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PRELIMS 2025

ENVIRONMENT

QUICK AND COMPREHENSIVE REVISION SERIES

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QUICK AND COMPREHENSIVE REVISION SERIES FOR PRELIMS 2025

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1 Basics of Environment and Ecosystem

BASIC DEFINITIONS

Environment

- A natural component constituting the **interaction of biotic and abiotic factors** to shape the habitat and ecosystem of an organism.
- Constitutes **physical** (water, air), **biological** (biomolecules), and **chemical interactions** (chemical cycles) that affect an organism or a group of organisms.
- All organisms depend on the environment to carry out their natural life processes and meet their physical requirements (food, energy, water, oxygen, shelter, etc.).

Ecology

- The term "ecology" was coined by the German zoologist, Ernst Haeckel, in 1866.
- Branch of biology dealing with the study of relations of organisms to one another (energy flow and mineral cycling) and their physical surroundings (environment).
- Studies individuals, organisms, populations, communities, ecosystems, biomes, and biospheres (various levels of ecological organisation).

PRINCIPLES OF ECOLOGY

Adaptation	Appearance/behaviour/structure/mode of life of an organism that allows it to **survive in a particular environment**. Types: • **Morphological** e.g., the Fennec fox living in the desert has large ears (allows heat radiation from the body to allow its cooling); mammals from colder climates generally have shorter ears and limbs to minimise heat loss. (This is called **Allen's Rule**.) • **Physiological** e.g., venomous animals produce poison to catch their prey, to protect themselves or to ward off predators • **Behavioural** - Hibernation as a winter survival technique. E.g., the phenomenon of hibernation observed in bats, bears and rodents. **[UPSC 2014]**
Variation	• **Changes in genetic makeup** due to the addition or deletion of specific genes. Eg: difference in the colour of skin, and type of hair among different ethnic groups. • Mutations, changes in climate, geographical barriers etc., induce variations over a period of time. • **Adaptive radiation:** Process in which organisms diversify from an ancestral species into new forms under new environmental challenges or new environmental niches.
Speciation	• Process of **formation of new species.** • A species comprises many populations. Often, different populations remain isolated due to geographic barriers. • Over a period, geographic isolation leads to speciation, i.e., **geographic speciation or allopatric speciation**. • **Sympatric speciation:** New species develop spontaneously (maybe due to different food sources) despite no **physical barriers** to inter-breeding.
Mutation	• **Changes in genetic material** that result from an error in DNA replication, causing the **rise of new genes**. • As a result, members of the same species show 'variation' and are not identical.

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Natural Selection	• Proposed by **Darwin** and **Wallace**, it is a process by which species adapt to their environment. • An **evolutionary force** that selects among variations, i.e. genes that help the organism to have better chances of surviving, reaching reproductive age and passing on suitable adaptations to their progeny.
Evolution	• **The process by which living organisms change over time through changes in the genome.** • May give rise to new species and make the organism better suitable for the present environment through natural selection, variation etc. • **Charles Darwin** and **Alfred Wallace: Theory of Evolution** in **1859**. This theory has been extended in light of progress in genetics and is known as **Neo-Darwinism**.
Extinction	• The **complete disappearance** of a species from Earth primarily due to environmental changes, biological competition or inability to evolve fast enough to cope with the changing environment. • Currently, the **6th Mass Extinction (Anthropogenic Extinction – human-induced)** is in progress, exacerbated by mankind's over-exploitation/misuse of natural resources, fragmentation/loss of natural habitats, destruction of ecosystems, pollution, and global climate change. **[UPSC 2018]**

Notable Extinct Species and Their Causes of Extinction

Here's a table of species that went extinct along with the reasons behind their extinction and the timeline:

Species	Extinction Year	Habitat	Cause of Extinction
Dodo	1681	Mauritius (forests)	Overhunting by humans and predation by introduced species (e.g., rats, pigs)
Passenger Pigeon	1914	North America (forests)	Mass hunting and habitat destruction due to deforestation
Tasmanian Tiger (Thylacine)	1936	Tasmania (grasslands, forests)	Hunting by humans, habitat loss, and competition with introduced species like dogs
Baiji (Yangtze River Dolphin)	2006 (functionally extinct)	Yangtze River, China	Habitat degradation due to dam construction, pollution, and overfishing
Great Auk	1844	North Atlantic Ocean	Overhunting for feathers, meat, and eggs; habitat exploitation by humans
Pyrenean Ibex	2000	Pyrenees Mountains, Spain	Overhunting, habitat loss, and competition with domestic livestock
Steller's Sea Cow	1768	North Pacific (coastal waters)	Overhunting for meat and fat by humans shortly after its discovery
Caribbean Monk Seal	1952	Caribbean Sea	Overhunting and habitat degradation due to human activities
Golden Toad	1989	Costa Rica (cloud forests)	Climate change, habitat loss, and fungal infections (chytridiomycosis)
Pinta Island Tortoise	2012 (death of "Lonesome George")	Galápagos Islands	Habitat destruction, hunting, and predation by introduced species (e.g., goats, rats)

Species Showing Hibernation

Category	Species	Notable Features
Mammals	Bears (e.g., Black Bear, Grizzly Bear)	Slight decrease in body temperature; metabolic rate slows significantly.
	Bats (e.g., Little Brown Bat, Big Brown Bat)	Enter torpor; conserve energy during food-scarce winters.
	Ground Squirrels (e.g., Arctic Ground Squirrel)	Body temperature drops to near-freezing levels.
	Hedgehogs (e.g., European Hedgehog)	Heart rate and body temperature drop significantly.
	Marsupials (e.g., Mountain Pygmy Possum)	Hibernate for months in alpine regions of Australia.

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Reptiles	Turtles (e.g., Painted Turtle)	Hibernate underwater, relying on anaerobic metabolism.
	Snakes (e.g., Garter Snake)	Gather in communal dens to hibernate.
	Lizards (e.g., Green Iguana)	Hibernate in burrows during cold conditions.
Amphibians	Frogs (e.g., Wood Frog, Bullfrog)	Produce antifreeze-like substances to survive freezing.
	Salamanders (e.g., Spotted Salamander)	Hibernate underground or in aquatic environments.
Fish	Carp (e.g., Common Carp)	Hibernate at the bottom of water bodies with reduced activity.
	Catfish (e.g., Channel Catfish)	Metabolism slows down during colder months. The **suckermouth catfish, or pleco**, showcases extraordinary survival by enduring months in dried mud without water. Equipped with specialized breathing organs, it enters dormancy, akin to hibernation, until rain rehydrates its environment.
Insects	Ladybugs	Cluster in sheltered places for warmth during hibernation.
	Bees (e.g., Bumblebee)	Queen bumblebees hibernate during winter.
	Butterflies (e.g., Mourning Cloak)	Hibernate in tree hollows or cracks.
Birds	Common Poorwill (Phalaenoptilus nuttallii)	Only bird known to hibernate for extended periods; enters a torpor-like state.

Ecological Hierarchy

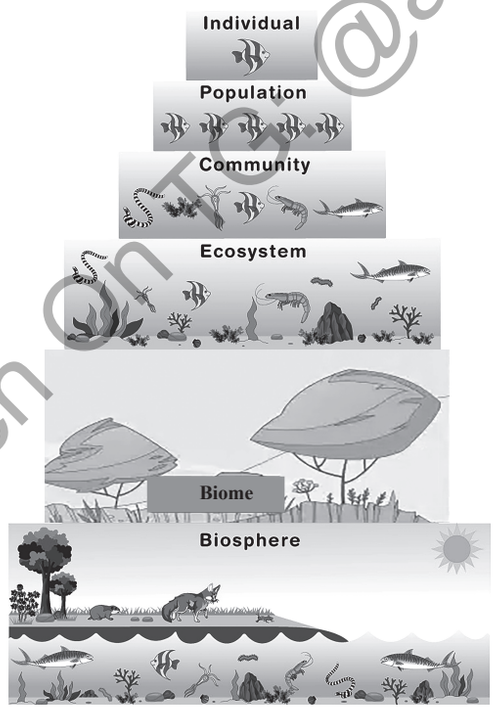

Fig. Ecological Hierarchy

Individual and Species	• **Individual:** An organism that can act or function independently. • **Species:** A group of living organisms consisting of similar individuals capable of exchanging genes (interbreeding). e.g., Homo sapiens. • Basic unit of taxonomy
Population	• Community of interbreeding organisms (same species) occupying a defined area during a specific time.

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Community	• Named after the dominant plant form. Eg:, a grassland community is dominated by grasses, though it may contain herbs, trees, etc. • **Major Communities:** Large-sized and relatively independent. They depend only on the Sun's energy from outside. E.g., Tropical evergreen forests. • **Minor Communities:** Depend on neighbouring communities and are often called societies. They are secondary aggregations within a major community. E.g., a mat of lichen on a cow dung pad. • **Stable community:** Does not show much variation in productivity from year to year. It is resilient to occasional disturbances (natural or human-made) and invasions by alien species.
Ecosystem	• The **structural and functional unit of ecology** where the living organisms interact with each other and the surrounding environment
Biome	• A large geographical area of distinctive plant and animal groups that are adapted to that particular environment. • **Five major types of biomes: Aquatic**, **Grassland**, **Forest**, **Desert**, and **Tundra**. • Biomes are distinct from habitats; a biome **can comprise a variety of habitats**. • Plants and animals in a biome have common characteristics due to similar climates and can be found on various continents. ❍ Eg: **taiga forests** are found beyond the temperate regions of all the continents in the northern hemisphere.
Biosphere	The region on, above, and below the Earth's surface where life exists. • The biological components (supporting life) of the Earth include the **lithosphere**, **hydrosphere** and **atmosphere** (all living organisms and dead organic matter produced by them). • **Absent at extremes** of the North and South poles, the highest mountains, and the deepest oceans (hostile conditions). Occasionally, spores of fungi and bacteria do occur at a great height beyond 8,000 metres, but they are metabolically inactive (dormant life.)

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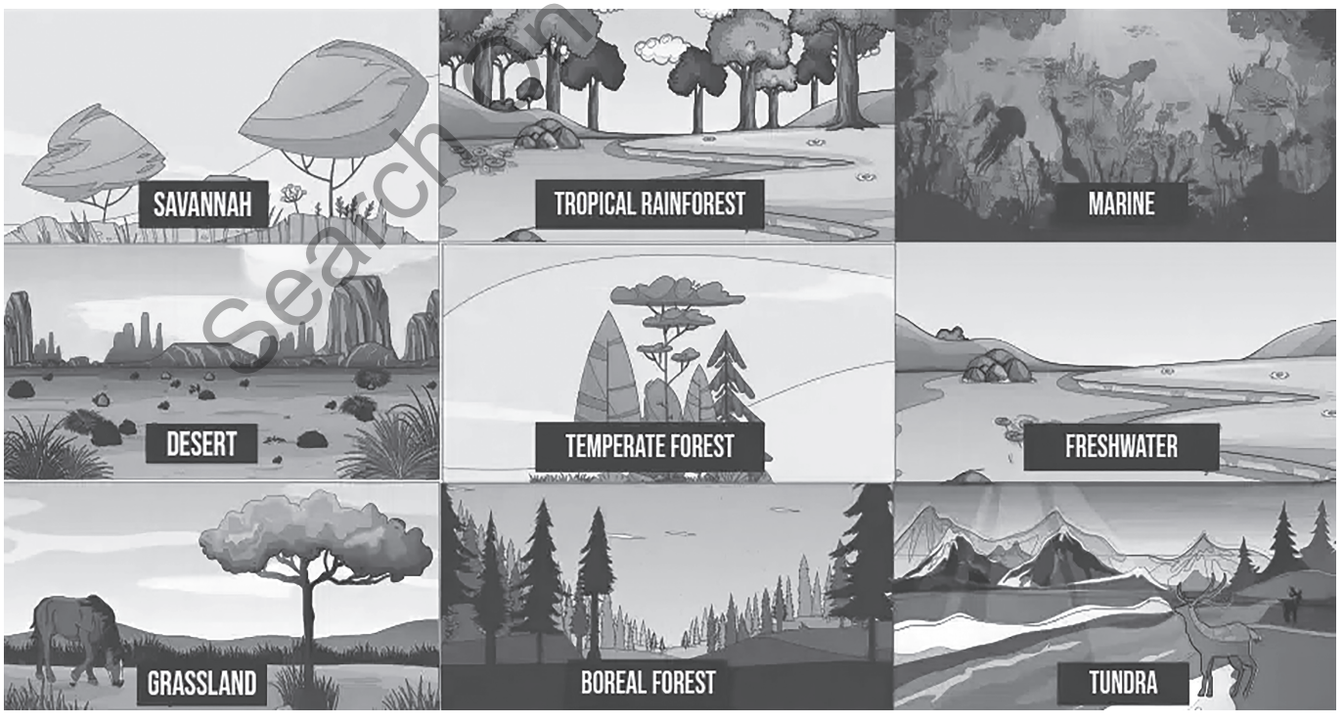

Fig. Types of Biomes

ECOLOGICAL NICHE

- **Unique functional role and position** of a species in its habitat or ecosystem **[UPSC 2013]**
- **No two species in a habitat can have the same niche** because of competition with one another until one is displaced.
- **Components of a Niche:**
  - **Habitat:** The physical environment where the species lives.
  - **Resources:** The food, water, and nutrients the species consumes.
  - **Interactions:** Relationships with other species, such as competition, predation, or mutualism.
  - **Role in Ecosystem:** The ecological functions the species performs, like pollination or seed dispersal.
- Niche knowledge plays an essential role in the conservation of organisms.
  - **Mangroves** occupy a niche in saline intertidal zones, stabilizing coastlines and supporting aquatic biodiversity.
  - **Bees** perform the critical role of pollination, essential for plant reproduction.
- **Types of Ecological Niches:**
  - **Fundamental Niche:** The full range of environmental conditions and resources a species can theoretically use in the absence of competition.
  - **Realized Niche:** The actual conditions and resources a species uses, often narrower due to competition and other biotic interactions.
- **How Niche Influences Extinction?**

Factor	Explanation	Example
Specialized Niche	Species with specialized niches are highly adapted to specific conditions and resources.	The **Giant Panda,** reliant on bamboo, faces extinction risks if bamboo forests are depleted.
Competition	When multiple species compete for the same niche, weaker competitors may be outcompeted and decline.	The **Red Squirrel** in the UK has declined due to competition with the invasive **Grey Squirrel.**
Habitat Loss	Destruction of a species' habitat can render its niche uninhabitable.	The **Bengal Florican**, a grassland bird, faces risk of extinction due to the loss of grassland habitats.
Climate Change	Alterations in temperature, rainfall, and ecosystems may disrupt a species' niche.	The **Polar Bear** is threatened by shrinking Arctic ice, reducing its hunting grounds.

Examples of Niche Adaptation by Organisms to Escape Extinction

Organisms adapt their niches to changing environmental conditions or competition to avoid extinction. These adaptations can be behavioral, structural, or ecological. Here are some notable examples:

Organism	Original Niche	Adaptation	Outcome
Peppered Moth (Biston betularia)	Light-colored moths blending with lichen-covered trees.	During the Industrial Revolution in England, dark-colored moths became dominant to blend with soot-covered trees.	The population survived heavy predation by adapting coloration to match their new environment.
Galápagos Finches	Original seed-eating finches with uniform beaks.	Diversified beak shapes and sizes to specialize in different food sources (e.g., seeds, insects, cactus).	Avoided competition by occupying unique feeding niches, leading to adaptive radiation.
Coral Species	Warm, shallow water in tropical seas.	Some corals adapted to tolerate slightly warmer temperatures and increased acidity in oceans.	Partial survival of coral reefs amidst climate-induced bleaching events.
Polar Bears	Ice-dependent hunting of seals.	Increasing land-based scavenging (e.g., eating bird eggs, berries) as ice melts.	Temporary survival strategy, though long-term effects are uncertain.
Coyotes (Canis latrans)	Plains and grasslands of North America.	Adapted to urban and suburban environments by exploiting human food waste and smaller prey.	Population expansion into areas dominated by human development.

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Cichlid Fish	Different depths and food preferences in African lakes.	Specialized feeding strategies such as eating algae, plankton, or snails to avoid competition.	High biodiversity in lakes like Lake Victoria through niche differentiation.
Kangaroo Rats	Arid desert regions in North America.	Developed efficient water retention and nocturnal habits to avoid predators and dehydration.	Survival in extremely dry environments by minimizing water loss.
Hummingbirds	Feeding on general nectar sources in forests.	Specialized beak shapes to access specific flowers, reducing competition with other birds.	Co-evolved with specific plants, ensuring mutual survival.

Habitat

- **Physical environment in which an organism lives**. Multiple organisms may share a common habitat, depending on common requirements.
- **Multiple habitats together make up the environment**.
- **All habitats constitute environments, whereas not all environments are habitats**.

ECOTONE, ECOCLINE, AND EDGE EFFECT

Ecotone

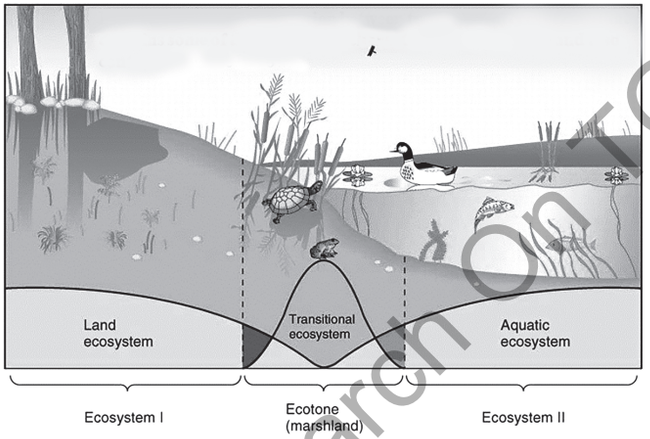

Fig. Ecotone

- **Zone of transition** between two biomes where **two communities meet and integrate** (diverse ecosystems). It has characteristics of both ecosystems. **Eg: mangrove forests** (between marine and terrestrial ecosystems); **grassland** (between forest and desert).
- May be **narrow** (between grassland and forest) or **wide** (between forest and desert).
- **Zone of tension:** conditions intermediate to the adjacent ecosystems.
- **Far greater productivity than natural ecosystems** due to wide-ranging species from the adjacent ecosystems being present in the ecotone.
- Well-developed ecotone **may contain some organisms entirely different** from those of the adjoining communities.

Ecocline

- Zone of gradual but continuous change from one ecosystem to another.
- No sharp boundary between the two in terms of species composition. It occurs across the environmental gradient (gradual change in abiotic factors such as altitude, temperature, salinity, depth, etc.)

Edge Effect and Edge Species

- The appearance of diverse ecological characteristics, a high number of species and population density in the ecotone compared to either community is termed the **edge effect.**
- The species that occur primarily or most abundantly in this zone are known as **edge species.**
- **Eg:** in terrestrial ecosystems, the edge effect is especially applicable to birds. The density of birds is greater in the ecotone between the forest and the desert.

ECOSYSTEM

- **Functional unit of nature,** where **living organisms interact among themselves and with the surrounding physical environmen**t in which they live, such that energy is exchanged and system-level processes, such as the cycling of elements, emerge. **[UPSC 2015]**

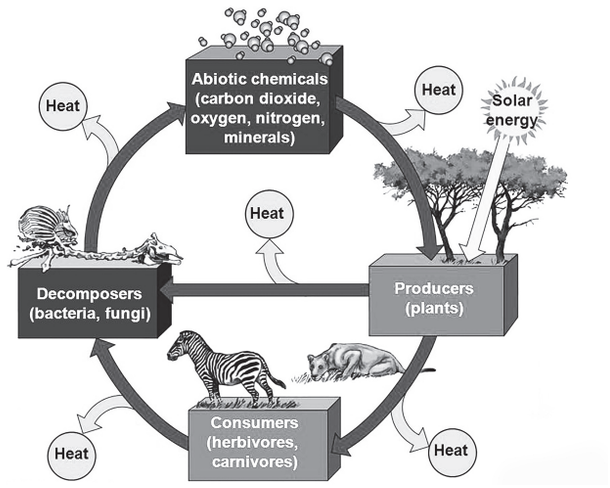

Fig. Ecosystem

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- **All ecosystems are environments**, but not vice versa.
- **The ecosystem has two components:** Biotic and Abiotic.

Biotic Components

Biotic components refer to the living organisms in an ecosystem that interact with each other and their environment. These include producers, consumers, and decomposers, playing distinct roles in maintaining ecological balance.

- **Primary Producers/Autotrophs**
  - Organisms that synthesize their own food using sunlight and inorganic substances.
  - **Examples:** Green plants, certain bacteria, cyanobacteria, diatoms , and microscopic algae in aquatic ecosystems. **[UPSC- 2021]**
- **Consumers / Heterotrophs:** Organisms that rely on other organisms for food.
  - **Macro Consumers:**
    - **Herbivores:** Feed on plants. (*e.g., sheep, rabbit*)
    - **Secondary Consumers:** Feed on herbivores. (*e.g., wolves, dogs*)
    - **Tertiary Consumers:** Carnivores feeding on secondary consumers. (*e.g., lions*)
    - **Omnivores:** Feed on both plants and animals. (*e.g., humans, bears*)
  - **Micro Consumers:**
    - **Phagotrophs**: Ingest organic matter.
    - **Osmotrophs:** Absorb dissolved nutrients.
    - **Saprotrophs / Decomposers:** Feed on dead organic material. (*e.g., fungi, bacteria*) **[UPSC-2013]**
    - **Detritivores:** Consume detritus and help in decomposition. (*e.g., earthworms*)

Abiotic Components

Abiotic components are the non-living physical and chemical elements in an ecosystem that influence living organisms. They form the foundation for the functioning of ecosystems by providing essential resources and conditions for life**.** Eg: air, water, soil, minerals, sunlight, temperature, nutrients, wind, altitude, turbidity, etc

Abiotic Components and Their Effects on Terrestrial Autotrophs

Abiotic Component	Effects on Terrestrial Autotrophs
Light	• High intensity favors root growth, shortens stems, and results in smaller, thicker leaves. • Low-intensity light retards growth, flowering, and fruiting. • Only red and blue light are effective in photosynthesis. • Blue light: Plants are small • UV light: Causes dwarfing • Red light: Leads to elongated, etiolated plants.
Temperature	• High temperatures cause coagulation of protoplasmic proteins, desiccation of tissues, and moisture depletion. • Low temperatures and frost freeze soil moisture, increase transpiration, and dehydrate cells, leading to canker formation.
Snow	• Shortens vegetative growth periods. • Acts as a blanket to protect seedlings from extreme cold and frost.
Nitrogen	• Nitrogen is a limiting nutrient due to competition between plants and microbes for soil nitrogen.
Water	• Essential for physiological processes, influences distribution, and supports nutrient uptake.
Soil	• Provides nutrients, water, and anchorage for plant roots.
pH Levels	• Determines soil and water acidity or alkalinity, affecting plant and microbial growth.
Minerals	• Vital for plant development and biological functions.
Wind	• Influences seed dispersal, transpiration rates, and temperature regulation.
Precipitation	• Determines water availability, affecting plant growth and ecosystem productivity.
Dieback	• It is the progressive dying, usually backward from the tip of any portion of the plant (adaptive mechanisms to avoid adverse conditions like drought). Generally, the root • remains alive for years together, but the shoots die. E.g. sal, red sanders, silk-cotton tree etc.

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FUNCTIONS OF AN ECOSYSTEM

The ecosystem's function is expansive and encompasses a dynamic system that can be explored through the following three aspects

- Ecological Succession
- Energy Flow
- Biogeochemical cycles (Nutrient Cycling)

Ecological Succession

The process where plant and animal communities in an area change over time due to large-scale changes or destruction. Its speed is influenced by geographical location and occurs faster in areas in the middle of large continents.

Stages in Ecological Succession

It Involves directional changes in vegetation.

- **Pioneer Community:** The first plant to colonize an area.
- **Successional Stages/Seres:** Progressive series of changes where one community replaces another. Transitional communities are also replaced (seral community) and characterized by increased productivity, nutrient shift, organism diversity, and food web complex.
- **Climax Community:** Final stage, stable and mature. It is more complex and long-lasting.

Type of Ecological Succession

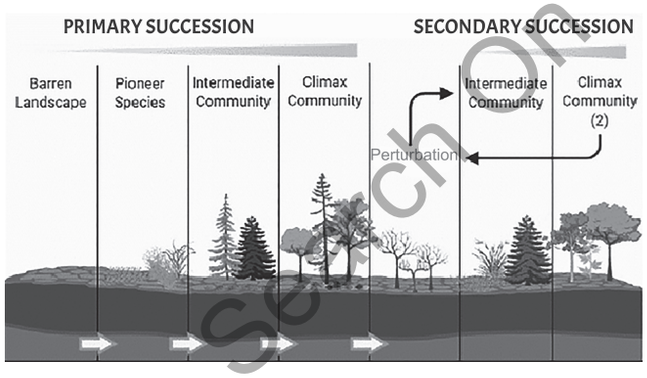

Fig. Ecological Succession

Primary Succession:

- Occurs in areas where no previous community existed i.e. bare, often harsh environments (rock outcrops, sand dunes).
- **Pioneer species**: Hardy species like microbes, mosses, and **lichens (symbiotic association of Fungi and algae) Species like Cnidarians, Fungi, Protozoa can establish a symbiotic relationship with other organisms.**

[UPSC 2021]

- Pioneers alter the habitat through growth and development.
- **Relatively slow,** starting from barren conditions.

Secondary Succession:

- Follows **complete** or **partial destruction of an existing community** by natural events like floods, droughts, fires or by human interventions like deforestation, agriculture etc.
- Well-developed **soil already present** at the site.
- Hardy grasses initially, followed by herbaceous plants and eventually trees.
- **Faster,** as it builds upon existing soil and community remnants.

Types of Succession Based on Cause:

- **Autogenic succession:** Brought about by biotic components (living inhabitants) of that community itself.
- **Allogenic succession:** Brought about by the abiotic components (fire, flood) of the ecosystem.

Type of Succession based on Habitats

- **Xerarch Succession:** Occurs on land with low moisture content (e.g., bare rock)
  - **Pioneers:** Colonizing plants adapted to arid conditions
  - **Progression:** Succession leads to mesophytic habitat (moderate water)
- **Hydrarch Succession:** Takes place in water bodies (ponds, lakes)
  - **Pioneers:** Phytoplankton in primary succession
  - **Progression:** Phytoplankton → Floating angiosperms → Rooted hydrophytes → Sedges/grasses → Trees.
- **Lithosere (Rock-Based Succession)**
  - A type of primary succession starting on bare rocks.
  - **Stages:**
    - Lichens and mosses break down rock to form soil. Followed by grasses, shrubs, and trees.
    - Psammosere (Sand-Based Succession)
- Succession occurring on sand dunes.
  - **Stages:**
    - Pioneer plants like marram grass stabilize the sand.
    - Gradual development of shrubs and woodland.
    - Halosere (Saltwater-Based Succession)
- Succession in saline environments like salt marshes or mangroves.
  - **Stages:**
    - Begins with salt-tolerant plants (halophytes).
    - Progresses to less salt-tolerant species as soil salinity decreases.

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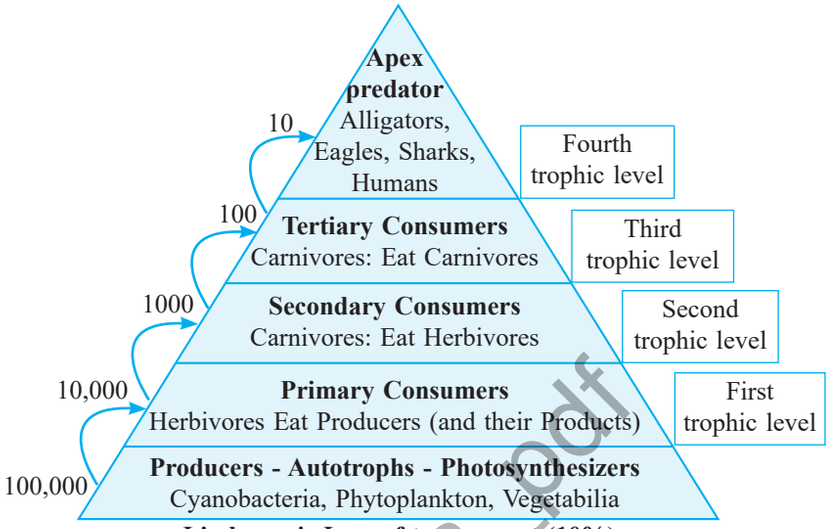
ENERGY FLOW THROUGH THE FOOD CHAIN

- **Trophic level** represents energy flow in an ecosystem. A trophic level is a position occupied by an organism in a food chain.
- **Unidirectional Energy Flow:** Energy in an ecosystem flows in a unidirectional manner, typically from the lower trophic levels to the higher ones. This means that energy is transferred from producers (plants or autotrophs) to consumers (herbivores, carnivores, etc.) and rarely moves in the opposite direction.
- **Energy Loss in Trophic Levels:** At each trophic level, there is a significant loss of energy, primarily in the form of heat, during the process of metabolism and other life activities. This is often represented by the **ecological pyramid**, where the energy decreases as you move up the trophic levels.



Lindeman's Law of ten percent (10%)
The Efficiency of Energy Transfer from one Trophic level to the next is about 10%

- **The Lindeman's 10 Percent Law:** Lindeman's 10 percent law, proposed by ecologist Raymond Lindeman, states that only about 10 percent of the energy available at one trophic level is transferred to the next trophic level in an ecosystem.

Trophic level interaction

The trophic level interaction involves three concepts, namely:

- **Food Chain**
- **Food Web**
- **Ecological Pyramids**

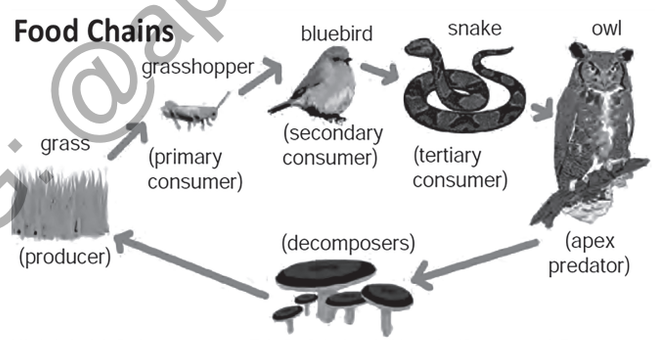


Fig. Food Chains

Food Chain

[UPSC 2013]

A **food chain** represents the feeding relationships in an ecosystem, describing how energy and nutrients flow from one organism to another. It shows "who eats whom" in a linear sequence.

Types of Food Chains

Aspect	Grazing Food Chain	Detritus Food Chain
Primary Energy Source	Living producers (plants).	Decomposing organic matter (detritus).
Initial Organism	Herbivores (consume living producers).	Decomposers (break down dead organic matter).
Intermediate Consumers	Carnivores (consume herbivores).	Detritivores (consume detritus).Some detritivores are **Earthworms, Millipedes, and Woodlice**. **[UPSC 2021]**
Energy Flow	Direct consumption pathway.	Indirect consumption pathway through decay.
Example	Grass → Grasshopper → Frog → Snake. Diatoms→ Crustaceans (Krills, Prawns, Lobsters, Crabs, Barnacles, Copepods) → Herrings (small Fish). **[UPSC 2021]**	Fallen leaves → Earthworms → Birds.

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- On Earth, the **grazing food chain is dominant** in the marine ecosystem.
- In the **terrestrial ecosystem**, the **detritus food chain is more dominant**.
- Honey Bees perform a waggle dance for others of their kin to indicate the direction and the distance to a source of their food **[UPSC 2023]**

Food Web

A food web refers to the complex network of feeding relationships among various organisms in an ecosystem, depicting multiple interconnected food chains.

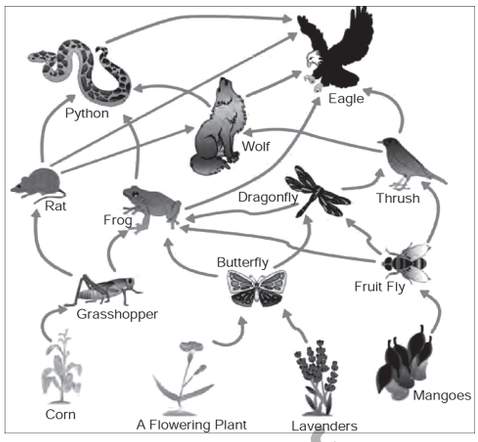

Fig. Food Web

Types of Biotic Interactions in a Food Web

Interaction	Definition	Example 1	Example 2	Example 3
Mutualism	Both species benefit from the interaction.	Bee pollinating flowers, both get nectar and pollen.	Clownfish and sea anemones, mutual protection.	Lichen (fungus and algae), mutualistic relationship.
Commensalism	One species benefits, the other is unaffected.	Barnacles attaching to whales, barnacles benefit, whales unaffected.	Epiphytic plants growing on tree branches, plants benefit, tree unaffected.	Remoras hitching a ride on sharks, remoras get protection and scraps, shark unaffected.
Parasitism	One species benefits at the expense of the other.	Tick feeding on a dog's blood, tick benefits, dog harmed.	Tapeworms living in the intestines of animals, tapeworm benefits, host harmed.	Mosquitoes feeding on human blood, mosquitoes benefit, humans harmed.
Predation	One species kills and consumes the other.	Lion hunting and eating a zebra.	Snake capturing and eating a mouse.	Eagle preying on fish in a river.
Competition	Both species are negatively affected by sharing limited resources.	Lions and hyenas competing for prey in the savanna.	Plants competing for sunlight and nutrients in a forest.	Birds competing for nesting sites in a tree.
Amensalism	One species is harmed, the other is unaffected.	Black walnut trees releasing toxins that inhibit the growth of nearby plants.	Antibiotic-producing bacteria inhibiting the growth of other bacteria.	Allelopathic plants releasing chemicals that inhibit the growth of nearby plants.
Facilitation	One species indirectly benefits another.	Nurse plants providing shade and shelter for seedlings.	Coral reefs providing habitat for a diverse range of marine species.	Dead trees providing nesting sites for woodpeckers and other cavity-nesting birds.

Ecological Pyramids

Graphical presentation of the relationship between various trophic levels. Horizontal bars depict specific trophic levels, with the length of the bar indicating the total number of individuals, biomass, or energy at each trophic level.

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Categories of Ecological Pyramids

- **Pyramid of Numbers:** Represents the number of individuals at each trophic level. Generally, numbers decrease as you move up the pyramid.

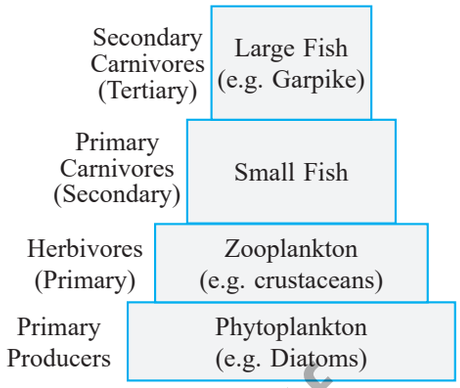

Fig. Pyramid of Number

- **Pyramid of Biomass:** Depicts total biomass **(dry weight)** of organisms at each trophic level. Generally, biomass decreases as you move up due to energy loss.

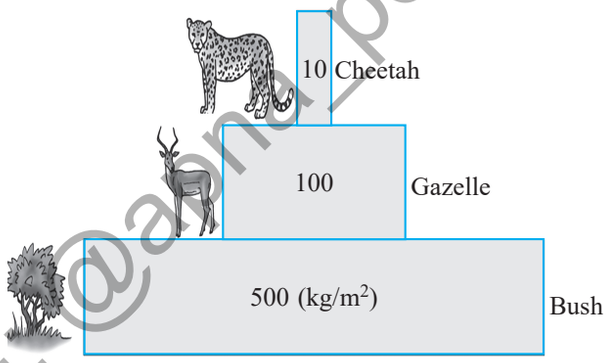

Fig. Pyramid of Biomass

- **Pyramid of Energy or Productivity:** Represents energy flow through trophic levels. Generally, energy availability decreases moving up the pyramid, hence the pyramid is always upward.

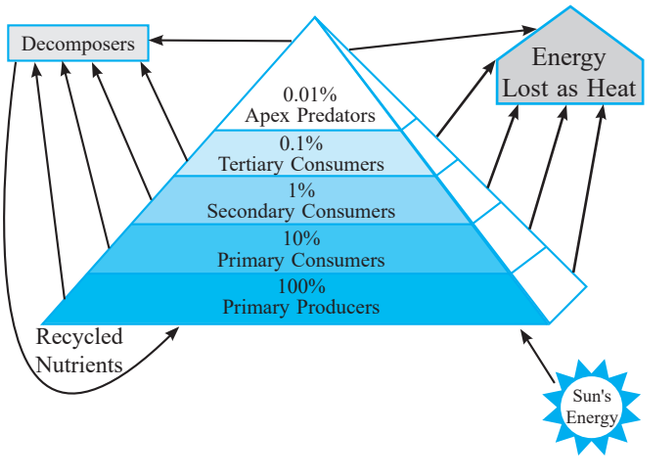

Fig. Pyramid of Energy

Ecosystem	Pyramid of Energy	Pyramid of Biomass	Pyramid of Numbers
Grassland	Upright	Upright	Upright
Aquatic	Upright	Inverted	Upright
Forest	Upright	Upright	Spindle Shaped
Parasite food-Chain	Upright	Upright	Inverted

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Inverted Aquatic Biomass Pyramid: In aquatic ecosystems, the biomass pyramid is often inverted because phytoplankton, the primary producers, have a low standing biomass due to their rapid turnover, despite their high production rates. This allows for a larger biomass of primary and secondary consumers, such as zooplankton and fish, to be supported. The efficient energy transfer from small producers to large consumers contributes to the inverted pyramid structure.

Inverted Detritus Pyramid of Numbers: The detritus pyramid of numbers can be inverted because large, slowly decomposing detritus (like fallen trees) can support a large number of smaller detritivores. Although the biomass of detritivores is low, their numbers can be much higher than the biomass of the detritus, leading to an inverted pyramid where fewer large detritus items support many smaller decomposers.

MOVEMENT OF NON-DEGRADABLE POLLUTANTS IN ECOSYSTEMS

Non-degradable pollutants (persistent pollutants) cannot be easily broken down by detritivores. For instance, Chlorinated Hydrocarbons (Perfluoro Chlorides) are particularly damaging and long-lasting. The movement of these pollutants involves: Bioaccumulation and Biomagnification.

Bioaccumulation Vs Biomagnification

Aspect	Bioaccumulation	Biomagnification
Definition	Gradual buildup of pollutants **in an organism** over time.	Progressive increase in pollutant concentration **across trophic levels** in a food chain.
Mechanism	Pollutants accumulate when the rate of intake exceeds the rate of excretion or breakdown.	Higher trophic levels consume organisms with accumulated pollutants, leading to magnified levels.
Substance Characteristics	Persistent, long-lasting pollutants with low degradation (e.g., DDT).	Long biological half-life, fat-soluble, and insoluble in water (e.g., DDT).
Key Example	Accumulation of mercury in fish.	Increase in mercury concentration from small fish to larger predatory fish to humans.
Impact on Organism	Affects individual organisms, leading to potential toxicity or health issues.	Amplifies impact at higher trophic levels, affecting entire ecosystems.
Process	Within a single organism over its lifetime.	Across the food chain through predator-prey relationships.

NUTRIENT CYCLING (BIOGEOCHEMICAL CYCLES)

- Energy flow and nutrient circulation are vital functions in ecosystems. While energy is lost as heat and is non-recoverable, nutrients from food matter can be recycled indefinitely. Essential elements like carbon, hydrogen, oxygen, nitrogen, and phosphorus play critical roles in living organisms. Nutrient cycling refers to the continuous movement of these elements between living and non-living components of the ecosystem.
- **Types of Nutrient Cycles**
- Nutrient cycles are classified into **perfect** and **imperfect** types based on the speed of replacement.
  - **Perfect Nutrient Cycle:** Nutrients are replenished as quickly as they are used. Gaseous cycles, such as the carbon, nitrogen, and water cycles, are typically perfect, with rapid nutrient replacement.
  - **Imperfect Nutrient Cycle:** Nutrients are not replaced as quickly as they are consumed, often linked to sedimentary cycles. Some nutrients become locked in sediments and are temporarily unavailable.
  - **Gaseous Cycle:** In this cycle, the atmosphere or hydrosphere acts as the reservoir. Examples include the water, carbon, nitrogen, and methane cycles.
  - **Sedimentary Cycle:** The earth's crust serves as the reservoir for sedimentary cycles. Examples include the phosphorus, sulfur, calcium, and magnesium cycles.

CARBON CYCLE

It involves an exchange between the atmosphere and organisms. Typically considered a **short-term cycle.** Cycle steps include: **[UPSC 2011]**

- Carbon is mainly in the form of carbon dioxide in the atmosphere.
- **Photosynthesis** absorbs carbon into green plants and phytoplankton.
- **Respiration and decomposition** return carbon to the atmosphere.
- Some carbon enters a long-term cycle in marshy soil, aquatic sediments, or fossil fuels. Long-term carbon may take a long time to be released, such as in marshy soil or bottom sediments. In deep oceans, carbon can remain buried for millions of years until geological movements expose rocks above sea level.

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- **Fossil fuels (coal, oil, natural gas)** are organic compounds that were buried before getting decomposed. Through geological processes, they transformed into fossil fuels. When burned, the stored carbon is released back into the atmosphere as carbon dioxide.
- **Congo Basin** has the world's largest tropical peatland, which holds about three years worth of global carbon emissions from fossil fuels; and the possible destruction of which can exert detrimental effect on the global climate. **[UPSC 2024]**

NITROGEN CYCLE

- Nitrogen in the atmosphere is converted into ammonia, nitrites, or nitrates in the nitrogen cycle.
- **Sources of Nitrogen:** **[UPSC 2013]**
  - Lightning, ultraviolet radiation, industrial processes, forest fires, automobile exhausts, and thermal power-generating stations contribute to atmospheric nitrogen oxides (NO, NO_2, N_2O).
  - Animal waste like urea, uric acid, dead vegetation & organisms add nitrogen as nitrates directly into the soil.
  - Burning coal releases CO, CO_2, sulphur dioxide and nitrogen oxides. Oxides of nitrogen fall on earth as smog and acid rain. Acidic rain is a complex mixture of nitrous, nitric, sulphurous, and sulfuric acids.

Nitrogen Cycle Steps: N_2 Fixing → Nitrification → Ammonification → Denitrification.

- **Nitrogen fixation** is done by N_2-fixing microbes, industrial processes, and lightning.
- **N2-fixers:** Microbes with nitrogenase (nitrogen reduction enzyme) fix atmospheric nitrogen into ammonia and ammonium ions. Examples include free-living soil bacteria **(e.g., Azotobacter), symbiotic nitrogen-fixing bacteria (e.g., Rhizobium), and some cyanobacteria.**
- **Nitrogen-fixing plants** include Alfalfa, Chickpea, Clover , Peas, Beans , Soybean and Lentils . These plants improve soil fertility by converting atmospheric nitrogen into forms usable by plants. **[UPSC 2022]**
- **Nitrification** oxidizes ammonia to nitrites and nitrates. Ammonium ions are oxidized to nitrites and then to nitrates by specialized nitrifying bacteria (**Nitrosomonas, Nitrococcus, Nitrobacter**). **Nitrates are absorbed by plants** and reduced to ammonia in leaves, forming amino acids.
- **Ammonification:** Bacteria convert nitrogenous waste products (urea, uric acid) and dead remains into ammonia/ ammonium ions.
- **Denitrification** reduces nitrates to elemental nitrogen, e.g by special denitrifying bacteria (**pseudomonas and thiobacillus**). This nitrogen escapes into the atmosphere, thus completing the cycle.

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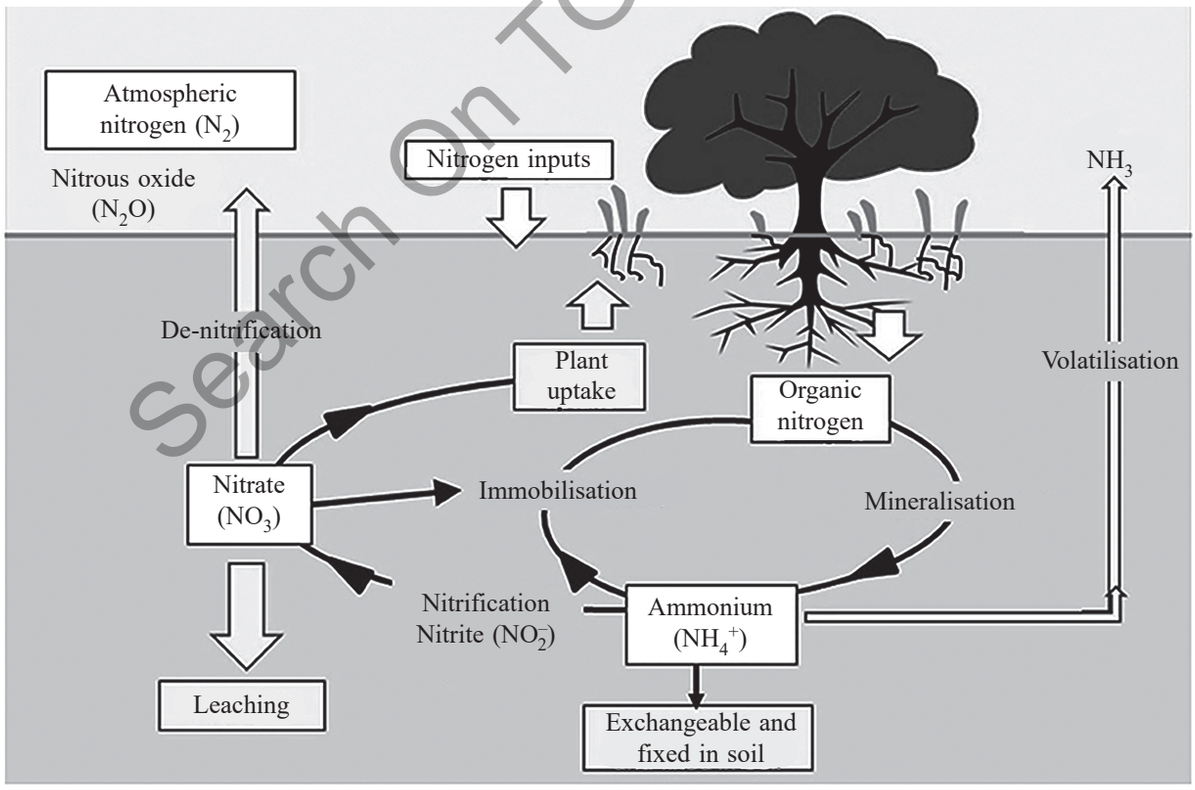

Fig: Nitrogen Cycle

OXYGEN CYCLE

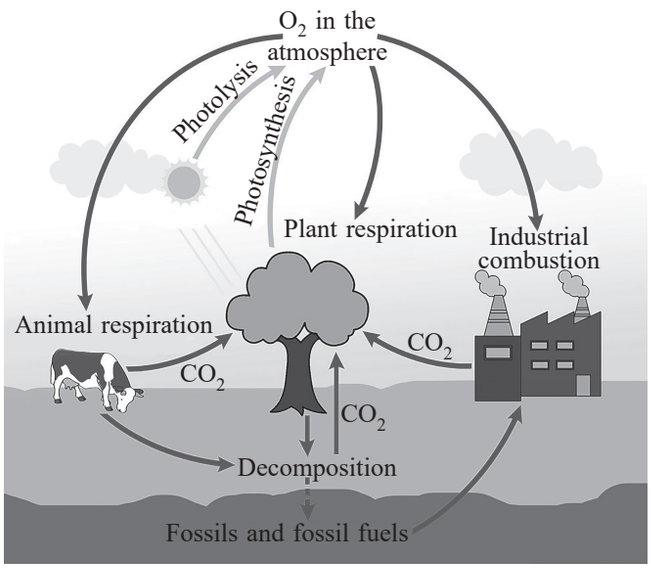

Fig. Oxygen Cycle

The oxygen cycle regulates oxygen (O_2) distribution in Earth's atmosphere, biosphere, hydrosphere, and lithosphere, supporting life processes like respiration and combustion. Understanding the cycle is key to ecosystem dynamics and global biogeochemical cycles.

Reservoirs of Oxygen:

- **Atmosphere:** 21% oxygen, produced by photosynthesis.
- Biosphere: Oxygen in biological molecules, produced by photosynthesis and consumed in respiration.
- **Hydrosphere:** Oxygen dissolved in water, supporting aquatic life.
- **Lithosphere:** Oxygen in Earth's crust, cycled through geological processes.

Flow Processes:

- **Photosynthesis:** Organisms like plants and algae produce oxygen using sunlight, water, and CO_2.
- **Respiration:** Organisms consume oxygen for energy, producing ATP and water.
- **Combustion:** Rapid oxidation of organic matter releases energy, heat, and CO_2.
- **Diffusion and Exchange:** Oxygen moves between reservoirs, supporting metabolic functions.

Exchanges:

- **Atmosphere-Biosphere:** Oxygen is produced by photosynthesis and consumed during respiration.
- **Hydrosphere-Lithosphere:** Oxygen exchanges in aquatic environments and through geological processes.
- **Human Activities:** Deforestation reduces oxygen production, while urbanization and industry contribute to oxygen depletion.

METHANE

- Methane (CH_4) is a more potent greenhouse gas (GHG) than carbon dioxide (CO_2). Despite its potency, methane has a shorter atmospheric lifetime than carbon dioxide.
- **Natural Sources of Methane:**

Natural Source	Description
Wetlands	Methanogens (prokaryotic archae-bacteria) in hypoxic (low oxygen) conditions produce methane during the decomposition of organic matter. Wetlands contribute approximately 80% of global methane (CH_4) emissions from natural sources.
Termites	Microbes in the guts of termites produce methane through anaerobic fermentation during digestion.
Oceans	Methane is produced by:
	• Anaerobic digestion in marine zooplankton and fish.
	• Methane production in sediments and drainage areas.
Methane Hydrates	Formed when hydrogen-bonded water and methane gas interact under high pressures and low temperatures in oceans. Found as crystalline ice in deep ocean sediments or trapped in permafrost.
	Destabilization Risks: Ocean acidification, climate change, or anthropogenic disturbances can release large amounts of methane, potentially causing mass extinction.

- **Human Sources of Methane Emissions:** Globally, 50-65% of total CH_4 emissions come from human activities, with significant contributions from: Agriculture (40%), Fossil Fuels (35%), Waste (20%).
- **Specific Human Sources:**

Human Source	Description
Landfills	Methane is generated as waste decomposes under anaerobic conditions.
Wastewater Treatment	Methane is produced during treatment processes if conducted in the absence of oxygen (anaerobic conditions).
Fossil Fuels	Methane is released during the production, storage, and transmission of natural gas. Additionally, methane trapped in coal deposits is released during coal mining (Coalbed Methane).

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Livestock	Domesticated livestock, such as cattle, emit methane during their digestive processes (enteric fermentation).
Rice Cultivation	Flooded rice fields produce methane as organic matter decomposes under water.
Biomass Burning	Incomplete combustion of organic matter releases methane.

Human source > Natural Source

Natural Source: Wetlands > Termites > Oceans > Methane Hydrates

Human Source: Agriculture > Fossil Fuels > Waste

- **Methane Sink:** Soils act as a major sink for atmospheric methane through methanotrophic bacteria that use methane in a process called Methane Oxidation.
- **Removal from Atmosphere:** Methane is removed from the atmosphere by reacting with the hydroxyl radical (OH), converting it to CO_2 and water vapor. Hydroxyl radicals (cleanser of the atmosphere) are a form of sink because they scrub the atmosphere clean of pollutant molecules and break them down.
- **Impact of Methane:** Contributes to the formation of ground-level ozone, a dangerous air pollutant. Methane hydrates can release a significant amount of methane with warming, contributing to climate change.

THE PMOH CYCLE: PHOTOSYNTHESIS, METHANOGENESIS, AND HYDROXYL RADICAL CYCLE

The PMOH cycle describes the interconnected processes of carbon and methane transformations within ecosystems, involving photosynthesis, methanogenesis, and hydroxyl radical oxidation.

Photosynthesis: Carbon Fixation and Biomass Creation

- **CO_2 Utilization:** Atmospheric and soil-respired CO_2 is fixed by plants into glucose via the **Calvin Cycle**.
- **Conversion:** Glucose is transformed into various carbon compounds such as **proteins**, **monoterpenes**, **fats**, **cellulose**, and **root exudates**.
- **Biomass Role:** Part of the CO_2 becomes plant biomass, some is stored, and some is respired back into the atmosphere to be reused in photosynthesis.

Methanogenesis: Rumen Fermentation

- **Consumption by Cattle:** Cellulose in plant biomass is ingested by ruminants like cattle.
- **Fermentation in Rumen:** Microbial communities, including methanogenic archaea, convert cellulose into:
  - **Short-Chain Fatty Acids (SCFAs):** Utilized by cattle to build fats and proteins.
  - **Hydrogen (H_2):** An intermediate by-product.
  - **Methane (CH_4):** Released as a by-product primarily through "burping."

Hydroxyl Radical Oxidation: Methane Breakdown

- **CH_4 in Atmosphere:** Methane released into the atmosphere interacts with **hydroxyl radicals (OH)** via **hydroxyl oxidation**, breaking down into:
  - **CO_2:** Reintroduced into the photosynthesis cycle.
  - **Water Vapor (H_2O):** Joins the hydrological cycle, contributing to rain or forming more hydroxyl radicals through interaction with excited oxygen.

Cycle Repetition

- The CO_2 and H_2O produced re-enter the photosynthesis process, completing the PMOH cycle.

Significance of the PMOH Cycle

- **Carbon Recycling:** Efficient use of CO_2 through fixation, biomass conversion, and methanogenesis.
- **Methane Dynamics:** Role of livestock and microbial methanogenesis in the carbon cycle.
- **Atmospheric Methane Regulation:** Hydroxyl oxidation as a natural mechanism for CH_4 breakdown, mitigating its greenhouse effect.
- **Ecosystem Interconnectivity:** Integration of biological, atmospheric, and hydrological processes.

PHOSPHORUS CYCLE

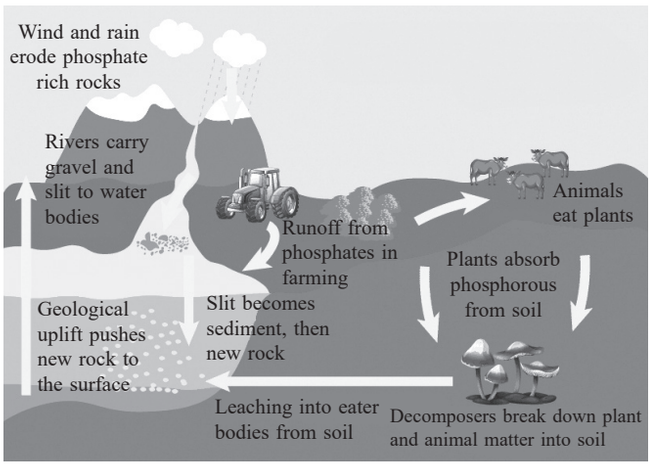

Fig. Phosphorus Cycle

- Phosphorus cycle involves the movement of phosphates from rocks to rivers and oceans, then back to the crust through geological processes.
- **Sources of Phosphorus:** Phosphorus occurs as a mineral in phosphate rocks, unlike carbon and nitrogen that come primarily from the atmosphere.

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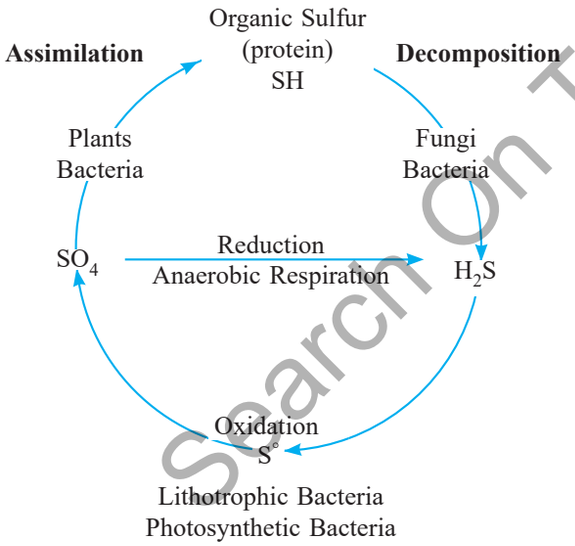
- **Phosphorus Cycle Steps:**
  - Weathering, erosion, and mining release phosphates, which enter rivers and oceans. **[UPSC 2021]**
  - In the ocean, phosphates accumulate on continental shelves as insoluble deposits.
  - Over millions of years, crustal plates rise from the seafloor, bringing phosphates to the crust, and the geochemical phase of the cycle repeats.
  - Phosphorus plays a central role in aquatic ecosystems and water quality, contributing to phytoplankton blooms in lakes and eutrophication

SULPHUR CYCLE

- The sulphur cycle includes atmospheric input, deposition as acid rain, plant uptake, transfer through the food chain, and return to soil and water through excretion and decomposition.
- **Sources of Sulphur:** Sulphur is locked in organic (coal, oil, peat) and inorganic (pyrite rock, sulphur rock) soil deposits as sulphates, sulphides, and organic sulphur. Released by weathering of rocks, erosional runoff, and decomposition of organic matter, it is carried to terrestrial and aquatic ecosystems in salt solutions.
- **Steps in the Sulphur Cycle**



  - **Atmospheric Input:** Sulphur enters the atmosphere as sulphur dioxide from volcanic eruptions, combustion of fossil fuels, ocean surfaces (Dimethyl Sulfide - DMS), and gases released by decomposition. DMS is an organosulfur compound derived from marine algae, plants, and animals, serving as a primary source of marine sulphate aerosols.
  - **Atmospheric Deposition:** Sulphur dioxide in the atmosphere is carried back to the earth as weak sulphuric acid (acid rain).
  - **Plant Uptake:** Sulphates in the form of atmospheric deposition or other sources are taken up by plants. Incorporation into sulphur-bearing amino acids occurs through metabolic processes.
  - **Food Chain Transfer:** Sulphur, incorporated into amino acids, passes through the grazing food chain.
  - **Return to Soil and Water:** Sulphur bound in living organisms is returned to the soil, bottom of ponds, lakes, and seas through excretion and decomposition of dead organic material.

ECOSYSTEM SERVICES AND GOODS

Ecosystem services

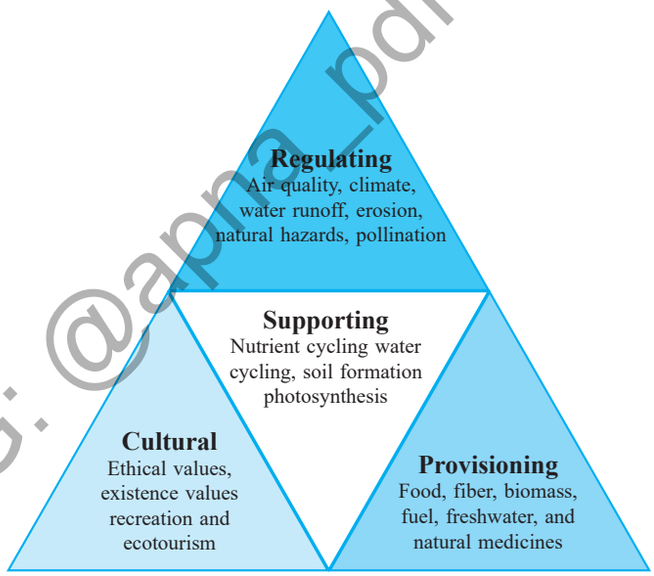


Fig. Ecosystem services

- Diverse benefits provided to humans by the natural environment and from healthy ecosystems.
- The Millennium Ecosystem Assessment describes the following major categories of ecosystem services: cultural, provisioning, regulating and supporting. **[UPSC 2012]**

Ecosystem goods

- Natural products harvested by humans from the environment, such as wild fruit and nuts, forage, timber, game, natural fibres, medicines, etc. For Example- Lemongrass is used in preparing a natural mosquito repellent. **[UPSC 2021]**
- **Natural Capital:** ecosystems providing invaluable ecosystem services. E.g., Flood protection by mangroves.

Ecosystem Valuation

Economic process assigning monetary value to an ecosystem and its services; tool for policymakers to evaluate management impacts and compare a cost-benefit analysis of potential policies.

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The Economics of Ecosystems and Biodiversity (TEEB) [UPSC 2016]

- Study hosted by the United Nations Environment Programme (UNEP) and led by Indian environmental economist Pavan Sukhdev.
- **Objectives:** To establish a global standard for natural capital accounting, mainstream the values of biodiversity and ecosystem services into decision-making at all levels, and highlight the growing cost of biodiversity loss.

ECOSYSTEM PRODUCTIVITY

Ecosystem productivity refers to the rate at which energy is produced and transferred within an ecosystem. It is measured as the generation of biomass. [**UPSC 2013**]

Ecosystem Productivity

Ecosystem productivity refers to the rate at which energy is captured and stored by producers (like plants) in an ecosystem. It is categorized as:

- **Gross Primary Productivity (GPP):** Total energy fixed by plants through photosynthesis.
- **Net Primary Productivity (NPP):** Energy left after plants use some for respiration (NPP = GPP – Respiration).

Factors Influencing Productivity

- **Climate:** Temperature, sunlight, and water availability.
- **Nutrient Availability:** Higher nutrients often lead to higher productivity.
- **Biodiversity:** More species can lead to efficient energy utilization.

