks.
- The Himalayas are the source of major river systems like the **Indus, Ganges, and Brahmaputra.**

Indo-Ganga-Brahmaputra Plain

- Originally, this area was a **geo-synclinal** depression; These plains were gradually filled with sediments (alluvial deposits) carried by the Indus, Ganga and Brahmaputra rivers.

The Peninsular Block

- **Northern boundary**: Irregular line **extending from Kachchh** along the western flank of the Aravali Range near Delhi, and continuing roughly **parallel to the Yamuna and the Ganga** until reaching the **Rajmahal Hills** and the **Ganga delta**, also encompasses extensions like **Karbi Anglong, Meghalaya, and Rajasthan;** composed mainly of **ancient gneisses and granites**;
- Block remained **stable** since the Cambrian period, despite tectonic activities; **oldest physiographic feature;** Experienced various vertical movements and block faulting with geological features - **rift valleys** like the **Narmada, Tapi, and Mahanadi**; **Satpura block mountains** and mountain ranges such as **Aravali, Nallamala, Javadi, Veliconda, Palkonda, and Mahendragiri.**
- Area's **east-flowing rivers** create **shallow valleys** and form significant **deltas**, such as those of the Mahanadi, Krishna, Kaveri, and Godavari. **Tectonic activity** has led to the **submergence of parts of the western coast.**

Physiography of India

- Physiography, the result of geological structure, ongoing processes, and developmental stages, showcases India's diverse physical features.
- Based on these macro variations, India can be divided into the following physiographic divisions:
  1. The Northern and North-eastern Mountains
  2. The Northern Plain
  3. The Peninsular Plateau
  4. The Indian Desert
  5. The Coastal Plains
  6. The Islands

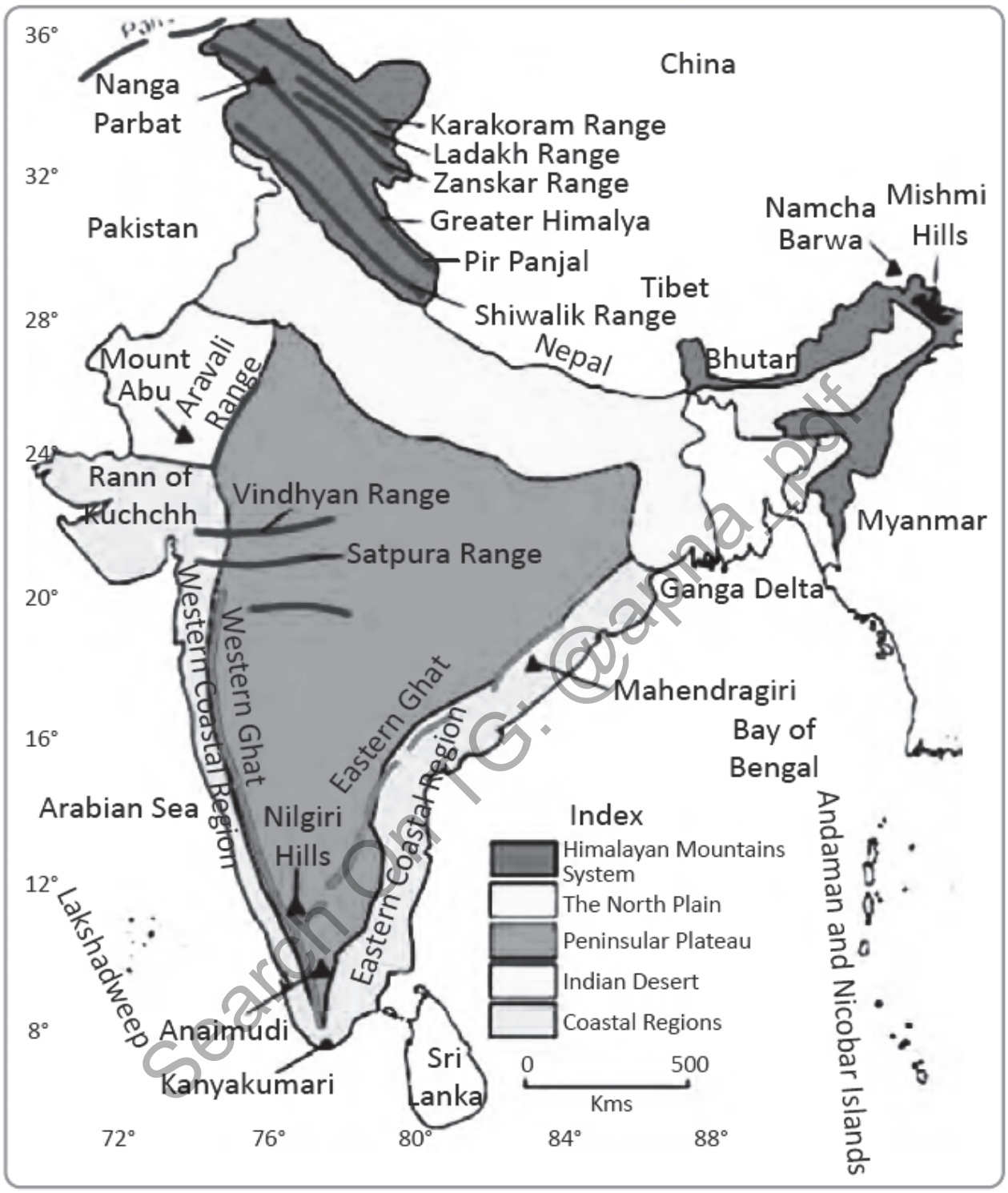


Fig. Physiographic Divisions of India

Northern and Northeastern Mountains [UPSC 2017]

The Northern and Northeastern mountains are represented by the **Himalayas** and their eastern extension, the **Purvanchal Hills**. These ranges are young fold mountains and showcase a range of geological and ecological features.

The Trans-Himalayas Mountain Region, also known as the Tibet Himalayan Region, is situated to the north of the Great Himalayas and includes the mountain ranges of Karakoram, Ladakh, Zaskar, and Kailash. The Karakoram Range is also known as the 'backbone of high Asia'.

A. North-South Division of Himalayas

Himalayan Range	Composition	Characteristics	Peaks	Passes	Other Features
Great Himalayas (Inner Himalayas) [UPSC-2012]	Central crystallines: granites and gneisses overlain by metamorphosed sediments.	Loftiest and most continuous range (Avg. elevation: 6,100 m). Asymmetrical folds with steep southern slopes. Convex shape, terminates abruptly at **Nanga Parbat** and **Namcha Barwa.**	Mount Everest, Kanchenjunga, Lhotse, Makalu, Dhaulagiri, Nanda Devi, Trishul, etc.	**Jammu & Kashmir**: Zoji La, Burzil Pass; **Himachal Pradesh**: Bara Lacha La, Shipki La; **Uttarakhand**: Niti Pass, Lipu Lekh; **Sikkim**: Nathu La, Jelep La	Home to glaciers (e.g., Siachen, Baltoro). Significant valleys: Kashmir Valley.
Lesser Himalayas (Middle Himalayas)	Sedimentary rocks and volcanic rocks (Pir Panjal Range).	Altitude: 3,500–4,500 m. Rugged terrain with valleys (Kashmir, Kullu, Kangra). Contains famous hill stations: Shimla, Mussoorie, Dharamshala.	Peaks: Nag Tibba, Mahabharat Lekh.	Pir Panjal Pass, Banihal Pass, Golabghar Pass.	Major rivers like Jhelum, Beas, and Chenab cut through these ranges.
Shiwaliks (Outer Himalayas)	Mio-Pleistocene sands, gravels, and conglomerates deposited by rivers.	Low-altitude range (900–1,100 m). Characterized by duns (Dehradun, Kotli Dun) and seasonal streams (Chos).	No major peaks.	No major passes	Formed after the Great and Lesser Himalayas. Scarps and anticlinal crests dominate the landscape.

B. East-West Division of Himalayas

Region	Key Ranges	Peaks	Passes	Other Features
Kashmir or Northwestern Himalayas	Karakoram, Ladakh, Zaskar, Pir Panjal.	K2, Nanga Parbat, Gasherbrum, Rakaposhi.	Zoji La, Banihal, Khardung La, Photu La	Valley of Kashmir (Dal Lake, Wular Lake, Pangong Tso (Ladakh)). Karewas for saffron cultivation. **Baltoro and Siachen** Glacier (north of Nubra Valley). **[UPSC 2020]** Changpa' tribe found in the Changtang, a high plateau that stretches across the cold desert of Ladakh. They rear the Pashmina goats that yield fine wool. They are kept in the category of Scheduled Tribes. **[UPSC 2014]** Pilgrimage sites: Vaishno Devi
Himachal and Uttarakhand Himalayas	Great Himalayas, Lesser Himalayas (Dhauladhar, Nag Tibba), Shiwalik.	Kamet, Nanda Devi, Kedarnath, Trishul, Bandarpunch. **[UPSC 2022]**	Lipu Lekh, Niti Pass, Bara Lacha La	Famous valleys (e.g., Valley of Flowers). Hill stations: Shimla, Ranikhet, Mussoorie. Pilgrimage sites: Badrinath, Kedarnath.

Nepal Himalayas	Mahabharat Range, Churia Range.	Dhaulagiri, Everest, Annapurna, Makalu.	No significant passes	Tallest section of the Himalayas. Famous tea plantations in the southern foothills.
Darjeeling and Sikkim Himalayas	Kangchenjunga, Mahabharat Range.	Kanchenjunga (8,586 m).	Jelep La, Nathu La	Tea plantations and orchid diversity. Lepcha tribe resides here.
Arunachal Himalayas	Patkai Bum, Naga Hills, Abor Hills.	Namcha Barwa, Kangtu. **[UPSC 2023]**	Diphu Pass	Tribal groups: Monpa, Abor, Mishmi. Shifting cultivation (Jhum) is practiced.

C. Purvanchal Hills and Mountains

Sub-Range	Composition	Characteristics	Peaks	Other Features
Patkai Bum	Dissected hills with dense forests.	Forms the boundary between Arunachal Pradesh and Myanmar.	No major peaks	Important for biodiversity.
Naga Hills	Igneous and metamorphic rocks.	Acts as a watershed between India and Myanmar.	Mount Saramati	Practiced by tribal groups (Jhum cultivation).
Manipur Hills	Sedimentary rocks and clay deposits.	Southward extension of Naga Hills.	Barail Range Separates it from Naga Hills, Mount Tempu is highest peak of Manipur present in Barail range.	Characterized by narrow valleys and moderate elevation.
Mizo Hills (Lushai)	Unconsolidated sedimentary rocks (Molassis basin).	Characterized by the Blue Mountain (Phawngpui) - the highest peak.	Blue Mountain (Phawngpui)	Known for tribal populations and the practice of Jhum cultivation.

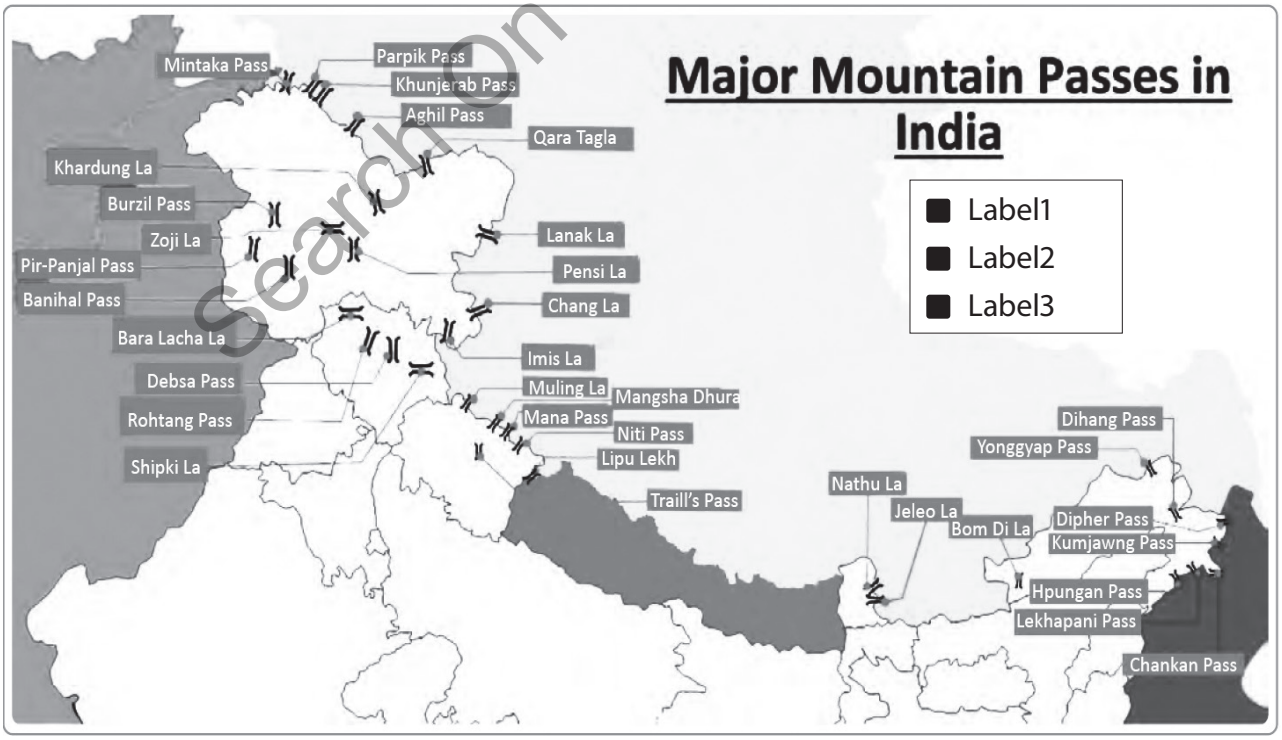


Fig. Major Mountain Passes in the Himalayas

Important Himalayan Glaciers

Glacier Name	Location	Important Features
Siachen	Karakoram	Largest in Nubra Valley of the Himalayas; second longest glacier outside the Polar region
Biafo	Karakoram (Baltistan region, Ladakh)	Flows into the Shigar River
Chogo Lungma	Karakoram	Located in Gilgit-Baltistan
Gangotri	Uttarakhand	Originates below the Chaukhamba Peak; also known as 'Gomukh'
Rimo	Siachen Area, Ladakh	Drains into the Shyok River
Hispar	Gilgit-Baltistan	World's longest glacial system
Zemu	Sikkim/Nepal	Largest glacier in the Eastern Himalaya; feeds River Teesta
Sonapani	Chandra Valley, Lahaul & Spiti, HP	Longest glacier in the Pir Panjal range near Rohtang Pass
Milam	Uttarakhand	Major source of River Gori Ganga; biggest glacier in Kumaon Himalaya
Rupal	Kashmir	Located in the Greater Himalaya; flows northeastward
Gangri (Nun Kun)	Himalayan Range	Largest glacier in the Nun Kun mountains
Bara Shigri	Chandra Valley, Lahaul, HP	Second longest glacier in the Himalayas; source of water for River Chenab; antimony deposits
Diamir (Nanga Parbat)	Kashmir (Pakistan Occupied)	Located in Diamir mountains, known as the 'King of Mountains'
Pindari	Kumaon Region, Uttarakhand	Gives rise to River Pindari
Chong Kumdan	Karakoram, Ladakh	Feeds and poses a threat to Shyok River due to potential blocking

THE NORTHERN PLAINS OF INDIA

The Northern Plains are expansive alluvial deposits formed by three major river systems: the **Indus**, the **Ganga**, and the **Brahmaputra**, along with their tributaries. These plains are characterized by fertile alluvial soil, a general elevation of **50-150 m**, and are agriculturally productive due to the rich riverine deposits.

Broad Divisions of the Northern Plains

Division	Geographical Extent	Features	Significant Features
Western Part: Punjab Plains	Dominated by the doabs (fertile land between two rivers), these plains lie primarily in Punjab and Haryana.	Fertile agricultural land formed by the convergence of tributaries of the **Indus** River system, including the **Jhelum, Chenab, Ravi, Beas, and Sutlej.**	Known for intensive farming.
Central Part: Ganga Plains	Spread between the **Ghaggar** and **Teesta** rivers, covering Haryana, Delhi, Uttar Pradesh, Bihar, Jharkhand, and West Bengal.	Fertile plains dominated by the Ganga and its tributaries, with sandbars, oxbow lakes, meanders, and braided streams.	Haryana and Delhi act as a water divide between the **Indus** and **Ganga** systems.
Eastern Part: Brahmaputra Plains	Found primarily in Assam.	Characterized by **riverine islands**, **sandbars**, and **periodic floods**. Shifting channels form braided streams and deltas.	**Majuli** (Brahmaputra) is the world's largest inhabited riverine island. Brahmaputra turns sharply southward at Dhubri (Assam) before entering Bangladesh.

Deltaic Features

- The **mouths of these rivers** form large deltas.
  - **Sundarbans Delta**: Formed by the Ganga and Brahmaputra rivers, it is the largest delta in the world, rich in biodiversity.

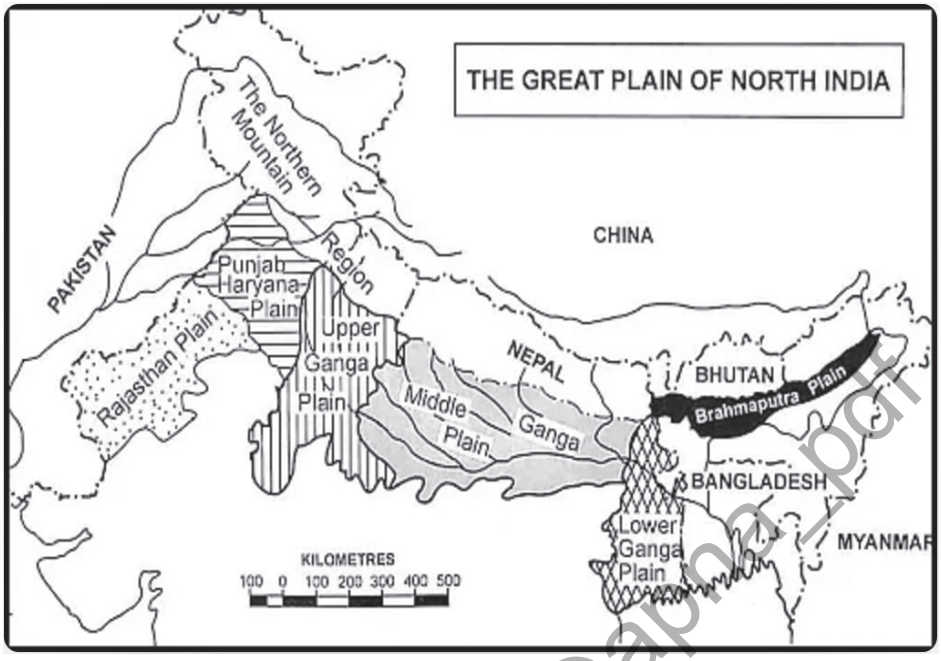


Fig. Division of Northern Plains

North-South Division of the Northern Plains

The Northern Plains are further divided into three zones running parallel to the Shiwalik foothills from **north to south**:

Zone	Description	Features	Notable Areas/Features
Bhabar	A narrow belt, **8-16 km wide**, lying parallel to the Shiwalik slopes where rivers deposit rocks and boulders after descending from the mountains.	• Porous region where streams disappear • Coarse material deposition	Found along the base of the Shiwaliks
Tarai	Wet, swampy, and marshy land where streams and rivers re-emerge without well-defined channels.	• Thickly forested region, rich in biodiversity	**Dudhwa National Park** is located in this region
Alluvial Plains (Bhangar & Khadar)	Composed of fertile alluvial soil with relief features like sandbars, oxbow lakes, and meanders.	• **Bhangar**: Older alluvium deposits, calcareous (kankar) in nature • **Khadar**: Younger floodplain deposits, more fertile and regularly renewed.	Khadar being more fertile is ideal for intensive agriculture, while the Bhangar is suitable for less intensive agriculture.

Key Geographical Features

- **Relief Features**
  - Sandbars, oxbow lakes, meanders, braided streams, and riverine islands.
  - **Majuli Island**: Largest riverine island located in the Brahmaputra River.
- **Doabs**
  - Fertile tracts of land lying between two rivers, essential for agriculture in the region.

PENINSULAR PLATEAU

- The **Peninsular Plateau** is an ancient tableland composed of crystalline, igneous, and metamorphic rocks, featuring a general elevation that slopes from west to east, as indicated by the flow of rivers. It extends from the **Delhi Ridge in the northwest** (an extension of the Aravallis) to the **Cardamom Hills** in the south, with other notable features like the **Rajmahal Hills** in the east and the **Gir Range** in the west. An extension is also observed in the northeast, encompassing the **Meghalaya Plateau, Shillong,** and the **Karbi-Anglong Plateau.**
- Block has remained **stable** since the Cambrian period, despite tectonic activities; **oldest physiographic feature;** Experienced various vertical movements and block faulting with geological features - **rift valleys** like the **Narmada, Tapi, and Mahanadi; Satpura block mountains** and mountain ranges such as **Aravali, Nallamala, Javadi, Veliconda, Palkonda, and Mahendragiri.**
- Area's **east-flowing rivers** create **shallow valleys** and form significant **deltas,** such as those of the Mahanadi, Krishna, Kaveri, and Godavari. **Tectonic activity** has led to the **submergence of parts of the western coast.**
- The region showcases varied physiographic features, such as tors, **block mountains, rift valleys, spurs, hummocky hills, and quartzite dykes** that naturally store water. **Patland plateaus** include the Hazaribagh, Palamu, Ranchi, Malwa, Coimbatore and Karnataka plateaus.

Divisions of the Peninsular Plateau

Division	Boundaries & Extent	Key Features
Deccan Plateau	Western Ghats (west), Eastern Ghats (east), Satpura, Maikal, and Mahadeo Hills (north).	• **Subdivisions:** Satpura Range, Maharashtra Plateau, Karnataka Dharwad Plateau, Telangana Plateau. • **Satpura Range:** Highly denuded and scarped plateaus.
Central Highlands	Aravalli Range (west), Vindhya Range (south), Rajmahal Hills (eastern extension).	• **Elevation:** 700–1,000 m, sloping towards the north and northeast. • Includes Bundelkhand, Baghelkhand, Malwa Plateau. • **Rivers:** Chambal, Sindh, Betwa, Ken, Banas.
Northeastern Plateau	Extension of the Peninsular Plateau into Meghalaya, Karbi-Anglong Plateau, and North Cachar Hills.	• Subdivided into Garo, Khasi, and Jaintia Hills. • Rich in minerals like coal, limestone, and uranium. • **Cherrapunji:** Heavy rainfall leads to extensive erosion and a rocky surface.

Key Features of Divisions

- **Deccan Plateau**
  - The plateau is bordered by the Western and Eastern Ghats and the Satpura ranges.
  - It includes major uplifts like the **Maikal and Mahadeo hills.**
- **Central Highlands**
  - **Aravalli Range**: One of the oldest fold mountains, home to rivers like Sabarmati, Luni, and Banas.
  - **Vindhya Range**: Extends from Gujarat to Bihar; a block mountain sourcing Yamuna's tributaries like Chambal, Sindh, Betwa, and Ken.
  - **Malwa Plateau** is a prominent part of the Central Highlands, historically known as Khandesh.
- **Northeastern Plateau**
  - Formed due to the northeastward movement of the Indian plate during the Himalayan uplift, creating the **Malda Gap** between the Rajmahal Hills and Meghalaya Plateau **[UPSC 2014].**
  - **Cherrapunji,** a part of Meghalaya, features bare rock due to heavy monsoonal erosion **[UPSC 2014].**
  - **In Nokrek Biosphere Reserve,** Nokrek is the highest peak of Garo Hills situated on Meghalaya Plateau.

[UPSC 2013, 2023]

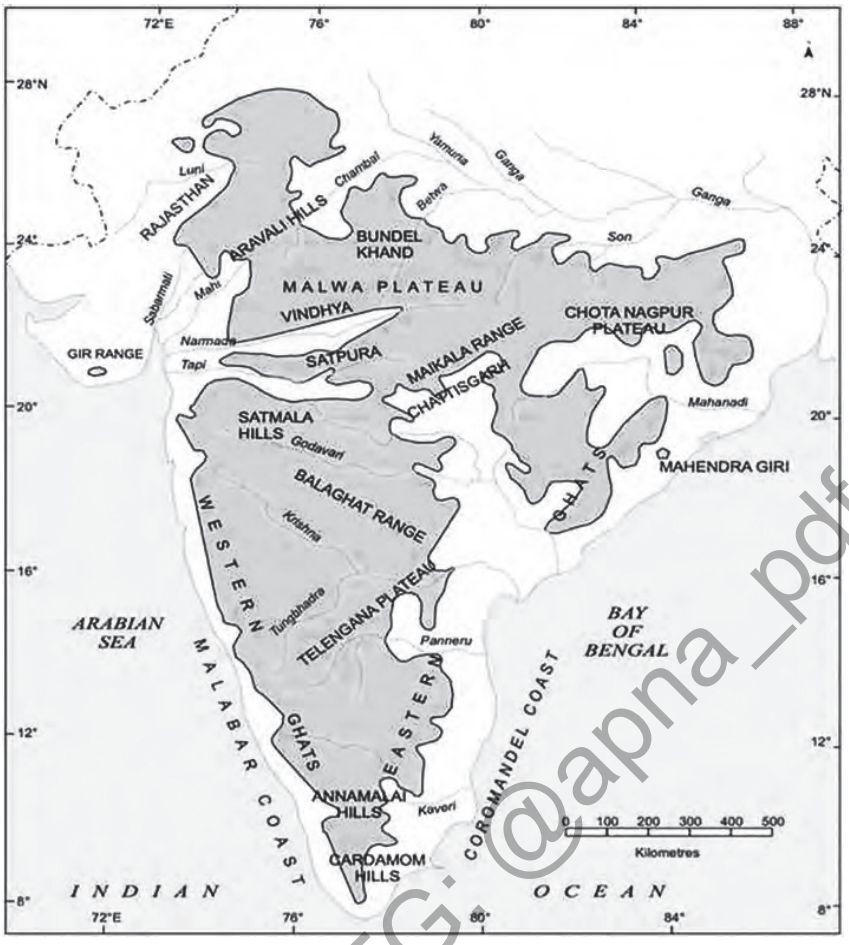


Fig. Peninsular Plateau of India

THE INDIAN DESERT

- Located northwest of the Aravali hills; also known as **Marusthali**; undulating topography with longitudinal dunes, barchans and sandy plains. **Barchans** are crescent-shaped dunes.
- Average annual rainfall below 150 mm per year.
- Believed to have been underwater during the **Mesozoic era**, evidence of which has been found in wood fossils in **Aakal** and marine deposits near **Brahmsar, near Jaisalmer** (estimated to be 180 million years old).
  - **Akal Wood Fossil Park** is a National Geological Monument of India located in **Jaisalmer, Rajasthan.**
- While the underlying rock structure is an extension of the Peninsular plateau, surface features have been shaped by physical weathering and wind actions.
- Prominent desert features include **mushroom rocks**, shifting dunes, and oases (primarily in the southern part).
- Rivers in the region are mostly **ephemeral**, with **the Luni** River being the largest in the region.
- Some streams vanish into the sand and exhibit inland drainage by joining lakes or playas. Lakes and **playas** have brackish water, a major source of salt production.

WESTERN GHATS

Western Ghats has various local names: **Sahyadri** in Maharashtra, **Nilgiri** Hills in Karnataka and Tamil Nadu, and **Anaimalai Hills** and **Cardamom Hills (Malabar Coast)** in Kerala. **[UPSC 2014]**

- Higher in elevation (average elevation about 1,500m) and more continuous compared to the Eastern Ghats, with height increasing from north to south.
- Covers 6 states - **Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat** **[UPSC 2017]**
- Rivers originating in the Western Ghats: Godavari, Krishna, Kaveri, etc.
- **Peaks: Anamudi** (2,695 meters, highest peak of Peninsular plateau) on **Anaimalai Hills; Dodabetta** (2,637 meters) on **Nilgiri Hills** - Highest peak of Tamil Nadu and second highest of South India.
- **Hill Stations: Ooty (Nilgiri Hills); Munnar (Annamalai Hills); Kodaikanal (Palani Hills)**

EASTERN GHATS

Eastern Ghats consist of discontinuous and low hills due to erosion by rivers.

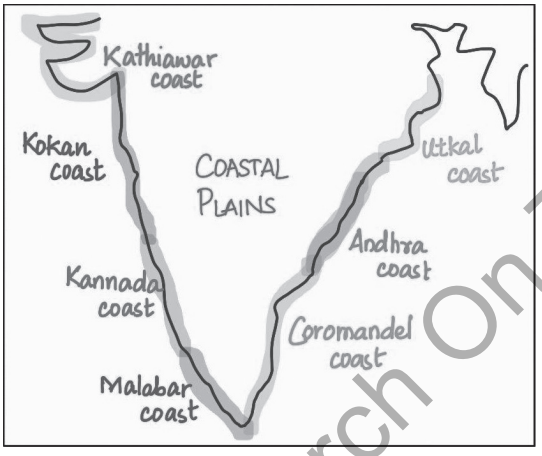
- Passes through Odisha, Andhra Pradesh, Tamil Nadu and parts of Karnataka and Telangana.
- **Hill ranges (North to South): Mahendragiri Hills** (Odisha; the **highest peak** in the Eastern Ghats); **Nallamala Hills (Srisalam temple) [UPSC-2015], Velikonda & Palkonda** (Andhra Pradesh); **Javadi** Hills, **Shevaroy** Hills, **Pachamalai** Hills & **Sirumalai** Hills.

Eastern and **Western Ghats converge** at the **Nilgiri Hills.**

- **Amarkantak hills** are situated at the confluence of Vindhyan and Satpura ranges; The **Biligirirangana Hills** is a hill range situated in Karnataka; Seshachalan hills (Andhra Pradesh) are part of eastern ghats. **[UPSC 2023]**
- **Sathyamangalam Tiger Reserve (TN)**is situated in a key position between the Western and Eastern Ghats**.** **[UPSC 2017]**

COASTAL PLAINS

India's extensive coastline can be broadly divided into **two main regions:** Western Coastal Plains and Eastern Coastal Plains.



Western Coastal Plains

These plains have **submerged coastal plains** because of which it is a narrow belt and have natural conditions **favourable for port development**. The west coast of India is both emergent and submergent.

The northern portion of the coast is **submerged** as a result of faulting and the southern portion, that is the Kerala coast, is an example of an emergent coast.

- **Divisions**: **Kachchh** and **Kathiawar** coasts (Gujarat), **Konkan** coast (Maharashtra and Goa), **Kannada** coast (Karnataka), and **Malabar** coast (Kerala).
- Notably, the ancient city of **Dwaraka** on the west coast is submerged.
- **Important natural ports:** Kandla, Mazagaon, JLN port Navha Sheva, Marmagao, Mangalore, Cochin, etc..
- The western coastal plains narrow in the middle and broaden towards the north and south.
- Rivers do not form deltas.
- Malabar coast is known for its **"Kayals"** (backwaters) used for fishing and tourism.
- The Nehru Trophy Vallamkali (boat race) is held in Punnamada Kayal in Kerala.

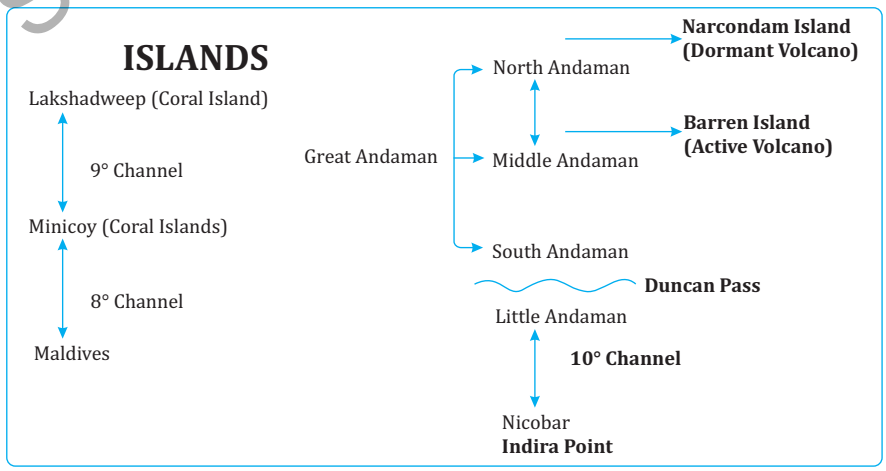
Eastern Coastal Plains

These plains are **emergent coasts** and are broader than western coastal plains. Coastline of emergence is formed either by an uplift of the land or by the lowering of the sea level.

- **Northern Circar** in the northern part and **Coromandel Coast** in the southern part
- Well-developed deltas of rivers - **Mahanadi, Godavari, Krishna**, and **Kaveri** deltas.
- **Lake Chilika (Odisha)**, along the eastern coast, is the largest saltwater lake in India lying south of the Mahanadi delta.
- Due to its emergent nature, there are **fewer ports and harbours** along this coast. The continental shelf here extends up to 500 km into the sea, making it a challenge for port development.

THE ISLANDS

India has two major island groups, one in the Bay of Bengal and the other in the Arabian Sea.



Bay of Bengal Islands

- Comprising approximately 572 islands/islets, located between 6°N-14°N and 92°E -94°E; entire group divided into the **Andaman Islands in the north and the Nicobar Islands in the south**. Sumatra is geographically closest to Great Nicobar. **[UPSC-2017]**

  Other important islets: **Ritchie's archipelago** and **Labrynth island.**
- The Andaman sea lies to the east and the Bay of Bengal to the west.
- These islands are believed to be an elevated portion of submarine mountains, with some smaller islands being volcanic.
- **Features**: **Barren Island**, the only active volcano in India. The last time the volcanic eruptions were reported and linked to 28 September 2018 earthquakes in Sulawesi, Indonesia. **[UPSC 2018]**;

  Mountain peaks - Saddle Peak (North Andaman-highest peak on the Islands), **Mount Diavolo** (300 m, Middle Andaman), **Mount Koyob** (460 m, South Andaman), and **Mount Thuiller** (642 m, Great Nicobar).
- **Renamed Islands: Ross** Island- **Netaji Subhash Chandra Bose** Island; **Havelock** Island- **Swaraj** Dweep; **Neil** Island- **Shaheed** Dweep
- These islands experience convectional rainfall and have equatorial vegetation.

Arabian Sea Islands

It Includes **Lakshadweep and Minicoy** islands, located between 8°N-12°N and 71°E -74°E. Entire group built from **coral deposits,** located off the coast of Kerala

- Formerly known as **Laccadive, Minicoy, and Amindive**, they were renamed Lakshadweep in 1973. **Minicoy** is the **largest island**. Other islands: **Amini** Island & **Cannanore** Island
- The eastern seaboard has storm beaches with pebbles, shingles, cobbles, and boulders.

Channels	Division
9 Degree channel	Minicoy island and Lakshadweep Archipelago
10 Degree Channel	Andaman Islands and Nicobar Island **[UPSC 2014]**
11 Degree Channel	Amindivi and Cannanore Island
Duncan passage	South/Great Andaman and little Andaman
St. George Channel	Little Nicobar and Great Nicobar
Grand Channel	Great Nicobar and Sumatra island (Indonesia)

Identify the State and Places

1. A state in India has the following characteristics 1. Its northern part is arid and semi-arid. 2. Its central part produces cotton. 3. Cultivation of cash crops is predominant over food crops. → **Gujarat** **[UPSC 2011]**
2. Two important rivers- one with its source in Jharkhand (and known by a different name in Odisha), and another, with its source in Odisha- merge at a place only a short distance from the coast of Bay of Bengal before flowing into the sea. This is an important site of wildlife and biodiversity and a protected area. →**Bhitarkanika** **[UPSC 2011]**
3. A particular State in India has the following characteristics: 1. It is located on the same latitude which passes through northern Rajasthan. 2. It has over 80% of its area under forest cover. 3. Over 12% of forest cover constitutes the Protected Area Network in this State. → **Arunachal Pradesh** **[UPSC 2012]**
4. In a particular region in India, the local people train the roots of living trees into robust bridges across the streams. As the time passes, these bridges become stronger. These unique 'living root bridges' are found in →**Meghalaya** **[UPSC 2015]**
5. At one of the place in India, if you stand on the seashore and watch the sea, 'you will find that the sea water recedes from the shore line a few kilometres and comes back to the shore, twice a day, and you can actually walk on the seafloor when the water recedes.' This unique phenomenon is seen at → **Chandipur, Odisha.** **[UPSC 2017]**

2 Drainage System

The drainage system of a region is determined and controlled by two main factors

- Nature of initial surface and slope.
- Geological structure (e.g. folds, faults, joints etc.).

Drainage systems are divided into two categories on the basis of the adjustment of the streams to the initial surface and geological structures:

1. **Sequent streams** follow the regional slope and are well-adjusted to geological structures. Eg. **Consequent**, **Subsequent**, **Obsequent** and **Resequent** streams.
2. **Insequent streams** do not follow the regional slope and are not adjusted to geological structures. Eg. **Antecedent** and **Superimposed** streams.

MAJOR DRAINAGE SYSTEMS

Sequent Drainage Systems

Consequent Streams

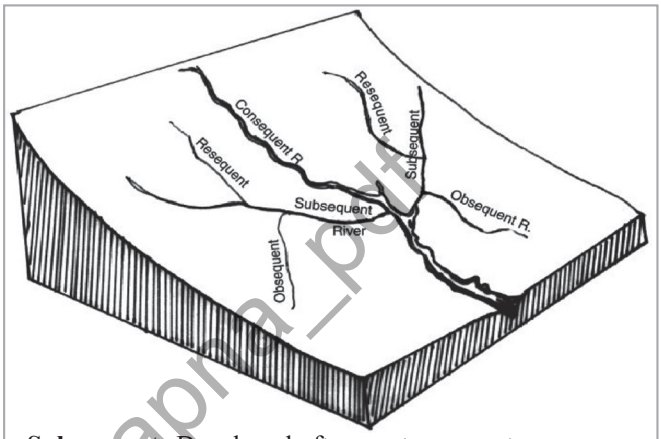
- These are the first streams to form, following the regional slope, and are often referred to as *dip streams*.
- The longest stream among these is called the *master consequent*.
- **Lateral consequent streams** join the master stream as tributaries.
- **Examples:** *Yamuna* and *Ganga* are the master consequent streams, while *Asan* (tributary of Yamuna) and *Son* (tributary of Ganga) are subsequent streams.

Subsequent Streams

- These streams form after the master consequent and follow the axis of anticlines or ridges, along the strike of beds.
- **Examples:** *Asan* and *Son* rivers.

Obsequent Streams

- These streams flow in the opposite direction to the master stream, following the slopes of mountain ranges, often due to geological shifts.
- They generally appear later than the master stream and are a reversal of its flow.



Subsequent: Developed after master current.
Obsequent: Flow opposite to the master current.
Resequent: Flow in the direction of the master current.
Consequent: Courses are the direct consequence of the initial topography.

Fig. Types of Drainage System

Resequent Streams:

- Tributary streams that flow in the direction of the master stream. They originate later than the master stream, following the same slope, but are usually smaller tributaries.

Insequent Drainage Systems

Antecedent Drainage

- These rivers existed before the upliftment of mountains or highlands and maintain their course through continuous downcutting into the rising land.
- **Examples:** The *Indus*, *Sutlej*, *Ganga*, *Ghaghra*, *Kali*, *Gandak*, *Kosi*, and *Brahmaputra* rivers are antecedent drainage systems, as they have carved their courses through the rising Himalayan terrain.

Superimposed Drainage

- Rivers that have developed over a newer geological surface, often due to erosion or changes in surface material. The drainage system here is not aligned with the regional geological structures and slopes.
- **Example:** In the Deccan Trap region of Peninsular India, many rivers are superimposed. These rivers evolved after lava solidification, which created a new surface, and the drainage pattern was formed after the removal of lava covers.

TYPES OF DRAINAGE PATTERNS

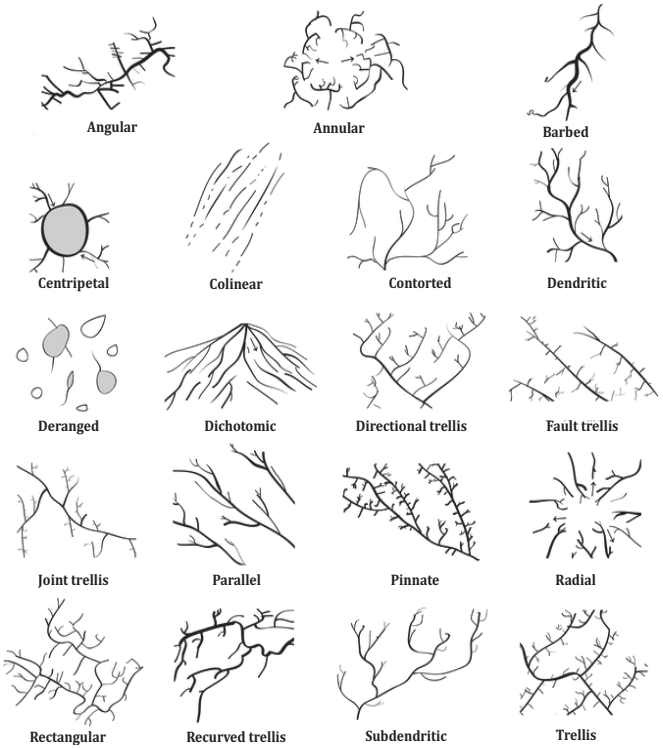


Fig. Type of Drainage Pattern

- **Dendritic Drainage Pattern:** Resembles the branches of a tree; develops in region with uniform lithology, e.g., **Indus, Godavari, Mahanadi**; Rivers of the northern plain.
- **Trellis Drainage Pattern:** Short streams meet the main stream at right angles, differential erosion through soft rocks, e.g., **Singhbhum, Seine basin (France)**.
- **Angular Drainage Pattern:** Tributaries join the main stream at acute angles, common in **Himalayan foothills**.
- **Rectangular Drainage Pattern:** Main stream and tributaries join at right angles, formed in regions with faulting, e.g., **Colorado River (USA), Vindhyan Mountains (India)**.
- **Radial Drainage Pattern:** Tributaries from summit drain in all directions, originate from a central point, e.g., **Amarkantak Hills, Girnar Hills**.
- **Centripetal Drainage Pattern:** Streams from all sides converge in a low-lying basin, low-lying central depression, e.g. **Streams of Ladakh, Tibet, Baghmati (Nepal)**.
- **Deranged Drainage Pattern:** Uncoordinated pattern in ice-sheet vacated regions, found in glaciated valleys, e.g., **Karakoram glaciated valleys**.
- **Barbed Drainage Pattern:** Tributaries meet the main river discordantly; tributaries flow in opposite direction to their master streams, e.g., **Arun River (Nepal), Kosi tributary**.
- **Annular Drainage Pattern:** Circular path around summit with subsequent tributaries, rare in India, e.g., **Pithoragarh, Nilgiri Hills (India)**.
- **Parallel Drainage Pattern:** Tributaries run parallel in a uniformly sloping region, e.g., Rivers of **Western Coastal plains**.

THE INDIAN DRAINAGE SYSTEM

The Indian drainage system can be distinguished on the basis of **discharge of water, size of watershed** and on the **basis of origin** i.e. Himalayan or Peninsular.

On the Basis of Discharge of Water (Orientations to the Sea)

The Indian drainage system can be grouped into two, the Arabian Sea drainage and the Bay of Bengal drainage. Both the drainage systems are **separated through the Delhi ridge, the Aravallis and the Sahyadris**.

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

On the Basis of the Size of the Watershed

- **Major river basins: More than 20,000 sq. km of catchment area**; **includes 14 drainage basins** - Ganga, Brahmaputra, Krishna, Tapi, Narmada, Mahi, Pennar, Sabarmati, Barak, etc
- **Medium river basins: Catchment areas between 2,000-20,000 sq. km incorporating 44 river basins** - Kalindi, the Periyar, the Meghna, etc.
- **Minor river basins: Catchment areas of less than 2,000 sq. km,** rivers in the areas of low rainfall.

THE HIMALAYAN DRAINAGE

- It comprises three major river basins: **Ganga**, **Indus**, and **Brahmaputra**.

Characteristics:

- **Perennial flow**, nourished by both melting of snow and precipitation.
- Perform **intensive erosional activity** in their **upper courses** with **features: gorges**, **V-shaped valleys**, **turbulent rapids**, and **waterfalls.**
- **Features** in the **middle and lower course: flat valleys, meanders**, **oxbow** lakes, and depositional features in their **floodplains**; **braided channels** and **deltas** near river mouths; shift their courses frequently eg. River Kosi (sorrow of Bihar)

The Indus River System

- It is also known as the **Sindhu**; represents the western most of the Himalayan rivers in India. In the **Tibetan region**, it is referred to as **'Singi Khamban'** or Lion's mouth.
- **Origin: Glacier near Bokhar Chu** (Kailash Mountain range, Tibetan region)
- A little **over a third** of the Indus basin is located in **India. Leh** is situated on the bank of **Indus.**
- Flows between the **Ladakh and Zanskar ranges** and passes through **Ladakh, Baltistan and Gilgit**. It cuts across the Ladakh range, forming a gorge near Gilgit & enters Pakistan in the **Dardistan** region.
- Flows southward and **receives 'Panjnad' (**Satluj, the Beas, the Ravi, the Chenab and the Jhelum) near Mithankot (Pakistan).
- Discharges into the Arabian Sea, east of Karachi.

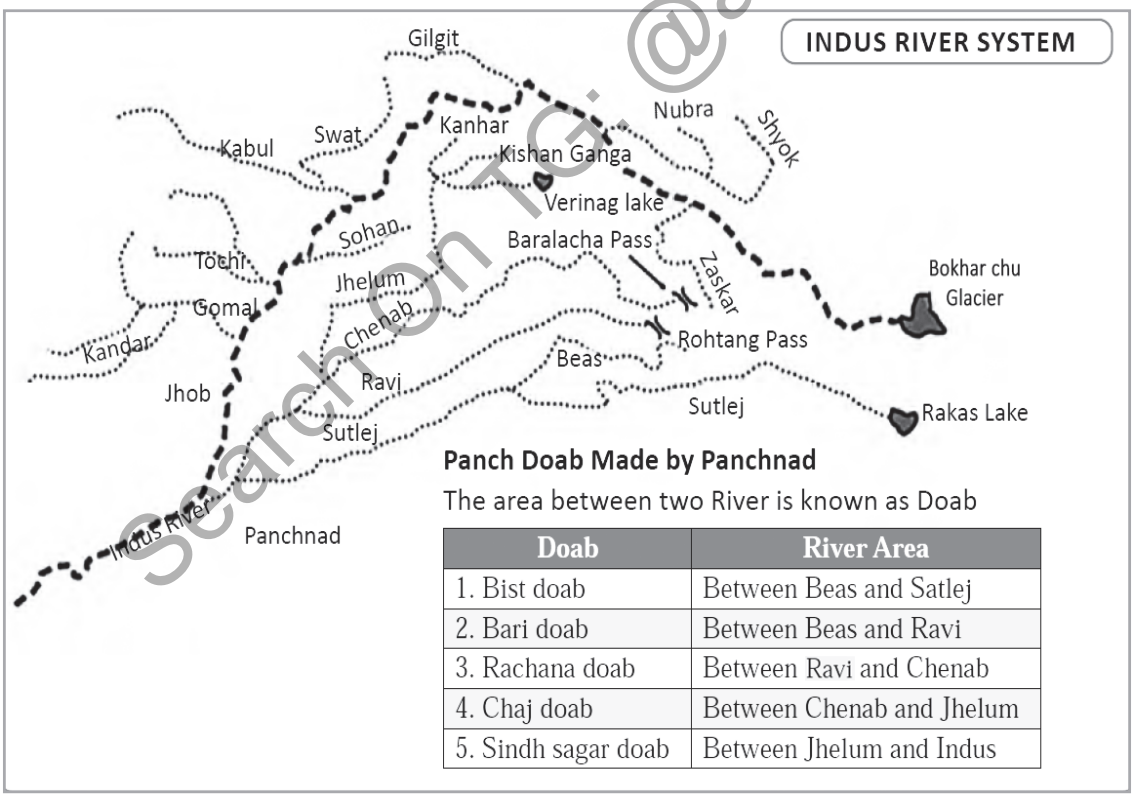
Jhelum and Ravi join Chenab; Beas joins Sutlej; Chenab then joins Sutlej, which finally merges with the Indus **[UPSC 2021]**

Right Bank Tributaries

- **Shyok** (origin -Siachen Glacier)**; Hunza, Gilgit** (Last tributary in India), **Khurram, Tochi, Gomal, Viboa and Sangar** (all originate in the Sulaiman ranges); and **Kabul.**
- Shyok River drains the northern **Karakoram** mountains and is joined by a major tributary, the **Nubra (Origin: Siachen glacier)** river from the north, and the combined course of the two rivers enters the Pak-occupied Kashmir

Left Bank Tributaries

- **Jhelum** is known as Vyeth in Kashmiri, Vitasta in Sanskrit and Hydaspes in Greek.
  - **Origin:** A spring in Verinag, located at the **southeastern part of the Kashmir Valley**, near the foot of the **Pir Panjal** mountain range.
  - Traverses through **Srinagar** and the **Wular** Lake. **[UPSC 2023]**
  - Enters Pakistan near Baramulla and meets the Chenab near Jhang in Pakistan.
  - **Tributaries**: Kishanganga (Right), Dudhganga river, Pohru, Nalla Lidder, Rambiara Nallah, Nallah Sindh.
  - **Multipurpose projects**: Mangla Dam, Rasul Barrage, Kishanganga.



Doab	River Area
1. Bist doab	Between Beas and Satlej
2. Bari doab	Between Beas and Ravi
3. Rachana doab	Between Ravi and Chenab
4. Chaj doab	Between Chenab and Jhelum
5. Sindh sagar doab	Between Jhelum and Indus

Fig. Indus River Tributaries

- **Chenab:** The river Chenab (or Chandra Bhaga) is formed after the two streams, the **Chandra** and the **Bhaga** merge with each other which originate from the south-west and north-west faces of **Bara Lacha pass** respectively in **Lahaul and Spiti valley** (Himachal Pradesh); Bara Shigri glacier feeds the river.
  - **Largest tributary** of the **Indus**.
  - **Marusudar** is the biggest tributary of the Chenab.

- Passes through **Himachal Pradesh and J&K**.
- **Tributaries**: Chandra, Bhaga, R. Tawi
- **Multipurpose projects**: Salal Project, Dulhasti Dam, Baglihar Dam, Trimmu Barrage

- **Ravi**
  - **Origin**- Kullu Hills (Himachal Pradesh), west of the **Rohtang Pass.**
  - Flows through the **Chamba valley** (Himachal Pradesh) and between **Pir Panjal and Dhauladhar**.
  - **Tributaries:** Budhil, Nai/Dhona Ujh
  - **Multipurpose projects:** Thein (Ranjit Sagar) Dam
- **Beas**
  - **Origin**: **Beas Kund** near the **Rohtang Pass**
  - Flows through the **Kullu valley**, forming gorges in the **Dhauladhar range**. Upon entering the Punjab plains, it **merges** with the **Satluj River near Harike**.
  - **Tributary**: Parbati River
  - **Multipurpose projects**: Beas Project, Pong Dam, Pandoh Dam
- **Satluj**
  - **Origin: 'Raksas Tal'** near Mansarovar, Tibet. It is known as Langchen Khambab in Tibet.
  - Enters India through **Shipki La (Himachal Pradesh)**
  - **Tributaries: Beas, Spiti - Rupi etc.**
  - **Multipurpose projects**: Bhakra Nangal Project, Harike, Sirhind, Gobind Ballabh Sagar, Karcham Wangtoo Hydroelectric Plant, Naphtha Jhakri Dam
- **Suru River:** originates from the **Deosai** mountains and is an **obsequent tributary**. **Kargil** is situated on its bank
- **Other Tributaries of Indus:**
  - Shigar, Gasting and Dras.

THE GANGA RIVER SYSTEM

The river has a length of **2,525 km**. It is shared by **Uttarakhand** (110 km) and **Uttar Pradesh** (1,450 km), **Bihar** (445 km) and **West Bengal** (520 km). Ganga basin covers the states of **Uttar Pradesh, Madhya Pradesh, Rajasthan, Bihar, West Bengal, Uttarakhand, Jharkhand, Haryana, Chhattisgarh, Himachal Pradesh and Union Territory of Delhi** draining nearly **26%** of the total geographical area of the country.

Course of the Ganga River

- **Originates** as **Bhagirathi** from **Gangotri Glacier.**
- **Alaknanda** originates from the **Satopanth glacier**, located above Badrinath. It is formed by the convergence of the **Dhauli** and the **Vishnu Ganga** at **Joshimath (Vishnu Prayag)**;
- **Mandakini (Origin: Chorabari glacier)** is a tributary of Alaknanda, their confluence called as Rudra Prayag.
- **Pindar River** meets **Alaknanada** at **Karnaprayag.**
- **River Nandakini** also joins the Alaknanda froming the **Nand Prayag**.
- **Alaknanda** and **Bhagirathi** meet at **Dev Prayag.** From where it is known as **Ganga.**

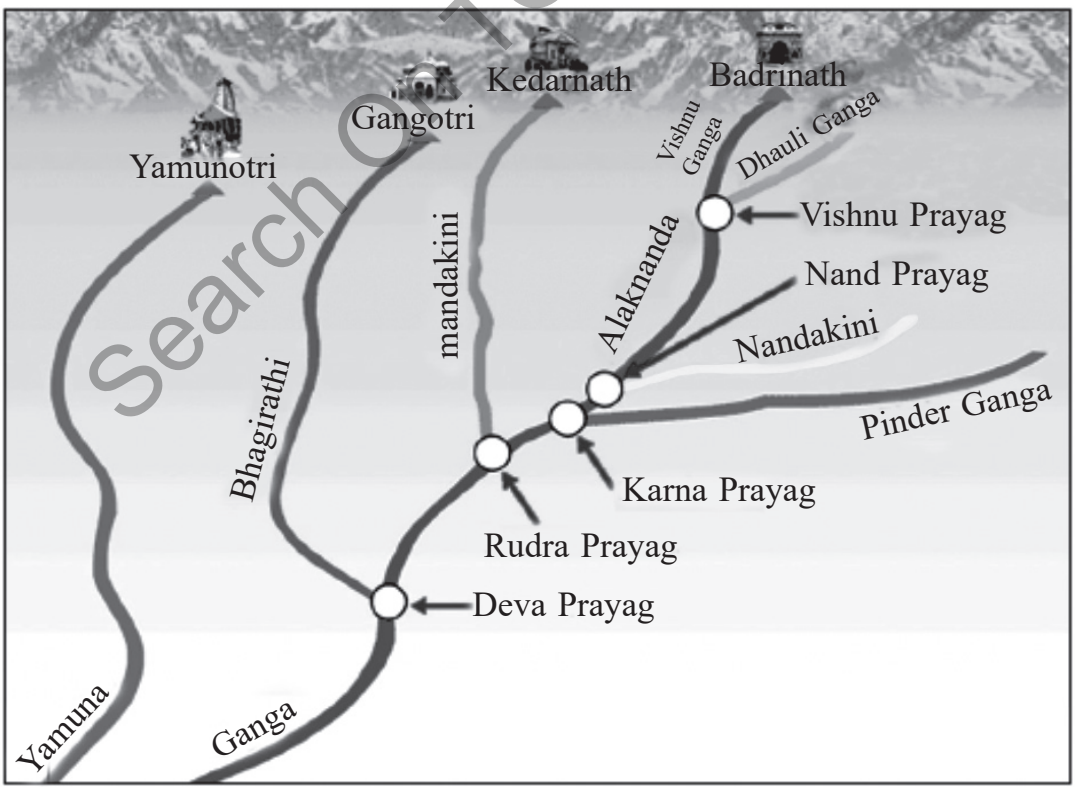


Fig. Panch Prayag

- At **Haridwar, Ganga** emerges from the mountains onto the plains.
- It splits into two **distributaries**, namely the **Bhagirathi** and the **Padma** near the mouth.
- It discharges itself into the Bay of Bengal near the **Sagar** Island.
- **Farakka** in West Bengal is the **northernmost point** of **Ganga delta**.
- Ambala is located on the water divide between the Indus and the Ganga river systems.

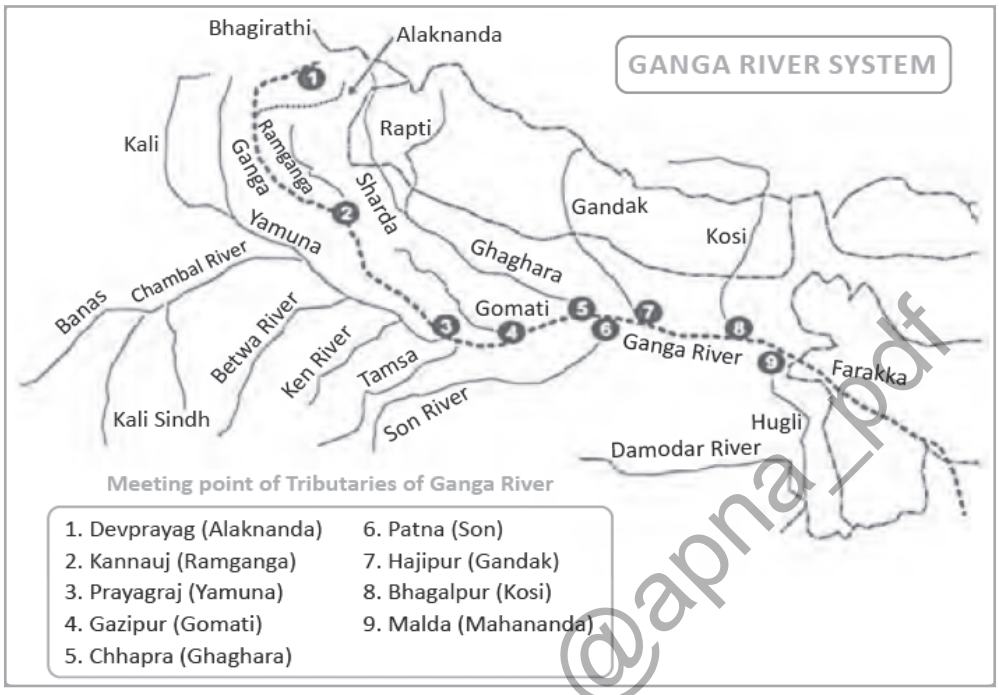


Fig. Ganga River System

Left Bank Tributaries of Ganga

- **Ramganga: Origin** is **Garhwal hills**; joins **Ganga** near **Kannauj**.
- **Gomati**
  - **Origin:** It originates from the Gomat Taal in Pilibhit district, Uttar Pradesh.
  - **Confluence:** The Gomti eventually merges with the Ganga River near Saidpur in Ghazipur district.
  - **Tributaries:** Sai River, Chauka River, Kathina River and Sarayan River
  - **Cities:** The Gomti flows through several cities, including: **Lucknow, Sultanpur** and **Jaunpur.**
- **Ghaghara**
  - **Origin:** Glaciers of **Mapchachungo** (Gurala Mandhata peak); Emerging from the mountains, it creates a deep gorge at **Shishapani**.
  - **Tributaries**: **Tila, Seti, Beri** and **Sarda**
  - **Sarda (Kali or Kali Ganga)** joins it before it finally meets **Ganga** at **Chhapra**.
  - **Sarayu** is the largest **tributary** of the **Sharda** River. **Ayodhya** is situated on **Sarayu** river**.**
  - **Sarda: Origin** is **Milam glacier** in the Nepal Himalayas where it is known as **Goriganga.** Along the India-Nepal border, it is known as **Kali** or **Chauk** and eventually **joins** the **Ghaghara River**.
- **Gandak**
  - Comprises two streams- **Kaligandak** and **Trishulganga**.
  - **Origin: Nepal Himalayas** between the **Dhaulagiri** and **Mount Everest** and drains the central part of Nepal.
  - Enters Ganga plain in **Champaran** (Bihar); joins Ganga near **Patna**.
  - **Kanwar lake** (Ox Bow lake) is fed by the river. **[UPSC 2023]**
- **Kosi**
  - It is an **antecedent river**
  - **Origin**: **North** of **Mount Everest** in **Tibet** where its main stream **Arun** rises
  - Joined by **Son Kosi** (West) and **Tamur Kosi** (East) after crossing the Central Himalayas in Nepal; forms **Sapt Kosi** after uniting with Arun.
- **Mahananda: Origin** is in **Darjeeling hills**; final left bank tributary of the Ganga which joins it in West Bengal.

Right Bank Tributaries of Ganga

- **Yamuna**
  - **Westernmost** and **longest tributary** of the Ganga; Joins **Ganga** at **Prayag (Allahabad)**

- **Origin**: **Yamunotri glacier** near **Bandarpoonch peaks** in the **Mussoorie range**.
- **Tributaries: Right Bank** - Chambal, Sind, Betwa, and Ken**; Left Bank -** Tons (largest), Hindan, Rind, Sengar and Varuna.
- The **Tons** (largest tributary) has some magical spots in its upper reaches. Forests of Alder and Blue pine lead to the famous **Har-ki-Dun** catchment area.
- **Gobind Pashu Vihar Sanctuary** is situated in the upper reaches of **Tons**.
- It is the frontier of the Indian elephant. **West of the Yamuna**, there is **no elephant** in 900 Km of the western Himalaya or its foothills

Chambal

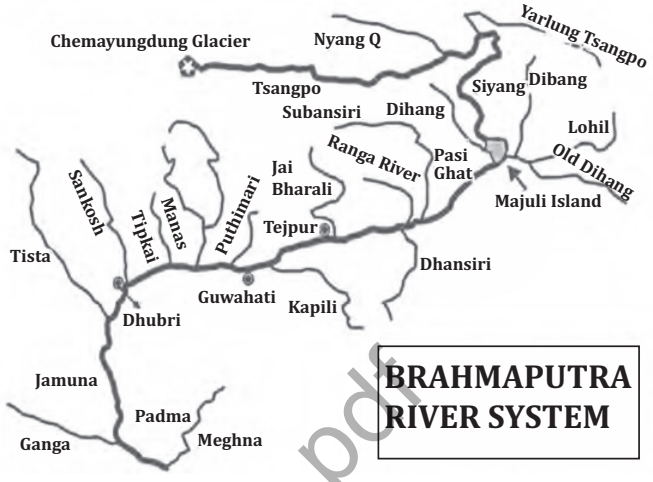
- **Origin: Near Mhow** in the **Malwa plateau** (Madhya Pradesh); joins **Yamuna; Gandhi Sagar dam (Kota)** is constructed on it. **[UPSC 2022]**
- The Chambal is renowned for its **unique badland topography**, known as the **Chambal ravines.**

- **Son**
  - **Origin: Amarkantak plateau**
  - **Tributaries**: Rihand, North Koel
  - Near **Arrah**, located to the west of Patna, it joins Ganga.
- **Damodar**
  - The Damodar River flows along the eastern margins of the **Chotanagpur Plateau** through a rift valley before joining **Hugli** River.
  - **Tributary**: **Barakar river (Maithon dam)** **[UPSC-2022]**
  - Known as "**sorrow of Bengal"** due to its frequent flooding

THE BRAHMAPUTRA SYSTEM

- **Origin**: **Chemayungdung glacier** in the **Kailash** range **near Mansarovar Lake**
- In southern Tibet, it is known as the **Tsangpo**. Rango Tsangpo serves as the major right-bank tributary in Tibet.
- At **Namcha Barwa**, it takes a 'U' turn and enters India as **Dihang . This "U" turn is due to Syntaxial bending of geologically young Himalayas.** **[UPSC 2011]**

  It enters **Assam Plains** near **Sadiya** from where it is known as **Brahmaputra.**
- Enters **Bangladesh** near **Dhubri.** In Bangladesh, it is joined by **Tista** (right bank), after which it is called **Jamuna**.
- When it merges with **Ganga,** it is known as **Padma**. After the Padma river is joined by **Meghana** River, it is collectively known as **Meghana**.
- Its basin is spread over the states of **Arunachal Pradesh, Assam, West Bengal, Meghalaya, Nagaland and Sikkim**.



BRAHMAPUTRA RIVER SYSTEM

- It forms the world's largest and fastest growing **delta**.
- It is well-known for **floods**, **channel shifting** and **bank erosion**. Reasons - large tributaries, large quantity of sediments and heavy rainfall in its catchment area.

Tributaries of the River Brahmaputra

- **Left Bank tributaries**: Burhi Dihing, Lohit, Dibang, Desang, Dikhow, Dhansiri and Kopili
- **Right Bank Tributaries**: Subansiri (Origin: Tibet, antecedent in nature), Jiabharali Kameng, Manas (Transboundary river, this River flows through the **Manas National Park** in Assam, India. This park is known for its diverse wildlife, including endangered species like the pygmy hog and the golden langur.) **[UPSC-2013]**, Torsa, Sankosh, Raidak, Jaldakha and Teesta. **[UPSC 2016]**

Teesta: Origin - Teesta Kangse glacier; forms the **border between Sikkim and West Bengal; Rangeet river** is the main tributary which **originates in Sikkim**; It merges with Brahmaputra before falling into the Bay of Bengal. **[UPSC 2017]**

THE PENINSULAR DRAINAGE SYSTEM

The Peninsular drainage system is older than the Himalayan one.

- **Features:** broad, largely-graded shallow valleys, fixed course, absence of meanders and non perennial flow of water
- Western Ghats act as a water divide between rivers discharging their water in the Bay of Bengal and rivers joining the Arabian Sea.

The Evolution of Peninsular Drainage System

Geological events that influenced present drainage systems of Peninsular India:

1. **Subsidence of the Western Flank:** It **disrupted the symmetrical plan of the rivers** on either side of the original watershed.
2. **Upheaval of the Himalayas:** It caused subsidence on the northern flank of the Peninsular block, leading to trough faulting. The **Narmada** and **Tapi** rivers flow in these **trough faults (rift valleys)** and have filled the original cracks with their detritus materials. Consequently, there is a **lack of alluvial and deltaic deposits** in these rivers.
3. **Tilting of the Peninsular Block** from northwest to southeast during the same period. It gave the entire drainage system an **orientation towards the Bay of Bengal.**

East Flowing Rivers

These rivers make deltas at their mouths.

- Small east flowing rivers:
  - **Rushikulya** (Origin: Nayagarh hills)
  - **Baitrani (**Rises from Garhjat hills),
  - **Subarnarekha** (Rises from Ranchi Plateau),
  - **Brahmani** (confluence of the Sankh and South Koel rivers origin of both these rivers is Chota Nagpur plateau)**,**
  - **Vamsadhara and Nagavali river (Origin:** Eastern Ghat-Odisha**)** **[UPSC 2015, 2021];,**
  - **Penner (Origin:** Eastern Ghat-Nandi Hills, Gandikota canyon of South India was created by it)

[UPSC 2015, 2022],

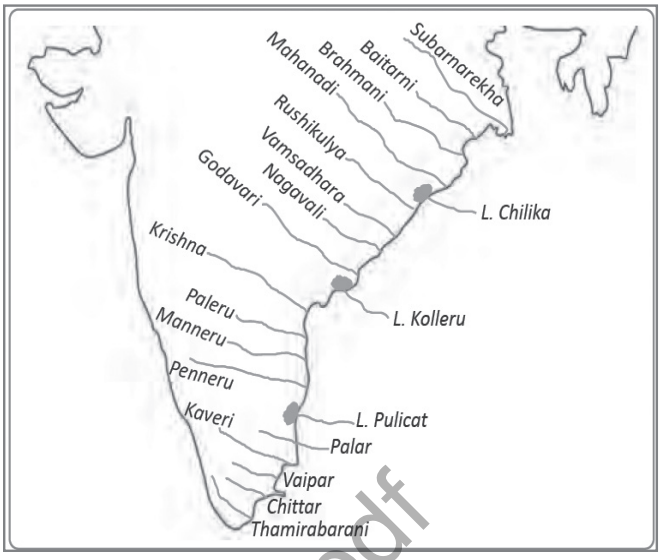


Fig. East Flowing Rivers

  - **Palar (Origin:** Eastern Ghat-Shervoroy Hills**)**
  - **Vaigai (Origin:** Western Ghat-Nilgiri Hills**).**

[UPSC 2021]

- **Mahanadi**
  - **Origin**: Raipur district of **Chhattisgarh.**
  - **Drainage Basin: 53%** in Madhya Pradesh and Chhattisgarh; remaining **47%** in Odisha.
  - **Tributaries: Left Bank** - Sheonath, Hasdo, Mand, Ib; **Right Bank -** Tel, Jonk, Ong.

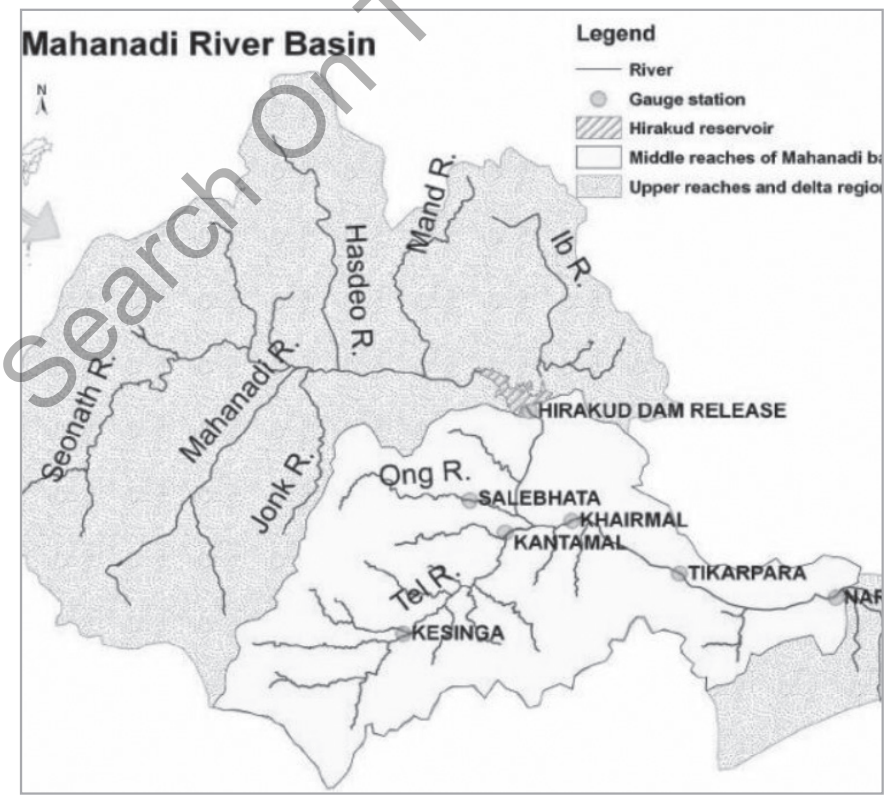


Fig. Mahanadi River System

- **Godavari**
  - **Origin**: At **Trambekeshwar** in Nasik district of **Maharashtra.**
  - **Largest river system** in the **Peninsular drainage;** also called **Dakshin Ganga.**

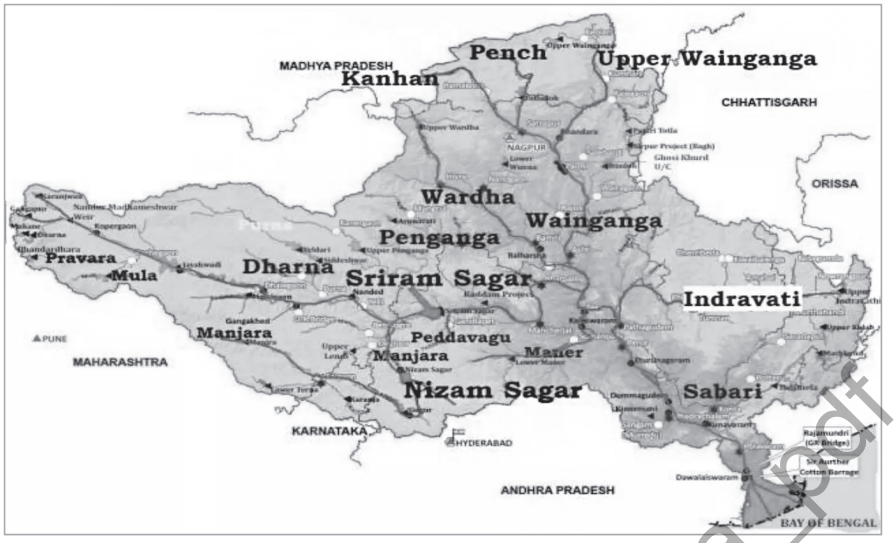


Fig. Godavari River System

  - **Drainage Basin:** Almost Half of it in Maharastra and remaining in Madhya Pradesh, Chhattisgarh, Telangana and Andhra Pradesh.
  - **Tributaries: Left Bank -** Indravati, Dudhna, Purna, Pranhita (formed by confluence of Penganga and Wardha)**; Right Bank -** Manjra, Pravara, Maner**.** **[UPSC 2015]**
- **Krishna**
  - **Origin: Mahabaleshwar** in the Sahyadri (Western Ghats).
  - **Tributaries**: **Right Bank**- Ghatprabha, Malaprabha, Tungabhadra (Hampi is located near the river); **Left Bank**- Bhima, Dindi, Musi, Munneru, Koyna.
  - **Catchment Area**: **27%** in Maharashtra, **44%** in Karnataka, and **29%** in Andhra Pradesh and Telangana.

Kolleru Lake: lies between the deltas of Godavari and Krishna. It is **not directly fed by** the **Krishna River [UPSC 2023]**

Fig. Krishna River System

- **Kaveri**
  - **Origin: Brahmagiri Hills** (Karnataka)
  - **Drainage Basin: 3%** in **Kerala**, **41%** in **Karnataka**, and **56%** in **Tamil Nadu.**
  - **Tributaries: Left Bank** - Hemavati, Arkavati, Shimsha; **Right Bank** - Kabani, Bhavani, Lakshmantirtha, Amaravati.
  - It makes the second biggest waterfall in India known as **Shivasamudram Falls (Karnataka)**; **Tiruchirapalli** is located along the River.
  - Nagarhole National park, Sathyamangalam Tiger Reserve and Wayanad Wildlife Sanctuary Protected Areas are located in kaveri basin.

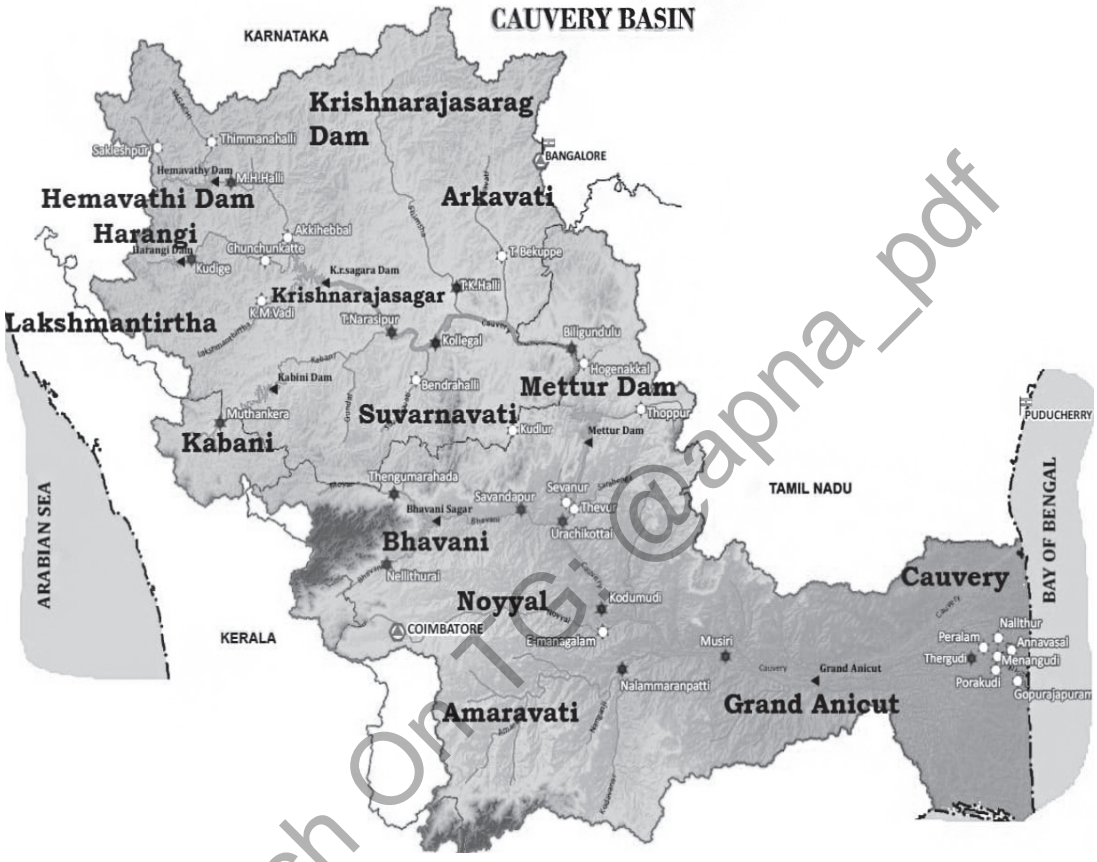


Fig. Kaveri River System

West Flowing Rivers

- Some Indian rivers flow westward into the Arabian Sea due to specific geographical and tectonic factors. The **Western Ghats**, located near the western coastline, create a steep gradient, causing rivers originating on their slopes to flow swiftly westward.
- Rivers like the **Narmada** and **Tapi** follow **rift valleys** formed by tectonic activity, providing natural westward channels. Ancient **crustal tilting** further sloped parts of the Peninsular Plateau towards the west, influencing rivers such as the **Mahi** and **Sabarmati**.
- Unlike east-flowing rivers, west-flowing ones are shorter, carry less sediment, and **form estuaries** rather than extensive deltas. Notable examples include **Narmada**, **Tapi**, **Mandovi**, and **Periyar**.
- **Narmada**
  - **Origin**: **Amarkantak plateau**
  - **Course**: Flows through a rift valley between **Satpura** (South) and **Vindhyan Range** (north); meets the Arabian sea south of Bharuch. **[UPSC 2013]**
  - **Dhuandhar Falls** near Jabalpur (MP); **Sardar Sarovar dam and Indira Sagar dam (Madhya Pradesh) are located on it.** **[UPSC 2022]**
  - **Tributaries**: **Left Bank**: Tawa River; **Right Bank**: Barna River, Kolar River.