Productivity Ranking of Major Ecosystems

Ecosystem	NPP ($g/m^2/year$)	Characteristics
Tropical Rainforests	~2,200	High sunlight, temperature, and rainfall; dense biodiversity.
Coral Reefs	~2,000	Warm, shallow waters with symbiotic relationships (e.g., coral and algae).
Estuaries	~1,800	Nutrient-rich zones where rivers meet the sea; high productivity and fish nurseries.
Temperate Forests	~1,200	Seasonal climates with moderate rainfall and biodiversity.
Grasslands	~600-800	Open lands with grasses; moderate productivity due to limited water.
Lakes and Rivers	~250-500	Productivity varies with nutrient content and sunlight penetration.
Deserts	~50-200	Extremely low due to harsh climates and water scarcity.
Open Oceans	~125	Low nutrient availability limits productivity despite vast area.
Tundra	~100	Cold, harsh conditions with short growing seasons limit productivity.

Global Importance

- **Tropical Rainforests:** Major oxygen producers, carbon sinks, and biodiversity reservoirs.
- **Coral Reefs and Estuaries:** Critical for marine biodiversity and coastal economies.
- **Grasslands and Temperate Forests:** Vital for agriculture and timber industries.
- **Deserts and Oceans:** Though less productive, deserts are key for specific biodiversity, and oceans are critical for global carbon cycling.

Secondary Productivity

Secondary productivity refers to the rate at which energy is assimilated by consumers (herbivores, carnivores, omnivores, and detritivores) in an ecosystem. It represents the transfer of energy from producers to higher trophic levels through consumption.

Importance of Secondary Productivity

- **Energy Transfer:** Determines the energy available to higher trophic levels, including apex predators.
- **Ecosystem Stability:** Supports food webs and species diversity.
- **Human Relevance:** Impacts food production systems, including livestock and fisheries.

TYPES OF ECOSYSTEMS

There are broadly **two types** of ecosystems:

- **Natural Ecosystem:** An assemblage of plants and animals which functions as a unit and can maintain its identity on its own.
  - Terrestrial Ecosystem /Biomes
  - Aquatic Ecosystem
- **Artificial Ecosystem:** Human-made structures where biotic and abiotic components are made to interact with each other for survival. It is not self-sustaining and can perish without human help. Eg: aquariums, agriculture fields, zoos, etc.

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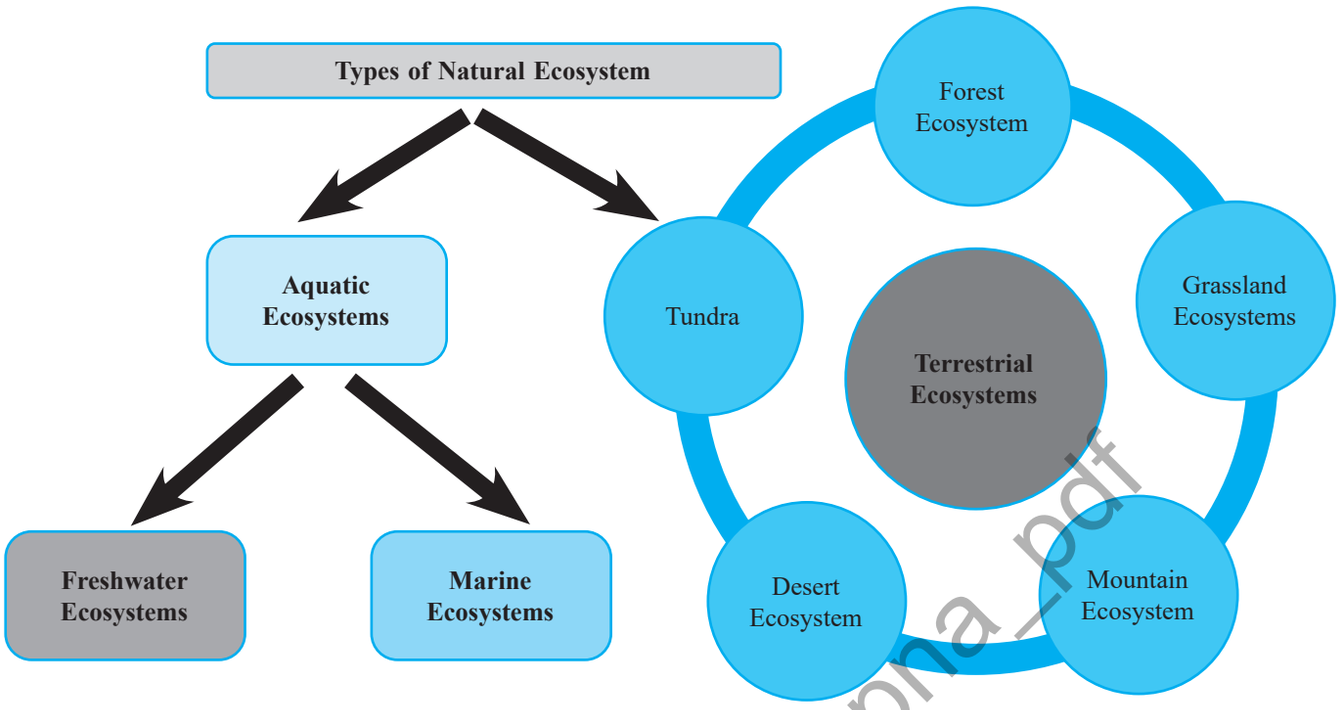


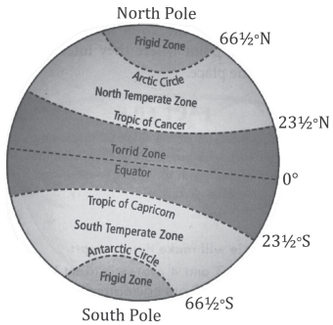
Fig. Types of natural Ecosystem

Terrestrial Ecosystem Vs Aquatic Ecosystem

Aspect	Aquatic Ecosystems	Terrestrial Ecosystems
Habitat	Water bodies like oceans, rivers, lakes, and ponds.	Land surfaces, including forests, grasslands, deserts, and mountains.
Primary Producers	Algae, phytoplankton, and aquatic plants.	Grasses, trees, shrubs, and other terrestrial plants.
Primary Consumers	Zooplankton, fish, aquatic insects, and mollusks.	Herbivores like insects, birds, mammals, and reptiles.
Secondary Consumers	Predatory fish, larger aquatic insects, and carnivorous mammals like otters.	Predators like carnivorous mammals (e.g., lions, wolves), birds of prey, and snakes.
Oxygen Availability	Dissolved oxygen in water for aquatic organisms.	Atmospheric oxygen for terrestrial organisms.
Adaptations	Specialized structures like gills for respiration and fins for movement.	Features like lungs for respiration and limbs for movement.

TERRESTRIAL ECOSYSTEMS

These are exclusively **land-based** ecosystems. **The terrestrial part of the biosphere is divisible into enormous regions called biomes**. No two biomes are alike.



Tundra

- Two types of tundra – **Arctic and Alpine.**
- **Devoid of trees due to permafrost**, the lowest form of vegetation like mosses and lichens are sparsely found on bare rocks, coastal lowlands have reindeer moss which provides the only pasturage for reindeer.

[UPSC 2021]

- **Animals:** Reindeer, arctic fox, wolves, musk ox, polar bear, lemming, arctic hare, and arctic willow. **Reptiles and amphibians are almost absent**.
  - **Adaptation:** Most animals have a long life, thick cuticle and epidermal hair or fur. **Mammals have a large body size, small tails and ears to avoid heat loss from the surface**.

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Forest

Taiga or Boreal Biome (Evergreen Coniferous forests)

- **Lowest productivity** amidst all forest ecosystems (harsh weather, thin and poor soils for agriculture. i.e., podzols).
- **Podzols** are very poor because weathering of rocks proceeds slowly in cold climates; litter derived from conifer leaves decomposes very slowly and is **not rich in nutrients** (low humus and organic matter, acidic soil, poor drainage, low pH); conifers do not shed their leaves frequently.
- **Vegetation:** Evergreen coniferous forest with species such as spruce, fir, and pine(require little moisture).
- **Animals:** Siberian tiger, wolverine, lynx, wolf, bear, red fox, squirrel, and amphibians like Hyla, Rana, etc.

Temperate Deciduous Biome (North Western Europe – British Type Climate)

- **Podzolic** and fairly **deep soil**.
- **Vegetation:** Deciduous (trees shed their leaves in the cold season); adaptation for protecting themselves against winter snow and frost. Shedding begins in autumn. Growth begins in spring. Eg: oak, elm, ash, birch, beech, and poplar.

Temperate Rainforest Biome

- **Less percentage of area** covered over Earth (north-western coast of N. America from N. California through S. Alaska; small areas in S. Chile, New Zealand, Australia and a few other places worldwide)
- **Vegetation:** Large coniferous trees including Douglas fir, Western red cedar, Mountain hemlock, Western hemlock, Sitka spruce, Lodgepole pine, mosses and lichens often growing as epiphytes (a plant that grows harmlessly upon another plant (commensalism)).

Sub-Tropical Deciduous Biome in Eastern China, South Eastern USA

- **Luxuriant vegetation:** Lowlands- both evergreen broadleaved forests and deciduous trees (hardwood). Highlands- various species of conifers, such as pines and cypresses.

Temperate Deciduous Biome (Mediterranean Climate)

- **Xerophytic** (drought tolerant) plants due to heat, dry air, excessive evaporation, and prolonged droughts.
- **Small broad-leaved trees** are widely spaced, never very tall.
- **Low, broad-leafed evergreen trees** (mostly evergreen oaks) in regions of adequate rainfall.
- **Frequent fire episodes**, adaptations of the plants enable them to regenerate quickly after being burnt.

Tropical Deciduous Biome (Monsoon Climate)

- **Drought-deciduous/dry deciduous/tropical deciduous forests**.
- **Vegetation:** Teak, neem, bamboo, sal, sheesham, sandalwood, khair, mulberry

Tropical Rainforest Biome [UPSC 2013]

- High temperatures, abundant rainfall, luxuriant evergreen rainforests (lungs of the Earth), large number of species and epiphytes.
- **Vegetation:** mahogany, ebony, dyewoods, etc., mangrove forests (salty water).
- All plants, including epiphytes, struggle upwards for sunlight resulting in a peculiar layer arrangement **(canopy)**.
- In recent years **threatened by deforestation and burning**, 17 per cent of the entire rainforest and about 20 per cent of the Brazilian rainforest have been deforested.
- If a tropical rainforest is removed, it does not regenerate quickly as compared to a tropical deciduous forest. This is because the soil of the rainforest is deficient in nutrients. **[UPSC 2012]**

Importance of Rainforests

- Produce ~20% of the earth's oxygen and act as **Carbon sink.**
- **Precipitation:** Responsible for creating 50-75 % of their precipitation through evapotranspiration.
- **Source of many rivers:** Amazon, Mekong, and Congo (Zaire) are fed by the rainforests.
- **Biodiversity:** >30 million species of plants and animals (half of the earth's wildlife and at least ⅔ rd of its plant species)
- **Commercial Agriculture:** Conducive climate for cultivating coffee, cocoa, palm, rubber, etc. (100-200 cm of rainfall).
- **Indigenous communities:** depend on it for their food, shelter, medicines and subsistence agriculture (slash-and-burn agriculture).
- Controls **local and regional climates** as well as influences the **circulation of ocean currents.**

Mushroom [UPSC 2023]

Some mushrooms exhibit diverse properties. Medicinal mushrooms like *Ganoderma lucidum* boost immunity and have anti-cancer benefits. Psychoactive species, such as *Psilocybe,* contain psilocybin, influencing brain activity. Insecticidal mushrooms like *Beauveria bassiana* are used for pest control, while bioluminescent varieties, such as *Mycena chlorophos*, produce natural light. These properties make mushrooms valuable in medicine, pest control, and ecological studies.

Grassland

Steppe or Temperate Grassland Biome

- **Practically treeless**, grasses are much shorter, fresh, and nutritious.
- Poleward, **transition to a zone of wooded steppes** due to increase in precipitation (some conifers may gradually appear).
- Do **not have much animal diversity**.

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Savanna or Tropical Wet and Dry Biome (Tropical Shrublands and Grasslands)

- Characterised by **tall grass and short trees** (deciduous, umbrella-shaped broad trunks with water-storing devices, shed leaves in the cool dry season to prevent water loss through transpiration, **e.g., acacias**.
- **Rich in mammal, bird, and reptile diversity**.
- The vegetation of savannah consists of grassland with scattered small trees, but extensive areas have no trees. The forest development in such areas is generally kept in check by one or more or a combination of some conditions.
- In the grasslands, trees do not replace the grasses as a part of an ecological succession because of Water limits (due to seasonal rainfall) and fire. **[UPSC 2013, 2021]**
- **Managed Fires:** Lighting dry savanna grasslands is a key ecosystem management activity by cattle farmers and authorities to stimulate the growth of fresh, nutritious grass for their animals, control the numbers of parasitic ticks or manage the growth of thorny scrub.
- **Fires in savannahs are carbon-neutral:** burn mainly dry grasses (CO_2 released is reabsorbed by growth of new grass).

Desert

Tropical and Mid-Latitude Desert Biome

- **Vegetation:** xerophytic or drought resistant. Eg: cacti, thorny bushes, long-rooted wiry grasses, scattered dwarf acacias.
- **Herbs and grasses:** Thick, tough skins of seeds to protect them while they lie dormant.
- **Shrubs:** long, well-spaced roots to gather moisture and search for groundwater.
- **Plants:** Few or no leaves; waxy, leathery, hairy, or needle-shaped foliage to reduce water loss through transpiration. **[UPSC 2018]**

AQUATIC ECOSYSTEM

Ecosystems present in a **body of water**. Broadly classified into **three sub-groups** based on salinity:

- **Freshwater Ecosystem:** low salt content due to continuous recycling of water; < 5 ppt). 2 types:
  - **Static/still water (Lentic) ecosystems:** ponds, lakes, bogs and swamps
  - **Running water (Lotic) ecosystems:** Springs, streams, rivers, etc.
- **Marine Ecosystem:** salt concentration **equal to or > seawater (i.e., 35 ppt or above)**. E.g., shallow seas and open oceans.
- **Brackish water ecosystems:** salt content **between 5 - 35 ppt.** e.g., estuaries, salt marshes, mangrove swamps and mangrove forests.

Classification of Aquatic Organisms (based on the zone of occurrence)

- **Neuston:** Live at the air-water interface, e.g. floating plants.
- **Periphyton:** Remain attached to stems and leaves of rooted plants or substances emerging above the bottom mud, such as sessile algae. e.g. Water striders (insects), some species of algae.
- **Plankton:** Microscopic floating organisms such as algae (plant-like protists), diatoms, protozoans, larval forms, etc.
  - Includes microscopic plants like algae (phytoplankton – primary producers or autotrophs), animals like crustaceans and protozoans (zooplankton – heterotrophs).
  - If phytoplankton of an ocean is completely destroyed for some reason, the ocean as a carbon sink would be adversely Affected and the food chains in the ocean would be adversely affected. **[UPSC 2012]**
  - Locomotory power of the planktons is limited so that their distribution is controlled, essentially, by currents in the aquatic ecosystems.
- **Nekton:** Powerful swimmers that can overcome water currents.
- **Benthos:** Found living at the bottom of the water mass. e.g. Fish, turtles, squid

Phytoplankton

- Tiny microscopic **autotrophs** found in the ocean. They have **chlorophyll** to capture sunlight and use photosynthesis to turn it into chemical energy.
- All phytoplankton **photosynthesise,** but some get additional energy by consuming other organisms.
- Phytoplankton include **diatoms [UPSC 2021], dinoflagellates, cryptomonads, green algae, blue-green algae, etc.**, which are at the base of the aquatic food web and are important ecological indicators.
- They **contribute to more than half of the oxygen that we breathe** and influence climate by absorbing human-induced CO_2.

Factors Limiting Productivity of Aquatic Ecosystems

Sunlight	• Determines the extent of plant distribution according to light penetration- photic and aphotic zones. • **Photic (euphotic) zone):** extends from the water surface down to where the light level is 1% of that at the surface. Photosynthetic activity is confined to the photic zone. • **Aphotic (profundal) zone:** light penetration and plant growth are restricted. It extends from the end of the photic zones to the bottom of the lake. No photosynthesis.

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Dissolved Oxygen	• **Freshwater:** the average concentration of dissolved oxygen is **10 ppm by weight** (150 times lower than the concentration of oxygen in an equivalent volume of air).
	• Oxygen enters: through the air-water interface and the photosynthetic activities of aquatic plants.
	• Dissolved oxygen escapes: through the air-water interface, respiration, and decomposition of organisms.
	• **Winterkill:** fish mortality event due to appearance of a layer of ice on top of a water body that effectively cuts off the light. Photosynthesis stops, but respiration continues causing depletion of dissolved oxygen, and the fish die.
	• **Impact of Global Warming on Dissolved Oxygen**
	  ○ The amount of dissolved oxygen retained in water is indirectly proportional to temperature. Oxygen is less soluble in warm water.
	  ○ Warm water also enhances decomposer activity which further increases the rate at which oxygen is depleted in water. If dissolved oxygen levels fall below 3-5 ppm, many aquatic organisms are likely to die.

Temperature	Aquatic organisms are more prone to survival threats compared to terrestrial organisms owing to narrow temperature tolerance limits.
Eutrophication	Process of o**ver-enrichment of water body with nutrients (nitrogen, phosphorus),** leading to the **plentiful growth of simple plant life (algae, plankton)** eventually leading to anoxic conditions for the seagrass and other organisms.

WETLAND ECOSYSTEM

What are Wetlands?

Definition of Wetlands

Wetlands are ecosystems where water is the dominant factor influencing the environment, as well as the plant and animal life within it. These areas occur where the water table is at or near the surface or where land is periodically or permanently submerged.

According to the Ramsar Convention (Article 1.1):

"Wetlands are areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water where the depth at low tide does not exceed six meters."

For site protection, Article 2.1 further expands the definition:

"Wetlands may include riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands."

Types of Wetlands

Wetlands are broadly categorized into five natural types and human-made types:

Natural Wetlands

1. **Marine Wetlands (Coastal):** Include coastal lagoons, rocky shores, seagrass beds, and coral reefs.
2. **Estuarine Wetlands:** Found in deltas, tidal marshes, mudflats, and mangrove swamps.
3. **Lacustrine Wetlands:** Associated with lakes and their surroundings.
4. **Riverine Wetlands:** Found along rivers and streams, including floodplains.
5. **Palustrine Wetlands:** Encompass marshes, swamps, bogs, and other marshy ecosystems.

Human-Made Wetlands

Examples include:

- Fish and shrimp ponds
- Farm ponds
- Irrigated agricultural land, such as rice paddies
- Salt pans
- Reservoirs and dams
- Gravel pits, wastewater treatment ponds, and canals.

The **Ramsar Classification of Wetland Types** includes 42 categories grouped into:

- **Marine and Coastal Wetlands**
- **Inland Wetlands**
- **Human-Made Wetlands**

Key Features of Wetlands

- **Global Distribution:** Wetlands exist across all climates, from the tundra to the tropics.
- **Extent of Wetlands:**
  - The UNEP-World Conservation Monitoring Centre estimates wetlands cover about 570 million hectares (~6% of the Earth's land surface).
  - Other sources estimate the range to be between **748–778 million hectares** (minimum) and **999–4,462 million hectares** (maximum), depending on the inclusion of additional data.
- **Significant Ecosystems:**
  - **Mangroves:** Cover approximately **147,256 km km^2** globally.
  - **Coral Reefs:** An estimated **600,000 km^2** remain worldwide.

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- **Marine Wetland Depth Criteria:**
  - Marine wetlands are considered up to a depth of **6 meters** at low tide, corresponding to the diving limit of sea ducks during feeding.
  - Waters deeper than 6 meters and islands within wetlands can also be protected under the Ramsar definition.
- **Inclusion of Lakes and Rivers:**
  - The Ramsar definition covers lakes and rivers entirely, irrespective of their depth.

Measures to Protect Wetlands of India

National Plan for Conservation of Aquatic Eco-systems (NPCA)	• **Centrally Sponsored Schemes (CSS)** to implement integrated and cross-sectoral conservation of aquatic ecosystems (lakes and wetlands); halting and reversing the continued degradation and loss of wetlands • Formed by merging the **National Lake Conservation Plan (NLCA) + National Wetlands Conservation Programme (NWCP).** • **Funding pattern of 70:30 (90:10 for the NE States)**. • **MOEF coordinates**, and provides guidelines and financial and technical assistance to the state govt. • **State/UT governments manage the aquatic ecosystems**. • Criteria for identifying wetlands of national importance under NPCA are similar to those under the Ramsar Convention on Wetlands.
Wetlands (Conservation-Management) Rules 2010	• MoEF notified **legally enforceable rules** under the provisions of the **Environment (Protection) Act, 1986**, to ensure that there is no further degradation of wetlands. • **Central Wetland Regulatory Authority (CWRA) (chairmanship of the Secretary, MoEF):** Ensure implementation of the Rules. • **Wetlands classification** for better management and easier identification. • **Specify and prohibit harmful activities** to wetlands (industrialisation, construction of permanent nature, solid waste dumping etc.) • **Activities** like aquaculture, agriculture, harvesting of living and non-living resources, dredging to remove siltation, etc., may be carried out in the wetlands but **only with prior permission** from the concerned authorities. • **Central Government may permit any prohibited activities** or non-wetland use in the protected wetland on the recommendation of CWRA. • Encompasses the drainage area or catchment regions of the wetlands as determined by the authority. **[UPSC 2022]**
Wetlands (Conservation and Management) Rules, 2017	• State Wetland Authority (SWA): • **Establishment** of a SWA in each state and union territory, led by the state's environment minister. • **Composed** of experts in hydrology, socioeconomics, landscape design, fisheries, and wetland ecology. • Management Principles: • **Adoption** of the "smart use principle" for sustainable wetland management. • **Emphasis** on "wise use" to balance conservation and utilization, with decentralized powers. • Regulatory Functions of SWA: • **Compilation** of activities requiring governance and approval within notified wetlands and their zones. • **Authority** to prohibit activities harmful to wetlands and promote better utilization plans. • **Community Engagement and Awareness:** SWA to **promote** awareness and **involve** local communities in wetlands conservation. • **National Wetland Committee (NWC): Creation** of NWC, **replacing** the Central Wetlands Regulatory Authority, led by the MoEFCC secretary. • **Prohibited Activities: Prohibition** on encroachment, industrial growth, waste disposal, and untreated waste discharge in wetlands. • **State-Level Responsibilities:** State authorities must **compile** lists of wetlands and **identify** those needing notification within six months. • **Digital Inventory: Development** of a comprehensive digital inventory of wetlands, **updated** every 10 years.

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RAMSAR CONVENTION

- **International treaty** established by **UNESCO** for " maintenance of ecological character for sustainable use of wetlands" signed on the **2nd Feb (World Wetlands Day)**, 1971, in the city of Ramsar in Iran.
- Covers over 2,400 Ramsar Sites, 2.5 million sq km worldwide. The number of parties is **172**. **India has been a party since 1982**.
- After acceding to the convention, a party must designate **at least one wetland** as a Wetland of International Importance.
- **2024 theme: 'Wetlands and Human Wellbeing'**
- **World's first site:** the **Cobourg Peninsula in Australia** (1974)
- Countries with the **most Ramsar Sites**: **United Kingdom** (175) and Mexico (142).
- Country with the largest area under Ramsar protection: **Bolivia**
- India's Ramsar wetlands are spread over **11,000 sq km — around 10% of the total wetland area in the country** — across 18 States.
- **Largest Site in India: Sundarbans** (West Bengal)

Criteria for Identification of Wetlands	• **Unique wetland:** Contains rare or unique examples of a natural or near-natural wetland type. • **Endangered species:** Supports threatened, vulnerable, endangered, or critically endangered species/ communities. • **Essential species:** Supports populations of plant and/or animal species important for maintaining biological diversity. • **Species protection:** Supports plant and/or animal species at a critical stage in their life cycles or provides refuge during adverse conditions. • **Waterbirds:** Regularly supports 20,000+ water birds. • **Single species of water birds:** Regularly supports 1% of the individuals in a population of one species or subspecies of water birds. • **Indigenous fish:** Supports a significant proportion of indigenous fish subspecies. • **Multirole:** Is an essential food source for fishes, spawning ground, nursery and/or migration path. • **Ecotourism:** Is an essential source of food and water resources, increased scope for recreation and ecotourism.
Removal from list	• Upon urgent **national interest** of contracting party (delete or restrict boundaries) • Deletions/restrictions **to be compensated** by creating additional nature reserves in the same area or elsewhere. • **No Ramsar Site** has ever been "deleted". Parties have only extremely rarely restricted the boundaries of a Site on this basis (success of Ramsar Convention).
Transboundary Sites	In these cases, **COP** allows the **establishment** of Ramsar Sites along with the **agreement of authorities on both sides** of the border to collaborate on-site management.
Montreux Record	• Register of Ramsar sites where **changes in ecological character** have **occurred**, are **occurring**, or are **likely to occur** as a result of technological developments, pollution or other human interference. **[UPSC 2014]** • Currently, **two wetlands of India are in Montreux record: Keoladeo National Park (Rajasthan)** and **Loktak Lake (Manipur).**
Contracting Parties (COP) to Ramsar Convention	• **Policy-making** organ. Meets every **3 years** at the Conference of the Contracting Parties (COP). • **COP14 (2022):** Held in a hybrid format in Wuhan, China, and Geneva, Switzerland. **Wuhan Declaration** and **2025-2030 Global Strategic Framework for Wetlands Conservation** were • adopted.
Responsibilities of the Contracting Parties	• To identify, and place suitable wetlands onto the Ramsar List. • **Expected (not mandated) to manage their Ramsar Sites** to maintain their ecological character and retain their essential functions and values for future generations. **[UPSC 2022]**

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International Organisation Partners (IOPs)	**The Ramsar Convention works closely with six organisations**: Birdlife International International Union for Conservation of Nature (IUCN) International Water Management Institute (IWMI) Wetlands International World Wide Fund for Nature (WWF) International Wildfowl & Wetlands Trust (WWT)

Wetlands International **[UPSC 2014]**

Global non-governmental organisation (NGO) to sustain and restore wetlands and their resources for people and biodiversity: includes research, advocacy, engagement with governments, corporate, etc.

LAKES

A lake is defined by the Ramsar Convention as "a body of water wholly or partly surrounded by land, containing permanent or temporary water." Lakes are typically larger than ponds, contain standing water, and can have connecting rivers and outlets. They are broadly classified as follows:

Classification of Lakes

- **Temporary Lakes:** Formed after heavy rainfall in undulating terrain; water evaporates quickly.
  - **Example:** Temporary lakes in the Thar Desert post-monsoon.
- **Permanent Lakes:** Maintain consistent water levels with precipitation exceeding evaporation.
  - **Example:** Wular Lake (Jammu & Kashmir), Chilika Lake (Odisha).
- **Freshwater Lakes: Contain freshwater, often fed by rivers with outflowing streams.**
  - **Example: Dal Lake (Jammu & Kashmir), Nainital Lake (Uttarakhand).**
- **Saline Lakes: High salt content due to rapid evaporation and lack of outlets.**
  - **Example: Great Salt Lake, Sambhar Salt Lake (Rajasthan).**
- **Natural Lakes:** Result from tectonic activity, landslides, or lagoon formation.
  - **Example:** Vembanad Lake (Kerala), Pangong Lake (Ladakh).
- **Artificial Lakes:** Human-made for purposes like irrigation, hydropower, or water supply.
  - **Example:** Dhebar Lake (Rajasthan), Gobind Sagar (Himachal Pradesh).

Oligotrophic Vs Eutrophic Lakes

Parameters	Oligotrophic	Eutrophic
Definition	Few nutrients, low primary productivity	Abundant nutrients, high primary productivity
Water Parameters	Low turbidity, high oxygenation at depth, and clear water	High turbidity, low oxygenation at depth, and water often is brown or with greenish tint
Primary Producers	Low concentration	High concentration
Primary Productivity	<100mg carbon/m^2 a day	>100mg carbon/m^2 a day
Consumers	Many fishes at deep level	Few fishes at deep level
Microbes	Reduced Biomass	Increased Biomass

Eutrophication Mitigation

- **Phytoremediation:** Use of plants to remove contaminants from soil and water. Estuarine vegetation/ Mangroves/ other wetland vegetation carry out natural phytoremediation.
- **Phytoextraction/phytoaccumulation** is the accumulation of contaminants into the roots/leaves of plants/ above ground shoots. An aquatic weed named **water hyacinth** can cleanse water by taking toxic materials and many heavy metals from water.

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ESTUARY

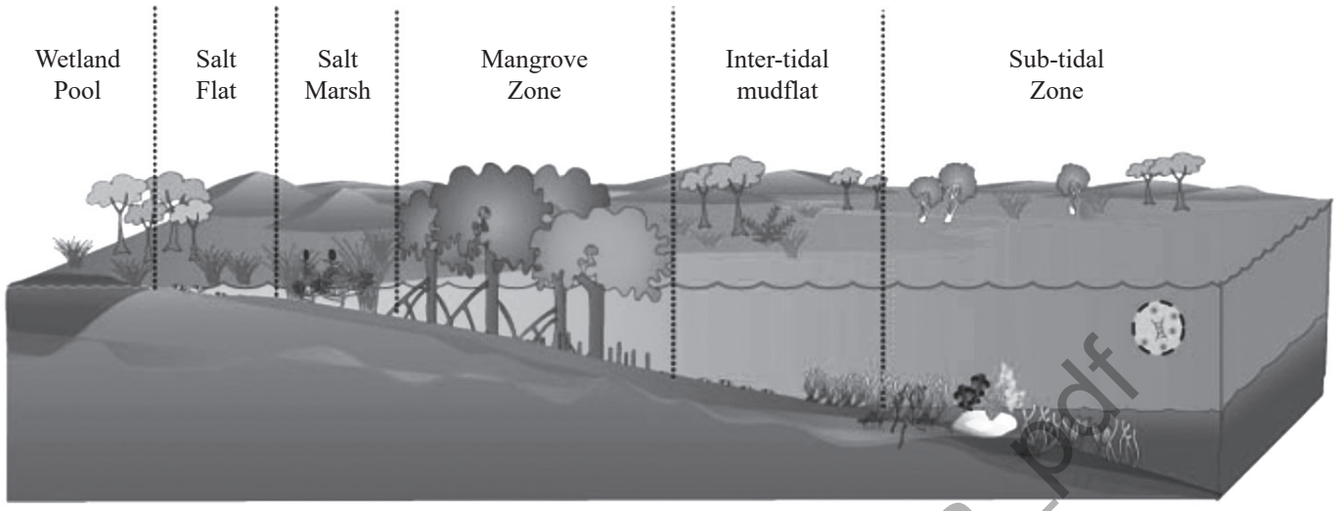

Fig. Estuarine Ecosystem

- **Definition: An estuary is a partially enclosed** coastal area of **brackish water** (salinity of **0-35** ppt) where a river or a stream opens into the sea (freshwater carrying fertile silt and runoff from the land mixes with salty seawater). Eg: **river mouths, coastal bays, tidal marshes, lagoons, and deltas**.
- **Formed due to:** rise in sea level, movement of sand and sandbars, glacial processes, and tectonic processes. They are greatly influenced by tidal action and are periodically washed by seawater once or twice a day based on the number of tides.
- In some narrow estuaries, **tidal bores are significant** (damage to the estuarine ecology).

Ecological Importance of estuaries	• **Most productive** (more productive than other wetlands) water bodies in the world due to mixing of freshwater and saline water zones where marine organisms of both ecosystems meet. • **Refuge from the open sea:** Due to minimal wave action, ideal for the survival of numerous aquatic species. Mangrove forests on the seaward side of an estuary act as a barrier for the coastal habitat to check the wind speed during cyclones and high-velocity landward winds. • **Precipitation of clay and alluvium particles:** Due to exposure to saline water. Mangroves trap suspended mud and sand carried by rivers which leads to delta formations around estuaries. • **Nutrient storage and recycling:** Trap sediment; buffer between coastal catchments and the marine environment; absorb, trap and detoxify pollutants, **acting as a natural water filter**.
Economic Importance of Estuaries	• ~60% of the **world's population live** along estuaries and coasts. • Rich in **natural resources**, including fisheries. • Ideal locations for the construction of **ports and harbours**: Deep and well protected from marine transgressions.

Estuarine Vegetation	• Salinity and flooding determine the distribution (diversity and density) of organisms.
	• **Diverse habitats:** Mangroves, salt marshes, seagrass, mudflats etc.
	• **Terrestrial plants and animals:** Wood storks, pelicans, coniferous and deciduous trees, and butterflies etc.
	• **Aquatic plants and animals:** Sea turtles, sea lions, sea catfish, salt grasses, seagrass, bulrush, etc.
	• **Phytoplankton:** Diatoms, dinoflagellates, green algae, and blue-green algae.
	  ❍ Towards the seacoast: algae and seagrasses.
	  ❍ Near the mouth of the rivers and deltas: mangrove forests.

Indian Estuarine Ecosystem	• 14 major, 44 medium, and 162 minor rivers drain into the sea • **The majority of major estuaries occur on the east coast**. • Estuaries on the west coast are smaller. ❍ **Serve as locations of major seaports.** E.g., Mormugao Port on the Zuari Estuary.

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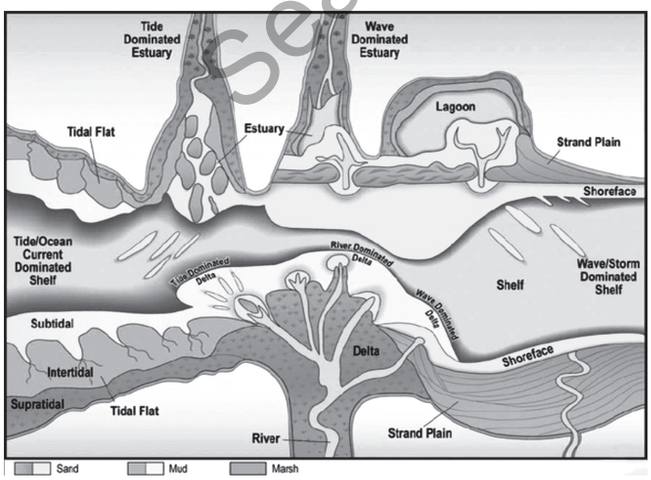
Threats Faced by the Estuarine Ecosystem	• **Changes in water flow** due to modifications of the catchments (E.g., Hooghly, Godavari, Pulicat, etc.). • **Pollution** through industries, city sewage discharge, feeding stocked fish and prawns in pens (Chilika). • **Navigation, dredging and shipping** (e.g. Hooghly). • **Expansion of urban and rural settlements**, mining and industries, agriculture and dumping of solid wastes. • **Intensive aquaculture** in pens and obstructing the migratory routes of fish and prawns (e.g., Chilika, Pulicat). • **Biodiversity destruction** through prawn seed collection through small-meshed nets (e.g., Hooghly, Chilika, Pulicat). • **Submergence** of catchment areas due to water level rise.

LAGOON

- Stretch of salt water separated from the sea by a low sandbank or coral reef. E.g: backwaters in Kerala where seawater flows inwards through a small inlet that is open towards the sea.
- The water is shallower and flows sluggishly compared to fast-flowing water in estuaries.

Name	Location	Type	Rivers Feeding It	Significance
Chilika Lake	Odisha	Brackish water lagoon	Daya and Bhargavi Rivers	Asia's largest brackish water lagoon, major stop for migratory birds, rich biodiversity.
Kaliveli Lake	Tamil Nadu	Wetland and lagoon	Local runoff and monsoonal rains	Ramsar Wetland site, known for birdlife, especially migratory birds.
Kayamkulam Kayal	Kerala	Lagoon	Pamba and Achankovil Rivers	Major lagoon in Kerala, important for fisheries and biodiversity.
Muthupet Lagoon	Tamil Nadu	Coastal lagoon	Koriayar and Pamaniyar	Known for mangrove forests, biodiversity, and importance to local fisheries.
Pulicat Lake	Tamil Nadu, Andhra Pradesh	Brackish water lagoon	Arani and Kalangi Rivers	One of India's largest lagoons, vital for migratory birds and fisheries.
Vembanad Lake (Punnamada Lake or Kochi Lake)	Kerala	Freshwater lake with lagoon features.	Meenachil, Pamba, Achankovil Rivers	Longest lake in Kerala, important for ecology, tourism, and aquatic life. It contains Kutannad-Rice Bowl of Kerala.



MANGROVES

- Salt-tolerant (halophytes) evergreen shrubs or small trees (vary in height from 8 to 20 m) that represent a characteristic littoral (near the seashore) forest ecosystem.
- Grow below the high water level of spring tides. Best locations are where abundant silt is brought down by rivers or on the backshore of accreting sandy beaches. Includes brackish waters of sheltered low-lying coasts, estuaries, mudflats, tidal creeks, backwaters, marshes and lagoons of tropical and subtropical regions.
- Decreasing order of productivity: Mangroves, grasslands, lakes, oceans. **[UPSC 2013]**

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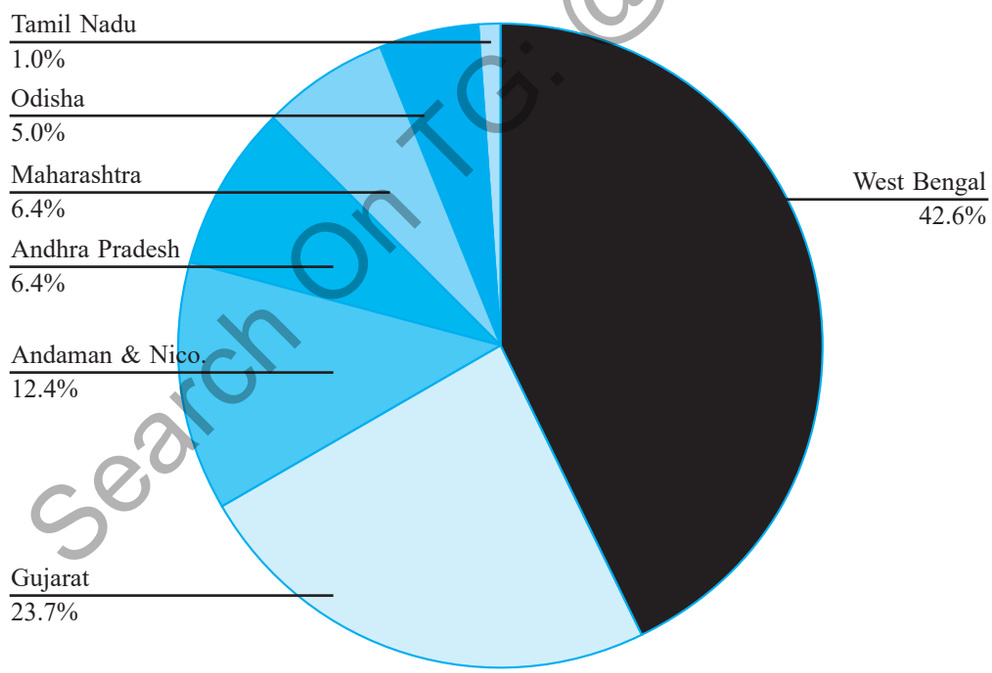
Kharai camel: a breed found in India, capable of swimming upto 3km in seawater, grazes on mangroves. **[UPSC 2016]**

Adaptations Exhibited by Mangroves

- **Succulent Leaves**
  - Thick leaves that store water and reduce water loss through **evapotranspiration**.
- **Sunken Stomata**
  - Stomata are embedded deeper in leaf tissue to minimize exposure to drying winds, reducing moisture loss.
- **Salt-Secreting Glands**
  - Specialized glands in leaves flush out excess salt, helping mangroves survive in saline environments.
- **Aerial Breathing Roots (Pneumatophores)**
  - Also known as blind roots, they extend above the soil or water surface, enabling mangroves to breathe in oxygen-deficient (anaerobic) conditions.
- **Viviparous Reproduction**
  - Seeds or embryos germinate while still attached to the parent tree, ensuring survival in harsh environments. After maturation, they fall into the water or soil and continue to grow.
- **Stilt and Prop Roots**
  - Fibrous roots that provide structural support, stabilizing the tree against strong wave action and tidal flows.
- **Buttresses**
  - Large, wide support roots at the base of shallow-rooted mangrove trees, enhancing stability.
- **Adventitious Roots**
  - These roots, including **prop and stilt roots**, emerge from the trunk above ground, supporting the tree in soft, waterlogged soil.
- **Complex Root System**
  - The intricate root system combats:
    - **Strong wave action**
    - **Diurnal tidal inundation**
    - **Respiration challenges** in oxygen-poor soil.
- **Species-Specific Root Adaptations**
  - **Arching Prop Roots:** Found in species like *Rhizophora*, extending into water for stability.
  - **Vertical Pneumatophores:** Seen in species like *Avicennia*, protruding vertically from the mud for oxygen intake.

Mangroves in India



The **ISFR 2023** indicates a decrease of 7.43 sq km in mangrove cover compared to the previous assessment in 2021.While some states like **Andhra Pradesh and Maharashtra have reported increases** in mangrove cover, others, notably **Gujarat and Andaman & Nicobar Islands** have experienced declines.

The largest increase in mangrove cover in terms of area has been observed in Andhra Pradesh,largest decline in Gujarat.

Mangroves of Sundarbans

- The name is derived from the Sundari mangrove tree.
- Largest single block of tidal halophytic mangroves in the world.

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- Eco-geography is dependent on the tidal effect: deposits silt back on the channels, raising the bed and forming new islands and creeks.
- **Only mangrove forests are inhabited by the tigers.**
- **Major fauna:** Royal Bengal tiger (EN), saltwater crocodile (LC), river terrapin, olive ridley turtle (VU), Ganges river dolphin (EN), hawksbill turtle, mangrove horseshoe crab, etc.

Mangrove Forests on the East Coast

- Mangroves of **Bhitarkanika** (Orissa): 2nd largest in India, cover the area of Brahmani and Baitarani river deltas.
- Godavari-Krishna deltaic regions of Andhra Pradesh.
- **Pichavaram** and **Vedaranyam** are degraded due to aquaculture ponds and salt pans.

On the west coast of India

- Mostly **scrubby** (stunted) and **degraded,** occur along the intertidal region of estuaries and creeks in **Maharashtra, Goa, and Karnataka**.
- **Kerala:** very sparse and thin.
- **Gujarat** (north-west coast): Gulf of Kutch and the Kori Creek region (paleo delta of the Indus River (once upon a time, it was part of the Indus delta).

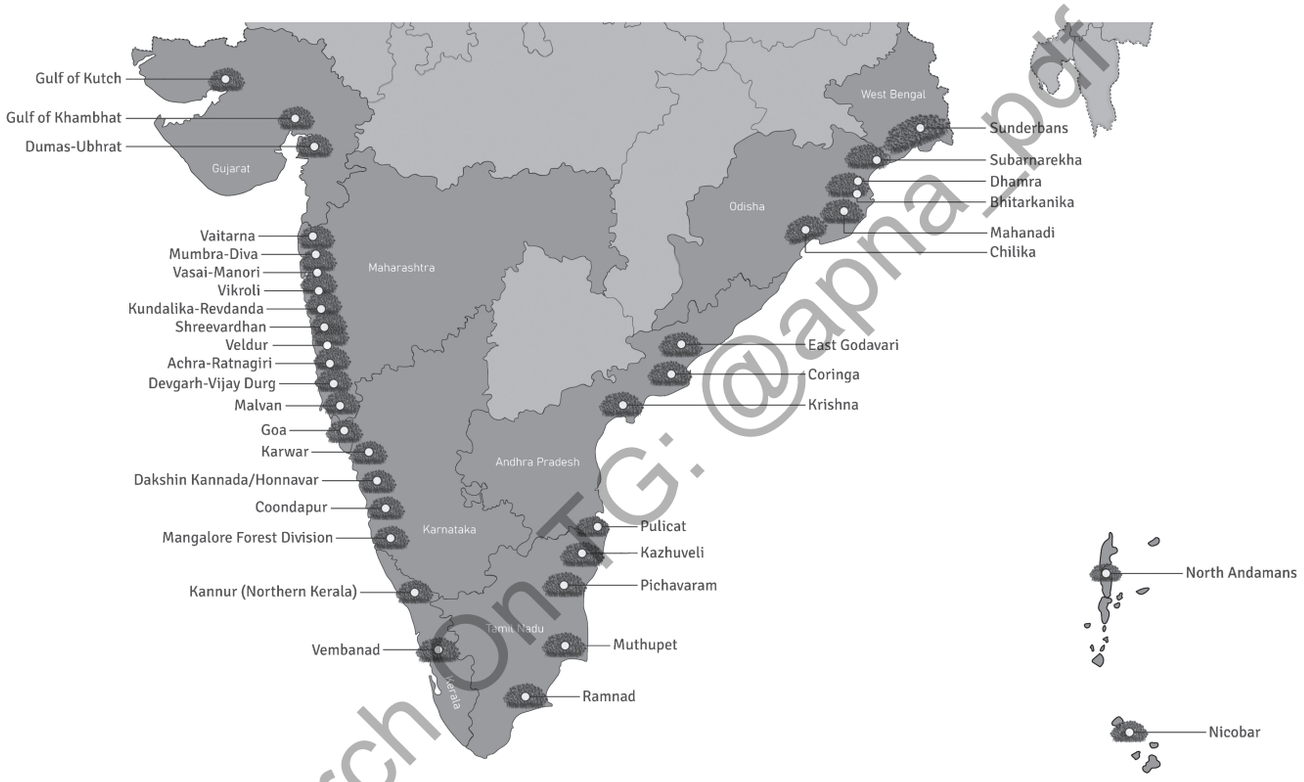

Fig. Mangroves in India

Global Status

- **FAO's Global Forest Resource Assessment, 2020:** 113 countries have mangrove forests covering ~14.79 million ha (1% of the tropical forests), primarily in tropical and subtropical regions.
- **Largest mangrove area is in Southeast Asia** (5.55 mha), followed by Africa, the Americas and Oceania (1.30 mha).
- **>40 per cent of the total area in just four countries:** Indonesia (19%), Brazil (9%), Nigeria (7%) and Mexico (6%).
- **Confined to the tropics and subtropics** (intertidal regions between latitudes 24° N and 38° S) as adaptive mechanisms are energy-intensive and require high solar radiation.

Importance of Mangroves

- **Highly Productive Ecosystems:**
  - Mangroves are among the most productive ecosystems, supporting a rich biodiversity.
  - They provide food, shelter, and breeding grounds for numerous terrestrial and aquatic species.
- **Coastal Protection:**
  - Mangroves protect coastal areas from tsunamis, storm surges caused by cyclones, and soil erosion.
  - Their complex root systems stabilize shorelines and reduce wave energy.
- **Land Accretion:**
  - They slow down water flow, promoting sediment deposition and acting as zones of land accretion.

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- **Flood Moderation:**
  - Mangroves reduce the inundation of coastal lowlands by moderating monsoonal tidal floods.
- **Riparian Buffer:**
  - Mangroves act as natural riparian buffers along coastal and estuarine zones.
  - They filter pollutants, including heavy metals, from surface runoff and prevent them from entering water bodies.
  - Enhance natural nutrient recycling and act as carbon sinks, aiding in climate regulation.
- **Habitat for Aquatic Life:**
  - Provide a safe and favorable environment for breeding, spawning, and rearing various fish and marine species.
- **Livelihood Support:**
  - Mangroves are essential for the livelihood of coastal communities.
  - Communities derive resources such as honey, tannins, wax, firewood, medicinal plants, edible plants, and fish from mangroves.

Threats to Mangroves

Threat	Description	Consequences
Aquaculture, Agriculture, and Salt Ponds	Nutrient-rich mangroves cleared for shrimp farming, mariculture, agriculture, and salt ponds.	Chemicals enter the food chain; eutrophication due to excess nutrients.
Coastal Development and Lumbering	Exploitation for charcoal and wood products; conversion of wetlands for coastal development projects.	Habitat loss, reduced biodiversity, imbalance in fresh and saltwater, and increased climate vulnerability.
Climate Change	Mangroves as carbon sinks release stored carbon when deforested, compounding the climate crisis.	Rising sea levels damage mangroves, causing habitat loss and reduced resilience to saltwater intrusion.
Replantation Limitations	Focused on a single species instead of a diverse mix; mangroves have lower species richness than tropical forests.	Reforestation/afforestation fails to fully restore lost habitats or ecosystem functions.

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2 Biodiversity and Related Issues

Biodiversity is the variety of life on Earth, encompassing the diversity of species, ecosystems, and genetic diversity within species. It is measured by two components:

TYPES OF BIODIVERSITY

- **Genetic Diversity:** encompasses the **variety of genetic characteristics within a species**. For example, in Homo sapiens, diverse genetic characteristics are evident among different ethnic groups, such as Chinese, Indian, and African. **This diversity is crucial for species adaptation to changing environments, ensuring survival through significant environmental changes.**
- **Species Diversity:** A measure of the diversity within an ecological community, considering both species richness and the evenness of their distribution.
- **Ecological Diversity: Refers to the variety of habitats within a region.**
  - For example, India exhibits significant ecological diversity with deserts, rainforests, mangroves, coral reefs, wetlands, estuaries, and alpine meadows.

MEASURES OF BIODIVERSITY

Species Richness

A measure of the **number of different species present** in a particular ecological community, ecosystem, or area.

- It **quantifies the diversity of species** and provides information about the variety of life within a specific habitat.
- **Tropical rainforests** in the terrestrial ecosystem and **coral reefs** in the marine ecosystem have the highest degree of species richness.

Species Evenness

A measure of **how evenly individuals are distributed among the different species** in a given area.

- It **assesses the balance in the abundance of each species**, indicating whether one or a few species dominate the ecosystem or if the distribution of individuals is more uniform across various species.

Formula:

$$E = \frac{H'}{\ln(S)}$$

Where:

- H' = Shannon-Wiener Diversity Index
- S = Species Richess
- ln(S) = Natural logarithm of species richess

Shannon-Wiener Diversity Index Formula:

$$H' = -\sum_{i=1}^{S} (p_i \ln(p_i))$$

Where:

- pi = Proportion of individuals of species i (calculated as $\frac{ni}{N}$, where *ni* is the count of species i and N is the total number of individuals).
- **Example:** A sample forest A has 3 tigers, 5 deer and 7 rabbits and sample forest B has 1 tiger, 6 deer and 8 rabbits. Both samples have the same richness (3 species) and the number of individuals (15). However, sample forest A has more evenness than sample forest B. this can be verified using the above mentioned formulae.

R.H. WHITTAKER'S ALPHA, BETA AND GAMMA DIVERSITY

R.H. Whittaker introduced three levels of biodiversity to assess variations within and across ecosystems: **alpha, beta, and gamma diversity**.

Alpha Diversity (Within-Community Diversity)

- **Definition:** Measures species diversity within a specific area, community, or ecosystem.
- **Focus:** Local diversity.
- **Indicators:** Species richness and species evenness.
- **Example:**
  - A forest patch has **10 species** of plants.
  - The alpha diversity of this patch is **10 species**.

Beta Diversity (Between-Community Diversity)

- **Definition:** Measures the change in species composition between two ecosystems or communities.

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- **Focus:** Comparison of species diversity across habitats or ecosystems.
- **$\beta = S1 + S2 - c$**
  - Where:
    - S1 = Species in the first community.
    - S2 = Species in the second community.
    - c = Common species between both communities.
- **Example:**
  - **Forest A: 10 species, Forest B: 15 species, 5 species are common.**
  - **$\beta = 10 + 15 - 5 = 20$**

Gamma Diversity (Regional Diversity)

- **Definition:** Measures overall species diversity in a large geographical area (e.g., landscape or region) encompassing multiple ecosystems.
- **Focus:** Total diversity of all ecosystems combined.
- **Example:**
  - A landscape with three ecosystems (forest, grassland, and wetland):
    - Forest: 10 species
    - Grassland: 12 species
    - Wetland: 8 species
    - Total distinct species **(removing overlap): 25 species**
    - **Gamma diversity is 25 species.**

SPECIATION

Speciation is the process by which new species arise from a single ancestral species over time. There are several types of speciation, each driven by different mechanisms of reproductive isolation:

Type of Speciation

Type of Speciation	Mechanism	Example	Key Features
Allopatric Speciation	Geographic isolation through physical barriers (e.g., mountains, rivers).	**Darwin's Finches:** Geographical separation in the Galápagos Islands.	Genetic divergence due to mutation, genetic drift, and natural selection.
Sympatric Speciation	Occurs without geographic isolation, often through polyploidy, habitat differentiation, or disruptive selection.	**Apple Maggot Fly:** Evolved to specialize on different host plants in the same area.	New species arise within the same geographic area.
Parapatric Speciation	Limited gene flow between populations along a geographical gradient.	**Ensatina Salamanders:** Ring species where adjacent populations interbreed, but distant ones do not.	Genetic differences accumulate despite physical proximity.
Peripatric Speciation	Small, isolated populations on the periphery of a species' range evolve into new species.	**Anolis Lizards:** Island populations in the Caribbean.	Rapid evolution and genetic drift in small founder populations.
Adaptive Radiation	Rapid diversification into multiple species to exploit different ecological niches.	**Galápagos Finches:** Diversified with various beak shapes to exploit different food resources.	Single ancestral species gives rise to multiple species adapted to diverse niches.

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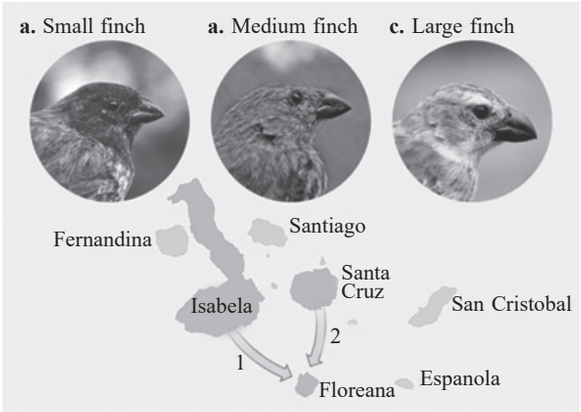

Fig. Allopatric Speciation among Darwin Finches

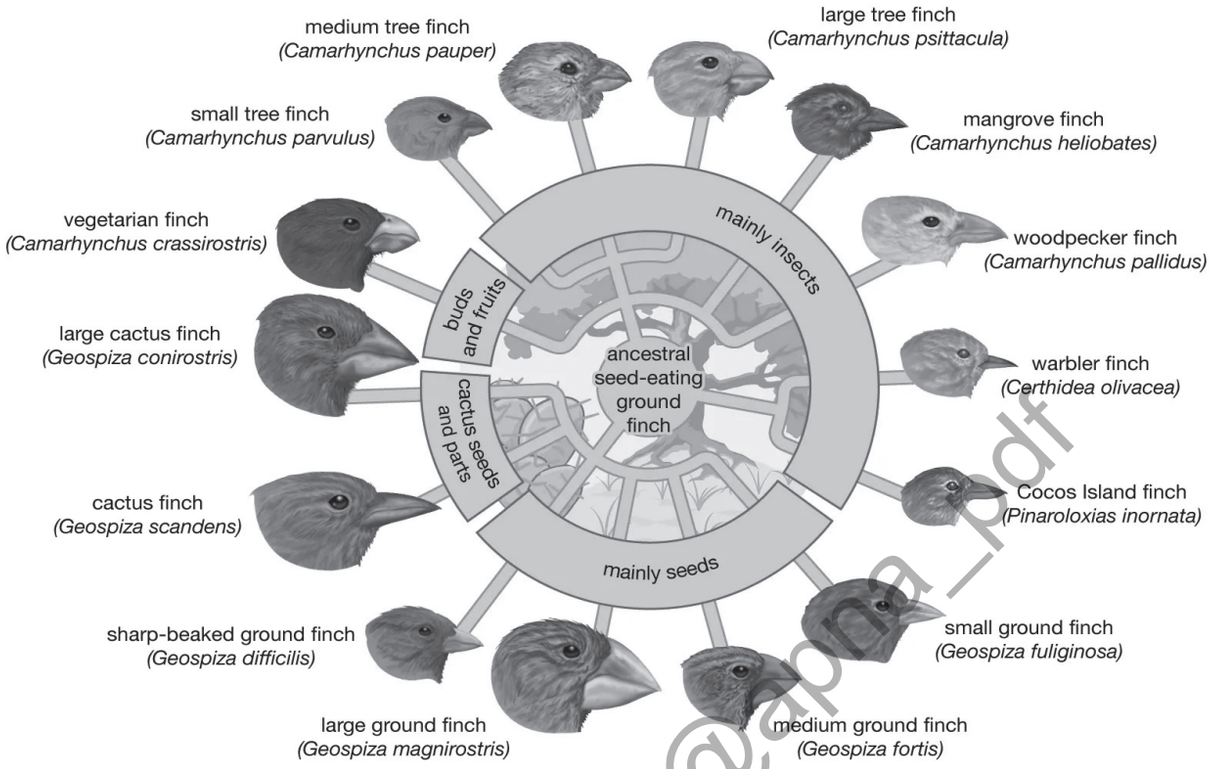

Fig. Adaptive Radiation in Galapagos Finches

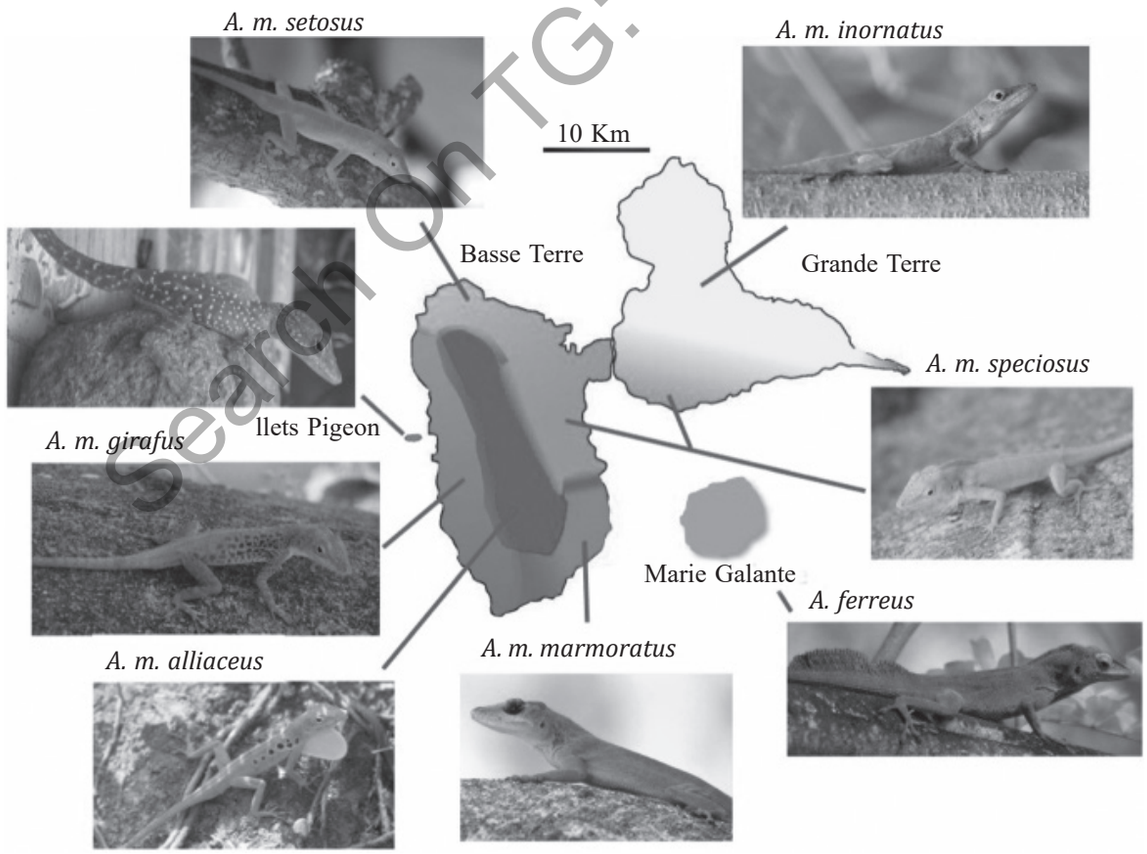

Fig. Peripatric Speciation-Led to Anolis Lizard

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SPECIES CATEGORIES IN ECOSYSTEM CONSERVATION

Ecosystem conservation relies on the unique roles of various species. Below are key categories with examples from India, highlighting their ecological importance and geographical locations:

Keystone Species

Every ecosystem has certain species that are critical to the survival of the other species in the system. The keystone species could be a huge predator or an unassuming plant, but without them the ecosystem may not survive.

- **Examples:**
  - **Asiatic Lion:** Found in the Gir Forest, Gujarat, it regulates herbivore populations, ensuring vegetation sustainability.
  - **Dhole (Indian Wild Dog):** Inhabits the Western and Eastern Ghats, controlling prey populations to maintain ecological stability.
  - **Fiddler Crab:** Found in the Sundarbans and East Coast mangroves, it aerates sediments and supports nutrient cycling.
  - **Beavers:** Beavers are one of the few animals that modify their habitat. Beavers build watertight dams made of woven sticks, reeds, branches and saplings caulked together with mud and rocks. The dams form slow-moving ponds that reduce stream erosion and provide brand new habitat for small fish and other aquatic wildlife. They are keystone species in North America.
  - **Other examples:** Sharks, Bees, Mangroves

Fig. Beaver Building a Dam

Indicator Species

These species reflect the overall health of ecosystems and act as early warning signs of environmental changes.

- **Examples:**
  - **Frogs and Amphibians:** Common in wetlands and forests across India, they are sensitive to water quality and habitat changes.
  - **Mahseer Fish:** Found in Himalayan and Western Ghats rivers, they indicate freshwater ecosystem health.
  - **Coral Reefs:** Located in the Gulf of Mannar and Lakshadweep, they signal marine ecosystem health.

Endemic Species

Native and restricted to specific geographic areas, these species represent unique biodiversity and require focused conservation efforts.

- **Examples:**
  - **Lion-tailed Macaque:** Found in the Western Ghats, critical for forest ecosystem preservation.
  - **Sangai Deer:** Unique to Loktak Lake, Manipur, it represents wetland ecosystem health.
  - **Beddome's Toad:** Restricted to the Western Ghats, reflecting microhabitat specificity.

Invasive Alien Species

Non-native species introduced to ecosystems often disrupt local biodiversity and outcompete native species.