Fig. Narmada River System

- **Tapi**
  - **Origin**: Betul (Madhya Pradesh), Satpura range
  - **Drainage Basin: 79%** in **Maharashtra**, **15%** in **Madhya Pradesh**, and **6% in Gujarat**.

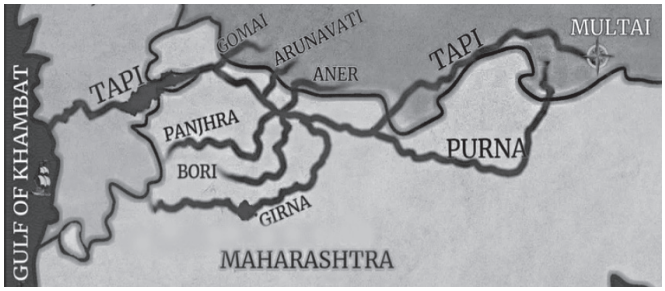


Fig. Tapi River System

- **Luni**
  - **Origin**: near **Pushkar** in **Rajasthan** in two branches, i.e. the Saraswati and the Sabarmati that join together.
  - Drains into the **Rann of Kachchh (Gujarat)**
  - The entire river system of the Luni is **ephemeral** (seasonal flow)
- **Sabarmati:** originates in the **Aravalli Range** and drains into the Gulf of Khambhat (Arabian Sea).
- **Mahi River** originates from **Vindhyas** in Dhar (Madhya Pradesh) and after flowing through Rajasthan, enters Gujarat and falls into the Arabian Sea.

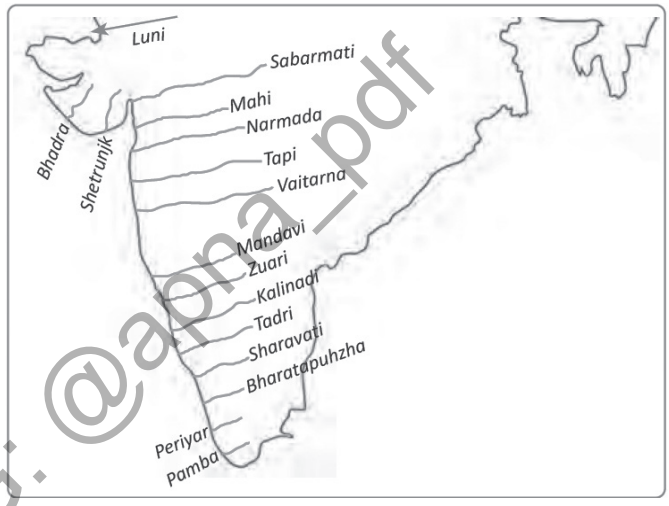


Fig. West Flowing Rivers

- **Periyar, Pamba, Bharathapuzha**
  - Rivers of Kerala; Periyar is the longest river and Bharathpuzha is the second longest river of Kerala; Pamba River falls in Vembanad lake.
- **Other West Flowing Rivers**
  - **Shetruniji, Bhadra** and **Dhadhar** (Gujarat); **Vaitarna River** (Trimbak hills; Nasik, Maharashtra)**; Mandovi and Zuari** (Goa); **Kalinadi** (falls in Karwar Bay), **Bedti** and **Sharavati** (Karnataka).
  - **Gersoppa (Jog) fall** is on **Sharavati** river.

Comparison between the Himalayan and the Peninsular River		
Aspect	**Himalayan River**	**Peninsular River**
Place of origin	Himalayan mountains covered with glaciers	Peninsular plateau and central highland
Type of drainage	Antecedent and Consequent leading to dendritic drainage pattern in plains	Superimposed, rejuvenated resulting in trellis, radial and rectangular patterns
Nature of river	Long course, flowing through the rugged mountains experiencing headward erosion and river capturing; In plains experiences meandering and shifting of course	Smaller, fixed course with well-adjusted valleys
Catchment area	Very large basins	Relatively smaller basin
Age of river	Young and youthful, active erosion and witnesses valley deepening	Older rivers with graded profiles and have reached almost their base level.

MAJOR RIVERS AND CITIES IN INDIA

River	Famous Cities
Yamuna	Delhi, Agra, Mathura
Ganga	Varanasi, Allahabad, Kanpur, Patna, Kolkata, Haridwar, Rishikesh
Indus	Srinagar, Jammu
Brahmaputra	Guwahati, Dibrugarh
Godavari	Nasik, Nanded, Rajahmundry, Ramagundam, Karimnagar, Golegaon
Krishna	Vijayawada, Amaravati, Sangli, Karad
Kaveri	Mysore, Bengaluru, Trichy, Thanjavur, Erode
Narmada	Jabalpur, Bharuch
Tapi	Surat
Mahanadi	Cuttack, Bhubaneswar, Banki, Sambalpur
Sabarmati	Ahmedabad
Luni	Jodhpur

WETLANDS OF INDIA

- Wetlands are areas of land that are saturated with water, either permanently or seasonally. They play a crucial role in maintaining ecological balance, biodiversity, and water quality.
- The country's total geographical area under the category of wetlands is recorded more in Gujarat as compared to other States. In India, the total geographical area of inland wetlands is larger than that of coastal wetlands. **[UPSC 2012]**

Types of Wetlands

- **Inland Wetlands:** Marshes, Swamps, Lakes, Ponds and Riverine Wetlands
- **Coastal Wetlands:** Mangroves, Estuaries, Lagoons, Coral Reefs

Major Wetlands in India

- **The Sundarbans:** The world's largest delta, located in West Bengal and Bangladesh.
- **Chilika Lake:** A brackish water lagoon in Odisha.
- **Wular Lake:** A freshwater lake in Jammu and Kashmir.
- **Keoladeo National Park:** A wetland in Rajasthan, known for its bird diversity.
- **Ranganathittu Bird Sanctuary:** A bird sanctuary in Karnataka

LAKES

- **Largest freshwater lake** in India – **Wular Lake**, Jammu and Kashmir
- **Largest brackish water lake** with estuarine character, **largest lagoon** in India – **Chilka Lake**, Orissa
- **Highest lake** in India – **Cholamu lake,** Sikkim
- **Longest Lake** in India – **Vembanad lake**, Kerala
- **Largest Artificial Lake** in India – **Govind Vallabh Pant Sagar** (Rihand Dam), UP

Aliyar, Isapur and Kangsabati well known places for Water reservoirs. **[UPSC 2019]**

Lakes in India

Lake Type	Lake(s)	State(s)	Feeding River(s)
Freshwater Lakes	Kolleru Lake	Andhra Pradesh	Krishna River, Godavari River
	Nagarjuna Sagar	Andhra Pradesh	Krishna River
	Haflong Lake	Assam	formed by local streams and rainfall
	Deepor Beel	Assam	Brahmaputra River
	Loktak Lake	Manipur	Imphal River
	Dal Lake	Jammu & Kashmir	Jhelum River
	Wular Lake	Jammu & Kashmir	Jhelum River
	Sasthamkotta Lake	Kerala	Fed by underground springs.
	Bhojtal Lake	Madhya Pradesh	Kolans River
	Salim Ali Lake	Maharashtra	No major river directly feeding
	Shivsagar Lake	Maharashtra	No major river directly feeding
	Harike Lake	Punjab	Sutlej River

	Kanjli Lake	Punjab	Beas River
	Tsomgo Lake	Sikkim	Rangpo River
	Renuka Lake	Himachal Pradesh	Giri River
	Vembanad Lake	Kerala	Punnappra River, Meenachil River, Pamba river
	Lake Pichola	Rajasthan	No major river feeding (man-made lake)
Brackish Water Lakes	Pulicat Lake **[UPSC-2017]**	Andhra Pradesh, Tamil Nadu	Arani River, Kalangi River
	Ashtamudi Kayal	Kerala	Kallada river
	Kuttanad	Kerala	Pampa, Achenkoil and Meenachil Rivers
	Chilika Lake	Odisha	Daya River, Mahanadi River
	Didwana Lake	Rajasthan	No major river feeding
	Kuchaman Lake	Rajasthan	No major river feeding
	Sargol Lake	Rajasthan	No major river feeding
	Khatu Lake	Rajasthan	No major river feeding
Oxbow Lakes	Kanwar Lake	Bihar	Gandak River
	Vynthala Lake	Kerala	Chalakudy River
Artificial Lakes	Hussain Sagar	Telangana	Musi River
	Gobind Sagar Lake	Himachal Pradesh	Sutlej River
	Kodaikanal Lake **[UPSC-2018]**	Tamil Nadu	No major river feeding (rain-fed)
	Narmada Sagar Lake	Madhya Pradesh	Narmada River
	Ranjit Sagar Dam Lake	Jammu & Kashmir	Ravi River

DAMS IN INDIA

State	Dams (Rivers)
Uttar Pradesh	Rihand Dam (Rihand River), Rajghat Dam (Betwa River)
Madhya Pradesh	Indira Sagar Dam (Narmada River), Bargi Dam (Narmada River), Gandhisagar Dam (Chambal River), Bansagar Dam (Sone River), Tawa Dam (Tawa River)
Gujarat	Sardar Sarovar Dam (Narmada River), Dholi Dam (Sabarmati River)
Maharashtra	Koyna Dam (Koyna River), Jayakwadi Dam (Godavari River), Ujani Dam (Bhima River), Tansa Dam (Tansa River), Bhatsa Dam (Bhatsa River)
Karnataka	Krishna Raja Sagara Dam (Kaveri River), Almatti Dam (Krishna River), Tungabhadra Dam (Tungabhadra River), Linganamakki Dam (Sharavathi River), Ghataprabha Dam (Ghataprabha River)
Tamil Nadu	Mettur Dam (Kaveri River), Vaigai Dam (Vaigai River), Pechiparai Dam (Kodayar River)
Andhra Pradesh	Srisailam Dam (Krishna River), Nagarjuna Sagar Dam (Krishna River)
Kerala	Idukki Dam (Periyar River), Mullaperiyar Dam (Periyar River), Parambikulam Dam (Parambikulam River)
Odisha	Hirakud Dam (Mahanadi River), Indravati Dam (Indravati River)
Telangana	Kaleshwaram Dam (Godavari River), Nizam Sagar Dam (Manjira River), Lower Manair Dam (Manair River)
Himachal Pradesh	Bhakra Nangal Dam (Sutlej River), Chamera Dam (Ravi River), Pong Dam (Beas River)
Jammu & Kashmir	Baglihar Dam (Chenab River), Dul Hasti Dam (Chenab River)
West Bengal	Maithon Dam (Barakar River), Chandil Dam (Swarnarekha River)

3 Climate

Climate refers to the sum total of weather conditions and variations over a large area for a long period of time. The Climate of **India** is **"monsoon" type** (characterised by a distinct seasonal pattern) which is found mainly in South Asia and South-East Asia.

- Monsoon word come from Arabic word 'Mausim'means season. It is seasonal reversal of wind direction during a year.

Weather refers to the state of the atmosphere over an area at any point of time.

FACTORS AFFECTING INDIA'S CLIMATE

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

1. Factors Related to Location and Relief

- **Latitude:** The **Tropic of Cancer** divides India, placing the **northern part in the sub-tropical and temperate zones, and the southern part in the tropical zone.**
- **Altitude:** Elevated regions are cooler due to the **decline in temperature with height.**
- **The Himalayas:** It **shields** India from **cold northern winds** originating near the Arctic circle. They also help **trap** the **monsoon winds.**
- **Distribution of Land and Water:** Differential heating of land and sea (water heats up or cools down slowly) creates different air pressure zones in different seasons in the Indian subcontinent that cause reversal in the direction of monsoon winds.
- **Proximity to the Sea:** The coastal areas have a balanced climate and distant locations from the sea, experience more pronounced seasonal contrasts.
- **Relief:** India's topography influences temperature, rainfall, and wind patterns. Eg. The windward side of the Western Ghats receives high rainfall, while the leeward side remains relatively dry.

2. Factor Related to Air Pressure and Wind

- Surface pressure and wind: India lies in the region of north easterly winds (origin: subtropical high-pressure belt of the northern hemisphere; bring little or no rain)
- Monsoon Winds: The southwest monsoon, which lasts from June to September, is the most significant factor influencing India's climate. The monsoon winds, originating over the Indian Ocean, bring substantial rainfall to most parts of the country.
- Jet stream and upper air circulation
- Western cyclonic disturbances and Tropical cyclones

KEY CONCEPTS IN GLOBAL AIR CIRCULATION

Jet Streams: Formation, Mechanism, and Global Climate Impact

Jet streams are narrow, fast-moving air currents located at high altitudes in the atmosphere, typically between 9 to 16 kilometers (30,000 to 50,000 feet) above Earth's surface. They form due to the **temperature contrast** between the cold polar regions and the warmer tropical zones. This temperature difference creates a strong pressure gradient, causing air to move quickly from high-pressure areas to low-pressure areas, resulting in the formation of jet streams.

The primary jet streams are:

- **Polar Jet Stream:** Forms between the cold polar air and warmer mid-latitude air.
- **Subtropical Jet Stream:** Forms between the tropical air and the mid-latitude air.

Jet streams typically flow from west to east, but their **meandering** (changes in direction and intensity) is influenced by several factors, including seasonal changes, the Earth's rotation, and variations in surface temperatures.

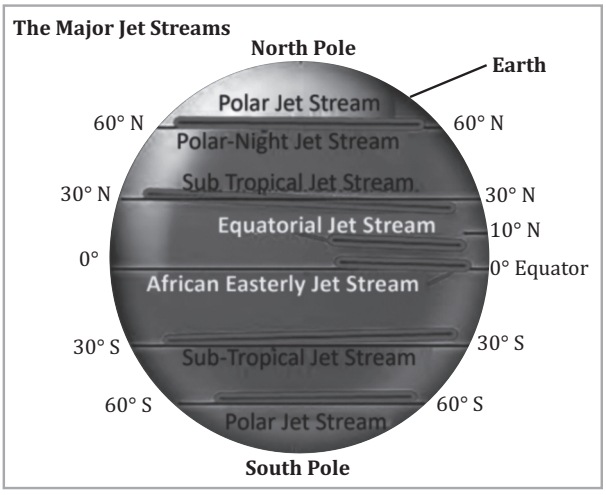


Fig. The Major Jet Streams

Walker Circulation (Normal State), El Nino, La Nina

- **Mechanism:** The differential heating of the equatorial Pacific Ocean creates a temperature gradient between the eastern (cooler) and western (warmer) Pacific. This leads to low pressure in the west and high pressure in the east. Warm air rises in the western Pacific, leading to heavy rainfall in Southeast Asia, while descending air over Australia creates high pressure, suppressing cloud formation and resulting in dry conditions.
- **Effect:** This pattern leads to normal rainfall distribution, with wetter conditions in Southeast Asia and drier conditions in Australia.

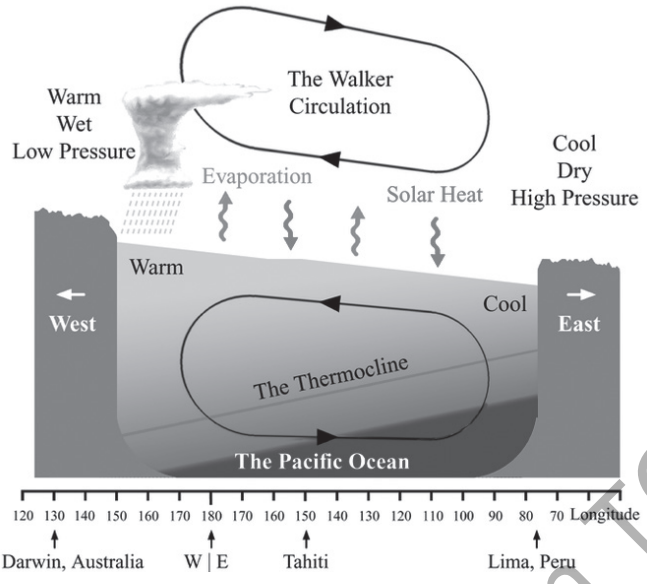


Fig. Walker Cycle

El Niño

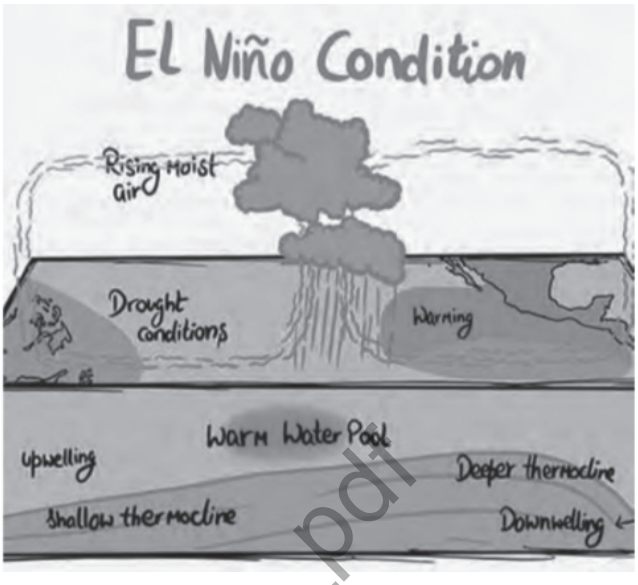


Fig. El-Niño

- **Mechanism:** El Niño occurs when the usual westward movement of warm water in the Pacific Ocean weakens or reverses, causing sea surface temperatures to rise in the central and eastern Pacific. This disrupts the normal atmospheric circulation by weakening the trade winds and reducing upwelling in the eastern Pacific. Consequently, the rising air over the western Pacific weakens, and areas like Southeast Asia experience lower rainfall.
- **Effect:** Over Australia, the usual descending air from the east no longer occurs, reducing pressure and increasing the likelihood of drought and heatwaves. In contrast, the western Pacific, including South America, experiences more intense rainfall and flooding.

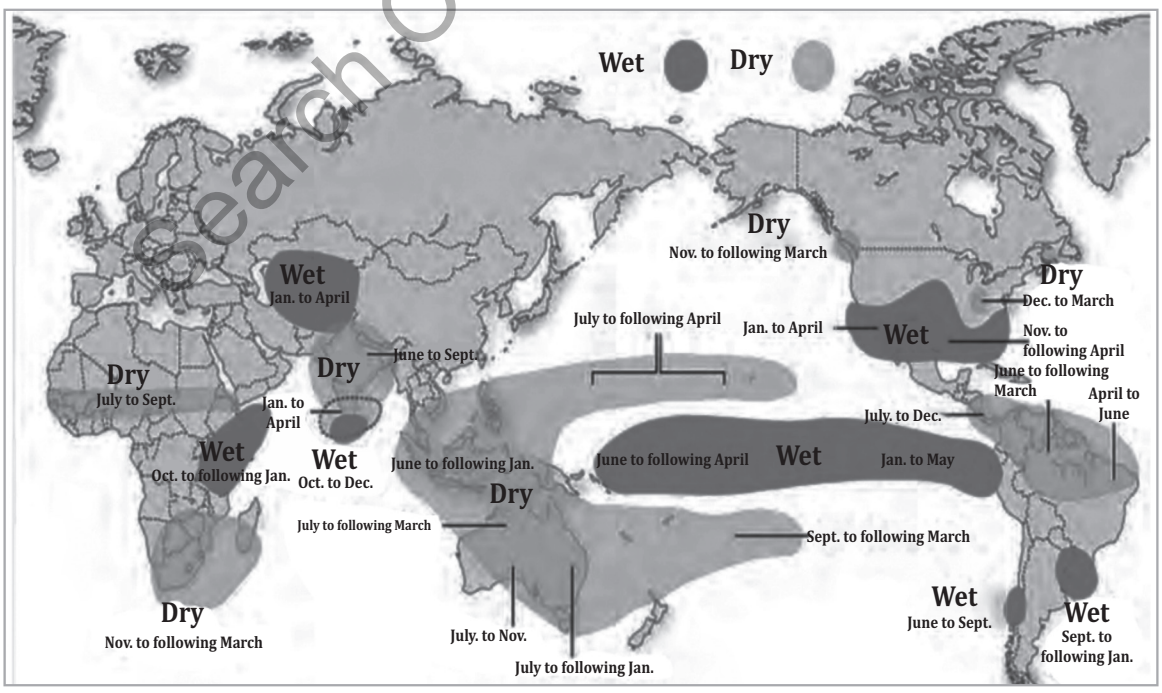


Fig. El Nino and Rainfall

La Niña [UPSC 2011]

- **Reason for Impact:** La Niña is the opposite of El Niño and is characterized by stronger-than-normal trade winds that push cold water towards the western Pacific. This strengthens the normal Walker Circulation, enhancing upwelling in the eastern Pacific and creating lower sea surface temperatures. Rising air in the western Pacific is intensified, enhancing rainfall in Southeast Asia and the western Pacific.
- **Effect:** In Australia, the usual dry conditions are reversed, and increased moisture leads to higher rainfall, flooding, and stronger monsoon patterns. The eastern Pacific (e.g., South America) experiences reduced rainfall, resulting in drought conditions.

Indian Ocean Dipole (IOD) [UPSC 2017]

- **Mechanism:** The IOD is caused by temperature differences between the western and eastern Indian Ocean. A positive IOD occurs when the western Indian Ocean is warmer than the eastern Indian Ocean, creating an east-to-west pressure gradient. Whereas a Negative IOD sets up a temperature difference across the tropical Indian Ocean, with warmer than normal water in the east and cooler than normal water in the west.
- **Effect:** A negative IOD results in drier conditions over India, especially during the monsoon season, leading to weakened monsoon rains. In contrast, a positive IOD (when the western Indian Ocean is warmer) can lead to increased rainfall in the region, strengthening the monsoon.

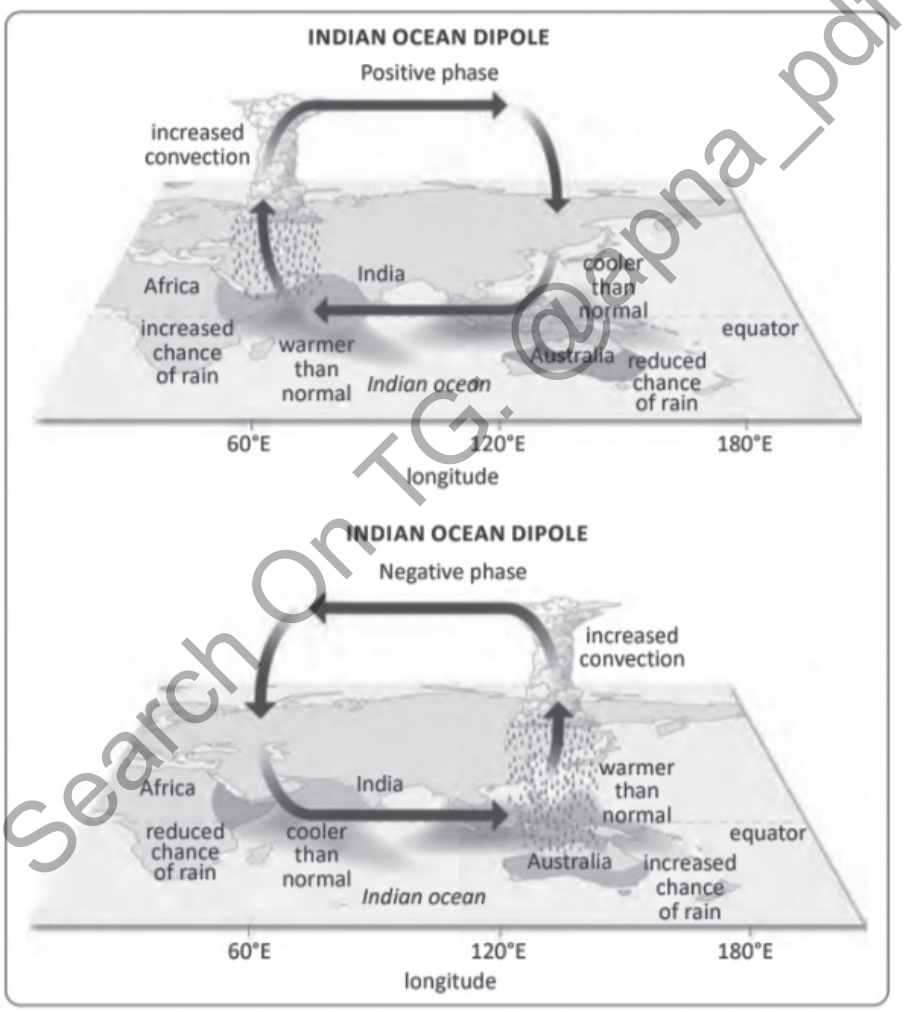


Fig. The Indian Ocean Dipole (IOD)

Madden-Julian Oscillation (MJO)

- **Mechanism:** The MJO is an eastward-moving pulse of convection that influences tropical rainfall patterns. The phase of the MJO can modulate the intensity and duration of the monsoon by strengthening or weakening the monsoonal winds.
- **Effect:** The active MJO phase leads to enhanced rainfall in the Indian subcontinent, while its suppressed phase can cause drier conditions and delay the onset of monsoon rains. The MJO also influences tropical cyclones by promoting or inhibiting cyclogenesis depending on its phase.

These mechanisms are crucial in shaping the climate of various regions by affecting atmospheric circulation patterns, sea surface temperatures, and moisture transport. Understanding these dynamics provides valuable insights into seasonal variability, particularly for agriculture, water management, and disaster preparedness in affected regions.

SEASONS IN INDIA

The meteorologists recognise the following four seasons:

- Cold weather season (Mid November to February)
- Hot weather season (March to May)
- Southwest monsoon season (June to September)
- Retreating monsoon season (October-November)

COLD WEATHER SEASON

Surface Pressure and Winds: Weather conditions are generally influenced by the distribution of pressure in Central and Western Asia.

- During winters a **high pressure zone** develops over **Central Asia.** The surface **winds blowing out of that region, reach India** in the form of **dry continental air mass** that **comes in contact** with **trade winds** over northwestern India.
- The contact zone is not stable and sometimes it shifts up to the middle Ganga valley, thus bringing the entire North-western India the influence of the North-Westerly winds.

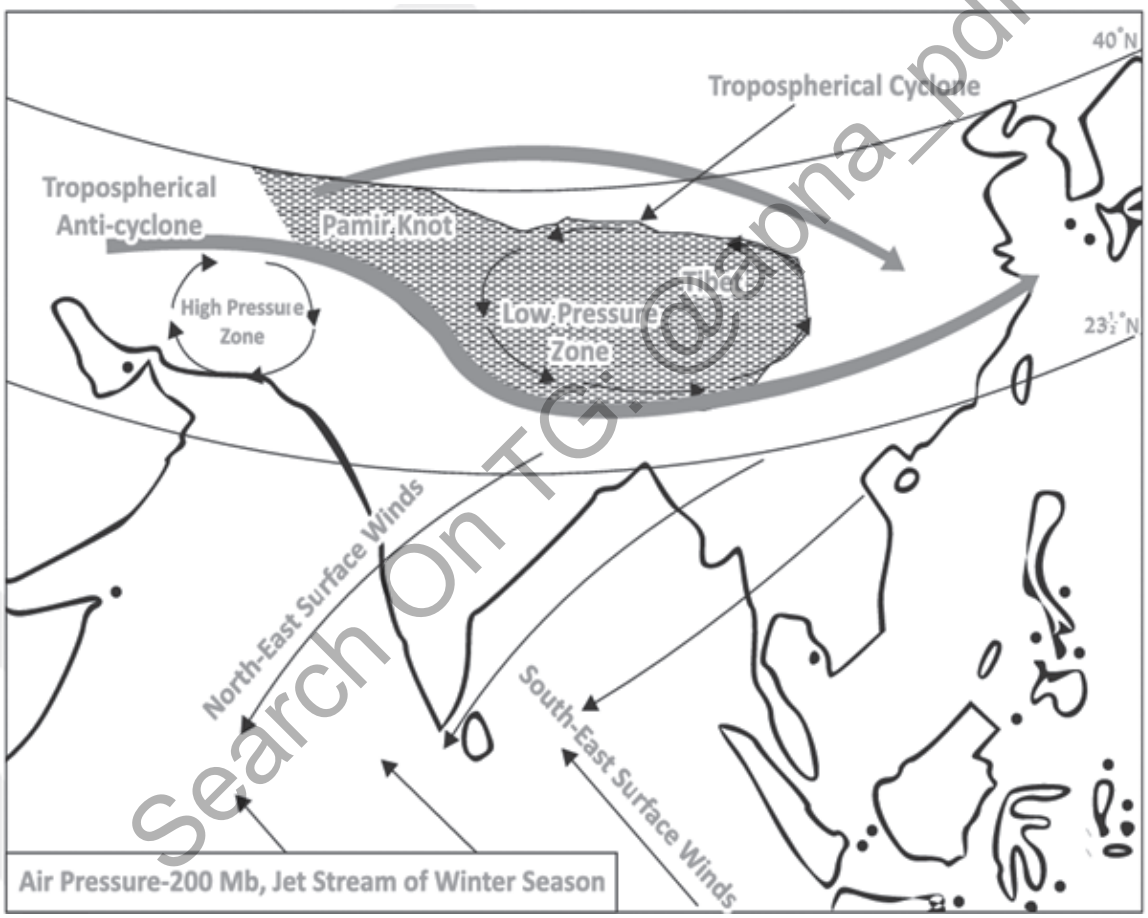


Fig. Jet Stream of Winter Season

- **Feeble high-pressure** conditions prevail over the **northern plain**; air **pressure** is **slightly lower** in **South India**. Winds start blowing from the northwestern high pressure zone to the low air pressure zone over the Indian Ocean in the south.

Jet Stream and Upper Air Circulation

- During winters the **SubTropical Westerly Jet Streams** flowing across the Asian continent gets **bifurcated** at the **Tibetan Himalayas**. **Northern branch** blows north of the Tibetan highlands and **southern branch** blows in an eastward direction, south of the Himalayas.
- **Southern branch** has a **significant influence** on the **winter weather.** In winter, the STWJ is more prominent and helps maintain dry conditions by pushing moist air away from the subcontinent as high pressure is maintained over the subcontinent.

Western Cyclonic Disturbance and Tropical Cyclones

- The **western cyclonic disturbances** originate over the **Mediterranean Sea** and are brought into India by the **westerly jet stream.** An **increase in the prevailing night temperature** generally indicates an advance in the arrival of these cyclone disturbances.
- They pick up the moisture from the **Caspian Sea** in the north and the **Persian Gulf** in the south and cause **winter rainfall** in **North west** India. Although the total amount of winter rainfall locally known as **'mahawat'** is small, they are of immense importance for the **cultivation of 'rabi' crops**.
- **Tropical cyclones** develop in the Bay of Bengal during the **late summer season**. These cyclones are pushed towards India's eastern coast by **North East monsoon winds** causing rain. They hit the **Tamil Nadu, Andhra Pradesh and Odisha coast.**
- **Tamil Nadu coast** experiences **rain during winter.**

Winter in northern India can be very cold, with temperatures sometimes dropping below freezing. This cold is attributed to three reasons**:**

- States like Punjab, Haryana, and Rajasthan are far away from the moderating influence of sea and experience continental climate.
- Snowfall in the Himalayan ranges creates a cold wave situation;
- Around February, the cold winds coming from the Caspian Sea and Turkmenistan bring cold waves along with frost and fog over the north-western parts of India.

In contrast, the **Peninsular region** does not have any well-defined cold weather season due to the moderating influence of the sea and its equatorial proximity.

Rainfall: Winter monsoons do not cause rainfall (move from land to the sea) because of little humidity and due to anticyclonic circulation on land. Some exceptions-

- In **northwestern India**, some **weak temperate cyclones** from the Mediterranean Sea cause rainfall in **Punjab, Haryana, Delhi and western Uttar Pradesh**. It is in the form of snowfall in the **lower Himalayas**. Precipitation decreases from west to east in the plains and from north to south in the mountains. **[UPSC 2012]**
- **Central parts** and **northern parts of the southern Peninsula** occasionally get winter rainfall.
- Arunachal Pradesh and Assam in the northeastern parts (meagre amount).
- **Northeast monsoon** during October and November crosses over Bay of Bengal, picks up moisture and causes rainfall over the **Tamil Nadu coast, southern Andhra Pradesh, southeast Karnataka and southeast Kerala.**

HOT WEATHER SEASON

- Southern India has a milder summer due to its peninsular location and the ocean's moderating effects.
- Coastal regions see minimal temperature variation from north to south; rather temperature increases from coast to interior.

Mechanisms of Weather in Summer Season Surface Pressure and Winds

- With the onset of summer and the sun's northward movement, **India's wind circulation** sees a **reversal** at both lower and upper levels.
- **Low pressure belt [Inter Tropical Convergence Zone (ITCZ)] shifts northwards,** roughly parallel to the Himalayas between 20° N and 25° N by the middle of July.
- By this time, **the Westerly jet stream withdraws** from the North Indian Plain. Northward shift of the equatorial trough (ITCZ) and withdrawal of the westerly jet stream are interrelated.
- ITCZ (low-pressure zone), attracts inflow of winds from different directions; **maritime tropical air mass (mT)** from the **southern hemisphere crosses the equator** and moves towards the low-pressure area in a **southwesterly** direction which results in **southwest monsoon**.

Jet Streams and Upper Air Circulation

In June, an easterly jet stream flows in upper atmosphere over the southern part of the Peninsula. In August it flows - at 15 degree north and in september - at 22 degree north.

Tropical Cyclone

Eastern jet stream steers tropical depression. Track of Depression is an area of highest rainfall in India.

Some Famous Local Storms of Hot Weather Season

1. **Loo: Hot** and **dry** winds blowing in the **Northern plains.**
2. **Mango Shower: Pre-monsoon showers** towards the end of summer in **Kerala** and coastal areas of **Karnataka** that help in the early ripening of mangoes.
3. **Blossom Shower:** It helps coffee flowers to blossom in Kerala and nearby areas.
4. **Nor Westers:** Evening thunderstorms in Bengal and Assam locally known as 'Kalbaisakhi'. They are useful for tea, jute and rice cultivation. They are known as "Bardoli Chheerha" in Assam

SOUTH-WEST MONSOON SEASON

The onset of the Indian monsoon typically occurs in early June, marked by the arrival of the southwest monsoon winds over the Kerala coast, signifying the beginning of the rainy season. This phenomenon is driven by the differential heating of land and water, creating a low-pressure area over the Indian subcontinent and a high-pressure area over the Indian

Ocean (Mascarene High). The Inter-Tropical Convergence Zone (ITCZ) shifts northward, drawing moisture-laden winds from the ocean toward the land. The monsoon onset is accompanied by heavy rainfall, thunderstorms, and a drop in temperatures, bringing relief from the intense summer heat. It gradually progresses northward, covering most of India by mid-July, crucial for agriculture and water resources across the country.

Mechanism

The **Mascarene High** plays a crucial role in the monsoon mechanism, particularly in the dynamics of the Indian summer monsoon.

- **Role during the Southwest Monsoon:** The Mascarene High, a high-pressure system located over the Indian Ocean near the Mascarene Islands (Mauritius), influences the monsoon by driving winds across the Indian Ocean towards India. As the high-pressure system strengthens during the summer, it intensifies the **southwest winds**, which are moisture-laden, towards the subcontinent. This enhances the monsoon rains, particularly on the western coasts and inland regions of India.
- **Impact on Indian Monsoon:** The position and intensity of the Mascarene High affect the strength and onset of the monsoon. When it is strong, it helps in maintaining a steady flow of moist air towards India. Conversely, a weak or displaced Mascarene High can cause disruptions in the monsoon, leading to weaker rainfall patterns. The **Indian Ocean Dipole** and the **Seychelles High** are other systems that interact with the Mascarene High, influencing seasonal variability in rainfall patterns.
- **Thermal Theory of Monsoon:**
  - **Overview:** This theory, proposed by **Sir Halley** in the 17th century, links monsoon rainfall to the differential heating of land and ocean.
  - **Mechanism:**
    - **Summer:** The Indian subcontinent heats up intensely, causing a drop in atmospheric pressure over the land. The surrounding oceans, which heat up slowly compared to the land, have higher pressure. This causes moist air from the ocean to flow inland towards the low-pressure zone, bringing rain.
    - **Winter:** In contrast, during winter, the land cools faster than the ocean, creating a high-pressure zone over the land and low pressure over the sea. This causes dry winds to blow from the land towards the sea, resulting in a dry winter season.
- **Role of ITCZ (Inter-Tropical Convergence Zone):**
  - **Overview:** The ITCZ is a band of low-pressure air that forms at the equator where the trade winds of the northern and southern hemispheres meet.

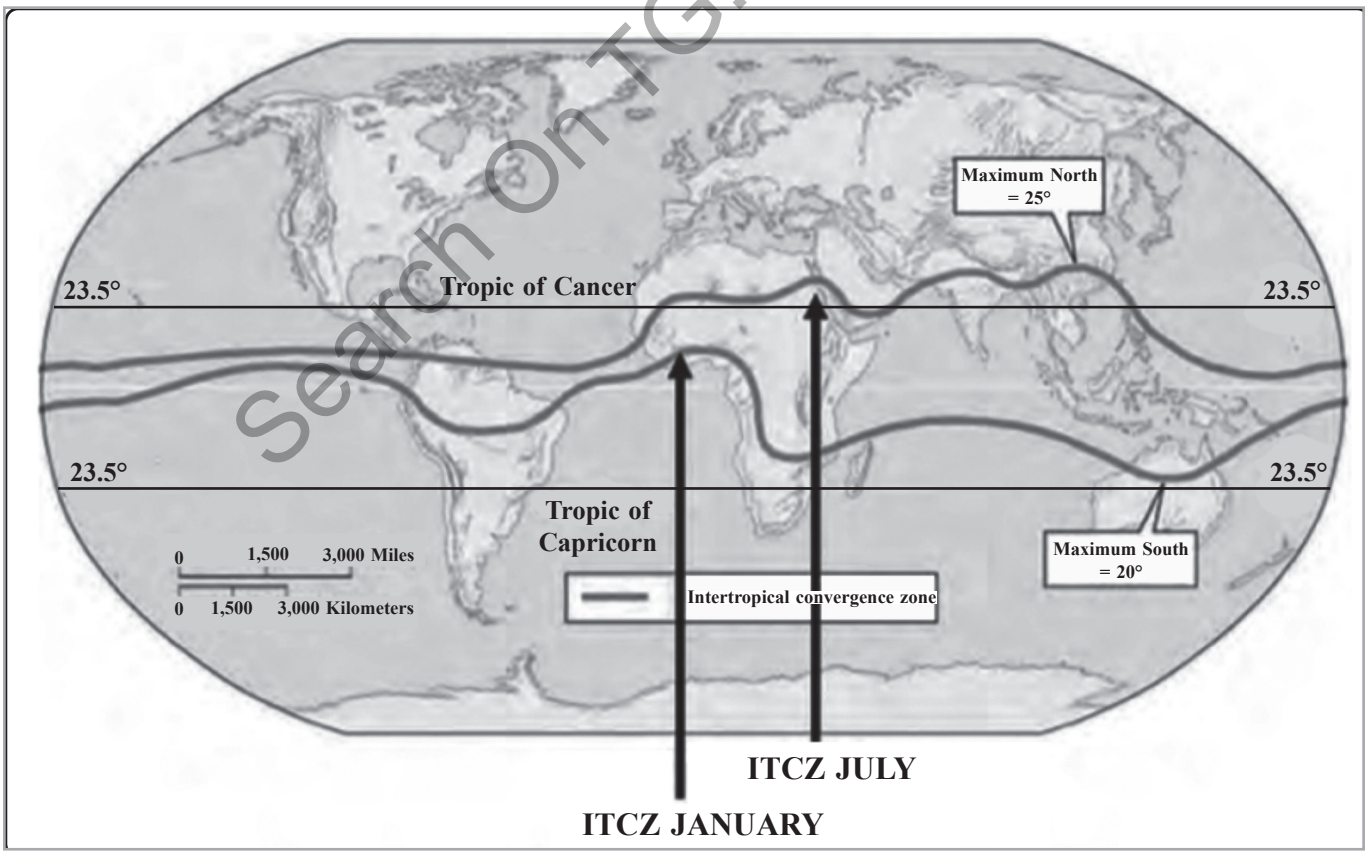


Fig. Movement of ITCZ

- **Mechanism:**
  - **Summer Shift:** During the monsoon season, the ITCZ shifts northward, typically between 20°N and 25°N over the Indian subcontinent. This creates a low-pressure system, drawing moist air from the Indian Ocean towards the land.
  - **Winter Shift:** The ITCZ shifts southward during the winter, moving near the equator and thus causing a reversal of the monsoon winds.
- **Impact on Monsoon Onset:** The northward shift of the ITCZ in summer is a key driver in the onset of the southwest monsoon, as it acts as a "magnet" for moist winds to converge from the southern hemisphere, resulting in rainfall.

- **Dynamic Theory and Role of Jet Streams:**
  - **Overview:** This theory emphasizes the role of jet streams in controlling monsoon dynamics, particularly the sub-tropical westerly jet (STWJ) and the Somali jet.
  - **Sub-Tropical Westerly Jet (STWJ):**
    - **Mechanism:** The STWJ, which blows from west to east across northern India during the winter, weakens and shifts northward in the summer. Its withdrawal is crucial for the onset of the monsoon. The retreat of the STWJ allows the establishment of a low-pressure zone over India, which facilitates the inflow of moist air from the southwest.
    - **Monsoon Break:** It is explained by re-establishment of STWJ over India which leads to High pressure again and a resultant break in monsoon.

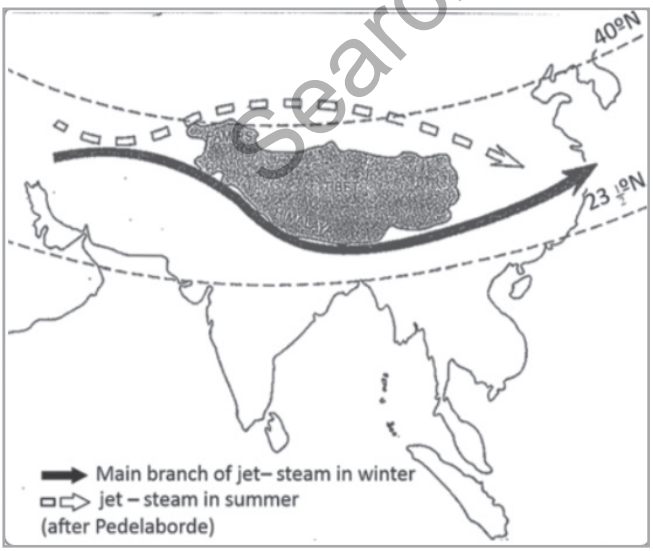


Fig. Jet Stream During Summer

  - **Somali Jet:**
    - **Mechanism:** The Somali jet is a low-level jet stream that strengthens during the summer months. It forms over the Arabian Sea due to differential heating between the land and ocean. This jet stream helps to channel moisture-laden winds from the Indian Ocean into India, thereby enhancing the southwest monsoon.
    - **Impact on Monsoon:** The Somali jet directs the flow of monsoon winds towards the subcontinent, which is critical for the strength and timing of the monsoon rains.
- **Tibetan Plateau and Tibetan Low:**
  - **Overview:** The Tibetan Plateau plays a central role in the monsoon dynamics due to its large size and high elevation, creating significant atmospheric effects during summer.
  - **Mechanism:**
    - **Thermal Heating:** During the summer, the Tibetan Plateau heats up intensely, creating a low-pressure zone known as the **Tibetan Low.** This low-pressure area attracts moist air from the surrounding oceans.
    - **Elevation Impact:** The Plateau's high elevation also leads to the development of strong upper-level circulations, including the formation of the sub-tropical westerly jet and the Somali jet, both of which influence the monsoon's strength and direction.
    - **Monsoon Onset:** The Tibetan Low is critical for the onset of the Indian monsoon, as it acts as a focal point for air convergence and the creation of a monsoon trough.

Branches of Monsoon

- **Arabian Sea branch**
  - **Western Ghats and Rain-shadow Effect:**
    - The monsoon winds from the Arabian Sea ascend the Western Ghats' slopes, cooling down in the process and causing Orographic rainfall. Sahyadri and coastal plain get high rainfall- 250 to 400 cm.
    - After crossing the windward side, wind descends, warms up and loses moisture thus resulting in minimal rainfall on the leeward side of Ghats.
  - **Central India Impact:**
    - Another branch **moves through the Narmada and Tapi river valleys,** bringing rainfall to vast areas of central India. Eventually, these winds **reach the Ganga plains** and **merge** with the **monsoon winds of the Bay of Bengal.**
    - The Chota Nagpur plateau receives some rainfall from this branch.

- **Northwest India and Himalayan Influence:**
  - The third branch hits the Saurashtra Peninsula and Kachchh, **moving parallel to Aravallis** producing limited rainfall.
  - In Punjab and Haryana, it **converges** with the **Bay of Bengal monsoon branch,** producing rain in the western Himalayas.

- **Bay of Bengal Branch**
  - Initially **hit the Myanmar coast** and parts of southeast Bangladesh.
  - **Arakan Hills** along Myanmar's coast, **redirects** a significant portion of this branch **towards** the **Indian subcontinent.** Monsoon enters West Bengal and Bangladesh from the south and southeast.
  - Influenced by the Himalayas and the thermal low in northwest India, this monsoon branch divides into **two major streams: One** stream **moves westward** along the Ganga plains, extending to the Punjab plains; The **other heads north,** traveling up the **Brahmaputra valley,** its sub-branch targets the Garo and Khasi hills in Meghalaya.
    - Mawsynram (Khasi Hills) receives the highest average annual rainfall due to the **funneling effect**.
  - The **Tamil Nadu** coast is situated parallel to and in the rain shadow area of the Bay of Bengal branch and Arabian sea branch respectively. It receives rain from the North East branch of retreating monsoon winds.

THE RETREATING MONSOON SEASON (THE TRANSITION SEASON)

- The months of **October and November** mark the phase of retreating monsoons.
- By September's end, the southwest monsoon weakens due to the southward shift of the low-pressure trough from the Ganga plain due to southward movement of the sun.
- During this retreat, **clear skies dominate**, and **temperatures rise**. While day temperatures are high nights are cool and pleasant. High temperature and humidity leads to the **'October heat'.**

October Heat

- October Heat refers to the hot and oppressive weather conditions experienced in India during the post-monsoon or retreating monsoon season, typically in October. It is characterised by **rising temperatures, high humidity** and **calm winds.**
- It can lead to health issues such as dehydration, heat exhaustion, and discomfort, especially in the northern plains and central India.
- The onset of the northeast monsoon in the southern states and cooler winds from the north signal the end of October heat.

- **Cyclonic Influences: Rainfall** in this season is **primarily due to cyclonic depressions** originating over the Andaman Sea affecting deltas of rivers like the Godavari, Krishna, and Kaveri. Cyclones are **less prevalent in the Arabian Sea**. The **Coromandel coast** mainly gets its rain from these cyclonic events.

Characteristics of Monsoon Rainfall

- Rainfall from the southwest monsoon is seasonal (June to September).
- Monsoonal rainfall is **largely governed by relief or topography** (Windward side of the mountains receives more rainfall)
- Rainfall **decreases** with **increasing distance** from the **sea.**
- The wet spells are interspersed with **rainless intervals ('breaks').** These breaks in rainfall are **related to the pathways of cyclonic depressions** (mainly formed in the Bay of Bengal) that determines the spatial distribution of rainfall.

Traditional Indian Seasons

Seasons	Months (According to the Indian Calendar)	Months (According to the Gregorian Calendar)
Vasanta	Chaitra-Vaisakha	March-April
Grishma	Jyaishta-Asadha	May-June
Varsha	Sravana-Bhadra	July-August
Sharada	Asvina-Kartika	September-October
Hemanta	Margashirsa-Pausa	November-December
Shishira	Magha-Phalguna	January-February

In Indian tradition, the year is distinctively divided into **six seasons,** each lasting two months.

Distribution of Rainfall

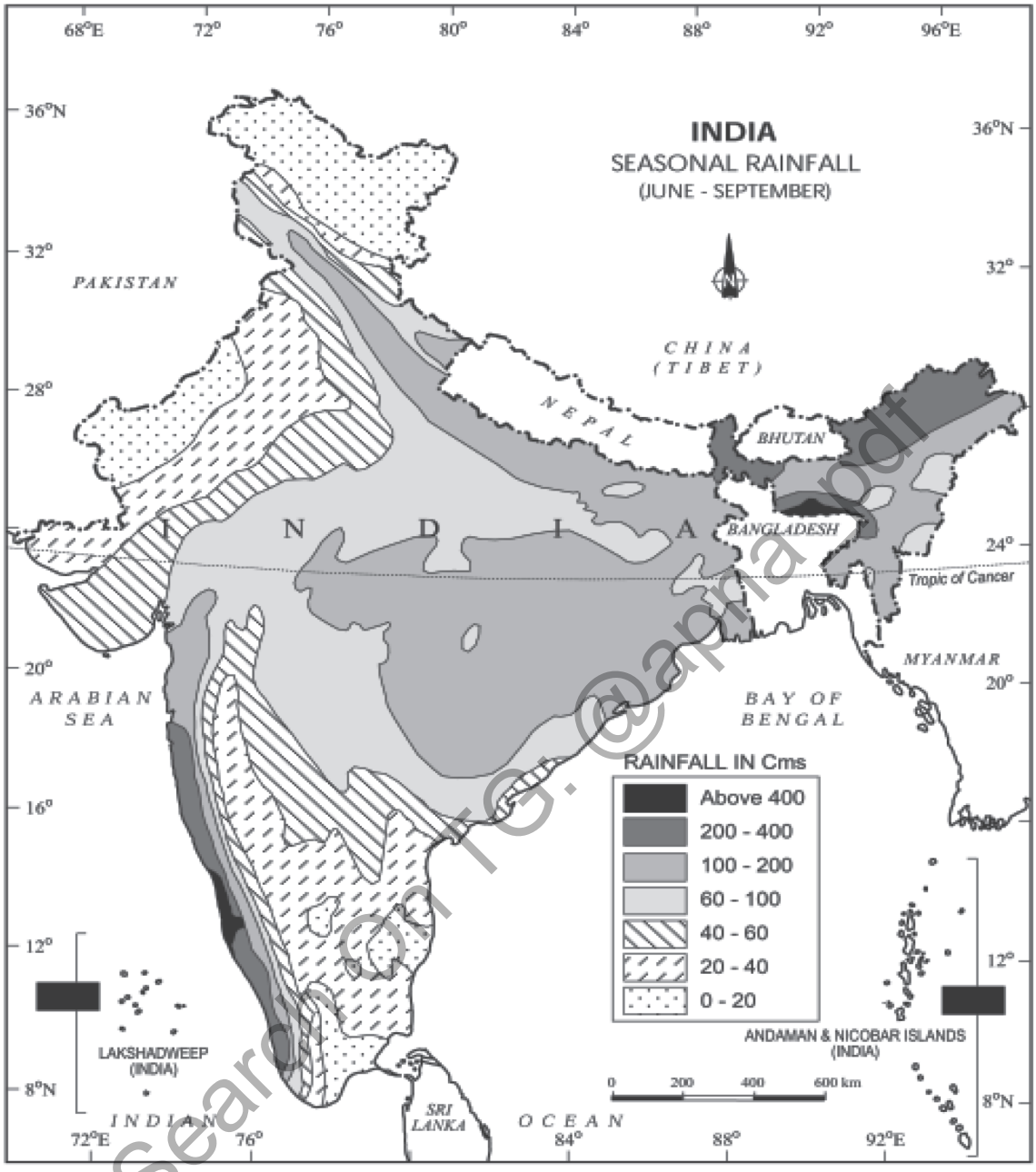


Fig. Annual Rainfall of India

- The average annual rainfall in India is about **125 cm** with great spatial variations.
- **High Rainfall Zones** with rainfall **over 200 cm:** West coast, Western Ghats, and the sub-Himalayan areas in the northeast**; Rainfall > 1000 cm** in some parts of the Khasi and Jaintia hills; Brahmaputra valley and adjoining hills get slightly less, under 200 cm.
- **Medium Rainfall Zones** with rainfall between **100-200 cm:** southern Gujarat, east Tamil Nadu, northeastern Peninsula covering Odisha, Jharkhand, Bihar, eastern Madhya Pradesh, northern Ganga plain along the sub-Himalayas and the Cachar Valley and Manipur.
- **Low Rainfall Zones** with rainfall **between 50-100 cm;** western Uttar Pradesh, Delhi, Haryana, Punjab, Jammu and Kashmir, eastern Rajasthan, Gujarat, and the Deccan Plateau.
- **Inadequate Rainfall Zones** with rainfall **less than 50cm**; Parts of the Peninsula, especially in Andhra Pradesh, Karnataka, Maharashtra, Ladakh, and most of western Rajasthan.
- **Snowfall:** This phenomenon is limited to the Himalayan region.

Variability of Rainfall

- The values of **coefficient of variation** show the change from the mean values of rainfall.
- **Areas with < 25% variability:** Western coasts, Western Ghats, north-eastern Peninsula, eastern Ganga plains, north-eastern India, Uttarakhand, Himachal Pradesh, and southwestern Jammu and Kashmir. These areas have annual rainfall > 100cm
- **Areas with >50% variability:** Regions like western Rajasthan, northern Jammu and Kashmir, and the interior Deccan plateau. These areas have annual rainfall < 50cm
- **Areas with 25%-50% variability:** The remaining parts of India receiving between 50-100 cm of rainfall.

CLIMATIC REGIONS OF INDIA

- **Koeppen's classification:** It is based upon specific letter symbols such as **'S' for semi-arid regions and 'W' for arid regions.** Further sub-divisions were marked by additional lowercase letters like **'f' for sufficient precipitation or 'm' for rainforests with a dry monsoon season.**
- He delineated five primary climatic types:
  - **Tropical climates (A):** Mean monthly temperatures are consistently above 18°C throughout the year.

Fig. India: Climatic Regions According to Koppen's

- **Dry climates (B):** Precipitation is notably low relative to temperature. These are further categorized as semi-arid (S) or arid (W).
- **Warm temperate climates (C):** The coldest month has a mean temperature ranging between 18°C and -3°C.
- **Cool temperate climates(D):** The warmest month averages above 10°C, while the coldest month falls below -3°C.
- **Ice climates (E):** The warmest month's mean temperature remains below 10°C.

- As per Koeppen's scheme, India comprises eight distinct climatic regions

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 - Topical savannah	Most of the Peninsular plateaus, south of the Tropic of Cancer North-western Gujarat, some parts of western Rajasthan and Punjab
Bwhw - Semi-arid steppe climate	Extreme western Rajasthan
Bwhw - Hot desert	Ganga plain, eastern Rajasthan, northern Madhya Pradesh, most of North-east India
Cwg - Monsoon with dry winter	Arunachal Pradesh
Dfc - Cold humid winter with short summer	Jammu and Kashmir. Himachal Pradesh and Uttarakhand
E - Polar type	

4 Natural Hazards and Disasters

BASIC CONCEPTS

Hazard

A dangerous condition or event that threatens or has the potential to cause injury, property damage, or environmental harm.

Vulnerability

The extent to which a community, structure, service, or geographic area is likely to be damaged or disrupted by a particular hazard due to its characteristics, construction, and proximity to hazardous areas.

- **Physical Vulnerability:** Relates to the physical condition of people and structures at risk, such as buildings and infrastructure.
- **Socio-economic Vulnerability:** Refers to individuals' and communities' susceptibility to harm from disasters due to their social and economic status.

Risk

A measure of expected losses due to a hazard event occurring in a given area over a specific time period.

Disaster

A disaster is defined as "A serious disruption in the functioning of the community or a society causing widespread material, economic, social, or environmental losses which exceed the ability of the affected society to cope using its own resources." Disasters result from the interplay of hazards, vulnerabilities, and insufficient capacity to mitigate risks.

- **Meteorological Disaster:** Disaster caused by extreme weather produced by the earth's atmosphere.
- **Geological Disaster:** Natural disasters caused by a geological process are called geological disasters. These are earthquakes, tsunamis, volcanic eruptions, and landslides.

COMMON DISASTERS IN INDIA

Traditionally India has been prone to disasters such as Earthquakes, Floods, Cyclones, etc due to it's geographical and hydrological profile. Moreover with rapid urbanization and infrastructure development newer threats such as Heat waves, Urban Floods, Forest fires, etc have also become prominent in the recent years.

EARTHQUAKES

Earthquake refers to the sudden shaking of the earth's crust.

Causes of Earthquakes

- Earthquakes due to Plate Tectonics
- **Earthquakes due to other causes:** Volcanic eruption, rock falls, landslides, subsidence, particularly in the mining areas, impounding of dams and reservoirs, etc.

Measuring Earthquakes

Earthquakes can be measured by the use of two distinctively different scales of measurement:

- **Richter Scale:** Measures the magnitude (strength/elastic energy released by earthquake) of the earthquake. It is a logarithmic scale—an increase of 1 in magnitude corresponds to a 10-fold increase in the amplitude of shaking. It is expressed numerically, ranging from 0 to 10.
- **Mercalli Scale:** Measures the intensity (effects) of an earthquake where it occurs; scale spans from 1 to 12 Intensity indicates the violence of shaking or the extent (or potential) of damage at a given location due to a particular earthquake. The most commonly used intensity scales are: Modified Mercalli (MM) Intensity Scale and Medvedev-Sponhener-Karnik (MSK) Intensity Scale.
  - **Modified Mercalli Scale:** Enhanced and more detailed version of the original Mercalli Intensity Scale, providing a better description of the effects of an earthquake at a specific location.
- The five seismic zones I, II, III, IV and V in the Indian seismic code (IS:1893-1984) correspond to areas that have potential for shaking intensity on the MMI scale of V or less, VI, VII, VIII, and IX or more, respectively.

Distribution Pattern of Earthquakes in India

- The seismic zoning map of India is divided into the following four earthquake zones:
  - Zone - II: This is said to be the least active seismic zone.
  - Zone - III: It is included in the moderate seismic zone.
  - Zone - IV: This is considered to be the high seismic zone.
  - Zone - V: It is the highest seismic zone.

Fig. India-Seismic Zones

TSUNAMI

Tsunami refers to a series of large waves on ocean surfaces caused by a sudden displacement of water. These are also called shallow water waves.

Causes of a Tsunami

The geological movements that cause tsunamis are produced in three major ways:

1. Fault movements on the seafloor, accompanied by an earthquake that causes tsunamis.
2. Landslides either occurring underwater or originating above the sea.
3. Volcanic activity near the shore or underwater. Eg. Krakatoa eruption (1883) in Indonesia, produced a tsunami in Java and Sumatra.

General Characteristics of Tsunami

- Tsunamis move at great speeds and have tremendous energy; the speed depends on the depth of the water it is traveling through. The deeper the water, the faster they move.
- In the deep ocean, tsunamis can move as fast as a jet plane, over 500 mph (800 km/h), and can cross entire oceans in less than a day.
- The distance between waves is the wavelength. Because of a tsunami's long wavelengths, which can be hundreds of miles, a tsunami is barely noticeable in the deep ocean and rarely more than three feet (one meter) high.
- Mariners at sea will not normally notice a tsunami as it passes beneath their hulls.
- As a tsunami enters shallow water near land, it slows down, wavelengths decrease, waves grow in height, and currents intensify. At the shore, most tsunamis slow to the speed of a car, approximately 20 to 30 mph (30 to 50 km/h).
- Impact of tsunamis is less over the ocean and more near the coast.
- Tsunamis are frequently observed along the Pacific Ring of Fire, particularly along the coast of Alaska, Japan, the Philippines and other islands of Southeast Asia, Indonesia, Malaysia, Myanmar, Sri Lanka, and India. India has volunteered to join the International Tsunami Warning System after the 2004 tsunami disaster.

TROPICAL CYCLONE

Tropical cyclones are intense low-pressure areas confined to the area lying between 30°N and 30° S latitudes around which high-velocity winds blow. .

- It is energised by the release of latent heat condensation of moisture that the wind gathers after moving over the oceans and seas.

Condition for Tropical Cyclone

- Warm sea surface temperature above 27 degrees Celsius.
- Large and continuous supply of warm and moist air drives it due to the release of latent heat.
- Strong Coriolis force that can prevent the filling of low pressure at the centre (absence of Coriolis force near the equator prohibits the formation of tropical cyclones between 0°-5°latitude).
- Unstable conditions in the troposphere that create local disturbances around which a cyclone develops.
- Absence of strong vertical wind wedge, which disturbs the vertical transport of latent heat.

Spatio-Temporal Distribution of Tropical Cyclones in India

- Owing to its Peninsular shape, the tropical cyclones in India originate in - Bay of Bengal (majority of cyclones) and Arabian Sea.
- Most of the cyclones originate between 10°-15°north latitudes during the monsoon season. However, in the case of the Bay of Bengal, cyclones mostly develop during the months of October and November.

FLOODS

Distributional Pattern of Floods in India

Rashtriya Barh Ayog (National Flood Commission) identified 40 million hectares of land as flood-prone in India. Most flood-affected states are Assam, West Bengal and Bihar.

- Most of the rivers in the northern states like Punjab and Uttar Pradesh are also vulnerable to occasional floods.
- Sometimes, Tamil Nadu experiences flooding during November-January due to the retreating monsoon.

DROUGHTS

- **Drought** is a period of abnormally dry weather that persists long enough to cause serious hydrological imbalance. It occurs when there is a deficiency of precipitation over an extended period, resulting in a water shortage.

Types of Droughts

Meteorological Drought

Characterized by a **prolonged period of inadequate rainfall.** Rainfall distribution is uneven both spatially and temporally. Often leads to other types of drought.

Hydrological Drought

Occurs when water availability in reservoirs, lakes, and aquifers **falls below normal levels.** Can result from prolonged meteorological drought or excessive water usage.

Agricultural Drought

Characterized by **low soil moisture, affecting crop growth and yield.** Areas with significant irrigation may be less susceptible to agricultural drought.

Ecological Drought

Occurs when a natural ecosystem's **productivity declines due to water scarcity.** Can lead to ecosystem degradation and loss of biodiversity.

Drought Areas in India

On the basis of the severity of droughts, India can be divided into the following regions:

- **Extreme Drought Affected Areas:** Most parts of Rajasthan, particularly areas to the west of the Aravali hills, i.e. Marusthali and Kachchh regions of Gujarat.
- **Severe Drought Prone Area:** Parts of eastern Rajasthan, most parts of Madhya Pradesh, eastern parts of Maharashtra, interior parts of Andhra Pradesh and Karnataka Plateau, northern parts of interior Tamil Nadu and southern parts of Jharkhand and interior Odisha are included in this category.

- **Moderate Drought Affected Area:** Northern parts of Rajasthan, Haryana, southern districts of Uttar Pradesh, the remaining parts of Gujarat, Maharashtra except Konkan, Jharkhand and Coimbatore plateau of Tamil Nadu and interior Karnataka.

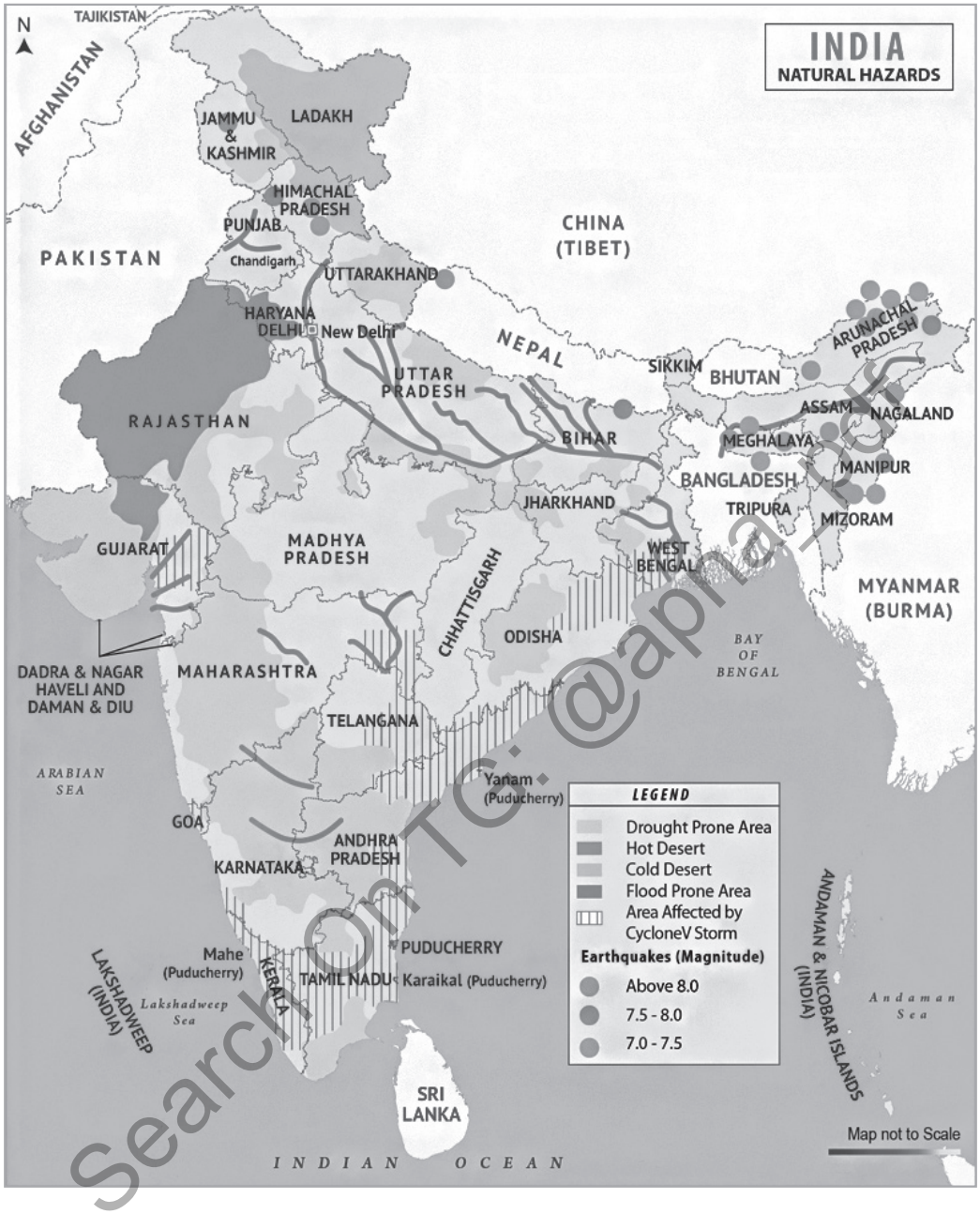


Fig. Disaster Profile of India

LANDSLIDES

A sudden movement of rock, boulders, earth or debris down a slope is termed a landslide. Landslides occur mainly in mountainous terrains where there are conducive conditions of soil, rock, geology and slope.

Landslide Vulnerability Zones

Very High Vulnerability Zone

- **Himalayan Region:** Areas with unstable slopes, high rainfall, and frequent earthquakes.
- **Western Ghats and Nilgiris:** Steep slopes and high rainfall make these regions susceptible to landslides.
- **Northeastern Region:** Similar to the Himalayas, the region is prone to landslides due to high rainfall and unstable slopes.

- **Areas of Intense Human Activity:** Regions with significant infrastructure development, such as roads and dams, can increase the risk of landslides.

High Vulnerability Zone

- **Himalayan States:** All states in the Himalayan region, except the plains of Assam.
- **Northeastern States:** Most states in the Northeast, excluding the plains of Assam.

Moderate to Low Vulnerability Zone

- **Trans-Himalayan Regions:** Areas with less rainfall and stable terrain.
- **Aravali Range:** Undulating and stable relief with low rainfall.
- **Rain Shadow Areas:** Western and Eastern Ghats.
- **Deccan Plateau:** Generally stable, but occasional landslides can occur.
- **Mining and Subsidence Areas:** States like Jharkhand, Odisha, Chhattisgarh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Goa, and Kerala.

Other Areas

- **Rajasthan, Haryana, Uttar Pradesh, Bihar, West Bengal (except Darjeeling), Assam (except Karbi Anglong), and Coastal Regions of Southern States** are generally less prone to landslides.

Other Disasters

Natural Disaster	Causes	Impact	Distribution in India	Mitigation Strategies
Urban Flood	Intense rainfall, poor drainage, encroachment on water bodies, climate change	Waterlogging, property damage, loss of life, disease outbreaks	Major cities like Mumbai, Chennai, Kolkata, Delhi	Improved urban planning, storm water drainage systems, green infrastructure, early warning systems
Glacial Lake Outburst Flood (GLOF)	Climate change, glacial melting, dam breaches	Flash floods, damage to infrastructure, loss of life, ecological damage	Himalayan region, especially Uttarakhand and Sikkim	Early warning systems, construction of dams and channels, monitoring of glacial lakes
Cloudburst	Rapid orographic lifting of warm air and associated atmospheric instability.	Flash floods, landslides, erosion, property damage, loss of life	Hilly and mountainous regions, especially Uttarakhand and Himachal Pradesh	Early warning systems, disaster preparedness, evacuation plans, land-use planning
Land Subsidence	Excessive groundwater extraction, mining activities, natural compaction of soil	Ground sinking, damage to infrastructure, flooding, waterlogging	Coastal areas, mining regions, urban areas	Sustainable groundwater management, proper mining practices, land-use planning

Recent Disasters Across World

Disaster	Location	Primary Cause	Geographical/Geological Factors
2004 Indian Ocean Tsunami	Indian Ocean	Underwater earthquake	Subduction zone along the Sunda Plate
2011 Tōhoku Earthquake and Tsunami	Japan	Underwater earthquake	Subduction zone along the Pacific Plate
2015 Nepal Earthquake	Nepal	Tectonic activity	Himalayan orogenic belt, active fault lines

Disaster	Location	Primary Cause	Geographical/Geological Factors
2020 Beirut Explosion	Lebanon	Explosion of ammonium nitrate	Port city, dense urban area
2021 Haiti Earthquake	Haiti	Earthquake	Caribbean Plate boundary, seismic activity
2022 Pakistan Floods	Pakistan	Heavy monsoon rains	Indus River basin, Glacial melt.
2023 Turkey-Syria Earthquake	Turkey and Syria	Earthquake	East Anatolian Fault, active seismic zone
2023 Hawaii Wildfires	Hawaii, USA	Strong winds, dry conditions	Volcanic islands, dry climate, invasive grasses
2023 Uttarakhand Floods	Uttarakhand, India	Heavy rainfall, landslides	Himalayan region, steep slopes, fragile ecosystem
2023 Himachal Pradesh Floods	Himachal Pradesh, India	Heavy rainfall, cloudbursts	Himalayan region, steep slopes, fragile ecosystem
2023 Raigad Landslide	Raigad, Maharashtra, India	Heavy rainfall, unstable slopes	Western Ghats, monsoon climate, soil erosion
2022 Hurricane Ian	Florida, USA	Tropical cyclone	Warm ocean waters, hurricane season
2022 Hurricane Fiona	Caribbean, Canada	Tropical cyclone	Warm ocean waters, hurricane season
2021 Heatwave in North America	North America	Climate change, heat dome	Continental climate, urban heat island effect
2020 Australian Bushfires	Australia	Drought, heatwave, lightning strikes	Dry climate, eucalyptus forests, El Niño
2019 Amazon Rainforest Fires	Amazon Rainforest, Brazil	Deforestation, climate change	Tropical rainforest, human activity
2018 Camp Fire	California, USA	Wildfire	Dry climate, strong winds, fuel accumulation
2017 Hurricane Maria	Puerto Rico, Caribbean	Tropical cyclone	Island geography, hurricane season

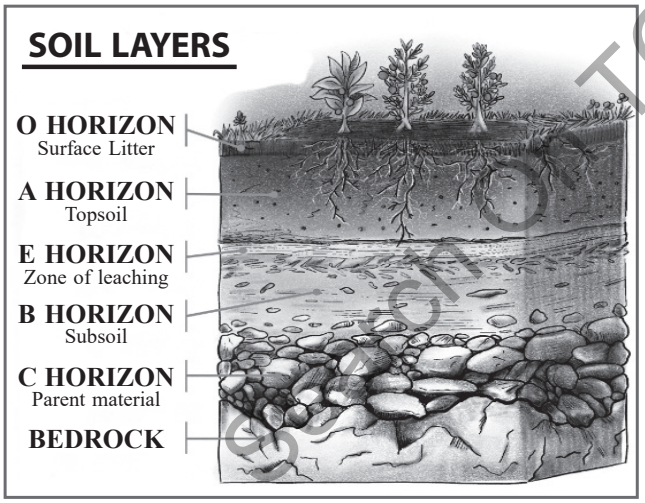
5 Soils and Natural Vegetation

Soil is a mixture of rock debris and organic materials that develop on the earth's surface.

- **Gravel:** Particles greater than 2 mm in diameter.
- **Coarse Sand:** Particles less than 2 mm and greater than 0.2 mm in diameter.
- **Fine Sand:** Particles between 0.2 mm and 0.02 mm in diameter.
- **Silt:** Particles between 0.02 mm and 0.002 mm in diameter.
- **Clay:** Particles less than 0.002 mm in diameter.

SOIL PROFILE

The arrangement of layers of soil is known as the **soil profile**. Different layers in the soil profile are called **Horizons.**



- **Horizon O:** Surface litter and partially decomposed organic matter.
- **Horizon A: Topmost zone** where organic materials have got incorporated with the mineral matter; includes humus, living creatures and inorganic minerals.
- **Horizon E: Eluviated** Horizon, **zone of leaching**.
- **Horizon B:** Iron, Aluminium and Humic compounds are accumulated and clay leached down from A and E horizon; **zone of illuviation** (accumulation); transition zone between the 'horizon A' and 'horizon C',
- **Horizon C:** Composed of the **loose parent material**. This layer is the **first stage** in the **soil formation process**

Elluviation: The process of removal and transport of dissolved or suspended material, such as clay, organic matter, or minerals, from one soil horizon to another due to leaching or percolation of water.

Illuviation: The process of accumulation and deposition of materials, such as clay, organic matter, or minerals, in a lower soil horizon that have been transported from upper horizons through elluviation.

SOIL FORMING FACTORS

- **Parent material is a passive factor** in soil formation, encompassing in-situ weathered rock debris (residual soils) or transported deposits (transported soils).
- **Topography, another passive factor, i**nfluences soil formation through sunlight exposure and drainage. On gentler slopes, soil formation is quite favourable.
- **Climate** is an important active factor; **Precipitation** provides soil moisture vital for chemical and biological activities; **Dry climates with high temperatures** cause evaporation to exceed precipitation, leading to salt deposits called **hardpans**; Chemical activity is increased in higher temperatures, reduced in cooler temperatures (with an exception of carbonation) and stops in freezing conditions; tropical soils with higher temperatures show deeper profiles.
- **Biological Activity:** Active factor; Vegetative cover and organisms act on parent materials; Bacterial activity etc.
- **Time:** Passive factor; mature soils result from extended operation of soil-forming processes.