- **Examples:**
  - **Water Hyacinth:** Common in wetlands across India, clogs waterways, depletes oxygen, and impacts aquatic species.
  - **Prosopis Juliflora:** Found in Rajasthan, Tamil Nadu, and Andhra Pradesh, it alters soil chemistry and reduces native vegetation.
  - **African Catfish:** Introduced in Indian rivers and lakes, it competes with and threatens native fish populations.

Fig. Water Hyacinth

Flagship Species

These charismatic species are used to mobilize public and financial support for conservation efforts.

- **Examples:**
  - **Indian Elephant:** Inhabits forests of South, Northeast, and Central India, driving forest conservation.
  - **Great Indian Bustard:** Found in Rajasthan and Gujarat, it advocates for arid grassland conservation. It was the **mascot of CMS COP-13 held in Gandhinagar in 2020.**

Fig: Great Indian Bustard

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- **Sangai Deer:** Promotes wetland conservation in Loktak Lake, Manipur.

Umbrella Species

Protecting these species aids in the conservation of their habitats and co-inhabitant species.

- **Examples:**
  - **Bengal Tiger:** Found in the Sundarbans, Western Ghats, and Terai grasslands, its conservation protects vast ecosystems.
  - **Black-necked Crane:** Found in high-altitude wetlands of Arunachal Pradesh, aiding in alpine wetland protection.
  - **Indian Rhino:** Inhabits Kaziranga National Park, Assam, securing wetland biodiversity.

Foundational Species

These species shape and maintain ecosystems, providing structure and essential resources for other organisms.

- **Examples:**
  - **Mangroves**: Located in the Sundarbans, they prevent coastal erosion and provide nurseries for fish.
  - **Sacred Fig (Peepal Tree)**: Found across urban and rural landscapes, it supports pollinators and provides oxygen.
  - **Shola Grasslands**: Found in the Western Ghats, crucial for regulating hydrology and supporting endemic species.

Fig. Mangroves

Fig. Shola Grasslands and Forests of Nilgiri

HOMEOSTASIS IN ORGANISMS

Homeostasis refers to the ability of organisms to maintain a stable internal equilibrium despite changes in the external environment. It is achieved through various physiological and behavioral functions, ensuring survival under different conditions.

Physiological Homeostasis

- **Temperature Regulation:**
  - **Humans:** Sweating to cool down in hot weather and shivering to generate heat in cold climates.
  - **Dogs:** Panting to regulate body temperature.
- **Osmoregulation:**
  - **Fish:** Marine fish excrete concentrated urine to conserve water, while freshwater fish excrete diluted urine to remove excess water.
- **Blood Glucose Levels:**
  - **Humans:** Insulin lowers blood glucose after a meal; glucagon raises it during fasting.

Behavioral Homeostasis

- **Migration:**
  - **Siberian Cranes:** Migrate to India during harsh winters for favorable conditions.
  - **Bar-headed Geese:** Fly over the Himalayas to warmer regions.
- **Thermal Regulation:**
  - **Desert Lizards:** Bask in the sun to warm up and seek shade to cool down.
  - **Elephants:** Use their large ears to dissipate heat and mud baths to cool down.

Adaptations in Extreme Conditions

- **Hibernation (Cold):**
  - **Polar Bears**: Enter a dormant state during winters to conserve energy.
  - **Bats:** Hibernate in caves to survive food scarcity during winter.
- **Aestivation (Heat and Dry):**
  - **Lungfish:** Survive drought by burrowing into mud and reducing metabolic activity.
  - **Snails:** Seal their shells and remain inactive during extreme heat.
- **Diapause (Unfavorable Growth Conditions):**
  - **Zooplankton**: Pause development during periods of food scarcity or temperature extremes.

Plant Examples

- **Stomatal Regulation:**
  - **Cacti:** Open stomata at night (CAM photosynthesis) to minimize water loss.
  - **Rice Plants:** Close stomata during midday heat to prevent excessive water loss.
- **Seed Dormancy:**
  - **Acacia:** Produces stress-resistant seeds that sprout after rainfall in deserts.
  - **Lotus:** Seeds can remain dormant for centuries and germinate when conditions improve.

Microbial Examples

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- **Spore Formation:**
  - **Bacteria (Bacillus):** Form endospores to survive extreme heat and desiccation.
  - **Fungi:** Produce spores to endure unfavorable conditions like drought or lack of nutrients.

BIODIVERSITY DYNAMICS: ENDEMISM, BIOPROSPECTING, AND BIOPIRACY

- Endemism refers to the **ecological condition where a species is exclusively found in a specific defined geographic area**, such as an island, nation, country, or distinct habitat.
- If organisms native to a particular place are also found in other locations, they are not considered endemic. For example - **Red Sanders**, **sandalwood, peepal tree, banyan tree and neem tree.** **[UPSC-2024]**
- The contrasting concept to endemism is a cosmopolitan distribution, where a species is widespread and found across various regions or habitats.

Native Species Across the World [UPSC-2023, 2024]

The main difference between native and endemic species is that native species can be found in multiple areas, while endemic species are only found in a specific areas.

Country	Important Native Animals	Important Native Plants	Superfoods/Fruits/Vegetables/Produce
India	Royal Bengal Tiger, Asian Elephant, Indian Peacock, Lion-tailed Macaque	Banyan Tree, Indian Sandalwood, Neem	Moringa, Mango (Alphonso), Banana, Turmeric, Cardamom
Brazil	Jaguar, Giant Anteater, Capybara, Amazon River Dolphin	Açaí Palm, Brazil Nut Tree, Rubber Tree	Açaí Berry, Pineapple, Guava, Brazil Nut
Indonesia	Komodo Dragon, Orangutan, Bali Starling	Clove Tree, Teak, Mangroves	Nutmeg, Clove, Durian, Coffee
Madagascar	Indri, Ring-tailed Lemur, Tomato Frog	Baobab, Traveller's Palm	Vanilla, Lychee, Baobab Fruit
Australia	Kangaroo, Koala, Emu, Platypus	Eucalyptus, Wattle, Waratah	Macadamia Nut, Kakadu Plum, Wattleseed
South Africa	African Elephant, Cheetah, White Rhinoceros, Meerkat	Baobab, Protea, Aloe	Marula Fruit, Rooibos Tea, Baobab Powder
China	Giant Panda, Red Panda, Golden Snub-nosed Monkey	Bamboo, Ginkgo Biloba, Chinese Tea Plant	Lychee, Soybean, Goji Berry
USA	American Bison, Bald Eagle, Grizzly Bear	Giant Sequoia, Joshua Tree, Prairie Grass	Corn, Cranberries, Almonds, Avocados
New Zealand	Kiwi, Kakapo, Tuatara	Pohutukawa, Kauri Tree, Manuka	Kiwi Fruit, Manuka Honey
Mexico	Axolotl, Jaguarundi, Mexican Gray Wolf	Agave, Nopal (Prickly Pear Cactus)	Avocado, Tomato, Vanilla, Maize (Corn)

Endemic Species of the World

Country	Endemic Animal Species	Endemic Plant Species
India	Asiatic Lion (Gujarat), Lion-tailed Macaque (Western Ghats), Kashmir Stag, Nilgiri Tahr	Nilgiri Mountain Holly, Indian Rosewood, Beddome's Oak, Andaman and Nicobar Islands Palm
Australia	Platypus, Koala, Wombat, Tasmanian Devil, Short-beaked Echidna	Eucalyptus (various species), Banksia, Waratah, Kangaroo Paw
Brazil	Golden lancehead pit viper (Isla da Queimada Grande), Brazilian Merganser, Uakari Monkey	Brazil Nut Tree, Pau Brasil (Brazilwood), Cacto do Sertão
Madagascar	Indri **[UPSC 2024]**, Aye-aye, Fossa, Ring-tailed Lemur	Baobab, Traveller's Palm, Madagascar Periwinkle
New Zealand	Kiwi, Kakapo, Tuatara, New Zealand Sea Lion	Pohutukawa, Manuka, Kauri Tree

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South Africa	Cape Mountain Zebra, Bontebok, Dung Beetle (Cercyon), Golden Mole	Protea (national flower), Silver Tree, Cycad
China	Giant Panda, Chinese Alligator, Golden Snub-nosed Monkey, Tibetan Antelope	Chinese Ginseng, Chinese Yew, Wuling Mountain Cucumber
Mexico	Axolotl, Mexican Gray Wolf, Mexican Beaded Lizard	Mexican Marigold, Nopal (Prickly Pear Cactus), Mexican Fan Palm
Indonesia	Komodo Dragon, Javan Rhinoceros, Sumatran Tiger	Rafflesia, Indonesian Orchid, Clove (native to the Moluccas)
USA	California Condor, Hawaiian Monk Seal, San Joaquin Kit Fox, Bison (Yellowstone)	Joshua Tree, Giant Sequoia, California Poppy, Saguaro Cactus

Bioprospecting

- **Exploration of biodiversity to discover commercially valuable genetic resources and biochemicals.**
- Involves deriving economically important products by **exploring molecular, genetic, and species diversity** in nations rich in biodiversity.

Biopiracy

- **Unauthorized taking of genetic resources and traditional knowledge from biodiverse developing countries.**
- Stolen traditional knowledge benefits non-indigenous entities through products or patents without compensating the indigenous people.
- **Regulation:** Addressed by the **Nagoya Protocol** to the **Convention on Biological Diversity**, ensuring fair and equitable sharing of benefits from using traditional knowledge and genetic resources.

BIODIVERSITY DISTRIBUTION PATTERNS

Latitudinal Gradient [UPSC 2011]

- Biodiversity is richer in tropical regions (low latitudes) compared to temperate or polar regions (high latitudes).
- **Example:** The Amazon rainforest, located near the equator, hosts millions of species, making it one of the most biodiverse ecosystems on Earth, whereas the Arctic regions have significantly fewer species.

Altitudinal Gradient

- Biodiversity typically declines as altitude increases because of harsher environmental conditions at higher elevations.
- **Example:** In the Himalayas, lower altitudes support lush forests with diverse flora and fauna, while higher altitudes have sparse vegetation and fewer species like snow leopards or yaks.

BIODIVERSITY OF INDIA

- **Mega-Diverse Country:** India is classified as a mega-diverse country, characterized by extraordinarily rich biodiversity that supports a significant portion of the Earth's species. These countries, constituting only about 10% of the Earth's surface, house around 70% of terrestrial biological diversity.
- **UN-identified Mega-Diverse Countries:** According to the World Conservation Monitoring Centre (WCMC) of the United Nations Environment Program (UNEP), **India is among 17 megadiverse countries**, alongside Australia, Brazil, China, and others.
- **Biodiversity Statistics: India possesses 25.17% of its area under forest and tree cover**. Despite occupying only 2.4% of the global land area, **India harbors nearly 7-8% of recorded species** while supporting almost 18% of the human population.
- **Biogeographic Diversity:** India represents two realms, five biomes, ten biogeographic zones, and twenty-five biogeographic provinces. It is home to 91,000 species of animals and 45,500 species of plants.
- **Endemism:** A notable feature is the **high endemism**, with 12.6% of mammals, 4.5% of birds, 45.8% of reptiles, 55.8% of amphibians, and 33% of Indian plants being endemic to the region.
- **Biogeographic Realms: Large spatial regions where ecosystems exhibit broadly similar biota or biological communities**. **Globally, there are eight recognized terrestrial biogeographic realms.** The Indian region is situated in two biogeographic realms**:**
  - **Himalayan Region:** Represented by the Palearctic Realm. The Himalayan Range is very rich in species diversity because it is a confluence of different biogeographical zones. **[UPSC 2011]**
  - **Rest of the Subcontinent:** Represented by the Malayan Realm.
- **Biomes:** Main groups of plants and animals in areas with specific climate patterns, depicting interactions among animals, vegetation, and soil. **5 Indian Biomes:** Tropical Humid Forests, Tropical Deciduous Forests (Monsoon Forests), Warm deserts and semi-deserts, Coniferous forests, Alpine meadows.

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- **Biogeographic Provinces:** Ecosystemic or biotic subdivisions of realms. **India is divided into 25 biogeographic provinces.**
- **Biogeography:** Study of the geographical distribution of plants and animals. **10 Biogeographic Zones in India:** Trans Himalaya, The Himalaya, The Indian Desert, The Semi-Arid, The Western Ghats, The Deccan Peninsula, The Gangetic Plain, The Coasts, Northeast India, Islands. **[UPSC 2010]**

Biodiversity Hotspots

- Term coined by British biologist **Norman Myers**; adopted by Conservation International (CI).
- **Conservation International Criteria for Hotspots. [UPSC-2011]**
  - **Endemism-** Must have at least 1,500 species of vascular plants as endemics (> 0.5% of the world's total).
  - **Threat perception-** Must have lost at least 70% of its original habitat (30% or less of its original natural vegetation).

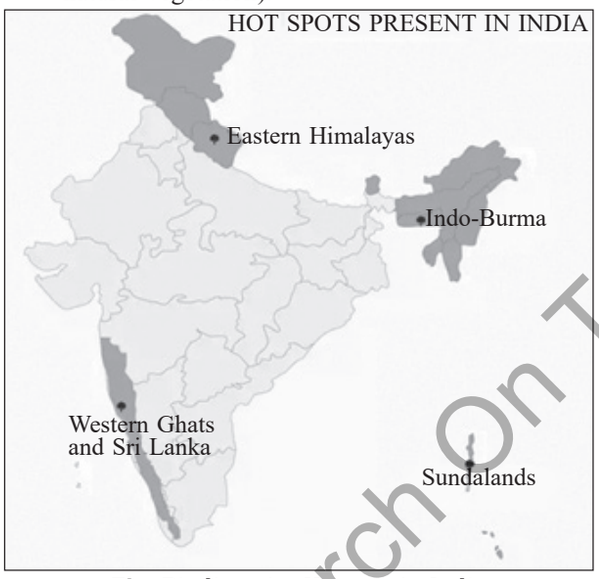

Fig. Biodiversity Hotspot in India

- **Number of Hotspots:** Initially, 25 hotspots were identified in 1999; currently, **36 hotspots cover 2.5% of the Earth's land surface.**
- **Significance:** Hotspots support over half of the world's plant species as endemics and nearly 43% of bird, mammal, reptile, and amphibian species as endemics.
- **India's Biodiversity Hotspots: [UPSC 2010]**
  - **Himalaya:** Includes the entire Indian Himalayan region and neighbouring countries.
  - **Indo-Burma:** Covers North-Eastern India, the Andaman Islands, and several Southeast Asian countries.
  - **Sundalands:** Encompasses Nicobar Islands, Indonesia, Malaysia, Singapore, Brunei, and the Philippines.
  - **Western Ghats and Sri Lanka.**

Hope Spots

- Marine Protected Areas requiring special protection due to wildlife and significant underwater habitats.
- **Initiative:** Joint effort by **Mission Blue (a global coalition) and IUCN.**
- **India's Hope Spots:** Lakshadweep Islands and Andaman Nicobar Islands.

LOSS OF BIODIVERSITY

- **IUCN Red List (2014)**
  - Documents the extinction of 784 species in the last 500 years.
  - Examples include the Passenger Pigeon, Steller's Sea Cow, and three tiger subspecies (Bali, Javan, Caspian).
- **Mass Extinctions**
  - Five episodes of mass extinctions occurred over more than 3 billion years.
  - The **ongoing Sixth Extinction (anthropogenic)** is estimated to be 100 to 1,000 times faster than pre-human times.

Global Biodiversity and Ecosystem Crisis: Key Reports and Findings

Report	Key Findings	Impacts/Highlights
IPBES 'Global Assessment Report on Biodiversity and Ecosystem Services 2019	Nearly half of natural ecosystems have vanished due to human activities.	• Land degradation • Agricultural expansion • Sea-level rise • Greenhouse gas emissions • Plastic pollution • 100-300 million people at risk due to coastal habitat loss.
Living Planet Report 2024	Biennial WWF report showing a 73% decline in global wildlife populations over the last 50 years.	• Highest decline (95%) in Latin America and the Caribbean. • Africa recorded a 76% decline. • Asia-Pacific region recorded a 60% decline. • Freshwater species reduced by 85%.

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State of the World's Birds 2022	Annual report by BirdLife International highlighting that 49% of bird species are declining globally.	• 1 in 8 bird species threatened with extinction. • Trophic cascade effect identified as a major threat, affecting ecosystem balance.

Causes Behind Biodiversity Loss

- **Natural Ecological Disturbances**
  - Weather, wildfires, floods, and volcanic eruptions cause temporary ecosystem changes.
  - Natural disturbances are part of ecological succession and are usually adapted by ecosystems.
- **Evil Quartet - Major Causes**
  - **Habitat Loss:** Reduction in space for species, often due to activities like deforestation and urbanization.
  - **Overexploitation:** Excessive use of natural resources, leading to depletion of species like fish and trees.
  - **Alien Species:** Introduction of non-native species that disrupt ecosystems.
  - **Secondary Extinction:** Extinction of one species triggers the loss of others dependent on it.
- **WWF's Six Key Threats:** Agriculture, hunting, logging, pollution, invasive species, and climate change contribute to biodiversity loss.
- **Habitat Loss and Fragmentation**
  - **Habitat Loss:** Reduction in space where species can survive, notable in tropical rainforests.
  - **Habitat Fragmentation:** Large habitats are transformed into smaller, isolated patches, leading to inbreeding and local extinction risks.
  - **Barrier Effect:** Increases the risk of inbreeding and limits gene pool diversity.
- **Alien Species Invasions**
  - Non-native species spreading rapidly and threatening native biodiversity.
  - Invasive species are a significant cause of biodiversity loss.
- **Over-exploitation:** Excessive use of natural resources, endangering species like marine fish, whales, and trees.
- **Species Extinction:** Traits leading to increased species' vulnerability to extinction include rarity, poor dispersal ability, high trophic status, and low adult survival rates.
- **Genetically Modified Organisms (GMOs)**
  - Genetic modification can lead to dominant GMO species that reduce biodiversity.
  - Unintended effects and cross-pollination can contribute to biodiversity loss.
- **Trade in Wildlife**
  - Unsustainable harvest and trade threaten wildlife and biodiversity.
  - Illegal wildlife trade contributes to habitat destruction and disease spread.
- **Pollution and Climate Change**
  - Ocean acidification affects marine biodiversity.
  - Climate change influences ecosystem health, affecting the distribution of species

Consequences of Loss of Biodiversity [UPSC 2011]

- **Affects Livelihood**
  - Changes in ecosystem services affect livelihoods, income, and migration.
  - Loss of biodiversity may limit the discovery of potential treatments for diseases.
- **Food and Nutritional Security Crisis**
  - Biodiversity influences world food production and sustainable soil productivity.
  - Nutrition and biodiversity are linked, impacting global nutritional status.
- **Human-Animal Conflict**
  - Interaction between wild animals and humans causing negative impacts.
  - Causes include human encroachment, land use changes, habitat loss, and climate change.
  - Impacts include crop and property damage, livestock depredation, injuries, and deaths.
- **Preventive and Mitigation Strategies for Human-Animal Conflict:** Artificial and natural barriers, guarding, alternative livestock husbandry practices, relocation, waste management, and community-based management.
- **Culling - Conservation or Biodiversity Loss**
  - Natural Culling: Natural processes like starvation, disease, and predation control populations.
  - Controlled Culling by Humans: Necessary for managing wildlife populations due to human-animal conflict and threats to life and livelihood.
- **Increased Zoonoses due to Habitat Loss**
  - Zoonotic diseases (transmitted from animals to humans) thrive in environments with changes in ecosystems and biodiversity loss.
  - Zoonoses are closely linked with ecosystem health, and habitat loss facilitates spillover from wildlife to humans.
- **Adverse Changes to Biotic Interactions**
  - Diminishing niches and roles of species in ecosystems lead to adverse changes.
  - Sudden declines in species can significantly alter ecosystem structure and functions.

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Consequences of Butterfly Population Decline [UPSC-2017]

Reduced Pollination: Many plants depend on butterflies for pollination. A decline could negatively impact their reproduction and survival.

Impact on Food Chains: Butterflies serve as prey for species like wasps, spiders, and birds. Their decline could disrupt these populations.

IN SITU CONSERVATION

In situ conservation refers to the conservation of species in their natural habitats, allowing them to continue their evolutionary processes. It contrasts with ex situ conservation, where species are conserved outside their natural environment (e.g., in zoos or botanical gardens). In situ conservation ensures the survival of species by protecting the ecosystem, allowing species to maintain their roles within their natural environment.

Methods

- **Protected Areas:** Establishing national parks, wildlife sanctuaries, and biosphere reserves to protect species in their habitats.
- **Community Involvement:** Engaging local communities in conservation efforts by providing education and sustainable livelihood alternatives.
- **Legislation:** Enforcing laws that protect endangered species and their habitats, such as the Wildlife Protection Act, 1972 in India.
- **Restoration Projects:** Rehabilitating degraded ecosystems to restore the natural habitat for species.

Biosphere Reserves

- Large protected areas involving terrestrial, marine, and coastal ecosystems.
- Few biosphere reserves are recognised under UNESCO's Man and the Biosphere Programme.
- Learning places for sustainable development.
- Managed under the sovereign jurisdiction of countries.
- The most important strategy for the conservation of biodiversity together with traditional human life.
- **Seville Strategy**
  - Adopted in 1995, emphasizing a community-based approach for biosphere reserves.
  - Includes social, cultural, spiritual, and economic needs alongside scientific research.
- **Core Buffer Strategy**
  - **Core Area:** Strictly protected with no human activity.
  - **Buffer Zone:** Limited human activity allowed for research, monitoring, and education.
  - **Transition Area:** Permits ecologically sustainable human settlements and economic activities.

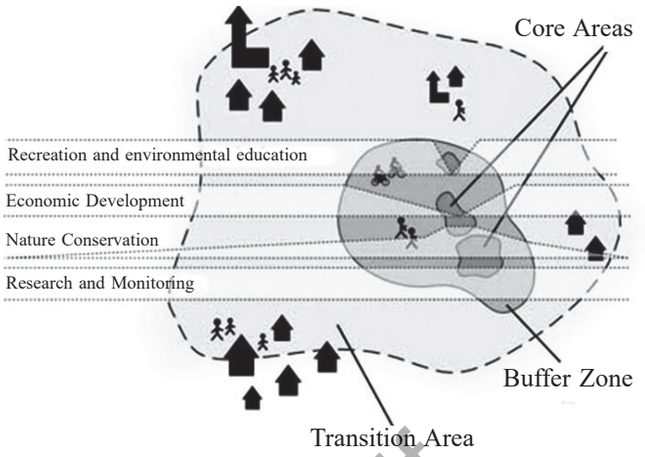

Fig. Core, Buffer and Transition Zones

- **Protected Areas in terms of protection:** Protected forests < Reserved forests < Wildlife Sanctuaries < National Parks. **[UPSC 2014]**
- The **"Miyawaki method"** is well known for the Creation of mini forests in urban areas National Parks. **[UPSC 2022]**

Community and Conservation Reserves (WPA Amendment 2002)

Under the **Wildlife Protection Act (WPA), 1972**, as amended in **2002, Community Reserves** and **Conservation Reserves** were introduced to promote biodiversity conservation with community involvement.

- **Community Reserves**
  - **Purpose:** Protects ecosystems with active community participation.
  - **Management:** Local communities collaborate in conservation, balancing biodiversity protection with sustainable use of resources.
  - **Rights of Communities:** Communities can access forest resources sustainably, but activities that harm biodiversity are restricted.
- **Conservation Reserves**
  - **Purpose:** Protects wildlife habitats outside existing protected areas, often acting as buffer zones.
  - **Management:** Managed by government, with some community involvement.
  - **Rights of Communities:** Limited, focusing on sustainable resource use.

Sacred Groves in India

Sacred groves are forested areas preserved by local communities due to religious or spiritual significance, playing a key role in biodiversity conservation and cultural heritage.
Famous Examples:

- **Kerala: Kavu** groves dedicated to deities like **Bhagavati**.
- **Madhya Pradesh: Bhoramdeo Sacred Grove**, preserved due to religious practices.
- **Northeast India:**

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- **Meghalaya: Sohra Sacred Groves** (Cherrapunji region), rich in biodiversity.
- **Nagaland: Mokokchung Sacred Groves**, integral to the Ao tribe's traditions.
- **Manipur: Loktak Lake Sacred Groves**, important for both ecology and spirituality.

Ecologically Sensitive Zones (ESZs)

Purpose: ESZs, notified by the Ministry of Environment, act as buffers around national parks and wildlife sanctuaries to minimize forest depletion and human-animal conflict.

Key Features:

- **Regulations:** Mandated by the **National Wildlife Action Plan (2002–2016)** for areas within 10 km of protected zones. Additional ecologically important corridors may also be designated.
- **Supreme Court Directive (2022):** Minimum 1 km ESZ around protected areas.
- **Core and Buffer Model:** ESZs follow this model for conservation.

Legal Framework:

- Governed by the **Environment (Protection) Act, 1986**, allowing regulation of activities in sensitive zones. **[UPSC 2014]**

Activities:

- **Prohibited:** Commercial mining, polluting industries, hydropower projects, aerial tourism.
- **Regulated:** Tree felling, agriculture, water use, hotels.
- **Permitted:** Local agriculture, organic farming, rainwater harvesting, renewable energy. **[UPSC 2014]**

Preservation of Western and Eastern Ghats

[UPSC 2016]

- **Western Ghats spans six states**, showcasing high species endemism and is recognized as a UNESCO World Heritage Site.
- Eastern Ghats face threats like deforestation, sand mining, and human encroachment.
- **The Madhav Gadgil Committee** recommended stringent measures for the conservation of the Western Ghats, but the **Kasturirangan Committee** diluted some proposals.
  - Recommendations of the Kasturirangan-led Panel: It notified **only 37% (against 64% by Gadgil commission**) of the area as ecologically sensitive.
- October 2018 notification by MoEF aimed to protect the Western Ghats by declaring ~57,000 sq km as ecologically sensitive areas.

EX SITU CONSERVATION

Ex situ conservation involves relocating threatened animals and plants from their natural habitats to protected environments for special care and management. Examples include:

- **Zoological Parks:** For animal conservation and breeding.
- **Botanical Gardens:** For preserving plant species. **[UPSC 2011]**
- **Wildlife Safari Parks:** For conserving wildlife in semi-natural settings.
- **Seed Banks:** For storing seeds of plants for long-term preservation.

Advanced Techniques in Ex Situ Conservation

- **Cryopreservation**
  - Involves preserving gametes (e.g., sperm and eggs) of threatened species at very low temperatures.
  - Ensures the storage of viable and fertile gametes for extended periods.
- **In Vitro Fertilization (IVF)**
  - Eggs are fertilized in a laboratory setting to produce offspring for conservation purposes.
- **Tissue Culture**
  - Plants are propagated in controlled environments using tissue culture techniques to produce genetically identical plants.

INDIA'S INITIATIVES AND INSTITUTION TO PRESERVE BIODIVERSITY

Quarantine Centres to Check Invasive Species

- Plant quarantine centers at major entry points are **under the Central Board of Indirect Taxes and Customs in coordination with the DDQS (Directorate of Plant Protection and Quarantine Storage).**
- DPPQS of the Ministry of Agriculture and Farmers' Welfare is responsible for the control of invasive pests/ weeds.
- **Governed by the Destructive Insects and Pests Act, 1914,** these centers check imported agricultural products for phytosanitary certificates.
- **Fumigation with methyl bromide is done if needed,** and a phytosanitary certificate is issued.

National Biodiversity Authority (NBA) (UPSC 2012)

- **Established:** 2003 under the **Biological Diversity Act, 2002**.
- **Headquarters:** Chennai, Tamil Nadu.
- **Purpose:** Regulate access to India's biological resources. Ensure fair and equitable sharing of benefits from resource utilization. Protect indigenous and traditional knowledge.
- **Key Roles:**
  - Prevent biopiracy and unauthorized use of genetic resources.

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- Approve IPR applications involving genetic/ biological resources.
- Advise the Central and State Governments on biodiversity conservation.
- Safeguards traditional crop varieties and genetic resources.
- Supports sustainable agricultural practices and benefit-sharing with farmers.

Historic Citizen Movements

- **Sundarlal Bahuguna**, an environmentalist known as the **Defender of the Himalayas and Environmental Gandhi**, led the Chipko and Tehri dam movements.
- The Chipko Movement, starting in 1973, involved tree hugging to prevent deforestation and led to people-sensitive forest policies.
- The **Appiko Movement** (1983) in Karnataka and the **Anti-Tehri Dam Protest** were inspired by the success of the Chipko Movement.
- Women played a crucial role in the **Chipko Movement**, with **Gaura Devi** leading in Reni Village.
- Sundarlal Bahuguna's efforts resulted in a 15-year ban on cutting green trees after a meeting with Indira Gandhi in 1980.

GLOBAL INITIATIVES AND FRAMEWORKS FOR BIODIVERSITY CONSERVATION

Convention on Biological Diversity (CBD)

- **Legally binding multilateral treaty established in 1992** during the Earth Summit in Rio de Janeiro.
- Aim to achieve sustainable development through **3 main goals:**
  - The conservation of biological diversity.
  - Sustainable utilization of its components.
  - Fair sharing of benefits arising from genetic resources.
- 196 parties to the Convention- all UN member states, excluding the United States, have ratified.

Cartagena Protocol (on Biosafety)

- International agreement adopted in 2000, part of the CBD. (entered into force in 2003)
- **Focuses on the safe handling, transport, and use of living modified organisms resulting from modern biotechnology.**
- Aims to address technology development, transfer, benefit-sharing, and biosafety issues.
- India is a party.

Nagoya Protocol (on Access and Benefit-sharing)

- Adopted in 2010, it is a supplementary agreement to the CBD.
- **Focuses on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization.**
- Entered into force in 2014, with currently 142 parties, including India.
- In India, the **Biodiversity Management Committees** are key to the realisation of the objectives of the Nagoya Protocol. The Biodiversity Management Committees have important functions in determining access and benefit sharing, including the power to levy collection fees on the access of biological resources within its jurisdiction. **[UPSC 2023]**

Aichi Biodiversity Targets

- **Agreed upon at CBD COP 12 in 2014 as a part of Strategic Plan for Biodiversity 2011-2020.**
- Includes goals to address underlying causes of biodiversity loss, reduce direct pressures, safeguard ecosystems, enhance benefits from biodiversity, and promote participatory management.
- **None of the 20 targets have been met** according to CBD's Global Biodiversity Outlook 5 report.

COP-15 of the UN CBD, 2022: Montreal, Canada

- **Adopted the Kunming-Montreal Global Biodiversity Framework (post 2020 Global Biodiversity Framework).**
- **Sets four global goals to be achieved by 2050**, including reducing extinction rates, sustainable biodiversity use, fair benefit-sharing, and closing the biodiversity finance gap.
- A new **Global Biodiversity Framework Fund** will be established **under the Global Environment Facility**. It targets at least USD 200 billion annually by 2030.
- **India's Demands at COP 15:**
  - Urgent need for a dedicated fund to assist developing countries.
  - Emphasis on **'Common but Differentiated Responsibilities and sRespective Capabilities'** for biodiversity conservation.

Post-2020 Global Biodiversity Framework: Kunming-Montreal Protocol

- **4 global goals by 2050:** Reducing the extinction rate and risk of all species tenfold (by 2050); sustainable biodiversity use; fair benefit-sharing; and adequate finance and technology to implement the **Kunming-Montreal Global Biodiversity Framework**, progressively closing the biodiversity finance gap of 700 billion $ annually.
- **23 targets by 2030,** covering threat reduction, sustainable use, implementation tools, and mainstreaming biodiversity.

COP-16 of the UN CBD, 2024: Cali, Colombia:

- Establishment of a Permanent Body for Indigenous Peoples and Local Communities (IPLCs)
- A new subsidiary body was created to ensure the active participation of IPLCs in biodiversity-related decision-making processes.
- This initiative acknowledges the vital role of traditional knowledge in conservation efforts.

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- **Launch of the 'Cali Fund' for Digital Sequence Information (DSI)**
  - An agreement was reached to implement a 0.1% fee on large biotechnology companies utilizing genetic resources.
  - The revenue will be directed into the newly established 'Cali Fund,' with 50% allocated to support Indigenous communities.
- **Advancements in Monitoring Frameworks**
  - Delegates agreed on frameworks to monitor progress toward the goals set by the Kunming-Montreal Global Biodiversity Framework.
  - These frameworks are designed to enhance transparency and accountability in conservation efforts.
- **Recognition of the Role of People of African Descent**
  - The conference acknowledged the significant contributions of people of African descent in biodiversity conservation.
  - This recognition aims to promote inclusive conservation strategies that leverage diverse cultural perspectives.
- **Unresolved Issues on Financial Resource Mobilization**
  - Despite progress in several areas, the conference concluded without a consensus on a comprehensive roadmap for funding biodiversity conservation.
  - This impasse highlights ongoing challenges in securing adequate financial commitments to meet global biodiversity targets.

International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) [UPSC 2014]

- Known as the **International Seed Treaty,** aligns with CBD.
- **Aims to guarantee food security** through the conservation, exchange, and sustainable use of plant genetic resources, ensuring fair and equitable benefit-sharing.

Global Partnership on Forest and Landscape Restoration (GPFLR)

- A global network to restore lost and degraded forests **(initiated by IUCN)**.
- **Aligns with the Bonn Challenge, aiming to restore 150 million hectares by 2020 and 350 million hectares by 2030.**

Bonn Challenge [UPSC 2021]

- Launched in 2011(**Government of Germany and IUCN**), targets **restoring 350 million hectares of deforested and degrasssded land by 2030(under New York Declaration on Forests). [UPSC 2021]**
- **India joined voluntarily**, pledging to restore 26 million hectares by 2030.

Forest Landscape Restoration (FLR)

- **Coined in 2000 by IUCN and WWF,** FLR aims to regain ecological integrity and enhance human well-being in deforested and degraded landscapes.
- Involves a planned process focusing on entire landscapes.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) (IPBES)

- **IPBES, based in Bonn, Germany, comprises almost 150 member countries, including India.**
- Estimated 8 million species on Earth, with 1 million threatened with extinction, including 40% of amphibians, 33% of reef-forming corals, and over a third of marine mammals.
- **IPBES is often termed the "Intergovernmental Panel on Climate Change (IPCC) for biodiversity."**

XV World Forestry Congress and Seoul Declaration

- Held in Seoul with a theme of building a green, healthy, and resilient future with forests.
- Held every six years since 1926 under the auspices of FAO (entrusted the responsibility in 1954) and organised by the government of the host country.
- **Seoul Declaration** stresses a transition to a **circular bioeconomy** and achieving climate neutrality.

FEW INITIATIVES BY THE UN

United Nations Strategic Plan for Forests 2017–2030

- Adopted at the UN Forum on Forests in 2017 and ratified by the UN General Assembly.
- Features six Global Forest Goals with 26 associated targets to be achieved by 2030.
- **Includes a voluntary and universal target to increase global forest area by 3% by 2030,** equivalent to a 120 million-hectare increase.

Decade on Ecosystem Restoration (2021–2030)

- Proclaimed **by the United Nations General Assembly.**
- Aims to work towards ecosystem restoration from 2021 to 2030.

Biodiversity Finance Initiative (BIOFIN)

- **Launched by UNDP in 2012** to address the biodiversity finance gap at the national level.
- Aids in implementing the National Biodiversity Action Plan (NBAP) and making progress towards achieving National Biodiversity Targets (NBTs).
- **In India, BIOFIN is hosted by the National Biodiversity Authority (NBA – MoEF),** working with State Biodiversity Boards, with technical assistance from the Wildlife Institute of India (WII) and the National Institute of Public Finance and Policy (NIPFP).

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3 Wildlife Conservation

Wildlife conservation is to protect wild species and prevent harmful utilisation of resources to keep the natural ecosystems healthy.

INTERNATIONAL EFFORTS TO CONSERVE WILDLIFE

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

- It is an international agreement also known as the **Washington Convention** aimed at safeguarding endangered species from the perils of international trade. **[UPSC 2015]**
- This multilateral treaty involves 184 Parties. It was drafted due to a resolution adopted by members of **IUCN in 1963** and came into force from **1975**.
- **CITES CoP (World Wildlife Conference):** Convenes every 2-3 years to regulate endangered species' trade, deciding on species listing or alterations in CITES appendices.
- **CITES Functioning:** Controls international trade for selected species, requiring authorization via a licensing system for all imports and exports under CITES coverage.
- **Authorities:** Each country appoints Management Authorities overseeing the licensing system and Scientific Authorities advising on trade effects on species' status.
  - **Management Authority in India** – Director of Wildlife Preservation (MoEFCC);
  - **Permit issuance Authority** – Wildlife Crime Control Bureau (WCCB);
  - **Scientific Authorities** – Zoological Survey of India, Botanical Survey of India, Wildlife Institute of India, etc.
- **Species Protection**: CITES categorises species into three Appendices.
  - **Appendix I** for species **threatened with extinction**, allowing trade only in exceptional cases such as captive breeding.
  - **Appendix II** includes species **not immediately endangered but requiring controlled trade** to protect their survival.
  - **Appendix III** encompasses species **protected in at least one country** and seeking assistance from CITES Parties in controlling the trade.

19th Conference of the Parties to CITES (CoP-19)

- Held in Panama in November 2022.
- Release of the **First World Wildlife Trade Report at CoP19**, providing insights into international trade in CITES-regulated species.
- **CITES Tiger Enforcement Task Force:** CoP19 proposed a tentative budget of $150,000 for the Big Cat Task Force to curb illegal trade in big cats.

India at COP-19

- Acknowledgement of **Operation Turtshield**, India's initiative to **combat turtle wildlife crime**.
- Proposal to move the **Red-Crowned Roofed Turtle (Batagur Kachuga)** and **Leith's softshell turtle** from Appendix II to I. Inclusion of the **Jeypore Ground (Indian) Gecko** in Appendix II, addressing threats like the international pet trade, habitat loss, and more.
- **North Indian Rosewood/Shisham:** Shisham (Dalbergia sissoo) included in CITES Appendix II due to challenges in distinguishing different species. **Agreement at CoP19 allowing export of shisham timber-based items below 10kg without CITES permits.**

Monitoring the Illegal Killing of Elephants (MIKE)

- **Establishment:** MIKE is an international collaboration **initiated by a CITES Resolution in 1997.**
- **Aim:** It aims to measure trends and causes of elephant mortality globally. The core mandate includes building capacity in elephant range states.
- **Information Base and Usage:**
  - Supports international decision-making related to elephant conservation in both Asia and Africa.
  - Information and analyses from MIKE are presented at annual CITES meetings.
- **Participating Sites:**
  - Currently, there are **28 MIKE sites in Asia**, spread across 13 countries.
  - **India leads with 10 MIKE sites**, followed by two sites each in Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, and Thailand. Additionally, there's one site each in Bangladesh, Bhutan, China, Nepal, Sri Lanka, and Vietnam.

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- **Donor Support:** MIKE is **entirely dependent on donor support**. The European Union (EU) has been a significant donor for the MIKE program in Africa since 2001 and in Asia since 2017.

Wildlife Trade Monitoring Network (TRAFFIC) [UPSC-2017]

- **Formation**
  - TRAFFIC is a non-governmental organization (**NGO**) **founded in 1976.**
  - Established as a **joint program** of the World Wide Fund for Nature (**WWF**) **and** the International Union for Conservation of Nature **(IUCN)**.
  - **Headquarters** located in **Cambridge, UK.**
- **Mission and Role: Complementary to CITES**
  - **Mission:** To ensure that trade in wild plants and animals does not pose a threat to the conservation of nature.
  - Investigates wildlife trade trends, patterns, impacts, and drivers to provide a leading knowledge base on trade in wild animals and plants.

Coalition Against Wildlife Trafficking (CAWT)

- **Formation:** CAWT is a coalition established in 2005 with the aim of collaborating in the fight against illegal trade in wildlife and wildlife parts.
- **Leadership and Membership: US-led coalition, and India is a member.**
  - Initial partners of CAWT include Conservation International, Save the Tiger Fund, Smithsonian Institution, and TRAFFIC International.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

- **Establishment:** An international treaty concluded **under the UN Environment Programme** in **1979 in Bonn, Germany**. Entered into force in 1983. Also known as the **Bonn Convention or Global Wildlife Conference.**
- **Scope and Purpose:** The only global and UN-based intergovernmental organization exclusively established for the conservation of terrestrial, aquatic, and avian migratory species throughout their range.
- **Appendices under CMS**:
  - Migratory species threatened with extinction listed in **Appendix I** (CMS global conservation list), with Parties striving for strict protection.
  - Migratory species benefiting from international cooperation listed on **Appendix II.**
- **13th Conference of the Parties to CMS (CoP13):** Organized in 2020 in Gandhinagar, Gujarat, with India designated as the President of the COP for the next three years.
- **CMS CoP 14:** The first-ever "State of the World's Migratory Species" report launched. Also added 14 migratory species to CMS appendices.

Central Asian Mammals Initiative (CAMI)

- Part of CMS aiming to **conserve 15 migratory mammal species** and their habitats in Central Asia. CAMI's working approved for 2021-2026, incorporating IUCN Save Our Species' Central Asia initiative as a potential funding mechanism.
  - **Major Animals Included in Central Mammals Initiative:** Wild Yak, Snow Leopard, Asiatic Wild Ass / Khulan, Cheetah / Asiatic Cheetah, Leopard etc.

International Union for Conservation of Nature (IUCN)

- **Establishment:** An international non-governmental organization (NGO) working in the field of nature conservation and sustainable use of natural resources. **Headquarters** located in **Gland, Switzerland.**
- **Functions and Activities:** Engaged in research, field projects, advocacy, lobbying, and education. IUCN group's **Invasive Species Specialist Group develops Global Invasive Species Database. [UPSC 2023]**
- **IUCN Red List / Red Data Book :** Founded in 1964, the IUCN Red List is the world's most comprehensive inventory of the global conservation status of Threatened plant and animal species. **[UPSC 2011]**
- **Pages in the IUCN Red List:**
  - **Pink Pages:** Include information on critically endangered species.
  - **Green Pages:** Used for species that were formerly endangered but have recovered to a point where they are no longer threatened.

Criteria to add Species in IUCN Red List

Category	Description
Extinct	No known individuals remain
Extinct in the Wild	Survives only in captivity or cultivation.
Critically Endangered	Extremely high risk of extinction in the wild. Population size reduction ≥ 90% over the last 10 years or three generations, whichever is longer.
Endangered	Very high risk of extinction in the wild. Population size reduction ≥ 70% over the last 10 years or three generations, whichever is longer.
Vulnerable	High risk of extinction in the wild. Population size reduction ≥ 50% over the last 10 years or three generations, whichever is longer.
Near Threatened	Close to qualifying for Vulnerable status.
Least Concern	Lowest risk category; widespread and abundant.

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Data Deficient	Insufficient data to make an assessment.
Not Evaluated	Not yet evaluated against the criteria.

IUCN Protected Area Categories

- **Category I: Strict Nature Reserve (Ia) / Wilderness Area (Ib)**
  - **Strict Nature Reserve (Ia)**: Areas where biodiversity is preserved with minimal human interference. Access is generally restricted to research and monitoring purposes only. These areas have high ecological significance.
  - **Wilderness Area (Ib)**: Areas that remain in their natural state and are large enough to maintain their ecological integrity, allowing limited human activity like research, tourism, or traditional practices under strict control.
- **Category II: National Park**
  - Areas set aside for **ecosystem protection and recreation**. National Parks are strictly protected, and human activities are carefully regulated. The primary purpose is the conservation of biodiversity, and public access for recreation, education, and tourism is often allowed under regulated conditions.
  - **No human settlements** or major exploitation of natural resources are permitted within these parks.
- **Category III: Natural Monument**
  - These are **protected areas that contain specific natural features** such as landforms, caves, waterfalls, or geological formations. The focus is on preserving the special features of these areas while allowing tourism and research.
  - Human activities may be permitted in a limited manner, but the natural monument's features must not be disturbed.
- **Category IV: Habitat/Species Management Area**
  - Protected areas managed for the **conservation of specific species or habitats**. Active interventions may be carried out to maintain or restore biodiversity, especially for species at risk.
  - Human activities like agriculture or forestry may be allowed if they do not adversely affect the species or habitat being conserved.
- **Category V: Protected Landscape/Seascape**
  - These areas are managed to protect both **biodiversity** and **cultural landscapes**. The aim is to sustain the relationship between people and the natural environment, balancing conservation and the sustainable use of natural resources.
  - Human activities such as agriculture, forestry, and tourism are allowed if they maintain the area's ecological and cultural integrity.
- **Category VI: Protected Area with Sustainable Use of Natural Resources**
  - Areas where **conservation of biodiversity** is the primary objective, but **sustainable use of natural resources** is allowed. These areas provide a balance between protecting the environment and allowing activities like grazing, fishing, and sustainable agriculture.
  - Local communities are often involved in the management and sustainable use of these areas.

BirdLife International (BI)

- **World's largest nature conservation partnership for birds and their habitats**, consisting of 120 national nature conservation organizations across the globe.
- **Mission**
  - BI is dedicated to the conservation of birds, their habitats, and global biodiversity.
  - Aims to work collaboratively with people to promote sustainability in the use of natural resources.
- **Role as Red List Authority:** BI serves as the **official Red List authority for birds** on behalf of the (IUCN).
- **Identification of Important Bird and Biodiversity Areas (IBA)**
  - BI identifies sites known as Important Bird and Biodiversity Areas (IBA), which either harbor significant numbers of one or more threatened bird species or support exceptionally large numbers of migratory birds.
  - There are over 13000 IBAs worldwide out of which 554 sites have been identified in India.
  - The **Bombay Natural History Society** (BNHS), a BirdLife International partner from India, collaborates with BI in identifying IBAs.

Bombay Natural History Society (BNHS): [UPSC 2014]

- **Establishment:** Founded in 1883, the BNHS is one of the oldest and largest non-governmental organizations (NGOs) in India.
- **Mission and Focus:** Engaged in conservation and biodiversity research, BNHS plays a crucial role in the study and protection of India's rich natural heritage.
- **Journal of the BNHS:** Publishes the "Journal of the Bombay Natural History Society".
- **Prominent Naturalists Associated:** Notable figures include ornithologists Salim Ali ("birdman of India") and S. Dillon Ripley, etc.

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World Wildlife Fund for Nature (WWF)

- **Establishment:** Established in 1961, WWF (formerly known as the World Wildlife Fund) is a Non-Governmental Organization (NGO) **headquartered in Gland, Switzerland.**
- **Mission and Focus:** Aims to "stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature."
- **Initiatives by WWF**
  - **Wildlife Trade Monitoring Network (TRAFFIC)**
  - **Living Planet Report:** Published **every two years by WWF** since 1998, providing insights into the state of the world's biodiversity.
  - **Earth Hour:** A worldwide movement organized by WWF **since 2007**. Encourages people to switch off lights from 8:30 pm to 9:30 pm, local time, on the last Saturday of March each year. Symbolic call for environmental protection by reducing non-essential lighting.
  - **Debt-for-Nature Swap:** A transaction where a country's debt is purchased, renegotiated, or forgiven by creditors, with the condition that the savings on debt are invested in environmental conservation activities.

International Whaling Commission (IWC)

- **Establishment:** A **non-UN body** established by the terms of the **International Convention for the Regulation of Whaling (ICRW).** Headquarters located in the United Kingdom.
- **Mission:** Established to provide for the proper **conservation of whale stocks** and the orderly development of the **whaling industry**.
- **Whaling Sanctuaries:** Empowered to **designate areas as whaling sanctuaries** such as the Indian Ocean Whale Sanctuary in Seychelles.
- **Membership:** Membership in the IWC is open to any country that formally ratifies the 1946 Convention. **India is a member.**
- **Moratorium on Commercial Whaling (1982), but whaling under Scientific Research and aboriginal subsistence provisions of ICRW are still allowed.**
- **Florianopolis(Brazil) Declaration (2018):** Members rejected a proposal by Japan to renew commercial whaling. Following this rejection, Japan announced its withdrawal from the IWC.

INDIA'S EFFORTS TO CONSERVE WILDLIFE

Wildlife (Protection) Act, 1972 [UPSC 2022]

- Extended to the whole of India, **administered by the Wildlife wardens and their staff.**
- **Provides** for **State wildlife advisory boards**, defines **wildlife** related terminologies like habitat, hunting, zoo, sanctuary, NP, Reserve forest etc., Regulations for hunting wild animals and birds
- **Establishment of sanctuaries and national parks** — State government by Notification (no need to pass any law) declare an area as a Sanctuary/NP.
- Set Regulations for trade in wild animals, animal products and trophies.
- **Central Zoo Authority** manages the Zoo **under Section 38(C) of WPA 1972. (WPA amendment 1991)**
- Judicially imposed penalties for violating the Act.
- **The Chief Wildlife Warden** is appointed by the State Government and the Central government may appoint directors and assistant directors.
- WPA, 1972 is against **taxidermy** (preservation of dead wild animals as trophies or in the form of skins, antlers, horns, eggs, teeth or nails).

Amendments: 8 times so far **1982, 1986, 1991, 1993, 2002, 2006 and 2013, 2022**

WPA amendment 1982	Introduced a provision permitting the capture and transportation of wild animals for the scientific management of animal population.
WPA amendment 2002	Provision for **National Board for Wildlife (NBWL)**
WPA amendment 2006	**National Tiger Conservation Authority** **Wildlife Crime Control Bureau (WCCB)**
WPA amendment 2013	Provision of imprisonment up to 7 years. Protects hunting rights of STs in Andaman and Nicobar Island.

Bodies Constituted under the Wildlife Protection Act

Organization	Purpose	Composition	Functions
National Board for Wildlife (NBWL)	Apex advisory body for wildlife conservation and project approvals in and around protected areas	• **Chairperson:** Prime Minister • **Vice-Chairperson:** Minister of Environment, Forest, and Climate Change	• Advises on wildlife conservation policies • Promotes conservation and development of wildlife and forests

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Standing Committee of NBWL	Approves projects within protected wildlife areas or within a 10 km radius	• **Chairperson:** Minister of Environment, Forest, and Climate Change	• Approves projects impacting protected areas
State Board for Wildlife (SBWL)	Advisory body for wildlife protection at the state level	• **Chairperson:** Chief Minister of the state/UT	• Advises on the management of protected areas • Formulates policies for wildlife protection • Reviews wildlife-related schedule amendments
Central Zoo Authority	Regulates and provides recognition to zoos across India.	• **Chairperson:** Environment Minister • 10 Members and a Member-Secretary	• Prescribes guidelines for zoo operations. • Regulates animal transfers nationally and internationally.
National Tiger Conservation Authority (NTCA) **UPSC[2014]**	Strengthens tiger conservation efforts.	• **Chairperson:** Union Environment Minister • **Vice-Chairperson:** Minister of State for MoEFCC	• Recommends areas for Tiger Reserves. • Manages over 50 Tiger Reserves under the Wildlife Protection Act, 1972.
Wildlife Crime Control Bureau (WCCB)	Combats organized wildlife crimes in India.	• **Headquarters:** New Delhi	• Collects and disseminates intelligence on wildlife crimes. • Maintains a centralized wildlife crime database. • Assists states in prosecutions. • Advises the government on policies and international wildlife crime issues.

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Delineation of Powers

- **No human activity** is permitted inside a NP except for ones permitted by the Chief Wildlife Warden of State.
- **Chief Wildlife Warden may permit hunting** of any wild animal if it has become dangerous to human life or is so disabled or diseased as to be beyond recovery.
- **Notification of National Parks and Wildlife Sanctuaries** can be done both by **State/ Central Governments** under the act.
- **Alteration of boundaries** can be done **by States** only with prior approval of the National Board for Wildlife (NBWL).
- Central Government may add or delete any entry to or from any Schedule or transfer any entry from one Part of a Schedule to another Part of the same Schedule or from one Schedule to another.

Wild Life (Protection) Amendment Act, 2022

Reduces the number of schedules to 4, which involves the **removal of the schedule for vermin** and insertion of a new schedule for specimens (any animal or plant (dead or alive) under CITES. Commonly declared vermin include: **Rats, Mice, Crows and Fruit Bats** **[UPSC 2024]**

Updated Schedules Under 2022 Amendment	
Schedule 1	Animal species that will enjoy the highest level of protection
Schedule 2	Animal species that will be subject to a lesser degree of protection
Schedule 3	Protected Plant species
Schedule 4	Specimens listed in the Appendices under CITES (scheduled specimens)

- **Regulation of Invasive Alien Species**
  - The **Central Government** is empowered to regulate or prohibit the **import, trade, possession**, or **proliferation** of **invasive alien species**, which threaten the biodiversity of India.
- **Surrender of Captive Animals/Animal Products**
  - Individuals can **voluntarily surrender** any **captive animals** or **animal products** to the **Chief Wildlife Warden**.
  - No **compensation** is provided for such voluntary surrender.

- **Conservation Reserves**
  - The **Central Government** is empowered to declare areas adjacent to **National Parks** and **Wildlife Sanctuaries** as **Conservation Reserves** to protect flora and fauna and their habitats. Previously, this power was solely vested with state governments.
- **Role of the Chief Wildlife Warden**
  - The **Chief Wildlife Warden (CWW)** is entrusted with the responsibility to **control**, **manage**, and **maintain** all **sanctuaries** within a state.
  - The actions of the **Chief Warden** must align with the **sanctuary management plans** prepared under the guidelines of the **Central Government**, and must be approved by the **CWW**.
- **Standing Committee for Wildlife Management**
  - A **Standing Committee** is to be constituted to exercise powers delegated by the **State Board for Wildlife** for the effective management of wildlife and protected areas.
- **Captive Elephant Management**
  - The **Central Government** permits the transfer or transport of a **captive elephant** (a **Schedule I** animal) for **religious** or **other purposes** provided the person has a **valid certificate of ownership**.
- **Scientific Authority and Management Authority**
  - **Management Authority**: The **Central Government** can appoint a **Management Authority** to grant permits for the **export** or **import** of specimens under **CITES (Convention on International Trade in Endangered Species)**.
  - **Scientific Authority**: The **Central Government** can appoint a **Scientific Authority** to advise on the **impact** of trade on the **survival** of specimens.
  - These provisions are designed to ensure **sustainable exploitation** of flora and fauna while protecting biodiversity.
- **Registration and Reporting for Scheduled Specimens**
  - Individuals possessing **live specimens** of **scheduled animals** must obtain a **registration certificate** from the **Management Authority**.
  - Individuals involved in the **trade** of scheduled specimens must report transaction details to the **Management Authority**.
  - The **Management Authority** may use an **identification mark** for specimens, and it is prohibited to alter or remove these identification marks.
- **Enhanced Penalties for Violations**
  - **General Violations**: The maximum fine for general violations has been increased from **Rs. 25,000** to **Rs. 1 lakh**.
  - **Specially Protected Animals**: For violations related to specially protected animals, the minimum fine has been enhanced from **Rs. 10,000** to **Rs. 25,000**.

Enforcement Through Wildlife Crime Control Bureau (WCCB)

The **Wildlife Crime Control Bureau (WCCB)**, established in 2007 under the **Wildlife Protection Act, 1972**, plays a crucial role in enforcing the provisions of the Act and ensuring the protection of wildlife. Key functions include:

- **Nodal Agency for CITES Enforcement:**
  - The **WCCB** is the **nodal agency** for the enforcement of **CITES-related** regulations in India.
- **Regional and Border Units:**
  - The WCCB has **5 regional offices** and **5 border units** spread across India to monitor and curb wildlife-related crimes.
- **Key Functions of WCCB:**
  - **Intelligence Gathering:** Collects and collates intelligence related to wildlife crime.
  - **Wildlife Crime Data Bank:** Maintains a comprehensive database on wildlife crimes.
  - **Coordination:** Coordinates actions to curb wildlife crime and collaborates with international organizations.
  - **Capacity Building:** Builds capacity for wildlife crime control and advises the government on enforcement strategies.
- **Operations and Campaigns:**
  - **Operation Clean Art:** A pan-India operation by WCCB to crack down on the illegal smuggling of **mongoose hair**, protected under the **Wildlife Protection Act** and **CITES**.
  - **Awareness Campaigns:** WCCB launched the **'Not All Animals Migrate by Choice'** campaign, in collaboration with the **UN Environment Programme**, to raise awareness about illegal wildlife trade.

Animal Welfare Board of India (AWBI)

- A **statutory advisory body** established under the **Prevention of Cruelty to Animals Act, 1960.**
- It advises the government on animal welfare laws, promotes animal welfare, and oversees Animal Welfare Organizations (AWOs).

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- AWBI is concerned about the abuse of animals in research and cruelty in animal entertainment, providing financial assistance to recognized AWOs

- **Foreign Trade (Development and Regulation) Act, 1992:** Empowers the Government of India (GOI) to regulate the import or export of goods, including wildlife specimens and their products.
- **EXIM Policy:**
  - Allows export/import of wild animals and plants for research and exchange between zoos, subject to licensing by the Director-General of Foreign Trade (DGFT).
  - Commercial import of African ivory is not permitted due to the CITES ban.
  - Import of other wildlife derivatives is restricted and requires prior permission from DGFT.
  - Import of wild animals as pets is subject to CITES provisions.

TIGER CONSERVATION

- There are **eight subspecies** of tigers; **five present in the wild** (Bengal, South China, Indochinese, Sumatran, Siberian), **three are extinct** (Caspian, Bali, Javan). The IUCN status of Tiger is **Endangered (EN).**

Challenges to Tiger Conservation

- **Habitat Pressure:** Large-scale development projects cause habitat destruction, fragmentation, and pressure.
- **Invasive species destroy local producers** having a cascade effect on food chain and affecting tigers at the top of the food chain.
- **Poaching and Wildlife Crime:** Tigers are killed for Traditional Chinese Medicine, and poaching remains a significant issue.
- **Canine Distemper Virus (CDV):** A contagious disease affecting the respiratory, gastrointestinal, and nervous systems of dogs and puppies, can be transmitted to wildlife from infected dogs around wildlife sanctuaries.

National Tiger Conservation Authority (NTCA)

- **Statutory body** under MoEF, established under the Wild Life (Protection) Amendment Act, 2006.
- Administers **Project Tiger**, lays down standards and guidelines for tiger conservation.
- **Members**: **Minister for Environment & Forests (Chairman)**; 8 experts on wildlife conservation; 3 MPs; Inspector general of Forests, incharge of Project Tiger (ex-officio Member Secretary) and others.
- No alteration in the boundaries of a Tiger reserve shall be made except on a recommendation of the NTCA and approval of the National Board of Wildlife.
- No State Government shall de-notify a tiger reserve, except in public interest with the approval of the NTCA and National Board for Wildlife

Project Tiger

- Launched **in 1973 in Jim Corbett National Park** to protect tigers from extinction.
- Administered by National Tiger Conservation Authority (**NTCA**).
- Aims to ensure a viable tiger population in natural habitats, funding relocation of villagers, and combating poaching.
- **Core and Buffer Zones in Tiger Reserves**
  - Core zones are areas freed of human activities; buffer zones allow co-existence of human activities on a sustainable basis.
  - **Forest Rights Act of 2006** recognizes rights of some forest-dwelling communities in buffer areas.

Critical Wildlife Habitat

As envisaged in the **Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006**, Critical Wildlife Habitats are to be declared by the **Central Government** in the Ministry of Environment and Forests after a process of consultation by Expert Committees.

Critical Tiger Habitat

Area demarcated for sustenance of a viable populations of tiger and other wild animals in tiger reserves and protected areas vis-à-vis the **Wildlife (Protection) Act, 1972**, as per amendment in 2006.It forms the core area of a Tiger reserve.

Tiger Census 2023

- Released in April 2023, announced by PM Modi on the 50th year of Project Tiger in India. It is held every four years.
- **Tiger Population in India (2023)**: 3,682 tigers.
- **Population Growth:** Increase of 715 tigers in the last four years (2,967 to 3682). Significant improvement from the 1973 census, indicating the success of conservation efforts.

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- India houses more than **75% of the global tiger population**, growing at a rate of 6% annually.
- **Top 10 states** with the highest number of tigers are Madhya Pradesh, Karnataka, Uttarakhand, Maharashtra, Tamil Nadu, Assam, Kerala, Rajasthan, Odisha, and Chhattisgarh.
- India now has **57 tiger reserves**, covering over 2.4% of the country's total geographical area.
- The 2023 census reflects India's commitment to tiger conservation and marks a significant achievement.