CLASSIFICATION OF SOILS

Historically, the soil was initially categorised simply as **fertile (Urvara) or sterile (Usara).**

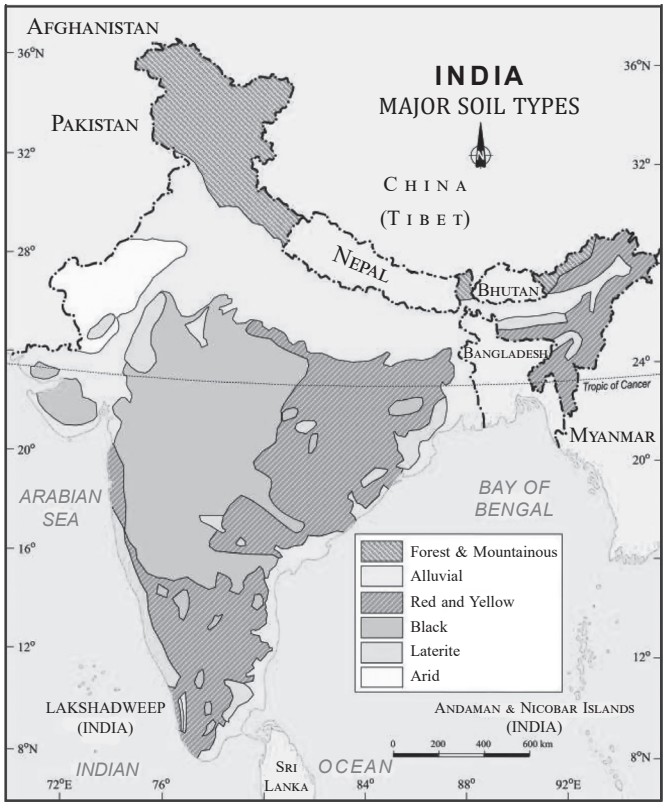


Fig. Major Soil Type of India

Alluvial Soils

Area: Covers around 43% area; Inland alluvium in **Punjab, Haryana, UP, Bihar, West Bengal,** Parts of **Gujarat and Rajasthan,** Deltaic alluvium in **deltas of Ganga-Brahmaputra, Mahanadi, Godavari, Krishna** and **Kaveri,** Coastal alluvium along the **coastal strips of peninsula.**

Characteristics

- Notably, in the **Upper and Middle Ganga plains**, two distinct types, **Khadar (new alluvium) and Bhangar (older alluvium)**, are found. Both types bear calcareous concretions known as **Kankars.**
  - **Khadar** is enriched annually by flood deposits.
  - **Bhangar** is located away from flood plains.
- Become more loamy and clayey in the lower and middle Ganga plain and Brahmaputra valley; sand content **reduces from west to east; Color:** Light grey to ash grey depending on deposition depth, material texture, and maturity time; Heavily cultivated due to their fertility;

Black Soil

Area: Covers around **15%;** Predominantly covers the **Deccan Plateau** that includes parts of **Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh,** and some parts of **Tamil Nadu,** with significant depth in **upper reaches** of **Godavari and Krishna rivers** and **north-western Deccan Plateau.**

Characteristics

- **Clayey, deep, and impermeable nature;** formed due to weathering of fissure volcanic rock; also referred to as **'Regur Soil' or 'Black Cotton Soil'.** **[UPSC 2021]**
- **Swell** and become **sticky** when **wet; shrink** when **dried** (develop wide cracks); **'self ploughing'**; Slow absorption and loss of moisture and **good water retention**;
- **Colour: Deep black to grey;**

Red and Yellow Soil

Area: Cobers around **18.5%** area; **Red soil** develops on **crystalline igneous rocks** in the **eastern and southern regions** of the **Deccan Plateau** with **low rainfall** and extends along the piedmont zone of the **Western Ghat** as red loamy soil. Also present in parts of **Odisha, Chattisgarh,** and southern areas of the **Middle Ganga Plain.**

Characteristics

- While coarse-grained soils found in arid upland regions are usually poor in fertility, fine-grained red and yellow soils are typically fertile; Soil is well drained;
- **Colour: Reddish colour** due to a wide diffusion of **iron** in crystalline and metamorphic rocks; **yellow** in **hydrated** form;

Laterite Soil

Area: They are found in the higher areas of the Peninsular plateau, notably found in Karnataka, Kerala, Tamil Nadu, Madhya Pradesh, and the hilly regions of Odisha, Ranchi and Assam.

Characteristics **[UPSC 2013]**

- Develop in areas with **high temperatures** and **high rainfall**, resulting in intense leaching; **Lime and silica are leached away**, and soils **rich in iron oxide and aluminium** compounds are left behind;
- **Low humus content** due to bacterial activity that thrives well in high temperatures; **Highly acidic** and **low water retention;**
- Unsuitable for cultivation, requiring manures and fertilizers to enhance fertility; widely used in **brick making;** Red laterite soils are favorable for tree crops like **cashew nuts** in regions of **Tamil Nadu, Andhra Pradesh, and Kerala;**

Arid Soil

Area: Mainly found in **western Rajasthan**

Characteristics

- 'Kankar' layers in the lower horizons due to increasing calcium content that restricts water infiltration but ensures soil moisture retention when irrigation is introduced; **Sandy structure** and **saline nature**; Fertility is hindered by the low humus and organic matter content;_
- **Color: Red to yellow.**

Saline Soils

Area: Arid and **semi-arid** regions, and waterlogged and swampy areas; more widespread in **western Gujarat,** deltas of the **eastern coast** and in **Sundarban** areas of West Bengal; Southwest Monsoon brings salt particles and deposits there as a crust in the **Rann of Kuchchh;** Seawater intrusions in the deltas result in formation of saline soils; Fertile alluvial soils are becoming saline in areas of **green revolution** due to **capillary action.** Excessive irrigation with dry climatic conditions promotes capillary action leading to salt deposition in the top layer.

Characteristics

- Also known as **Usara soils**; Structure ranges from sandy to loamy; **Gypsum** is added as a remedial measure against soil salinity;

Peaty Soils

Area: Prominently found in regions with **heavy rainfall** and high humidity with good vegetation growth; widely distributed in **northern Bihar and southern Uttarakhand,** along with coastal stretches of **West Bengal, Odisha,** and **Tamil Nadu.**

Characteristics

- Heavy, **black in colour**, and, in many places, exhibit **alkaline properties**
- Large quantities of dead organic matter with high **humus** and **organic** content. Organic matter may go up to **40-50 percent.**

Forest Soils

Area: Forest areas with sufficient rainfall; found in **Himalayan region, Western and Eastern Ghats** as well as in some parts of the **Peninsular plateau.**

Characteristics

- **Loamy and silty** on **valley sides** and **coarse-grained** on **upper slopes**;
- Structure and texture vary depending on the mountain environment; Particularly in the **snow-clad regions of the Himalayas,** these soils undergo denudation, becoming **acidic** with a **low humus content;** soils in the **lower valleys** are **fertile.**

Mineral Composition of Soils

Soil Type	Rich In	Deficient In
Alluvial Soil	Potash, Lime	Nitrogen, Phosphorus, Humus
Black Soil	Lime, Iron, Magnesia, Alumina	Phosphorus, Nitrogen, Organic Matter
Red and Yellow Soil	Iron Oxide	Nitrogen, Phosphorus, Humus
Laterite Soil	Iron Oxide, Potash	Organic Matter, Nitrogen, Phosphate, Calcium
Arid Soil	-	Moisture, Humus, Organic Matter, Nitrogen
Saline Soil	Sodium, potassium and magnesium.	Nitrogen, Calcium
Peaty Soil	Humus, Organic Matter	-
Forest Soil	-	Nitrogen, Phosphorus

Mineral Cycles

Mineral Cycle	Key Processes	Reservoirs	Importance	Human Impact
Carbon Cycle	• Photosynthesis, Respiration, Decomposition • Combustion of Fossil Fuels • Carbon Sequestration	• Atmosphere (CO_2) • Fossil Fuels • Oceans • Forests	• Regulates Earth's temperature • Source of energy in food chains	• Deforestation • Fossil fuel burning increases CO_2, leading to global warming
Nitrogen Cycle	• Nitrogen Fixation (by bacteria and lightning) • Nitrification • Ammonification • Denitrification	• Atmosphere (78% N_2) • Soil • Biomass • Excretion of urea by animals, Burning of coal by man and Death of vegetation adds nitrogen to the soil. **[UPSC-2013]**	• Essential for DNA, RNA, and proteins • Enhances soil fertility	• Overuse of fertilizers leads to eutrophication • Release of nitrogen oxides contributes to air pollution and acid rain

Phosphorus Cycle	• Weathering of rocks • Absorption by plants • Consumption • Decomposition	• Rocks (main reservoir) • Soil • Water bodies	• Crucial for DNA, RNA, and ATP • Important for plant and animal growth	• Excessive use of phosphate fertilizers causes water pollution and algal blooms
Oxygen Cycle	• Photosynthesis • Respiration • Oxidation reactions	• Atmosphere (O_2) • Water (H_2O) • Rocks (Bound oxygen)	• Supports respiration in living organisms • Forms ozone layer (O_3)	• Deforestation reduces oxygen production • Pollution affects ozone stability
Water Cycle	• Evaporation • Condensation • Precipitation • Runoff • Infiltration	• Oceans • Atmosphere • Groundwater	• Maintains Earth's temperature balance • Essential for all life processes	• Over-extraction of groundwater • Pollution disrupts the cycle • Climate change alters precipitation patterns

SOIL EROSION

Soil erosion, described as the destruction of soil cover, results from an imbalance between soil-forming and erosional processes, intensified by natural or human factors.

Causes of Soil Erosion [UPSC 2014]

Natural Causes:

- **Water Erosion:** Heavy rainfall and flooding can wash away topsoil.
- **Wind Erosion:** Strong winds can erode topsoil, especially in arid and semi-arid regions.

Human-Induced Causes:

- **Deforestation:** Removing trees and vegetation exposes soil to erosion.
- **Overgrazing:** Overgrazing by livestock can damage vegetation and lead to soil erosion.
- **Poor Agricultural Practices:** Practices like monoculture, over-cultivation, and inappropriate tillage can degrade soil and increase erosion.
- **Construction and Development:** Clearing land for construction and infrastructure projects exposes soil to erosion.
- **Mining:** Mining activities can strip away vegetation and expose soil to erosion.

Types of Soil Erosion

- **Splash Erosion:** First stage of erosion process that occurs when raindrops hit bare soil;
- **Sheet Erosion:** Uniform removal of a thin layer of finer and fertile top soil on **level lands** devoid of vegetative cover after a **heavy shower** and soil removal is not easily noticeable;

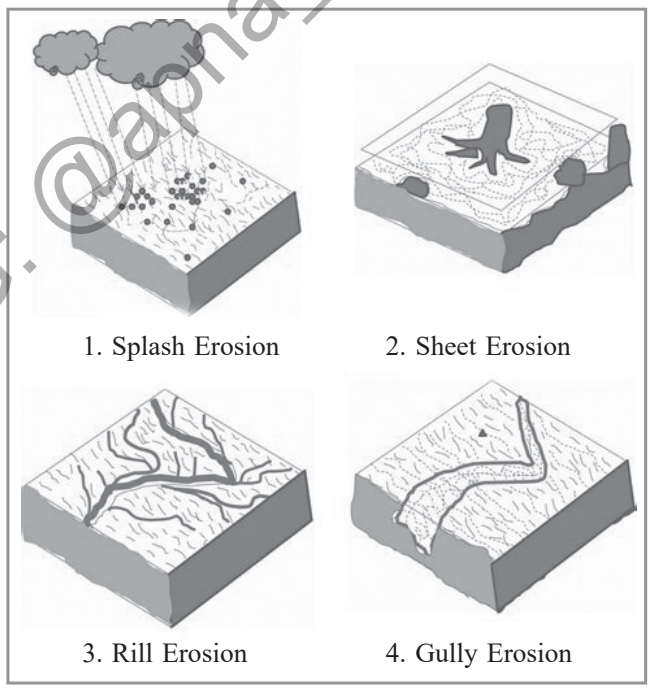


Fig: Types of soil Erosion

- **Rill Erosion:** Occurs when sheet flows begin to concentrate on the land surface; leaves visible scouring on the landscape;
- **Gully Erosion:** Rill erosion evolves into gully erosion. Gullies resemble small valleys and are common on **steep slopes**. Gullies deepen with rainfall, cutting agricultural lands into small fragments and making them unfit for cultivation. A region with a large number of **deep gullies or ravines** is called a **badland topography**. Ravines are prominent in the **Chambal basin** and are also found in **Tamil Nadu** and **West Bengal**.

Soil Conservation

Technique	Description	Purpose
Mulching	Covering the ground with organic matter	Retain soil moisture, reduce weed growth, and regulate soil temperature
Contour Bunds/Barriers **[UPSC-2013]**	Building barriers along contours of slop with stones, grass, or soil	Prevent soil erosion, conserve water
Rock Dams	Piling up rocks to slow water flow	Reduce soil erosion, prevent gully formation
Terrace Farming	Creating flat steps on slopes	Reduce soil erosion, increase cultivable land
Intercropping	Planting different crops in alternate rows	Reduce soil erosion, improve soil fertility, and control pests
Contour Ploughing	Ploughing parallel to the contours	Reduce soil erosion, conserve water
Strip Cropping	Dividing fields into strips of different crops	Reduce wind erosion, improve soil fertility
Shelterbelts	Planting lines of trees	Protect crops from wind erosion, create microclimates

NATURAL VEGETATION

India boasts diverse natural vegetation due to variations in climate and soil. Indian forests can be categorized into distinct groups:

- Tropical Evergreen and Semi-Evergreen Forests
- Tropical Deciduous Forests
- Tropical Thorn Forests
- Montane Forests
- Littoral and Swamp Forests

Tropical Wet Evergreen

- Found in **warm** and **humid** areas with precipitation of **over 200 cm** and mean annual temperature **above 22°C**.
- **Location: Western slope of Western Ghat, Lakshadweep, Andaman & Nicobar Island & Tamil Nadu Coast, Purvanchal hills [UPSC 2015]**
- **Characteristics:** Well-stratified forest, featuring layers near the ground covered in shrubs and creepers, followed by short and tall trees, creating a multi-layered forest; Leaf litter decomposes faster than in any other biome and as a result the soil surface is often almost bare. **[UPSC 2013, 2021]**
- **Flora: Ebony, Mahogany, Rosewood, rubber, Aini, Jackfruit** and **Epiphytes. [UPSC 2023]**

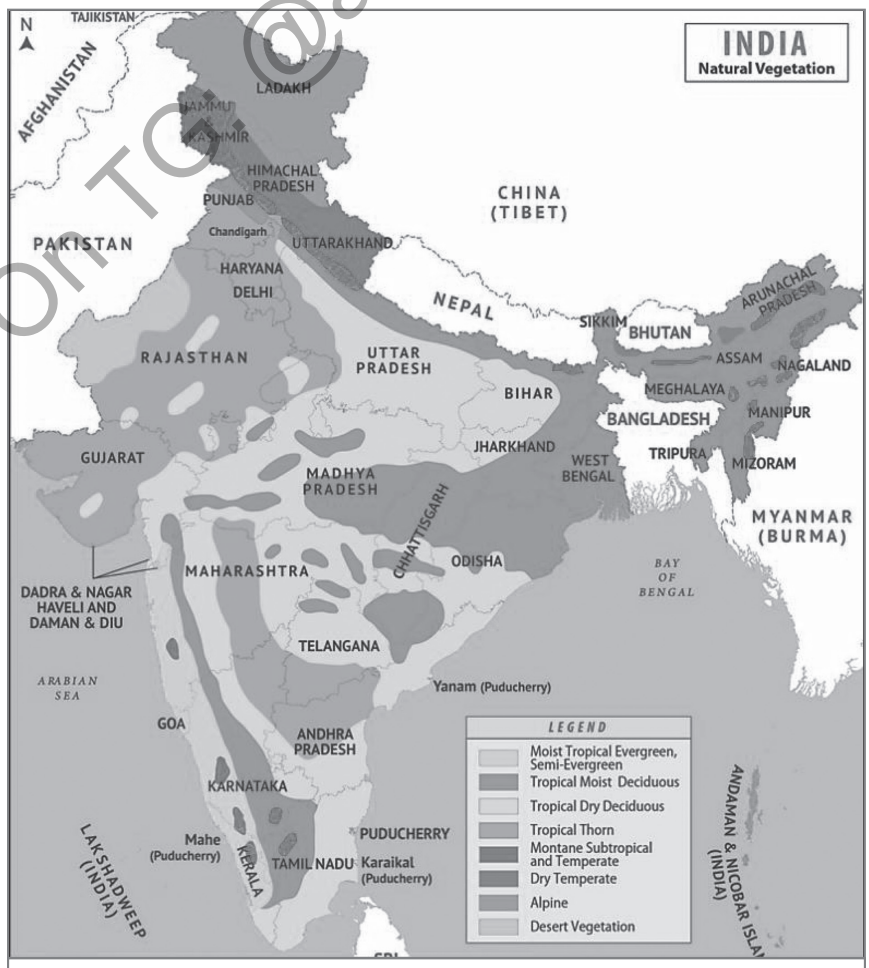


Fig. India- Natural Vegetation

Tropical Semi Evergreen Forests

- **Location: Western coast, Assam, Lower slopes of the Eastern Himalayas, Odisha, Andamans**
- **Characteristics:**
  - Located in regions with lower rainfall.
  - Mixture of evergreen and moist deciduous trees with the presence of under growing climbers.
  - Transitional forests between tropical evergreen and tropical deciduous forests and are less dense;
  - Dry season is not short like a tropical evergreen forest.
- **Flora: White Cedar, Hollock, and Kail.**

Tropical Deciduous Forests

These are the **most widespread forests** in India and are also called **monsoon forests** which receive **rainfall** between **70-200 cm.**

Classification on the Basis of the Availability of Water		
	Moist Deciduous Forests	**Dry Deciduous Forests**
Rainfall	100-200 cm	70-100 cm
Location	**Northeast States** along **foothills of Himalayas, eastern slopes of Western Ghats & Odisha, Chota Nagpur Plateau, Manipur & Mizoram.**	Rainier areas of Peninsula & Plains: **Uttar Pradesh & Bihar.** (Transitions to moist deciduous on the wetter margins, while on the drier margins to thorn forests.)
Flora	Teak, sal, shisham, hurra, mahua, amla, semul, kusum, and sandalwood etc. **[UPSC 2015, 2023]**	Tendu, palas, amaltas, bel, khair, axlewood etc.

Tropical Thorn Forests

- **Rainfall: less than 50 cm**.
- **Location:** Semi-arid areas of **southwest Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh** and **Uttar Pradesh.**
- **Characteristics:**
  - Adaptations to drier regions to conserve water - **Succulent Stems**; **Thick and small leaves**; **Long roots** penetrating deep into the soil **[UPSC 2013].**
  - Plants remain leafless for the most part of the year and give an expression of **scrub vegetation**.
- **Flora: babool, ber, wild date palm, khair, neem, khejri, palas, acacias, palms, euphorbias and cacti** etc.**; Tussocky grass** as the undergrowth.

Montane Forests [UPSC 2014]

Northern Mountain Forests

Succession of vegetation **with** the **altitude** from the **tropical to the tundra.**

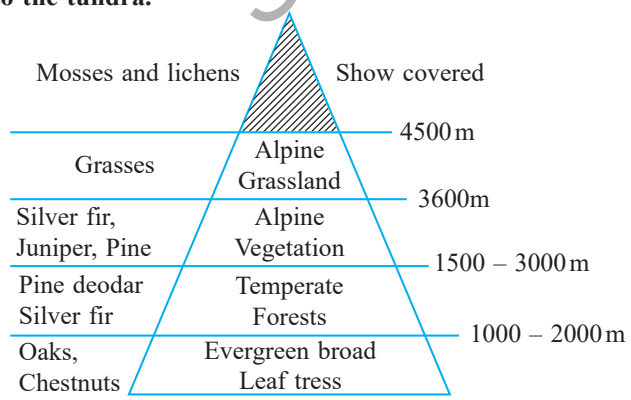


Fig. Montane Forest

- **Deciduous forests** in the foothills of the Himalayas; succeeded by the **wet temperate type of forests** between an altitude of **1,000-2,000 m**.
- **Evergreen broadleaf trees** such as oak and chestnut are predominant in the **higher northeastern hill ranges**, hilly areas of **West Bengal** and **Uttarakhand.**
- **Pine forests** between **1,500-1,750m** in this zone, with Chir Pine as a very useful commercial tree. **Deodar** (used in construction) is found mainly in the **western part of the Himalayas**. Chinar and walnut (support Kashmir handicrafts) belong to this zone.
- **Blue pine and spruce** found at altitudes of **2,225-3,048 m**. **Temperate grasslands** are also found in many places in this zone. There is a transition to Alpine forests and pastures in the higher reaches.
- **Silver firs, junipers, pines, birch**, **rhododendrons**, etc. occur between **3,000-4,000 m.**
- Tribes like the **Gujjars, Bakarwals, Bhotiyas and Gaddis** use pastures for **transhumance**.
- At higher altitudes surpassing **4,000 meters**, **mosses and lichens** as part of the tundra landscape are present.
- Himalayas have a **thicker vegetation cover** on **southern slopes** because of relatively higher precipitation than drier north-facing slopes.

Southern Mountain Forests

- Found in three distinct areas of Peninsular India: **Western Ghats, Vindhyas and Nilgiris.**
- **Temperate** vegetation (higher regions) and **subtropical** (lower regions) in Western Ghats, especially in Kerala,

Tamil Nadu and Karnataka as they are **closer to** the **tropics**, and only 1,500 m above sea level,

- The temperate forests are called **Sholas** also known as **rolling grassland** in the **Nilgiris, Anaimalai** and **Palani hills.**
- Trees of **economic significance** in these forests: **Magnolia, laurel, Cinchona and Wattle**.

MANGROVES

- They grow along the coasts in **salt marshes, tidal creeks, mud flats and estuaries** and consist of **salt-tolerant species of plants.**
- **Areas: Deltas** of **Ganga, Mahanadi, Krishna, Godavari and Kaveri**; In the Ganga-Brahmaputra delta, **Sundari trees** are found, which provide durable hard timber.
- **State wise area: West Bengal (2,114.4 sq. km) > Gujarat** (1,177.8 sq. km) > Andaman & Nicobar Islands (616.5 sq. km) > Andhra Pradesh (404 sq. km) > Maharashtra (320 sq. km) > Odisha (259 sq. km) > Tamil Nadu (57 sq. km) > Goa (26 sq. km) > Kerala (9 sq. km) > Karnataka (3 sq. km) > Puducherry (1 sq. km).

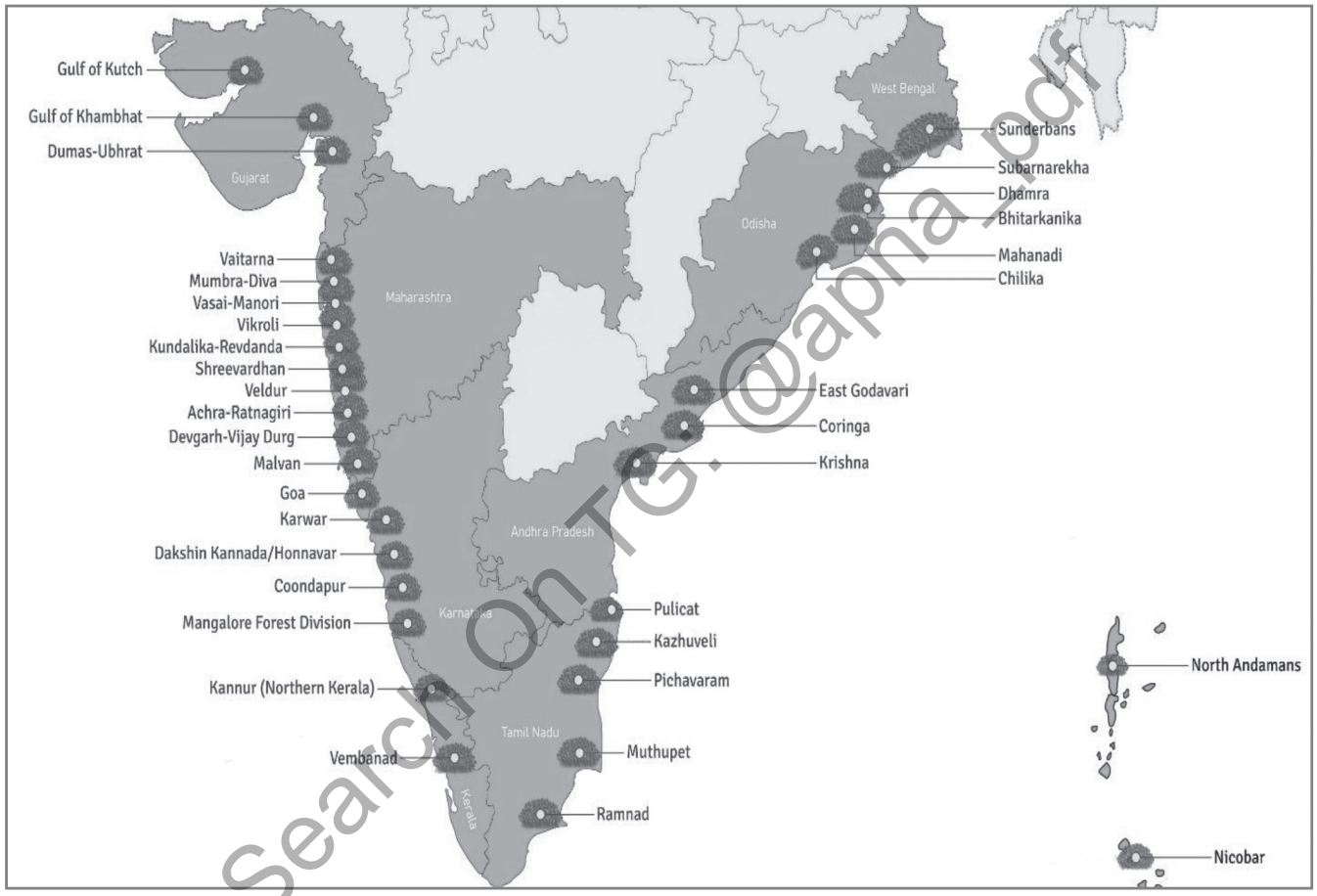


Fig. Mangroves in India

MEDICINAL PLANTS

Medicinal Plants

- **Sarpagandha:** Used to treat blood pressure; found only in India.
- **Jamun:** Powder of the seed is used to control diabetes; juice is used to prepare vinegar, which is carminative and diuretic and has digestive properties.
- **Arjun:** Fresh juice of leaves is a cure for earaches; also used to regulate blood pressure.
- **Babool:** Leaves are used as a cure for eye sores; Its gum is used as a tonic.
- **Neem:** Antibiotic and antibacterial properties.
- **Tulsi:** Cures cough and cold.
- **Kachnar:** Cures asthma; Buds and roots are good for digestive problems.

SACRED GROVES

Sacred groves refer to natural vegetation that is protected by a certain community due to religious reasons. It is usually dedicated to a local deity.

- These sacred groves are found in Himachal Pradesh, Kerala, Rajasthan, Bihar, Meghalaya and Maharashtra; Shipin in **Himachal Pradesh is believed to be the largest deodar grove;** The groves in **Maharashtra** are called **devrais**; **Umang Lai** (sacred grove) is found in **Manipur**. **The Festival of Lai Haraoba** is celebrated especially in regard to these holy sacred groves.

State	Regional Names
Maharashtra	Devrai, Devrahati
Manipur	Umang Lai
Rajasthan	Orans, Kenkris
Meghalaya	Law Kyntang, Mawphlang, Sacred Khasi Groves
Kerala	Sarpa Kavu, Kavu
Karnataka	Kans, Devarakadus, Kavus
Jharkhand	Sarana, Jaherthan, Jaher
Tamil Nadu	Kovikaadugal, Vanakkoil
Sikkim	Gumpa Forest Areas, Holy Groves
Goa	Devachi Rai, Nirankarachirai
Andhra Pradesh	Pavithra Vana, Devatala Cheruvu
Haryana	Gurudwara Groves
Uttarakhand	Bugyals, Sacred Alpine Groves
Gujarat	Sabarkantha Groves, Sacred Forests
Assam	Namghar Forest Patches

SOCIAL FORESTRY

Management and protection of forests and afforestation on barren lands with the purpose of helping in environmental, social and rural development. The **National Commission on Agriculture (1976)** has classified social forestry into three categories:

1. **Urban forestry:** Raising and management of trees on public and privately owned lands in and around urban centers.
2. **Rural forestry: Agroforestry** - Raising **trees** and **agriculture** crops on the same land; **Community Forestry** - Raising of trees on **public or community land.**
3. **Farm Forestry: Farmers grow trees for commercial and non-commercial purposes on their farm lands**, the margins of agricultural fields etc.

Other Classification of Forest

- **Protected Forest:** An area notified under the provisions of Indian Forest Act or the State Forest Acts having **limited degree of protection.** In Protected Forests, all activities are permitted unless prohibited.
- **Reserved Forest:** An area notified under the provisions of Indian Forest Act or the State Forest Acts having **full degree of protection.** In Reserved Forests, all activities are prohibited unless permitted.
- **Unclassed Forest:** An area **recorded as forest** but **not included** in **reserved or protected forest** category. Ownership status of such forests varies from state to state.
- **Virgin Vegetation:** Virgin vegetation refers to plant communities that have developed naturally without human interference and have remained untouched by human activities.

6 Resource and Manufacturing Industries

LAND RESOURCES AND AGRICULTURE

India holds about 18% of world population and the largest livestock population on **2.5 % of land area**. **Land use records** are maintained by the **Land Revenue Department**. **Survey of India** is responsible for **measuring the geographical area** of administrative units of India.

Land Use Categories

1. **Forests:** Areas demarcated for forest growth, which may not necessarily represent actual forest cover.
2. **Land put to Non-agricultural Uses:** Land under settlements (rural and urban), infrastructure (roads, canals, etc.), industries, etc. An expansion in the secondary and tertiary activities would lead to an increase in this category of land- use.
3. **Barren and Wastelands:** Land such as barren hilly terrains, desert lands, ravines, etc.; normally cannot be brought under cultivation with the available technology.
4. **Area under Permanent Pastures and Grazing Lands:** Includes all grazing lands whether they are permanent pastures and meadows or not. Village common grazing land is included under this head.
5. **Area under Miscellaneous Tree Crops (Not included in Net sown Area):** This includes all cultivable land which is not included in 'Net area sown' but is put to some agricultural uses. Lands under Casurina trees, thatching grasses, bamboo bushes and other groves for fuel, etc. which are not included under 'Orchards' are classed under this category.
6. **Culturable Waste-Land:** Land which is left fallow (uncultivated) for more than five years. It can be reclaimed for cultivation.
7. **Current Fallow:** Land left uncultivated for one agricultural year or less, allowing it to regain fertility naturally.
8. **Fallow other than Current Fallow:** Cultivable land left uncultivated for more than a year but less than five years.
9. **Net Area Sown:** Land on which crops are sown and harvested.

India has more arable area and land under irrigation as compared to China but the productivity per hectare of Indian agriculture is lower than that of China. **[UPSC 2023]**

AGRICULTURE

Agriculture is the practice of cultivating soil, growing crops, and raising livestock to produce food, fiber, medicinal plants, and other products essential for human sustenance and economic activity. It is a primary activity that forms the backbone of rural economies and has shaped human civilization through its role in settling communities and developing trade.

Operational Land Holding in India

Category	Indicator	2015-16
Size of Operational Holdings	Average size of operational holding (ha)	1.08
Total Number of Operational Holdings	Total number of operational holdings (millions)	146.18
Operational Area	Total operated area (million hectares)	155.09
Female Participation	Percentage of female operational holders	13.96%
Holding Size Distribution	Marginal (0-1 ha.) and Small (1-2 ha.) holdings (%)	86.08%
	Share in operated area (Marginal & Small)	46.94%
Medium Holdings	Semi-medium (2-4 ha.) and Medium (4-10 ha.) holdings (%)	13.35%
	Share in operated area (Semi-medium & Medium)	43.99%
Large Holdings	Large holdings (10 ha. and above) (%)	0.57%
	Share in operated area (Large holdings)	9.07%

Types of Agriculture

- **Dryland Farming**
  - **Regions:** Practised in areas with annual rainfall below 75 cm, including India's Deccan Plateau, Rajasthan, and Gujarat.
  - **Conditions:** Adapted to arid and semi-arid climates.
  - **Crops: Millets (Bajra, Ragi)**, **Sorghum (Jowar)**, and **Pulses** such as gram and lentils.
  - **Specific Requirements:**
    - **Millets:** Thrive in temperatures of 25-30°C, sandy or loamy soils, and precipitation of 40-70 cm.
    - **Sorghum (Jowar):** Requires 25-32°C, loamy or alluvial soil, and 40-100 cm of rainfall.
    - **Pulses:** Grow well in 20-28°C temperatures, well-drained loamy soils, and 50-75 cm rainfall.
  - **Techniques:** Use of **drought-resistant crops** and efficient irrigation systems like drip and sprinkler irrigation, along with **water conservation** methods like contour ploughing, mulching, and rainwater harvesting.
- **Wetland Farming**
  - **Regions:** Predominantly in areas with excess rainfall during the rainy season, such as coastal areas, river deltas, and northeastern India.
  - **Conditions:** Adapted to waterlogged environments.
  - **Primary Crop: Rice**
  - **Specific Requirements:**
    - **Rice:** Grows best in temperatures of 20-30°C, clayey soils with high water-holding capacity, and requires annual rainfall of 150-300 cm.
  - **Techniques:** Installation of **drainage systems** and **flood control** methods to manage excess water, with rice cultivation benefiting from waterlogged conditions.
- **Primitive Subsistence Agriculture**
  - **Shifting Cultivation:** Known as **slash-and-burn** or **swidden agriculture**, where land is cleared by burning vegetation, temporarily enhancing soil fertility.
  - **Local Names:**
    - Northeast India – **Jhum,** Manipur – **Pamlou,** Chhattisgarh and Andaman & Nicobar – **Dipa,** Madhya Pradesh – **Bewar or Dahiya**
    - Andhra Pradesh – **Podu or Penda,** Odisha – **Pama Dabi, Koman, or Bringa**
    - Western Ghats – **Kumari,** Rajasthan – **Valre or Waltre,** Himalayan belt – **Khil**
    - Jharkhand – **Kuruwa**
  - **Global Variants:** This practice is known as **Milpa** in Central America and Mexico, **Ladang** in Indonesia/ Malaysia, **Conuco** in Venezuela, **Roca** in Brazil, **Masole** in Central Africa, and **Ray** in Vietnam.
  - **Specific Requirements:** Crops like **maize, tubers, and upland rice** are grown under 20-28°C temperatures in loamy or clayey soils, with precipitation generally above 100 cm.
- **Intensive Subsistence Agriculture**
  - **Description:** Small plots are cultivated using simple tools and intensive labor.
  - **Crops:** Mainly **rice, wheat, and pulses** (gram, lentils).
  - **Specific Requirements:**
    - **Rice:** Requires temperatures of 20-30°C, clayey soils, and 150-300 cm of rainfall.
    - **Wheat:** Thrives at 10-25°C with loamy soils and precipitation of 50-90 cm.
    - **Pulses:** Favor temperatures of 20-28°C, loamy soils, and rainfall of 50-75 cm.
- **Commercial Farming**
  - **Purpose:** Cultivation and rearing are aimed at market sales.
  - **Crops and Animals:** Includes **maize, cotton, and livestock** like cattle and sheep.
  - **Specific Requirements:**
    - **Maize:** Requires 18-27°C, loamy soil, and 50-100 cm of rainfall.
    - **Cotton:** Best grown at 25-35°C in black (Regur) soil, with 50-100 cm of rainfall.
  - **Livestock Rearing:** Generally practiced in regions with moderate rainfall (50-100 cm) and good grazing land for fodder.
- **Plantation Farming**
  - **Description:** Large-scale, single-crop cultivation.
  - **Crops:** Primarily **tea, coffee, rubber, and sugarcane**.
  - **Specific Requirements:**
    - **Tea:** Requires 20-30°C, acidic, humus-rich soil, and 150-300 cm rainfall.
    - **Coffee:** Thrives at 15-28°C in well-drained loamy soil, with 150-250 cm of rainfall.
    - **Rubber:** Prefers temperatures of 25-35°C, lateritic soil, and above 200 cm of rainfall.
    - **Sugarcane:** Grows well at 20-35°C in fertile loamy or alluvial soil, with 75-150 cm rainfall.
  - **Regions in India:** Tea is cultivated in Assam and Kerala, coffee in Karnataka, and sugarcane in Uttar Pradesh and Maharashtra.

- **Mixed Farming** **[UPSC 2012]**
  - **Description:** Involves both crop cultivation and livestock rearing.
  - **Crops and Livestock:** Often includes **maize, wheat, barley**, along with cattle or sheep.
  - **Specific Requirements:**
    - **Maize:** 18-27°C temperature, loamy soil, 50-100 cm rainfall.
    - **Wheat:** 10-25°C, loamy soils, 50-90 cm precipitation.
    - **Barley:** Grows well at 15-25°C with low rainfall.
  - **Regions:** Widely practiced in **Punjab, Haryana, and parts of Maharashtra**.
- **Co-operative Farming**
  - **Description:** Farmers form societies to pool resources, enhancing efficiency and profitability.
  - **Benefits:** Access to shared equipment, bulk purchase discounts, and better market access due to collective bargaining.

Cropping Seasons in India

There are **three distinct crop seasons** in the northern and interior parts of the country: **kharif, rabi, and zaid.**

Table: Cropping Seasons in India

Season	Description	Crops
Kharif	Occurs during the Southwest Monsoon; begins in June and ends in September.	Tropical crops: Rice, Cotton, Jute, Jowar, Groundnut, Bajra, Maize, Tur **[UPSC-2013]**
Rabi	Begins with the onset of winter, from October-November, and ends in March-April.	Temperate and subtropical crops: Wheat, Gram, Barley, Mustard, Rapeseeds
Zaid	Short duration summer cropping season after harvesting Rabi crops, typically in April-June.	Watermelons, Cucumbers, Vegetables, Fodder crops (on irrigated lands)

Note:- Southern states do not experience distinct Kharif and Rabi cropping seasons and similar crops like Rice, Maize, Ragi, Jowar and Groundnut are cultivated in both the seasons.

MAJOR CROPS IN INDIA

Crops/Groups of Crops	Top 3 States	Production (Million Tonnes)
I. Foodgrains		
Rice	Telangana	16.63
	Uttar Pradesh	15.72
	West Bengal	15.12
Wheat	Uttar Pradesh	35.43
	Madhya Pradesh	21.28
	Punjab	17.78
Maize	Karnataka	5.49
	Bihar	4.61
	Madhya Pradesh	4.33
Total Nutri/Coarse Cereals	Rajasthan	8.03
	Karnataka	7.61
	Madhya Pradesh	5.49
Tur	Karnataka	1.02
	Maharashtra	0.86
	Uttar Pradesh	0.38

Gram	Madhya Pradesh	3.19
	Maharashtra	2.86
	Rajasthan	2.23
Total Pulses	Madhya Pradesh	6.18
	Maharashtra	4.00
	Rajasthan	3.63
Total Foodgrains	Uttar Pradesh	59.29
	Madhya Pradesh	39.84
	Punjab	32.59
II. Oilseeds		
Groundnut	Gujarat	4.64
	Rajasthan	2.02
	Madhya Pradesh	0.99
Rapeseed & Mustard	Rajasthan	5.98
	Uttar Pradesh	1.87
	Madhya Pradesh	1.75
Soyabean	Madhya Pradesh	5.47
	Maharashtra	5.23
	Rajasthan	1.17
Sunflower	Karnataka	0.07
	Haryana	0.03
	Odisha	0.02
Total Oilseeds	Rajasthan	9.57
	Madhya Pradesh	8.37
	Gujarat	7.19
III. Commercial Crops		
Sugarcane	Uttar Pradesh	205.56
	Maharashtra	112.09
	Karnataka	41.81
Cotton@	Gujarat	9.06
	Maharashtra	8.05
	Telangana	5.08
Jute & Mesta$	West Bengal	7.87
	Bihar	0.99
	Assam	0.68

- "@" Cotton production in million bales (170 kg each).
- "$" Jute & Mesta production in million bales (180 kg each).
- Data based on 3rd Advance Estimates for 2023-24.

Food Grains

Food grains occupy about **two-thirds of the total cropped area** in India. Based on the structure of grains, they are classified as **cereals and pulses.**

Cereals

- Occupy about 54% of the total cropped area in India.
- India ranks third in production after China and the USA.
- Types of cereals: **fine grains (rice, wheat)** and **coarse grains or millets (jowar, bajra, maize, ragi)**

Rice **[UPSC 2011]**

- **Kharif crop:** Considered to be a crop of tropical humid areas; **Temperature: 16 to 20 degree celsius** for **flowering and fertilisation** and **18 to 32 degree celsius** during **ripening; Rainfall**: **150 to 300 cm** of average Rainfall; **Soil:** Clayey or alluvial moisture retentive soils are ideal.
- Occupy around **1/4th of total cropped area;** India contributes 21.6% of rice production worldwide, ranking **second after China** in 2016.
- Successfully grown from **sea level to about 2,000 m** altitude and from humid areas in **eastern India** to dry but irrigated areas of **Punjab, Haryana, western U.P. and northern Rajasthan;** In **southern states** and **West Bengal** the climatic conditions allow the cultivation of two or three crops of rice in an agricultural year. Three crops of rice in **West Bengal**: **'aus', 'aman' and 'boro'**; In Himalayas and northwestern parts of the country, it is grown as a kharif crop.

Fig. Distribution of Rice

Fig. Distribution of Wheat

Wheat

- Primarily a crop of temperate zone, hence its cultivation in India is done during winter (Rabi Crop); **Second** largest producer of wheat with around **12.3** percent of world production.*(2023 data)*; **Temperature: 10 to 15 degree celsius for sowing and 20 to 25 degree celsius during harvest; Rainfall: 80 cm**; **Soil: Well drained loamy and clayey soils**.
- About 14 percent of the total cropped area under wheat cultivation; **North and central regions** i.e. Indo-Gangetic Plain, Malwa Plateau and Himalayas up to 2,700 m altitude constitute around **85% of the total wheat cultivation area.**

Coarse Cereals or Millets

Coarse cereals, which include crops like **Jowar**, **Bajra**, **Maize**, and **Ragi**, occupy about **17%** of India's total cropped area. These cereals are primarily grown in regions with semi-arid climates and are significant for both food and fodder production.

Temperature: average **20°C- 30°C; Rainfall: 40 - 60 cm;** Occupy about **16.50%** of total cropped area.

Jowar (Sorghum)

- **Temperature**: **27-32 degrees Celsius** during **germination.** Crop does not do well at temperatures below 16 degrees Celsius; **Rainfall**: Can be grown in **arid and semi arid areas** having rainfall **under 45cm**; **Soil**: Variety of soils including **clayey, sandy**.
- Accounts for about **5.3%** of total cropped area; main food crop in **semi-arid** areas of **central and southern India**; Mainly a **kharif crop** in **northern India** where it is mostly grown as a fodder crop; sown in both **kharif and rabi seasons** in **southern states; Half of the total jowar production is attributed to Maharashtra**. Other **leading producers: Karnataka, Madhya Pradesh, Andhra Pradesh**, and **Telangana.**

Bajra

- **Temperature**: **25 to 30 degree celsius**; **Rainfall: 40-50 cm**; **Soil: sandy loams, black** and **red soils**;
- Sown in **hot and dry climatic conditions** in **northwestern and western** parts; occupies about 5.2% of the total cropped area.

Maize

- **Food** as well as **fodder** crop; grown under **semi-arid** conditions and on **inferior soils.**
- Occupies about 3.6% of the total cropped area; sown **all over India except eastern and north-eastern regions.** Yield level of maize is higher than other coarse cereals. It is high in southern states and declines towards central parts.

Pulses

- Legume crops that improve soil fertility through nitrogen fixation; **Temperature: 20 to 25 degrees celsius**; **Rainfall**: **50 to 75 cm**; **India** is a **leading producer** of pulses in the world.
- Pulses Occupy about 11% of the total cropped area; Main pulses cultivated in India: **Gram and Tur (Arhar).**
- Cultivation is concentrated in the drylands of Deccan and central plateau and northwestern part of the country.

Gram

- Cultivated in **subtropical** areas; grown mainly in **central, western, and northwestern** India during Rabi season; covers about **2.8% of the total cropped area.**

Although pulses are grown in both the Kharif and Rabi seasons, over **60% of the production comes from Rabi pulses.** It is possible to grow **black gram** as a **kharif and rabi crop**; **Chickpeas** is the **most dominant pulse** with a share of around 40 per cent in the total production **[UPSC 2020]**

Tur (Arhar)

- Also known as **red gram or pigeon pea**; grown in the dry areas of **central** and **southern** states; Occupies about 2% of India's total cropped area.

Oilseeds

- Account for about 14% of total cropped area; Oilseeds growing regions of India: **Drylands of Malwa plateau, Marathwada, Gujarat, Rajasthan, Telangana, Rayalaseema region of Andhra Pradesh and Karnataka plateau.**

Groundnut

- It is a rainfed **kharif crop in drylands,** however **in southern India** it is grown as **rabi crop as well** and covers about 3.6% of total cropped area; **Temperature: 20 to 25 degree celsius; Rainfall: 50 to 100 cm**; **Soil: sandy loams, loams** and **well drained soils**.
- India produces about 16.6% of total groundnut production in the world (2016); **Leading producers: Gujarat (45%) > Rajasthan > Tamil Nadu (ES 2022-23)**.

Rapeseed and Mustard

- **Temperature: 10 to 20 degree celsius; Rainfall: 25 to 40 cm**; **Soil:** Heavier **loams** for mustard; Light loams for rapeseed; Comprise oilseeds: **rai, sarson, toria and taramira; Subtropical crop** grow during **rabi season;** frost-sensitive crop.
- Grown in **north-western and central parts** and covers about 2.5% of total cropped area.

Soyabean

- **Kharif Crop; Temperature:** 13 to 24 degree celsius**; Rainfall:** 40 to 60 cm**; Soil: friable loamy acidic.**
- **Maharashtra and Madhya Pradesh** together produce about **90 per cent of total output** of soyabean.

Sunflower

- **Temperature: 26 to 30 degree celsius; Rainfall: < 50 cm; Soil:** well drained loamy soil.
- Cultivation concentrated in **Karnataka, Andhra Pradesh, Telangana and adjoining areas of Maharashtra.**

Mangos are grown in **central and south India**, **areca nuts** are planted primarily in the **southern region,** and **soybeans** are grown mostly in **central India.** **[UPSC 2014]**

Fiber Crops

Cotton (White Gold)

- **Tropical crop** grown in **kharif season** in **semi-arid areas**; **Temperature: 21°C- 30°C**; **Rainfall: 50 - 75cm**; **Soil: Black soil;** Requires **clear sky** during **flowering** stage; Requires **approx. 210 frost free days** and mineral rich **black lava soil (Regur)**. **[UPSC 2020]**
- India is **2nd** (**23.83%** of world production; 2022-23) in **global cotton production**. Both **short staple (Indian) cotton** as well as **long staple (American) cotton** called are grown in north-western parts of the country; Occupies about **4.7 per cent** of total cropped area; Cotton growing states, grouped into three diverse agro-ecological zones, as under:
  - i. **Northern Zone** - Punjab, Haryana and Rajasthan
  - ii. **Central Zone** - Gujarat, Maharashtra and Madhya Pradesh
  - iii. **Southern Zone** - Telangana, Andhra Pradesh and Karnataka

It is also grown in the state of Odisha and Tamil Nadu; **India** is the **only country** which grows **all four species** of cotton : G. Arboreum & G. Herbaceum (**Asian cotton**), G. Barbadense (**Egyptian cotton**) and G. Hirsutum (**American Upland cotton**). G. Hirsutum represents 90% of the hybrid cotton production in India and all the current Bt cotton hybrids are G. Hirsutuim.

Jute (Golden Fiber)

- **Principal varieties** of jute in India are **tossa** and **white jute;** Requires **Hot & Humid climate ; Temperature: 24 to 35 degree celsius**; **Rainfall: ~150 cm** with 90% of relative humidity; **Soil: rich delta or alluvial soil,** Very high **carbon dioxide assimilation ability,** several times higher than trees.
- It has about **0.5% of total cropped area**, and **India** produces about **60% of world jute; Leading producer: West Bengal (81%) > Assam> Bihar** (ES 2022-23); **West Bengal** accounts for over **3/4th of total jute production in India**.

Silk

- India grows all important varieties of silk: **Mulberry, Tasar, Oak Tasar, Eri and Muga (Assam)**;India is the **second largest silk producer;** Mulberry silk is grown mainly in southern states **(Karnataka, Tamil Nadu, Andhra Pradesh) and West Bengal & Jharkhand;** Non Mulberry silk is mainly grown in **Jharkhand, Chhattisgarh, Odisha and North East.**

Other Crops

Sugarcane

- Sugarcane is a **tropical** crop; Under rainfed conditions, cultivated in sub-humid and humid climates but in India it is largely an irrigated crop; a highly water inefficient crop **Temperature: 20°C- 26°C; Rainfall: 100 - 150 cm**. **[UPSC 2021]**.
- Covers 2.4% of total cropped area; India is the **second-largest producer** of sugarcane after Brazil in 2022-23; **Areas: Indo-Gangetic plain (Uttar Pradesh); western India (Maharashtra and Gujarat); southern India** (irrigated tracts of **Karnataka, Tamil Nadu, Telangana and Andhra Pradesh); Leading cultivators: Uttar Pradesh (41%) > Maharashtra (25%) > Karnataka.**
- **Method of propagation:** Ratooning- Ratooning is an agricultural technique that involves cutting most of a monocot crop's above-ground parts after harvest, while leaving the roots and growing shoot apices intact. This allows the plants to recover and produce a new crop in the next season.

Plantation Crops

Tea

- **Temperature: 24°C- 30°C**; **Rainfall: at least 150 cm**; **Soil: Forest soil; rich in humus and iron; Black tea** leaves are fermented whereas **green tea** leaves are unfermented; tea leaves have rich content of **caffeine** and **tannin.**
- Cultivated over **hilly** areas and **well drained soils** in **humid** and **sub-humid tropics and sub-tropics;** Tea plantation started in **Brahmaputra valley of Assam (1840s);** later introduced in the sub-Himalayan region of **West Bengal (Darjeeling, Jalpaiguri and Cooch Behar districts);** also cultivated on the lower slopes of **Nilgiri and Cardamom hills** in **Western Ghats.**
- India is the leading producer and **ranks second among tea exporting countries**; accounts for **about 21.1% of total production in the world** (2016); **Assam** is a major producer, about **53.2% of total tea cropped area** is in Assam.
- **Leading producers: Assam, West Bengal, Tamil Nadu; Other producers:** Kerala, Tripura, Karnataka, Himachal Pradesh and Uttarakhand. **[UPSC 2022]**

Coffee

- **Tropical plantation crop; Temperature: 15°C- 2**8°C; **Rainfall:** 150 - 200 cm; **Soil: Well drained, friable loamy soil, rich in vegetable mould is ideal**.
- There are three varieties of coffee i.e. **arabica, robusta and liberica**; Production of **Robusta** coffee is greater than **Arabica** coffee in India.
- It is grown under a canopy of thick natural shade of the Western and Eastern Ghats; Cultivated in the **Western Ghats in Karnataka, Kerala, Tamil Nadu;** India produces only about 3.7% coffee of the world and ranks seventh.
- **Karnataka** accounts for over **two-thirds (70%) of total coffee production. Baba Budan Hills** in Karnataka and **Araku Valley** in Andhra Pradesh are famous coffee growing regions.

Rubber

- Typically grown in **equatorial regions** but it has also found a place in **tropical and subtropical areas of India; Temperature: 25°C-35°C; Rainfall: 152 to 200 cm; Soil: Rich well drained alluvial or laterite soils are ideal.**
- **Major producers: Kerala, Tamil Nadu, Karnataka, Andaman and Nicobar Islands**, as well as the **Garo Hills** of Meghalaya.

Cropping Intensity (CI): It is defined as the number of crops a farmer grows in a given agricultural year on the same field and is another means for intensification of production from the same plot of land.

Orchids cultivation **[UPSC 2011]**

Arunachal Pradesh has the most suitable climatic conditions for the cultivation of a large variety of orchids with minimum cost of production, and can develop an export oriented industry in this field.

Top Producer and Top Exporting Nations

Crop/Product	Top 2 Producer Countries	Top 2 Exporting Countries
Rice	1. China, 2. India	1. India, 2. Thailand
Wheat	1. China, 2. India	1. Russia, 2. United States
Maize	1. United States, 2. China	1. United States, 2. Brazil
Sugarcane	1. Brazil, 2. India	1. Brazil, 2. India
Coffee	1. Brazil, 2. Vietnam	1. Brazil, 2. Vietnam
Milk	1. India, 2. United States	1. India, 2. United States
Pulses	1. India, 2. Myanmar	1. Canada, 2. Australia
Oilseeds	1. United States, 2. Brazil	1. United States, 2. Brazil
Jute Fibre	1. India, 2. Bangladesh	1. Bangladesh, 2. India
Fruits	1. China, 2. India	1. China, 2. India
Coarse Grains	1. United States, 2. China	1. United States, 2. China
Potato	1. China, 2. India	1. China, 2. India
Onion	1. China, 2. India	1. China, 2. India
Tomato	1. China, 2. India	1. China, 2. India
Cocoa	1. Côte d'Ivoire, 2. Ghana	1. Côte d'Ivoire, 2. Ghana
Rubber	1. Thailand, 2. Indonesia	1. Thailand, 2. Indonesia
Palm Oil	1. Indonesia, 2. Malaysia	1. Indonesia, 2. Malaysia
Groundnut	1. China, 2. India	1. China, 2. India
Cotton	1. India, 2. United States	1. United States, 2. Brazil
Tobacco	1. China, 2. India	1. China, 2. India
Tea	1. China, 2. India	1. China, 2. India

MINERALS

Mode of Occurrence of Minerals

Mineral is a natural substance of organic or inorganic origin with definite chemical and physical properties. They are usually found in the form of "ores". The mineral content of the ore must be in sufficient concentration to make its extraction commercially viable. Minerals generally occur in these forms:

- Minerals obtained from cracks, crevices and joints of igneous and metamorphic rocks: **tin, copper, zinc, lead** etc.
- Minerals deposited in strata of sedimentary rocks: **Coal, gypsum, potash salt and sodium salt.**
- **Decomposition of surface rocks**, and the removal of soluble constituents, leaving a residual mass of weathered material containing ores. **Bauxite** is formed this way.
- **Placer deposits** occur as alluvial deposits in sands: **Gold, silver, tin and platinum**.
- **Common salt, magnesium, Manganese nodules and Bromine** are largely derived from ocean waters.

Global Distribution of Minerals

Asia

- **China, Malaysia and Indonesia** are the **leading producers of tin**.
- **China** also **leads** in the **production of iron ore, lead, antimony and tungsten.**
- The **continent has deposits** of **iron, manganese, bauxite, nickel, zinc and copper** and **produces more than half of the world's tin.**

Europe

- **Russia, Ukraine, Sweden and France** have large deposits of **iron ore**.
- Deposits of **copper, lead, zinc, manganese and nickel** are also found in **eastern Europe and European Russia**.

North America

The mineral deposits in North America are located in three zones:

- The **Canadian region,** north of the Great Lakes, has deposits of **iron ore, nickel, gold, uranium and copper.**
- The **Appalachian region** has **coal.**
- Western cordillera has vast deposits of **copper, lead, zinc, gold and silver**.

South America

- **Brazil** has **large deposits** of **high grade iron-ore**.
- **Peru, Brazil and Bolivia** are among the world's **largest producers of tin**.
- **Chile and Peru** are **leading producers** of **copper.**
- The continent has large deposits of **gold, silver, zinc, chromium, manganese, bauxite, mica, platinum, asbestos and diamond**.

Africa

- Africa is the world's **largest producer of diamonds, gold and platinum.**
- Presently, the **Democratic Republic of Congo** (DRC) has over **70%** of the worldwide **cobalt production**, and is **home to half of the world's known cobalt deposits**. **[UPSC 2023]**
- **South Africa, Zimbabwe Zaire and Ghana** produce a large portion of the world's **gold**.
- **Copper, iron ore, chromium, uranium, cobalt and bauxite** are also found
- **Oil** is found in **Nigeria, Libya and Angola**

Australia

Australia is the **largest producer of bauxite** in the world; It is a **leading producer of gold, diamond, iron ore, tin and nickel**. **Copper, lead, zinc and manganese** are also found; **Kalgoorlie and Coolgardie** areas have the largest deposits of gold.

Antarctica

Deposits of **coal** in the Transantarctic Mountains and iron near the Prince Charles Mountains of East Antarctica are forecasted; **Iron ore, gold, silver and oil** are also present in commercial quantities.

Distribution of Minerals in India

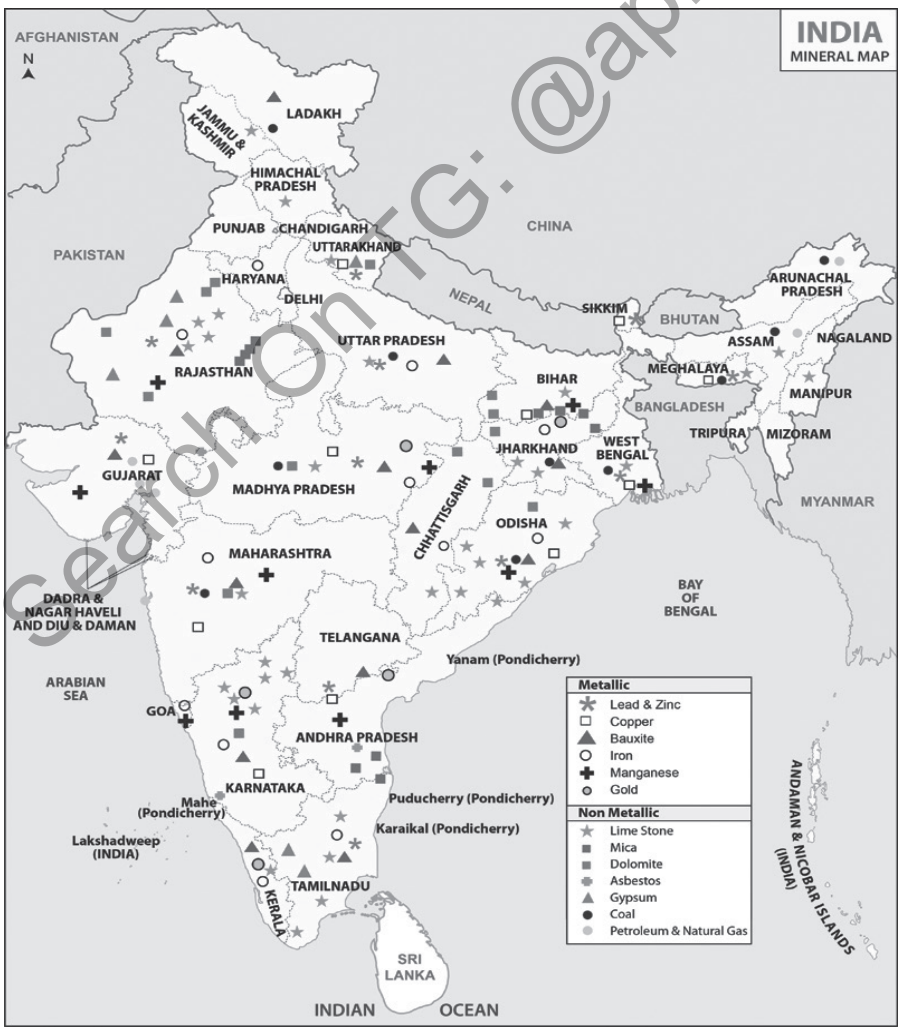


Fig: Minerals in India

Bulk of the valuable minerals are products of pre-paleozoic age that are mainly associated with metamorphic and igneous rocks of peninsular India. The vast alluvial plain tract of north India is devoid of minerals of economic use.

- **Peninsular rocks** contain reserves of **coal, metallic minerals (most of the reserves in India occur here in old crystalline rocks), mica** and many other **non-metallic minerals**. Sedimentary rocks on the **western and eastern flanks of the peninsula**, in **Gujarat and Assam**, off-shore-areas near **Mumbai Coast (Mumbai High)** have most of the **petroleum deposits**.

Minerals are generally concentrated in four broad belts in India. These belts are:

- **The North-Eastern Plateau Region: Chotanagpur (Jharkhand), Orissa Plateau, West Bengal and parts of Chhattisgarh**
  - **Over 97% of coal reserves** occur in the valleys of **Damodar, Sone, Mahanadi and Godavari**.
  - It has a variety of minerals viz. iron ore, coal, manganese, bauxite, mica; major iron and steel industries are located in this region.
- **The South-Western Plateau Region:** This belt extends over **Karnataka, Goa and contiguous Tamil Nadu uplands and Kerala**.
  - **Rich in ferrous metals and bauxite**.
  - Contains **high grade iron ore, manganese** and **limestone.** Goa has iron ore deposits.
  - **Lacks coal deposits except Neyveli lignite.**
  - **Kerala** has deposits of **monazite and thorium, bauxite clay**.
- **The North-Western Region:** This belt extends along **Aravali in Rajasthan and part of Gujarat** and minerals are associated with the **Dharwar system of rocks.**
  - **Copper and Zinc are major minerals.**
  - **Rajasthan** is rich in building stones i.e. **sandstone, granite, marble.**
  - **Gypsum and Fuller's earth deposits** are also extensive.
  - **Dolomite and limestone** provide raw materials for the cement industry.
  - **Gujarat** is known for its **petroleum deposits**.
  - Both **Gujarat and Rajasthan** have rich sources of **salt.**
- **The Himalayan Belt:** Copper, lead, zinc, cobalt and tungsten occur in both the eastern and western parts. Assam Valley has mineral oil deposits.

Types of Mineral Resources

Based on Characteristics [UPSC 2019, 2020]

- **Major Minerals:** Abundantly present in the Earth's crust; major minerals such as Coal, Iron ore, Bauxite, Copper, Gold, Limestone, chromite, kyanite and sillimanite significantly contribute to the economy. Major minerals are those that are crucial for the nation's industrial development and are regulated by the Central Government.
- **Minor Minerals:** Occurring in smaller quantities, minor minerals like Mica, Garnet, Barite, Talc, Beryl, and Silica sand have limited economic importance. Extracted on a smaller scale, they find usage in niche applications. Minor minerals are those that are not specifically mentioned in the Mines and Minerals (Development and Regulation) Act, 1957. They are regulated by state governments. The State Government has the power to frame rules to prevent illegal mining of minor minerals.
  - **Building Stones:** Granite, marble, sandstone, limestone, etc.
  - **Clay Minerals:** Clay, bentonite, and kaolin.
  - **Other Minerals:** Gypsum, silica sand, gravel, and gemstones.

Based on Metallic Content

- **Metallic Minerals:** Primarily valued for their metal content, metallic minerals like Gold, Silver, Copper, Iron ore, Zinc, Lead, and Aluminum exhibit a characteristic metallic luster, high electrical and thermal conductivity. They are economically significant, used in industries such as construction, manufacturing, and transportation. Extraction involves mining and subsequent smelting or refining processes.
- **Non-Metallic Minerals:** While lacking metallic elements and luster, non-metallic minerals such as Quartz, Feldspar, Mica, Calcite, Talc, Gypsum, and Diamond find applications in construction, ceramics, glass-making, and more. These minerals are generally brittle, lack malleability and ductility, and have lower electrical and thermal conductivity. They are often widely distributed in various geological formations.

Based on Iron Content

- **Ferrous Minerals:** Mainly constituted by iron, ferrous minerals like **Iron ore (Hematite, Magnetite), Manganese, Chromium, and Nickel**. They are crucial for industries like steel production. They exhibit **magnetic properties**, are strong and durable but susceptible to rusting and corrosion when exposed to moisture.
- **Non-Ferrous Minerals:** Without iron as the main constituent, non-ferrous minerals like **Copper, Lead, Zinc, Aluminum, Gold, Silver, and Tin** find applications in various industries, including electrical, construction, and aerospace. Generally **lacking magnetic properties**, they vary in strength and hardness, and are resistant to rusting and corrosion.

Based on Origin

- **Organic:** Derived from plant or animal organic materials; examples include coal, petroleum and peat; associated with fossilised organic remains.
- **Inorganic:** Formed through geological processes; examples include quartz, limestone, graphite, feldspar, gypsum, and mica; lack a biological origin.

METALLIC MINERALS

Ferrous Minerals

These account for about **3/4th of the total value of the production of metallic minerals**. India is well-placed in respect of ferrous minerals both in reserves and production. It exports substantial quantities of ferrous minerals.

Iron Ore

- Iron Ore Types and Uses
  - **Magnetite (Fe_3O_4):** 72% iron content; Used in electronic industries.
  - **Hematite (Fe_2O_3):** Iron content 60-70%; Utilized in iron and steel industries.
  - **Limonite ($FeO(OH)\cdot nH_2O$):** Iron content 40-60%; Serves as a pigment for paints.
  - **Siderite ($FeCO_3$):** Iron content 40-50%; Acts as a source of manganese.
- The two main types found in India are **haematite and magnetite**.
- The iron ore mines occur in close proximity to the coal fields in the north-eastern plateau region of the country.
- About **95 per cent of total reserves** of iron ore are located in **Odisha, Rajasthan, Jharkhand, Chhattisgarh, Karnataka, Goa, Telangana, Andhra Pradesh and Tamil Nadu. [UPSC 2018]**
- The **major iron ore belts in India** are:
  - **Odisha:** in a series of hill ranges in **Sundergarh, Mayurbhanj and Jhar. Important mines: Gurumahisani, Sulaipat, Badampahar (Mayurbhanj), Kiruburu (Kendujhar) and Bonai (Sundergarh)**
  - **Jharkhand: Important mines: Noamundi, Gua.**
  - **Chhattisgarh:** Dantewada and Bailadila. Dalli, and Rajhara in Durg.
  - **Karnataka:** Sandur-Hospet area of **Bellary district**, **Baba Budan hills** and **Kudremukh** in Chikmagalur district and **Shivamogga, Chitradurga and Tumkur districts.**
  - **Maharashtra:** Districts of **Chandrapur, Bhandara and Ratnagiri.**
  - **Telangana: Karimnagar and Warangal** district; **Andhra Pradesh: Kurnool, Cuddapah and Anantapur** districts.
  - **Tamil Nadu: Salem and Nilgiris** districts; **Rajasthan:** Bhilwara; **Goa** has also emerged as an important producer.
- India's iron ore is mostly – Hematite; India –2nd largest producer of hematite after Russia.
- Global Iron Ore Production
  - **Africa:** Liberia, South Africa, and Algeria.
  - **China:** Reserves in Shenyang, Manchuria, Wuhan, Tai-ye, and Hainan Island.
  - **Australia:** Primary producer with reserves in Western Australia.
  - South America: Brazil.
  - **North America:** USA and Canada, with rich deposits in the Great Lakes area.
  - **Russia:** Key areas include Kerch Peninsula, Kursk region, and Ural Mountains.
  - **Europe:** Major reserves in Sweden and France, with key centres in Rhine Valley (Germany), Lorraine, Normandy, and Pyrenees (France).

Manganese

- Important raw material for **smelting iron ore** and also used for steel manufacturing (10 kg Mn for 1 ton steel) and **ferro-manganese alloys**. It is also used in manufacturing **bleaching powder, insecticides and paints**.
- Manganese deposits are found in almost all geological formations, however, they are mainly associated with the **Dharwar system.** Producers are:
  - **Madhya Pradesh:** Balaghat-Chhindwara-Nimar-Mandla and Jhabua districts
  - **Orissa: Leading producer;** Major mines in Orissa are located in **Bonai, Kendujhar, Sundergarh, Gangpur, Koraput, Kalahandi and Bolangir**
  - **Karnataka:** Mines are located in **Dharwad, Bellary, Belgaum, North Canara, Chikmagalur, Shimoga, Chitradurg and Tumkur**
  - **Maharashtra:** Mines are in **Nagpur, Bhandara and Ratnagiri districts**
  - **Telangana, Goa, and Jharkhand** are other **minor producers** of manganese.
  - **State-wise Distribution in India:** Odisha (44%); Karnataka (22%); Madhya Pradesh (13%); Maharashtra (8%); Andhra Pradesh (4%); Jharkhand and Goa (3% each); Rajasthan, Gujarat, and West Bengal (remaining 3%)
- **Global Reserves:** South Africa, Ukraine, and Australia hold the largest reserves; Abundant deposits in Ukraine, Caucasus mountains, Urals, and Republic of Georgia; China and India are leading producers; Other major producers include Australia, Ghana, Gabon, Morocco, and South Africa.

Non-Ferrous Minerals

They do not have iron content such as **copper, bauxite, lead, zinc, gold** etc. India's reserves and production of these minerals is not very satisfactory except for Bauxite.

Copper

- India is critically **deficient in the reserve and production** of copper.
- Being **malleable, ductile and a good conductor**, copper is mainly used in **electrical cables, electronics and chemical industries**. It is also **mixed with gold** to provide **strength to jewellery.**
- **Copper-Rich Regions in India - Jharkhand:** Raka mines, Mosabani mines; **Andhra Pradesh:** Kurnool, Guntur, Nellore; **Himachal Pradesh:** Kangra valley, Kullu valley; **West Bengal:** Jalpaiguri, Darjeeling.
- **Copper Reserves Globally:** Chile and Peru possess over one-third of the world's copper reserves; North America's copper mining areas span Mexico, USA, and Canada along the Western Cordilleras; Europe has resources in Russia and Poland, and significant reserves in Armenia, Georgia, Uzbekistan, and Kazakhstan.

Bauxite

- Alumina and later aluminum is obtained from bauxite; Aluminum has the strength of metals such as iron, with extreme **lightness** and has **good conductivity** and **great malleability**. Bauxite deposits are **formed by the decomposition** of a wide variety of rocks rich in aluminium silicates.
- **Distribution in India:** Bauxite is mainly found in **tertiary** deposits, associated with **laterite** rocks.
  - Orissa: Largest producer; Kalahandi and Sambalpur.
  - Jharkhand: Noteworthy production in Lohardaga's **patlands**.
  - Gujarat: Khed, Amreli, Bhavnagar, Jamnagar.
  - Chhattisgarh: Amarkantak plateau is significant.
  - Madhya Pradesh: Amarkantak, Balaghat.
  - Maharashtra: Kolaba, Thane, Ratnagiri, Satara, Pune, Kolhapur.
  - Minor producers: Tamil Nadu, Karnataka, Goa.
- **Bauxite Reserves Globally:** Australia, Guinea, Jamaica, and Brazil are major reserves; USA has deposits in Arkansas, Alabama, and Georgia; Russian deposits are situated in the Urals.

NON-METALLIC MINERALS

Among the non-metallic minerals produced in India, mica is the most important one. The other minerals extracted for local consumption are limestone, dolomite and phosphate.

Mica

- Mica is a naturally occurring non-metallic mineral that is based on a collection of silicates.
  - **Nature:** Natural, non-metallic mineral; silicate-based.
  - **Insulation:** Due to its **excellent di-electric strength, low power loss factor, insulating properties and resistance to high voltage**, mica is one of the most indispensable minerals used in **electric and electronic industries**. Excellent insulator; widely used in electronics.
- **Major Producers in India:** Jharkhand, Odisha (Kodarma - the world's largest), Bihar (Munger), Andhra Pradesh (best quality in Nellore district), Telangana, Rajasthan (Jaipur to Bhilwara, around Udaipur), Karnataka (Mysore, Hasan districts), Tamil Nadu (Coimbatore, Tiruchirapalli, Madurai, Kanyakumari), Kerala (Alleppey), West Bengal (Purulia, Bankura) and Madhya Pradesh(Balaghat).

Limestone

- **Composition:** Limestone comprises calcium carbonate or a mix with magnesium carbonate.
- **Origin:** Sedimentary rocks, found in geological sequences from Pre-Cambrian to Recent, excluding Gondwana.
- **Uses:** 75% in cement, 16% in iron and steel (as flux), 4% in chemicals; rest in paper, sugar, fertilizers, etc.
- **Production Centers:** Mainly Madhya Pradesh, Rajasthan, Andhra Pradesh, Gujarat, Chhattisgarh, and Tamil Nadu.
- **Top Producer:** Madhya Pradesh leads with 16% of India's limestone, found in districts like Jabalpur, Satna, Betul, etc.

Gypsum

- **Hydrated sulphate of calcium;** white opaque or transparent.
- Occurs in **sedimentary formations** like limestones, sandstones, and shales.
- Mainly used in **ammonia sulphate fertilizer**, **cement industry** (4-5% of cement); **plaster of Paris, ceramics, tiles, plastics;** applied as surface plaster in agriculture.
- Rajasthan leads India's production (99%), deposits in **Jodhpur, Nagaur, Bikaner, Jaisalmer, and Barmer.**

Chromite

- **Oxide of iron and chromium;** primary ore for chromium.
- Used in **chrome plating, alloying, metallurgy, and chemical industries.**
- India has estimated reserves of **203 MT, 93% in Odisha (Sukinda valley in Cuttack and Jajapur).**
- Odisha is the sole producer (99%), major deposits in **Keonjhar, Cuttack, and Dhenkanal.**

Lead and Zinc

- **Lead:** corrosion-resistant heavy metal; **Zinc:** silvery blue-grey metal.
- Both found in **galena, pyrites, and sulphide ores.**
- **Major global producers: USA, Russia, Australia, Canada, Peru, Spain, Mexico.**
- In India, Rajasthan has the largest lead-zinc ore resources (61%), followed by **Andhra Pradesh, Madhya Pradesh, Bihar, and Maharashtra.**

Gold

- **Precious metal** used in ornamentation, dentistry, electronics, and chemicals.
- Important reserves in **South Africa, Canada, USA, Zimbabwe, and Ghana.**
- Key gold fields: **Kolar Gold Field, Hutti Gold Field, Ramgiri Gold Field.**

Spread of gold deposits: Andhra Pradesh, Bihar (Jamui), Chhattisgarh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Tamil Nadu and Rajasthan.

Diamond

- **Hardest naturally occurring substance;** Formed in the **mantle,** brought to the Earth's crust through **volcanism.**
- Major uses: **ornaments, polishing, gem cutting, industrial cutting edges.**
- Important diamond regions in India: **Panna belt in Madhya Pradesh, Wajrakarur Kimberlite pipe in Andhra Pradesh(Anantpur), Krishna river basin gravels.**
- **Russia:** World's largest diamond resources; **Botswana:** Leading diamond-producing country.

Heavy Mineral Sands

The seven minerals that make up heavy mineral sands are **garnet, monazite, rutile, zircon, sillimanite, ilmenite, and leucoxene (brown ilmenite)**. The **two main minerals** that make up **titanium** are **rutile (TiO_2) and ilmenite ($FeO.TiO_2$)**.

These are significant components of beach sand deposits that can be found from the coast of Odisha in the east to the coast of Gujarat in the west. **[UPSC 2023]**

Distribution of Important Mineral Resources

Mineral	Ore Name	Major Occurrence	Major Producers	Major Exporters	India Imports From (Top 2 Nations)	Top Occurrence and Producer States in India
Iron	Hematite, Magnetite, Ilmenite	Australia, Brazil, China	China, Australia, Brazil	Australia, Brazil, South Africa	Australia, Brazil	Odisha, Chhattisgarh, Jharkhand
Copper	Chalcopyrite, Bornite	Chile, Peru, China	Chile, Peru, China	Chile, Peru, Australia	Chile, Zambia	Rajasthan, Jharkhand, Madhya Pradesh
Bauxite	Gibbsite, Boehmite	Australia, Guinea, China	Australia, Guinea, China	Australia, Guinea, Brazil	Guinea, Australia	Odisha, Gujarat, Maharashtra
Gold	Native Gold	South Africa, USA, China	China, Australia, Russia	Australia, South Africa, Canada	South Africa, Australia	Karnataka, Rajasthan, Jharkhand
Aluminum	Bauxite	China, Australia, Brazil	China, Russia, Canada	Australia, Brazil, Guinea	Australia, China	Odisha, Chhattisgarh, Gujarat
Manganese	Pyrolusite, Rhodochrosite	South Africa, China, Australia	South Africa, China, India	South Africa, Australia, Gabon	South Africa, Australia	Odisha, Madhya Pradesh, Maharashtra
Lead	Galena	Australia, USA, China	China, Australia, USA	Australia, USA, Mexico	Australia, China	Rajasthan, Andhra Pradesh, Telangana
Zinc	Sphalerite	Australia, China, Peru	China, Australia, Peru	Australia, Canada, Peru	China, Australia	Rajasthan, Andhra Pradesh, Jharkhand
Coal	Bituminous, Anthracite	USA, China, India	China, USA, India	Australia, Indonesia, Russia	Indonesia, Australia	Jharkhand, Odisha, Chhattisgarh

Mineral	Ore Name	Major Occurrence	Major Producers	Major Exporters	India Imports From (Top 2 Nations)	Top Occurrence and Producer States in India
Diamond	Kimberlite, Lamproite	Russia, Botswana, Canada	Russia, Botswana, Congo	Botswana, Russia, Canada	Russia, Botswana	Madhya Pradesh, Chhattisgarh, Andhra Pradesh
Limestone	Calcium Carbonate	India, USA, China	China, India, USA	India, China, USA	United Arab Emirates, China	Rajasthan, Madhya Pradesh, Gujarat
Gypsum	Anhydrite, Gypsum	USA, China, Iran	China, Iran, USA	Iran, China, Thailand	Oman, China	Rajasthan, Jammu & Kashmir, Gujarat
Nickel	Pentlandite	Indonesia, Philippines, Russia	Indonesia, Philippines, Russia	Indonesia, Russia, Canada	Indonesia, Russia	Jharkhand, Karnataka, Odisha
Tin	Cassiterite	China, Indonesia, Peru	China, Indonesia, Peru	China, Indonesia, Bolivia	Indonesia, China	Jharkhand, Odisha
Tungsten	Wolframite, Scheelite	China, Russia, Bolivia	China, Russia, Bolivia	China, Russia, Austria	China, Bolivia	Arunachal Pradesh, Kerala
Graphite	Natural Graphite	China, India, Brazil	China, India, Brazil	China, India, Brazil	China, Brazil	Kerala, Jharkhand, Odisha
Molybdenum	Molybdenite	China, USA, Chile	China, USA, Chile	China, USA, Chile	China, USA	Rajasthan, Jharkhand
Uranium	Pitchblende	Kazakhstan, Canada, Australia	Kazakhstan, Canada, Australia	Kazakhstan, Canada, Australia	Kazakhstan, Canada	Jharkhand, Rajasthan, Andhra Pradesh
Rare Earth Elements	Monazite, Bastnäsite	China, USA, India	China, USA, India	China, USA, Russia	China, USA	Tamil Nadu, Odisha, Andhra Pradesh

NON CONVENTIONAL/RENEWABLE SOURCES OF ENERGY

Non-conventional sources include solar, wind, tidal, geothermal, biogas and atomic energy. These energy sources are more equitably distributed and eco-friendly cheaper energy.

- **Current Status:** Achieved 203.18 GW as of October 2024. (including large hydro, source: Central Electricity Authority).

India's Renewable Energy Landscape (as of December 2023)

- **Total Capacity:** 203.18 (including large hydro)
- **Breakdown:** Solar: 92.12 GW Wind: 47.72 GW Biomass/Co-gen: 10.248 GW; Small Hydro Power: 4.944 GW; Waste To Energy: 554 MW; Large Hydro: 46.93 GW
- **Renewables Share:** 42% of total installed capacity.