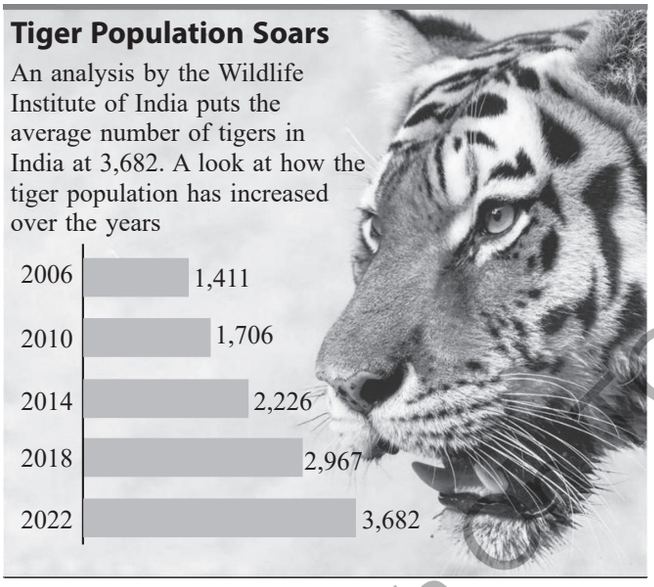

Fig. Tiger Census

Tiger Corridors

- **The National Tiger Conservation Authority in collaboration with the Wildlife Institute of India** has published a document titled **"Connecting Tiger Populations for Long-term Conservation",** which has mapped out 32 major corridors across the country, management interventions for which are operationalised through a Tiger Conservation Plan, mandated under section **38V of the Wildlife (Protection) Act, 1972.** The list of macro/landscape level tiger corridors are as under:

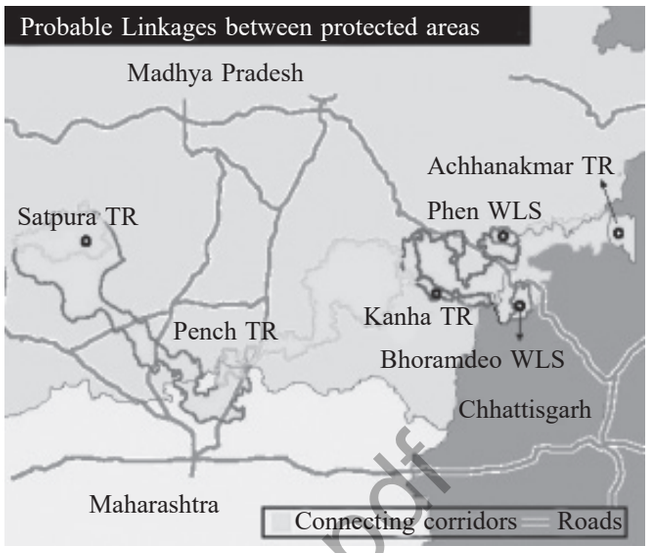

Fig. Tiger Corridors

M-STrIPES (Monitoring System for Tigers – Intensive Protection and Ecological Status) [UPSC-2017]

- **Launch:** Introduced in 2010 across Indian tiger reserves by the **NTCA** and the **Wildlife Institute of India.**
- **Purpose:** Enhance wildlife protection, particularly for tigers, through technology-driven monitoring and data analysis.
- **Components**
  - **Field-Based Protocols:** Guides patrolling, law enforcement, wildlife crime recording, and ecological monitoring.
  - **GIS Software:** Customized Geographic Information System software for storage, retrieval, analysis, and reporting.
  - **Real-Time Monitoring:** Forest guards record tracks using GPS, note observations, and upload geo-tagged pictures, contributing to a central GIS database.
- **Advantage:**
  - Identifies patrolling shortcomings in real-time.
  - Serves as proof of the presence and activities of forest guards.

International Big Cat Alliance

- Launched by India to safeguard and conserve seven significant big cat species.
- Includes **tigers, leopards, lions, snow leopards, jaguars, pumas, and cheetahs.**
- Celebrated on the 50th anniversary of Project Tiger.
- Announcement of the book "Amrit Kaal Ka Tiger Vision" outlining tiger protection strategy for the next 25 years.

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CONSERVATION OF SNOW LEOPARD

The snow leopard's habitat range extends across the mountainous regions of 12 countries across Asia: Afghanistan, Bhutan, China, India, Kazakhstan, Kyrgyz Republic, Mongolia, Nepal, Pakistan, Russia, Tajikistan, and Uzbekistan. The IUCN status of Snow Leopard is **Vulnerable (VU).**

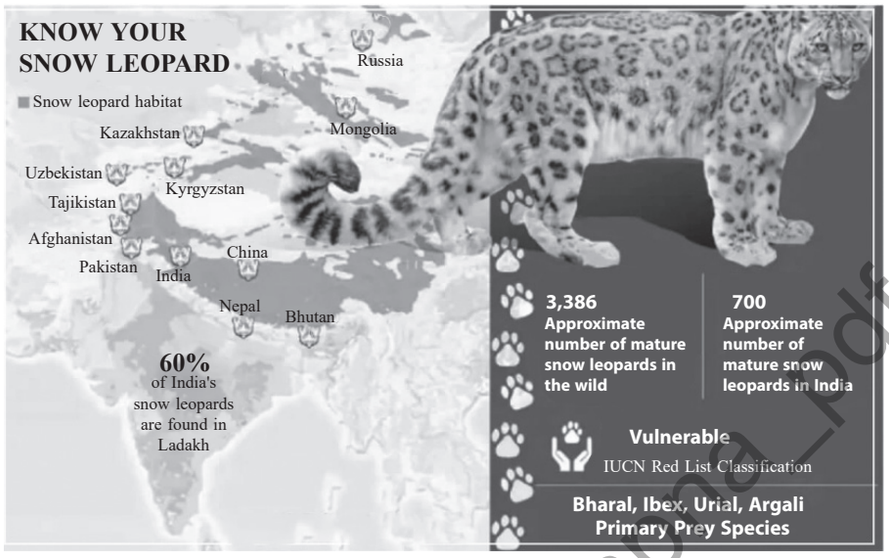

Fig. Snow Leopard Overview

Project Snow Leopard

- Launched in 2009 to conserve high-altitude wildlife populations and habitats.
- Identified landscapes include **Hemis-Spiti, Nanda Devi–Gangotri, and Khangchendzonga–Tawang.**
- High-altitude ecosystems support endangered species like the Snow Leopard, Red Panda, and various ungulates and birds.

GSLEP

The Global Snow Leopard and Ecosystem Protection Program (GSLEP) seeks to address high-mountain development issues using the conservation of the charismatic and endangered snow leopard as a flagship. **Secure 20 by 2020:** The snow leopard range countries agree, with support from interested organizations, to work together to identify and secure at least 20 snow leopard landscapes across the cat's range by 2020 or, in shorthand – "Secure 20 by 2020."

Reintroduction of Cheetahs in India

- Over 70 years after extinction, eight cheetahs (five females, three males) **from Namibia reintroduced in Kuno Palpur National Park, MP.** Later more Cheetahs are brought.
- **World's first intercontinental translocation of a carnivore**.
- Kuno Palpur National Park is **unfenced**, promoting co-existence with buffer zones **unlike** "**fortress conservation" in South Africa.**
- Cheetahs are expected to help restore open forest and grassland ecosystems in India.
- The government constituted a Task Force for monitoring the introduction and developing tourism infrastructure.

Attribute	African Cheetah	Asiatic Cheetah
IUCN	Vulnerable	Critically Endangered
CITES	Appendix-I	Appendix-I
Population	6,500-7,000 (Africa)	Around 40-50 (Iran)
Size	Bigger	Smaller, paler
Habitat	Africa	Historical range near Sal forests of Chhattisgarh
Eyes	Normal	Red (usually)

CONSERVATION OF LIONS

Asiatic Lion

- **Restricted to India**, specifically Gir National Park and Wildlife Sanctuary in Gujarat.

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- IUCN Red List: **Vulnerable** | **CITES: Appendix I** | WPA: **Schedule I**.

Project Lion

- Landscape ecology-based conservation in Gir landscape, Gujarat.
- Aims to secure and restore lion habitats, manage growing population, scale up livelihood generation, and involve local communities.

CONSERVATION OF ELEPHANTS

Ecological Importance of Elephants

- National Heritage Animal of India, elephants are keystone species, creating an umbrella effect for diverse ecosystems.
- Landscape architects, seed dispersal agents, nutrient providers, water providers, and contributors to the food chain.

Attribute	Asian Elephant	African Elephant	African Forest Elephant	African Savanna Elephant
Habitat	Varied	Savannah Grasslands, semi-arid regions	Tropical forests of Central and Western Africa	Savannah Grasslands, semi-arid regions of Sub-Saharan Africa
Tusks	Males have prominent tusks, while females usually lack them or have rudimentary tusks (tushes)	Tusks are generally larger, more curved, and point downward.	Point downward	Tusks curve outward
IUCN Red List	Schedule I	Schedule I	Critically Endangered	Endangered

Elephant Corridor: Linear, narrow habitat linkages for elephant movement without human disturbance.

Project Elephant (1992)

Centrally sponsored scheme addressing human-elephant conflict, conserving elephant populations in their natural habitats, and protecting elephants from poachers.

Other Initiatives

- **Haathi Mere Saathi**: Campaign to increase awareness and develop companionship between people and elephants, launched by MoEF along with Wildlife Trust of India.
- **RE-HAB (Reducing Elephant-Human Attacks using Bees) Project:** Uses bee boxes as a fence to prevent elephants from entering human habitation without harm to prevent elephant-human conflicts.
- **Asian Elephant Alliance:** Coalition of five NGOs securing elephant corridors across 12 states in India.
- **IUCN Asian Elephant Specialist Group (AsESG):** Global network providing scientific evidence on Asian elephant populations in 13 range states. Integral part of the Species Survival Commission (SSC) of the IUCN.

CONSERVATION OF GREAT ONE-HORNED RHINO

- Rhinos are killed for their horns, composed of keratin, used in traditional medicines in Southeast Asia.
- **Rhino Species Across the World:**
  - **White Rhino and Black Rhino:** Found in Africa. Black Rhino is smaller.
  - **Javan Rhino:** Few survive in Java and Vietnam.
  - **Sumatran Rhino: Smallest** species, 30-80 remaining, mainly on Sumatra.
  - **Great One-Horned Rhino: Only found in India,** the **largest** rhino species.

India's Greater One-Horned Rhinoceros

- **Habitat:** Tropical and Subtropical Savannas & Shrublands.
- **Distribution:** Confined to Terai alluvial grasslands of India, Bhutan & Nepal.
- **Populations:** Mainly in Kaziranga & Manas NPs & Pobitora WLS.
- **Threats:** Poaching, habitat loss, habitat fragmentation, human-animal conflict.

Conservation Measures

- **New Delhi Declaration on Asian Rhinos 2019** for conservation by five rhino range nations.
- DNA profiling project for all rhinos.
- National Rhino Conservation Strategy launched in 2019.
- **India Rhino Vision (IRV) 2020:**

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- Vision to build a wild population of 3000 Greater One-Horned Rhinos by 2020 across 7 protected areas in Assam.
- Translocations from Kaziranga NP and Pobitora WLS to potential rhino habitat areas like Manas NP, Dibru Saikhowa WLS, and Laokhowa-Bura Chapori WLS.

CONSERVATION OF INDIAN DOLPHINS

The Sub-species found in India are Ganges River Dolphin and Indus River Dolphin.

- **Distribution**: India, Bangladesh, Nepal, and Pakistan.
- **Threats:** Unintentional killing through fishing gear, habitat loss (water development projects, pollution), noise from vessel traffic.

Ganges River Dolphin (Susu: due to breathing sound)

- National Aquatic Animal and State Aquatic Animal of Assam.
- Indicator species for the Ganga, essentially blind, hunt by emitting ultrasonic sounds.
- **Distribution:** Ganges-Brahmaputra-Meghna.
- **Listed in Convention on Migratory Species.**
- **IUCN: Endangered (EN)**

Indus River Dolphin (Bhulan)

- State Aquatic Animal of Punjab.
- **Habitat:** Indus River in Pakistan, Beas (only habitat in India), and Sutlej.
- **IUCN: Endangered (EN)**

Irrawaddy Dolphin

- **Habitat:** Brackish water near coasts, river mouths, estuaries, and freshwater rivers.
- **Distribution**: Concentrated in lagoon populations, including Chilika Lake in Odisha.
- **Threats:** Human conflict, drowning in gillnets.
- **IUCN: Endangered (EN)**

Ganges River Dolphin Conservation Measures

- **Ganga Action Plan (1985):** Included Gangetic dolphins in WPA, 1972. National Ganga Council set up and **Vikramshila Gangetic Dolphin Sanctuary (Bihar)** created for dolphin conservation.
- **Project Dolphin (2020):** Announced by PM Modi, aimed at saving river and marine dolphins.
- **Conservation Action Plan for Gangetic Dolphin (2010-2020):** Identified threats and impact of river traffic, canals, and prey-base depletion.
- **Integrated Development of Wildlife Habitat:** Ganges River Dolphin among 21 species.
- **National Ganga River Basin Authority (2009):** Declared Gangetic River Dolphin as the national aquatic animal.
- **National Mission for Clean Ganga:** Celebrates October 5 as National Ganga River Dolphin Day.

CONSERVATION OF INDIAN CROCODILE SPECIES

Aspects	Crocodiles	Alligators	Gharials
Habitat	Saltwater	Freshwater	Freshwater
Distribution	Throughout the tropics	US, Mexico, China	Gharial: Ganges and Indus; False gharial: Indonesian Is.
Snout Shape	Pointed and V-shaped	Wide and U-shaped	Long and thin snout
Size	Large	Small	Medium
Diet	Opportunistic feeders	Opportunistic feeders	Fish

Gharial

- Fish-eating **freshwater crocodile**, among the longest of all living crocodilians.
- **Habitat:** Clean rivers with sandbanks
- **Distribution:** Viable population in **National Chambal Sanctuary (UP, Rajasthan, MP)**, small non-breeding populations in other rivers.
- **Threats:** Dams, barrages, embankments, pollution, sand-mining, agriculture, livestock.
- **Conservation Status: Critically Endangered (CR), CITES: Appx I, CMS: Appx I, WPA: Sch I.**

Mugger/Indian Crocodile

- **Freshwater species** found in lakes, rivers, marshes, and slow-moving water bodies.
- **Found throughout India, extinct in Bhutan.**
- **Threats:** Habitat destruction, superstitions, use in aphrodisiacs.
- **Conservation Status: Vulnerable (VU)**, CITES: Appx I, WPA: Sch I.

Saltwater Crocodile

- **Largest** living reptile and crocodilian.
- **Habitat:** Saltwater habitats, brackish wetlands.
- **Distribution:** India's east coast, Southeast Asia, Sundaic region to northern Australia.
- **Threats:** Hunting for skin, illegal killing, habitat loss.

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- **Conservation Status: Least Concern (LC),** CITES: Appx I, WPA: Sch I.

CONSERVATION OF TURTLES

- All tortoises are turtles. But not all turtles are tortoises.
- Terrapins are a combination of turtles and tortoises that live mostly in water but can also live on land.

Tortoise (Land-Dwelling)	Turtle (Water-Dwelling)
• Lives on land • Bad swimmers • Herbivores • Generally large • Heads can completely withdraw into shells • Long life span (80-120 years)	• Lives in water, comes to land to lay eggs • Good swimmers • Omnivores (Green Turtle is mostly herbivore) • Generally smaller • Heads can partially withdraw into shells • Short life span (20-40 years)

Batagur Turtles Species

- **Northern River Terrapin (CR):** Native to river deltas of Southeast Asia and **Sundarbans.**
- **Three-Striped Roofed Turtle (CR):** Endemic to the Ganges.
- **Red-Crowned Roofed Turtle (CR):** Endemic to the Ganges.
- **Burmese Roofed Turtle (CR): Irrawaddy River of Myanmar.**

Sea Turtle Species

- **Hawksbill Sea Turtle (CR):** Found in Andaman and Nicobar Islands, Tamil Nadu, Orissa.
- **Kemp's Ridley Sea Turtle (CR): World's smallest sea turtles,** found in subtropical to temperate Northern Atlantic. Known for Arribada.
- **Green Sea Turtle (EN): The only herbivore turtle species,** found in tropical and subtropical seas; rare in India.
- **Leatherback Sea Turtle (VU): Largest living sea turtle**, found in tropical and temperate seas.
- **Loggerhead Sea Turtle (VU):** Found in tropical and temperate seas.
- **Olive Ridley Sea Turtle (VU):** Known for synchronized nesting(Arribada), migrates to Indian coastal waters.

Nissilonia Turtle Species

- **Burmese Peacock Softshell Turtle (CR):** Found in Myanmar and Karbi Anglong district of Assam.
- **Leith's Softshell Turtle (CR):** Endemic to peninsular rivers.
- **Black Softshell Turtle (CR):** Native to the lower Brahmaputra River.
- **Indian (Ganges) Softshell Turtle (EN):** Found in the waters of the Ganges, Indus, and Mahanadi.
- **Indian Peacock Softshell Turtle (EN):** Found in the Indus, Ganges, and the Brahmaputra.
- **Indian Narrow (Small) Headed Softshell Turtle (EN):** Distributed in various rivers.

Sea Turtle Conservation Project

- Initiated by MoEF in collaboration with UNDP in 1999.
- Implemented in 10 coastal states, with emphasis in Odisha.
- Aims to conserve olive ridley turtles and other endangered marine turtles.
- Achievements include the use of Satellite Telemetry to locate migratory routes and promoting Turtle Exclusion Device (TED) in fishing trawlers to reduce turtle mortality in fishing nets.

CONSERVATION OF INDIAN VULTURES

- Nine vulture species in India, most endangered due to diclofenac, a veterinary drug.

Vulture Species	Conservation Status	Additional Information
White-Rumped Vulture	CR (Critically Endangered)	Once common in Gangetic plains
Red-Headed Vulture	CR (Critically Endangered)	Also known as Asian King Vulture
Indian (Long-Billed) Vulture	CR (Critically Endangered)	Native to India, Pakistan, Nepal
Slender-Billed Vulture	CR (Critically Endangered)	Native to sub-Himalayan region and Southeast Asia
Egyptian Vulture	EN (Endangered)	
Himalayan (Griffon) Vulture	NT (Near Threatened)	Native to Himalayas and Tibetan Plateau
Bearded Vulture	NT (Near Threatened)	Lives and breeds on high mountains
Cinereous Vulture	NT (Near Threatened)	Distributed throughout Eurasia.
(Eurasian) Griffon Vulture	LC (Least Concern)	

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Diclofenac and Indian Vulture Crisis

- Diclofenac, a common NSAID for livestock, leads to renal failure in vultures.
- **Diclofenac Alternative**
  - Diclofenac banned for veterinary use in 2006.
  - Meloxicam, a harmless alternative for vultures, developed and tested.
  - Challenges persist with diclofenac diversion for veterinary use through black markets.

Consequences of Vulture Depopulation

- Vultures played a vital role in public sanitation.
- Carcasses not consumed by vultures lead to contaminated water, an increase in rat population and wild dogs, and the spread of diseases.

Major Non-Indian Vulture Species

- **White-Backed Vulture (CR)**
- **Ruppell's (Griffon) Vulture (CR):** Native to Sahel region and East Africa.

Steps Taken by the Government

- Integrated Development of Wildlife Habitats (IDWH) **'Species Recovery Programme.'**
- **Upgraded protection status** of vultures under Wild Life (Protection) Act, 1972.
- **Vulture Restaurants** created by Maharashtra and Punjab Forest departments.
- **Vulture Conservation Breeding Programme** led by Central Zoo Authority and Bombay Natural History Society.
- **Vulture Safe Zones** to conserve and reintroduce vultures.
- **Action Plan for Vulture Conservation in India 2020-25:**
  - Aimed at actively increasing vulture numbers.
  - Objectives include strict regulation of veterinary NSAID sale, safety testing, banning toxic drugs, and establishing vulture safe zones.

OTHER INDIAN INITIATIVES

Project Hangul (Kashmiri Stag)

- The **Hangul**, a subspecies of the Central Asian Red Deer, is primarily found in **Dachigam National Park**, Kashmir. Historically numbering around 5,000, their population declined due to habitat destruction, over-grazing, and poaching. **Project Hangul**, initiated by Jammu & Kashmir in collaboration with **IUCN** and **WWF**, aimed at protection and population recovery. Despite efforts, the population remains critically endangered, with only 182 Hanguls reported in 2017.

Species Recovery Programme (SRP)

- The **Species Recovery Programme** aims to protect critically endangered species threatened by habitat loss, illegal wildlife trade, and reduced forest cover outside Protected Areas. The programme focuses on flagship species that migrate or disperse outside these areas.
- Initially launched as the **Assistance for the Development of National Parks and Sanctuaries**, it was reformed into the **Integrated Development of Wildlife Habitats (IDWH)** scheme during the **11th Five-Year Plan (2007-2012)**. The MoEF, with the **Wildlife Institute of India**, identified **16 terrestrial and 6 aquatic species for conservation.**
- **Species under the IDWH Scheme:**
  - Asian Wild Buffalo, Asiatic Lion, Brow-Antlered Deer (Sangai), Dugong, Edible Nest Swiftlet, Gangetic River Dolphin, Great Indian Bustard, Hangul (Kashmiri Stag), Indian Rhino (Great One-Horned Rhinoceros), Jerdon's Courser, Malabar Civet, Marine Turtles, Nicobar Megapode, Nilgiri Tahr, Snow Leopard, Swamp Deer, Vultures, Northern River Terrapin, Clouded Leopard, Arabian Sea Humpback Whale, Red Panda, Caracal.
- The programme has led to population increases in some species, like the **Lion** and **Rhinoceros**, but **Great Indian Bustard** and **Nicobar Megapode** face declines. Successful recovery efforts for **Vultures** are showing positive outcomes. **[UPSC 2014]**

National Wildlife Action Plan (2017-2031)

The third NWAP emphasizes **landscape-based conservation**, encourages private sector involvement, and utilizes **Corporate Social Responsibility (CSR)** funds for wildlife protection.

National Action Plan for Conservation of Migratory Birds (2018-2023)

- Developed by the **Ministry of Environment, Forest and Climate Change (MOEF)**, this plan focuses on conserving migratory birds along the **Central Asian Flyway**.
- A flyway is a flight path used by large numbers of birds while migrating between their breeding grounds and their overwintering quarters. Flyways generally span continents and often pass over oceans.

Asian Migratory Bird Flyways

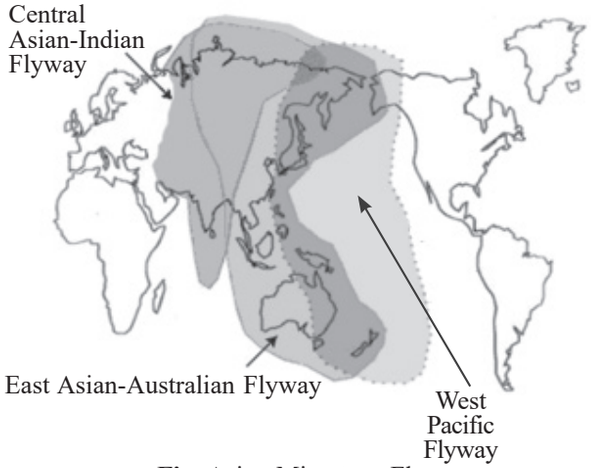

Fig. Asian Migratory Flyways

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4 Pollution and Conservation Measures

Pollution: Addition/release of undesirable physical, chemical or biological agents (substances/ pollutants) **into the environment** due to human (anthropogenic) activities.

Types of Pollution based on source

- **Point Source Pollution:** caused by discharge of effluents at a point; **Easy to treat**. E.g. Sewage outlets.
- **Non-Point Source Pollution:** It refers to diffuse pollution that does not come from a single, identifiable source like a pipe or outlet. It results from various widespread activities that contribute pollutants through processes such as runoff, seepage, or atmospheric deposition.

AIR POLLUTION

Air pollution occurs when solid, liquid, or gaseous substances, including forms of radiation, are introduced into the atmosphere in concentrations high enough to harm living organisms or disrupt environmental processes.

Classification of Air Pollutants

- **Primary Pollutants**:
  - These are pollutants directly emitted into the atmosphere from a specific source.
  - They can originate from natural processes (e.g., volcanic eruptions) or human activities (e.g., industrial emissions).
  - **Examples**: Sulfur dioxide (SO_2) from power plants, DDT from agricultural applications.
- **Secondary Pollutants**:
  - Secondary pollutants form in the atmosphere through chemical reactions involving primary pollutants and other atmospheric components.
  - These are more complex and often more harmful than their precursors.
  - **Examples**: Peroxyacetyl Nitrate (PAN), which is created when Nitrogen Oxides (NO_x) react with hydrocarbons under sunlight.
- **Quantitative Pollutants**:
  - These are **naturally occurring** substances, such as carbon dioxide and nitrogen oxides, that are beneficial or harmless in low concentrations. However, when their levels exceed a certain threshold, they become pollutants, causing adverse effects.
  - **Examples**: Excess carbon dioxide contributing to global warming, nitrogen oxides leading to acid rain.
- **Qualitative Pollutants**:
  - These are substances that **do not naturally occur** in the atmosphere but are introduced by human activities. These substances are entirely synthetic and have no natural threshold.
  - **Examples**: **Fungicides, herbicides, and persistent organic pollutants like DDT**, which have long-lasting harmful effects on ecosystems.

Common Air Pollutants

Fly ash

- Ejected mainly by **thermal power plants** as a **by-product of coal burning.**
- **Effect:** Pollutes air and water, causes **heavy metal pollution** in water bodies and affects crops and vegetation due to its direct deposition on leaves.
- **Composition: silica, alumina, oxides of iron, calcium, and magnesium and toxic heavy metals** like lead, mercury, cadmium, arsenic, cobalt, and copper. Oxides present in large quantities are aluminium, silicate, silicon dioxide (SiO_2), and calcium oxide (CaO) **[UPSC 2020]**
- **Uses** **(UPSC 2015)**
  - Can replace **cement** by up to 35%.
  - Better **fill material** for road embankments
  - Reclamation of **wastelands**.
  - **Increases crop yield** when added to the soil
  - Enhances the soil **water-holding capacity.**

Particulate Pollutants

Matter suspended in the air (E.g. Dust and Soot). Major sources are Industries, vehicles, power plants, construction activities, oil refineries, etc.

PM 1	PM 2.5	PM 10
Less than 1 µm	2.5 µm or smaller	10 µm or smaller
Vehicular and industrial emissions	Combustion processes like petroleum and fossil fuels	Various sources, including dust and combustion.
Lung injury, gene damage, and cancer	Penetrates the lung barrier, enters the bloodstream.	Affects the heart and lungs, causing serious health effects

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Nanoparticles (NPs)

- Size ~ **$1/10^9$ meter.**
- **Natural Sources**: forest fires, volcanic eruptions, weathering, dust storms, etc.
- Transported over long distances and **remain suspended in the air for days.**
- React rapidly in the atmosphere, with severe consequences for visibility and climate.

Effects on the environment [UPSC 2014]

- **Dust cloud formation**: Contains **soot** and **black carbon** (NP) and deposits them on the Himalayan glaciers **(reduces albedo)**; higher absorption of the Sun's heat; **increased melting of glaciers.**
- **NPs and hydroxyl radicals (OH)** bind, resulting in their **reduction in the troposphere** and reduced natural 'pollutant scrubbing capacity' of the atmosphere.
- **Ozone depletion:** Due to increased production of **free radicals** like Chlorine.

Carbon Monoxide (CO)

- **Natural Sources:** Photochemical reactions in the troposphere; volcanoes, forest fires etc.
- **Anthropogenic sources**: IC engine exhaust, partial combustion of other fuels and iron smelting.
- **Features**
  - **Short-life** of a few months in the atmosphere
  - burns with a blue flame, producing carbon dioxide.
- **Health effects: Poisoning** (Poor ventilation, heat management in electronics); **toxic** when conc.**>35 ppm;** combines with haemoglobin to **produce carboxyhemoglobin**, which affects oxygen transport.
- **Environmental effects:** formation of tropospheric ozone; elevates methane concentrations (a GHG).

Carbon Dioxide (CO_2)

- **Natural sources**: volcanoes, hot springs, geysers, carbonate rocks (by dissolution in water and acids). Also groundwater, rivers, lakes, ice caps, glaciers and seawater (due to water solubility).
- **Anthropogenic sources:** burning of fossil fuel, land use, deforestation, agriculture, etc.
- Colourless & odourless gas (heavier than air).
- **Effects on Health:** Asphyxiant gas (if concentrations >7%), may cause suffocation.
- **Effects on the Environment:** Global warming, ocean acidification (dissolves in water to form carbonic acid).
- **Social Cost of Carbon**: It is a measure, in monetary value, of the Long-term damage done by a tonne of CO_2 emissions in a given year. **(UPSC-2020)**

Black Carbon (Soot)

- Solid, short-lived air pollutant released from **incomplete combustion** at high-temperature.
- **Common Sources**: Vehicle emissions, Industrial Emissions, Residential Heating and Cooking, etc.
- **Disrupts** regional **cloudiness** and **monsoon** rainfall.
- Most **robust absorber of sunlight** and **heats the air directly**.
- **Reduces albedo** after deposition on snow by darkening and heating the surface directly
- **Largest emitters**: India and China. (**The Indo-Gangetic plain** in the case of India.)

Brown Carbon

- It is emitted mainly by the **combustion of organic matter (biomass combustion).** With Fossil Fuel Combustion, Wildfires, Agricultural Practices, etc being other sources.
- Brown carbon has significant implications for climate change as it can contribute to regional warming by absorbing sunlight. It also plays a role in air quality and human health, as inhaling these particles can be harmful.

Ozone (O_3)

- **Good ozone:** Formed in the stratosphere and absorbs harmful UV rays.
- **Bad Ozone or Tropospheric Ozone**: At the ground level, it is a pollutant, short-lived GHG and is toxic Majorly it is formed when **carbon monoxide, nitrogen dioxide, and VOC react in the presence of sunlight at the ground level and convert O_2 to O_3 (secondary pollutant).**
- 0.00005% by volume of the atmosphere and is unevenly distributed.
- **Harmful Effects of Ozone:** Smog; Itchy and watery eyes; Can affect sensitive vegetation and ecosystems, forests, especially during the growing season; Transported to long distances by wind, thus even rural areas can experience high O_3 levels.

Nitrogen Oxides (NOx)

- **Sources:** Internal Combustion engines & coal-burning power plants; lightning; **Agricultural fertilisation** and nitrogen-fixing plants.
- **Effects on Health and Environment:** React to form **acid rain** and **tropospheric ozone.**
- When NOx and VOCs react in the presence of sunlight, they form **photochemical smog.**

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Sulphur dioxide (SO_2)

- **Sources:** Released by **volcanic activity,** burning coal in thermal power plants, **diesel fuels** etc, **Industrial processes like production** of paper and the smelting of metals like copper, forest fires, shipping, etc.
- **Toxic gas** with a **pungent**, irritating smell.
- **Health Effect:** Poisonous air pollutants lead to the risk of stroke, heart disease, and lung cancer.
- India has been the **top emitter of SO_2** in the world for the fifth consecutive year (since 2019), with significant contributions **from electricity generation using coal.**

Polyaromatic Hydrocarbons (PAHs)

- **Sources:** Incomplete combustion of organics, cigarette smoke, high-temperature cooking.
- **Naphthalene** is a PAH produced commercially in the US to make other chemicals and mothballs.
- **Health Effect: Toxic, mutagenic & carcinogenic properties,** highly lipid soluble, readily absorbed from the gastrointestinal tract of mammals (Bioaccumulation).
- They associate with other particulate matter, **like PM2.5, and PM10** and make them more **toxic**.

Hydrofluorocarbons **[UPSC 2023]**

- **Sources:** They are entirely Human made and widely used in refrigeration, air conditioning, aerosol propellants, foam production, fire suppressants, and lubricants.
- **Chemical Composition:** Composed of hydrogen, fluorine, and carbon atoms.
- **Non-Ozone Depleting:** Do not harm the ozone layer as they lack chlorine and bromine, unlike CFCs and HCFCs.
- **Global Warming Potential (GWP):** Have high GWP, contributing significantly to climate change.
- **Stability:** Chemically stable, providing durability and efficiency in various applications.
- **Phasedown:** Subject to a global phasedown under the Kigali Amendment to the Mon

Volatile Organic Compounds (VOCs)

- **Primary indoor sources:** perfumes, hair sprays, furniture polish, glues, air fresheners, moth repellents, wood preservatives, and other products.
- **Carbon-based** chemicals that **quickly evaporate** at room temperature. Eg: **formaldehyde, benzene, ethylene glycol, formaldehyde, methylene chloride, tetrachloroethylene, toluene, xylene, and 1,3-butadiene (precursor to synthetic rubber).**
- **Health effects**: Irritation of the eye, nose and throat, headaches, nausea and loss of coordination. Long-term health effects include liver damage.

Some VOCs:

- **Ethylene** (Carcinogen)**:** Natural plant hormone used in agriculture to force the ripening of fruits.
- **Formaldehyde:** Natural, produced by decay of plant material in the soil. Used as fungicide, germicide, disinfectant and as a preservative in mortuaries and laboratories. Also a combustion product found in tobacco smoke.
- **Toluene:** Paint thinners, octane booster in gasoline engines.
- **Xylene**: Solvent in the printing, rubber, and leather industry.
- **Styrene:** Raw material for polystyrene (used to make parts of refrigerators, micro-ovens, automotive parts, computers, etc.).
- **Benzene**
  - Found in **crude oil** and is an elementary petrochemical, cigarette smoke. **[UPSC 2020]. Natural sources include** volcanoes & forest fires
  - Used to make plastics, resins, synthetic fibres, rubber lubricants, etc, high octane number thus becomes an essential component of gasoline (petrol).

Minor Air Pollutants

Lead

- Heavy metal present in petrol, diesel, batteries, paints, hair dyes, etc.
- Tetraethyl Lead (TEL) used as an anti-knock agent in petrol; industrial processes.
- Damages kidneys, liver, nervous system, and RBC development; digestive issues, cancer; mental retardation.
- Contaminates soil and water; a persistent pollutant which affects ecosystems

Ammonia

- Corrosive, colorless gas with a pungent odor.
- Decaying organic matter, human and animal waste, livestock management, agricultural fertilizers.
- Irritates eyes, nose, throat; forms PM2.5 when combined with sulfates/nitrates.
- Contributes to nitrification and eutrophication of aquatic systems.

Asbestos

- A group of 6 naturally occurring silicate fibrous minerals.
- Mining, construction materials (e.g., insulation, tiles).
- Causes lung cancer, mesothelioma, and asbestosis (pneumoconiosis) due to prolonged inhalation.

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Metallic Oxides

- Dust deposition from mining and metallurgical processes.
- Mining operations and metallurgical activities.
- Weakened immune response, organ damage (liver and kidney), respiratory issues, reproductive issues, etc
- Reduction in plant growth and photosynthesis.

Biological Pollutants

- Include pollen, mites, pet hair, fungi spores, parasites, and bacteria.
- Natural sources and human/animal activities.
- Trigger asthma and other allergic diseases.

Radon

- Naturally emitted radioactive gas trapped indoors in poorly ventilated houses.
- Emitted by soil and confined inside modern buildings.
- Causes lung cancer and neurodegenerative disorders like Alzheimer's disease.

MAJOR CAUSES OF AIR POLLUTION

Vehicular and Industrial Emissions [UPSC 2014, 2021]

- **Major Pollutants (>80%):** NOx, CO, SOx and Non-Methane Volatile Organic Compounds (NMVOCs - benzene, ethanol, formaldehyde, cyclohexane, or acetone).
- **Trace emissions:** CH_4, CO_2, SOx, and Total Suspended Particles (TSPs).
- **Critical industries:** Iron and steel, sugar, paper, cement, fertilizer, copper, and aluminium contribute to Suspended Particulate Matter (SPM), SOx, NOx, and CO_2.

Pyrolysis

The technique of breaking down synthetic material at high temperatures (300-400 °C) for an hour **without oxygen**. It is **safer than burning but leaves fine carbon matter, pyrogas** and oil as residue due to the use of sub-optimum pyrolysis technologies.

Fuel Adulteration

Gasoline and diesel with kerosene increases emissions of CO, NOx and Suspended Particulate Matter.

Emissions from Agriculture, Waste Treatment and Biomass Burning [UPSC 2019]

- **Critical Pollutants:** Ammonia (NH_3), methane (CH_4) and nitrous oxide, Carbon monoxide, Ozone, Sulphur dioxide
- **Major Pollutants from landfills and wastewater treatment plants:** methane, CO_2.
- **Stubble burning:** Intentional burning of crop residue after grain harvest. It results in air pollution resulting in thick smog formation; loss of soil fertility, and loss of soil moisture. **[UPSC 2015]**

100 Million Farmers

It is a platform for accelerating the transition towards food and water systems that are net-zero (carbon), nature-positive and that aims to increase farmer resilience. **[UPSC-2024]**

Indoor Air Pollution

- It is caused by the burning of coal, charcoal, wood, agricultural residue, animal dung, and kerosene, among others, for heating /cooking with **limited ventilation.**
- Pollutants: Particulate matter (PM2.5), black carbon, carbon dioxide, carbon monoxide and methane, VOCs (due to paints, carpets, furniture, etc.,)

Volcanism

- The release of sulphur dioxide (can lead to acid rain), sulphur aerosols (can lead to ozone destruction), carbon dioxide, hydrogen fluoride and hydrogen sulphide.

EFFECTS OF AIR POLLUTION

Smog (Smoke + Fog)

- Caused by the burning of coal, vehicular emission and industrial fumes (primary pollutants). It contains **soot particulates** like smoke, ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) & others.

Sulphurous Smog (London Smog)	Photochemical smog (summer smog or Los Angeles smog)
It results from a **high concentration of sulphur oxides** in the air and the use of sulphur-bearing fossil fuels, particularly coal. This smog is **aggravated by dampness and a high concentration of suspended particulate matter in the air.**	Occurs most prominently in **urban areas with high vehicular emissions**. It forms when **nitrogen oxides & volatile organic compounds react together in the presence of sunlight to form ozone**. Peroxyacetyl Nitrate (PAN) is an important component The resulting smog causes a light brownish colouration of the atmosphere, reduced visibility, plant damage, irritation of the eyes, and respiratory distress. Temperature inversions are accentuated, and precipitation is reduced due to smog.

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Formation of Photochemical Smog (UPSC 2013)

- **NO + VOC (volatile organic compounds) = NO_2 (Nitrogen Dioxide)**
- **NO_2 + UV (sunlight) = NO + O (Nitrogen Oxide + atomic oxygen)**
- **O + O_2 = O_3 (Ozone)**
- **NO_2 + VOC = PAN (peroxyacetyl nitrate – $C_2H_3NO_5$)**
- **Result: NO + VOC + O_2 + UV = O_3, PAN, and other oxidants like OH (Photochemical smog)**

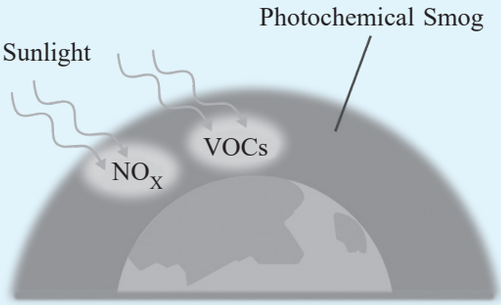

Fig. Photochemical Smog formation.

Acid Rain

- Any precipitation which is more acidic than usual. (pH < 5.6). Gases that cause acid rain: SOx (Sulphur Oxides); NOx (Nitrogen Oxides – NO, NO_2 and N_zO) **(UPSC-2013)**
- Acid rain, in turn, damages the environment by reducing soil fertility, harming aquatic life, and weakening forests through nutrient loss and toxin exposure. It corrodes buildings, monuments, and infrastructure while also contributing to respiratory problems in humans.
- Moreover it disrupts ecosystems, reducing biodiversity and favoring species that tolerate high acidity.

Ocean Acidification

- Ocean acidification occurs when the ocean absorbs excess carbon dioxide (CO_2) from the atmosphere, resulting in a chemical reaction lowering the seawater pH and reducing carbonate ion availability.
- This process negatively impacts marine ecosystems, as organisms like corals, shellfish, and some plankton struggle to build and maintain their calcium carbonate shells and skeletons.
- It disrupts food chains, affects biodiversity, and threatens fisheries and livelihoods dependent on marine resources.

Ozone Depletion

- **Ozone Delpleting Substances (ODS): Chlorofluorocarbons (CFCs), HCFCs and HBFCs, Halons** (used in fire extinguishers), **methyl bromide** (fumigant for pest control), **carbon tetrachloride**, **methyl chloroform** (aerosols, solvent for organic compounds, used for cleaning metals & circuit boards).
- These substances **release chlorine and bromine** when broken down by UV radiation, which destroys ozone molecules.
- Which causes increased harmful UV radiation reaching the Earth's surface, leading to health issues like skin cancer, cataracts, and immune suppression, as well as environmental impacts such as reduced crop yields and harm to marine ecosystems

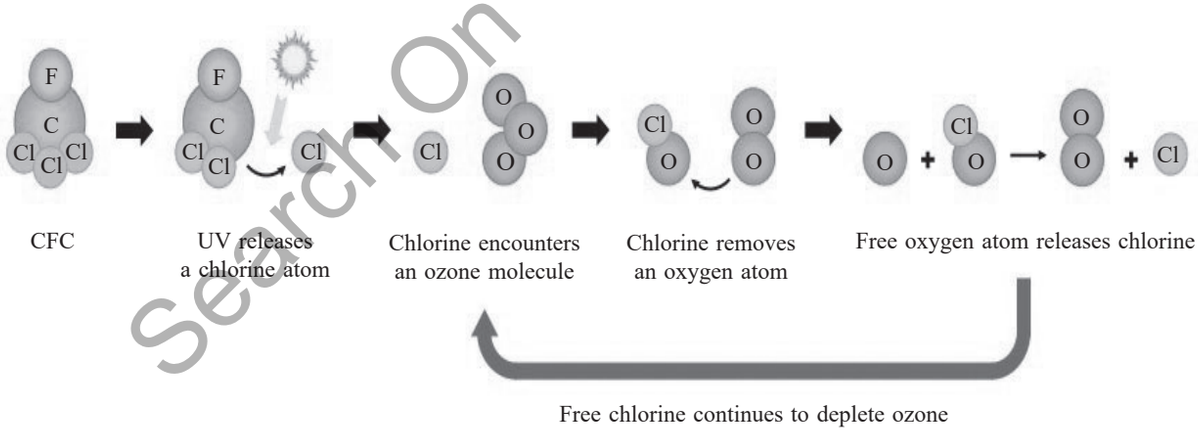

Fig. Chemical process of ozone depletion

- **Mechanism of Ozone Depletion**
  - Ozone depletion occurs when human-made chemicals, such as Chlorofluorocarbons (CFCs), release chlorine and bromine atoms in the stratosphere.
  - UV radiation breaks these compounds, freeing chlorine and bromine, which then react with Ozone (O_3) molecules, breaking them into Oxygen (O_2) and reducing ozone concentration.

- **Polar Stratospheric Clouds (PSCs) and Ozone depletion**
  - Polar Stratospheric Clouds (PSCs) are high-altitude clouds that form in the stratosphere at extremely low temperatures, typically in polar regions during winter. They consist of water, nitric acid, and sometimes ice particles.

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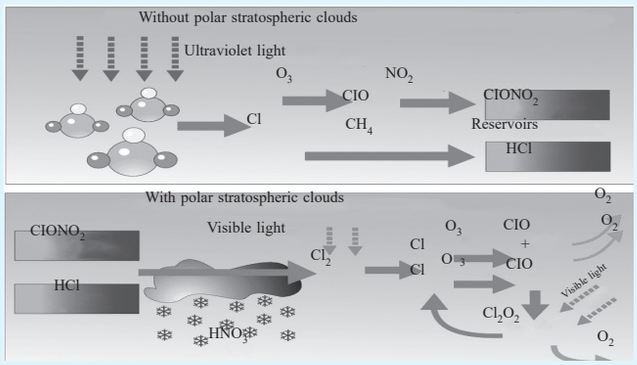

Fig. Polar Stratospheric Clouds (PSCs) and Ozone depletion

- They **provide surfaces for chemical reactions that convert inactive chlorine compounds, like hydrochloric acid (HCl) and chlorine nitrate ($ClONO_2$), into reeactive chlorine species.**
- When sunlight returns to polar regions in spring, these reactive chlorine species break down ozone molecules, causing significant ozone loss, such as the Antarctic ozone hole.
- **Ozone depletion and Global warming:** Global warming can lead to reduction in Polar Stratospheric Cloud formation , **which in turn can reduce the pace of Ozone depletion.** This might sound counter-intuitive but is true as per the mechanism and role of PSCs in ozone depletion explained above.

Health Hazards

- Air pollution contributed to 8.1 million deaths worldwide in 2021, with India and China recording 2.1 million and 2.3 million fatalities, respectively, according to a report published by the Health Effects Institute (HEI), making it the second leading risk factor for deaths globally.

Pneumoconiosis

- It is the general term for a **class of interstitial lung diseases** where inhalation of dust has caused interstitial fibrosis.
- It is an occupational health disease and mostly affects workers who work and inhale toxic dust in the mining and construction sectors, especially in mica and textile industry.
- Most common ones are:

Disease	Affected Workers
Black Lung Disease	Coal industry workers
Silicosis	Quarrying, manufacturing, and construction workers
Byssinosis	Yarn and fabric manufacturing workers
Asbestosis	Asbestos industry workers

PREVENTION AND CONTROL OF AIR POLLUTION

Measures to Control Industrial Pollution

1. Filters

- These devices remove particulate matter from the gas stream.
- Example: Baghouse filtration system.

2. Electrostatic Precipitators

- Utilized for removing particulate matter from emissions.
- Commonly used in furnaces, thermal power plants, cement factories, and steel plants.

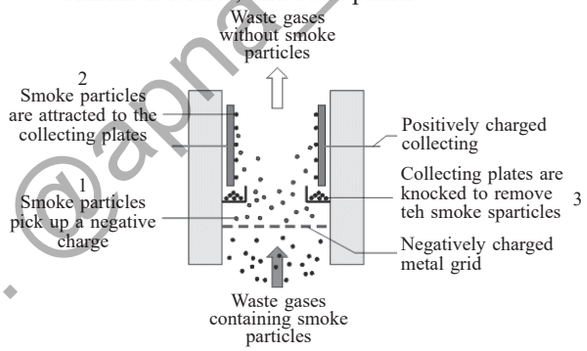

Fig. Electrostatic precipitator mechanism

3. Inertial Collectors

- Collect heavier particles through centrifugation with high efficiency.

4. Scrubbers

- Wet collectors that eliminate aerosols from gas streams.
- Particles are either collected on a surface or wetted by a scrubbing liquid.
- Capable of removing gases like sulfur dioxide (SO_2).

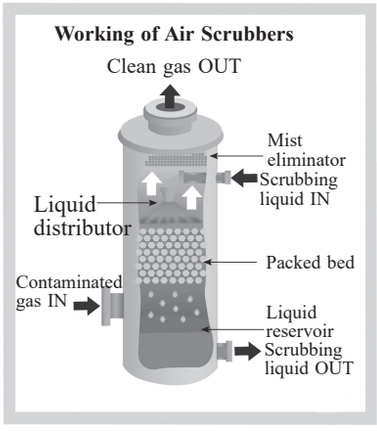

Fig. Air Scrubber mechanism.

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5. Catalytic Converters

- Fitted in automobiles to reduce the emission of poisonous gases.
- Require unleaded petrol as lead deactivates the catalyst.

Fig. Catalytic Converter

6. Coal Gasification

- A technological process where coal is partially oxidized using air, oxygen, steam, or carbon dioxide to produce synthetic gas (syngas).
- This gas serves as an energy substitute for natural gas and methane.
- **India's Target:** Achieve 100 MT coal gasification by 2030.

7. Flue-Gas Desulfurization (FGD) Systems

- Used for removing acidic gases like sulfur dioxide (SO_2) and hydrogen chloride (HCl) from flue gases via **wet or dry scrubbing methods.**
- Flue gas refers to the gas that is released from combustion plants and consists of the reaction products of fuel and combustion air, along with residual substances such as particulate matter, sulfur oxides, nitrogen oxides, and carbon monoxide
- Lime is commonly used in both techniques.
  - **Limestone-based FGD:** The limestone ($CaCO_3$) reacts with SO_2 in the presence of water to form calcium sulphite ($CaSO_3$) and carbon dioxide (CO_2).
  - **Lime-based FGD:** When lime (CaO) is used, it reacts directly with SO_2 to form calcium sulphite.

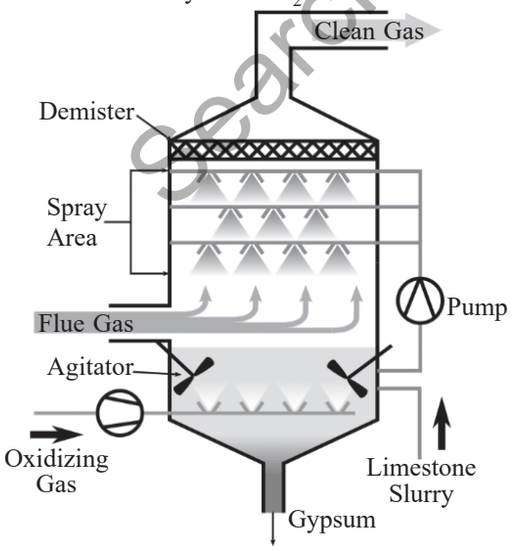

Fig. Flue Gas Desulphurisation.

8. Fly Ash Management

- Policy by MoEFCC mandates using fly ash-based products in construction projects, road embankments, and landfilling activities.
- Coverage: Within a 100 km radius of thermal power stations for construction and within 50 km for mine-filling activities.

10. Pollution Index for Industrial Pollution Control

Pollution Index (PI)

- Developed by the Ministry of Environment, Forest, and Climate Change (MoEFCC), this index rates industrial sectors on a scale of **0 to 100** to encourage cleaner technologies.

Categorization Based on Pollution Index

- **White Category:**
  - Industries with minimal pollution impact.
  - Do not require Environmental Clearance (EC) or Consent to Operate.
  - Industries must simply inform the State Pollution Control Board (SPCB) and Central Pollution Control Board (CPCB).
- **Red Category:**
  - High-pollution industries.
  - Not permitted in ecologically fragile or protected areas.

Colour	PI score	Industries
Red category (critically polluted)	60+ (60 industries)	Cement, Petrochemicals, pharmaceuticals, sugar, paper and pulp, nuclear power plants, organic chemicals, fertilizers, firecrackers, etc.
Orange category (severely polluted)	41 to 59 (83 industries)	Coal washeries, glass, paints, stone crushers, aluminum, & copper extraction from scrap, etc.
Green category (other polluted)	21 to 40 (63 industries)	Aluminum utensils, steel furniture, soap manufacturing, tea processing, etc.
White category (practically non-polluting)	Including and up to 20. (36 industries)	Air cooler or air conditioning units, chalk factories, biscuit tray units, etc.

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National Clean Air Program (NCAP, 2019)

- NCAP is the first national-level strategy to tackle the air pollution **(reduce PM2.5 and PM10)** problem across the country comprehensively with a time-bound reduction target (**40% by 2026 from 2017 level).**
- It is executed by the **Central Pollution Control Board (CPCB)** in exercise of powers under the **Air (Prevention and Control of Pollution) Act, 1981.**
- It covers **132 non-attainment cities** (cities that have fallen short of the National Ambient Air Quality Standards for over five years) which were **identified by the Central Pollution Control Board (CPCB).**
- **"PRANA"** - Portal for Regulation of Air-pollution in Non-Attainment Cities, is a portal for monitoring the implementation of NCAP.

- **CPCB** is a **Statutory body** constituted under the **Water (Prevention and Control of Pollution) Act, 1974.**

Measures to Regulate Ozone-Depleting Substances (ODS)

- **Vienna Convention For the Protection of the Ozone Layer**
  - Agreed in 1985, it established **global monitoring and reporting on ozone depletion**.
- **Montreal Protocol on Ozone-Depleting Substances [UPSC 2015]**
  - The Montreal Protocol under the Vienna Convention was agreed in 1987. It facilitates global cooperation in **reversing the rapid decline in atmospheric concentrations of stratospheric ozone** (good ozone).
  - To **phase out the production** and **consumption of certain chemicals that deplete ozone** by specific deadlines.
  - The Vienna Convention and its Montreal Protocol are the **first and only** global environmental treaties to achieve **universal ratification**, with 197 parties.
- **Kigali Amendment to Montreal Protocol 2016**
  - **Aims to phase out the manufacture and use of potent greenhouse gases called hydrofluorocarbons (HFCs) by 80-85%** from their respective baselines**, till 2045**. It is a **legally binding agreement** between the signatory parties with non-compliance measures. It came into effect from 1st January 2019.
  - India **consumes only 3% of HFCs**, India will complete its phase-down in 4 steps from 2032 onwards.
- **The Ozone Depleting Substances (ODS) Rules, 2000**
  - The rules are framed under the jurisdiction of **Environment (Protection) Act, 1986.** These Rules set the deadlines for phasing out of various ODSs, besides regulating production, trade import and export of ODSs and the product containing ODS.

HFCs

Hydrofluorocarbons (HFCs) are used as an alternative to CFCs and HCFCs/HBFCs.

HFCs do not contribute to ozone depletion. However, they are potent greenhouse gases with high global warming potential.

Measures Taken to Control Vehicular Pollution in India

- **Vehicle Scrappage Policy 2021**
  - All the central and state governments vehicles that have completed 15 years to be scrapped from April 1, 2023. The policy aims to **de-register** private cars over 20 years old and commercial vehicles over 15 years old.
- **Bharat Stage (BS) norms**
  - Instituted by GoI to regulate the air pollution from motor vehicles by using appropriate fuel and technology. It was introduced in 2000. The norms **limit the release of air pollutants** such as nitrogen oxides, carbon monoxide, hydrocarbons, particulate matter (PM) and sulphur oxides from vehicles.
- **BS VI from 2020**
  - India has decided to **leapfrog to BS VI norms from 2020 (skipping BS V)** to achieve carbon footprint obligations.

Advantages of BS VI vehicles and fuel

Reduced **Particulate Matter in diesel cars by 80 per cent; Nitrogen oxides** from diesel cars by 70 per cent and petrol cars by 25 per cent.

Reduction in **sulphur** makes it possible to equip vehicles with **better catalytic converters**.

Makes onboard diagnostics mandatory for all vehicles.

Changed the way of measurement of particulate matter (number standard instead of mass standard).

- **Electric Mobility**
  - **FAME India Scheme: Faster Adoption and Manufacturing of Electric (& Hybrid) Vehicles (Phase II)**
    - Notified by the Department of **Heavy Industries**, it promotes adoption of Electric vehicles.
    - It aims to convert 30% of vehicles to EV by 2030.
- **GOI has formulated other measures to promote EV adoption such as the EV Charging Guidelines and tax incentives, Green Tax**

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INDICES TO MONITOR AIR POLLUTION

Index	Implementing Authority	
National Ambient Air Quality Standards (NAAQS)	**Central Pollution Control Board (CPCB)**	It is applicable all over the country. Measures the concentration of particulate matter (PM 2.5 and PM 10), sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, ammonia, and lead, benzene, benzopyrene, arsenic and nickel.
National Air Quality Monitoring Programme	Central Pollution Control Board **(CPCB)**	Aim: To determine the status and trends of ambient air quality; to ascertain the **compliance of NAAQS;** to identify non-attainment cities; to understand the natural process of cleaning in the atmosphere; and to undertake preventive and corrective measures.. Regular monitoring of **four air pollutants** at all the locations**: Sulphur Dioxide (SO_2), Oxides of Nitrogen (NO_2), Respirable Suspended Particulate Matter (RSPM / PM10) and Fine Particulate Matter (PM2.5).**
National Air Quality Index (AQI)	Launched **MoEFCC** (April 2015) **under 'Swachh Bharat'. Developed by CPCB.**	AQI helps the citizens judge the air quality within their vicinity. It considers **eight pollutants: PM10, PM2.5, NO_2, SO_2, CO, O_3, NH_3, and Pb. [UPSC 2016]**
The System of Air Quality and Weather Forecasting and Research (SAFAR)	**(SAFAR)** is a national initiative introduced by the **Ministry of Earth Sciences (MoES)**	**Pollutants included: PM2.5, PM10, Ozone, CO, NOx (NO, NO_2), SO_2, Methane (CH_4), Xylene, Toluene Benzene, and Mercury.** It gives out a real-time **air quality index** on a 24x7 basis with colour-coding (along with 72 hours advance forecast). **Measures the air quality** of a metropolitan city **and all weather parameters** like temperature, rainfall, humidity, wind speed, and wind direction, UV radiation, and solar radiation.
2021 WHO Air Quality Guidelines (AQGs) [UPSC 2022]	**WHO**	**Pollutants**: PM 2.5/10, ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide.

MEASURES TO CONTROL AIR POLLUTION IN NCR

Graded Response Action Plan (GRAP)

- The **Environment Pollution (Prevention and Control) Authority:** A Supreme Court-appointed body notified in 1998 by MoEF under **Environment Protection Act, 1986.** Its present mandate is to prevent and control environmental pollution in the National Capital Region and enforce Graded Response Action Plan (GRAP).

Category	AQI Levels	Actions
Severe + or Emergency	451 and above	Stop truck entry (except essentials), halt construction, implement odd/even schemes for private vehicles.
Severe	401-450	Close brick kilns, hot mix plants, stone crushers; boost natural gas power generation; road cleaning/spraying.
Very Poor	301-400	Ban diesel generators, discourage winter fires in apartments.
Poor	201-300	Impose fines for garbage burning, enforce firecracker bans, regulate industries; road cleaning/spraying.
Other Measures: **Ban old vehicles, curtail open burning, and use expressways for vehicles bypassing Delhi.**		

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However from 2021 the EPCA has been replaced by a statutory body, named **Commission for Air Quality Management in NCR and Adjoining areas.**

Measures to Reduce Stubble Burning

- **PUSA Decomposer:** It is a mix of fungal solution+ jaggery +gram flour to be sprinkled on the stubble, after which it would bio-degrade in 20 days.
- **Super SMS and Happy Seeders:** Super Stubble Management Systems (Super SMS) helps in chopping the stubble and spreading that evenly. The Happy Seeder helps in direct sowing of wheat without clearing the stubble.

Other Measures

- **Smog towers:** These are structures designed to work as large-scale air purifiers. They are fitted with multiple layers of carbon nanofiber air filters, which clean the air of pollutants as it passes through them.
- **Green crackers: In 2019 the SC** mandated the use of green crackers which substituted barium nitrate with **potassium nitrate** and **zeolite** to reduce PM10 and PM2.5 by 30%. They are developed by CSIR-NEERI.

WATER POLLUTION

It is defined as the presence of undesirable substances/ pollutants in water, be it organic, inorganic, biological, radiological and thermal, which degrades water quality so that it becomes unfit for use.

Measuring Pollution Load in Water

- **Dissolved oxygen (DO)**
  - Refers to the level of **free oxygen present in water.** Optimum DO content in water is important for the survival of aquatic organisms.
  - **Factors affecting DO in water**: surface turbulence, photosynthetic activity, O_2 consumption by organisms, presence of organic/inorganic wastes, and the decomposition of organic matter.
  - DO content **<8.0 mg/L: contaminated** water.
  - DO content **<4.0 mg/L: highly polluted** water.
- **Biological Oxygen Demand (BOD):**
  - It represents the **amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic** (oxygen is present) conditions at a **specified temperature.** It is expressed in **milligrams of oxygen per litre of water**. **[UPSC 2017]**
  - The **higher value of BOD indicates high pollution** due to biodegradable organic wastes and low DO content of water.
  - Since BOD is limited to biodegradable materials, it is **not a reliable method of measuring water pollution.**
- **Chemical Oxygen Demand (COD)**
  - It measures the **amount of oxygen** in parts per million **required to oxidize organic** (biodegradable and non-biodegradable) and **oxidisable inorganic compounds** in the water sample.It gives a more comprehensive idea about the level of pollution in the water sample.

Causes of Water Pollution

- **Industrial Waste**
  - Discharge of **heavy metals (mercury, cadmium, copper, lead, chromium, arsenic)** and a variety of organic compounds. According to the CWC report, iron is the most common contaminant.
- **Thermal and Radiation Pollution**
  - An increase in water temperature **decreases dissolved oxygen** in the water. **A sudden rise in temperature kills fish and other aquatic animals.** Nuclear accidents near water bodies or during natural calamities like tsunamis and earthquakes pose the risk of radiation leakage (radiation exposure) into water bodies.
- **Mining**
  - Much water is used in various mining operations alongside chemicals such as cyanide, sulphuric acid, and mercury, increasing the potential for these chemicals to contaminate ground and surface water.
  - Further, heavy sand mining in river beds also causes pollution of groundwater and lowering of the water-table. **[UPSC-2018]**
- **Freshwater Salinization Syndrome (FSS)**
  - FSS is the process of **salty runoff contaminating freshwater ecosystems.** Salts naturally occur in fresh waters, typically caused by rock weathering & naturally saline groundwater. This is further catalysed by anthropogenic activities.
- **Sewage Water**
  - Includes discharges from houses /other establishments containing human and animal excreta, food residues, cleaning agents, detergents, etc. Domestic and hospital sewage contain many pathogenic microbes.
  - **Ammonia Pollution in Sewage:** The acceptable limit of ammonia in drinking water, as per BIS, is 0.5 ppm.
- **Agricultural Sources**
  - Agricultural runoff contains dissolved salts such as potassium, ammonia, toxic metal ions and organic compounds.
  - **Fertilizers:** Nitrogen, phosphorus and potassium. Excess fertilizers reach the groundwater/get mixed with surface water.
  - **Pesticides:** Contain chemicals such as **chlorinated hydrocarbons (CHCs – E.g., DDT, Endosulfan, etc.)**, organophosphates, metallic salts, carbonates, etc. Many pesticides are **non-degradable,** and their residues have a long life (persistent pollutants).
  - Wastes from **poultry, piggeries and slaughterhouses** etc., reach the water through runoff.
- **Invasive Aquatic Species**
  - For instance, **Water Hyacinth:** Native to the Amazon basin, is the world's most problematic aquatic **weed('Terror of Bengal')**. It grows abundantly in eutrophic (nutrient-rich) water bodies and leads to an imbalance in the ecosystem by creating stagnation of

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polluted water and draining off oxygen from the water bodies, resulting in the devastation of fish stock.

EFFECTS OF WATER POLLUTION

- **Effects on the Human Health**
  - Domestic and hospital sewage contain many undesirable pathogenic microorganisms, and its disposal into the water without proper treatment may cause an outbreak of serious diseases, such as typhoid, cholera, etc.
  - Metals such as lead, zinc, arsenic, copper, mercury and cadmium in industrial wastewaters adversely affect humans and other animals.
- **Effects on the Environment**
  - **Impact on Aquatic Ecosystems:** Water pollution causes loss of biodiversity as pollutants like heavy metals and pesticides kill aquatic organisms or disrupt their life cycles, while sensitive species face extinction.
  - Excess nutrients from agricultural runoff lead to **eutrophication**, causing oxygen depletion and "**dead zones**," suffocating aquatic organisms.
  - It also disrupts food chains through **bioaccumulation** and **biomagnification**, affecting predators and ecosystems.

Eutrophication

Eutrophication: Process of **over-enrichment of water body with nutrients(nitrogen, phosphorus)**, leading to the **plentiful growth of simple plant life (algae, plankton)** eventually leading to anoxic conditions for the seagrass and other organisms.

Natural eutrophication: Excessive but gradual enrichment (mineral & organic matter) of water bodies via natural events.