Solar Energy

- The western part of India has greater potential for the development of solar energy in Gujarat and Rajasthan.
- **Advantages:** Abundant sunlight, low maintenance, clean power, grid tie-up benefits.
- **Challenges:** Grid integration, energy storage improvements needed.

Wind Energy

- **Distribution: Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat** (Lamba is famous for wind power plants), **Kerala, Maharashtra and Lakshadweep** have important wind farms. Nagercoil and Jaisalmer are well known for the effective use of wind energy in the country.
- **Position:** 5th globally in wind power capacity.
- Gujrat has highest wind power potential (in GW) at 120 m Above Ground Level.

Tidal and Wave Energy

The Gulf of Khambhat, the **Gulf of Kachchh** in Gujarat on the western coast and Gangetic delta in Sunderban regions of West Bengal provide ideal conditions for utilising tidal energy.

Geothermal Energy

Geothermal energy refers to the **heat and electricity produced** by using the **heat from the interior of the Earth.** There are several hundred hot springs in India; two experimental projects have been commissioned at **Manikaran in Himachal Pradesh** and in the **Puga Valley, Ladakh.**

Bio-energy

Bio-energy refers to energy derived from biological products which includes agricultural residues, municipal, industrial and other wastes. It can be converted into electrical energy, heat energy or gas for cooking.

CONVENTIONAL SOURCES OF ENERGY

Coal

Coal occurs in rock sequences mainly of two geological ages, namely **Gondwana and tertiary deposits**. About **80 per cent** of the coal deposits in India is of **bituminous** type and is of **non-coking grade.**

Coal Types and Classification

- **Gondwana Coal (Metallurgical):** Over 200 million years old; found in Damodar Valley (Jharkhand-Bengal).
- **Tertiary Coal:** 55 million years old; in northeastern states and Himalayan foothills.
- **Lignite:** Low-grade brown coal with high moisture; used for electricity generation; prominent in Neyveli, Tamil Nadu

Characteristics of Indian Coal

- **High Ash Content:**
  - Indian coal typically contains **20-40% ash**, which is higher compared to international standards. This is due to the geological formation of Indian coal, which often has impurities like silica and alumina.
  - **Impact:** High ash content reduces the calorific value, making the coal less efficient for energy production and causing higher maintenance costs for boilers and furnaces.
- **Low Sulphur Content:**
  - Sulphur content in Indian coal is generally **below 1%**, which is advantageous as it reduces the release of sulphur dioxide (SO_2), a major pollutant, during combustion.
  - **Impact:** Low sulphur content makes Indian coal environmentally favourable for thermal power plants.
- **High Ash Fusion Temperature:**
  - Indian coal has an **ash fusion temperature of 1200-1500°C**, which means the ash remains in solid form at high temperatures, reducing the risk of clinker formation in furnaces.
  - **Impact:** This property is beneficial for thermal power plants as it improves operational efficiency and reduces equipment damage.

Indian coal has high ash content, low sulphur content and high ash fusion temperature. **[UPSC 2013]**

Distribution in India

- **Gondwana Coal Fields:** Located in **Damodar Valley** (Jharkhand-Bengal coal belt). Coal fields: Raniganj, Jharia, Bokaro, Giridih, Karanpura.
  - Other river valleys associated with coal are **Godavari, Mahanadi and Sone**.
  - Important coal mining centres: **Singrauli in Madhya Pradesh** (part of Singrauli coal field lies in Uttar Pradesh); **Korba in Chhattisgarh**; **Talcher** and Rampur in **Odisha**; Chanda–Wardha, Kamptee and Bander in **Maharashtra** and **Singareni** in **Telangana** and Pandur in **Andhra Pradesh**.
- **Tertiary Coals:** Tertiary coals occur in **Assam, Arunachal Pradesh, Meghalaya and Nagaland**. It is extracted from Darangiri, Cherrapunji, Mewlong and Langrin (**Meghalaya**); Makum, Jaipur and Nazira in upper **Assam**, Namchik – Namphuk (**Arunachal Pradesh**) and Kalakot (**Jammu and Kashmir**).
- **Lignite (Brown Coal) Areas:** Coastal regions of Tamil Nadu, Pondicherry, Gujarat, Jammu and Kashmir.
- **Private Sector in Coal Mining:** Not all coal power plants are government owned.In March 2020, the Government of India enacted the Mineral Laws (Amendment) Act to remove the five-decade-old restrictions on commercial coal mining. Before this only **Captive mining** for end use by industries was allowed. Presently 100% FDI is also permitted in commercial coal mining. **[UPSC 2023]**

Miscellaneous Facts

- **Rat Hole Mining:** Involves digging small tunnels for coal extraction; Prevalent in Meghalaya.
- Coal deposits are absent in African continent
- Switzerland has no known mineral deposit in it.
- Coastal Gujarat Power Limited is a coal fired power plant which uses sea water.
- Shift of Coal power plants to Northern and eastern river basins, catchment areas of these river basins are experiencing water stress.

Natural Gas [UPSC 2013]

- **Composition:** Primarily methane (around 95%); also includes ethane, propane, butane, and pentane.
- **Formation:** Organic matter (plants and animals) decomposes under high pressure and heat over millions of years.
- **Distribution in India**
  - **India:** Krishna Godavari Basin (KG Basin), Assam Shelf, Gulf of Cambay, Barmer Basin (Rajasthan), Tripura, Tamil Nadu coast, and offshore wells in Gujarat and Maharashtra

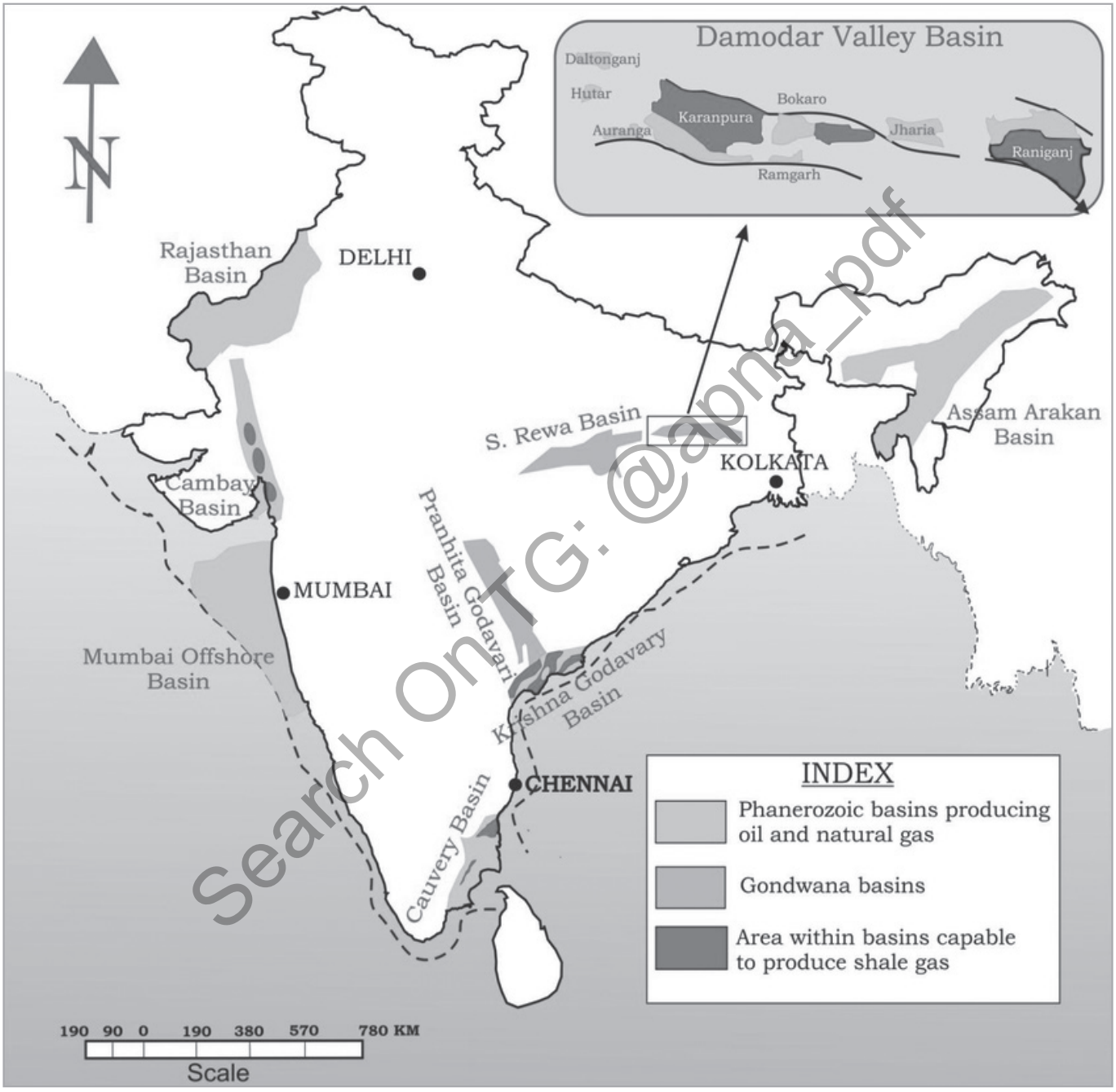


Fig. Oil, Natural Gas and Shale Gas Basins

- **Types**
  - **Associated gas (wet gas):** Produced along with crude oil.
  - **Non-associated gas (dry gas):** Found in separate reservoirs.
  - **Sour gas:** Contains hydrogen sulfide, requiring additional processing.
  - **Sweet gas:** Hydrogen sulfide-free, like coalbed methane.

- **Environmental benefits:** Lower carbon dioxide emissions than coal or oil, making it a cleaner fossil fuel.
- **Uses**
  - **Energy source:** Power generation (15% of India's electricity (as of December 2023), industrial boilers, heating homes.
  - **Chemical feedstock:** Used in fertilizers, plastics, and other products.
  - **Transportation fuel:** Compressed Natural Gas (CNG) for vehicles.

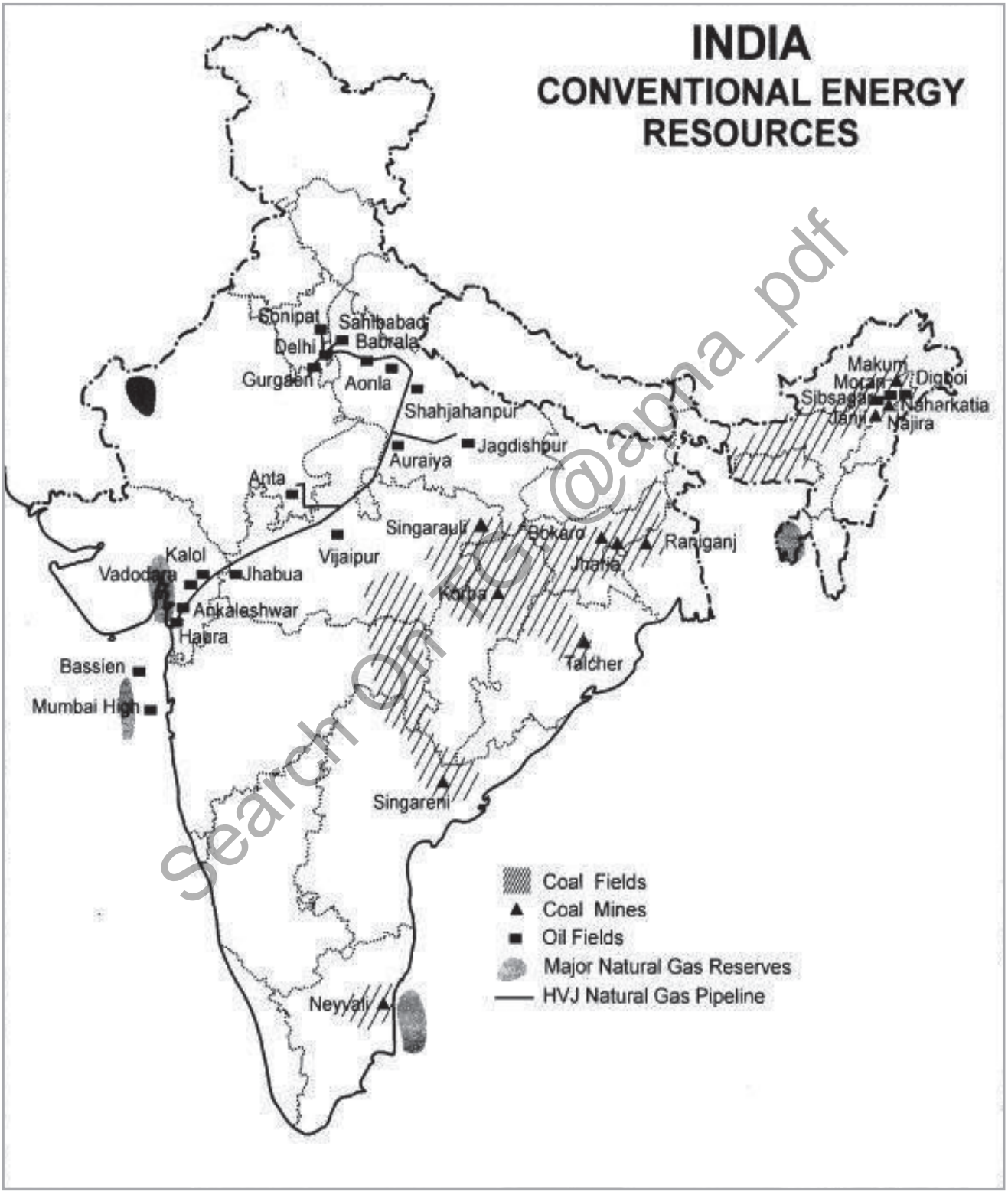


Fig: Convetional Energy Resources in India

Petroleum and Mineral Oil (Liquid Gold)

Crude petroleum occurs in **sedimentary** rocks of the **tertiary period.** It is formed from ancient marine organisms buried in the ocean floor.

- **Distribution of Petroleum and Mineral Oil in India:** Major reserves associated with anticlines and fault traps in sedimentary rocks
  - **Regions:** Mumbai High, Bassein, Aliabet; Assam (Digboi, Naharkatiya and Moran), Gujarat (Ankaleshwar, Kalol, Mehsana, Nawagam, Kosamba and Lunej); Krishna-Godavari and Kaveri basin on the east coast
- **Petroleum Refining in India:** Refining started in 1901 in **Digboi, Assam**. Two types of refineries in India: (a) **Field based** (Digboi) (b) **Market based** (Barauni).
- **Strategic Petroleum Reserve (SPR):** India's SPR facilities at **Visakhapatnam** (Andhra Pradesh), **Mangalore** and **Padur** (Karnataka)are managed by **ISPRL**. Additional reserves planned for **Chandikhole (Odisha)** and **Bikaner (Rajasthan)**.

Unconventional Hydrocarbons

- **Types:** Shale gas, and coalbed methane trapped in low-permeability rock formations, requiring specialized technologies.
- **India's potential:**
  - **Shale gas:** NITI Aayog estimates India's recoverable shale gas resources at 96 Tcf, with potential in six basins.
  - **Coal Bed Methane:** India has vast CBM reserves in 12 states, offering a clean and efficient source of energy; Fifth-largest proven reserves globally, estimated at around 92 Tcf (2600 BCM).

Coal-Bed Methane

Coal bed methane (CBM), also known as coal seam gas, is a natural gas trapped within coal seams. It forms over millions of years as organic matter decomposes and releases methane, which gets adsorbed onto the coal's internal surface.

India's CBM

- Estimated 92 TCF (2600 BCM) recoverable CBM resources in India.
- **Key Regions:** Damodar Valley, Son Valley, Godavari Basin.

Shale Gas

Shale gas, produced over millions of years as organic matter decomposes within shale, is trapped in the rock's pores and fractures. Unlike conventional gas, it requires hydraulic fracturing, or "fracking," for extraction.

Global Distribution

- **North America:** US leads in recoverable shale gas; Canada follows closely.

Shale Gas in India

- **Reserves:** 96 TCF estimated; spread across six basins.
- **Key Basins: Cambay, Assam-Arakan, Gondwana, Krishna Godavari, Cauvery, Indo-Gangetic.**

NUCLEAR ENERGY RESOURCES

- **Raw Materials:** Uranium, Thorium, Heavy water, Zirconium, Helium.
- **Uranium:** Silvery-gray, naturally in supernova explosions.
  - **Distribution in India:** Jharkhand, Meghalaya, Andhra Pradesh, Karnataka, Rajasthan (Dharwar rocks, Singhbhum Copper belt, Udaipur, Alwar, Jhunjhunu, Durg, Bhandara, Kullu)
  - **Global Distribution: Major Deposits:** Australia, Kazakhstan, Canada.
- **Thorium:** Thorium is mainly obtained from **monazite** and **ilmenite** in the beach sands along the coast of **India**. World's richest monazite deposits occur in Palakkad and Kollam districts of **Kerala**, near Vishakhapatnam in **Andhra Pradesh** and **Mahanadi river delta** in **Odisha.**
- **Indian Nuclear Plants:** Tarapur (Maharashtra); Rawatbhata (Rajasthan); Kudankulam (Tamil Nadu); Kaiga (Karnataka); Kakrapar (Gujarat); Kalpakkam (Tamil Nadu); Narora (Uttar Pradesh)

Monazite is a mineral mainly containing rare earths and thorium-a prescribed substance to be handled by the Department of Atomic Energy (DAE).

Accordingly, Indian Rare Earths Ltd. (IREL) wholly owned by the Govt. of India, under the administrative control of the Dept. of Atomic Energy (DAE) utilises **monazite mainly for production of rare earth compounds, and thorium**, as needed in the Department of Atomic Energy. **[UPSC 2022]**

Monazite Deposits in India

State	Monazite (Million Tonne)
Odisha	2.41
Andhra Pradesh	3.72
Tamil Nadu	2.46
Kerala	1.90
West Bengal	1.22
Jharkhand	0.22
Total	**11.93**

Mines and Minerals (Development and Regulation) (MMDR) Act, 1957, State Governments have the power to frame rules to grant mining leases of minor minerals. State government also has the power to frame rules to prevent illegal mining of minor minerals. **[UPSC 2019]**

SUMMARY OF ENERGY RESOURCES IN INDIA

Energy Resource	Locations (States/Regions)
Solar Parks	Rajasthan (Bhadla Solar Park), Gujarat (Charanka Solar Park), Karnataka (PavagadaSolar Park), Andhra Pradesh, Tamil Nadu
Wind Energy	Tamil Nadu (Muppandal Wind Farm), Gujarat (Kutch), Maharashtra (Satara), Karnataka (Chitradurga), Rajasthan (Jaisalmer, Barmer), Kerala, Lakshadweep
Gas Hydrates	Krishna-Godavari Basin, Mahanadi Basin, Andaman-Nicobar Basin
Geothermal Provinces	Puga Valley (Ladakh), Manikaran (Himachal Pradesh), Tattapani (Chhattisgarh), Surajkund (Jharkhand)
Tidal Energy	Gulf of Khambhat (Gujarat), Gulf of Kachchh (Gujarat), Sundarbans (West Bengal)
Natural Gas	Krishna-Godavari Basin (Andhra Pradesh), Mumbai Offshore Basin (Maharashtra), Cauvery Basin (Tamil Nadu), Barmer Basin (Rajasthan), Tripura
Nuclear Power Plants	Tarapur (Maharashtra), Kakrapar (Gujarat), Rawatbhata (Rajasthan), Kalpakkam (Tamil Nadu), Kudankulam (Tamil Nadu), Kaiga (Karnataka), Narora (Uttar Pradesh)
Petroleum Reserves	Mumbai High (Maharashtra), Cambay Basin (Gujarat), Krishna-Godavari Basin (Andhra Pradesh), Cauvery Basin (Tamil Nadu), Assam (Digboi, Naharkatiya, Moran)
Coal Bed Methane (CBM)	Jharia (Jharkhand), Raniganj (West Bengal), Sohagpur (Madhya Pradesh), Godavari Basin
Shale Gas	Cambay Basin (Gujarat), Krishna-Godavari Basin (Andhra Pradesh), Cauvery Basin (Tamil Nadu), Assam-Arakan Basin, Gondwana Basin (Jharkhand, West Bengal)
Bio-energy	Available nationwide, with specific emphasis on agricultural and municipal waste processing facilities
Lignite Deposits	Neyveli (Tamil Nadu), Kutch (Gujarat), Barmer (Rajasthan), Pondicherry, Jammu & Kashmir
Coal Reserves	Damodar Valley (Jharkhand, West Bengal - Jharia, Raniganj, Bokaro), Mahanadi Basin (Odisha - Talcher), Singrauli Basin (Madhya Pradesh, Uttar Pradesh), Wardha Valley (Maharashtra)
Uranium	Singhbhum (Jharkhand), Tummalapalle (Andhra Pradesh), Domiasiat (Meghalaya), Alwar (Rajasthan), Kullu (Himachal Pradesh)
Thorium	Monazite-rich sands in Kerala (Kollam, Palakkad), Tamil Nadu (Chennai coast), Andhra Pradesh (Visakhapatnam coast), Odisha (Mahanadi delta)

WATER RESOURCES

India accounts for **2.45% of world surface area** and **4%** of **world's water resource**s. Rainfall in India is highly irregular in place and time. Country receives 80% of the annual rainfall from June to September from the south-west monsoon.

- Presently about **92% of water** is used for **agriculture, 2% for industries** and **6% for drinking** and **domestic purposes.**

Ranking of industries based on their water consumption in India: **[UPSC 2013]**

Industry	Percentage of Water Usage
Thermal Power Plants	~40%
Textile Industry	~20%
Pulp and Paper Industry	~15%
Steel Industry	~10%
Chemical Industry	~5%

Falkenmark Indicator or Water Stress Index

- It is one of the most commonly used measures of water scarcity. It defines water scarcity **in terms of the total water resources that are available to the population of a region** by measuring scarcity as the amount of renewable freshwater that is available for each person each year. If the **amount of renewable water** per person per year in a country is:
- Below **1,700 m^3**, the country is said to be experiencing **water stress**.
- Below **1,000 m^3**, it is said to be experiencing **water scarcity**.
- Below **500 m^3**, it is experiencing **absolute water scarcity**.

MANUFACTURING AND INDUSTRIES

This forms the secondary sector and can be classified in following manner:

Manufacturing and Industries refer to the processes involved in the production of goods using raw materials, labor, machinery, and technology on a large scale. Manufacturing transforms raw materials into finished products, while industries encompass all economic activities involved in production, including services and processing.

Based on Raw Materials

- **Agro based Industries:** Raw material sourced from the **agriculture sector.** E.g. Cotton, sugar etc.

- **Mineral based Industries:** Raw material sourced from **mining.** E.g. Iron & steel, cement etc.
- **Forest based Industries:** Raw material sourced from **forest.** E.g. Paper industry, Timber etc

Based on Output

- **Basic or key industries:** Supply their **goods** to **other industries**. E.g. Iron & steel
- **Consumer Industries:** Produce **goods** for **direct consumption**. E.g. Toothpaste, Television etc

Based on Ownership

- **Public sector:** Owned & operated by the government. E.g. BHEL, SAIL etc.
- **Private sector:** Owned & operated by private individuals. E.g. TISCO, RIL.
- **Joint sector:** Jointly run by state & private players. E.g. OIL
- **Cooperative sector:** Owned & operated by the producers and suppliers of raw materials, workers or both. E.g. Sugar industry in Maharashtra.

Based on Mode of Operation

- **Labour Intensive Industry:** Large no. of skilled unskilled or semi-skilled labour is employed. E.g. Textile, leather & footwear.
- **Capital goods Industry:** Manufactures machine tools, heavy electrical equipment, heavy transport vehicles, mining & earth moving tools etc.
- **Industries with strategic significance:** Industries which are critical for the purpose of earning foreign exchange, research & defence. E.g. Aerospace, shipping, electronics & telecommunication, defence equipment etc.

Based on Size

- **Small-scale industries:** Use a lesser amount of capital investment and technology, and produce a small volume of products. E.g.: handicrafts, cottage industries etc.
- **Large-scale industries:** Investment of capital is higher and the technology used is superior in large scale industries. E.g.: automobile industry, heavy machinery industry etc.

Types of Manufacturing Industries (Micro Small and Medium Enterprises)

Revised MSME Classification Composite Criteria: Investment and Annual Turnover			
Classification	**Micro**	**Small**	**Medium**
Manufacturing and Services	Investment < Rs. 1 cr. and Turnover < Rs. 5 cr.	Investment < Rs. 10 cr. and Turnover < Rs. 50 cr.	Investment < Rs. 20 cr. and Turnover < Rs. 100 cr.

Location of Industries

Location of industries is influenced by several factors like access to **raw materials, power, market, capital, transport and labour**.

- **Raw Materials:** Industries using weight-losing raw materials are located in the regions where raw materials are located. E.g. sugar mills, pulp industry, copper smelting and pig iron industries
- **Power:** Certain industries, like **aluminium** and **synthetic nitrogen manufacturing industries** tend to be located near sources of power because they are power intensive and require huge quantum of electricity.
- **Market:** Markets serve as the places where manufactured goods are sold. Market orientated industries: Heavy machine, machine tools; heavy chemicals; Cotton textile (non-weight-losing raw material) e.g. Mumbai, Ahmedabad, Surat, etc.; Petroleum refineries e.g. Koyali, Mathura and Barauni refineries. Ports also play a crucial role in the location of oil refineries.

Footloose Industries: Footloose industries are those that are not bound by location constraints and can be established anywhere without being affected by the availability of raw materials or market proximity. They often involve light manufacturing or service-based activities, such as IT, software development, call centres, and tourism.

Footloose industries are generally ones that do not produce products that experience large weight change during production and transportation.

Weight losing Industries: Weight-Losing Industries are located near raw material sources as the raw materials are bulkier than the finished products, reducing transport costs. **Examples** include the iron and steel industry near iron ore mines (Odisha, Jharkhand), sugar industry near sugarcane fields (Uttar Pradesh, Maharashtra), aluminum industry near bauxite mines (Chhattisgarh, Odisha), and paper industry near forests (Assam, Madhya Pradesh). These industries optimize costs and resource use by processing heavy raw materials at the source.

AGRO-BASED INDUSTRY

Textile Industry

- The **first textile mill** in the country was established at Fort Gloster near Kolkata in 1818; The **first successful modern textile** mill was established in Mumbai in 1854; **Ahmedabad** is often referred to as the **'Manchester of India'**.

Cotton Textile

- It is closely **linked with agriculture**.
- While **spinning** remains **centralised** in Maharashtra, Gujarat, and Tamil Nadu, **weaving** is highly **decentralised** to incorporate traditional skills and designs in fabrics like cotton, silk, zari, and embroidery.
- Uninterrupted supply of raw cotton from large cotton growing areas of **west India** benefited the industry in centres like **Ahmedabad (Manchester of India)**, Nagpur, Surat, Indore and Coimbatore
- **Major centres: Ahmedabad, Bhiwandi, Kanpur, Coimbatore, chanderi, kancheepuram, Solapur, Kolhapur, Nagpur, Indore** and **Ujjain**; **Tamil Nadu** has the **largest number of mills** and most of them produce yarn rather than cloth. **[UPSC 2014]**
- At 18% of the global total, India is the world's largest producer of cotton.

Jute Textiles

- **India is the largest producer of raw jute and jute goods** and stands in **second place as an exporter** after Bangladesh. Most of the mills are located in **West Bengal**, mainly along the banks of the Hugli river, in a narrow belt. According to Jute Packaging Material Act 1987, 100% of food grains and 20% of sugar must be packed in jute bags.
- The British setup the **first jute industry** in India in 1855 near Hooghly river near **Kolkata.**
- Producer of jute: West Bengal alone accounts for over 90% of India's jute production.

Sugar Industry

- India is the **largest producer** of both **sugarcane and cane sugar**. Sugar industry is a **seasonal industry**.
- Sugarcane is a **weight-losing crop**; Sugar factories hence, are located within the cane producing regions.
- **Maharashtra** has emerged as a **leading sugar producer** in the country.
- In **UP**, the **sugar factories** are **concentrated in two belts** – the **Ganga-Yamuna doab** and the **Terai region**.
- **Tamil Nadu:** Coimbatore, Vellore, Tiruvannamalai, Villupuram and Tiruchchirappalli districts.
- **Karnataka:** Belagavi, Ballari, Mandya, Shivamogga, Vijayapura and Chitradurga.
- The other States which produce sugar are **Bihar, Punjab, Haryana, Madhya Pradesh** and **Gujarat.**
- In recent years, **the mills have shifted in the southern and western states,** especially in Maharashtra because **the cane produced here has a higher sucrose content.**

MINERAL BASED INDUSTRIES

Iron and Steel Industry

- **Raw material:**
  - Bulk inputs of the iron & steel industry are **iron ore**, **coal** (fuel), **limestone** (flux) & water (required for cooling & worker safety). 85% of the coking coal requirement of the domestic steel industry is presently being met through imports. **[UPSC 2015]**
  - Mostly large integrated steel plants are located close to the **source of raw materials**, as they use large quantities of heavy and **weight losing raw materials**.
  - Concentration of Iron and steel industry in **Chota Nagpur region** - Presence of Iron ore & coal in this region. E.g., TISCO at Jamshedpur
- **China** is the **largest steel producer** and **consumer in the world.**
- Currently, all the **important steel producing centers** such as Bhilai, Durgapur, Burnpur, Jamshedpur, Rourkela, Bokaro are situated in a region that spreads over four states — **West Bengal, Jharkhand, Odisha and Chhattisgarh.**
- Bhadravati and Vijay Nagar in Karnataka, Visakhapatnam in Andhra Pradesh, Salem in Tamil Nadu are other important steel centres utilizing local resources.
- **Purvodaya Initiative (2020):** Set up steel plants in Eastern India

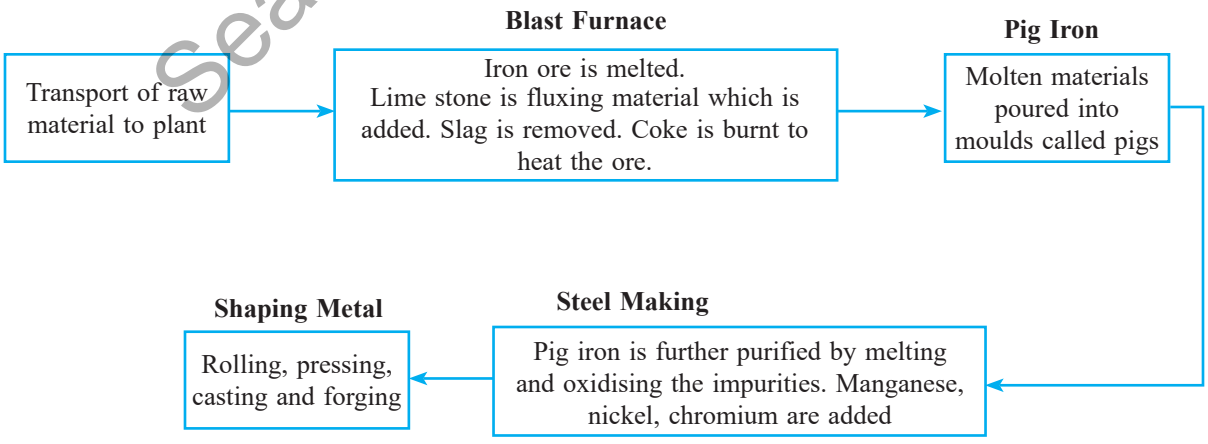


Fig. Process of Manufacture of Steel

Coking coal is imported as the coal deposits of India are not of coking grade **[UPSC 2015]**

Aluminium Smelting

- It is light, resistant to corrosion, a good conductor of heat, malleable and becomes strong when it is mixed with other metals.
- It is used to manufacture aircraft, utensils and wires.
- Aluminum smelting plants in India are **located in Odisha, West Bengal, Kerala, Uttar Pradesh, Chhattisgarh, Maharashtra and Tamil Nadu**.

Fertilizer Industry

- About 70% of units producing nitrogenous fertilizers use **naphtha** as **basic raw material**. That's why they are located near oil refineries.
- Phosphatic fertilizer plants are dependent on **mineral phosphate** which is largely imported but **reserves** are also found in **Rajasthan, Madhya Pradesh and Jharkhand.**
- **Potash is entirely imported** since the country **lacks any reserves of commercially usable potash or potassium compounds in any form**.
- **Gujarat, Tamil Nadu, Uttar Pradesh, Punjab, and Kerala** collectively contribute to **half of the total fertilizer production**.
- **Hajira – Vijaipur - Jagdishpur gas pipeline** has given birth to plants at Vijaipur, Jagdishpur, Babrala etc.

Petrochemical Industries

- Derived from crude petroleum and Mumbai is the hub of the petrochemical industries.
- It divided into four sub-groups:

  (i) Polymers, (ii) Synthetic fibers, (iii) Elastomers, and (iv) Surfactant intermediate.
- Polymers are made from ethylene and propylene. Polymers are used as raw materials in the plastic industry; About 75 percent of these units are in small scale sector.

Cement Industry

- It requires bulky and heavy **raw materials like limestone, silica and gypsum** and is therefore located close to the raw material source regions (Limestone rich regions).

Automobile Industry

- Key **automotive manufacturing hubs** in India include Delhi, Gurugram, Mumbai, Pune, Chennai, Kolkata, Lucknow, Indore, Hyderabad, Jamshedpur, and Bengaluru.

Major Industrial Regions

- **Mumbai-Pune Region**

  Industries: Cotton textiles, petrochemicals, engineering goods, automobiles, and IT.

  Significance: Proximity to the port of Mumbai facilitates imports and exports.
- **Hugli Region**

  Industries: Jute textiles, engineering, chemicals, and food processing.

  Significance: Access to the Hooghly River and fertile Gangetic plains.
- **Bengaluru-Tamil Nadu Region**

  Industries: IT, electronics, textiles, and silk production.

  Significance: Known as India's "Silicon Valley" due to the IT industry in Bangalore.
- **Gujarat Region**

  Industries: Textiles, petrochemicals, pharmaceuticals, and diamonds.

  Significance: Important for ports and industrial hubs like Ahmedabad and Surat.
- **Chotanagpur Region**

  Industries: Steel, coal, iron, and heavy engineering.

  Significance: Rich in mineral resources like iron ore, coal, and bauxite.
- **Vishakhapatnam-Guntur Region**

  Industries: Shipbuilding, petrochemicals, and steel.

  Significance: Port city with a strategic location.
- **Gurgaon-Delhi-Meerut Region**

  Industries: IT, electronics, automobiles, and consumer goods.

  Significance: Large consumer base and excellent connectivity.
- **Kollam-Thiruvananthapuram Region**

  Industries: Cashew processing, coir manufacturing, and software development.

  Significance: Major exporter of processed cashews and coir products, with growing prominence as an IT hub due to the Technopark in Thiruvananthapuram.

Tertiary, Quaternary and Quinary Activities

Tertiary Activities: It pertains to the service industry, where skilled labour, professionally trained specialists, and consultants offer their expertise and services in return for compensation.

Quaternary Activities: It revolves around knowledge-based endeavors like IT and research, requiring specialized expertise.

Quinary Activities (Gold collar jobs), on the other hand, focus on high-level decision-making and human-centric roles such as healthcare and policy-making, representing the apex of specialised service sectors.

7 Trade, Transport and Communication

ROAD TRANSPORT IN INDIA

India has the second largest road network in the world, spanning about **66.71 lakh km**, which includes national highways, state highways, district roads, and rural roads. The length of various categories of roads: National Highways: 1,46,145 km; State Highways: 1,79,535 km; Other Roads: 63,45,403 km.

- Road transport carries **~87%** of India's **total passenger traffic** and more than **60%** of its **freight.**
- **100% FDI** in roads and highways is allowed under **automatic route.**

Road density is the **length of road per 100 sq. km** of area and it varies across the country.

CLASSIFICATION OF ROADS IN INDIA

National Highways

It account for **2% of the total road network** and carry **over 40% of total traffic; constructed and maintained by the Central Government (NHAI)**. NH44:Srinagar to Kanyakumari is the longest highway in India.

- **Golden Quadrilateral Super Highways:** links **Delhi-Kolkata-Chennai-Mumbai** by six-lane Super Highways.
  - The **North-South Corridor** links **Srinagar** (Jammu & Kashmir) and **Kanyakumari** (Tamil Nadu), and **East-West Corridor** connects **Silcher** (Assam) and **Porbandar** (Gujarat). **[UPSC 2023]**

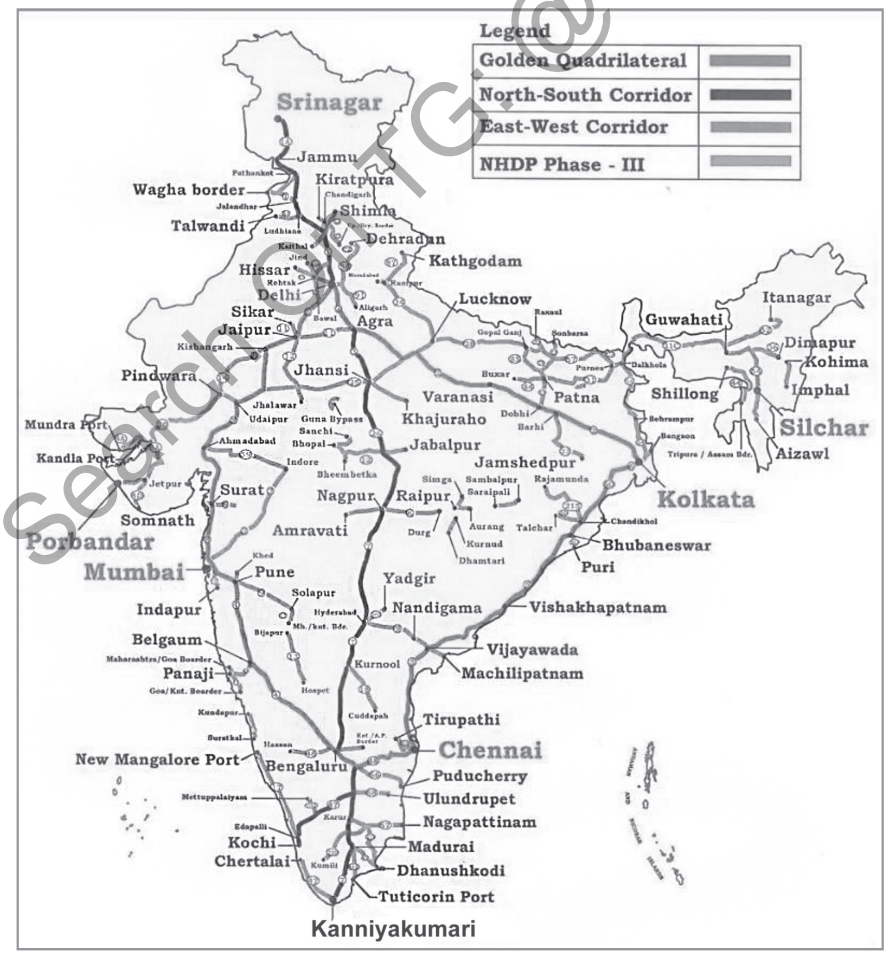


Fig. Roads in India

- **National Highways Authority of India (NHAI)** is an autonomous body under the **Ministry of Road Transport and Highways,** operationalized in **1995.** It is entrusted with the responsibility of **development, maintenance and operation of National Highways.**

State Highways

It links the state capital with different district headquarters and other important towns. They constitute **4%** of the **total road length** in the country and are constructed and maintained by **state governments.**

District Roads

It acts as connecting links between District Headquarters and the other important nodes in the district. They account for **14% of the total road length** of the country and are maintained by the **Zila Parishad.**

Rural Roads

It provides links to rural areas and account for about **80%** of the total road length in India.

- **Border Road Organisation:** Established in **1960** to strengthen defence preparedness through the improvement of strategically important roads along the northern and north-eastern boundaries. It comes under the **Ministry of Defence**
- **Bharatmala Pariyojana** is an umbrella program for the highways sector that focuses on optimising efficiency of freight and passenger movement through interventions like development of **Economic Corridors, Inter Corridors and Feeder Routes, National Corridor Efficiency Improvement, Border and International connectivity roads, Coastal and Port connectivity roads, Green-field expressways** and **completing balance NHDP works.**

RAILWAYS IN INDIA

- It was **first introduced in 1853, from Bombay to Thane** during the Governor Generalship of **Lord Dalhousie.**
- India has the **4th largest railway system** in the world, behind only **US, Russia and China.**
- The Indian Railways has been divided into 18 zones: **Northern Railway (Largest),** North Eastern Railway, **Northeast Frontier Railway (Smallest),** Eastern Railway, South Eastern Railway, etc.
- **100% FDI** is allowed in railway infrastructure under the automatic route.
- Classification based on the width of track: **Broad** gauge (1.676 metres), **Metre** gauge (1m) and **Narrow** gauge (0.762m or 0.610m; generally confined to hilly areas)
- Indian Railways has two **UNESCO World Heritage Sites:**
  - The **Chhatrapati Shivaji Maharaj Terminus, Mumbai** (2004)
  - The **Mountain Railways** of India (1999, 2005, 2008): **Darjeeling** Himalayan Railway, **Nilgiri** Mountain Railway, **Kalka-Shimla** Railway.

Railway Infrastructure Projects in India

- **Dedicated Freight Corridors (DFCs)**
  - **Eastern DFC (EDFC):** 1,856 km long from **Ludhiana (Punjab)** to **Dankuni (West Bengal);** Covers **Punjab, Haryana, Uttar Pradesh, Bihar, Jharkhand** and **West Bengal.**
  - **Western DFC (WDFC):** 1,504 km long from **Dadri (UP)** to **Jawaharlal Nehru Port (Maharashtra);** Covers **Haryana, Rajasthan, Gujarat, Maharashtra** and **Uttar Pradesh.**

The **Diamond Quadrilateral** is an Indian Railways project to establish a **high-speed rail network** that will connect the four mega cities of India, viz. **Delhi, Mumbai, Kolkata and Chennai**

Trans-Continental Railway Lines of the World	
Trans-Siberian Railway (Russia)	St. Petersburg (west) to Vladivostok (east)
Trans-Canadian Railways	Halifax (east) to Vancouver (west)
Australian Trans-Continental Railway	Perth (west coast) to Sydney (east coast)
Orient Express	Paris to Istanbul

PIPELINES IN INDIA

Pipelines are extensively used to transport liquids and gases such as water, petroleum and natural gas. The initial cost of laying pipelines is high, but subsequent running costs are minimal.

- There are **three important networks of pipeline transportation** in the country:
  - Asia's first cross-country pipeline was constructed by OIL from **Naharkatiya oilfield (Assam)** to **Barauni refinery (Bihar)** via Guwahati. It was further extended up to Kanpur in 1966.
  - From **Salaya in Gujarat to Jalandhar in Punjab**, via Viramgam, Mathura, Delhi and Sonipat.
  - **Hazira(Gujarat)-Vijaipur-Jagdishpur(UP) HVJ: First interstate natural gas** pipeline, constructed by **GAIL** linked Mumbai High and Bassein gas fields with various fertiliser, power and industrial complexes in western and northern India. The project started in **1986**.

Institution

- **Gas Authority of India Ltd. (GAIL)** was set up in **1984** as a public sector undertaking to transport, process and market **natural gas** for its economic use.
- **Oil India Limited (OIL),** under the administrative set-up of the **Ministry of Petroleum and Natural Gas,** is engaged in the exploration, production and transportation of crude oil and natural gas. It was incorporated in **1959** as a company.

WATER TRANSPORT

Water transport is of two types– (a) Oceanic waterways and (b) Inland waterways.

Oceanic Waterways/Sea Routes

India has a vast coastline of approximately **7,517 km**, including islands with **12 major and 205 notified minor ports**. While the **major ports** are under the administrative control of **Ministry of Shipping**, the **non-major ports** are under the jurisdiction of respective **State Maritime Boards/ State Government**.

- Approximately **95% of India's foreign trade by volume** and **70% by value** moves through ocean routes.
- **57%** of the total traffic is handled by **major ports** and **43%** by others.
- **Maharashtra** has the most non major ports in India, followed by **Gujarat**.
- **Foreign Direct Investment (FDI) of up to 100%** under the **automatic route** for port and harbour construction and maintenance projects is allowed.

Types of Ports

- **Based on location**
  - **Inland Ports:** located away from the sea coast, linked to the sea through a river or a canal. Eg: Kolkata is located on Hooghly, a branch of the river Ganga.
  - **Out Ports: deep water ports** built **away from the actual ports**. These serve the parent ports by receiving those ships that are unable to approach them due to their large size.
- **Based on specialised functions**
  - **Oil Ports:** Deal in the processing and shipping of oil. Maracaibo (Venezuela), Esskhira (Tunisia), Tripoli (Lebanon) are tanker ports. Abadan (Iran) on the Gulf of Persia is a refinery port.
  - **Ports of Call:** Ports where ships stop for refuelling, watering and taking basic necessities.
  - **Packet Station:** Also known as ferry ports. They transport passengers and mail across water bodies covering short distances. These stations occur in pairs.
  - **Entrepot Ports:** These are collection centres where the goods are brought from different countries for export. E.g., **Singapore** is an entrepot for Asia.
  - **Naval Ports:** Have strategic importance & serve warships. E.g.,. **Kochi** and **Karwar** ports in India.

MAJOR SEA PORTS OF INDIA

Eastern Coast

- **Chennai (Tamil Nadu): Artificial** harbour built in 1859; not very suitable for large ships because of the shallow waters near the coast. Tamil Nadu and Puducherry are its hinterlands.
- **Ennore/Kamarajar Port (Tamil Nadu):** constructed north of Chennai to relieve the pressure at Chennai port; India's **First corporatised** port. **[UPSC 2023]**
- **Tuticorin/V.O. Chidambaranar Port (Tamil Nadu):** also developed to relieve the pressure of Chennai port; located in the Gulf of Mannar; deals with fertilizers and petrochemical products.
- **Kolkata/Syama Prasad Mookerjee Port (West Bengal):** located on the **Hugli** river (riverine port); problem of silt accumulation.
- **Paradip (Odisha): Natural** harbour situated in the **Mahanadi** delta that specialises in the export of iron ore. It has the **deepest harbour**, suited to handle very large vessels.
- **Visakhapatnam (Andhra Pradesh): land-locked harbour**, connected to the sea by a channel; deals with the export of iron ore to Japan.

Western Coast

- **Kochi (Kerala): Natural harbour** situated at the head of **Vembanad Kayal**, also known as the **'Queen of the Arabian Sea'**
- **Kandla/Deendayal Port (Gujarat):** First port developed soon after Independence (also called the child of partition) to ease the volume of trade on the Mumbai port. It is a **tidal** port on the **Gulf of Kachch; largest cargo handling capacity (2020-21).**
- **Mundra Port (Gujarat):** Situated in **the Gulf of Kutch**; **first private port**; **largest privately owned port**. **[UPSC 2023]**
- **Mangalore (Karnataka):** Caters to the needs of the export of iron-ore and iron-concentrates from Kudremukh mines.
- **Mormugao (Goa): Natural** harbour situated at the entrance of the **Zuari** estuary; used for iron ore export.
- **Mumbai (Maharashtra): Natural port** and biggest harbour in India; busiest port in India; country's largest oil terminal.
- **Jawaharlal Nehru Port Trust:** developed as a **satellite port** to decongest the Mumbai port**;** also known as **Nhava Sheva**, Navi Mumbai; Largest Artificial Port; **Largest Container Port** in India. **[UPSC 2023]** **JNPT SEZ** became the first of its kind operational **port-based multi-product SEZ** in India.

INLAND WATERWAYS IN INDIA

India has about **14,500 km of navigable waterways** which comprise of rivers, canals, backwaters, creeks, etc.

- **Inland Waterways Authority (IWAI), set up in 1986**, is a **statutory** Body created under the **IWAI ACT, 1985** for the regulation and development of inland waterways for the purpose of shipping and navigation.
- **111 waterways** have been declared as National Waterways (NWs) under the **National Waterways Act, 2016.**

Inland Waterway	Length (km)	Major Rivers	States Covered
National Waterway 1 (NW-1)	1,629	Ganga-Bhagirathi-Hooghly (Haldia - Allahabad)	Uttar Pradesh, Bihar, Jharkhand, West Bengal
NW-2	891	Brahmaputra-(Dhubri- Sadiya)	Assam, Meghalaya, Bangladesh
NW-3	205	West Coast Canal, Champakara and Udyogmandal Canals	Kerala
NW-4	82	Krishna-Godavari River systems	Andhra Pradesh
NW-5	-	Eat Coast Canal	Odisha

INDUSTRIAL CORRIDORS

Government of India is developing eleven (11) Industrial Corridor Projects as part of the National Industrial Corridor Programme across the country in a phased manner.

As per the approved institutional and financial structure for the industrial corridors, the Government of India, through **National Industrial Corridor Development & Implementation Trust (NICDIT)**, provides funds as equity/debt.

These funds are used for the development of world-class trunk infrastructure in the industrial nodes/regions under industrial corridors and the States are responsible for making available contiguous and encumbrance free land parcels.

Following are the Industrial Corridors:

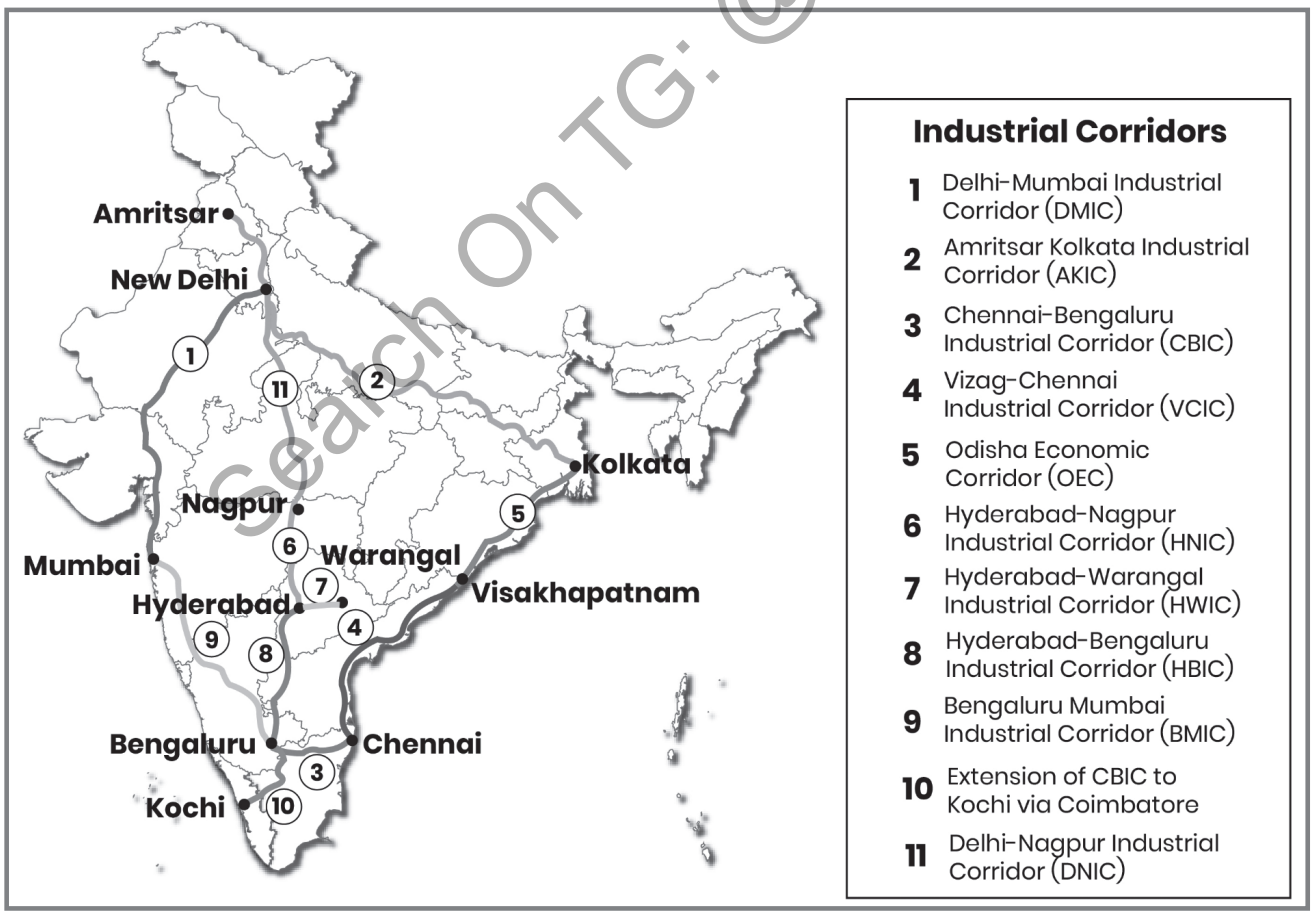
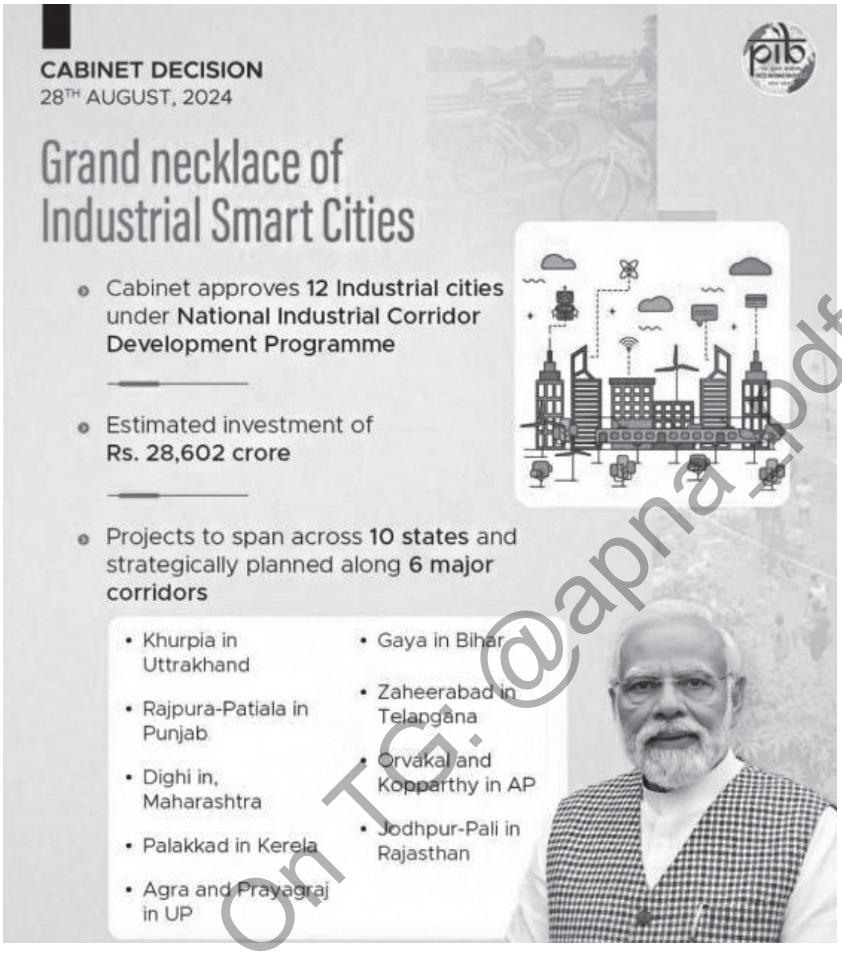


Fig. National Industrial Corridor Development Programme

Grand Necklace of Industrial Smart Cities

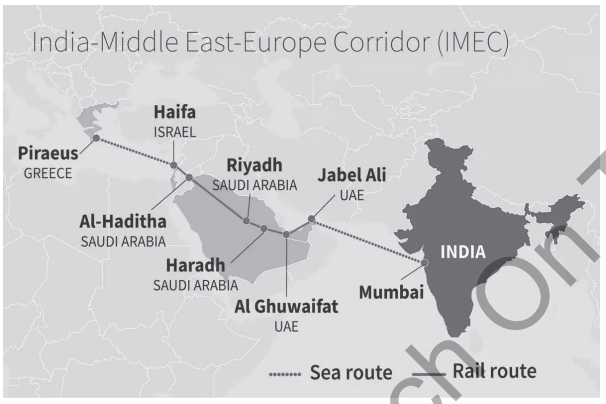
India is set for a major industrial shift with the Cabinet Committee on Economic Affairs approving 12 new projects under the **National Industrial Corridor Development Programme (NICDP)**. With an investment of ₹28,602 crore, the initiative aims to develop industrial nodes across 10 states along six key corridors. Chaired by PM Narendra Modi, the program seeks to boost manufacturing, drive economic growth, and enhance global competitiveness.



International Connectivity Projects

Project Name	Route/Linkage	Participating Countries	Transport Modes
BCIM-EC (Bangladesh-China-India-Myanmar Economic Corridor)	Kolkata (India) → Dhaka (Bangladesh) → Mandalay (Myanmar) → Kunming (China)	Bangladesh, China, India, Myanmar	Multimodal (road, rail, trade corridors)
IMTTH (India-Myanmar-Thailand Trilateral Highway)	Moreh (India) → Mandalay (Myanmar) → Mae Sot (Thailand)	India, Myanmar, Thailand	Road network
KMTTP (Kaladan Multimodal Transit Transport Project)	Kolkata (India) → Sittwe Port (Myanmar) → Paletwa → Aizawl (India)	India, Myanmar	Waterways, roads, railways
BBIN Agreement	Road links between key cities in Bangladesh, Bhutan, India, and Nepal	Bangladesh, Bhutan, India, Nepal	Road network.
INSTC (International North-South Transport Corridor)	Mumbai (India) → Bandar Abbas (Iran) → Baku (Azerbaijan) → Moscow (Russia) → European cities	India, Iran, Russia, Azerbaijan, Kazakhstan, others	Multimodal (road, rail, waterways)

Ashgabat Agreement	India → Iran → Turkmenistan → Uzbekistan → Kazakhstan → Oman	India, Iran, Turkmenistan, Uzbekistan, Kazakhstan, Oman	Multimodal (road, rail)
Bhutan-India Friendship Highway Broadband Project	Bhutan → India (Cities not specific to project)	Bhutan, India	Digital connectivity
India-Myanmar-Thailand Digital Connectivity Project	Key cities in India → Myanmar → Thailand	India, Myanmar, Thailand	Digital connectivity
TAPI (Turkmenistan-Afghanistan-Pakistan-India Pipeline)	Mary (Turkmenistan) → Herat (Afghanistan) → Quetta (Pakistan) → Fazilka (India)	Turkmenistan, Afghanistan, Pakistan, India	Gas pipeline
International North South Trade Corridor (INSTC)	The objective of the corridor is to increase trade connectivity between major cities such as Mumbai, Moscow, Tehran(Iran) , Baku(Azerbaijan), Bandar Abbas (Iran) , Astrakhan, Bandar Anzali (Iran), etc	The current members are India, Iran, Russia, Azerbaijan, Kazakhstan, Armenia, Belarus, Tajikistan, Kyrgyzstan, Oman, Syria, Turkey, Ukraine, and Bulgaria (observer).	The International North–South Transport Corridor (INSTC) is a 7,200-km (4500 mile) long multi-mode network of ship, rail, and road route for moving freight between India, Iran, Azerbaijan, Russia, Central Asia and Europe
IMEEC (India-Middle East-Europe Economic Corridor)	Mumbai (India) → Dubai (UAE) → Riyadh (Saudi Arabia) → Haifa (Israel) → European cities	India, UAE, Saudi Arabia, Jordan, Israel, Europe	Multimodal (road, rail, waterways)



8 Population and Settlements

POPULATION: DISTRIBUTION, DENSITY AND GROWTH

- The current population of India is **1.44 billion** (2024), which is equivalent to **18% of the total world population** living on **2.4%** of the **world's area. India** has surpassed China to become the world's **most populous nation** with 1.44 billion people [UN Population Fund (UNFPA)].
- **Decadal growth rate** of population in India between **2001- 2011** was **17.64%**. It decreased from **21.54%** during **1991- 2001 (Census 2011)**.
- **Population Density** in India (2011) is **382** persons per sq km (Census 2011).

Density of population is expressed as the number of persons per unit area.

- **Physiological density:** Computed by dividing the total population by the net cultivated area.
- **Agricultural density:** Computed by dividing the agricultural population by the net cultivable area, where the agricultural population encompasses cultivators, agricultural labourers, and their families.

INDIA'S POPULATION

Population Growth

Refers to the change in the number of inhabitants over a specific period. Population growth has two components:

- **Natural growth** assesses the crude birth and death rates.
- **Induced growth** is explained by the volume of inward and outward movements of people in any given area.

- **Natural Growth of Population** = Births - Deaths
- **Actual Growth of Population** = Births - Deaths + In Migration - Out Migration

Population Momentum: Tendency of a highly fertile population that has been increasing rapidly in size to continue to do so for decades even after a substantial decline in fertility. This results from the youthful age structure of such a population.

Phase	Key Characteristics
Phase I: Stagnant Phase (1901-1921)	• Very low growth, negative during 1911-1921. • High birth and death rates due to poor health & medical services, illiteracy, and inefficient distribution of basic necessities.
Phase II: Steady Growth (1921-1951)	• Decrease in mortality due to better health, sanitation, transport, and communication. • High birth rate led to higher growth.
Phase III: Population Explosion (1951-1981)	• Rapid fall in mortality, but high fertility rate; annual growth rate was 2.2%. • Improved living conditions; Increased international migration to India (Tibetans, Bangladeshis, Nepalis, and people from Pakistan)
Phase IV: Decelerating Growth (Post-1981)	• Growth rate started slowing, though still high. • Downward trend in birth rate due to increased marriage age, better quality of life, and female education.

Total Fertility Rate: The Total Fertility Rate (TFR) in India reflects the average number of children born to a woman during her lifetime.

- India's Total Fertility Rate (TFR) is 2.0 (NHFS-5) below the replacement level of 2.1, but it varies across states. States like **Punjab**, **West Bengal**, **Himachal Pradesh**, **Maharashtra**, and **Karnataka** show TFRs between **1.6-1.7**, while **Bihar** and **Uttar Pradesh** have higher TFRs (above 2.3).
- In **developed countries**, lower fertility rates result from better healthcare, education, and economic conditions, while **developing countries** often exhibit higher fertility rates due to limited access to family planning and cultural preferences for larger families. This pattern is also evident in India, where southern states tend to have lower fertility rates compared to the north and central regions.

Population Composition

- **Population pyramids**
  - It is a graphical representation of the age and sex structure of a population.
  - **Broad base and narrow top** suggest **high birth and death rates**.
  - **Bell-shaped pyramids** suggest an **equal birth rate and death rate,** thus indicating a **constant population.**
  - Pyramid with a **narrow base and a tapered top** shows **low Birth rate and death rate,** thus indicating **declining population.**

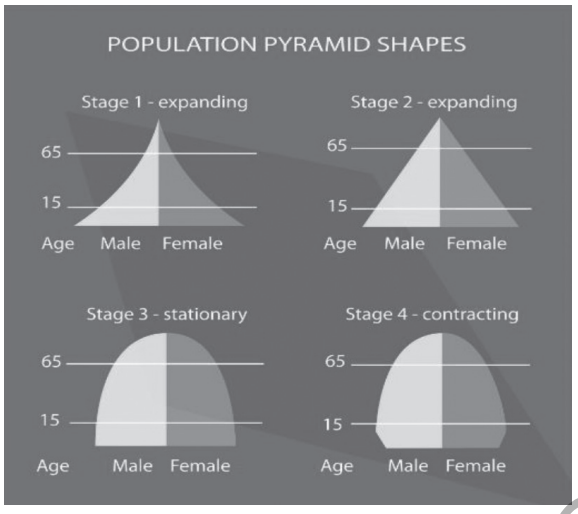


Fig. Population Pyramid Shapes

- **Age Composition (2011 Census): 0-14 yrs - 30.8%; 15-59 yrs - 60.7%.**
- **Rural–Urban Composition:** About **68.8%** of India's population resided in **villages** as of 2011.

Linguistic Composition

- **Hindi speakers** make up the **highest** percentage among the **scheduled languages.**
- **Bengali** is the **second** most spoken language in India.

Religious Composition

- **Hindus:** Constitute **79.8%** of total population. They are predominant in many states, **except** some border districts, **Jammu & Kashmir, North Eastern hill states,** and parts of **Deccan Plateau and Ganga Plain.**
- **Muslims:** Constitute **14.2%** of total population. They are concentrated in areas like **Jammu & Kashmir, parts of West Bengal, Kerala, Uttar Pradesh, Delhi, and Lakshadweep.**
- **Christians:** Constitute **2.3%** of total population. Their population is found mainly on the Western coast around **Goa and Kerala, and hill states like Meghalaya, Mizoram, and Nagaland**.
- **Sikhs:** constitute **1.7%** of total population. They reside primarily in **Punjab, Haryana, and Delhi.**
- **Jains:** Constitute **0.4%** of total population. They are largely in urban areas of **Rajasthan, Gujarat, and Maharashtra.**
- **Buddhists:** Constitute **0.7%** of total population. They are predominant in areas of **Maharashtra, Sikkim, Arunachal Pradesh, Ladakh, Tripura, and Lahaul & Spiti.**

CENSUS 2011 OVERVIEW (15TH CENSUS)

Category	Parameter	Detail
Population Distribution	Total Urban Population	31.165% of the total population
	Most Urbanized State	Goa (62% urban population)
	State with Highest % of Rural Population	Himachal Pradesh (89.9%)
	State with Highest Population	Uttar Pradesh, followed by Maharashtra and Bihar
	State with Lowest Population	Sikkim
	Union Territory with Least Population	Lakshadweep
	Union Territory with Highest Population	Delhi
Population Density	State with Highest Population Density	Bihar
	State with Lowest Population Density	Arunachal Pradesh
	Union Territory with Highest Population Density	Delhi
	Union Territory with Lowest Population Density	Andaman and Nicobar

Sex Ratio	Overall Sex Ratio	943 females per 1000 males
	State with Highest Sex Ratio	Kerala
	State with Lowest Sex Ratio	Haryana
Literacy Rate	Overall Literacy Rate	74%
	Male Literacy Rate	82.14%
	Female Literacy Rate	65.46%
	State with Highest Literacy Rate	Kerala (93.91%)
	State with Lowest Literacy Rate	Bihar (63.82%)

A census is the official count of the population done periodically; 1st Census in India in 1872 and 1st complete census in 1881; Subsequent censuses: every 10th year.
However census 2021 was delayed and the Centre plans to initiate the next census in 2025 after a four-year delay.

KEY DEMOGRAPHIC TERMS

Terms	Definition
Crude birth rate	Annual number of live births per 1,000 people.
General fertility rate	Annual number of live births per 1,000 women of childbearing age (From 15 to 49 years)
Crude death rate	Annual number of deaths per 1,000 people
Infant mortality rate	Annual number of deaths of children of age less than 1 year old per 1,000 live births.
Life expectancy	Number of years which an individual at a given age can expect to live at present mortality levels. Life expectancy in India is 69.16 years (2017).
Total fertility rate	Expected number of live births per woman during her reproductive life.
Gross reproduction rate	Average number of daughters a woman would have if she survived all of her childbearing years, subject to the age-specific fertility rate and sex ratio at birth throughout that period.
Maternal mortality Ratio (MMR)	Number of maternal deaths per 100,000 live births. (India's MMR -97/lakh live births in 2020)
Sex ratio	Number of females per thousand males. India: 943 (2011 Census)
Child Sex Ratio	Number of females per thousand males in the age group of 0–6 years. India: 919 (2011 Census)
Child mortality rate	Number of child deaths under the age of 5 per 1000 live births.
Dependency ratio	Ratio of the number of dependents aged zero to 14 and over the age of 65 to the total population aged 15 to 64.
Demographic window	Period of time in demographic evolution when the proportion of the population of the working age group is particularly prominent.
Demographic dividend	Economic growth potential due to shifts in a population's age structure, mainly when the share of the working-age population (15 to 64) is larger than the non-working-age share of the population (14 and younger, and 65 and older).

SETTLEMENTS

Settlement refers to a permanent or semi-permanent human community that has established a home in a particular place. It can range from a small village to a large city.

Types of Rural Settlements

Settlement Type	Characteristics	Examples/Locations
Clustered	Compact or closely built up area of houses with a recognisable pattern.	Found in fertile **alluvial plains and northeastern states, Bundelkhand** region, and areas in **Rajasthan** for water scarcity reasons.
Semi-Clustered	Results from fragmentation of a large compact village or clustering in a dispersed settlement. Dominant community occupies the central part.	Found in the **Gujarat plain** and parts of **Rajasthan.**
Hamleted	Settlement fragmented into several units bearing a common name (e.g., **panna, para, palli, nagla, dhani**).	Found in the **middle and lower Ganga plains, Chhattisgarh, and lower valleys of the Himalayas.**
Dispersed	Appears as isolated huts or hamlets in remote areas due to the terrain and fragmented land resource base.	Found in **Meghalaya, Uttarakhand, Himachal Pradesh, and Kerala**

URBANISATION IN INDIA

India's urbanisation, driven by migration and economic growth, has led to rapid development in urban areas. Census 2011 and data from the Ministry of Housing and Urban Affairs categorise urban areas in India as follows:

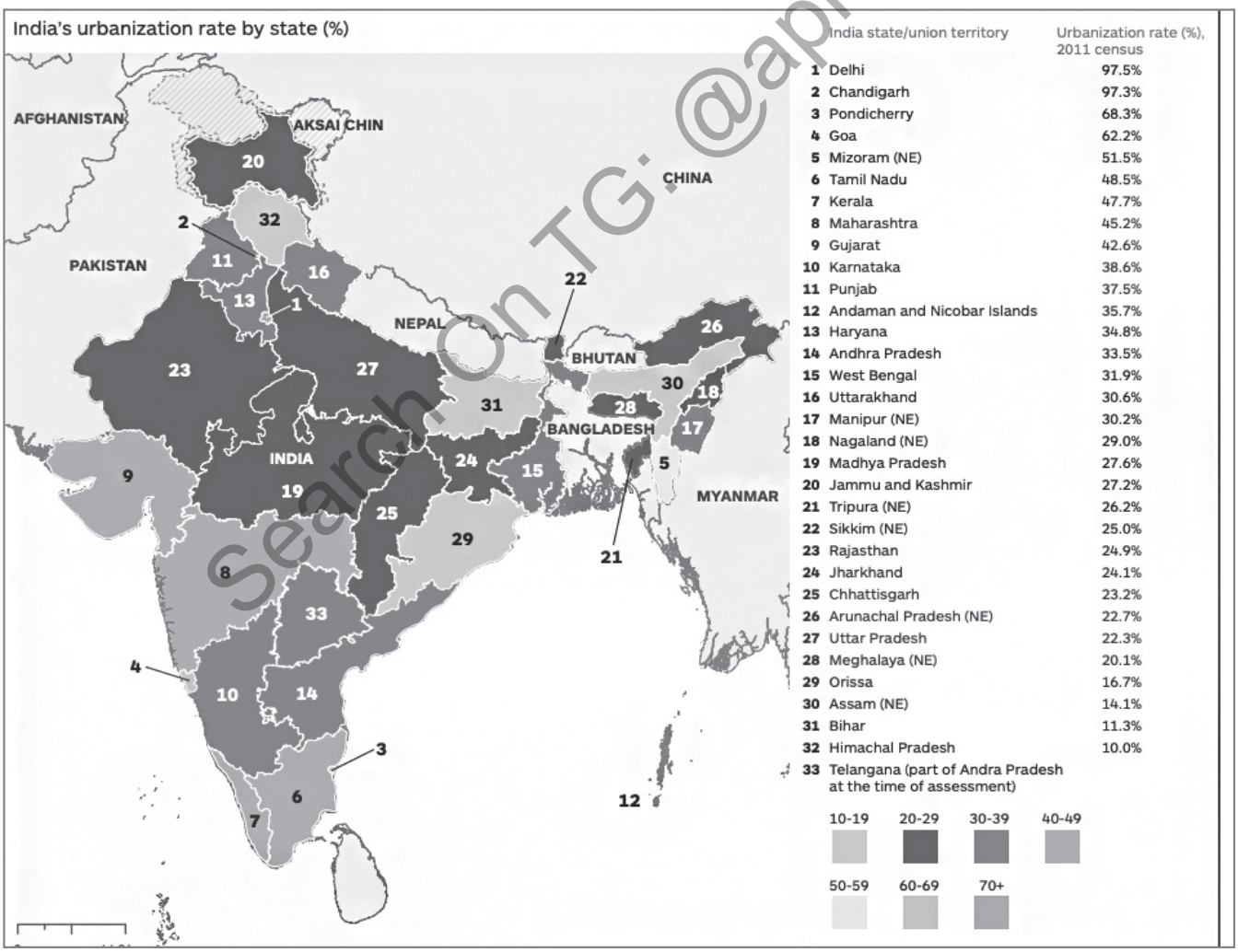


Fig. India's Urbanization Rate by State(%)

Types of Urban Areas

- **Statutory Towns:** Defined legally as urban areas, including Municipal Corporations, Municipalities, and Cantonment Boards.
- **Census Towns:** Areas with:
  - Population of at least **5,000**
  - **75% of male** workers in non-agricultural jobs,
  - Density of at least **400 persons** per sq. km.

Categories of Major Urban Centers

- **Metropolitan Cities:** Urban centres with populations over 1 million; increased from 12 in 1981 to 53 in 2011.
- **Megacities:** Defined as cities with populations exceeding 10 million (e.g., Mumbai, Delhi, Kolkata).
- **Megalopolis and Conurbation:** Expansive urban zones and merged settlements, especially along transport corridors.

Trends and Global Context

- **Urban Population Growth:** As per UN Habitat's *World Cities Report 2020*, India's urban population could reach 40% by 2035. Census 2011 reported 31.2% urban population, up from 27.8% in 2001.
- **Urban Housing Initiatives:** Aligned with the UN's SDG 11, programs like *Pradhan Mantri Awas Yojana (PMAY-Urban)* aim for affordable housing, with 112 lakh houses sanctioned by 2021.
- **Smart Cities Mission:** Focuses on sustainable urban development in 100 cities, enhancing infrastructure and digital connectivity.
- **Slum Conditions:** According to UNDP's *Human Development Report 2020*, 24% of India's urban population lives in slums, and Census 2011 identified 13.7 million urban households in such conditions.
- **Population Density and Environmental Challenges**
  - **Density:** Mumbai's density exceeds 11,000 persons per sq. km in central areas, posing infrastructure challenges.
  - **Sustainability Initiatives:** Efforts to increase green spaces and develop sustainable urban infrastructure align with UNDP recommendations for environmental quality.
- **Economic and Migration Patterns**
  - **Migration:** Rural-to-urban migration accounts for 31% of the urban population, driven by economic opportunity, contributing over 60% of India's GDP.

ONLYIAS BY PHYSICS WALLAH

INTERVIEW GUIDANCE PROGRAM 2024

English / हिन्दी

- Simulated Mock Interviews
- 1-to-1 Sessions with Bureaucrats
- 3rd Eye View
- Personalized Mentorship
- Personalized DAF Filling Session
- Interview Oriented Content & Discussion

Our Panellists

SUNIL OBEROI
Ex-IAS Officer,
Fr. UPSC Examiner

SANGEETA GUPTA
Ex-IRS Officer,
Fr. UPSC Board Member

SUNIL GULATI
Ex-IAS Officer,
Retd. Spl. C.S. (Delhi)

ANIL K. MEHRA
Ex-IRS Officer,
Fr. Comm'r (CBEC)

D.S. MALIK
Ex-IIS Officer

JALAJ SHRIVASTAVA
Ex-IAS Officer
Addl. C.S. (MoA & FW)

300+ Selections in UPSC CSE 2023

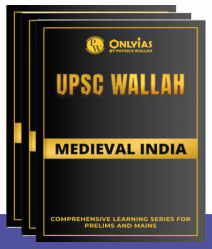
SCAN Here or at 9971899954

Online / Offline
REGISTRATION FREE
for CSM 2024 Qualifiers

IGP Centre : 2/3, West Patel Nagar, Near Pillar No. 195, New Delhi 110008

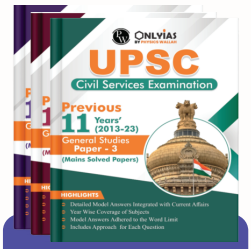
ONLYIAS BY PHYSICS WALLAH

OUR CONTENT



BOOKS

Comprehensive Coverage

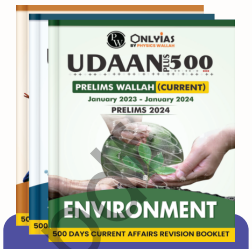


BOOKS

11 Year PYQs Solution (Prelims + Mains)

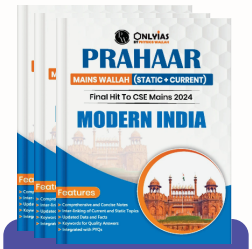
FREE MATERIAL

UDAAN (Prelims Static Revision)



FREE MATERIAL

UDAAN PLUS 500 (Prelims Current Affairs Revision)

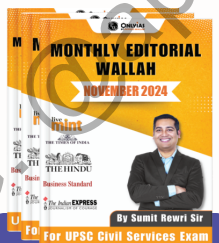


FREE MATERIAL

Mains Revision

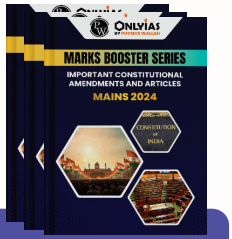
CURRENT AFFAIRS

Monthly Current Affairs Magazine



CURRENT AFFAIRS

Monthly Editorial Compilation



FREE MATERIAL

Quick Revision Booklets