Cultural eutrophication: It is the similar nutrient enrichment of lakes at an accelerated rate due to human activities and consequent ageing phenomenon. Eutrophication leads to collapse of **food chains**, new **species invasion**, loss of freshwater lakes. loss of **coral reefs** due to increased turbidity, algal blooms, etc.

Algal Bloom: Population of phytoplanktons restricting the penetration of sunlight is known as an algal bloom. It **results in the death of aquatic plants** and hence restricts the replenishment of oxygen. Algal blooms can be any colour, but the most common ones are **(red/ brown tides).** Further, unusually **warm water is conducive to blooms.**

Bioluminescence: It is the **property of a living organism to produce and emit light**. It is an **antipredator response**. **Animals, plants, fungi, and bacteria** show bioluminescence. Luminescence is generally higher in deep-living & planktonic organisms than in shallow species.

Blue tides along the coast as seen along beaches during night is due to this phenomenon.

- **Marine Pollution:** Plastic waste, oil spills, and microplastics harm marine life, leading to ingestion, entanglement, and death.
- **Effects on Terrestrial Ecosystems**: Polluted water contaminates drinking water sources, impacting wildlife and human health. Using polluted water for irrigation degrades soil quality, reducing agricultural productivity. Terrestrial animals drinking contaminated water may suffer from poisoning, reproductive failure, or death.
- **Climate and Atmospheric Impacts**: Decomposition of organic pollutants in water releases greenhouse gases like methane and nitrous oxide, contributing to climate change.
- **Effects on Wetlands**: Pollution disrupts wetlands' natural balance, causing habitat loss and reducing biodiversity. Wetlands, which act as natural filters, become overwhelmed by excessive pollution, rendering them ineffective in maintaining ecological health.
- **Pollution in River Ganga**
  - Almost the entire wastewater and industrial effluents generated by various urban and industrial centres, viz. Haridwar, Kannauj, Kanpur, Allahabad, Varanasi, Patna and Kolkata are disposed of into the river Ganga **(Tannery, Sugar & Distillery, Pulp and Paper mills).**
  - It is polluted by Faecal Coliforms bacteria in its entire length along with high BOD.
  - **Microplastics present in the Ganga:** Ethylene Vinyl, Polyacetylene, Polypropylene, Persistent Inorganic Pollutant (PIP),Polyamide(nylon).

GROUND WATER POLLUTION

- Polluted surface water seeps into aquifers, spreading harmful bacteria, viruses, and protozoa. Toxic chemicals like pesticides and industrial waste penetrate groundwater, reducing its quality over time.
- **Central Ground Water Authority** has been constituted **under Section 3 (3) of the Environment (Protection) Act, 1986** to regulate and control development and management of ground water resources in the country.
- The Central Ground Water Board was formed in 1970 by renaming erstwhile **Exploratory Tube well Organization.**
  - **Central Ground Water Board** is also discharging the functions **as Central Ground Water Authority** to regulate and control the development and management of ground water in the country **since 1997.**
- **Aquifer:** An aquifer is a body of rock and/or sediment that holds groundwater. Groundwater is the word used to describe precipitation that has infiltrated the soil beyond the surface and collected in empty spaces underground. There are two general types of aquifers: confined and unconfined.

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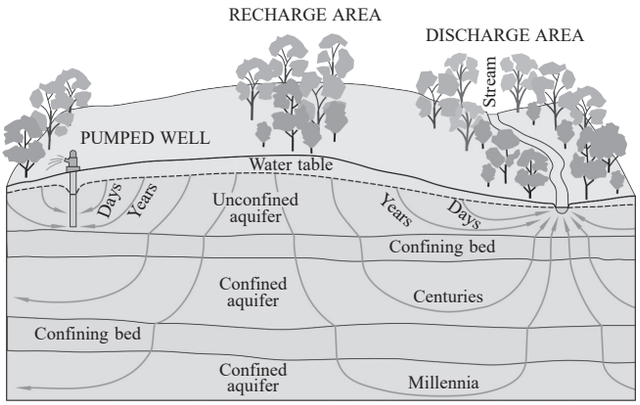

Fig: Aquifer showing confined zones

The common ground water contaminants are as follows:

Contaminant	Affected Regions/States	Sources/Causes	Remediation Options
Inland Salinity	Rajasthan, Haryana, Punjab, Gujarat, Uttar Pradesh, Delhi, Madhya Pradesh, Maharashtra, Karnataka, Bihar, Tamil Nadu	Natural salinity, surface water irrigation without considering groundwater, waterlogging, evaporation.	Reverse osmosis, ion exchange, water management practices.
Coastal Salinity	Coastal areas of Gujarat, Tamil Nadu, Odisha, Andhra Pradesh, West Bengal, Pondicherry	Sea water ingress, connate water, leachates from salt pans, navigation canals.	Reverse osmosis, ion exchange, control withdrawal from freshwater aquifers.
Fluoride	Andhra Pradesh, Gujarat, Rajasthan, Haryana, Karnataka, Maharashtra, Tamil Nadu, Uttar Pradesh, Bihar, Odisha	Geogenic origin, fluoride minerals in rocks (e.g., fluorite, apatite).	Adsorption (activated alumina), ion exchange, Nalgonda technique, reverse osmosis.
Arsenic	West Bengal, Bihar, Uttar Pradesh, Assam, Chhattisgarh	Geogenic sources, sedimentary formations, volcanics (e.g., Dongargarh-Kotri rift zone in Chhattisgarh).	Groundwater from arsenic-free aquifers, surface water use, dilution with surface water, adsorption.
Iron	Assam, West Bengal, Odisha, Chhattisgarh, Karnataka, localized areas in many states	Geogenic origin, organic decay, microbial activity, low pH and redox potential.	Chemical oxidation, aeration, ion exchange methods.
Nitrate	Alluvial plains, areas of intense agriculture across India	Fertilizers, septic systems, livestock manure, decaying organic matter.	Prevention of nitrate leaching, dilution, treatment of groundwater (denitrification, reverse osmosis).

Uranium Pollution in Groundwater

Parameter	Details
WHO Standard	30 µg/L (ppb).
AERB Standard	60 µg/L (ppb, radiological).
Top States (>30 µg/L)	Punjab (24.2%), Haryana (19.6%), Telangana (10.1%), Delhi (11.7%), Rajasthan (7.2%).
Top States (>60 µg/L)	Punjab (6.0%), Haryana (4.4%), Delhi (5.0%), Telangana (2.6%), Rajasthan (1.2%).
Districts Affected	151 districts across 18 states.
Health Risks	Kidney toxicity, potential cancer risk.
Treatment Methods	Reverse osmosis, membrane separation, coagulation, and precipitation.

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**AERB: Atomic Energy Regulatory Board- established as per Atomic Energy Act, 1962 in 1983.*

Major Government Initiatives and Programs

Initiative	Details
Jal Shakti Abhiyan (JSA)	Launched in 2019 for water-stressed blocks; extended countrywide in 2021-2023 with a focus on rainwater harvesting.
Amrit Sarovar Mission	Launched on 24 April 2022 to rejuvenate 75 water bodies per district under Azadi ka Amrit Mahotsav.
Atal Bhujal Yojana	Rs. 6,000 crore scheme in Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh to manage groundwater sustainably.
CGWA Regulations	Regulates groundwater extraction under Environment (Protection) Act, 1986. Guidelines amended on 29 March 2023.
National Aquifer Mapping	25.15 lakh sq. km area covered; reports shared with States/UTs for interventions.
Master Plan for Artificial Recharge	Envisages 1.42 crore recharge structures to harness 185 BCM of water. Shared with States/UTs for implementation.
Model Building Bye Laws (2016)	Rainwater harvesting mandatory for buildings on plots ≥100 sq. m.; adopted by 35 States/UTs.
Groundwater Assessment	Periodic monitoring supervised by a Central Level Expert Group.

Groundwater Over-exploitation (2018 vs. 2022)

Year	Over-exploited Units (Assessment Units)	States with >25% Over-exploited Units
2018	1186 units (17%) of 6881	Delhi, Haryana, Punjab, Rajasthan, Tamil Nadu
2022	1006 units (14%) of 7089	Delhi, Haryana, Punjab, Rajasthan, Tamil Nadu
Punjab's Over-exploited Units	43.68% (2018); 39.7% (2022)	76.47% over-exploited units (2022).

*mbgl (Meters Below Ground Level)

WATER POLLUTION CONTROL MEASURES

Bioremediation

The use of living organisms to remove contaminants, pollutants, or unwanted substances from soil or water. Microorganisms can be specifically designed for bioremediation using genetic engineering techniques. **[UPSC 2017]**

In-situ (at the site) bioremediation

- **Bioventing**: Supply of nutrients through wells to contaminated soil to stimulate the growth of bacteria.
- **Biosparging**: Injection of air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of contaminants by bacteria.
- **Bioaugmentation**: Microorganisms are imported to a contaminated site to enhance the degradation process.
  - Using bioremediation techniques, TERI has developed a mixture of bacteria called **'Oilzapper and Oilivorous-S'**, which degrades the pollutants of oil-contaminated sites, leaving behind no harmful residues.

Ex-situ bioremediation

- **Landfarming**: Contaminated soil is spread on a prepared bed and tilled regularly to aerate it and encourage microbial activity. Microorganisms degrade organic pollutants in the soil,eventually rendering it clean.
- **Bioreactors**: These require the processing of contaminated solid water through an engineered containment system.
- **Composting**: Composting is nature's recycling of decomposed organic materials into a rich soil known as Compost. For example **Bacillus flexus and Acinetobacter junii (**Both bacteria have a special gene, which aids in arsenic detoxification).

Anaerobic Biodegradation	Aerobic Biodegradation
More than 99% pathogen inactivation.	Incomplete aeration leads to a foul smell.
Complete anaerobic conditions.	Forced aeration is essential, which is energy intensive
Sludge generation is significantly less.	Generate a large amount of sludge.
One-time bacterial inoculation is enough.	Repeated addition of bacteria/enzymes is required.
Minimal maintenance and no recurring cost.	Maintenance and the recurring cost is high.
Anaerobes can even degrade detergents/phenyl.	Cannot tolerate detergents.

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Sewage Water Treatment for Domestic Use

Contains suspended solids, bacteria, algae, viruses, fungi, and minerals such as iron and manganese. The processes involved in removing these contaminants are:

- **Coagulation/Flocculation:** In coagulation, coagulants like ferric sulphate or sodium aluminate, aluminium sulphate, are added to untreated water.
- **Filtration:** The filters are created of layers of sand and gravel, and in some circumstances, crushed anthracite (coal). Filtration collects the suspended impurities in water and enhances the effectiveness of disinfection.
- **Disinfection:** The addition of chlorine or chlorine compounds to drinking water is called **chlorination**. Water is disinfected using chlorine before it enters the distribution system to ensure that pathogens are destroyed. It can combine with certain naturally occurring organic compounds in water to produce **chloroform and other potentially harmful by-products. Ozone gas** may also be used for the disinfection of drinking water. However, since **ozone is unstable,** it cannot be stored and must be produced on-site, making it more expensive than chlorination.
- **Fluoridation:** Water fluoridation is the controlled adjustment of fluoride to a public water supply solely to reduce tooth decay. This can occur naturally or by adding fluoride.
- **Defluorination** at the domestic level can be carried out by mixing water for treatment with an adequate amount of aluminium sulphate (alum) solution, lime or sodium carbonate and bleaching powder depending upon its alkalinity and fluoride contents. BIS prescribes 1.0 mg/l as desirable and 1.5 mg/l as the permissible limit for drinking water.
- **pH Correction:** Lime is added to the filtered water to adjust the pH and stabilise the naturally soft water to minimise corrosion in the distribution system and within customers' plumbing.
- **Removal of iron:** BIS prescribes a **desirable limit for iron as 0.3 mg/l.** A significant part of iron is oxidised. Then the water is made to react with oxidising media (lime). By aeration and further oxidation, the dissolved iron is converted to insoluble ferric hydroxide. The insoluble iron can thus be easily removed through filtration.
- **Removal of arsenic:** BIS prescribed desirable limit for arsenic is 0.05 mg/l. Bleaching powder & alum are used for the removal.

WATER POLLUTION CONTROL MEASURES IN INDIA AND INDIAN RIVER SYSTEMS

The Government of India safeguards the water resources under **Water (Prevention and Control of Pollution) Act, 1974.**

- Central Pollution Control Board (**CPCB**) in collaboration with the concerned State Pollution Control Boards (SPCB), has developed a **concept of "designated best use"** based on pH, dissolved oxygen, BOD, total coliform, free ammonia, electrical conductivity, etc.
- The classification helps the water quality managers and planners to set water quality targets and identify needs and priorities for water quality restoration programmes.

Major River Conservation Initiatives

- **Ganga Action Plan (GAP)**
  - First river action plan taken up by MoEF in 1985 as a **centrally sponsored** scheme. It was partially successful and closed in 2002 making a significant difference to water quality.
- **National River Conservation Plan (NRCP)**
  - Provides financial/ technical assistance to the States/ UTs on cost sharing basis to bring the river to bathing quality standards.
  - It included treatment of raw sewage before flowing into the river, prevention and control of industrial pollution, electric crematoria to ensure proper cremation of bodies brought to the burning ghat and Riverfront development works such as improvement of bathing ghats, etc.
- **Namami Gange Programme (2014)**
  - It was launched to accomplish the twin objectives of effective abatement of pollution and conservation and rejuvenation of National River Ganga.
  - The main pillars of the programme are Sewerage Treatment Infrastructure, River-Front Development, River-Surface Cleaning, Biodiversity, Afforestation, Public Awareness, Industrial Effluent Monitoring and Ganga Gram.
  - **Clean Ganga Fund:** Set up in 2014 as a trust under the Indian Trust Act, 1882. It allows **resident Indians, Non-Resident Indians (NRIs), Persons of Indian Origins (PIOs), Corporates (Public as well as private sector) to contribute** towards the conservation of the river Ganga. The contributions to the Clean Ganga Fund fall within the purview of Corporate Social Responsibility CSR).
  - **National Ganga Council:** Established by the River Ganga (Rejuvenation, Protection, and Management) Authorities Order, 2016. It **replaced the National Ganga River Basin Authority (NGRBA) and is headed by the Prime Minister.**
  - **National Mission for Clean Ganga (NMCG)** – registered as a society under the Societies Registration Act 1860) is the **implementation wing of NGC**, which is implementing the Namami Gange Programme.
- **Swachh Bharat Mission (SBM, 2014)**
  - It is implemented by the **Ministry of Drinking Water and Sanitation (Ministry of Jal Shakti from 2019).** SBM seeks to achieve universal sanitation coverage by making Gram Panchayats Open Defecation Free

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(ODF). Under SBM, incentives are provided for the construction of household latrines.
    - **Swachh Bharat Mission II (**2020-21 to 2024-2025): It **focuses on Open Defecation Free Plus (ODF Plus),** which includes ODF Sustainability and Solid and Liquid waste Management (SLWM). The ODF Plus will **converge with MGNREGA** and will complement the newly launched Jal Jeevan Mission.
- **National Water Quality Monitoring Programme:** Executed by CPCBs in association with the SPCBs.

INTERNATIONAL EFFORTS TO COMBAT WATER POLLUTION

- **The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972) (replaced by the 1996 Protocol)**

The London Convention, aimed at international control and putting an end to marine pollution. The convention's objectives include preventing marine pollution from dumping waste at sea, controlling all sources of marine pollution, and taking steps to prevent pollution.

Dumping: Deliberate disposal at sea of wastes or other materials from vessels, aircraft, platforms & other man-made structures. 'Dumping' here does not cover wastes derived from the exploration & exploitation of sea-bed minerals.

1996 Protocol: Replaces the 1972 Convention and calls for appropriate preventive measures to be taken when wastes thrown into the sea are likely to cause harm "even when there is no conclusive evidence to prove a relation between inputs and their effects. "**The International Maritime Organization (IMO) is responsible for Secretariat duties concerning the Protocol.**

- **International Maritime Organization (IMO): Global standard-setting authority for the safety,** security and environmental performance of international shipping. Its headquarters is in the **UK**. IMO's Maritime Environment Protection Committee is responsible for coordinating the organization's activities in the prevention and control of marine pollution. Its measures cover accidental and operational oil pollution.
- **Bunker Convention (2001):** It ensures that **adequate compensation is available to persons who suffer damage caused by oil spills**. It applies to damage caused on the territory, including the territorial sea and exclusive economic zone of state parties.
- **Ballast Water Management Convention (2004):** This IMO convention aims **to prevent the spread of harmful aquatic organisms from one region to another through ballast water,** which is widely regarded as the most critical vector for spreading potentially invasive alien species.
- **Regional Oil Spill Contingency Plan:** It was jointly launched by South Asia Co-operative Environment Programme **(SACEP) and IMO** to facilitate international cooperation and mutual assistance in preparing and responding to major oil pollution incidents in the seas around Bangladesh, India, Maldives, Pakistan & SriLanka.

WATER CONSERVATION

- **India's Water Situation:** With 18% of the world's population, 2.5% of the global area, India has just 4% of the worldwide water resources.
- Water-scarcity conditions are prevalent in the basins of the Indus, Krishna, Cauvery, Subarnarekha, Pennar, Mahi, Sabarmati west-flowing rivers of Kutch and Saurashtra, including Luni.
- **Per-Capita water situation:** As per CWC, per capita availability in the country will decrease from 1,434 cubic metres/person/year in 2025 to 1,219 cubic metres in 2050.

- **Water Stressed Condition:** 1700 cubic meters/person/year – 1000 cubic meters/ person/ year
- **Water Scarcity Condition:** <1000 cubic meters/ person/year
- **Chronic Water Scarcity:** 1000 cubic meters/person/year – 500 cubic meters/person/year
- **Absolute Scarcity**: Less than 500 cubic metres/person/year

India's Groundwater Situation [UPSC 2020]

- According to CWC, the annual replenishable groundwater resources in India (2017) are 432 BCM, out of which 393 BCM is the yearly "extractable" groundwater availability.
- The current annual groundwater extraction is 249 BCM, **the largest user being the irrigation sector.**
- About **85% of the rural water supply in India** is dependent on groundwater.
- An average drop in groundwater level increases total carbon emissions as it would need power to pump out water which is largely met by conventional fossil fuels.
- The Indo-Gangetic Plain, North-western, Central & Western parts of India account for the most intensive groundwater-based irrigation.

Measures by the Government

- Water being a **state subject**, steps for conservation are undertaken by the State government, and the Central Government supplements the efforts.
- Creation of a **new Ministry of Jal Shakti** by merging Ministries of Water Resources, River Development & Ganga Rejuvenation with Drinking Water & Sanitation for dealing with all matters relating to water at one place in an integrated manner.
- The government has launched **various programmes:**
    - Atal Bhujal Yojana (Atal Jal)

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- Jal Shakti Abhiyan for water conservation would focus on 1,592 "water-stressed" blocks in 257 districts.
- Jal Jeevan Mission (JJM)
- **Micro Irrigation Fund** under NABARD
- **National Perspective Plan (NPP)** for water resources development to transfer water from surplus to deficit areas.

- Projects related to rainwater harvesting, rejuvenation of water bodies, and recharging of groundwater through:
  - Atal Mission for Rejuvenation and Urban Transformation (**AMRUT**) by MoHUA
  - Mahatma Gandhi National Rural Employment Guarantee Scheme (**MGNREGS**)
  - Pradhan Mantri Krishi Sinchayee Yojana – Watershed Development Component (**PMKSY-WDC**).
- **Central Ground Water Board (CGWB):** CGWB is a **subordinate** office & the apex organization of the Ministry of **Jal Shakti** dealing with groundwater and related issues.
- **Central Ground Water Authority (CGWA)** has been constituted by GOI under **Environment (Protection) Act, 1986** to regulate & control the development & management of groundwater resources in the country. It works **under the Department of Water Resources, Ministry of Jal Shakti.**

Powers & Functions of CGWA Include [UPSC 2022]
- Exercise of powers under the Environment (Protection) Act, 1986
- To **resort to penal provisions**
- To regulate & control, management & development of groundwater in the country and issue directions for mandatory rainwater harvesting

Central Water Commission (CWC): CWC was established in **1945**. It is a technical organization that functions as part of the Ministry of Jal Shakti. It is entrusted with providing consultation to various state governments on water bodies related issues, and coordinating various governmental schemes for the conservation, control, and utilization of water resources.

- **National Aquifer Mapping & Management Programme (NAMMP):** A **central sector scheme** of the **Department of Water Resources,** which is aimed at delineating aquifer and water availability, is being **implemented by the CGWB** to facilitate sustainable management of groundwater resources. It is a part of the Ground Water Management and Regulation Scheme (a central sector scheme).
- **National Hydrology Project (NHP):** NHP is a **pan India, World Bank assisted Central Sector Scheme**, with a **100% grant to the States.** It is to be implemented for 8 years from **2016-17 to 2023-24.** It intends to provide a system for **real-time water resources data acquisition, storage, collation & management.**

Sponge City Concept

It indicates a particular type of **city in which water is conserved + stored + recharged + sustainably used**. A sponge city is a **permeable system** acting like a sponge & absorbs the rainwater. The absorbed water is naturally filtered by the soil & allowed to reach into the urban aquifers. This allows for the extraction of water from the ground through urban or peri-urban wells. This water can be easily treated and used for the city water supply.

NOISE POLLUTION

Unwanted sound that causes annoyance, irritation and pain to the human ear is termed noise.

- Measured in dB (decibels)- which indicates the loudness of the sound).
- Prescribed optimum noise level: 45 dB by day and 35 dB by night as per WHO.
- The human ear can tolerate noise levels up to 85 dB, and anything beyond that can affect the quality of life.
- >80 dB: loud and hazardous; 100-125 dB: uncomfortable.

Permissible Noise Level in India

Zone	Daytime (dB)	Night (dB)
Industrial Zone	75	70
Commercial Zone	65	55
Residential Zone	55	45
Silent Zone (areas within 100 metres of the premises of schools, colleges, hospitals & courts.)	50	40

Laws to control Noise pollution

- **Earlier:** Air (Prevention and Control of Pollution) Act, 1981.
- **Currently:** Noise Pollution (Regulation and Control) Rules, 2000, under Environment (Protection) Act, 1986.
- Noise standards for motor vehicles, air-conditioners, refrigerators, diesel generators and certain construction equipment are prescribed under: Environment (Protection) Act, 1986.
- Noise emanating from industry is regulated by State Pollution Control Boards (SPCBs) under the Air (Prevention and Control of Pollution) Act, 1981.

PLASTIC POLLUTION

Accumulation of plastic objects and particles in the Earth's environment that adversely affects humans, wildlife and their habitat.

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Types of Plastics

- **Microplastics:** These are shreds of plastic **<5 mm in length but >1 micrometre** and come from various sources, including the breakdown of larger plastic debris.
  - **Uses**: In **cosmetics, personal care products, industrial scrubbers, microfibers in textiles and virgin resin pellets** used in plastic manufacturing processes. The particles can **travel around the body and may lodge in organs/ outer membranes** of red blood cells & may limit their ability to transport oxygen. Microplastics have also been **detected in human blood.**
  - Many chewing gums found in the market are considered a source of environmental pollution. Many chewing gums contain plastic as gum base. **[UPSC-2024]**
- **Microbeads:** Microbeads **(>0.1 µm and < 5 mm)** are very tiny pieces of plastic that are added to health and beauty products, such as in some cleansers and toothpaste (cooling crystals). One of the main contributors to microbeads pollution is regular plastic waste, 90% of which is not recycled. **[UPSC-2019]**
- **Nanoplastics:** They are **tiny plastic particles smaller than 1,000 nanometres (1 micron)** and can pass through physiological barriers and enter organisms and their food chains.
  - **Primary nanoplastics:** Intentionally produced, used in various products, such as cosmetics, washing powders, research and diagnostics.
  - **Secondary nanoplastics:** Formed in the environment, especially in rivers and oceans, by fragmenting larger pieces of plastic.

Major Plastics in Use

Code	Plastic Type	Common Uses	Recycling Potential
1.	Polyethylene Terephthalate (PET or PETE)	Water bottles, soft drink bottles, food packaging	Easily recycled into fibers, containers
2.	High-Density Polyethylene (HDPE)	Milk jugs, detergent bottles, grocery bags	Recycled into pipes, plastic lumber
3.	Polyvinyl Chloride (PVC)	Pipes, vinyl flooring, toys, shower curtains	Rarely recycled due to toxic additives
4.	Low-Density Polyethylene (LDPE)	Plastic bags, shrink wraps, squeezable bottles	Difficult to recycle, used for liners, tiles
5.	Polypropylene (PP)	Yogurt containers, bottle caps, straws, medicine bottles	Recycled into trays, cables, lights
6.	Polystyrene (PS)	Disposable cups, plates, food trays, egg cartons	Hard to recycle, used for insulation, packaging

Effects of Plastic Waste

- **Impact on Health and Life: Carcinogenic chemicals** can cause developmental, reproductive, neurological, and immune disorders They are also known to be **endocrine disruptors**, causing weight gain, insulin resistance, and decreased reproductive health
- **Microplastics:** These particles can be found in drinking water, blood, and plaque lining arteries causing serious health problems such as heart attack and stroke
- **Burning Plastic:** Releases toxic substances into the air, which can be harmful to human health and the environment.
- **Impact on the Environment: Primary emissions from plastic production include** sulphur oxides, nitrous oxides, methanol, ethylene oxide, dioxin & furan and other VOCs. Plastics contaminate foodstuffs due to chemicals leaching into foods /beverages eg: polycarbonate leaches bisphenol A and polystyrene leaches styrene.

Status of Plastic Waste in India

India has secured the top spot as biggest plastic polluter in the world, releasing 9.3 million tonnes (Mt) annually, amounting to roughly one-fifth of global plastic emissions. Nigeria, with 3.5 Mt of emissions and Indonesia, with 3.4 Mt are second and 3rd largest producers of plastic waste in the world.

Measures to Curb Plastic Waste

India collects only 60% of its plastic waste, and the remaining 40% enter the environment.

- **Plastic Waste Management Rules, 2016**
  - It replaced the Plastic Waste (Management and Handling) Rules, 2011 extending rules to rural areas, which were earlier applicable only up to municipal areas.
  - Increased the minimum thickness of plastic carry bags from 40 to **50 microns** & stipulated minimum thickness of 50 microns for plastic sheets.

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- **Extended Producer's Responsibility (EPR):** pins responsibility on producers, generators & brand owners in waste management and collect back systems.
- **Plastic waste management fee** collection through pre-registration of the producers, importers of plastic carry bags/multilayered packaging and vendors selling the same for establishing the waste management system.
- **Responsibility:** Makes local bodies responsible for setting up, operationalisation & coordination of the waste management system & for performing associated functions. Retailers or street vendors shall not sell, or provide commodities in plastic sheet or multilayered packaging, or they are liable to pay fines.
- **Reuse of plastic waste**: in road construction, waste-to-oil, and waste-to-energy, which will enhance plastic recycling, **phasing out non-recyclable multilayered plastic.**
- **2018 Amendment:** Only "non-recyclable, or non-energy recoverable, or with no alternate use" MLP to be phased out.

- **Plastic Waste Management Amendment Rules 2021**
  - Prohibition of identified single-use plastic (low utility and high littering potential) items from July 2022.
  - **CPCB list of Banned Plastics (Single use Plastic):** Plastic sticks used in earbuds, balloons, candy & ice cream; Plastic cutlery; Plastic packaging/wrapping films; polystyrene (thermocol) for decoration, **PVC banners with < 100 microns and plastic stirrers**
  - Minimum thickness of plastic carry bags increased from 50 to **75 microns** (2021) and to **120 microns** (2022).
  - Guidelines for EPR to be given legal force.
  - The plastic packaging waste (not banned) to be collected and managed through the Extended Producer Responsibility as per the 2016 rules.
- **Plastic Waste Management (Amendment) Rules, 2024:**
  - **Biodegradable Plastics:** New requirements for labelling and certification.
  - **Extended Producer Responsibility (EPR):** Producers must report quantities of goods and pre-consumer waste.
  - **EPR Targets:** Recycling targets set for different categories of plastic packaging.
  - **Mandatory Reporting:** Annual reports for manufacturers, importers, and brand owners.
  - **Category-Based Recycling:** Specific targets for rigid, flexible, and multilayered plastics.
  - **Collaboration with Local Authorities:** Voluntary guidelines for working with authorities.
- **Alternatives to Plastics:** Glass, Bagasse (made from the pulp of sugarcane or beets), Bioplastics, Natural textiles, Edible seaweed cups, Algae-blended ethylene-vinyl acetate, Compostable plastics.
- **Plastic waste in road construction: Polyblend** is a fine powder of recycled and modified plastic waste used to make fabrics. It can be mixed with bitumen that is used to lay roads. It enhances the bitumen's water-repellent properties and helps to increase road life by a factor of three.

SOLID WASTE

- It includes garbage, construction debris, sludge from waste treatment plants and other discarded solid materials coming from industrial, commercial, mining, and agricultural operations and from household and public activities.

Sources of Solid wastes

- **Municipal Solid Waste:** solid waste type consisting of everyday items like paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc. that are discarded by the public.
- **Industrial Waste:**
  - **Thermal power plants:** Coal ash/fly ash (fly ash in concrete increases the life of roads);
  - **Integrated iron and steel mills:** Produces blast furnace slag (can be used in portland cement concrete, road and railway construction, and soil conditioning); **[UPSC 2020]**
  - **Non-ferrous industries** like aluminium, copper and zinc: red mud (as construction material in bricks, lightweight aggregates, roofing tiles, etc.);
  - **Sugar industries:** Press mud (as a soil conditioner, soil fertiliser)
  - **Pulp and paper industries**: Lime mud (used in bricks, cement, wastewater treatment, and agricultural soils)
  - **Fertilizer and allied industries:** Gypsum (used to treat soil alkalinity; used in portland cement and plaster of Paris (POP))
- **Residential and Commercial Waste:** Includes food waste, plastics, paper, glass, leather, household items such as electronics, tires, batteries, old mattresses, used oil, wood, cardboard materials, etc.
- **Construction & Demolition Sites:** Includes new construction sites for buildings and roads, road repair sites, building renovation sites and building demolition sites that produce solid wastes such as steel materials, concrete, wood, plastics, rubber, copper wires, dirt, glass, etc.
- **Bio-Medical Waste:** Solid waste such as syringes, bandages, gloves, drugs, plastics, chemicals, etc., from hospitals, biomedical equipment & chemical manufacturing.
- **Treatment & Disposal of Solid Waste**
  - Solid waste management is the process of collecting & treating solid wastes and recycling items that do not belong in the trash.

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Solid Waste Management Techniques

Waste Management Technique	Description	Key Features/Challenges
Open Dumps	Untreated, uncovered waste left in an open area.	No waste treatment; environmental hazard.
Landfills	Waste is placed in a pit in the ground and covered with mud after the landfill is full.	Can later be developed into usable land (e.g., parking lot, park).
Sanitary Landfills	A more hygienic version of landfills with proper waste containment.	Expensive to construct, more controlled than regular landfills.
Incineration Plants	Waste is burned in large furnaces at high temperatures. Recyclable material is segregated before burning.	Air and water pollution, produces toxic ash, used for infectious waste.
Pyrolysis **[UPSC-2019]**	Combustion in the absence of oxygen or with controlled oxygen levels, producing products like tar, alcohol, and fuel gas.	Alternative to incineration, yields useful by-products.
Plasma Gasification	High temperature process (with plasma) converts organic waste into syngas; inorganic waste becomes slag.	Cleaner than incineration, reduces toxicity and avoids landfilling.
Biomining for Recycling	Extracting metals from ores and solid waste using organisms like bacteria or fungi to bioleach metals.	Environmental recycling technique for metal recovery.
Waste to Energy (WTE)	Converts waste into electricity or heat. Wet waste can produce compost or biogas, while dry waste can be burned to generate energy.	Generates energy, reduces waste volume.

Measures to Manage Solid Waste

Solid Waste Management Rules (2016)

- **Responsibilities of Waste Generators**
- **Segregation of Waste**: Waste must be **segregated** into three streams:
  - **Wet Waste (Biodegradable)**
  - **Dry Waste** (e.g., plastic, paper, metal, wood)
  - **Domestic Hazardous Waste** (e.g., diapers, napkins, empty cleaning agent containers).
- **Waste Handover**: Segregated waste should be **handed over** to authorized rag-pickers, waste collectors, or local bodies.
- **User fee and Penalties**:
  - **User Fee** for waste collection services.
  - **Spot Fine** for littering and non-segregation of waste.
- **Disposal of Used Sanitary Waste:** Sanitary waste (e.g., diapers, sanitary pads) must be **securely wrapped** in manufacturer-provided pouches or appropriate wrapping materials and disposed of in bins for dry or non-biodegradable waste.
- **Responsibility of Manufacturers and Brand Owners:** Manufacturers of disposable products (e.g., tin, glass, plastic packaging) must provide **financial support** to local authorities for waste management system development.
- **Processing and Disposal of Biodegradable Waste:** Biodegradable waste should be **processed, treated, and disposed of** through composting or bio-methanation within the premises wherever feasible.
- **Residual Waste Management:** Residual waste should be **handed over** to waste collectors or agencies designated by local authorities.
- **Waste processing facilities** to be set up by local bodies within the stipulated time frame.
- **Promotion of Waste to Energy:** All industrial units within 100 km of a solid waste-based Refuse-Derived Fuel (RDF) plant to make arrangements to replace at least 5 percent of their fuel requirement with RDF so produced.
- **The Ministry of New and Renewable Energy** should facilitate **infrastructure creation** for Waste to Energy plants and provide **appropriate subsidies or incentives** for such Waste-to-Energy plants.
- **Revision of Parameters:** Landfill site shall be 100 metres away from a river, 200 meters from a pond, 500 meters away from highways, habitations, public parks and water supply wells and 20 km away from airports/air bases.
- **Promoting the use of compost: Ministry of Chemicals and Fertilizers** should provide market development **assistance on city compost. The Ministry of Agriculture** should provide **flexibility** for the manufacturing & sale of compost and propagating the use of compost on farmland.

Bio-Medical Waste (Management and Handling) Rules, 2016: Improvement to the 1998 rules.

- **Biomedical waste:** It comprises human & animal anatomical waste and treatment apparatus used in Health Care Facilities (HCF)

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- **Ambit:** The rules cover **healthcare activities** beyond hospitals, including **vaccination camps**, **blood donation camps**, and **surgical camps**.
- **Salient features:**
  - **Phase out chlorinated plastic bags, gloves and blood bags** within two years.
  - **4 categories of biomedical waste** instead earlier 10 to improve segregation at source
  - Pre-treatment of the laboratory waste, microbiological waste, and blood samples through sterilization onsite.
  - **Bar-code system** for bags/ containers containing bio-medical waste for disposal.
  - **Procedure to be followed:** The hospitals must put in place the mechanisms for effective disposal either directly or through common biomedical waste treatment and disposal facilities. The hospitals servicing 1000 patients or more per month must obtain authorisation and segregate biomedical waste into categories as specified by the rules.

Other Measures

- **Waste Minimization Circles (WMC)**
  - WMC helps small/ medium industrial clusters minimise waste in their industrial plants with assistance from the **World Bank and the National Productivity Council,** New Delhi, with the **MoEFCC** as the nodal ministry. The policy also recognises the role of citizens and NGOs in environmental monitoring and enables them to supplement the regulatory system.
- **Lakshya Zero Dumpsite**
  - Launched by the **Ministry of Housing & Urban Affairs** under the SBM 2.0 to remediate 16 crore metric tons (MT) of legacy waste dumpsites occupying nearly 15,000 acres of city land and rejuvenate the urban landscapes furthering the vision of New India.

HAZARDOUS WASTE

- Any substance present/released in the environment that causes substantial damage to public health and the environment's welfare. It could exhibit one or more of the following characteristics: toxicity, ignitability, corrosivity or reactivity (explosive).
- **Persistent Organic Pollutants (POPs)**
  - Chemical substances that persist in the environment, bioaccumulate through the food web, & pose a risk of causing adverse effects to human health & the environment.
  - Chemicals of global concern due to **their potential for long-range transport and ability to biomagnify & bio-accumulate in ecosystems.** For instance, the traces of POPs have been found in the breast milk of several mammals. In females, the concentration is lower due to the transfer of the compounds to their offspring through lactation.
  - The most commonly encountered POPs are organochlorine pesticides, such as:
    - **Dichlorodiphenyltrichloroethane (DDT), once** widely used as an effective **pesticide & insecticide**. It was later identified as POP, & its **usage was phased out** in all developed/ developing countries.
    - **Endosulfan, Chlordane, Endrin, and Heptachlor** (were used as pesticides, wood preservatives). In 2011, SC banned the production, distribution & use of endosulfan in India.
    - **Hexachlorobenzene** (fungicide)
    - **Polychlorinated biphenyls** (PCB — released from the burning of plastics and electrical components; resistant to extreme temperature & pressure, hence widely used in electrical equipment like capacitors transformers)
    - **Dioxins** (toxic by-products produced when organic matter is burned), etc.
    - **Chlorinated Hydrocarbons (Organochlorides):** POP hydrocarbons in which one or more hydrogen atoms have been replaced by chlorine E.g., DDT. Uses include production of polyvinyl chloride (plastic polymer used to make PVC pipes); Chloroform, dichloromethane, dichloroethane, & trichloroethane (as solvents effective in cleaning applications like degreasing & dry cleaning); heptachlor & endosulfan(as pesticides).
    - **Perfluoroalkyl Acids (PFAAs):** PFAAs are used in **water/stain-resistant coatings and oil-resistant coatings** etc. they have a **long life** and are one of the major pollutants stored in the glaciers (do not biodegrade and are passed through several organisms and ecosystems). The glaciers release PFAAs into lakes, which can lead to bioaccumulation of PFAAs in fish. **PFAS are found to be widespread in drinking water, food and food packaging materials.** PFAS are not easily degraded in the environment. Himalayan glaciers may have higher levels of PFAAs than any other glaciers worldwide. This is because of their proximity to south Asian countries (the most polluted regions of the world). **[UPSC-2024]**

Regulation of Persistent Organic Pollutants Rules, 2018

Notified by MoEFCC under the provisions of the **Environment (Protection) Act, 1986.**

The rules prohibit the manufacture, trade, use, import and export of **seven chemicals,** namely: i. Chlordecone, ii. Hexabromobiphenyl, iii. Hexabromodiphenyl ether and Heptabromodiphenyl Ether (Commercial octa-BDE), iv. Tetrabromodiphenyl ether and Pentabromodiphenyl ether (Commercial penta-BDE), v. Pentachlorobenzene, vi. Hexabromocyclododecane, and vii. Hexachlorobutadiene.

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International Efforts to Contain Hazardous Wastes

Stockholm Convention on POPs

- International treaty enacted in **2004** to eliminate or restrict the production and use of POPs. Important Listed substances: Aldrin, Heptachlor, Hexachlorobenzene, Endrin, Polychlorinated biphenyl and DDT.
- **Annexes under Stockholm Convention**
  - **Annex A:** Chemicals to be eliminated.
  - **Annex B:** Chemicals to be restricted.
  - **Annex C:** Chemicals to minimize unintentional production and release
- **COP9 to Stockholm Convention:** The COP decided to list **"Dicofol"** in Annex A without any exemption. **PFOA** was also **listed with some exemptions in Annex A of the Stockholm Convention**
  - **Dicofol**: Organochlorine pesticide used in a wide variety of industrial and domestic applications, including non-stick cookware and food processing equipment, as well as carpets, paper and paints.
  - **Perfluorooctanoic acid (PFOA):** Used in the process of making Teflon (used in non-stick cookware). It is a carcinogen, a liver toxicant, developmental and immune system toxicant and can stay in the environment/ human body for long periods of time

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal

- It's an international treaty, entered into force in **1992** to prevent the transfer of hazardous waste from developed to Less Developed Countries (LDCs) **unless the waste is destined for recycling or disposal in an environmentally sound manner.**
- **Basel Ban Amendment to the Basel Convention(1995):** Introduces complete ban on the shipment of hazardous waste from a list of developed (mostly OECD) countries to developing countries including exports for recycling. Countries like the **US**, Canada, Japan, Australia, New Zealand, South Korea, Russia, **India**, Brazil, and Mexico **are yet to ratify the ban.**
- **COP14 to Basel Convention:** It amended the convention to **include plastic waste in the Prior Informed Consent** procedure. Even though the US and a few others have not signed the accord, they cannot ship plastic waste to countries on board with the deal. India has already imposed a complete prohibition on the import of solid plastic waste into the country.

Bamako Convention: It is a treaty of African nations prohibiting the import into Africa of any hazardous (including radioactive) waste. The convention came into force in 1998.

Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade 2004

- It is a multilateral treaty and the convention **promotes an open exchange of information and calls on exporters of hazardous chemicals to use proper labelling and safe handling, and inform purchasers of any known restrictions or bans**. Signatory nations can decide whether to allow or ban the importation of chemicals listed in the treaty.
- **COP9 to Rotterdam Convention:** Two new chemicals (acetochlor, hexabromocyclododecane (HBCD) and phorate) were added to the list for mandatory PIC (Prior Informed Consent) procedures in international trade.

Hong Kong Convention on Recycling of Ships (2009)

- It was developed in cooperation with the International Labour Organization and the Parties to the Basel Convention to address all the issues around ship recycling, including the fact that ships sold for scrapping may contain hazardous substances such as asbestos, heavy metals etc.

Regulatory Measures by India

Hazardous Wastes (Management and Handling) Rules, 2016

- **Objectives**
  - Promote **recycling and reuse** of waste while minimizing hazardous waste.
  - Differentiate **hazardous waste** from **other wastes** such as waste tyres, paper waste, metal scrap, and used electronics, which are considered resources for recycling and reuse.
- **Waste Management Priority Sequence**
  - Standardized priority: **Prevention > Minimization > Reuse > Recycling > Recovery/Utilisation (including co-processing) > Safe Disposal.**
- **Standard Operating Procedures (SOPs)**
  - Infrastructure and SOPs specific to waste types established to protect health and the environment.
  - Compliance verified by **SPCBs/PCCs** (State Pollution Control Boards/Pollution Control Committees).
- **Import/Export Regulations**
  - **Prohibited**: Import of hazardous waste for final disposal.
  - **Permitted**: Import for recycling, reuse, or utilization following procedural rules.
  - **Prohibited Waste Imports:** Waste edible fats and oils of animal/vegetable origin,Household waste, Critical care medical equipment, Tyres for direct reuse, Solid plastic waste (including PET bottles), Electrical and electronic assemblies scrap, Chemical wastes, especially solvent
  - Solid plastic waste has been prohibited from being imported into the country, including in SEZ and by Export Oriented Units (EOU). **Exporters of silk waste have now been given an exemption from requiring permission from MoEFCC.**

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- Electrical/electronic assemblies and components manufactured in and exported from India, if found defective, can now be imported back into the country without obtaining permission from MoEFCC.
- Industries that do not require consent under the **Water (Prevention and Control of Pollution) Act 1974** and the **Air (Prevention and Control of Pollution) Act 1981**, are now exempted from requiring authorisation under the **Hazardous and Other Wastes Rules, 2016.**

RADIOACTIVE POLLUTION

- As per estimates India generates around **4 tonnes of radioactive waste per Gigawatt (GW)** of nuclear power capacity annually.

Common Terminologies

- **Radioactivity:** It is a phenomenon of **spontaneous emission** of protons (alpha-particles), electrons (beta particles) & gamma rays (short-wave EMR) due to the disintegration of atomic nuclei of some elements.
- **Radioactive Pollution:** It is defined as the increase in the radiation levels (nuclear radiation/radioactive contamination) in the environment that pose a severe threat to humans and other life forms.
- **Radioactive Contamination:** Presence of radioactive substances on surfaces/ within solids/ liquids/gases, where their presence is unintended or undesirable.

Sources

- **Natural radiation sources:** Cosmic rays from space and terrestrial radiations from radionuclides present in the earth's crust, such as radium-224, uranium-238, thorium-232, potassium-40, carbon-14, etc.
- **Artificial radiation pollution: Accidental leaks** from nuclear power plants and unsafe disposal, mining of radioactive material like uranium and thorium (monazite is the ore of thorium), exposure to radiation for diagnostic purposes (e.g. X-rays, CT Scan), chemotherapy, etc. and slow nuclear radiations emanating from nuclear reactors, laboratories, etc.
- **Types of radiation**: non-ionizing radiations and ionizing radiations:

Ionizing Radiation	Non Ionizing Radiation
Energetic enough to remove tightly bound electrons from atoms, creating ions. Eg. X-rays, Gamma rays, Alpha particles, Beta particles	Radiation that does not have enough energy to ionize atoms or molecules. E.g Radio waves, Microwaves, Infrared radiation, Visible light, UV radiation (non-ionizing part)
Can damage living cells, DNA, and cause cancer or genetic mutations	Generally considered less harmful but excessive exposure can cause tissue heating or skin damage.

- **Types of Radioactive Wastes**
  - **Low-level Radioactive Wastes (LLW)**: which include civilian applications of radionuclides in medicine, research and industry, materials from decommissioned reactors, protective clothing worn by persons working with radioactive materials or working in nuclear establishments.
  - **High-level Radioactive Wastes (HLW):** resulting from spent nuclear fuel rods and obsolete nuclear weapons.
- **Impact**
  - **Impact of Ionizing Radiation:** These are highly damaging to living organisms. They can cause chemical changes by breaking chemical bonds and damaging living tissues.
  - **Short-term effects:** Burns, impaired metabolism, dead tissues, and death of the organisms.
  - **Long-term effects:** Mutations increasing the incidence of tumours and cancer, shortening of lifespan and developmental changes.
  - It is **lethal at high doses**, but at lower doses, it creates various disorders, the most frequent of all being cancer.
  - **Biological Damage:** Radiation damage may be:
    - **Somatic damage/ radiation sickness**: Damage to cells that are not associated with reproduction. Only impact individual
    - **Genetic damage:** Damage to cells associated with reproduction. This can subsequently cause genetic damage from gene mutation resulting in abnormalities.

Measures to Control Radioactive Pollution

- **Global Measures:** National Regulatory frameworks, waste management practices like deep geological disposal and engineered containment facilities along with radiation monitoring networks are the gamut to steps adopted to tackle the harmful effects of radioactive pollution.
- **India's efforts**
  - **Atomic Energy Regulation Board:** regulates and monitors nuclear and radiation-related activities to ensure safety and prevent radioactive pollution.
  - Environmental monitoring and nuclear waste management strategies ensure safe handling and disposal of radioactive waste.

ELECTRONIC WASTE (E-WASTE)[UPSC-2013]

- The discarded and end-of-life Electrical/Electronic Equipment (EEE) and products ranging from computers, equipment, home appliances, audio and video products and all of their peripherals are known as electronic waste.
- It is not hazardous if it is stocked in safe storage or recycled by scientific methods, or transported from one place to the other in parts or totality in the formal sector. But if recycled or disposed of unscientifically it may prove to be fatal.
- In India, **only 32.9% of the e-waste out of the total 1.6 MMT generated in 2022-23 was collected, dismantled, and recycled or disposed of.**

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Major E-waste Component	Environmental Hazards
Cathode Ray Tubes (used in TVs, computer monitors, etc.)	Cadmium, lead, barium, and nickel leach into the groundwater
Printed Circuit Board (PCB) and switches	Atmospheric release and discharge into rivers of tin, lead, brominated dioxin, cadmium and mercury due to desoldering/open burning
Batteries	Cadmium, lead, lithium, mercury, nickel, etc., depending upon the type of batteries.

E-Waste Pollutants, Sources and Health Effects

Particulars	Source	Health Effects
Toners	Found in the plastic printer cartridge containing black and colour toners.	Respiratory tract irritant. Black Carbon is a carcinogen.
PVC	Plastics, cables, computer housings and mouldings, Chlorinated PVC (Chloro-benzenes)	Dioxins produced on burning are endocrine disrupters.
Phthalates	Used to soften plastics, especially PVC	Toxic to reproduction.

Common e-Waste

Phosphor additives	The phosphor coating on cathode ray tubes contains toxic heavy metals, such as cadmium, and other rare earth metals, for example, zinc, and vanadium as additives.
Lithium	PVC stabilisers, lasers, LEDs, thermoelectric elements, circuit boards, etc. Lithium-ion batteries contain metals such as cobalt, nickel, and manganese, which are toxic.
Acid	Sulphuric and hydrochloric acids are used to separate metals from circuit boards. Fumes contain corrosive chlorine and sulphur dioxide, which cause respiratory problems.
Plastics	Found in circuit boards, cabinets and cables, they contain carcinogens.
BFR	Brominated Flame Retardants (BFR) are used in circuit boards (plastic), cables and PVC cables. BFRs give out carcinogenic brominated dioxins and furans. They are highly resistant to degradation in the environment. They are able to accumulate in humans and animals. **(UPSC-2014)**
PCB	Polychlorinated Biphenyls (PCB) are used in transformers, capacitors, as softening agents for paint & plastics.
Selenium	Photoelectric cells, pigments, photocopiers, fax machines
Silver	Capacitors, switches (contacts), batteries, resistors

Measures to tackle E-waste

E-Waste Management Rules, 2016

GOI passed the first law on e-waste management in 2011, based on Extended Producer Responsibility (EPR). E-Waste Rules 2016 replaced 2011 Rules. **[UPSC 2019].**

- **Salient Features:**
  - **Over 21 products,** including Compact Fluorescent Lamp (CFL) & mercury-containing lamps, were included under the purview of the rules.
  - **EPR:** Manufacturers, dealers, refurbishers & Producer Responsibility Organization (PRO) have been introduced as additional stakeholders in the rules to strengthen EPR further.
  - **Manufacturers responsibility:** They are to take **back their sold products** with recommended mechanisms and to collect e-waste generated during the manufacture of any EEE and channelise it for recycling or disposal and seek authorisation from SPCB.
  - CPCB shall conduct **random sampling of EEEs** placed on the market to monitor compliance with the law on Restriction of Hazardous Substances (RoHS). The producer shall bear the cost of sampling.
  - **Liability for damages** caused due to improper management of e-waste, including provision for levying financial penalty for violation of provisions of the rules, has also been introduced.
  - **Finance**
    - Option has been given for setting up of e-waste exchange, e-retailer, and **Deposit Refund Scheme** as an additional channel for implementing EPR by producers to ensure efficient channelisation of e-waste.
    - The e-waste exchange as an option has been provided as an **independent market instrument offering assistance** for selling and purchasing e-waste generated from end-of-life EEE between agencies or organisations.

Rules have further been amended in 2019 and 2022. Key provisions of these amendments are as follows:

- **Amendment in 2019:**
  - to channelise the E-waste generated towards authorised dismantlers & recyclers to formalise the e-waste recycling sector.
  - The collection targets under the provision of EPR in the Rules have been revised, and targets have been introduced for new producers who have started their sales operations recently.

E-Waste Management Rules, 2022

- **Widen the coverage of electronic goods** from **21 to 106** and restrict the use of hazardous substances (such

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as lead, mercury, and cadmium) in manufacturing EEE that have an adverse impact on human health and the environment.

- **EPR Certificates** (similar to carbon credits) will allow the offsetting of e-waste responsibility to a third party.
- **Targets:** Producers of electronic goods have to ensure at least 60% of their e-waste is collected and recycled by 2023, with targets to increase them to 70% and 80% in 2024 and 2025, respectively.
- **'Environmental compensation':** Provided by the companies that don't meet their target.
- **Responsibilities:** State Governments will earmark industrial space for e-waste dismantling and recycling facilities, undertake industrial skill development and establish measures for protecting the health and safety of workers.
- **Manufacturers**: Making the end product recyclable and a component made by different manufacturers be compatible with each other.
- **CPCB**: Shall conduct random sampling of EEE placed on the market to monitor and verify the compliance of reduction of hazardous substances provisions.

E-Waste (Third Amendment) Rules, 2024:

- **E-Waste Definition Expansion:** More products now fall under the category of electronic and electrical waste.
- **Extended Producer Responsibility (EPR):** The Central Government may establish platforms for trading Extended Producer Responsibility certificates as per guidelines issued by the Central Pollution Control Board with its approval.
- The Central Pollution Control Board will set the price range for Extended Producer Responsibility certificates at 100% (maximum) and 30% (minimum) of the environmental compensation for non-compliance. .
- **Strengthened Registration Requirements:** E-waste producers and recyclers need to register with authorities.
- **Reporting Obligations:** Enhanced reporting on e-waste management activities for producers.
- **Monitoring Mechanisms:** Stricter guidelines for monitoring compliance and penalties.

HEAVY METAL POLLUTION

- **Heavy Metals:** Metallic elements with a relatively high density compared to water. These are harmful (toxic/ poisonous) to the environment, humans and other organisms, even at low concentrations. **[UPSC 2013]**
- **Water-soluble heavy metals**: Arsenic, cadmium, lead, mercury, barium, chromium, platinum, palladium, and silver.
- Most of them are not broken down by biological degradation. They **bioaccumulate and biomagnify** posing danger to organisms at the top of the food chain.
- **Heavy metal poisoning (toxicity)** is the result of exposure to heavy metals which enter the human body systems and bind to cells preventing the normal functioning of organs. It can cause irreversible damage and can be life-threatening in some cases.
- Heavy metals **can be carried to places far away** from their source of origin by winds when they are emitted in gaseous form or form of fine particulates. Rain ultimately washes the air having metallic pollutants, and brings them to the land and water bodies.

Metal	Sources	Health Effects
Lead	**Major Sources**: Mining, lead-acid batteries, battery recycling, paints, pigments, fly ash, plastic toys. **Minor Sources:** Lead-soldered food cans, lead pipes (water), leaded petrol (phased out), glass, ayurvedic medicines, cosmetics. **E-waste Sources**: Lead batteries, solar panels, PCBs, PVC, transistors, glass panels, computer monitor gaskets	• Carcinogen (lungs, kidneys). • Neurological damage in children. • Developmental issues, miscarriages, stillbirths. • Lead poisoning: neurodegenerative diseases, CNS dysfunction. • Maternal exposure: developmental reprogramming, risk of Alzheimer's.
Mercury	**Natural**: Volcanic eruptions, fossil fuels, metal ores. **Human-Made**: Mining, coal burning, cement, caustic soda production. **E-waste Sources**: LCD screens, CFLs, CRTs, batteries, thermometers, medical equipment, lamps, mobile phones.	• Damages CNS, lungs, kidneys; causes paralysis, Alzheimer's, depression, and impotence. Inhalation is more harmful as it quickly reaches the brain.
Chromium	**Chromium 6 (hexavalent chromium**) is used as a corrosion protector of untreated and galvanised steel plates, metal housings and plates in computers, in chrome tanning (leather industry), and as a decorative or hardener for steel housings plastics (including PVCs).	Inhaling chromium or chromium 6 can damage the liver and kidneys and cause bronchial maladies, including asthmatic bronchitis and lung cancer. Chromium VI can cause damage to DNA.

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Cadmium	**Major Sources**: mining (especially of zinc & copper), metallurgical operations, electroplating industries, Etc. **E- waste sources:** Solar panels, batteries, PCBs, CRTs, SMT chips, semiconductor chips, PVC cables.	Hypertension, liver/kidney damage, lung cancer, **Itai-itai disease** (from cadmium in water/rice).
Arsenic	Copper, iron and silver ores, fly ash, liquid effluents from fertiliser plants, semiconductors, diodes, microwaves, LEDs(Light-emitting diodes), solar cells, etc.	Accumulation of arsenic in the body parts like blood, nails and hairs, causing skin lesions, rough skin, dry and thickening of the skin and ultimately skin cancer.
Antimony	Trace component of metal solders, lead alloys for batteries, lead/copper/tin alloys for bearings.	Antimony trioxide is a **possible carcinogen**
Tin	Preserved foods stored in tin cans.	Irritant, and excess tin can cause damage to the liver and kidneys.
Zinc	Mining, metal smelting (like zinc, lead and cadmium), fly ash, steel, brass, alloys, disposable and rechargeable batteries, luminous substances, etc.	Excess zinc is a skin irritant and affects the pulmonary system.
Barium	Oil and gas industries (used to make drilling mud which simplifies drilling through rocks by lubricating the drill), paint, tiles, fireworks (barium nitrate and chlorate for green colour), etc.	Nausea, brain swelling, muscle weakness, irregular heartbeat, paralysis, etc.
Beryllium	PCB motherboards (copper-beryllium alloy is used to strengthen connectors while maintaining electrical conductivity).	Lung cancer and lung damage, poor wound healing, etc.

Minamata Convention

In Japan, **mass mercury poisoning (Minamata disease)** was observed in the 1960s, caused by eating fish from Minamata Bay contaminated with methylmercury.

Its **aim is to protect the environment and the human health from anthropogenic emissions and releases of the toxic heavy metal.**

India ratified the Minamata convention in 2018**.**

INDUSTRIAL POLLUTION

Aspect	Highly Polluting Industries (HPIs)	Grossly Polluting Industries (GPIs)	Water Guzzlers
Definition	Industries closely monitored by MoEFCC for high pollution.	Industries discharging >100 kiloliters/day wastewater or using hazardous chemicals as per 1989 rules.	Industries with high water consumption.
Examples	Iron & steel, thermal power, sugar, cement, copper smelter, distillery, pharmaceuticals tannery, Refinery, Caustic soda, Pulp and paper, Dye and dye stuff, etc.	Fertilizers, pharmaceuticals, distilleries, textiles, slaughterhouses, food & beverage, automobile industry, etc	Thermal power plants, engineering, paper & pulp, textiles, sugar, cement.
Details	17 categories identified as HPIs.	Defined under Environment (Protection) Act, 1986.	India is home to almost 18% of world population, it has only 4% of global fresh water resources. And much of this water is used in agriculture. **FAO puts this figure at 90%, Indian Central Water Commission says it is 78%.**

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Industrial Emissions and Effluents Monitoring

- Every industry and its effluent treatment plant (ETP) outlets are connected to a **central monitoring system** that continuously reads and sends data to SPCB/ CPCB (regulator). Since 2014, the monitoring has been done through the **Online Continuous Emissions/ Effluents Monitoring Systems (OCEMS)**. All the HPIs are required to have OCEMS.
- **5 parameters are scrutinized for all industries:** BOD (Biological Oxygen Demand), TDS (Total Dissolved Solids), Ph value, COD (Chemical Oxygen Demand) and TSS (Total Suspended Solids).
- **The emissions monitored**: Particulate matter (PM), Carbon monoxide (CO), Nitrogen Oxides (NOx), Sulfur Dioxide (SO_2), and Fluoride.
- If the pollution control boards receive any number that exceeds the permissible limit, the industry is sent a notice and action is taken.

POLLUTANTS FROM HPIS

Thermal Power Plants (TPP) (UPSC- 2011, 2020)

- Efficiency and Techniques: Most TPPs in India operate with low efficiency (20-45%) and lack pollution-reducing technologies like Flue Gas Desulphurisation (FGD) and electrostatic precipitators. Indian coal has high ash content, exacerbating pollution issues.
- Major Pollutant - Fly Ash: Fly ash, a byproduct of coal combustion, is discharged into the air and ash ponds. Its collapse contaminates nearby farms, homes, surface water, and groundwater with toxic heavy metals and other pollutants.
- **Toxic Heavy Metals in Fly Ash:** Fly ash contains harmful metals such as mercury, cadmium, arsenic, lead, and zinc, polluting air and water bodies around TPPs.
- **Other Pollutants in Fly Ash:** Includes toxic elements like fluoride and sulphur.
- **Gaseous Pollutants:** TPP emissions include CO_2, SO_2, NOx, particulate matter (PM), methane (CH_4), carbon monoxide (CO), and volatile organic compounds (VOCs).
- **Water Pollution:** TPPs contribute to heavy metal pollution through acid mine drainage (AMD) from coal mines and effluents from cooling towers, ash handling, and wet FGD discharges.

Iron and Steel Industry [UPSC 2014]

- Unwanted impurities are removed by **smelting** iron ore in a blast furnace. **Major impurities:** sulphur, lead, oxygen etc.
- In a blast furnace, fuel (coke — has far fewer impurities than coal), iron ore, and flux (limestone — removes sulphur and other impurities into slag) are continuously supplied.
- **Byproducts**: liquid slag, liquid iron/pig iron and gases (CO and CO_2).
  - **Slag**: Full of impurities such as Calcium Sulphide (CaS) and oxides of silica, alumina, magnesia, calcium (CaO), etc. Only a small percentage of slag goes into landfills.
  - **Cement:** Made with blast furnace slag has lower permeability and is more durable than Portland (regular) cement. It is used as an aggregate in concrete, cement clinker, asphalt concrete, asphalt and road bases.
- **Soil Improvement:** Dissolution of slag generates alkalinity that can be used to precipitate out metals, sulfates, and excess nutrients (like nitrogen, phosphorus, potassium) in wastewater treatment.
- **Soil Conditioner:** Ferrous slags have been used to rebalance soil pH and as fertilizers (as sources of calcium and magnesium).
- **Air Pollution:** The burning of coal causes air pollution in the form of PM2.5 and PM10, Carbon Dioxide, Sulphur Oxides (sulphur is eliminated as SO_2 in the blast furnace), Nitrogen Oxides, Carbon Monoxide, Hydrogen Sulphide, Non-Methane Volatile Organic Compounds (NMVOC), etc. Coke ovens emit naphthalene which is highly toxic and can cause cancer (carcinogenic).
- **Magnetite Pollution:** It is the presence of a magnetic mineral called Magnetite (Fe_3O_4) in the environment, as a result of human activities such as mining, steel production and industrial processes. Magnetic particles can interfere with the migratory patterns of birds and the operation of electronic equipment, such as compasses and navigation systems. **[UPSC 2021]**
- **Water Pollution:** Heavy metal pollution occurs due to Acid Mine Drainage (AMD) in slag dumps. Wastewater from the **coking process (heating coal in the absence of oxygen (CO emissions) to drive off VOCs, leaving behind high carbon coke)** is highly toxic and contains several carcinogenic organic compounds as well as cyanide, sulfides, ammonia, etc. Dissolution of slags (full of oxides) can produce highly alkaline groundwater.

Cement Industry

- **Processes Involved:** Blasting limestone quarries; Crushing; Calcination; Grinding to form Portland Cement.
- **Limestone** (the most common form of calcium carbonate) is the most **crucial binder** in cement. It is heated in kilns to ~1,400 °C using **coal as fuel.**
- Carbon trapped in the limestone combines with oxygen and is released as **CO_2 (byproduct)**. A portion of limestone can be substituted by blast furnace slag and/ or fly ash to reduce CO_2 emissions.
- Emissions and Effluents are the same as in TPP, as coal is the primary fuel source in kilns.

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Copper Smelting Industry

- **Electrolytic refining:** Copper from the anode plates is electrolytically deposited on the stainless steel cathode plate, resulting in copper with a grade of 99.99%.
- **Byproduct: Slime** generated in electrolytic refining contains precious metals such as gold, silver, selenium, tellurium, etc. These metals are recovered in a slime treatment plant.
- **Copper slag:** Mainly used for abrasive surface blast-cleaning (used to shape the surface of the metal, stone, concrete, etc.). It can be used in road construction and the production of cement, mortar, and concrete as raw materials for clinker, coarse and fine aggregates.
- **Pollutants:** Leaching of impurities from copper ore concentrate and slag releases radon, iron, arsenic, antimony, mercury, lead, cadmium, selenium, magnesium, aluminum, cobalt, tin, nickel, manganese, nitrates, fluorides, etc. **[UPSC 2021]**
- As most copper ores are sulphur-based, the smelting process releases Sulphur Dioxide. When the concentration of sulphur dioxide is too high, the industries convert it into sulphuric acid, an irritant and water contaminant.

Zinc/Lead Smelting Industry

- Zinc protects the steel from corrosion (galvanisation). Lead is used in batteries. Zinc and lead often occur together as sulphides.
- **Raw materials**: zinc sulfide (ZnS) and/or lead sulphide (PbS – galena) ore concentrate.
- **Processes involved: Beneficiation** (concentration of the zinc/lead in the recovered ore done near the mine); Roasting; Leaching; Purification and Electrowinning (Specialized Electrolysis Process).
- **Byproducts**: gold, silver & copper are collected as slimes.
- **Granulated lead–zinc slag** has suitable particle sizes for sand replacement in mortar and concrete.
- **Principal air pollutants**: particulate matter (lead/zinc, arsenic, antimony, cadmium, copper, and mercury and metallic sulfates) and Sulfur Dioxide (SO_2).
- **Sources of wastewater**: Spent electrolytic baths, slime recovery, spent acid from hydrometallurgy processes, cooling water, air scrubbers, etc.
- **Heavy metal leaching from discarded slag**: cadmium, copper, lead, iron, bismuth, antimony, arsenic, copper, etc.

Aluminium Smelting Industry

- **The Bayer Process** separates alumina (aluminium oxide) from bauxite ore near the mine. The insoluble parts of the bauxite are removed by exposing the ore to very hot caustic soda (sodium hydroxide).
- **The Hall-Héroult Process** produces pure aluminium by electrolysis of alumina in an aluminium smelter. Due to the significant energy demand, the smelters must be set up close to a power station.
- **Byproduct: Red Mud:** The highly alkaline and hazardous bauxite residue from the **Bayer process** is known as red mud. It is composed mainly of iron oxides and various other oxides and heavy metals. In the past red mud was disposed of entirely in landfills but now it is being used in road construction, and as a source of iron, in producing iron-rich cements, low cost concrete, etc. It is applied to soils to improve phosphorus cycling, amelioration of soil acidity, carbon sequestration, etc.
- **Pollutants:** Most of the emissions are related to thermal power and electrolysis process — NOx, SO_2, ammonia (NH_3) and polycyclic aromatic hydrocarbons (PAH — formed from incomplete combustion during electrolysis).

Petroleum Refining & Petrochemicals

- The petroleum industry is subdivided into upstream, midstream, and downstream segments. The upstream deals with the exploration and mining of crude oil, the midstream includes storage and transport of crude, while the downstream involves refining.
- **Petroleum Refining**
  - **Processes involved: Fractional distillation** (separation of different fractions (hydrocarbon compounds) of crude oil based on their boiling point differences); **Conversion processes** (breaking down long chain molecules into more valuable smaller ones by heating); **Treating** (separating the impurities such as sulfur, nitrogen and heavy metals).
- **Air Pollution:** Particulate Matter (PM), Carbon Dioxide (CO_2), nitrogen oxides (NOx), carbon monoxide (CO), hydrogen sulfide (H_2S), sulfur dioxide (SO_2), natural gas (methane), lead, VOCs including cancer-causing benzene pollutants, etc.
- **Water Pollution**: Refineries use deep-injection into underground wells and coastal waters to dispose of wastewater and oil residues generated inside the plants, and some of these wastes end up in aquifers and groundwater.
- **Petrochemicals**
  - Petrochemical industry comprises the manufacture of synthetic fibres, polymers (PVC, polystyrene, performance polymers, etc.) and intermediates (styrene), synthetic rubber (elastomers), synthetic detergent intermediates, performance plastics, etc., using hydrocarbon feedstock (naphtha, ethylene, propylene, butadiene, etc.) derived mainly from crude oil and natural gas processing.
  - **Organic pollutants:** Complex Polycyclic Aromatic Hydrocarbons (PAHs).
  - **Wastewater effluents:** Toxic phenols, cyanide, and formaldehyde.

Furnace oil **[UPSC 2021]**

- It is a product of oil refineries;
- Some industries use it to generate power.
- Its use causes sulphur emissions into the environment.

Fertilizer Industry

- **Air Pollutants:** particulate matter, ammonia (NH_3), nitrogen oxides, sulphur and carbon dioxide. Prilling towers, which manufacture urea prills, are a significant source of urea dust particulates.

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- **Water Pollution:** Wastewater generated contains ammoniacal nitrogen, phosphates, heavy metals (vanadium and arsenic — used for carbon dioxide removal processt in ammonia plant —and Chromium — used as a corrosion inhibitor in cooling towers) and fluorides in varied amounts

Distilleries

- The distillery industry uses **sugarcane molasses, cereals, fruits, sugar beet,** and other agro products for producing alcohol through fermentation and distillation. **Alcohol** is an **essential** material in the chemical, pharmaceutical, cosmetics, beverage, food, and perfume industries.
- **Water pollution**: Ethanol fermentation results in the discharge of high-strength liquid effluents with high concentrations of organic matter (high BOD) and nitrogen compounds (eutrophication), low pH, high temperature, high turbidity and high salinity.

Paper and Pulp Industry

- Pulp is fibrous material prepared by separating cellulose fibres from wood, bagasse, fibre crops, waste paper, etc.
- The pulp mills are **energy intensive** and use a lot of unpolluted water and chemicals (sulfite salts, caustic soda, sodium sulfide, hydrogen peroxide, sulphonic acid, etc.) for pulping the wood (to remove lignin) and bleaching the pulp for producing paper of various quality and finish.
- **Wastewater pollution:** Complex organic (high BOD) and inorganic pollutants such as sodium hydroxide, sodium carbonate, sodium sulfide, chlorine dioxide, calcium oxide, hydrochloric acid, etc.
- **Air pollution:** Gaseous pollutants are hydrogen sulfides, sodium sulfide, methyl mercaptan, sulfur, etc.

Caustic Soda

- **Processes involved**: **Electrolysis of brine** (common salt dissolved in water; chloralkali process) using mercury cell and membrane cell process. It is a widely used industrial chemical in pulp and paper, detergents, packaging, agriculture, environmental protection, water treatment, textiles, etc.
- **Chlor-alkali industries produce caustic soda,** soda ash, chlorine and hydrogen, which are used as fuel or converted to HCl. These products are used to manufacture paper, soaps and detergents, chemicals, water treatment chemicals, textiles, PVC, glass, etc.
- **Pollution**: Owing to the environmental **risks associated with the mercury** process and risks associated with handling chlorine, its vapours and hydrogen, the industry is classified among the 17 polluting industry categories. Wastewater is generated from drying chlorine using sulphuric acid (H_2SO_4). Besides scrapped cell parts (membranes, anodes and cathodes) leach heavy metals.

Tannery

- **Beamhouse operations:** hides from slaughterhouses, soaking (removes dirt from hides), liming (unhairing by chemical dissolution of the hair with an alkaline medium of sulphide and lime), deliming (alkaline hides are neutralized with acid ammonium salts), bating or puering (to degrade proteins), pickling (increases the acidity of the hide, enabling chromium tannins to enter the hide).
- **Chrome tanning**: it is based on the cross-linkage of chromium ions with free carboxyl groups in the collagen. It makes the hide resistant to bacteria and temperature.
- **Pollution**: The discharge of solid waste and wastewater **containing chromium** is the leading environmental problem. Wastewater with high organic content (high BOD) emanates from the beam house (pre-tanning) operations. Emissions into the air are primarily related to energy use, and the use of organic solvents and dyes — hydrogen sulphide (H_2S) and ammonia (NH_3).

Sugar Industry

- **Processes involved:** sugar cane/sugar beet harvesting, juice extraction, filtration, crystallization, drying of crystals, sugar.
- **Byproducts: Press mud** produced during the filtration of cane juice is used as fertilizer, **soil amendment (any material added to a soil to improve its physical properties, such as water retention),** biosorbent (effectively adsorb metal ions and contaminants), animal feed, etc; **Molasses,** a dark viscous syrup resulting from refining sugar cane juice into sugar is used to sweeten and flavour foods, in making brown sugar for baking, ethanol production, as animal feed, soil amendment, etc; **Bagasse** is a dry pulpy fibrous material that remains after crushing sugarcane is used as fuel in sugar industries, raw material in paper, pulp, packaging industry.
- **Air Pollution:** Fly ash, sulfur dioxide, carbon monoxide, nitrogen oxides, nitrates, carbon compounds, and sulfates. Sulphitation (introduction of SO_2 into liquids) and carbonation (saturation of a liquid with CO_2 gas) are used as a process of purification (lightning) of cane juice by employing sulphur dioxide, carbon dioxide, lime (calcium hydroxide) and calcium carbonate (aids precipitation of impurities) producing SO_2 and CO_2.
- **GHGs:** The sugarcane residue burning results in not only CO_2, N_2O (nitrous oxide) and methane emissions but also other GHG precursors, including carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), etc.
- **Water intensive:** To mature in the field, one kilo of sugarcane requires 1,500-2,000 litres of water. After the harvest, crushing a single tonne of sugarcane requires another 1,500-2,000 litres of water, generating about 1,000 litres of wastewater.
- **Water Pollution:** The wastewater contains a **high amount of organic pollution load,** particularly in suspended solids, organic matter, press mud, bagasse, etc., raising the Biological Oxygen Demand**, coliform bacteria** (indicator species for pollution load) indicates a high presence of pathogen and **total dissolved solids** (TDS — inorganic salts such as calcium, magnesium, sodium, nitrates, etc.) in sugar industry effluents.

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5 Land Degradation

- Land degradation means reduction or loss, in arid, semi-arid and dry subhumid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns such as:
  - soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation.
- **There are a number of interrelated land degradation components,** all of which may contribute to a decline in agricultural production. The most important according to Douglas (1994) cited by FAO (1999):
  - **Soil degradation:** decline in the productive capacity of the soil as a result of soil erosion and changes in the hydrological, biological, chemical and physical properties of the soil.
  - **Vegetation degradation:** decline in the quantity and/or quality of the natural biomass and decrease in the vegetative ground cover.
  - **Water degradation:** decline in the quantity and/or quality of both surface and ground water resources.
  - **Climate deterioration:** changes in the micro and macro-climatic conditions that increase the risk of crop failure.
  - **Losses to urban/industrial development:** decline in the total area of land used, or with potential, for agricultural production as a result of arable land being converted to urban, industrial and infrastructure uses.
- **Land degradation has both on-site and off-site effects.**
  - **On-site effects** are the lowering of the productive capacity of the land, causing either reduced outputs (crop yields, livestock yields) or the need for increased inputs.
  - **Off-site effects** of water erosion occur through changes in the water regime, including decline in river water quality, and sedimentation of river beds and reservoirs. The main off-site effect of wind erosion is overblowing, or sand deposition (FAO, 1994).

LAND DEGRADATION IN INDIA

- From 2015-2019, 30.51 million hectares of India's total reported land was degraded, according to United Nations Convention to Combat Desertification (UNCCD). This means that 9.45 per cent of the country's landmass was degraded as of 2019. This was 4.42 per cent in 2015.

MAJOR CAUSES FOR LAND DEGRADATION

Causes of different types of land degradation include water erosion, wind erosion, soil fertility decline, waterlogging, salinisation, lowering of the water table, deforestation, forest degradation and rangeland degradation.

Deforestation

- Roots of trees and plants bind the soil particles and regulate water flow, preventing erosion.
- Population pressure leads to increased demand for forest resources, resulting in deforestation.
- Deforestation makes soil vulnerable, accentuating erosion in regions like the Shiwalik range, Chos of Punjab, and Chambal valley ravines.
- **Major causes of Deforestation** include shifting cultivation, demand for raw materials in industries like paper, plywood, etc, opencast mining, plantation agriculture for commodities like cocoa, coffee, tea, sugar, palm oil, rubber, etc.

Soil Salinity and Soil Alkalinity

- **Saline and Alkaline Soils:** Topsoil impregnated with saline and alkaline efflorescences (salt particles).
- **Causes of Salinity and Alkalinity**
  - Rock fragments weathering into sodium, magnesium, calcium salts, etc makes soil saline.
  - **Over-irrigation in canal-irrigated regions** like Uttar Pradesh, Punjab, Haryana, Rajasthan etc leads to salinity and alkalinity issues. **Example**: Indira Gandhi canal in Rajasthan has caused serious salinity and alkalinity problems.
  - Waterlogging, which leads to increased soil salinity degrading the quality of land.

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- **Steps to Treat Salinity and Alkalinity**
  - **Drainage Outlets** for lands to drain excess water, lowering the water table.
  - **Leakage Prevention** from canals, tanks, and water bodies through lining.
  - **Judicious Irrigation** to avoid waterlogging.
  - **Vegetal Cover Improvement** with salt-tolerant plants to prevent further degradation.
  - Implement **Crop Rotation**.
  - **Gypsum Application** to convert alkalis into soluble compounds.
  - Removing alkali by **adding sulphuric acid or acid-forming substances** like sulfur and pyrite.
  - Promote mild acid formation by **adding organic residues** such as rice husks and straw through decomposition.

Desertification

- Spread of desert-like conditions in arid or semi-arid areas due to human influence or climatic change.
- **Affected Regions:** Arid and semi-arid areas between the Indus and the Aravalli range.
- **Causes:** Uncontrolled grazing, reckless tree felling, growing population, and climate change.
  - **Faulty Methods of Agriculture:** Like ploughing along the slopes, monoculture and lack of crop rotation, shifting cultivation, etc lead to degradation of land.

Soil Erosion

- Agents like wind and water degrade land by removing the fertile topsoil, which contains essential nutrients and organic matter needed for plant growth. Over time, it can cause land to become barren, and exacerbate desertification, making the land unsuitable for agriculture and other uses.

Coastal Erosion

- **Causes:** Waves along the coast, storm surges during cyclones, tidal bores in estuaries.
- **Effects:** Heavy damage to coastal soils, destruction of beaches, and extensive damage to surrounding banks during cyclones and tidal bores.
- **Prevention:** Groynes(shore protection structures built perpendicular to the shoreline of the coast) serve as crucial engineering structures in coastal protection, offering an effective means to combat erosion and preserve the natural features of beaches and shorelines.

Causes of Coastal Erosion

- **Natural Factors**
  - **Bay of Bengal Influence:** The eastern coast, particularly West Bengal, faces more erosion due to rough seas and intense tide movements in the Bay of Bengal.
  - **Cyclonic Activities:** The eastern coast experiences more erosion due to frequent cyclonic activities originating from the Bay of Bengal, compared to the western coast.
- **Anthropogenic Factors**
  - **Construction Activities:** Ports and other constructions along coastlines contribute to erosion.
  - **Dredging and Sediment Dumping:** Improper practices, such as dredging in port areas and dumping sediments into deep seas, can intensify erosion.

Effects of Coastal Erosion

- **Vulnerability of Coastlines:** West Bengal, Odisha, Puducherry, Tamil Nadu, and Andhra Pradesh are particularly vulnerable, with significant portions undergoing erosion.
- Coastal erosion can lead to the **loss of infrastructure**, including roads and other constructions near the coastline.
- Areas with high erosion, like Visakhapatnam, face challenges, **affecting local populations and livelihoods**.

Management Techniques

- **Dynamic Approach to Beaches**: Treat beaches as dynamic landforms and part of the sea, necessitating continuous nourishment to act as a cushion against high wave action.
- **Submerged Breakwater:** Constructing a submerged breakwater about 500 meters from the shoreline can break wave energy and prevent erosion caused by wave currents.
- **Coastal Structures** like sea walls, revetments, and groynes to mitigate erosion effects.
- **Beach Nourishment:** Dredging sand from the sea and depositing it on eroding beaches helps create a wider beach, reducing the impact of erosion.
- **National Centre for Coastal Research (NCCR-attached office of Ministry of Earth Sciences):** Monitors shoreline changes along the Indian coast, providing crucial data for understanding erosion patterns.
- **National Centre for Sustainable Coastal Management (NCSCM-research institute under Ministry** of Environment) mandated to manage the Indian coast sustainably, focusing on conservation and addressing challenges posed by erosion.

Glacial Erosion

- Glacial erosion refers to the process of landform modification and soil removal caused by the slow movement of glaciers, primarily occurring in polar regions and high mountainous areas.

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METHODS OF SOIL CONSERVATION

Method	Description	Key Benefits
Crop Rotation	Cultivating different crops each year to prevent soil exhaustion.	Restores lost nutrients (e.g., legumes add nitrogen), maintains soil fertility.
Early Maturing Varieties	Using crops that mature faster.	Reduces soil pressure and allows for quicker crop cycles.
Strip Cropping	Planting alternate parallel strips of different crops.	Tall crops act as windbreaks; strips slow water runoff, reducing erosion.
Intercropping	Growing different crops in alternate rows and at different times.	Protects soil from rain-induced erosion n and washouts.
Contour Ploughing	Ploughing across the slope of a hill (perpendicular to the slope).	Reduces runoff, prevents gully formation, and minimizes wind erosion.
Checking Shifting Cultivation	Promoting settled agriculture instead of shifting cultivation.	Involves resettling tribal communities with necessary provisions to encourage stable farming.
Mulching	Covering bare ground with organic matter (e.g., grass clippings, straw).	Protects soil from erosion, reduces compaction, and conserves moisture.

ADDRESSING LAND DEGRADATION AND DESERTIFICATION

United Nations Convention to Combat Desertification (UNCCD) [UPSC 2016]

- **Objective:** Promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss.
- **Establishment and Ratification**
  - Emerged from the 1992 Rio de Janeiro Earth Summit.
  - Established in 1994 in Paris.
  - Ratified by 196 countries and the European Union.
  - India ratified in 1996.
- **Purpose and Significance**
  - Ensures global action against land degradation.
  - **Only legally binding international agreement linking environment, development, and sustainable land management.**
- **National Action Programmes (NAP):** Countries required to develop NAP using a bottom-up approach to restore degraded lands.
- **Conference of the Parties (CoP)**
  - Supreme decision-making body of UNCCD, **held every two years**.
  - Reviews Convention implementation, formulates strategies, and coordinates work with other agencies.
  - Recent COPs held in Ordos City (China), New Delhi (India), and Abidjan (Côte d'Ivoire).
  - **Future Meetings:** COP-16 in Saudi Arabia (2024) and COP-17 in Mongolia (2026)
- **India's Commitment**
  - **COP-14: India President:** "Restore land, sustain future" was the theme.
  - **COP-15:** India reaffirmed its commitment to restoring 26 million hectares of degraded land by 2030.
- **Gender Mainstreaming**
  - It was adopted by the United Nations Convention to Combat Desertification (UNCCD) in 2017. This was part of the UNCCD's Gender Action Plan (GAP), which was endorsed during COP13 in Ordos, China.
  - UNCCD mandates gender mainstreaming for achieving Land Degradation Neutrality (LDN) targets.
  - Aims to advance gender equality, enhance women's access to land and resources, reduce poverty, and restore ecosystems.
- **UNCCD Impact**
  - Drives Sustainable Development Goal 15 and Land Degradation Neutrality (LDN).
  - Initiatives include the Drought Initiative and the Great Green Wall Initiative.

Key Outcomes of COP15 of UNCCD

Theme: "Land Life Legacy: From Scarcity to Prosperity" emphasized drought resilience and land restoration for future prosperity.

Major Agreements

- **Drought Management Initiative:** Establishment of an Intergovernmental Working Group (2022-2024) to transition from reactive to proactive drought management.

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- **Land Restoration Commitment:** Restoration of one billion hectares of degraded land by 2030.
- **Report Release:** "Drought in Numbers, 2022" underscored the need for prioritizing drought preparedness and resilience.

Key Declarations

- **Abidjan Call:** Heads of State and Government pledged to promote long-term environmental sustainability.
- **Abidjan Declaration:** Focused on achieving gender equality to ensure effective land restoration.
- **"Land, Life, and Legacy" Declaration:** Addressed findings from the UNCCD's Global Land Outlook 2 report.

Reference to COP14 (2019)

The ***Delhi Declaration*** emphasized better land management and access, highlighting gender-sensitive transformative initiatives.

Land Degradation Neutrality (LDN)

Definition: LDN involves maintaining or enhancing the quantity and quality of land resources to support ecosystems, services, and food security. It focuses on halting land degradation and restoring degraded areas.

Key Concept

- Aims to keep land resources stable or increasing within specific timeframes and ecosystems.
- Balances the loss of productive land with the restoration of degraded areas.

Benefits

- Addresses growing competition for limited land resources.
- Promotes sustainable land management by reversing degradation through restoration efforts.
- Helps prevent social instability, poverty, conflict, and migration.

Implementation

- Involves multi-stakeholder participation and coordinated planning across different sectors and governance levels.
- Relies on local and regional governance with national oversight.
- Supported by international frameworks such as the UN Convention to Combat Desertification (UNCCD) and the UN Environment Programme (UNEP).

Global Progress

- Over 120 countries are part of the LDN Target Setting Programme.
- Significant advancements have occurred since the adoption of the 2030 Agenda for Sustainable Development.

Great Green Wall Initiative

- Launched in 2007 by the African Union across 22 African countries.
- Aims to restore 100 million hectares of degraded land, sequester 250 million tons of carbon, and create 10 million green jobs by 2030.
- **China's successful community engagement in greening deserts** serves as a model for the initiative.
  - China has converted the Gobi Desert through a massive tree-planting project called the **"Great Green Wall" or "Three-North Shelterbelt Program"**.

UNCCD Global Land Outlook Report

- **Loss of Cropland due to Urbanization**
  - Urbanization is projected to cause the loss of 1.6 to 3.3 million hectares of prime agricultural land annually (2000-2030).
  - Results in a 6% production loss in Asia and a 9% drop in Africa.
- **Impact of Increasing Meat Consumption**
  - Rising meat consumption puts pressure on land resources.
  - Reducing average meat consumption can benefit human health and address climate change.
  - Demand for land-intensive foods contributes to crises like land scarcity and food insecurity.
- **Water Scarcity**
  - Projected water demand to surpass extraction capacity by 40% by 2030.
  - Two-thirds of the world's population is expected to live in water-stressed countries by 2025.
  - Agricultural water demand is set to double by 2050.
- **Drought**
  - Strong nexus between land use and drought.
  - **UNCCD's 'Strategic Objectives' for 2018-2030 includes drought as a focus.**
  - Introduction of **'drought-smart land management'** within sustainable land management interventions.

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- **Cost of Climate Adaptation**

  Investment of $1.8 trillion in climate adaptation measures over the next decade deemed necessary for tangible transformation.
- **Desertification from Conservation Perspective**
  - Desertification refers to land degradation in arid, semi-arid, and dry sub-humid areas, **not natural desert expansion.**
  - Gradual loss of soil productivity, making crop cultivation impossible.
- **Importance of Reversing Land Degradation**
  - 34% of Earth's land surface and half of farmlands in drylands.
  - Over 2 billion people and half of the world's livestock depend on these lands.

Thematic Report on Rangelands and Pastoralists by UNCCD

- **Rangeland Degradation:** Approximately 50% of global rangelands are degraded due to climate change, population growth, land-use changes, and farmland expansion.
- **Low Public Awareness:** Despite their crucial ecological role, rangeland degradation receives little public attention compared to deforestation.

India-Specific Observations

- **Economic Role of Pastoralists:** Pastoralists significantly contribute to the economy through livestock rearing and milk production. The contribution of livestock in total agriculture and allied sector Gross Value Added (GVA) has increased from 24.38% in 2014-15 to 30.23% in 2022-23 (at Current Prices). Livestock sector contributed 5.50% of total GVA in 2022-23(at Current Prices)
- **Pastoralist Rights and Recognition:** Over 20 million pastoralists, including communities like the Maldharis, Van Gujjars, and Rabaris, depend on grasslands, shrubs, and plateaus. They require better recognition of their rights and improved market access.
- **Marginalization Issues:** Pastoralists face marginalization and limited policy influence, resulting in uncertain access to common lands and land rights.

Grassland Protection in India

- **Neglect and Threats:** Grasslands are among the most threatened ecosystems but are often overlooked in conservation efforts. Policies favor forestry-based interventions, converting natural grasslands into plantations. Protected grasslands cover less than 5% of India's total area, shrinking from 18 to 12 million hectares between 2005 and 2015.

Success Stories

- **Legal Empowerment:** The Forest Rights Act (2006) has empowered pastoralists. For instance, Van Gujjars gained grazing rights and land titles in Rajaji National Park through a court ruling.
- **Policy Advances:** There is increasing recognition of the socio-ecological importance of rangelands and pastoralism. Programs like the National Livestock Mission, Animal Husbandry Infrastructure Development Fund, and Rashtriya Gokul Mission promote sustainable pastoral practices and community welfare.

DROUGHT

- As defined by the IMD, drought is a consequence of the natural reduction in the amount of precipitation for a long period of time. It is associated with other climatic factors like high winds & temperatures & low relative humidity. These factors can aggravate the severity of the drought event.
- **Drought year:** a year in which the overall rainfall deficiency is more than 10% of the Long Period Average value (LPA) value + >20% of its area is affected by drought conditions, either moderate or severe or combined moderate & severe.
  - **LPA:** It is the rainfall recorded over a particular region for a given interval (like a month or season) averaged over a long period of time, like 30 years or 50 years.
- **All India Severe Drought Year:** When the spatial coverage of drought is >40%.

Types of Droughts

Type	Description	Key Impact
Meteorological Drought	Prolonged period of insufficient and unevenly distributed rainfall over time and space.	Leads to reduced precipitation and potential long-term water shortages.
Agricultural Drought	Prolonged absence of rainfall resulting in low soil moisture, insufficient for crop growth.	Causes crop failures; areas with more than 30% of irrigated gross cropped land are less affected.
Hydrological Drought	Decline in water levels in reservoirs, lakes, and aquifers, falling below replenishment levels.	Results in reduced water supply for domestic, agricultural, and industrial needs.

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Ecological Drought	Water shortages leading to reduced productivity in natural ecosystems.	Causes ecological distress, damaging ecosystems and biodiversity.

Drought-Prone Areas in India: Severity and Distribution

- **As per UNCCD,** 36.8% of land in India is drought prone and about 83.85% of the population is exposed to drought.

Severity-Based Regional Classification

Category	Affected Regions
Extreme Drought Zones	Western Rajasthan (Marusthali), areas west of the Aravali Hills, and Gujarat's Kachchh region.
Severe Drought Zones	Eastern Rajasthan, Madhya Pradesh, eastern Maharashtra, Andhra Pradesh (interior), Karnataka Plateau, interior Tamil Nadu, southern Jharkhand, and interior Odisha.
Moderate Drought Zones	Northern Rajasthan, Haryana, southern Uttar Pradesh, parts of Gujarat (excluding Konkan), Maharashtra, Jharkhand, Coimbatore Plateau (Tamil Nadu), and interior Karnataka.

- More than 85% of districts in the 'Very High' or 'High' drought risk category are located in Bihar, Assam, Jharkhand, Odisha, Uttar Pradesh, Maharashtra, West Bengal, Karnataka, Tamil Nadu, Chhattisgarh, Kerala, Uttarakhand, and Haryana.

Consequences of Drought

- **Agricultural Impact:** Crop failures causing food (akal) and fodder (trinkal) shortages.
- **Livestock Loss:** High mortality rates among cattle and other animals.
- **Migration:** Movement of people and livestock due to prolonged drought.
- **Health Risks:** Water scarcity leads to consumption of contaminated water, causing diseases such as gastroenteritis, cholera, and hepatitis.

Causes of Recurrent Droughts in India

India's recurrent droughts are primarily due to its unique physical and climatic vulnerabilities:

- **Low Rainfall:**
  - About 33% of cropped areas receive an annual average rainfall of only 75 cm.
  - Agriculture in these regions heavily depends on rainfall due to limited irrigation coverage.
- **Rainfall Variability:**
  - Significant variations in annual, seasonal, and regional rainfall patterns exist despite a high national average.
  - Approximately 73% of the annual rainfall occurs within a short period (less than 100 days) during the Southwest Monsoon.
- **Uneven Distribution:**
  - Rainfall is unevenly distributed across different regions.
  - Excess rainfall often leads to runoff instead of contributing to drought resilience through storage.
- **Water Resource Challenges:**
  - Over-exploitation of groundwater and insufficient conservation of surface water reduce irrigation potential.
  - Per capita water availability for humans and animals is steadily decreasing, even during non-drought years.
- **Pressure on Resources:** Migration of cattle and livestock from drought-affected areas strains resources in neighboring regions.

International Efforts for Drought Management

- The **United Nations Development Programme (UNDP)** launched the **Integrated Drylands Development Programme (IDDP)**, which aims to strengthen resilience by working on the twin vulnerabilities of Poverty & Unsustainable land management in the drylands.
- The **United Nations Office for Disaster Risk Reduction (UNDDR)** developed a **Drought Risk Reduction framework** that provides a comprehensive framework for both higher-level & local action.
- **2013: The World Meteorological Organization (WMO) and the Global Water Partnership (GWP)** launched the **Integrated Drought Management Programme (IDMP)** to address drought issues. The IDMP & its partners have adopted 3 pillars of drought management.

Drought Management in India

- There is **no single, legally accepted definition of drought in India**. Some states resort to their own definitions of drought.
- **Drought as Disaster:** Defined under Section 2(d) of the Disaster Management (DM) Act, 2005 – SC in **Swaraj Abhiyan Vs Union of India** in 2016.
- **National Disaster Management Authority (NDMA)** to be the agency responsible for drought management, particularly with respect to chalking out long term preventive & mitigation measures. However, **the state government concerned would be the final authority to declare a drought**.
- Droughts can also be **declared for a particular village in a district or a taluka or tehsil or block**.

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Flash Drought

Definition: Flash droughts are characterized by rapid intensification, posing significant risks to agriculture, ecosystems, and water availability. Unlike conventional droughts, which develop over months or years, flash droughts escalate quickly due to extreme weather conditions and typically last from a few weeks to several months.

Characteristics

- Can be localized or widespread.
- Develop at an unusually fast rate.
- Depletion of soil moisture in the topsoil layer, which can extend deeper, impacting crop root zones and vegetation.

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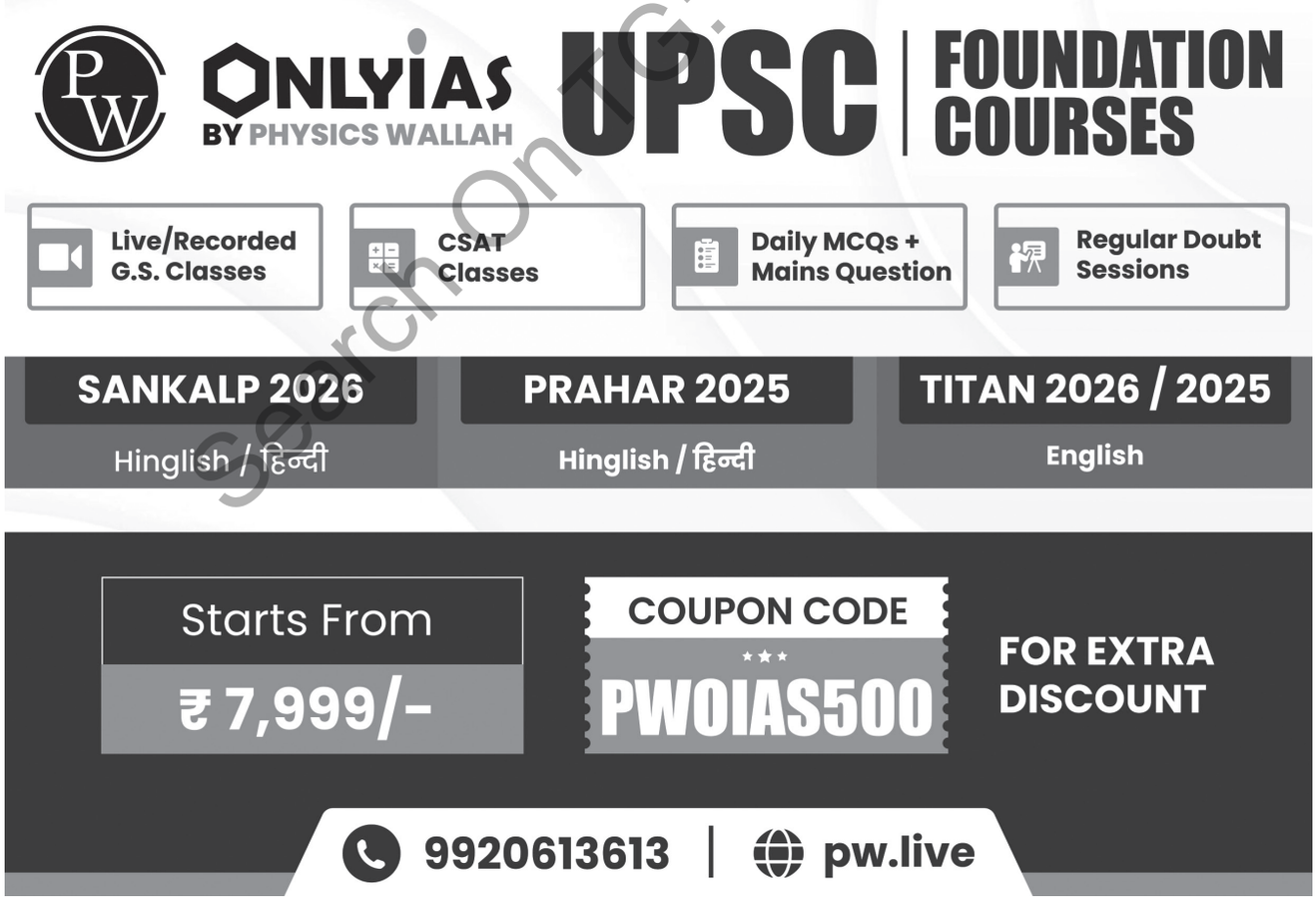

6 Climate Change And Related International Environmental Conventions

CLIMATE CHANGE

Long-term shifts in temperatures and weather patterns attributed to human activity altering the composition of the atmosphere.

Global Warming

It refers to the long-term rise in global temperatures, which is a part of climate change caused by the greenhouse effect. Rising temperatures due to global warming trigger a cascade of other effects, including rising sea levels, melting glaciers, loss of polar ice caps (cryosphere), ocean acidification etc.

Knowing Climate Change

- **Tree Rings as Climate Records:** The width and colour of these rings provide insights into past climate conditions, with wider rings indicating wetter periods and thinner rings indicating drier years.
- **Rock layers:** Sedimentary rocks record changes in temperature, rainfall, and ocean currents through their composition and fossil content.
- **Pollen records:** Pollen grains from different plant species are preserved in soils and lake sediments.
- **Ice cores:** Deep ice cores drilled from polar regions trap bubbles of air and layers of snow from thousands of years ago
- Further **Coral Reefs, Cave speleothems, lake sediment** also help in knowing past climate change events.

CAUSES OF CLIMATE CHANGE

The primary mechanism behind rising global temperatures and resultant climate change is the greenhouse effect caused by greenhouse gas emissions.

Greenhouse Effect

- The **greenhouse effect** is the natural process by which certain gases in Earth's atmosphere, such as carbon dioxide (CO_2), methane (CH_4), and water vapor, trap heat from the Sun, allowing sunlight to enter the atmosphere but prevent some of the heat from escaping back into space, keeping the planet warm enough to support life.
- **Importance**: Natural Greenhouse effect sustains life by maintaining average global temperatures around 15°C. Without it, temperatures might plummet to -17°C, rendering life unsustainable. However, excessive greenhouse gas emissions from human activities intensify this effect, leading to global warming and climate change.

Main causes of climate change

- **Greenhouse Gas Emissions**: Excessive release of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from burning fossil fuels, deforestation, agriculture, and industrial processes.
- **Deforestation**: Clearing forests reduces carbon sequestration, increasing atmospheric CO_2 levels.
- **Industrial Activities**: Factories emit greenhouse gases and pollutants, contributing to global warming.
- **Agriculture**: Livestock farming releases methane, and fertilizer use emits nitrous oxide.
- **Urbanization**: Increased energy use and waste generation amplify emissions.
- **Land Use Changes**: Converting natural habitats into agricultural or urban areas disrupts ecosystems and carbon cycles.
- **Aerosols**: Emitted by industries and vehicles, they affect atmospheric temperature and weather patterns.

IMPORTANT GREENHOUSE GASES

Greenhouse Gas	Key Features	Additional Information
Carbon Dioxide (CO_2)	• Transparent to incoming solar radiation but traps outgoing terrestrial radiation. • Highest contributor to the greenhouse effect.	• Total Earth carbon: 1.85 billion gigatons. • Human emissions: 40–100 times more than volcanic emissions. • Carbon Reservoirs Below the Surface: 97.73% of total carbon. Above the Surface: 2.27% (Breakdown: Deep Ocean: 85.1%; Marine Sediments: 6.9%; Terrestrial Biosphere: 4.6%; Surface Ocean: 2%; Atmosphere: 1.4%).

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Methane (CH_4)	• Second most significant greenhouse gas after CO_2, responsible for at least 30% of global warming. • Odourless, colourless, and lighter than air; burns with a blue flame.	• The Global Methane Budget estimates that annual global methane emissions are around 580 Mt, with 60% from human activity and 40% from natural sources • The largest sources of methane from human activities are: ○ Agriculture, including livestock, stubble burning, and rice paddies; fossil fuels, including oil and natural gas systems, coal mining, and the production and transportation of coal, natural gas, and oil; decomposition of landfill waste; Wastewater treatment,etc • Wetlands are the largest natural source of methane
Ozone (O_3)	• Found primarily in the stratosphere,where it absorbs harmful UV radiation. • Ground-level ozone is a secondary pollutant formed from precursor gases reacting with sunlight and oxygen.	• Formed from Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Volatile Organic Compounds (VOCs). • Crop/biomass burning releases CO, O_3, Methane (CH_4), and Sulphur Dioxide (SO_2). **UPSC [2019]** • Tropospheric ozone absorbs long wave terrestrial radiation, thus raising the earth's temperature.
Water Vapour	• Variable concentration (0.02%–4%) based on climate. • Decreases with altitude, with 90% of moisture within 6 km of Earth's surface. **UPSC[2024]** • Concentration diminishes from the equator to the poles. **[UPSC 2011-12]**	• The insulating effect is weaker than CO_2. • Contributes to atmospheric insulation by absorbing infrared radiation.
Nitrous Oxide (N_2O)	• NO and NO_2 act as global cooling gases, while N_2O is greenhouse gas. • N_2O is a potent greenhouse gas that traps heat in the atmosphere more than carbon dioxide	• Emissions increased by 30% (1980–2016), with 43% attributed to human activities. • Primarily released from agriculture,especially nitrogen-based fertilizers and burning of agriculture residues; industry; fuel combustion; etc.
Black Carbon (Soot)	• Strong absorber of sunlight, reduces Earth's albedo, and contributes significantly to warming after CO_2. • Short-lived, remaining in the atmosphere for only days to weeks.	• Black carbon is the sooty black material emitted from gas and diesel engines, coal-fired power plants, and other sources that burn fossil fuel. • It results from incomplete combustion of fossil fuels.
Carbon Monoxide (CO)	• Short-lived and indirect greenhouse gas. • Oxidizes into CO_2, indirectly increasing methane and tropospheric ozone concentrations.	• Carbon monoxide forms whenever carbon-based fuels including coal, oil, natural gas and wood are burned. • Carbon monoxide reacts with hydroxyl (OH) radicals in the atmosphere, reducing their abundance. As OH radicals help to reduce the lifetimes of strong greenhouse gases, like methane, carbon monoxide indirectly increases the global warming potential of these gases. • Carbon monoxide in the atmosphere can also lead to the formation of the tropospheric greenhouse gas ozone

Fluorinated Gases

Although primarily responsible for ozone depletion, they are also potent greenhouse gases.

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Compound	Characteristics
CFCs (Chlorofluorocarbons)	Used in refrigeration, solvents, aerosols, plastic foams, cleaning certain electronic components and industrial applications. **UPSC [2012]** Phased out due to ozone depletion. **Potent GHGs with higher greenhouse effect potential than CO_2.**
HFCs (Hydrofluorocarbons)	Used in refrigeration, aerosols, foam agents, fire retardants solvents, etc. as CFC replacements. **Potent GHGs** with long atmospheric lifetimes**.** **[UPSC 2023]** Hydrofluorocarbons (HFCs) GWPs range from 140 to 11,700, lifetimes vary between 1 to 270 years.
PFCs (Perfluorocarbons)	• Composed of carbon and fluorine. Emitted during aluminium production, semiconductor manufacturing. • **Perfluorocarbons (PFCs) GWPs between 6,500 to 9,200, lifetimes span from 800 to 50,000 years.**
SF_6(Sulphur Hexafluoride)	• Used in **magnesium processing,** semiconductor manufacturing, and as a **tracer gas**. • Sulphur hexafluoride (SF_6) GWP of 23,900, lasts around 3,200 years in the atmosphere.

Short-Lived Climate Pollutants (SLCPs)

They are atmospheric pollutants with a relatively short lifespan but a significant impact on climate change and air quality. Key SLCPs include **methane (CH_4)**, **black carbon (soot)**, **tropospheric ozone (O_3)**, and **hydrofluorocarbons (HFCs)**.

Global Warming Potential & Lifetime of GHGs

Global Warming Potential (GWP) measures heat absorbed by a greenhouse gas (GHG) compared to the same mass of CO_2 over a specific time (usually 100 years).

Table: Global Warming Potential of Major Gases

Common name (chemical formula)	Lifetime (years)	GWP			GTP		
		20-year	100-year	500-year	20-year	100-year	500-year
Carbon dioxide (CO_2)	150†	1	1	1	1	1	1
Methane (CH_4)	12	72	25	76	57	12	4
Nitrous oxide (N_2O)	114	289	298	153	303	322	265
Sulphur hexafluoride (SF_6)	3200	16,300	22,800	32,600	17,500	23,400	28,000
Black carbon	0.020	1600	460	140	470	77	64

IMPORTANT TERMS

Carbon Footprint

Measure of CO_2 produced through the impact from burning fossil fuels, is expressed in tons.

Carbon Bombs

- Covers coal, oil, or fossil gas projects with potential to emit over a Gigaton of CO_2. **Leave It In the Ground Initiative (LINGO)** identified 425 carbon bombs worldwide. According to LINGO, potential emissions exceed a 1.5°C carbon budget by a factor of two.
  - Examples are **Carmichael Coal Project (Australia), Gevra Coal Mines (Chhattisgarh), Rajmahal Coal Mines (Jharkhand).**

Emission Intensity

Emission intensity is a measure of the amount of greenhouse gases (GHGs) released per unit of activity or output.

Climate Sensitivity

- It refers to the measure of how much the Earth's global average temperature will increase in response to a doubling of atmospheric carbon dioxide (CO_2) concentrations compared to pre-industrial levels. The value typically ranges between **1.5°C to 4.5°C**, depending on various factors and feedback mechanisms
- Pre-industrial CO_2 was about 260 ppm, with a doubling expected around 520 ppm in the next 50-100 years.

Feedback Mechanisms

These are processes that either amplify (positive feedback) or diminish (negative feedback) the effects of climate change.

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- **Positive Feedback:**
  - **Ice-Albedo Effect:** Melting ice reduces surface reflectivity (albedo), leading to more heat absorption and further warming.
  - **Water Vapor Feedback:** Warmer temperatures increase water vapor (a greenhouse gas), amplifying the greenhouse effect.
  - **Permafrost Melting**: Releases methane and CO_2, enhancing global warming.
- **Negative Feedback**:
  - **Cloud Formation**: Increased evaporation can form more clouds, reflecting sunlight and cooling the surface.
  - **Plant Growth**: Higher CO_2 levels can boost plant growth, which absorbs more carbon.

IMPACT OF GLOBAL WARMING LED CLIMATE CHANGE

Climate change leads to multifaceted issues such as melting ice caps, rising sea levels, and extreme weather events. These changes disrupt ecosystems, threaten biodiversity, and pose severe risks to human health, food security, and economic stability.

Shrinking Cryosphere

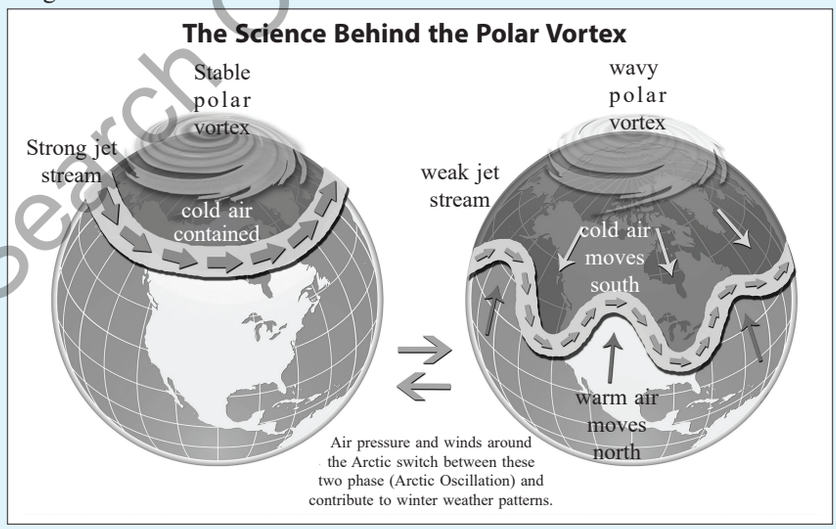
- Cryosphere comprises areas of snow or ice, including continental ice sheets, glaciers, permafrost, and frozen parts of oceans, rivers, and lakes.
- **Role of Cryosphere:** Reflects heat through high albedo, supplies freshwater to many parts of the world and is sensitive to climate shifts, acting as the Earth's "black box" for understanding past global climate changes.
- **Consequences of Shrinking Cryosphere**
  - **Vegetation Change:** Thawing of snow may increase arable land in high-latitude regions but reduce it along coastlines due to rising sea levels.
  - **Surge-Type Glaciers:** Surge-type glaciers can lead to catastrophic glacial lake outburst floods when they break due to global warming.
  - **New Sea Routes in the Arctic:** The Arctic is warming twice as fast as the global average, opening new sea routes, creating opportunities in shipping, energy, fisheries, and mineral resources.

Permafrost

- Permafrost is any ground that remains completely frozen—32°F (0°C) or colder—for at least two years straight.
- Permafrost is made of a combination of soil, rocks and sand that are held together by ice.

Arctic Oscillation

- The Arctic Oscillation (AO) is a phenomenon that describes how surface air pressure patterns relate to each other in the mid- to high-latitudes. This relationship influences the jet stream, which is a band of strong winds in the upper atmosphere that generally separates warm and cold air. Consequently, these strong winds influence weather in the midlatitudes, including the Great Lakes.



Arctic Oscillation

- The AO has two phases – positive and negative. It is typically measured via the AO index, which numerically describes the strength of the AO. During the positive phase of the AO, the jet stream is typically faster and located farther north, keeping cold polar air confined to the Arctic, and resulting in warmer, drier winter weather.

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- During the negative phase, the jet stream is weaker and wavier, leading to colder air being able to extend southward into the Great Lakes region. The AO is naturally quite variable, and can fluctuate daily, monthly, seasonally, or annually. It is difficult to predict the behavior of the AO beyond a few days.
- The Arctic is warming faster than other parts of the globe. In recent decades, the Arctic has warmed nearly twice as much as the rest of the world.
- **Reasons:**
  - The loss of sea ice is one of the most cited reasons. When bright and reflective ice melts, it gives way to a darker ocean; this amplifies the warming trend because the ocean surface absorbs more heat from the Sun than the surface of snow and ice. In more technical terms, losing sea ice reduces Earth's albedo: The lower the albedo, the more a surface absorbs heat from sunlight rather than reflecting it back to space.

Consequences : Melting polar ice and its resultant impact on climate patterns and extreme events.

Sea Level Rise (SLR)

- Sea level rise refers to the increase in the average height of the world's oceans due to global warming. It occurs primarily due to two factors: thermal expansion and melting of ice.
- The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) finds that global mean sea levels will most likely rise between 0.95 feet (0.29m) and 3.61 feet (1.1m) by the end of this century.
- The IPCC estimates that the rate of sea level rise is 3-6 times faster than over the last 100 years

More Severe Tropical Cyclones

- **Increasing Sea Surface Temperatures (SST)**
  - The South Indian Ocean is experiencing higher temperatures (30-32°C) compared to the previous norm of 26.5°C, contributing to more intense cyclones.
- **Global Forcing Mechanisms**
  - Regions farther from the equator are experiencing higher temperatures (24-26°C), expanding the potential range for cyclone formation.

Deterioration of Carbon Sinks

- **High Latitude Forests:** The **taiga and tundra regions store more carbon than tropical rainforests.** Global warming is causing the permafrost in these areas to melt, releasing stored carbon as carbon dioxide and methane.

Carbon Dioxide Fertilization

Stimulation of plant growth resulting from increased levels of atmospheric carbon dioxide. Higher levels of CO_2 can enhance this process, leading to increased plant growth in some cases. **[UPSC 2018]**

Ocean Deoxygenation

- Refers to the expansion of oxygen minimum zones (OMZs) in the world's oceans due to human-induced carbon dioxide emissions.
- **OMZs:** These zones are characterized by low oxygen concentrations **caused by** warmer oceans, which reduce oxygen solubility in water and contribute to temperature-driven stratification.
- **Effects of Ocean Deoxygenation: Element Cycling (**Reduction in the cycling of essential elements such as carbon, nitrogen, and phosphorus etc), biodiversity loss, changes in fishes habitats and livelihoods in coastal areas.

Ocean Acidification

- Ocean acidification refers to the ongoing decrease in the pH of the Earth's oceans caused by the absorption of excess atmospheric carbon dioxide (CO_2). Since the late 1980s, 95 percent of open ocean surface water has become more acidic. Oceans absorb about 30 per cent of carbon dioxide (CO_2) we produce, reducing the pH of seawater.
- When CO_2 dissolves in seawater, **it reacts to form carbonic acid,** which lowers the pH.
- **Today, the ocean's average pH is 8.1. This means that the ocean today is about 30 per cent more acidic than in pre-industrial times. By 2100, the pH of the ocean could decrease to about 7.8, making the ocean 150 percent more acidic** and affecting half of all marine life, according to the **Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report.**

Coral Bleaching or Coral Reef Bleaching

- **Coral bleaching** occurs when corals expel the symbiotic algae (**zooxanthellae**) living in their tissues, causing them to lose their color and appear white and is primarily caused by environmental stress, particularly rising sea temperatures due to global warming.

Causes for Coral Bleaching

- **Temperature Changes, Ocean Acidification, Increases Inorganic Nutrients** are the major causes.
- **Subaerial Exposure:** Exposure to the atmosphere during low tides or sea level drops induces bleaching.
- **Xenobiotics:** Exposure to high concentrations of contaminants like copper, herbicides, and oil can cause bleaching.

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- **Epizootics:** Coral diseases, although not directly related to bleaching, may cause adverse effects on coral health.

Biorock Technology for Coral Restoration [UPSC 2023]

- Biorock technology, involving mineral accretion or electro-accumulation on steel structures, is used for coral restoration.
- Passing electrical current through electrodes in the water results in the formation of biorock, aiding coral growth.

Other Technologies for Coral Restoration

- **Coral Gardening**:
  - Fragments of coral are grown in underwater nurseries or artificial structures until they are large enough to be transplanted back to reefs.
- **Microfragmentation**:
  - Breaks coral into small pieces to speed up growth rates. Useful for slow-growing coral species like brain corals.
- **3D-Printed Reefs**:
  - Artificial reefs made from eco-friendly materials (e.g., limestone, sandstone) are 3D-printed to mimic natural reef structures.
- **Cryopreservation**:
  - Freezing coral gametes, larvae, or polyps at ultra-low temperatures for future use in restoration projects.
- **Larval Propagation**:
  - Captures coral spawn during natural spawning events, raises larvae in controlled environments, and releases them onto damaged reefs.
- **Algae Manipulation:**
  - Coral relies on symbiotic algae (zooxanthellae) for energy. Introducing stress-tolerant algae strains can improve coral survival under adverse conditions.
- **Coral Adhesive Technology:** Development of underwater glues and bio-adhesives to securely attach coral fragments to substrates.
- **Sunshields and Cooling Devices**: Technologies to reduce ocean surface temperature or block excess sunlight to prevent coral bleaching.

Aspect	Mitigation	Adaptation
Definition	Actions aimed at reducing or preventing greenhouse gas emissions to slow down climate change.	Actions taken to adjust to the impacts of climate change to reduce harm and increase resilience.
Examples	Transition to renewable energy sources. Energy efficiency improvements. Afforestation and reforestation.	Building resilient infrastructure. Developing drought-resistant crops. Early warning systems for disasters.

Climate Change Mitigation

Clean Coal Technology

It refers to a collection of advanced technologies and processes designed to enhance the efficiency of coal usage while reducing its environmental impact.

- **Coal Preparation (Coal Washing):** Removes unwanted minerals by mixing crushed coal with a liquid, allowing impurities to separate and settle.
  - Unlike majority of American coal, Indian coal has low-sulphur coals. Studies show that the sulphur content in Indian coal is hardly 0.7%, which is not uniformly distributed in the coal but concentrated in the pyritic bands which are visible to the naked eye. The best solution to get rid of sulphur from Indian coal is to wash it.
- **Electrostatic Precipitators, Coal Gasification,Wet Scrubbers.**
- **Low-NOx Burners:** Reduce nitrogen oxides creation by restricting oxygen and manipulating the combustion process.
- **Replace India's Coal**
  - India's coal is poor-quality Gondwana coal with less carbon, high ash, and high moisture content.
  - The suggestion is to replace sub-critical coal power plants with super-critical and ultra-super-critical ones for increased efficiency.

Carbon Dioxide Removal (CDR) Techniques

CDR techniques aim to remove CO_2 from the atmosphere and store it securely to mitigate climate change. These can be categorized into nature-based and technology-based approaches.

Category	Technique	Description
Nature-Based	Afforestation/Reforestation	Planting trees to absorb CO_2 through photosynthesis and store it in biomass.
	Soil Carbon Sequestration	Enhancing soil's ability to store carbon through sustainable agriculture and organic matter addition.
	Blue Carbon Ecosystems	Protecting/restoring coastal ecosystems (e.g., mangroves, seagrasses) to capture CO_2 in vegetation and sediments.
	Biochar	Burning biomass in low-oxygen environments to produce a carbon-rich material that can enrich soil.

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Technology Based	Direct Air Capture (DAC)	Using chemical processes to capture CO_2 directly from the air, which is then stored or utilized.
	Carbon Capture and Storage (CCS)	Capturing CO_2 emissions from industrial processes or power plants and storing it underground. Storage options include geological (injecting CO_2 into the earth) and oceanic methods.
	Bioenergy with CCS (BECCS)	Burning biomass for energy, capturing the emitted CO_2, and storing it underground.
	Ocean Fertilization	Adding nutrients (e.g., iron) to oceans to stimulate phytoplankton growth, which absorbs CO_2.
Hybrid Approaches	Enhanced Weathering	Spreading crushed silicate rocks on land or ocean surfaces to accelerate natural CO_2 absorption.
	Marine Algae Cultivation	Growing algae in oceans to absorb CO_2 and potentially store carbon in deep sea ecosystems.
Others	Mineral Carbonation	Reacting CO_2 with minerals to form stable carbonates for long-term storage.
	Carbon capture and Utilization	Converting captured CO_2 into products like fuels, chemicals, or building materials.

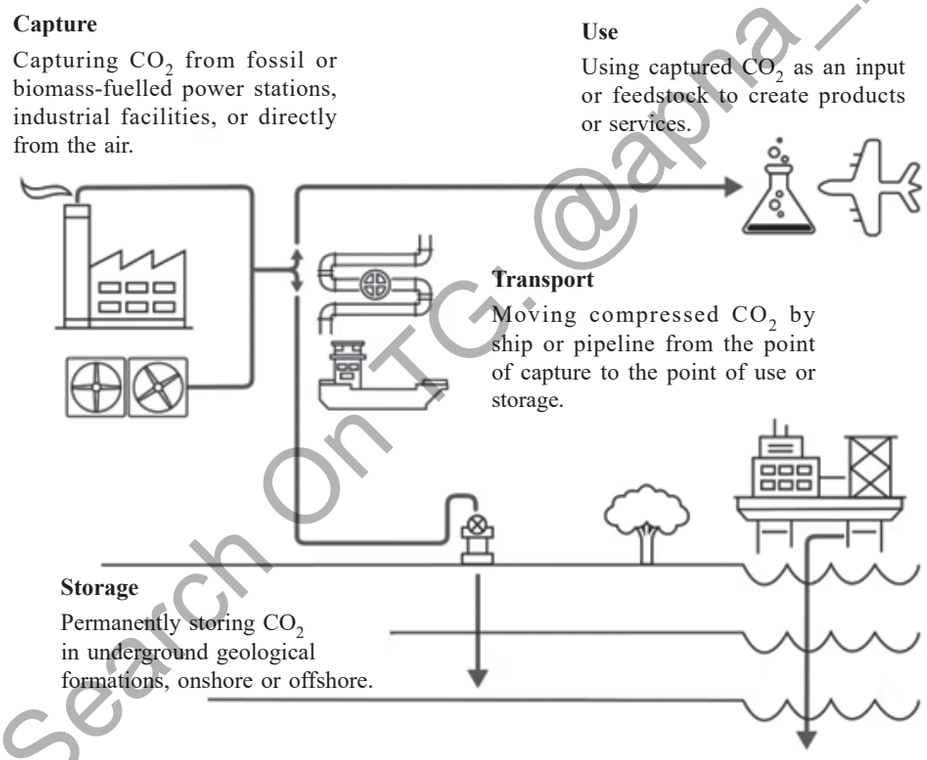

Fig: Carbon Dioxide Removal Techniques

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Geoengineering

- Deliberate large-scale interventions in Earth's natural systems to counteract climate change.
- Solar Radiation Management (SRM) techniques aim to reflect sunlight away, while GHG Removal (GGR) involves directly removing CO_2 or other GHGs.

Transition Away from Coal

- IPCC recommends a significant reduction in coal-powered electricity to limit global warming.
- Some countries, like the UK, France, Italy, and Germany, have committed to phasing out coal-fired electricity.
- **Barriers to Phasing Out Coal Power:** Economic and political barriers, including stranded assets, livelihood impacts, electricity prices, and irresponsible financing.

Climate-Smart Cities

- Integrated approaches to manage landscapes and ecosystems to address sustainable development and climate change.
- Measures include cool pavements, green roofs, decentralization, and improving ventilation.
- **Cooling Singapore Case Study:** Initiative to reduce the urban heat island effect in Singapore, including green roofs, vertical greenery, and district cooling.
- **Climate-Smart Cities Assessment Framework (CSCAF):** A framework to guide cities in combating climate change, covering energy, urban planning, mobility, water, and waste management.
- **Green Rating for Integrated Habitat Assessment (GRIHA):** National rating tool assessing the environmental performance of buildings.
- **Transition to Green Economy:** Priorities include decarbonizing the economy, ensuring justice and equity, and conserving the biosphere.
- **Green Contracts:** Commercial contracts mandating GHG emission reductions during the delivery of goods/ services.

INTERNATIONAL ENVIRONMENTAL CONVENTIONS, ORGANIZATIONS AND LAWS

United Nations Conference on the Human Environment (1972)

- Held in 1972 at **Stockholm, Sweden,** it played a role in the emergence of international environmental law.
- The conference led to the adoption of the Stockholm Declaration and the Action Plan for the Human Environment.
- The Stockholm Declaration is also known as The Declaration on the Human Environment.

UN Environment Programme (UNEP)

- **Role:** UNEP is a UN agency that coordinates environmental activities, assists developing countries in implementing environmentally sound policies, and has overall responsibility for environmental issues within the UN system formed as an outcome of the Stockholm conference.
- **Agencies Established/Implemented by UNEP**
  - Intergovernmental Panel on Climate Change **(IPCC) in 1988** (with the World Meteorological Organization).
  - **Implementing** agencies for the **Global Environment Facility (GEF)** and the Multilateral Fund for the Montreal Protocol.
  - **Member of the United Nations Sustainable Development Group (UNSDG)** to help achieve the 17 Sustainable Development Goals (SDGs).
  - Hosts the **secretariats** of various environmental agreements/research bodies, including **CBD, CMS, and CITES.**
  - Involved in successful agreements like the Montreal Protocol (1987) and the Minamata Convention (2012).
  - **Faith for Earth Initiative (FEI):** Launched: In **2017** by UNEP, to strategically engage with faith-based organizations to collectively achieve the SDGs, creating a global "Coalition for Creation" for policy dialogue on environmental issues.

UNCED/Earth Summit, Rio De Janeiro(1992)

- The conference played a crucial role in raising public awareness about the integration of environment and development.
- **Landmark Agreements:** Climate Change Convention (UNFCCC): Initiated at the Earth Summit, this led to subsequent agreements like the Kyoto Protocol and the Paris Agreement.
- **Legally Binding Agreements**
  - Convention on Biological Diversity (CBD)
  - United Nations Convention to Combat Desertification (UNCCD)
  - United Nations Framework Convention on Climate Change (UNFCCC)
- **Other initiatives**
  - **Agenda 21:** Non-binding action plan for global sustainable development. **[UPSC 2016]**
  - **Forest Principles:** Non-legally binding document on the Conservation and Sustainable Development of all types of forests.

World Summit on Sustainable Development (Rio+10, 2002)

- Held in **Johannesburg, South Africa.**
- Addressed issues such as toxic components in production, alternative energy sources, public transportation, pollution-related health problems, and water usage.
- Affirmed the UN commitment to Agenda 21 alongside the Millennium Development Goals (MDGs).

Rio+20 (2012) or Earth Summit 2012: [UPSC 2015]

- A 20-year follow-up to the Earth Summit 1992 and a 10-year follow-up to the Earth Summit 2002.
- Sustainable Development Goals **(SDGs) were born at Rio+20, later included in the Agenda 2030.**

Partnership for Action on Green Economy (PAGE):

- Launched in 2013 as a response to the Rio+20 Declaration, "The Future We Want." **[UPSC 2018]**
- Aims to assist countries in achieving SDG 8, promoting sustained, inclusive, and sustainable economic growth with full and productive employment.

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High-level Political Forum on Sustainable Development (HLPF)

- **Role:** A forum under the UN Economic and Social Council (**ECOSOC**) responsible for overseeing the outcomes of the 1992 Earth Summit.
- **Meetings:** Convenes every four years under the General Assembly and in other years under ECOSOC.
- **Responsibilities:** Oversees the implementation progress of various outcomes, including Agenda 21, Johannesburg Declaration (Rio+10), Rio+20, Barbados Programme of Action (Sustainable Development of SIDS), and LDC-IV (4th United Nations Conference on the Least Developed Countries).

TIMELINE OF IMPORTANT EVENTS

Year	Event	Key Highlights
1979	**First World Climate Conference (WCC)**	First global discussion on climate change.
1988	**Establishment of IPCC**	The Intergovernmental Panel on Climate Change (IPCC) was formed to assess climate science.
1990	**IPCC and WCC call for climate treaty**	The IPCC and Second WCC urged negotiations for a global climate treaty; the UN General Assembly initiated these discussions.
1992	**UNFCCC Text Adoption**	The text of the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in New York.
1994	**UNFCCC Enters Into Force**	The treaty became legally binding for signatories.
1995	**COP 1 (Berlin, Germany)**	First Conference of the Parties (COP) under the UNFCCC.
1996	**UNFCCC Secretariat Relocates**	Moved from Geneva to Bonn, Germany, establishing Bonn as an international sustainability hub.
1997	**COP 3 (Kyoto, Japan)**	Adoption of the Kyoto Protocol, legally binding developed countries to emission reduction targets.
1978	**Buenos Aires Plan of Action**	Defined strategies for implementing the Kyoto Protocol.
2001	**COP 6-2 (Bonn, Germany)**	Governments achieved a major breakthrough by agreeing on operational rules for the Kyoto Protocol.
2001	**COP 7 (Marrakesh, Morocco)**	Adoption of the Marrakesh Accords, finalizing rules for mechanisms like International Emissions Trading, Clean Development Mechanism (CDM), and Joint Implementation (JI).
2002	**COP 8 (New Delhi, India)**	The Delhi Declaration emphasized development needs of the poorest countries and technology transfer for climate change mitigation.
2005	**Kyoto Protocol Enters Into Force**	Became binding with Russian Federation ratification.
2005	**COP 11/CMP 1 (Montreal, Canada)**	First Meeting of the Parties (MOP) to the Kyoto Protocol.
2006	**Clean Development Mechanism (CDM) Launch**	Opened for emissions reduction projects to generate Certified Emission Reduction (CER) units for trading.
2007	**COP 13 (Bali, Indonesia)**	Adoption of the Bali Road Map, outlining post-2012 climate action plans focused on mitigation, adaptation, technology, and financing.
2008	**COP 14 (Poznan, Poland)**	Launch of the Adaptation Fund under the Kyoto Protocol and the Poznan Strategic Programme on Technology Transfer.
2009	**COP 15 (Copenhagen, Denmark)**	Drafting of the Copenhagen Accord, with developed countries pledging USD 30 billion in fast-start finance (2010–2012).
2010	**COP 16 (Cancun, Mexico)**	Adoption of the Cancun Agreements, establishing the Green Climate Fund, Technology Mechanism, and Cancun daptation Framework.
2011	**COP 17 (Durban, South Africa)**	Governments agreed on a new climate agreement beyond 2020, leading to the Paris Agreement.
2012	**COP 18/CMP 8 (Doha, Qatar)**	Adoption of the Doha Amendment, launching the second Kyoto Protocol commitment period (2013–2020).

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2013	**COP 19/CMP 9 (Warsaw, Poland)**	Establishment of the Warsaw Framework for REDD+ and the Warsaw International Mechanism for Loss and Damage.
2015	**COP 21 (Paris, France)**	Discussed below.
2016	**COP 22 (Marrakech, Morocco)**	Advanced the Paris Agreement rulebook and launched the Marrakech Partnership for Climate Action.
2017	**COP 23 (Bonn, Germany)**	Negotiated details of the Paris Agreement's operationalization. Hosted by Fiji, marking the first COP led by a small-island developing state.
2018	**COP 24 (Katowice, Poland)**	Finalized the Paris Agreement rulebook, covering NDCs and climate financing.
2019	**COP 25 (Madrid, Spain)**	Discussions yielded no concrete plans for addressing climate urgency.
2021	**COP 26 (Glasgow, UK)**	Discussed below
2022	**COP 27 (Sharm El Sheikh, Egypt)**	Discussed below
2023	**COP 28 (Dubai, United Arab Emirates (UAE)**	Discussed below
2024	**COP 29 (Baku, Azerbaijan)**	Discussed below

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

- **Establishment**
  - UNFCCC is an international environmental treaty established in 1992 at the Rio Earth Summit (UNCED).
  - Negotiated in New York City, signed in 1992, and as of February 2023, it has 198 parties.
- **Role and Objective**
  - The primary role of UNFCCC is to provide a framework for negotiating specific international treaties, known as "protocols."
  - UNFCCC itself sets no binding limits but aims to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level preventing dangerous consequences.
- **Legal Status:**
  - Considered legally non-binding, UNFCCC provides the foundation for legally binding protocols negotiated under its auspices.
- **Conferences of the Parties (COP)**
  - COP is the decision-making body of UNFCCC, representing all States that are Parties to the Convention.Annual meetings to review implementation and promote effective action.
- Parties to UNFCCC have been divided into 3 groups based on their commitments.

Group	Description	Countries Included	Commitment
Annex I Countries	Developed nations and economies in transition (EIT) with binding emission reduction targets.	Most European countries, Canada, Japan, Russia	Binding greenhouse gas emission reduction targets.
Annex II Countries	Annex I countries that are not EITs, required to provide financial resources to developing countries.	Developed Annex I countries (e.g., USA, UK, Germany)	Must provide financial resources for emission reduction and adaptation.
Non-Annex I Countries	Developing countries are not required to limit emissions under the Protocol.	China, India, countries in Africa and South America	No binding emission reduction commitments.

Kyoto Protocol (COP 3, 1997)

Aspect	Details
Kyoto Protocol Overview	Adopted on 11 December 1997, the Kyoto Protocol aimed to reduce carbon dioxide (CO_2) and greenhouse gas (GHG) emissions to mitigate climate change. Entered into force on 16 February 2005 with 192 signatories (as of 2022).
Target Gases	**Covered six GHGs:** CO_2, Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulfur Hexafluoride (SF6).

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Commitments	Focused on industrialized nations (Annex I countries), requiring them to cut emissions under the principle of "common but differentiated responsibilities".
First Commitment Period	**Annex B targets:** Reduce emissions by an average of 5% below 1990 levels during 2008–2012.
Market Mechanisms	Introduced flexible mechanisms for meeting emission targets: • **International Emissions Trading:** Sell unused emission allowances to other countries. • **Clean Development Mechanism (CDM):** Invest in emission-reducing projects in developing countries for credit. • **Joint Implementation (JI):** Collaborate on emission reduction projects between Annex I countries.
Monitoring and Compliance	Established systems for monitoring, reviewing, verifying emissions, and ensuring compliance. Developed nations' emissions were strictly tracked, while developing countries participated voluntarily.
Doha Amendment (2012)	• Adopted on 8 December 2012, introduced a second commitment period (2013–2020) with new targets: • Reduce GHG emissions by 18% below 1990 levels. • Updated GHG list and amended articles addressing the second commitment period.
Developing Nations	• Exempted from binding targets but could earn and trade carbon credits through emission-lowering projects (e.g., India, China). • **Carbon Credit:** **[UPSC 2011]** • The carbon credit system was ratified in conjunction with the Kyoto Protocol. • Carbon credits are awarded to countries or groups that have reduced greenhouse gases below their emission quota. • The goal of the carbon credit system is to limit the increase of carbon dioxide emission.

Flexible Market Mechanisms under Kyoto Protocol

Mechanism	Description
Joint Implementation	When an industrialized country invests in an emission reduction project in another industrialized country, the amount reduced counts toward the investor's emission total.
Clean Development Mechanism	When an industrialized country invests in an emission reduction project in a developing country, the amount reduced counts toward the investor's emission reduction total.
International Emission Trading	Industrialized countries may buy and sell emission credits.

Paris Agreement (COP 21)

- The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016.
- Aims to limit global warming to "well below 2°C" and pursue efforts for 1.5°C.
- Developed countries committed to mobilize **$100 billion** a year in climate finance by 2020.
- Countries set **voluntary GHG reduction targets (NDCs)** and update them every five years with more ambitious goals.
- To limit global warming to 1.5°C, greenhouse gas emissions must peak before 2025 at the latest and decline 43% by 2030.

India's NDC (Nationally Determined Contributions)

Target (for 2030)	Existing: First NDC (2015)	New: Updated NDC (2022)	Progress
Emission intensity reduction	33-35% from 2005 levels	45% from 2005 levels	33% reduction in emission intensity by 2019 from 2005 levels.
Share of non-fossil fuels in installed electricity capacity	40%	50%	45.4% achieved by the end of June 2024.
Carbon sink	Creation of 2.5 to 3 billion tonnes of additional sink through afforestation	Same as earlier	Carbon sink of 1.97 billion tonnes of CO2 equivalent has been created between 2005-2019

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Kyoto Protocol vs Paris Agreement

Aspect	Kyoto Protocol	Paris Agreement
Year Established	Created in 1997 and ratified in 2005. Had two periods from 1997-2020.	Signed in November of 2016. New commitments are due every 5 years.
Emission Goals	Original commitment to decrease overall emissions by 5% from 1990 levels.	Overall goal to limit global temperatures to 2 degrees Celsius above pre-industrial levels.
Scope of Responsibility	Only required developed nations to reduce emissions.	Asked all nations to reduce emissions.
Climate Finance	Provides for flexible market mechanisms like CDM, Carbon trading and Joint Implementation.	Article 6 of the Paris Agreement provides for countries to co-operate through market and non market mechanisms such as SDM (Sustainable Development Mechanisms)

COP 26 (Glasgow) Major Outcomes

- **Glasgow Climate Pact:** Affirms the Paris Agreement's temperature goals, urging countries to strengthen 2030 climate action plans by 2022. Calls for coal phase-down, subsidy elimination, and $100 billion annual funding till 2025.
- **Carbon Markets:** Allows unused carbon credits for meeting countries' first NDC targets until 2025.
- **Paris Rulebook:** Finalizes rules for Paris Agreement implementation, enabling emissions reduction target pledges and progress reporting.
- **Article 6:** Establishes conditions for bilateral markets and a central global market (SDM) to avoid double counting of emissions reductions.
- **Global Methane Pledge:** Over 100 countries commit to 30% methane emission reduction by 2030, India not a party to it.
- **Enhanced Climate Actions:** Nations pledge zero-emission cars, revised net-zero targets (e.g., Brazil, China), and a cooperative agenda (Glasgow Breakthrough Agenda).
- **Glasgow Finance Alliance for Net Zero (GFANZ):** Over 160 firms commit to net-zero emissions by 2050, aligning with UN Race to Zero criteria.
- **India's Commitments (Panchamrit):** 50% renewable energy, 1 billion tonne emission reduction by 2030, <45% emissions intensity, 500 GW renewables by 2030, net-zero by 2070. Calls for $1 trillion climate financing.
- **"Phase Down of Coal":** India advocates for "phase down" rather than "phase out" in the pact, aiming to boost new technology viability.
- **Leaders' Declaration on Forests:** Over 100 countries commit to halting deforestation by 2030; India abstains due to concerns about interlinking trade and climate issues.
- India, along with the UK, launched the **Green Grids Initiative-One Sun One World One Grid** (GGI-OSOWOG), aimed at promoting cross-border energy grids to enable global solar energy deployment.
- **Mission LiFE (Lifestyle for Environment):** PM Modi launches a global initiative promoting sustainable living, circular economy, and individual/environmental harmony.

COP27 Major Outcomes

- **Venue and Participants**
  - The 27th UNFCCC COP took place in November 2022 in Sharm El-Sheikh, Egypt.
  - It included the 4th meeting of the parties to the 2015 Paris Agreement (CMA4) and the 17th meeting of the parties to the Kyoto Protocol (CMP17).
- **Global Shield Against Climate Risks Initiative**
  - Launched at COP27, this initiative involves collaboration between the V20 Group (comprising 58 climate-vulnerable countries) and G7 countries.
  - Aims to provide pre-arranged financial support for swift deployment during climate disasters.
  - Initial beneficiaries include Pakistan, Bangladesh, Costa Rica, Fiji, Senegal, Philippines, and Ghana.
- **UNODC Paper on Illegal Wildlife Trade (IWT)**
  - Highlighting the overlooked impact of IWT on ecosystem services related to climate change.
  - Trees like Dalbergia (e.g., Indian Rosewood), essential for carbon sequestration, are globally trafficked.
  - Endangered species like African Forest Elephants, white rhinos, and pangolins, recognized as Ecosystem Engineers, are threatened by IWT.
- **Long-Term Low-Emission Development Strategy (LT-LEDS)**
  - India submitted its LT-LEDS during COP27, aligning with the 2015 Paris Agreement's requirements.
  - Focuses on rational resource utilization, low-carbon strategies, and building climate resilience.
  - Strategies include increased use of biofuels, three-fold nuclear capacity increase by 2032, and green hydrogen adoption for low-carbon development.
- **Loss and Damage Fund**
  - A decision to establish and operationalize the Loss and Damage fund was made at COP27.

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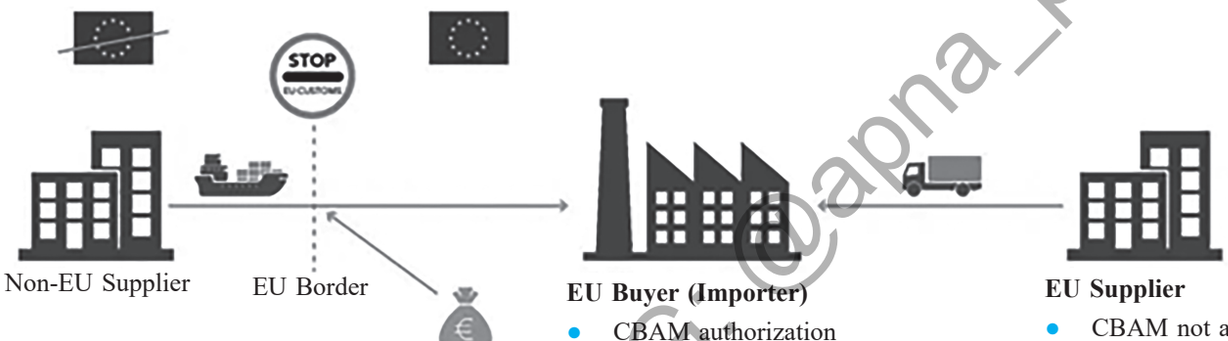
- Aims to assist vulnerable poor and developing countries impacted by climate change with reparations.

- **Methane Alert and Response System (MARS)**
  - It is a satellite-based monitoring system to track methane emissions globally.
  - Part of UNEP's International Methane Emissions Observatory (IMEO), it alerts governments and corporations.
  - Supports the implementation of the Global Methane Pledge initiated at COP26.
- **Mangrove Alliance for Climate**
  - It was launched at COP27 by UAE and Indonesia to promote the conservation, restoration, and sustainable management of mangrove ecosystems in the fight against climate change. Mangroves play a critical role in mitigating climate change by sequestering large amounts of carbon, protecting coastal areas from storm surges, and supporting biodiversity. It is voluntary in nature with members being the United Arab Emirates (UAE),Indonesia, India, Australia, Japan, Spain, Sri Lanka.
- **New Zealand's Agricultural Emissions Tax**
- **Carbon Border Tax**
  - The EU proposes a **carbon border tax** on imports based on their carbon emissions, starting from 2026.
  - The **BASIC group (India, China, Brazil, and South Africa) opposes the tax**, citing concerns about the principle of Common But Differentiated Responsibility (CBDR) from the Paris Agreement.

Cross Border Adjustment Mechanism (CBAM) Explained



* Including goods originating from Iceland, Liechtenstein, Norway, and Switzerland

COP 28 at Dubai (2023) Major Outcomes

Global Stocktake (GST)

- Periodic review mechanism under the Paris Agreement (2015).
- This first GST cycle synthesized data from countries, scientific reports, and stakeholders to highlight gaps in emissions reduction, adaptation efforts, and climate finance.
- Proposes **eight steps** to limit global temperature rise to **1.5°C**.
- **Calls for:**
  - **Tripling global renewable energy capacity** by 2030.
  - **Doubling energy efficiency improvements** annually by 2030.
  - Substantial reduction in **non-CO2 emissions**, including **methane**, by 2030.

Transition from Fossil Fuels

- Advocates a **just, orderly, and equitable energy transition**.
- Targets **net-zero emissions by 2050**, with accelerated action in the current decade.

Global Goal on Adaptation (GGA)

- Focuses on enhancing **adaptive capacity** and minimizing **vulnerability** for sustainable development.
- Calls for:
  - Doubling **adaptation finance**.
  - Setting 2030 targets for **water security**, **ecosystem restoration**, and **health**.

Loss and Damage Fund

- Operationalized to compensate nations impacted by climate change.
- Priority funding for **Least Developed Countries (LDCs)** and **Small Island Developing States (SIDS)**.
- Initially overseen by the **World Bank**.
- **Global Renewables and Energy Efficiency Pledge:** Commitments to:
  - **Triple global renewable energy capacity** to at least 11,000 GW by 2030.

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- **Double annual energy efficiency improvements** to over 4% by 2030.

Global Cooling Pledge: Aims to reduce **cooling-related emissions** by **68% globally** by 2050, with 66 national signatories.

Declaration to Triple Nuclear Energy: Targets tripling **global nuclear energy capacity** by 2050.

Major Engagements of India at COP28

Green Credit Initiative: Incentivizes **pro-planet actions** like reforestation on degraded lands and river catchment areas to restore ecosystems.

Leadership Group for Industry Transition (LeadIT 2.0): Promotes inclusive industry transitions through **low-carbon technology** development and financial support for emerging economies.

Global River Cities Alliance (GRCA)

- Led by India's **National Mission for Clean Ganga (NMCG)** to promote sustainable **river-centric development**.
- Encourages **knowledge sharing**, river-city collaborations, and adoption of best practices.

Quad Climate Working Group (QCWG): Focuses on empowering **local communities** and **regional governments** to foster **sustainable lifestyles**.

COP29 (Baku, Azerbaijan) Major Outcomes

New Climate Finance Goal

- Adoption of the **New Collective Quantified Goal on Climate Finance (NCQG)** to triple finance for developing countries to **USD 300 billion/year by 2035**, up from USD 100 billion.
- General call for scaling climate finance to **USD 1.3 trillion/year by 2035** from all sources, led by developed countries.
- It provides for the following mechanism for climate finance and emissions reduction.

Carbon Markets Agreement

- Finalized mechanisms for **carbon markets** under **Articles 6.2 and 6.4 of the Paris Agreement:**
  - **Article 6.2:** Allows country-to-country carbon credit trading through bilateral agreements.
  - **Article 6.4:** Introduces a centralised UN-managed carbon offset and trading system.

Declaration on Reducing Methane

- Over 30 countries signed the **Declaration on Reducing Methane from Organic Waste** (India excluded).
- Focused on five areas: **NDCs**, regulation, data, finance, and partnerships.
- Aims to reduce methane emissions, which contribute to 20% of global emissions.

Indigenous Peoples and Local Communities

- Adoption of the **Baku Workplan** and renewal of the **Facilitative Working Group (FWG)** under the LCIPP.
- Prioritizes integrating **indigenous knowledge** into climate policies and enhancing indigenous participation.
- Progress to be reviewed in **2027**.

Gender and Climate Change

- Extension of the **Lima Work Programme on Gender (LWPG)** for 10 years.
- Reaffirms gender-responsive climate action, with a new gender action plan to be adopted at COP30.

Baku Harmoniya Climate Initiative for Farmers

- Launched in partnership with FAO to streamline climate initiatives for farmers and improve access to finance.

India's Stance at COP29

- **Opposition to NCQG**
  - India rejected the **USD 300 billion pledge**, terming it inadequate.
  - Advocated for **USD 1.3 trillion/year**, including **USD 600 billion in grants**, to meet developing countries' needs.
- **Article 9 of the Paris Agreement:** Criticised shifting the responsibility for climate finance to all actors, emphasizing the **historical accountability** of developed countries.
- **Solidarity with Vulnerable Nations:** Supported LDCs and SIDS, who protested against inadequate financial targets for addressing their climate challenges.

REDD AND REDD+

UN-REDD

- **Establishment:** Created in 2008 in response to the UNFCCC decisions on the Bali Action Plan and REDD.
- **Programme Focus:** The UN Programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD).
- **Headquarters:** Geneva, Switzerland.
- **Membership:** 64 Partner Countries.
- **Role:** Engages in the conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries.
- **Collaboration:** It is a multilateral collaborative program initiated by the Food and Agriculture Organization (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

REDD+ [UPSC 2016]

- **Nature:** A voluntary climate change mitigation approach developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC).
- **Partnership**: Collaborates with developing countries to assist them in establishing the technical capacities

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necessary for implementing REDD+ and meeting UNFCCC requirements for REDD+ results-based payments.

- **Scope:** Goes beyond deforestation and forest degradation, **aiming to incentivize developing countries to reduce emissions from these activities, conserve forest carbon stocks, sustainably manage forests, and enhance forest carbon stocks.**
- **Objective:** Broadens the focus to include sustainable forest management and enhancement of forest carbon stocks, beyond just emission reduction.
- **Supporting Initiatives:** Besides the UN-REDD Programme, other initiatives supporting countries engaged in REDD+ include the World Bank's Forest Carbon Partnership Facility, the Global Environment Facility, the Green Climate Fund, among others.
- **Global Effort:** Part of a global effort to address climate change by promoting sustainable forestry practices and protecting carbon-rich forests.

OTHER INITIATIVES

Forest Carbon Partnership Facility (FCPF)

- **Global Partnership**: Involving governments, businesses, civil society, and Indigenous Peoples, primarily focusing on activities related to REDD+ (Reducing Emissions from Deforestation and Forest Degradation). **[UPSC 2015]**
- **Functionaries:** The World Bank serves as the trustee and secretariat, with additional delivery partners such as the Inter-American Development Bank and UNDP under the Readiness Fund, responsible for providing REDD+ readiness support.

Climate and Clean Air Coalition (CCAC) [UPSC 2017]

- **Establishment:** Formed in 2012, CCAC is a partnership involving nations, UNEP, and various stakeholders dedicated to protecting the climate by reducing short-lived climate pollutants **(SLCPs). SLCPs** include substances like **black carbon, methane, tropospheric ozone, and hydrofluorocarbons (HFCs).**
  - Despite their short atmospheric lifetimes, SLCPs can have a potent warming effect.
- **Benefits of Reducing SLCPs**
  - Preventing crop losses by reducing methane and black carbon emissions.
  - Slowing down the expected warming **by approximately 0.5°C by 2050,** contributing to the Paris Agreement's 2°C target.

BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL)

A multilateral fund managed by the World Bank, aiming to promote reduced greenhouse gas emissions from deforestation, forest degradation, and sustainable agriculture. [**UPSC 2015**]

Cool Coalition

Launched in 2019, it seeks to accelerate action toward clean and efficient cooling, led by UNEP, Climate and Clean Air Coalition, Kigali Cooling Efficiency Program, and Sustainable Energy for All.

GHG Protocol

Develops standards, tools, and training for tracking progress towards climate goals, focusing on measuring and managing greenhouse gas emissions.[**UPSC 2016**]

Global Climate Change Alliance + (GCCA+)

An EU initiative supporting vulnerable countries, particularly Small Islands Developing States (SIDS) and Least Developed Countries (LDCs), in increasing resilience to climate change. **[UPSC 2017]**

Global Alliance for Climate-Smart Agriculture (GACSA)

Promoted by FAO, it works towards improving food security, nutrition, and resilience in the face of climate change. [**UPSC 2018**]

Arctic Council

An intergovernmental forum promoting cooperation among Arctic states, Indigenous communities, and other inhabitants on common Arctic issues, particularly sustainable development and environmental protection.

EU Sets New Climate Goal for 2040

The European Parliament has recently approved the Net-Zero Industry Act to enhance net-zero technology production within the European Union.The European Union aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. It is part of the European Green Deal and is a legally binding target. **[UPSC 2024]**

India's Climate Action

In addition to India's active participation and leadership in global climate initiatives, India also has launched the National Action Plan on Climate change to combat climate change.

National Action Plan on Climate Change (NAPCC)

India's **National Action Plan on Climate Change (NAPCC)** was launched in **2008** to address climate change while promoting sustainable development. It outlines India's strategy for tackling climate change and enhancing adaptive capacity. The NAPCC consists of **eight core missions**, which focus on both mitigation and adaptation across different sectors.

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Missions under National Action Plan on Climate Change (NAPCC)

Mission	Objective	Ministry Responsible
• **National Solar Mission (NSM)**	Promote solar energy and increase its share in the energy mix.	Ministry of New and Renewable Energy (MNRE)
• **National Mission for Enhanced Energy Efficiency (NMEEE)**	Improve energy efficiency across sectors, including industry and transport.	Bureau of Energy Efficiency (BEE) under Ministry of Power
• **National Mission on Sustainable Habitat (NMSH)**	Promote energy-efficient and sustainable practices in urban areas.	Ministry of Housing and Urban Affairs (MoHUA)
• **National Water Mission (NWM)**	Conserve water resources and improve water use efficiency.	Ministry of Jal Shakti
• **National Mission for Sustainable Agriculture (NMSA)**	Promote sustainable agriculture practices, water-efficient irrigation, and organic farming.	Ministry of Agriculture and Farmers Welfare (MoA&FW)
• **National Mission on Green India (GIM)**	Increase forest and tree cover, enhance biodiversity, and protect ecosystems.	Ministry of Environment, Forest and Climate Change (MoEFCC)
• **National Mission for Sustaining the Himalayan Ecosystem**	Promote ecological resilience and protect key ecosystems in the Himalayan region.	Ministry of Science and Technology
• **National Mission on Strategic Knowledge for Climate Change (NMSKCC)**	Strengthen research, data collection, and technological capacity to address climate change.	Ministry of Earth Sciences (MoES)

Intergovernmental Panel on Climate Change (IPCC)

- **Established** in 1988 by the **World Meteorological Organization (WMO)** and **United Nations Environment Programme (UNEP)**.
- **Purpose**: To assess climate change science and provide policymakers with insights on:
  - The scientific basis of climate change.
  - Its impacts, future risks, and adaptation/mitigation strategies.
- **Role**
  - Supports climate-related policy development.
  - Informs negotiations under the **United Nations Framework Convention on Climate Change (UNFCCC)**.

IPCC Assessment Reports

- Comprehensive global scientific reports on climate change.
- Six assessment cycles completed with the following reports:
  1. **First Assessment Report (FAR)** – 1990.
  2. **Second Assessment Report (SAR)** – 1995.
  3. **Third Assessment Report (TAR)** – 2001.
  4. **Fourth Assessment Report (AR4)** – 2007.
  5. **Fifth Assessment Report (AR5)** – 2014.
  6. **Sixth Assessment Report (AR6)** – 2023.

The IPCC Sixth Assessment Report (AR6) Synthesis Highlights

- It flags the urgent need for action to address the escalating impacts of climate change
- It states that the global temperatures have already risen by 1.1°C above pre-industrial levels, with increasing frequency of extreme weather events and irreversible changes such as sea-level rise and biodiversity loss.
- Vulnerable populations, particularly in developing countries, face disproportionate risks, including food and water insecurity, health challenges, and ecosystem degradation.
- Without immediate and deep reductions in greenhouse gas emissions, global warming is likely to exceed 1.5°C, leading to severe and widespread consequences.
- The report calls for rapid emission reductions, global net-zero CO_2 emissions by 2050, and significant investments in renewable energy and carbon removal technologies.
- Adaptation efforts, such as climate-resilient infrastructure and nature-based solutions, must be scaled up urgently, though some regions are nearing adaptation limits.
- Bridging the finance gap, particularly for developing nations, and ensuring equity and justice in climate actions are critical.
- Achieving these goals requires transformative changes across energy, land use, and urban systems, underpinned by strong international cooperation and adherence to the Paris Agreement

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Current Status (2024)

- The IPCC is in its **Seventh Assessment Cycle (AR7)**, continuing its critical work on climate change research and guidance.

CLIMATE FINANCE

Climate finance involves local, national, or transnational funding from public, private, and alternative sources to support actions that address climate change, including:

- **Mitigation**: Reducing greenhouse gas emissions.
- **Adaptation**: Enhancing resilience to climate impacts.

It aligns with the principle of **"Common but Differentiated Responsibility and Respective Capabilities" (CBDR-RC)**, which mandates financial assistance from developed to developing countries, recognizing their varying capabilities and responsibilities.

Global Climate Financing Mechanisms

- **Green Climate Fund (GCF)**
  - Established to reduce GHG emissions in developing countries and support climate adaptation.

    [UPSC 2015]
  - The **COP in Cancun, Mexico (COP 16)**, decided to establish GCF.It's HQ is in Incheon,South Korea.
  - Equal emphasis on adaptation and mitigation.
  - The World Bank serves as the GCF's trustee.
- **Adaptation Fund (AF)**
  - Created under the **Kyoto Protocol in 2001.**
  - Committed over $532 million for adaptation and resilience activities.
  - In India, the **National Bank for Agriculture and Rural Development (NABARD)** is the National Implementing Entity (NIE) for the AF. This means that NABARD is responsible for the overall management of the projects and programs financed by the AF
- **Global Environment Facility (GEF)**
  - Operating since 1994 to fund clean energy and climate adaptation projects.
  - Manages the Special Climate Change Fund (SCCF) and Least Developed Countries Fund (LDCF).

Special Climate Change Fund (SCCF): Managed by the GEF, it provides resources for adaptation, technology transfer, and capacity building in developing nations.

Least Developed Countries Fund (LDCF): Specifically targets the adaptation needs of Least Developed Countries (LDCs), helping implement National Adaptation Programs of Action (NAPAs).

Hosts financial Mechanism for Conventions: CBD, UNFCCC, UNCCD, Stockholm Convention, and Minamata Convention

[UPSC 2014]

- **Loss and Damage Fund**
  - Established at the **2022 UNFCCC Conference (COP27) in Egypt.**
  - Operationalized to compensate nations suffering both economic and non-economic losses caused by climate change.
  - Priority funding for **Least Developed Countries (LDCs)** and **Small Island Developing States (SIDS)** facing the brunt of climate change.
  - LDF is **overseen by a Governing Board** that determines how the fund's resources are disbursed, with the **World Bank serving as** the **interim trustee** tasked with **hosting the fund for four years.**

Climate Finance at COP29 (Baku- Finance COP)

- **New Climate Finance Goal**
  - Adoption of the **New Collective Quantified Goal on Climate Finance (NCQG)** to triple finance for developing countries to **USD 300 billion/year by 2035**, up from USD 100 billion.
  - General call for scaling climate finance to **USD 1.3 trillion/year by 2035** from all sources, led by developed countries

Climate Financing and India

- **National Initiatives**
  - **National Adaptation Fund for Climate Change (NAFCC)**: Established in 2015 to support adaptation efforts in vulnerable states and UTs.
  - **National Clean Energy Fund**: Funded by a coal tax to promote clean energy technologies.
- **Programmes and Mechanisms**
  - Compensatory Afforestation Fund Management and Planning Authority (CAMPA).
  - Disaster Management Fund.
- **Policy and Governance**
  - A Climate Change Finance Unit under the Ministry of Finance guides climate finance policies and global engagements.

CAMPA

- The CAMPA funds are utilised for compensating the loss of forest land and ecosystem services by raising of compensatory afforestation, improving quality of forests through assisted natural regeneration, enrichment of biodiversity, improvement of wildlife habitat, control of forest fire, forest protection and soil and water conservation measures.
- **The Compensatory Afforestation Fund (CAF Act), 2016 and Rules, 2018** provide elaborate guidelines and activities for utilization of CAMPA Fund. CAMPA also supports creation of nurseries for multiplication of quality planting material of locally suitable plant species.The monitoring and evaluation of CAMPA activities is provided in the CAF Act, 2016.
- **The act also** provides for audit of the accounts of both National and States/UTs CAMPA Authorities by the Comptroller and Auditor- General of India (C&AG).

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7 National Environmental Legislation

CONSTITUTIONAL PROVISIONS

- The original Indian **Constitution lacked environmental safety provisions**.
- **42nd Amendment (1976):** added citizens' duty to protect the environment under **Article 51A(g)** while **Article 48A mandates State action.**
- **Article 21** guarantees the right to a healthy environment.
- The Department of Environment (1980) became the Ministry of Environment and Forests (1985), then the Ministry of Environment, Forests and Climate Change (2014).

POLLUTION RELATED LAWS

The Water (Prevention and Control of Pollution) Act of 1974

- Defined terms like **Pollution, sewage, effluent, stream and boards.**
- **Regulatory authority**: Led to the formation of State Pollution Control Boards (**SPCBs**), Central Pollution Control Board (**CPCB**) and grant them power to test equipment and samples for the purpose of analysis.
- The **1988 amendment act empowered SPCB and CPCB to directly close a defaulting industrial plant.**

Central Pollution Control Board (CPCB)

- **Statutory body** constituted under the **Water (Prevention and Control of Pollution) Act, 1974.**
- Entrusted more **powers and functions under the Air (Prevention and Control of Pollution) Act, 1981.**
- Provides technical services to the MOEFCC under provisions of the Environment (Protection) Act, 1986.
- Oversees the National Air Monitoring Programme (NAMP) and Water Quality Monitoring (WQM).

The Air (Prevention and Control of Pollution) Act of 1981

- Enacted under **Article 253** to implement the **1972 Stockholm conference** decisions.
- Defined terms like **Air Pollution and Air Pollutants**
- Central and state **water boards** have been entrusted with the **task of controlling and preventing air pollution.**
- The Act granted power to SPCBs to **test equipment and take samples**.
- The 1987 amendment extended the Act **to include noise pollution.**
- The **1988 amendment empowered SPCBs and CPCB to close defaulting industrial plants.**

Environment (Protection) Act of 1986 [UPSC 2019]

The **Environment (Protection) Act, 1986 (EPA)** provides a framework for safeguarding the **environment**, addressing **environmental threats**, and ensuring **swift responses** to such situations.

Background

Enacted to implement decisions from the **Stockholm Conference** aimed at **environmental improvement**. The Environment Protection Act (EPA) of 1986 was enacted to improve and protect India's environment in response to the Bhopal Gas Tragedy and gaps in environmental legislation

Powers of the Central Government

The Act grants **broad powers** to the **Central Government** to prevent **environmental pollution**, including:

- Establishing authorities to address **environmental issues** specific to different regions.
- Developing **national programs** for **pollution prevention** and **abatement**.
- Setting **standards** for **environmental quality** and **pollution control measures**.
- Issuing directions to:
  - Close or regulate **industries**, **operations**, or **processes**.
  - Control the supply of services such as **electricity** or **water**.
- **Authority to issue direct orders, including orders to close, prohibit or regulate any industry.**
- Power of **entry for examination, testing of equipment and other purposes and power to analyze the sample of air, water, soil** or any other substance from any place.
- Preparation of codes, guides and manuals.
- Such other matters as the **central government deems necessary or expedient for the purpose of securing the effective implementation** of the act.

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Offences and Penalties

- **Offences:** Non-compliance or violation of the Act's provisions constitutes an offence.
- **Cognizance:** Courts can only act on complaints filed by the **Central Government**, its authorized authority, or individuals providing 60-day prior notice to the Government.
- **Penalties:**
  - For violation: Imprisonment up to 5 years, a fine up to ₹1,00,000, or both.
  - For continued violations: Additional fine of ₹5,000 per day.
  - For extended violations (over one year): Imprisonment up to 7 years.

FOREST CONSERVATION AND RELATED PROVISIONS

Indian Forest Act 1865

The act allowed the British government to declare any land covered with trees as a government forest.

Indian Forest Act 1878

This act classified forests into **Reserve, protected and Village forest.**

Indian Forest Act 1927 (IFA, 1927)

The act is largely based on previous Indian Forest Acts implemented under the British. The most famous is the Indian Forest Act of 1878.

- Provides a legal framework for the **protection and management** of forests and duty leviable on Timber.
- Provides for a **procedure** to be followed for declaring an area to be Reserve/Protected/Village Forest **(Degree of protection: Reserved forests > Protected forests > Village forests)**
  - **Reserve Forest (RF): State government** may constitute any forest land or wasteland as reserved forest. All activities are prohibited unless permitted in RFs.
  - **Protected Forest (PF): State government** may constitute any forest land or wasteland not included in Reserve Forest as a Protected Forest. All activities are permitted unless prohibited in PFs.
  - **Village Forest:** Area of land constituted as a reserved forest that the state government can assign to a village community.
- The **Forest Settlement Officer** is appointed to **inquiry into and determine the existence, nature and extent of any rights.**
- **Recently Amended the definition of tree** to remove the word bamboos. It means bamboo growing in non-forest areas will be waived off the requirement of permission for its felling or transportation for economic use.

Forest (Conservation) Act 1980 (FCA 1980)

- **Prior approval of the Central Government** is required for diversion of forestlands for non-forest purposes.
- An Advisory Committee constituted under the Act advises GOI on these approvals.
- The Act deals with the **4 categories of forests**- Reserved forests, Village forests, Protected forests and Private forests.
- **1992 Amendment:** It provisioned for allowing some non-forest activities in forests, without cutting trees or limited cutting with prior approval of the Central Govt.
- **It gives states the responsibility and power** to identify and notify forests.
- The act **recognised the concept of Deemed Forest (**areas that are not officially classified as forest but are ecologically important and have forest-like characteristics) Such areas are included in this act.

Forest (Conservation) Amendment Act, 2023

The **Forest (Conservation) Amendment Act, 2023**, enacted in July-August 2023, aims to **clarify** the scope of **deemed forests** and address concerns related to **forest land management**.

Features	Details
Scope of Forest Land Under the Act	**Included Categories:** • Land declared as forest under the Indian Forest Act or any other law, or notified as a forest after October 25, 1980. • Land converted from forest to non-forest use before December 12, 1996.
Exemptions from the Act	**Land Use Exemptions:** • Up to 0.10 hectares for connectivity along roads and railways. • Up to 10 hectares for security-related infrastructure. • Up to 5 hectares for public utility projects in Left Wing Extremism Affected Districts. **Strategic Projects:** • Exemptions for national security projects within 100 km of international borders, the Line of Actual Control (LAC), and the Line of Control (LoC).

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Permitted Activities in Forest Land	• Activities for conservation, management, and development. • Exemptions for specific activities, such as zoos, ecotourism facilities, silvicultural operations, and certain surveys.
Assignment/Leasing of Forest Land	**Prior Approval Requirement:** • Central government approval is mandatory for assigning forest land to any entity, not limited to private organizations. **Regulatory Oversight:** • The central government has authority to define terms and conditions for such assignments.

The National Forest Policy 1988

- Envisages to have a minimum of one-third of the total land area of the country under forest or tree cover.
- As per India State of Forest Report, **Forest cover is defined as: All lands, more than one hectare in area, with a tree canopy density of more than 10 percent irrespective of ownership and legal status.** Such lands may not necessarily be a recorded forest area. It also includes orchards, bamboo and Palm.

Forest area vs Forest cover

Aspect	Forest Area	Forest Cover
Definition	Geographic areas recorded as forests in government records.	Lands with a tree canopy density of more than 10% and an area of more than one hectare.
Legal Basis	Denotes the legal status of land as forests under laws like the Indian Forest Act, 1927.	Mentioned as such in the state of Forest Report
Based on	Legal/Administrative definition	Physical characteristics
Constituents	Includes Reserved Forests (RF), Protected Forests (PF), and areas recorded as forests in revenue or state/local laws. May include areas with vegetation cover, blanks, or density less than 10%.	Includes natural forests, plantations, and areas outside recorded forests with tree canopy density greater than 10%.
Scope	Based on government records and administrative classification.	Based on tree canopy density and spatial assessment.
Additional Note	Not all recorded forest areas have vegetation cover or sufficient density.	Areas outside recorded forests with more than 10% canopy density are also included in forest cover assessment.

Forest Cover under Indian state of Forest report can be classified into the following categories.

Forest Type	Description
Very Dense Forest	All lands with tree cover (including mangrove cover) of canopy density of **70% and above.**
Moderately Dense Forest	All lands with tree cover (including mangrove cover) of canopy density between **40% and 70%.**
Open Forest	All lands with tree cover (including mangrove cover) of canopy density between **10% and 40%.**
Scrub	All forest lands with poor tree growth, mainly of small or stunted trees, having **canopy density < 10%.**

Forest Rights Act, 2006 (FRA 2006)

The Act provides for the restitution of deprived forest rights across India. It provides for integrating conservation and people's livelihood rights and strengthening the local self-governance. **[UPSC 2021]**

- For the first time FRA recognizes and secures:
  - **Community Rights** in addition to their Individual Rights
  - **Right to intellectual property and traditional knowledge** related to biodiversity and cultural diversity.
  - Rights of displaced communities and rights over developmental activities.
- **Applicable to Tribal and Other Traditional Forest Dwelling Communities**.
- The nodal agency for the implementation is the Ministry **of Tribal Affairs (MoTA)** **[UPSC 2021]**

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- Recognizes the **right of ownership access** to collect, use, and dispose of minor forest produce (FRA defines Minor Forest Produce to include non-timber forest produce of plant origin) by tribals.
- Rights conferred under the Act shall be **heritable but not alienable or transferable.**
- **National Parks and Sanctuaries have been included** along with Reserve Forest, and Protected Forests for the recognition of Rights.
- FRA **only recognises pre-existing rights** which are already being exercised by eligible persons in NPs and Sanctuaries.
- **Secures the tenure of existing forest dwellers**, but **no new rights** are being created.
- The FRA act identifies **4 types of rights:**
  - **Title rights**: Gives right to ownership to land-farmed forest dwellers(max. of 4 hectares)
  - **Use rights**: Rights of the dwellers extend to extracting Minor Forest Produce, grazing areas, etc.
  - **Relief and development rights:** Rehabilitation in case of illegal eviction.
  - **Forest management rights**: Right to protect, regenerate or conserve or manage any community forest resource.
- **Criteria** and evidence for **Forest Dwelling Scheduled Tribes (FDST)** to claim rights under FRA:
  - Must be **ST** in an area.
  - Primarily resided in forest or land before Dec 2005
  - Depend on forest or forest land for livelihood needs
- **Criteria for other Traditional Forest Dweller (OFTD) to claim rights under FRA:**
  - Primarily resided in forest for 3 generations (75 years) before December 2005.
  - Depend on forest for livelihood needs.
  - If an OTFD village establishes its eligibility under the act, there is no need for every individual to establish its eligibility separately.
- **Gram Sabha:** Designated as the **competent authority for initiating the process of determining the nature and extent of individual or community forest rights.** Decisions can be appealed before a court.

Critical Wildlife Habitat Notification under FRA, 2006

- **2011 Guidelines by MoEFCC for Critical Wildlife Habitat**
  - To notify a CWH, the FRA **requires state governments to establish that the presence of right-holders is causing irreversible damage to wildlife and their habitats.**
  - **Gram Sabha's free informed consent** must be given before any relocation of right-holders is carried out.
- **2018 Guidelines by MoEFCC**
  - **Identification**: Chief Wildlife Warden of a state will notify a **7-member expert committee**, **chaired by a chief conservator of forest in charge** of a national park or sanctuary, for identification of CWH in an NP or sanctuary based on scientific and objective criteria relevant to the protected area.
  - The Expert Committee shall **issue a public notice 15 days in advance on the intention to notify CWH.**
  - Final decision will be taken by the Standing Committee of the National Board for Wildlife.

OTHER LAWS AND REGULATIONS

Biodiversity Act, 2002

The Biological Diversity Act, 2002, aims to:

- **Conserve** biological resources.
- **Promote** their sustainable use.
- **Ensure** fair and equitable sharing of benefits derived from their use with local communities.

Key Features

Prohibited Activities Without Approval

Approval from the National Biodiversity Authority (NBA) is required for:

- **Access to Biological Resources**: Research or commercial use of Indian biological resources.
- **Research Transfer**: Transferring research outcomes based on Indian biological resources.
- **Intellectual Property Rights (IPR)**: Claiming IPR on inventions based on Indian biological resources.

Key Functions

- **Conservation and Sustainable Use**: Supervise the sustainable use of resources and regulate financial investments.
- **Threatened Species**: Notify and regulate the conservation and rehabilitation of threatened species.
- **Repositories**: Designate institutions to store and manage biological resources.

Legal Provisions

- Offences under the Act are **cognizable and non-bailable**.
- Grievances related to benefit-sharing or regulatory orders are handled by the **National Green Tribunal (NGT)**.

Exemptions

- **Commodities**: Indian biological resources traded as commodities (limited to this purpose).
- **Traditional Uses**: Traditional knowledge and practices involving biological resources.

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- **Collaborative Research**: Joint research projects with foreign institutions, subject to Central Government approval.
- **Agricultural Use**: Activities by farmers, livestock keepers, beekeepers, and traditional healers.

Regulatory and Institutional Framework

The Act establishes a 3 tier institutional framework at the national, state and local levels.

Entity	Established/Type	Functions
National Biodiversity Authority (NBA)	Established at the National level	Promote biodiversity conservation and sustainable use- Regulate access and benefit-sharing- Oppose unauthorized IPR claims on Indian resources abroad- Advise on biodiversity heritage sites
State Biodiversity Boards (SBBs)	Established by State Governments (Section 22 of the Act)	Advise State Governments on biodiversity conservation- Regulate commercial use and resource surveys
Biodiversity Management Committees (BMCs)	Constituted by local bodies (Section 41 of the Act)	**Prepare People's Biodiversity Registers** documenting local biological resources- Promote conservation and sustainable use of biodiversity

Biodiversity Heritage Sites (BHS)

Biodiversity Heritage Sites (BHS) are areas recognized for their exceptional ecological, faunal, floral, geological, or natural significance. Designated under the **Biological Diversity Act, 2002** in India, these sites aim to conserve and protect unique ecosystems, species, and habitats while promoting sustainable management. These are **notified** by State Governments.

Coastal Regulation Zone (CRZ) Rules

- Coastal stretches of seas, bays, estuaries, creeks, rivers and back waters which are **influenced by tidal action** were declared "Coastal Regulation Zone" (CRZ) in 1991. The regulation zone has been defined as the **area <500 m from the high-tide line.**
- **National Coastal Zone Management Authority (NCZMA) and State Coastal Zone Management Authority (SCZMA):** Established for enforcement and monitoring of the CRZ rules. These authorities have been delegated **powers under the Environmental (Protection) Act, 1986.** The implementation of CRZ rules is done by state governments through their SCZMA. The states need to frame their own coastal zone management plans in accordance with the central Rules.

Coastal Regulation Zone (CRZ) Rules 2011

The demarcation of zones is as follows:

- **CRZ-I**: **Ecological sensitive area**. **No new construction** is permitted **except for a few specified most essential activities** like support activities for Atomic Energy Plants and Defense requirements, **facilities required for disposal of treated effluents and extraction of natural gases and salt harvesting.**
- **CRZ-II:** Area that has been **developed up to or close to the shore line** which includes the designated urban areas that are substantially built up. **Buildings permitted only on the landward side** of the existing authorized structures.
- **CRZ-III:** Areas **not CRZ-I or CRZ-II,** like rural and less built-up urban areas, **are relatively undisturbed.** Within 200 meters of the High Tide Line (HTL), a "No Development Zone" prohibits construction except for repairs. **In CRZ-III, from 200 to 500 meters of HTL, development of vacant plots is allowed for dwelling units, hotels, or beach resorts under specific conditions.**
- **CRZ-IV:** The **activities impugning on the sea and tidal influenced water bodies** will be regulated **except for traditional fishing and related activities** undertaken by local communities. **No untreated sewage, effluents, pollution from oil drilling** shall be let off or dumped.

CRZ Rules 2018

- For the **CRZ-III (Rural) areas**, two separate categories-
  - **CRZ-IIIA:** For areas with a population density of 2,161 per sq km as per the 2011 Census, the no-development zone is now 50 m from the high-tide level, as against the 200 m stipulated earlier.
  - **CRZ-IIIB:** For areas with population density <2,161 per sq km continue to have a no-development zone extending up to 200 m from the high-tide line.
- **No-development zone:** 20 m for all islands close to the mainland coast, and for all backwater islands in the mainland.
- **Tourism infrastructure permitted in coastal areas**: Temporary tourism facilities such as shacks, toilet blocks, change rooms, drinking water, etc. have been permitted.
- **CRZ Clearances**: Projects which are located in the **CRZ-I and CRZ IV will be dealt with for CRZ clearance by the MoEFCC.** The powers for clearances with respect to **CRZ-II and III have been delegated at the State level.**

Integrated Coastal Zone Management Plan (ICZM)

- It is a process for the management of the coast using an integrated approach, regarding all aspects of the coastal zone, including geographical and political boundaries, in an attempt to achieve sustainability.
- The concept was born in 1992 during the Earth Summit of Rio de Janeiro.

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- It is a **World Bank assisted** project and is being implemented Union Ministry of Environment,
- Forests and Climate Change (MoEFCC).

Beach Environment & Aesthetics Management Services (BEAMS)

- It is one of the initiatives under the Integrated Coastal Zone Management Programme.
- It aims to develop and maintain eco-friendly, clean, and safe beaches to boost sustainable tourism
- The initiative aims to help Indian beaches meet the Blue Flag Standards, an international eco-label for clean and sustainable beaches.

Blue Flag Beaches

'Blue Flag' annual certification is an **eco-label certification** that a **beach, marina, or sustainable boating tourism operator can obtain**.

- It was **started in France** in 1985 and in areas out of Europe in 2001. It is **awarded by Denmark based Foundation for Environment Education (FEE).**
- Blue Flag Beaches are selected **based on 33 parameters.** These criteria are divided into **4 major heads- Water quality, Environmental management, Environmental Education, and Safety.**
- The jury that selects Blue Flag beaches comprises members of the: **UNEP**, UN World Tourism Organization (**UNWTO**), Foundation for Environmental Education (**FEE**) and **IUCN**. **Spain** has the highest number of Blue Flag beaches (729).

Blue Flag Beaches of India: There are 12 Blue Flag certification beaches in India. Chandrabhaga beach (or the Golden beach) in Odisha is the first beach in India as well as in Asia to win the Blue Flag certification. The Minicoy Thundi beach and Kadmat beach, located in Lakshadweep Islands are recent receivers of eco-label 'Blue Flag'.

State wise list

S.No.	Beach Name	State/UT
1	Shivrajpur Beach	Gujarat
2	Ghoghla Beach	Diu
3	Kasarkod Beach	Karnataka
4	Padubidri Beach	Karnataka
5	Kappad Beach	Kerala
6	Rushikonda Beach	Andhra Pradesh
7	Golden Beach	Odisha
8	Kovalam Beach	Tamil Nadu
9	Eden Beach	Puducherry
10	Radhanagar Beach	Andaman & Nicobar Islands
11	Thundi Beach	Lakshadweep
12	Kadmat Beach	Lakshadweep

Rules for Hazardous Microorganisms/ Genetically Engineered Organisms or Cells 1989

Aims to protect the environment, nature, and health (biosafety) in connection with application of gene technology and microorganisms.

Presently there are six committees

- **Recombinant DNA Advisory Committee (RDAC)**: **Advisory body** that recommends safety regulations in recombinant research and applications.
- **Review Committee on Genetic Manipulation (RCGM)**: Established under the Department of Biotechnology, Ministry of Science and Technology, to monitor the safety related aspects in respect of on-going research projects.
- **Genetic Engineering Appraisal Committee (GEAC)**: **Statutory body** constituted in the MoEFCC under 'Rules 1989', **under the Environment Protection Act, 1986. [UPSC 2015]**
- **State Biotech Coordination Committee (SBCC)**: Monitoring Role. It also has powers to inspect, investigate and take punitive action in case or violations of statutory provisions.
- **District Level Committees (DLCs): Role in** monitoring the safety regulations in installations engaged in the use of GMOs/hazardous microorganisms and its applications in the environment.
- **Institutional Biosafety Committee (IBSC)** is established to GMO research & to interface with RCGM in regulating it.

Protection Against Chemical Disasters

- **Environment Act of 1986:** Gives powers to the central government to undertake measures for improving the environment and set standards and inspect industrial units.
- **Bhopal Gas Leak (Processing of Claims) Act, 1985:** Gives powers to the central government to secure the claims arising out of or connected with the Bhopal gas tragedy.
- **The Public Liability Insurance Act, 1991**: To provide relief to persons affected by accidents that occur while handling hazardous substances.
- **The National Environment Appellate Authority Act, 1997:** To hear appeals regarding the restriction of areas in which any industries, operations or processes or class of industries shall not be carried out or shall be carried out subject to certain safeguards under the Environment (Protection) Act, 1986.
- **National Green Tribunal, 2010:** Establishment of the National Green Tribunal for effective and expeditious disposal of causes related to environmental protection and conservation of forests.

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Strict vs Absolute Liability Principle

- **Strict Liability Principle:** A party is **not liable and need not pay compensation** if a hazardous substance escapes its premises by accident or by an 'act of God'.
- **Absolute Liability Principle**: a party in a hazardous industry cannot claim any exemption. It has to **mandatorily pay compensation**, whether or not the disaster was caused by its negligence.
  - The **National Green Tribunal Act of 2010** incorporates the absolute liability principle and mandates its application even if the disaster caused is an accident. Absolute liability thus provides no exemptions and is **part of Article 21 (Right to Life).**

National Green Tribunal Act, 2010

- Mandated to **dispose of the cases within 6 months** of their respective appeals.
- It was enacted in consonance with Right to healthy environment, construed as a part of Right to life under Article 21. **[UPSC 2012]**
- **Principal Bench**: **New Delhi**
- **Regional benches: Pune** (Western Zone Bench), **Bhopal** (Central Zone Bench), **Chennai** (Southern Bench) and **Kolkata** (Eastern Bench)
- **Members:** Currently **10 expert members and 10 judicial members though the act allows for up to 20 of each.** Every bench of the tribunal must consist of **at least 1 expert member & 1 judicial member.**
- **Chairman**: Serving/ retired Chief Justice of a HC or a judge of the SC of India. The Chairman of the tribunal also serves as a judicial member.
- **Jurisdiction:** Original Jurisdiction on matters of "**substantial question relating to environment"** and "**damage to environment due to specific activity**".
- **Powers: Binding Orders**, **Power to grant relief in the form of compensation and damages** to affected persons. Right **to hear all civil cases relating to environmental issues** and questions that are linked to the implementation of laws listed in Schedule I of the NGT Act. **[UPSC 2018]**
  - These include the following: **The Water Act, 1974; The Water Cess Act, 1977; The Forest Act, 1980; The Air Act, 1981; The Environment Act, 1986; The Public Liability Insurance Act, 1991; The Biological Diversity Act, 2002 (Not WPA 1972, Indian Forest Act, 1927**).
- **Principles of Justice**: Not bound by the procedure laid down under the Code of Civil Procedure, 1908, Indian Evidence Act 1872 but shall be **guided by principles of natural justice.**
- While passing Orders/decisions/awards, the NGT will **apply the principles of sustainable development,** the **precautionary principle** and the **polluter pays principles.**
- **Review and Appeal: Powers to review its own decisions**. If this fails, an NGT Order can be challenged before the Supreme Court within 90 days.

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8 Energy

MAJOR ENERGY SOURCES

- **Conventional Non-Renewable:** Coal, Oil, Natural Gas: Fossil fuels found underground.
- **Non-Conventional Renewable:** Solar Energy, Hydro Power, Wind Energy, Nuclear Energy, Hydrogen Energy, Geothermal Energy, Biogas, Tidal Energy, Biofuel.

Energy Source	Production/Process	Applications	Key Features/Challenges
Solar Energy	• PV cells convert sunlight into electricity. • Solar thermal systems concentrate sunlight to heat fluids for power.	Electricity generation, heating.	Renewable, low emissions; efficiency depends on sunlight availability.
Hydro Power	Dams capture flowing water energy to turn turbines connected to generators.	Electricity generation.	Reliable, renewable; potential for ecological disruption.
Wind Energy	Wind turbines convert wind's kinetic energy into electricity through blade rotation.	Electricity generation.	Clean, renewable; depends on wind speed and location.
Nuclear Energy	• Fission: Splitting atoms releases energy for heat/electricity. • Fusion: Combines atoms at high temperatures (future potential).	Electricity generation.	High energy output; concerns about radioactive waste and safety.
Hydrogen Energy	• Electrolysis splits water into hydrogen and oxygen. • Steam methane reforming extracts hydrogen from natural gas.	Fuel cells, industrial processes.	Clean, versatile; production can be energy-intensive.
Biogas	Produced by anaerobic digestion of organic matter (animal waste, crop residues, sewage).	Heating, electricity generation.	Renewable; methane emissions can be captured but requires proper infrastructure.
Biofuel	Derived from biomass through fermentation, transesterification, or thermochemical processes.	Vehicle fuel, power generation.	Reduces emissions; may compete with food production and impact land use.
Biomass Conversion	• Direct burning for cooking/electricity. • Conversion to ethanol/methane via fermentation or anaerobic digestion.	Cooking, heating, electricity, fuel production.	Can deplete soil nutrients; energy-intensive ethanol production.
Solid Waste	Sorted and combusted for energy recovery.	Waste-to-energy plants.	Reduces landfill use; burning causes air pollution, especially plastics.
Geothermal Energy	Utilizes steam from underground reservoirs or hot springs to generate electricity.	Electricity generation, heating.	Renewable, reliable; potential pollution from hydrogen sulfide and toxic minerals.
Tidal Energy	Dams built across bays/estuaries control water flow to drive turbines.	Electricity generation.	Predictable; may disrupt habitats and alter natural water flows.
Methanol and Ethanol	• Methanol: Produced from natural gas/ biomass. • Ethanol: Derived from fermentation of biowaste/food crops.	Clean fuels, solvents, fuel additives.	Cleaner-burning; reduces pollution but production may compete with food resources.

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Liquefied Petroleum Gas (LPG)	By-product of natural gas processing and petroleum refining.	Heating, cooking, vehicle fuel.	Portable, efficient; odorized for leak detection.
Compressed Natural Gas (CNG)	Compressed methane stored in tanks.	Vehicle fuel.	Cleaner and cheaper than traditional fuels; requires specialized storage.

Distributed Energy Resources UPSC[2024]

Distributed energy resources are small, modular, energy generation and storage technologies that provide electric capacity or energy where you need it. Typically producing less than 10 megawatts (MW) of power, DER systems can usually be sized to meet your particular needs and installed on site.

Examples of distributed energy resources that can be installed include:

- **roof top solar photovoltaic units**
- wind generating units
- **battery storage**
- batteries in electric vehicles used to export power back to the grid
- combined heat and power units, or tri-generation units that also utilise waste heat to provide cooling
- **biomass generators**, which are fuelled with waste gas or industrial and agricultural by-products.
- open and closed cycle gas turbines
- reciprocating engines (diesel, oil)
- hydro and mini-hydro schemes
- **fuel cells**

BIOFUEL

Biofuels are hydrocarbon fuels produced from organic matter (living or once-living material) in a short period.

- **Types include**
  - **Solid**: Wood, manure
  - **Liquid:** Bioethanol, Biodiesel
  - **Gaseous**: Biogas
- **Environmental Impact:** Emit less CO_2 than conventional fuels, making them a viable option to reduce transport sector emissions. They constitute about 3% of global road transport fuels.

National Policy on Biofuels 2018 [UPSC 2020]

- **Blending Targets**
  - Target of 20% ethanol blending in petrol and 5% biodiesel blending in diesel by 2030.
  - **Current percentages:** 2% for petrol and less than 0.1% for diesel.
- **Categorization:**
- The policy categorizes biofuels into three types:
  - **First-Generation (1G) Biofuels:** Ethanol and biodiesel derived from food crops like sugarcane and vegetable oil.
  - **Second-Generation (2G) Biofuels:** Ethanol produced from non-food feedstocks like agricultural residues and waste.
  - **Third-Generation (3G) Biofuels:** Advanced biofuels from algae, and bio-CNG.
  - The Policy expands the scope of raw material for ethanol production by allowing use of Sugarcane Juice, Sugar containing materials like Sugar Beet, Sweet Sorghum, Starch containing materials like Corn, Cassava, Damaged food grains like wheat, broken rice, Rotten Potatoes, unfit for human consumption for ethanol production.
- **Ethanol Blended Petrol (EBP) Programme:**
  - Aims for 20% ethanol blending and 5% biodiesel blending by 2030.
  - **Revised E20 target for 2025;** phased rollout from April 2023.

Some Important Biofuels

Biofuel Type	Source and Production	Key Features	Applications
Bioethanol	Derived from corn and sugarcane through fermentation.	Contains about two-thirds of the energy of petrol. Improves combustion performance and reduces carbon monoxide and sulfur oxide emissions.	Mixed with petrol to enhance fuel efficiency and reduce emissions.
Biodiesel	Produced from vegetable oils (e.g., soybean, palm), waste oils, and animal fats using transesterification.	Emits fewer harmful gases than conventional diesel. Has intrinsic lubricating properties, low toxicity, and is biodegradable.	Alternative to diesel fuel; used in blends (e.g., B2, B5, B100).

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Biogas	Created through anaerobic decomposition of organic matter (sewage, animal and human waste).	Composed mainly of methane (50-65%) and carbon dioxide (35-50%), with traces of other gases. Can be purified into Compressed Bio-Gas (CBG).	Used for heating, electricity generation, and as automotive fuel.
Biobutanol	Produced similarly to bioethanol through starch fermentation.	Highest energy content among gasoline alternatives. Reduces emissions when added to diesel. Also used as a solvent and perfume base.	Added to diesel fuel; industrial solvent in the textile industry and as a base for perfumes.
Biohydrogen	Produced through processes like pyrolysis, gasification, or biological fermentation.	Clear, colorless, and biodegradable. Potential alternative to fossil fuels, with high energy efficiency.	Used for fuel cells, transportation, and industrial applications.

Sustainable Alternative Towards Affordable Transportation Scheme (SATAT)

- Encourages entrepreneurs to **set up CBG plants for green automotive and industrial fuel.**
- Aims to address urban air pollution, enhance farmers' income, and promote organic farming.

Sustainable Aviation Fuel (SAF) UPSC[2024]

- **Sustainable Aviation Fuel (SAF)**, also referred to as **bio-jet fuel,** is created using **domestically developed methods** using **cooking oil** and **oil-rich seeds from plants.**
- Agricultural residues, corn grain, wastewater treatment sludge, and wood mill waste—can be used as feedstock for producing Sustainable Aviation Fuel (SAF).

HYDROGEN AS A FUEL

- **Clean Source:** Zero-emission fuel, produces only water vapor as a byproduct.
- **Hydrogen Economy Vision:** Utilizing hydrogen as a low-carbon energy source to decarbonize sectors like steel, cement, and transportation.

Properties of Hydrogen

- **Abundance and Characteristics:**
  - Most abundant chemical substance in the universe.
  - Nontoxic, odorless, tasteless, colorless, and highly combustible diatomic gas (H2).
- **Energy Carrier:**
  - Hydrogen is not an energy source but an energy carrier.
  - Produced through processes like electrolysis, splitting water into hydrogen and oxygen.

Potential

- Abundance and Efficiency
  - Renewable, non-polluting fuel producing water as the only by-product.
  - More fuel-efficient compared to diesel or gas.

Challenges

- **Production Challenges:** Transportation and storage challenges, safety concerns due to high reactivity.
- **Environment constraints:** Energy-intensive **production methods with a high carbon footprint.**
- **Economic Challenges:** Cost of electrolysers, critical minerals access, and scaling up production.

Types of Hydrogen

Hydrogen	Source/Process
Brown Hydrogen	Coal without carbon sequestration.
Grey Hydrogen	Natural gas/fossil fuels without carbon sequestration.
Blue Hydrogen	Natural gas/fossil fuels with carbon sequestration.
Green Hydrogen	Produced using renewable energy without carbon sequestration.
Pink Hydrogen	Generated through electrolysis using electricity produced by nuclear energy. Sometimes referred to as purple or red hydrogen.
Turquoise Hydrogen	Made through methane pyrolysis, producing hydrogen and solid carbon. Production has not yet been proven at scale.
Yellow Hydrogen	Made through electrolysis powered by solar energy.
White Hydrogen	Naturally-occurring hydrogen found in underground deposits and extracted through fracking.

Current Status in India

- **Production and Usage**
  - Majority produced through methane reforming, contributing to CO_2 emissions.
  - National Hydrogen Energy Road Map (NHERM) adopted in 2006.
  - National Hydrogen Energy Mission (NHM) announced in the 2021-22 Union Budget.

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- **Hydrogen Blended Natural Gas:** Plan to blend 15% green hydrogen with piped natural gas.
- **Efficiency Ranking: Electric Vehicles > Hydrogen > Diesel > Petrol vehicles** (in decreasing order of overall efficiency)

National Green Hydrogen Mission (NGHM)

- Green hydrogen is hydrogen produced by the electrolysis of water, using renewable electricity. Production of green hydrogen causes significantly lower greenhouse gas emissions than production of grey hydrogen, which is derived from fossil fuels without carbon capture.
- **Launched in 2023**
  - Aims to make India an energy-independent nation and a green hydrogen hub.
  - Facilitates demand creation, production, and export of green hydrogen.
- **Salient Features**
  - Targets green hydrogen production capacity of at least 5 MMT per annum by 2030.
  - **SIGHT Program:** Incentives for manufacturing of electrolysers and production of green hydrogen

Hydrogen Fuel Cell

- **Fuel Cell Operation**
  - Uses the chemical energy of hydrogen or **other fuels to cleanly and efficiently produce electricity.** If hydrogen is the fuel, the only products are electricity, water, and heat.
  - Anode, cathode, and electrolyte components.
- **Advantages and Challenges**
  - More efficient than thermal power plants.
  - **Expensive production due to costly catalysts like platinum or palladium.**

CRITICAL MINERALS IN THE GREEN TRANSITION

- **Demand for Critical Minerals:** Solar PV plants, wind farms, and electric vehicles require minerals like **cobalt, copper, lithium, nickel, and rare earth elements (REEs).**
- **Significance of Minerals:** Lithium, nickel, cobalt, manganese, graphite, and REEs are crucial for battery performance, longevity, and energy density.
- **Supply Chain Challenges:** The global supply chain for critical minerals is concentrated, posing a supply risk due to uneven distribution.

Measures Taken by India

- **Geological Survey Discovery:** The Geological Survey of India discovered 5.9 mt of lithium deposits in J&K, the first such discovery in the country.
- **KABIL for Mineral Security**
  - **Formation:** The Ministry of Mines created Khanij Bidesh India Ltd. (KABIL) in collaboration with NALCO, HCL, and MECL to ensure mineral security.
  - **Objectives:** Aims to ensure a consistent supply of critical and strategic minerals to the Indian domestic market, with a focus on minerals like lithium and cobalt.
  - **Functions:** KABIL is responsible for identification, exploration, development, mining, and processing of strategic minerals overseas for commercial use.

Indian Renewable Energy Development Agency (IREDA)

- IREDA is a **Mini Ratna (Category – I) Public Limited Government Company under the Ministry of New & Renewable Energy.**
- Established in **1987**, it is engaged in promoting, developing, and extending financial assistance for projects related to renewable energy and energy efficiency.

ENERGY CONSERVATION MEASURES

- The **Energy Conservation Act of 2001** is a legal framework regulating energy consumption, promoting energy efficiency, and conservation.
- Major provisions include designated consumers, standards and labeling of appliances, energy conservation building codes, creation of Bureau of Energy Efficiency, and the establishment of the Energy Conservation Fund.
- **Bureau of Energy Efficiency (BEE)** is a statutory agency under the Ministry of Power, focusing on developing programs for energy conservation.
  - **Star Rating Mobile App**

    This app, linked to the Standards and Labeling database, empowers consumers to:
    - **Compare** energy-efficient devices within a product category.
    - **Access** real-time user feedback.
    - **Make informed purchase decisions.**
- **Energy Conservation Building Code** (ECBC) sets minimum energy standards for commercial buildings, and ECO Niwas Samhita 2018 does the same for residential buildings.
- The **Stars and Labeling Program (BEE Star Label)** provides consumers with information on energy-saving potential, covering various appliances.
- **UJALA and SLNP** are initiatives by Energy Efficiency Services Limited (EESL) for LED distribution and streetlight replacement, contributing to significant greenhouse gas emission reduction.
- New energy performance standards for room air conditioners, including a mandatory 24°C default setting, aim to save electricity and reduce carbon intensity.

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- **Indian Seasonal Energy Efficiency Ratio** (ISEER) is used for rating AC efficiency, considering season-wise temperature variations.
- **Smart Grid**
  - Utilizes **digital technology for two-way communication between utilities and consumers.**
  - **Components:** Smart grids consist of controls, computers, automation, and new technologies to respond digitally to changing electricity demand.
  - **National Smart Grid Mission (NSGM):** Launched in **2015**, NSGM plans and monitors the implementation of policies and programs related to smart grids.
  - **Benefits:** More efficient transmission, quicker restoration after disturbances, reduced peak demand, and increased integration of large-scale renewable energy systems.
- **Sustainable Energy for All (SE4All):** Launched in 2011, SE4All is a multi-stakeholder partnership aiming to achieve three interlinked objectives by 2030: double the rate of improvement in energy efficiency, double the share of renewable energy in the energy mix, and universal access to modern energy services.
- **Energy Conservation (Amendment) Bill, 2022**
  - The bill proposes amendments to the Energy Conservation Act of 2001 to address revised Nationally Determined Contributions (NDCs) and establish carbon markets.
  - Provisions **include mandatory use of non-fossil sources, carbon trading, an energy conservation and sustainable building code**, standards for vehicles and vessels, and strengthening the composition of BEE.
- **National Mission for Enhanced Energy Efficiency (NMEEE) under NAPCC:** NMEEE is one of eight missions under the National Action Plan on Climate Change (NAPCC). It aims to boost energy efficiency by fostering favorable regulatory frameworks and sustainable business models in energy-intensive industries.

Key Initiatives Under NMEEE

Initiative	Description	Key Components/Benefits
Perform, Achieve, and Trade (PAT)	Market-based mechanism to improve cost-effectiveness of energy efficiency in energy-intensive industries.	• Units exceeding targets earn Energy Saving Certificates (ESCerts). • ESCerts can be traded on power exchanges for compliance.
Market Transformation for Energy Efficiency (MTEE)	Aims to accelerate market adoption of energy-efficient products.	• Bachat Lamp Yojana (BLY): Promotes LED usage. • Super-Efficient Equipment Programme (SEEP): Financial incentives for efficient appliances.
Energy Efficiency Financing Platform (EEFP)	Facilitates financing mechanisms for demand-side energy management programs.	• MoUs with financial institutions. • Supports development of the energy efficiency market.
Framework for Energy Efficient Economic Development (FEEED)	Develops fiscal instruments to promote energy efficiency.	• Partial Risk Guarantee Fund (PRGFEE): Covers risks for banks lending to efficiency projects. • Venture Capital Fund (VCFEE): Provides equity for projects in government buildings and municipalities.

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9 Major Species and Invasive Species

MAMMALS – CRITICALLY ENDANGERED (CR)

Species and Conservation Status	Features
Andaman White Toothed Shrew **IUCN:** CR	**Characteristics:** Small mouse-like shrew **Distribution:** Endemic to Andaman Islands (South Andaman) **Main Threats:** Habitat loss (Disasters, logging, climate change etc), and Hunting.
Jenkin's Shrew	**Characteristics:** Small-sized shrew, grayish or brown in color and largely insectivorous. **Distribution:** Endemic to South Andaman island. **Main threats:** Habitat loss (deforestation, forest fires) anthropogenic threats (infra, mining tourism, etc)
Nicobar Shrew	**Characteristics:** Small, largely insectivorous, nocturnal or crepuscular shrew. **Distribution:** Endemic to Great Nicobar Islands **Main Threats:** Predation, Tourism, mining, etc
Kashmir Stag/Hangul **IUCN:** CR **CITES:** Appx I **CMS:** Appx I	**Characteristics:** Asiatic sub-species of Central Asian red deer. **Distribution:** Endemic to Kashmir (now in Dachigam NP) **Main Threats:** Over-grazing, poaching, habitat loss and predation.
Himalayan Brown Bear **IUCN:** CR (Brown Bear is Least Concern LC) **CITES**: Appx I **CMS**: Appx I	**Characteristics:** One of the largest carnivores in the Himalayas, omnivorous, hibernates during winter. **Distribution:** North India (J&K, HP, Uttarakhand), north Pakistan, Nepal, Tibet, China, Central Asia, (Brown Bear Across Eurasia and North America). **Habitat:** Forests at high altitudes, alpine meadows **Threats:** Human-animal conflict, rapid habitat loss, poaching for fur, claws, and organs, etc.
Orangutan **[UPSC 2023]** **IUCN:** CR **CITES:** Appx I	**Characteristics:** Great ape with reddish-brown fur, long arms, and high intelligence; primarily arboreal. Makes a tool with a stick to scrape insects from a hole in a tree or a log of wood. **Distribution:** Found in tropical rainforests of Borneo and Sumatra (Indonesia and Malaysia). **Threats:** Habitat destruction due to deforestation and palm oil plantations. • Illegal wildlife trade. • Poaching.
Pygmy Hog **[UPSC 2013]** **IUCN:** CR **CITES:** Appx I	**Characteristics:** World's smallest wild pig, an indicator species of grassland habitats. **Distribution:** Found only in Manas Wildlife Sanctuary (Assam). **Threats:** livestock grazing, fires and poaching.

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Species and Conservation Status	Features
Large Rock Rat/ Elvira Rat **IUCN:** CR	**Characteristics:** Social animals living in groups, omnivorous and highly active and agile. **Distribution:** Endemic to Eastern Ghats, Tamil Nadu. **Main Threats:** Habitat loss due to mining, quarrying, logging, and agriculture
Malabar Large-Spotted Civet **[UPSC 2024]** **IUCN:** CR **CITES:** Appx III	**Characteristics:** Nocturnal and solitary animal that feeds on small mammals, birds, insects, and fruits. It has a distinct appearance with a long body, short legs, and a bushy tail. Its fur is reddish-brown with white spots, and it has a white stripe that runs from the nose to the forehead. **Distribution:** Endemic to southern Western Ghats **Main Threats:** Habitat loss due to agriculture & plantations, poaching, etc.
Namdapha Flying Squirrel **IUCN:** CR	**Characteristics:** Nocturnal, arboreal species that glides between trees instead of flying like birds or bats. It has reddish, grizzled fur with white above, a pale grey crown, an orangish patagium, and white underparts. **Distribution:** Restricted to Namdapha NP and other adjacent areas in Arunachal pradesh **Main Threats:** Habitat loss & climate change
Bactrian Double Humped Camel	**Distribution:** They are native to the harsh and arid regions of Central Asia.They occupy habitats in Central Asia from Afghanistan to China, primarily up into the Mongolian steppes and the Gobi desert. **A small population of Bactrian camels exists in the Nubra Valley of Ladakh.** They have been deployed by **Indian Army** recently.

Fig. Andaman Shrew

Fig. Malabar Civet

Fig. Double Humped Camel

MAMMALS – ENDANGERED (EN)

Species and Conservation Status	Features
Asian Elephant (EN) **[UPSC-2020]** **IUCN:** EN **CITES:** Appx I **Three sub-species** • Indian Elephant • Srilankan Elephant • Sumatran Elephant	**Characteristics:** Asian elephants are smaller than African elephants. The tusks are typically present only in males. They live in matriarchal herds and are led by older females, while the males are solitary.They are highly intelligent and social, they play a key ecological role. **Distribution**: They are found in forests and grasslands across South and Southeast Asia. In India they are found in the Himalayan foothills, western ghats and central India. India has the world's largest population of wild elephants with Karnataka having the highest population followed by Assam and Kerala. **Threats:** Poaching, Human wildlife conflict, Electrocution and train collisions, habitat loss,etc.
Tiger **IUCN:** EN **CITES:** Appx I	**Characteristics:** The Indian tiger also known as the Bengal tiger, is characterised by a vibrant orange coat marked by black stripes and a white underbelly. It is the largest wild cat in India. It is a solitary and territorial species. **Distribution:** They are found across diverse landscapes of South and South-east Asia. India is home to 75% of the world's wild tiger population as per the tiger census, 2022. These are widely distributed in India, with major populations in states like Madhya Pradesh, Uttarakhand, Karnataka, Maharashtra, and Assam. **Threats: Poaching, habitat loss and fragmentation, prey depletion, etc.**

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Kharai camel[UPSC 2016] **IUCN Status: EN**	**Characteristics:** Unique breed capable of swimming up to 3 km in seawater. • Grazes on mangroves and other saline vegetation. • Can be domesticated, often reared by local communities **Distribution:** Found in the coastal regions of Gujarat, especially in the Kutch region.
Dhole/Asiatic wild dog **IUCN:** EN **CITES:** Appx II	**Characteristics:** Dog-like carnivorous mammal,Highly social, lives in large clans. **Distribution:**Central, South, East and SE Asia. India has the largest population in the world, commonly found in Western ghats, Central Indian forests and forests of North east. **Habitat:** All grassland and forested regions. **Threat:** Habitat loss, large infra projects, diseases, etc.
Gee's Golden Langur **IUCN:** EN **CITES:** Appx I	**Characteristics:** Old world monkey with golden fur. **Distribution:** Western Assam and Southern Bhutan and Manas NP (India), Royal Manas NP (Bhutan), Black Mountains (Bhutan). **Threats:** Inbreeding depression, habitat loss, electrocution, vehicular accidents, etc.
Himalayan Musk Deer/ Kasturi [UPSC 2012] **IUCN:** EN **CITES:** Appx I	**Characteristics:** Musk deer species, males secrete musk used in perfume industry, lacks antlers (distinguishing it from true deer) **Distribution:** Himalayas of Bhutan, India, Nepal, and China. In India found in Dachigam National park, Askot Wildlife sanctuary etc. **Threats:** Poaching for musk gland, habitat loss, etc.
Indian Hog Deer **IUCN:** EN, **CITES:** Appx III	**Characteristics**: It is a solitary creature and is sedentary and does not migrate. Males tend to be territorial and mark their territory with glandular secretions. This species exhibits sexual dimorphism. The females are slightly smaller than males and lack antlers. **Distribution:** Native to Indo-Gangetic Plain in Pakistan, India, Nepal, and mainland SE Asia. **Habitat:** Wet or moist tall grasslands, often associated with rivers,along the Terai region from Corbett to Assam. **Threats:** Habitat loss, poaching, feral dog attacks, etc
Lion-Tailed Macaque **IUCN:** EN **CITES:** Appx I **[UPSC 2013]**	**Characteristics:** Arboreal old world monkey recognised by its silver-white mane that surrounds the head from the cheeks down to its chin. **Distribution:** Endemic to Western Ghats of South India, mainly in the states of Karnataka, Kerala, and Tamil Nadu. **Threats:** Habitat destruction and fragmentation, hunting, electrocution ,etc.
Nilgiri Tahr **IUCN:** EN	**Characteristics**: State animal of Tamil Nadu, only mountain ungulate in southern India. **Distribution:** Endemic to Nilgiri Hills in Western Ghats (Kerala and Tamil Nadu). **Threats**: Habitat loss due to rampant deforestation, competition with domestic livestock, hydroelectric projects in Nilgiri tahr habitat, and monoculture plantations and occasional hunting for its meat and skin.
Red Panda [UPSC 2012] **IUCN:** EN **CITES:** Appx I	**Characteristics:** Arboreal mammal native to eastern Himalayas, southwestern China.Indicator species, umbrella species for Himalayan Ecosystem. Carnivorous but mainly feeds on bamboo, nocturnal and crepuscular. **Distribution:** Bhutan, India (Sikkim, West Bengal, Arunachal Pradesh, Meghalaya), Nepal, Myanmar, China. **Habitat:** Temperate montane forests with dense bamboo-thicket understorey. **Threats:** Forest fires, poaching and habitat loss.
Sangai (Brow-antlered deer) **IUCN:** EN, **CITES:** Appx I	**Characteristics:** Subspecies of **Eld's deer**, also known as Dancing deer. Restricted to Manipur, India. Endemic to Manipur, state animal of Manipur. **Distribution:** Found only at Keibul Lamjao National Park over the floating biomass in Loktak Lake (phumdi). **Threats:** Habitat destruction due to floods and invasive plants like Paragrass.

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Western Hoolock Gibbon **IUCN:** EN **CITES:** Appx I	**Characteristics:** One of three hoolock gibbon species, inhabits Bangladesh, North East India, Myanmar (west of the Chindwin River). Only ape found in India. **Distribution:** Found in tropical evergreen rainforests, semi-evergreen forests, etc. **Threats:** Deforestation, hunting, etc.

Fig. Kharai Camel

Fig. Dhole

Fig. Sangai

MAMMALS – VULNERABLE (VU)

Species and Conservation Status	Features
Asian Black Bear **IUCN:** VU **CITES:** Appx I	**Characteristics:** Himalayan Black Bear Subspecies of Asian Black Bear, Medium-sized arboreal bear species native to Asia. **Distribution:** Iran, north of the Indian subcontinent, Korean Peninsula, China, Russian Far East, Japan, Taiwan, SE Asia, Himalayan and NE regions.
Asiatic Lion [UPSC 2019, 2024] **IUCN:** VU **CITES:** Appx I	**Characteristics:** The Asiatic lion is slightly smaller than its African counterpart. These lions live in smaller prides and are highly territorial.Lions do not have a particular breeding season. **Distribution:** They are found primarily in the Gir Forest of Gujarat and inhabit dry deciduous forests and grasslands. **Threats:** Habitat loss, human-wildlife conflict, and inbreeding.
One Horned Rhino: [UPSC-2019] **IUCN:** VU **CITES:** Appx I **Other Asian Rhino Species** • **Javan Rhino (CR)** • **Sumatran Rhino (CR)** • **White Rhino**	**Characteristics:** The one-horned rhinoceros , also known as the Indian rhinoceros, is a large herbivore with a thick, armor-like skin with deep folds and a single black horn. It is the second-largest rhinoceros species. These solitary animals are excellent swimmers and graze on grasses, aquatic plants, and fruits. **Distribution:** Native to the grasslands and swamps of northern India and Nepal **Threats:** Habitat loss and poaching. • **White Rhino (only in protected sanctuary in Africa, 2 left , no females left)** • **Javan rhino: Critically endangered.**
Asian Small-Clawed Otter **IUCN:** VU, **CITES:** Appx I	**Characteristics: Smallest otter species**, semi aquatic carnivorous mammal. **Distribution:** Native to South & SE Asia, found in Himalayan region, Western & Eastern Ghats in India.
Smooth coated Otter **IUCN:** VU, CITES: Appx I	**Characteristics:** Characterized by a very smooth, sleek pelage. They are strong swimmers and hunt in groups. **Distribution:** Is a freshwater otter that lives in South and Southeast Asia. In India, it can be found in major rivers south of the Himalayas. **Threats:** Loss of wetland habitat, poaching, water contamination by pesticides, etc.
Barasingha (Swamp Deer) **IUCN:** VU **CITES:** Appx I **[UPSC- 2013]**	**Characteristics:** Deer species native to the Indian subcontinent, state animal of MP and UP. **Distribution:** Isolated localities in north-east, north and central India, southwestern Nepal and famous in Kanha Tiger Reserve (MP). **Habitat:** Open forests, tall grasslands, mangroves.
Bonnet Macaque **IUCN:** VU, **CITES:** Appx II	**Characteristics:** Endemic macaque species found in southern India. **Distribution:** South of rivers Godavari and Tapti.

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Capped Langur **IUCN:** VU **CITES:** Appx I	**Characteristics:** Arboreal herbivore, the capped langur is named for the dark patch of fur on its head that resembles a cap. **Distribution:** Found in Bangladesh, Bhutan, India (NE India south of Brahmaputra River), Myanmar. **Habitat:** Subtropical, evergreen, deciduous, bamboo, sub-montane forests, teak plantations.
Clouded Leopard **IUCN:** VU **CITES:** Appx I	**Characteristics:** A medium-sized cat with a distinctive cloud-like coat , state animal of Meghalaya. **Distribution:** Bangladesh, Bhutan, China, India, Nepal, SE Asia. **Habitat:** Highest population density in Dampa Tiger Reserve (Mizoram). **Threats:** Habitat destruction, poaching, commercial wildlife trade.
Eastern Hoolock Gibbon **IUCN:** VU **CITES:** Appx I	**Characteristics:** One of three species of hoolock gibbons, inhabits dense forests **Distribution:** Myanmar (east of the Chindwin River).In India they are found in Dibang valley in Arunachal Pradesh and Sasiya reserve Forest in Assam. **Habitat:** Evergreen, scrub, semi-deciduous forests, mountainous broadleaf, pine forests.
Fishing Cat **IUCN:** VU **CITES:** Appx II	**Characteristics:** Medium-sized wild cat, adept swimmer, nocturnal and apart from fish also preys on frogs, crustaceans, snakes, birds, and scavenges on carcasses of larger animals. **Distribution:** Plains of Ganga, Yamuna, Brahmaputra, Sundarbans delta, coastal wetlands along Bay of Bengal, Chilika lagoon. **Habitat**: Wetlands, mangroves, rivers, streams.
Four-Horned Antelope **IUCN:** VU, **CITES:** Appx III	**Characteristics:** Antelope with four horns,smallest antelope in Asia. **Distribution:** Endemic to India and Nepal, found from foothills of the Himalayas to the Deccan Plateau in India.
Gaur/Indian bison **IUCN:** VU, **CITES:** Appx I	**Characteristics:** Largest among wild cattle and bovids, social animals. State animal of Goa and Bihar. **Distribution:** South Asia, SE Asia, parts of Himalayan foothills, NE India, Eastern Ghats, Western Ghats
Nilgiri Langur **IUCN:** VU **CITES:** Appx II	**Characteristics:** Endemic to Nilgiri Hills, Silent Valley NP **Distribution:** Western Ghats (Karnataka, Tamil Nadu, Kerala) **Habitat:** Evergreen, semi-evergreen, moist deciduous, montane evergreen forests **Threats:** Habitat loss, human encroachment.
Nilgiri Marten **IUCN:** VU **CITES:** Appx III	**Characteristics:** Diurnal, arboreal and social creatures. **Distribution:** Endemic to Western Ghats **Habitat:** Evergreen forests, montane forest-grasslands **Threats:** Habitat loss, hunting for fur.
Sambar **IUCN:** VU,	**Characteristics:** India's largest deer, with a dark brown coat and majestic antlers. **Distribution:** Found throughout India, except high Himalayas, Kutch desert and coastal regions. **Threats:** Habitat loss, poaching, etc.
Sloth Bear **IUCN:** VU, **CITES:** Appx I	**Characteristics:** Native to the subcontinent, found in various habitats **Distribution:** Terai of India, Nepal, Bhutan, Sri Lanka **Habitat:** Moist and dry tropical forests, savannahs, grasslands
Snow Leopard (Keystone and Flagship species) **IUCN:** VU, **CITES:** Appx I	**Characteristics:** Keystone, indicator species in high-altitude Himalayan ecosystem **Distribution:** Central and South Asian mountain ranges, including Himalayas **Habitat:** Alpine and subalpine zones. **Threats:** Poaching, habitat loss and fragmentation, etc.

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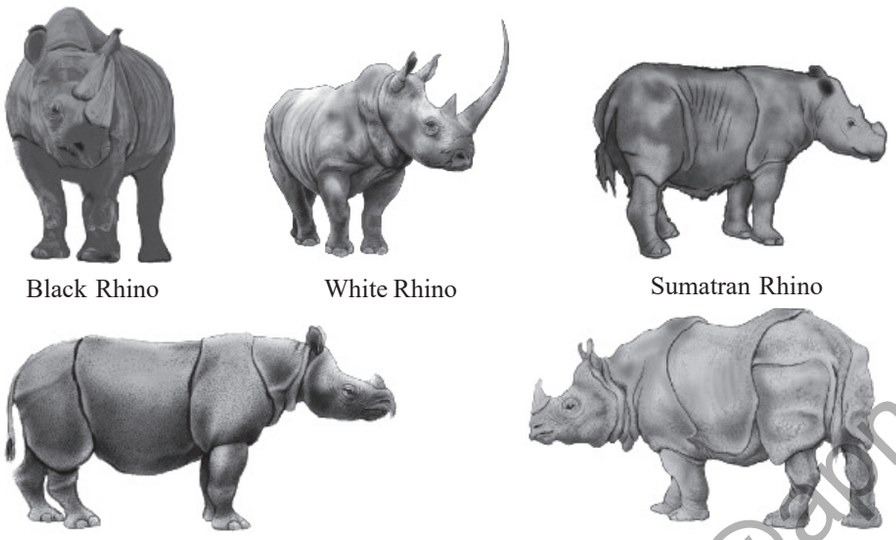
Stump-Tailed Macaque **IUCN:** VU, **CITES:** Appx II	**Characteristics:** Frugivore animals, with males bigger than females. **Distribution:** Native to South Asia, adept in various forest types. In India found in the region to the south of Brahmaputra river. **Habitat:** Tropical semi-evergreen, wet evergreen, moist deciduous forests

Types of Rhinos Found in the World



Black Rhino | White Rhino | Sumatran Rhino | Lesser One-Horned Rhino (Javan Rhino) | Greater One-Horned Rhino (Indian Rhino)

Fig. Rhinos of the World

Fig. Fishing Cat

Fig. Nilgiri Marten

MAMMALS – NEAR THREATENED (NT)

Species and Conservation Status	Features
Argali (Great Tibetan Sheep) **IUCN:** NT **CITES:** Appx II **CMS:** Appx II	**Characteristics:** World's largest wild sheep, native to Central Asia **Distribution:** East Asia, Himalayas, Tibet, Altai Mountains restricted in India to Ladakh, Hemis NP is famous. **Habitat:** Mountains, steppe valleys, rocky outcrops
Asiatic Golden Cat **IUCN: NT, CITES:** Appx I	**Characteristics:** Medium-sized wild cat with their furs ranging in color from cinnamon to various shades of brown, and also gray and black (melanistic). They are solitary and territorial. Once considered nocturnal, have now been found to be **diurnal and crepuscular.** In parts of China they are known as the 'rock cat'. **Distribution**:Native to Indian subcontinent, SE Asia, China. In India found in NE India, recently sighted in Buxa Tiger Reserve in West Bengal.
Grey Slender Loris **IUCN: NT, CITES:** Appx II	**Characteristics:** Small nocturnal primate, arboreal, omnivorous. **Distribution:** India and Sri Lanka, found in specific regions of India such as Eastern Ghats,Western Ghats etc. **Habitat**: Tropical rainforests, dry forests, various forest types. **Threat**: They face a threat from poachers due to the misplaced belief that these animals have magical and medicinal powers.
Chiru (Tibetan Antelope) **IUCN: NT** **CITES:** Appx I	**Characteristics:** Native to Tibetan plateau. Famous for its Shahtoosh wool. **Distribution:** Tibetan plateau; famous in Karakoram (Nubra Shyok) WLS, Changthang Cold Desert WLS in Ladakh **Habitat:** High altitude plains, hills, plateaus, alpine, desert steppe, meadows. **Threats:** Poaching for shahtoosh wool, climate change, etc. **[UPSC 2012]**

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Species and Conservation Status	Features
Grizzled Giant Squirrel **IUCN: NT** **CITES:** Appx II	**Characteristics:** Large tree squirrel, endemic to India and Sri Lanka **Distribution:** Kerala and Tamil Nadu, Southern India **Habitat:** Tropical dry deciduous and montane forests **Threats:** Habitat loss, hunting.
Himalayan Tahr **IUCN: NT**	**Characteristics:** Large ungulate, native to Himalayas **Distribution:** Himalayan region of India, Bhutan & Nepal
Indian Wild Ass/Khur [UPSC 2012] **IUCN: NT** **CITES:** Appx II	**Characteristics:** Subspecies of Asiatic wild ass, native to South Asia. **Distribution:** Western India, southern Pakistan, Afghanistan, Iran **Habitat:** Semi-desert, grassland areas.
Malayan Giant Squirrel **IUCN: NT**, **CITES:** Appx II	**Characteristics:** Large tree squirrel, native to Indo-Malayan zone **Distribution:** Bangladesh, NE India, Nepal, Bhutan, China, SE Asia
Rusty-Spotted Cat **IUCN: NT**, **CITES:** Appx I	**Characteristics:** One of the smallest cats **Distribution:** India (excluding West Bengal and North East India), Nepal (Terai region), Sri Lanka
Siberian Ibex **IUCN: NT**, **CITES:** Appx III	**Characteristics:** Wild goat species, native to Central Asia **Distribution:** North India (J&K, Ladakh, Himachal Pradesh), Pakistan, Russia, China, Central Asian countries

Fig. Argali

Fig. Siberian Ibex

Fig. Chiru

Fig. Grey Slender Loris

MAMMALS – LEAST CONCERN (LC)

Species and Conservation Status	Features
Blackbuck **IUCN:** LC, **CITES:** Appx III	**Characteristics:** Indian antelope species, one of the fastest running animals on earth and worshipped by the Bishnoi community. **Distribution:** India (found in Gujarat, Rajasthan, Punjab and Haryana); extinct in Bangladesh, Pakistan **Habitat:** Grasslands, scrublands, agricultural margins **Threats:** Habitat destruction, illegal hunting
Chinkara **IUCN:** LC,	**Characteristics:** Indian gazelle, six subspecies **Distribution:** Ganges Valley to Deccan Plateau, Thar Desert, Rann of Kutch
Chital **IUCN:** LC	**Characteristics:** Spotted deer species **Distribution:** Indian subcontinent (excluding high Himalayas, NW India) **Habitat:** Various habitats except dense evergreen forests, desert
Indian Flying Fox **IUCN:** LC, **CITES:** Appx III	**Characteristics:** Largest flying bat, nocturnal, feeds on fruits **Distribution:** Indian subcontinent

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Species and Conservation Status	Features
Indian Giant Flying Squirrel [UPSC 2024] **IUCN:** LC	**Characteristics:** Large flying squirrel. Many squirrels exhibit this behavior, known as **"caching"** to save food for future use. Indian squirrels primarily feed on fruits, nuts, and seeds but occasionally eat insects and small animals, making them omnivorous. **Distribution:** South Asia, SE Asia, patchy in Bangladesh, India, Sri Lanka **Habitat:** Deciduous and evergreen forests, plantations.
Rhesus Monkey **IUCN:** LC, **CITES:** Appx II	Hanuman langur is Gray langur distributed throughout India except NE India while Rhesus macaque occurs north of Godavari. In south of Godavari, it is replaced by Bonnet macaque.

OTHER MAMMALS

Species	Conservation Status & Features
Black Panther	**Characteristics:** Melanistic color variant of leopard or jaguar. **Distribution:** Found in Kabini WLS along the river Kabini.
Himalayan Wolf	**Characteristics:** Native to the Himalayas and the Tibetan Plateau. **Distribution:** Ladakh, Lahaul and Spiti (Himachal Pradesh), Uttarakhand. **Threats:** Climate change, killing by humans to protect their cattle.
Pangolin Two species in India: • Chinese Pangolin: **IUCN:** CR • Indian Pangolin: **IUCN:** EN	**Characteristics:** Nocturnal scaly-skinned insectivorous mammal; most trafficked mammal. **Threats:** Trafficking, hunting (meat and scales), habitat loss (mining, quarrying, agriculture).
Pig-Tailed Macaque	**Northern Pig-tailed Macaque (VU)** **Distribution**: Bangladesh, China, NE India, mainland SE Asia. **Habitat:** Tropical forests, coastal forest, swamp forest, montane forest. **IUCN**: VU | **CITES:** Appx II |
	Southern Pig-tailed Macaque (EN) **Distribution:** Maritime SE Asia (Thailand, Malaysia, Indonesia). **Habitat:** Mostly in rainforest, but also in plantations and gardens. **IUCN:** EN | **CITES:** Appx II
Porcupine **IUCN**: LC	**Indian Crested Porcupine (LC)** **Distribution:** North-west, entire Southern India. **Habitat:** Broad array of natural habitats, including plantations and gardens.
	Malayan Porcupine (LC) **Distribution:** Nepal, NE India, Bangladesh, China, SE Asia. **Habitat:** Various forest habitats, including agricultural areas. **Threats:** Indian Crested Porcupine is considered an agricultural pest and is trapped.

Fig. Pangolin

Fig. Porcupine

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MARINE MAMMALS

Species and Conservation Status	Features
Dugong (Sea Cow) **[UPSC 2013, 2015]** **IUCN:** VU **CITES:** Appx I **CMS**: Appx II	**Characteristics:** Herbivorous marine mammal, one of four living species of Sea cows. **Distribution:** East Africa, South Asia, SE Asia, East Asia, Australia and found in India in Palk Bay, Gulf of Mannar, Andaman and Nicobar Islands, Gulf of Kutch. **Threats:** Habitat loss (seagrass bed decline), hunting, marine pollution, etc.
River Dolphins **Major species:** • **Indus River Dolphin/ Bhulan (EN)** • **Ganges River Dolphin/Susu (EN)** **[UPSC 2014]** • **Irrawaddy River dolphin (EN)** • **Yangtze River Dolphin (CR)** • **Tucuxi River Dolphin (EN)** • **Amazon River Dolphin/Boto (EN)**	**Characteristics:** Dolphins are marine mammals. They surface to breathe air and give birth to live young. The gestation period of a dolphin lasts between 9 and 16 months. Dolphins make use of echolocation to navigate and hunt in the ocean. **Distribution:** River dolphins are found in the tropical and subtropical rivers of South America and Asia, as well as the coastal waters of Brazil, Argentina, and Uruguay. **In India, the distribution of river dolphins is as follows:** Ganges River Dolphin (National Aquatic Animal of india. **[UPSC 2015]** — The Ganga, Brahmaputra, Kosi, Karnaphuli, Sangu, and Karnali rivers. Indus River Dolphin — River Beas in India. Irrawaddy River Dolphin — Coastal areas like Lake Chilika, Bhitarkanika, Gahirmatha, Bay of Bengal, etc. **Threats:** Fishing, pollution, dams, habitat loss are causes for declining dolphin population.

DEER SPECIES IN INDIA

- India has the distinction of having the largest number of deer species in the world.
- Deer species of central India are known for their large size and big antlers. Whereas the species found in Eastern and Southern India have antlers smaller in size.

IMPORTANT DEER SPECIES IN INDIA

Deer	IUCN Status	State Animal	Distribution
Hangul/Kashmir Stag	Critically Endangered	Jammu & Kashmir	Dachigam and areas above Srinagar in Kashmir Valley.
Hog Deer	Endangered	–	Alluvial grasslands of Terai from Corbett to Assam.
Thamin/Eld's Deer/ Sangai/Brow-Antlered Deer	Endangered	Manipur	Loktak Lake, Manipur.
Chital/Spotted Deer	Least Concern	Telangana	Widely distributed in India except the Northeast.
Swamp Deer/Barasingha	Vulnerable	Madhya Pradesh, Uttar Pradesh	Terai region of UP (swamp), Madhya Pradesh (hard ground).
Musk Deer (Himalayan/ Alpine)	Endangered	Uttarakhand	Found in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh.
Sambhar	Vulnerable	Odisha	Across India: Himalayas, South India, Rajasthan, Northeast.

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BIRDS – CRITICALLY ENDANGERED (CR)

Species and Conservation Status	Features
Baer's Pochard **IUCN:** CR, **CMS:** Appx II	**Characteristics:** Freshwater diving duck in eastern Asia. **Distribution:** South Asia and mainland SE Asia; found in NE India, WB, Odisha, and terai areas. **Threat:** Habitat loss and degradation, Drainage of wetlands for agriculture and rice cultivation is a major threat to the Baer's pochard's habitat.
Bengal Florican **IUCN:** CR **CITES:** Appx I	**Characteristics:** Rare bustard known for mating dance. **Habitat:** Grasslands interspersed with scrublands. **Distribution:** Native to the Indian subcontinent, Cambodia, and Vietnam. In India found in the states of Assam, Arunachal Pradesh and UP.
Black-Naped Pheasant Pigeon **IUCN:** CR	**Characteristics:** Feeds on seeds and fallen fruits. Recently sighted after 140 years in Papua New Guinea. **Distribution:** Large, terrestrial pigeon endemic to Fergusson Island (Papua New Guinea).
Bugun Liocichla **IUCN:** CR	**Characteristics:** Discovered in 2006; named in honor of Bugun community in West Kameng district. **Distribution:** Endemic to Arunachal Pradesh; Eaglenest WLS famous for it.
Great Indian Bustard aka Godawan (UPSC 2012) **IUCN:** CR **CITES:** Appx I **CMS:** Appx I	**Characteristics:** Heaviest flying bird in the world; omnivorous flagship grassland species. **Distribution:** Native to Indian subcontinent, with the majority in Rajasthan. Also found in states of Gujarat, Maharashtra, MP, Andhra Pradesh, etc. **Mascot for the 13th COP of CMS in India (2020).** **Threats:** Collision with power lines, habitat loss, poaching are important threats
Himalayan Quail **IUCN:** CR	**Characteristics:** Last sighted before 1877; feared to be extinct. **Distribution:** Found only in Uttarakhand.
Jerdon's Courser **IUCN:** CR	**Characteristics:** Considered extinct until rediscovery in 1986. **Distribution:** Endemic to Eastern Ghats (Andhra Pradesh, Telangana). **Habitat:** Scrub jungles of Sri Lankamaleswara WLS.
Pink Headed Duck **IUCN:** CR **CITES:** Appx I	**Characteristics:** Last sighted in 1949; feared to be extinct. **Distribution:** Recorded in India & Myanmar.
Siberian Crane **IUCN:** CR **CITES:** Appx I **CMS:** Appx I	**Characteristics:** World's third rarest crane species; migrates to India during winter. **Distribution:** Resident of East and Central Asian Russia; migrates to India. **Habitat:** Most aquatic among crane species; wetlands. **Threats:** Pesticide pollution, habitat loss, hunting.
Sociable Lapwing **IUCN:** CR **CMS**: Appx I	**Characteristics:** Rarest and most threatened bird on Eurasian steppes. **Distribution:** Found in Central Asian countries; migrates to Sudan, Pakistan, North India during winter. **Habitat:** Dry grasslands, steppes, temperate deserts.
Spoon Billed Sandpiper **IUCN:** CR,**CMS**: Appx I	**Characteristics:** Known for spatula-shaped bill. **Distribution:** Breeds in Russia; migrates to South Asia and mainland SE Asia. In India found around coastal states of West Bengal, Odisha, Tamil nadu, etc. **Habitat:** Found in lagoon spits, estuaries and mudflats.
White-Bellied Heron **IUCN:** CR	**Characteristics:** Second largest heron species; brownish grey. **Distribution:** Found in India (Arunachal Pradesh, Assam), NE Bangladesh, Bhutan. **Habitat:** Inland swamp forests, forested rivers, submontane grasslands.

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Yellow-Breasted Bunting **IUCN:** CR	**Distribution:** Breeds in Finland to Bering Sea; migrates to South Asia, SE Asia during winter. **Habitat:** Wet meadows with tall vegetation, scattered scrub, cultivated fields, and grasslands.
Vultures Species in India: • **White rumped vulture (CR)** • **Slender billed vulture (CR)** • **Red headed vulture (CR)** • **Indian vulture (CR)** • **Egyptian vulture (EN)** • **Bearded vulture (NT)** • **Cinereous Vulture (NT)** • **Himalayan Vulture (NT)** • **Griffon vulture (LC)**	**Characteristics:** Vultures are a group of scavenging birds of prey that play a crucial ecological role by cleaning up carcasses and preventing the spread of disease. They belong to two groups: the Old World vultures found in Africa, Asia, and Europe, and the New World vultures found in the Americas. **Distribution:** Vultures are distributed across India in a variety of habitats, including grasslands, forests, open fields, and near garbage dumps and slaughterhouses: • **Indian Vulture:** Breeds in peninsular India south of the Gangetic plain, and is also found in southeast Pakistan, Bangladesh, and Nepal. • **Slender-billed Vulture:** Found in the northern parts of India, including the sub-Himalayan regions and the Gangetic plains. These vultures are characterized by their long, slender necks and dark, thin bills. • **White-rumped Vulture:** Found in Panchkula, Haryana. • **Eurasian Griffon:** Found in Surendranagar, Gujarat. • **Egyptian Vulture:** Found in Bikaner, Rajasthan. • **Cinereous Vulture:** Found in Bikaner, Rajasthan. • **Bearded Vulture:** Found in Leh, Ladakh **Threats:** Loss of Natural Habitats, Food Scarcity and Contamination: Vultures face challenges related to food scarcity, and the available food sources are often contaminated. Pollution and the presence of harmful substances in their food contribute to health issues. and electrocution from Power Lines are causes of decline in the vulture population.

Fig. Himalayan Quail

Fig. Nicobar Megapode

Fig. Yellow breasted Bunting

Fig. Indian Skimmer

Fig. Jerdon Courser

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OTHER IMPORTANT BIRDS

Species and Conservation Status	Features
Great Indian Hornbill [UPSC-2016] **IUCN:** VU **CITES:** Appx I	**Characteristics:** Largest hornbill in India; state bird of Arunachal Pradesh and Kerala. **Distribution:** Native to Indian Subcontinent, SE Asia, China; in India - North-east India and Western Ghats. **Habitat:** Tropical evergreen forests.
Indian Skimmer **IUCN:** EN **CITES:** Appx I **CMS:** Appx II	**Characteristics:** One of the three species in the skimmer genus. **Distribution:** Major rivers of the Indian Subcontinent and Indo-China.

Nicobar Megapode **IUCN**: VU (Vulnerable)	**Characteristics:** Builds large mound nests with soil and vegetation and eggs hatched by heat from decomposition. **Distribution:** Endemic to Nicobar Islands. **Habitat:** Coastal forests.
River Tern **IUCN:** VU	**Characteristics:** Found along inland rivers in Iran, Afghanistan, Indian Subcontinent, SE Asia. **Habitat:** Rivers and freshwater lakes. **Threats:** Hunting, pollution, invasive species.
Sarus Crane **IUCN:** VU **CITES:** Appx II	**Characteristics:** Large nonmigratory crane; tallest flying bird in the world. **Distribution:** Indian subcontinent, SE Asia, Australia; in India - Himalayan foothills, Northwest India, Central India. **Habitat:** Open wet & dry grasslands, agricultural fields.
Black Necked Crane **[UPSC 2014]** **IUCN:** NT **CITES:** Appx I **CMS:** Appx I	**Characteristics:** State bird of UT of Ladakh; native to Ladakh, Sichuan, Tibet; migrates to Arunachal Pradesh and Bhutan during winters. **Habitat:** Inland grassy wetlands at high elevation.
Painted Stork **[UPSC 2014]** **IUCN:** NT	**Characteristics:** Large shore bird endemic to Indian subcontinent and SE Asia. **Distribution:** River plains of Indian subcontinent, mainland SE Asia. **Habitat:** Freshwater marshes, lakes, reservoirs, flooded fields, river banks, etc. **Threats:** Hunting, pollution, invasive species.
Common Hill Myna **[UPSC 2014]** **IUCN:** LC **CITES:** Appx II	**Characteristics:** Native to eastern India, mainland SE Asia; state bird of Chattisgarh. **Habitat:** Evergreen and wet deciduous forests; prefers areas with high rainfall and humidity. **Threats:** Overexploitation for pet trade.
Greater Flamingo **IUCN:** LC **CITES:** Appx II	**Characteristics:** Most widespread and largest flamingo species. **Distribution:** Africa, Indian subcontinent, Middle East, southern Europe; in India - almost all over (except high-altitude areas, East and NE India). **Habitat:** Shallow eutrophic waterbodies such as saline lagoons, saltpans, saline or alkaline lakes.
Himalayan Bulbul **IUCN:** LC	**Characteristics:** Songbird in the bulbul family. **Distribution:** Endemic to the Himalayan region of the Indian subcontinent.

Fig. River Tern

Fig. Painted Stork

FISHES

Species and Conservation Status	Features
Ganges Shark **IUCN:** CR	**Characteristics:** Freshwater shark **Distribution:** Endemic to India, Bangladesh, also found in Myanmar, Malaysia, Indonesia

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Species and Conservation Status	Features
Humpback Mahseer **IUCN:** CR	**Characteristics:** Large freshwater fish, endemic to Cauvery River basin **Distribution:** Cauvery River basin, Western Ghats **Threat**: Habitat loss, overfishing, and pollution.
Golden Mahseer **[UPSC 2022]** **IUCN:** Endangered (EN)	**Characteristics:** Large golden-colored fish, tough sport fish **Distribution:** Basins of Indus, Ganges, Brahmaputra rivers **Threat**: Habitat loss, overfishing, and pollution, dam construction etc.
Magur **IUCN:** Endangered (EN)	**Characteristics:** Walking catfish endemic to India, Nepal, and Bangladesh **Habitat:** Freshwater, brackish water, flooded rice fields
Blue Finned Mahseer **[UPSC 2019]** **IUCN:**Least Concern (LC)	**Characteristics:** Large freshwater fish, also known as Black or Deccan Mahseer **Distribution:** Deccan Peninsula, Sri Lanka and Cauvery river. **Habitat:** Prefers cool, fast-flowing, rocky streams, also found in rivers, lakes, reservoirs
Helicopter Catfish **IUCN:** Vulnerable (VU)	**Characteristics:** Freshwater catfish native to South and SE Asia **Distribution:** South and SE Asia **Habitat:** Freshwater bodies, tidal waters

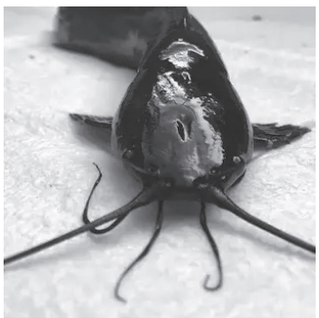

Fig. Magur Walking Catfish

Fig. Golden Mahseer

REPTILES

Species and Conservation Status	Features
Gharial **IUCN: Critically Endangered (CR)** Other important crocodiles: **Mugger (VU)** **Salt Water Crocodile (LC)**	**Characteristics:** Gharial is characterised by its long, slender snout with sharp interlocking teeth, adapted for catching fish. Adult males have a bulbous growth, called a "ghara," on the snout tip, used for vocalization and attracting mates. **Distribution:** Gharials inhabit deep, fast-flowing rivers like Chambal, Son, Gandak, Ghaghara etc in northern India and Nepal. They primarily bask on sandy riverbanks and lay eggs in burrows. **Threats:** Habitat loss, pollution, and fishing net entanglements.
Hawksbill Turtle **IUCN: Critically Endangered (CR)** **CITES:** Appx 1	**Characteristics:** The hawksbill turtle is marine turtle known for its striking, overlapping amber-colored scales on its heart-shaped shell, prized for "tortoiseshell" products. It feeds on sponges, algae, and other invertebrates, playing a crucial role in maintaining coral reef health. **Distribution:** Hawksbills are found in tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans, often near coral reefs, lagoons, and rocky coastlines. In India they are found in Andaman and Nicobar Islands. **Threat:** Loss of nesting and feeding habitats, excessive egg collection, fishery-related mortality, pollution,wildlife trade and coastal development.

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Species and Conservation Status	Features
Olive Ridley Turtle **IUCN: Critically Endangered (VU)** **CITES:** Appx 1	**Characteristics:** It is a small to medium-sized marine turtle known for its olive-green, heart-shaped shell. It is best recognized for its unique mass nesting behavior called "arribada," where thousands of females come ashore simultaneously to lay eggs. They are highly migratory, traveling vast distances between feeding and nesting grounds. **Distribution:** Found in warm, tropical oceans waters. In India,they are primarily found along the eastern coast, with major nesting sites in Odisha at Gahirmatha Beach, Rushikulya, and Devi River Mouth. Other important nesting areas include Andhra Pradesh (Kakinada and Krishna estuary), Tamil Nadu (Chennai coast and Nagapattinam), and sporadically in the Sundarbans of West Bengal. **Threats:** habitat loss from coastal development, bycatch in fishing nets, marine pollution, and illegal egg poaching.
Asian Giant Tortoise **IUCN: Critically Endangered (CR)**	**Characteristics**: Largest tortoises in mainland Asia **Distribution:** Found in Bangladesh, India, Indonesia, Malaysia.
Star Tortoise **IUCN:** Vulnerable (VU)	**Characteristics:** Medium-sized tortoise species **Habitat:** Parts of India below West Bengal and Gujarat

PLANTS

Species and Conservation Status	Features
Indian Rosewood **IUCN:** Vulnerable (VU)	**Characteristics:** Large evergreen tree native to low-elevation monsoon forests of south India. Drier subpopulations are deciduous. **Distribution:** Native to India (Tamil Nadu, Karnataka, Andhra Pradesh, Uttar Pradesh, and Sikkim)
North Indian Rosewood **IUCN:** Least Concern (LC)	**Characteristics:** Fast-growing, hardy, medium to large deciduous tree native to the foothills of the Himalayas. **Distribution:** Native to the Indian subcontinent and southern Iran. Endemic to tropical Himalayas.
Red Sanders (EN) **[UPSC-2016]**	**Characteristics:** Red sanders, also known as red sandalwood, is a rare and valuable deciduous tree. It is renowned for its dark reddish heartwood, prized for its rich color, durability, and use in high-value items like musical instruments, furniture, and traditional medicine. **Distribution:** It is endemic to the southern Eastern Ghats of India. Red sanders thrive in dry, rocky soils and semi-arid climates. **Threat:** Overexploitation for its wood, combined with habitat loss
Sandalwood (EN)	**Characteristics:** Sandalwood is a highly valued evergreen tree known for its fragrant, durable heartwood. It is renowned for its aromatic heartwood, which is used in perfumes, incense, and traditional medicines. Its essential oil is known for its soothing, anti-inflammatory properties. **Distribution:** It thrives in dry, well-drained soils, predominantly in India, Australia, and parts of Southeast Asia. In India it is found in most parts of Karnataka, Maharashtra, Andhra Pradesh, etc. **Threat:** Overharvesting and illegal logging

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Schedule III of WPA after The Wild Life (Protection) Amendment Act, 2022 - Plant	Scientific Name	Common Name
	1. Strobilanthes kunthianus	Neelakurinji
	2. Coptis teeta	Gold threat, Mishmi teeta
	3. Coscinium fenestration	Tree turmeric
	4. Taxus wallichiana	Himalayan Yew
	5. Vanda coerulea	Blue vanda
	6. Nepenthes khasiana	Pitcher plant
	7. Renanthera imootiana	Red vanda
	8. Ipsea malabarica	Daffodil orchid
	9. Podophyllum hexandrum	Indian podohyllum
	10. Dolomiaea costus	Kuth

NATIVE WILDLIFE OF PROMINENT COUNTRIES [UPSC 2012]

Country	Species Naturally Found
India	Black-necked Crane, Flying Squirrel, Snow Leopard, Indian Elephant, Bengal Tiger.
Australia	Kangaroo, Koala, Tasmanian Devil, Emu, Platypus.
Brazil	Jaguar, Giant Anteater, Capybara, Howler Monkey, Sloth.
United States	American Bison, Bald Eagle, Grizzly Bear, Prairie Dog.
South Africa	African Elephant, White Rhino, Leopard, Meerkat, Springbok.

INVASIVE SPECIES

Invasive Plant Species

Invasive plant species are non-native plants that spread rapidly in new environments, outcompeting native vegetation and disrupting ecosystems.

- **Acacia**
  - Evergreen drought-resistant plant native to Africa and Australasia.
  - Long root system for water and thorny leaves to prevent water loss.
  - Rapid reproduction forming a canopy, preventing growth of other species.
  - Used for tannin production, contributing to habitat destruction in the Western Ghats.
- **Billygoat Weed**
  - Native to Tropical America, medicinal properties, but invasive outside its native range.
  - Considered a moderate weed in rice cultivation in Asia.
- **Carrot Grass (Congress Grass)**
  - Native to the American tropics, invasive in India, Australia, and parts of Africa.
  - Produces allelopathic chemicals that suppress crop and pasture plants.
  - Releases allergens causing allergies in humans and domestic animals.
- **Eucalyptus**
  - Fast-growing evergreen tree native to Australia.
  - Medicinal properties, acts as an insect repellent.
  - Invasive species outside its native range, rapidly reproduces, impacting native fauna.
- **Forked Fanwort**
  - Pink flowering submerged aquatic plant native to South America.
  - Invasive species in freshwater, commonly used in aquariums, displacing native aquatic plants.
- **Lantana**
  - Flowering plant native to the American tropics, invasive once introduced into habitats.
  - Rapid spread, outcompetes native species, reduces biodiversity, and affects pastures and crops.
  - Toxicity affects livestock, poisonous when consumed.
- **Mexican Prickly Poppy**
  - Herb tolerant to drought and poor soil, naturalized widely outside Mexico.
  - Grows along roadsides, fallow lands, and cultivated areas, competing with native species.
  - Seeds resemble mustard seeds, used in adulteration, rendering mustard poisonous.

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- **Mikania Micrantha**
  - Tropical perennial creeper native to the Americas, invasive weed in high humidity regions.
  - Medicinal properties, but grows vigorously, suppressing the growth of various plant species.
- **Prosopis Juliflora (Ganda Babool)** **[UPSC 2018]**
  - Small tree native to Mexico, invasive in Africa, Asia, Australia, and more.
  - Rapid growth depletes water resources, prevents the growth of native species, and hampers animal movement.
  - Introduced in Banni grasslands, causing water depletion, aggravating droughts, and affecting pastures.
- **Water Hyacinth**
  - Native to South America, water hyacinth is a free-floating perennial hydrophyte found in tropical, subtropical, temperate, and rainforest zones.
  - Invasiveness: It's an invasive species worldwide, including regions like Bangladesh (known as 'German Weed'), South Africa ('Florida Devil'), and Sri Lanka ('Japanese Trouble'). Its rapid growth and reproduction cover ponds and lakes, depleting oxygen and harming aquatic biodiversity, especially in human-affected water bodies.

Sea Buckthorn **[UPSC-2012]**

- Found in Ladakh, has received GI tag.
- **Soil Erosion and Desertification:** The plant's deep and extensive root system helps control soil erosion and combats desertification.
- **Adaptability:** Grows in cold, high-altitude regions like the Himalayas, thriving in arid and challenging environments.
- **Nutritional Value:** Rich in vitamins (especially Vitamin C) and antioxidants, making its fruit highly nutritious and beneficial.

Nostoc: A Biofertilizer **[UPSC-2013]**

- **Type**: Cyanobacterium (Blue-Green Algae).
- **Role**: Capable of nitrogen fixation, converting atmospheric nitrogen into a form usable by plants.
- **Benefits**: Enhances soil fertility, particularly in paddy fields and other nutrient-deficient soils.
- **Ecological Significance**: Supports sustainable agriculture by reducing the need for chemical nitrogen fertilizers

Birds in India

- Ceylon Frogmouth, Coppersmith Barbet, Gray-chinned Minivet, White-throated Redstart **[UPSC 2020]**

Notable Insects in Indian Biodiversity

- Cicada, Froghopper and Pond skate **[UPSC 2024]**

Animals with Defensive Rolling Behavior **[UPSC 2024]**

- **Hedgehog:** Rolls up to protect its vulnerable parts with spines.
- **Marmot:** Does not roll up; instead, it relies on burrowing for safety.
- **Pangolin:** Rolls up into a ball, protecting itself with hard scales.

Filter Feeder **[UPSC 2021]**

- A filter feeder that extracts nutrients from water by filtering out plankton and organic particles.

Example: Oysters and others shown below.

Basking shark

Whale shark

Baleen shales

Greater Flamingos

Sandcastle worm

Poisonous Species Among Butterflies, Fish, and Frogs **[UPSC 2024]**

- **Butterflies:** Some species, like the Monarch butterfly, are toxic due to the consumption of poisonous plants (milkweed) during the caterpillar stage.
- **Fish:** Several species, such as Pufferfish, are highly poisonous due to the presence of tetrodotoxin.
- **Frogs:** Poison dart frogs are known for their potent toxins, used as a defense mechanism.

Invasive Fish and Amphibian Species

- **African Catfish**
  - **Species:** Nocturnal air breathing catfish native to Africa and the Middle East.
  - **Habitat:** Thrives in freshwater lakes, rivers, and swamps, adapting to turbid, low-oxygen waters. Illegally bred in polluted ponds and lakes.
  - **Threat:** A voracious carnivore, it endangers indigenous fish species, prompting the Central government to ban catfish farming (breeding, transportation, and sale) in 2000 due to health and environmental hazards.
- **Indian Bullfrog**
  - **Species:** Large fork-tongued frog prevalent in South and SE Asia.

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- **Distribution:** Introduced to Maldives, Madagascar, and India's Andaman Islands.
- **Threat:** To native wildlife, including fish, lizards, and frogs. Its invasive nature makes it a concern for biodiversity conservation efforts.

IMPORTANT TREES AND THEIR CHARACTERISTICS [UPSC 2014, 2021, 2022]

Aspect	Palm	Moringa (Drumstick Tree)	Tamarind Tree	Neem Tree	Gucchi
Native Region	• Not native to Southeast Asia; originally from West Africa.	• Native to India and Africa.	• Native to tropical Africa, not endemic to South Asia.	• Native to the Indian subcontinent.	• Found in Himalayan forest areas.
Industrial Uses	• Raw material for industries producing lipstick and perfumes. • Used in biodiesel production.	• Seeds used in biofuel production. • Leaves, pods, and seeds have nutritional and medicinal uses.	• Tamarind is collected as minor forest produce in India. • Seeds used for biofuels.	• Neem oil used as a pesticide. • Seeds used for biofuels. • Oil used in hospital detergents and pharmaceuticals.	• Gucchi is a high-value edible fungus used in gourmet cuisine; not commercially cultivated.
Environmental Importance	• Widespread plantation impacts biodiversity.	• Fast-growing tree with drought resistance.	• Tamarind trees contribute to forest ecosystems.	• Eco-friendly alternative to chemical pesticides.	• Promotes forest ecosystem health; grows naturally without human intervention.
Export Potential	• Major exporter globally (India imports palm oil).	• India exports seeds and pods.	• India exports tamarind and seeds.	• Limited export relevance; primarily local applications.	• Highly valued in international markets for its flavor and rarity.
Additional Notes	• Extensively used in food and cosmetic industries globally.	• Popular in agroforestry for its economic and ecological benefits.	• Widely used in traditional Indian cuisine.	• Multifunctional tree with environmental, medicinal, and industrial applications.	• Grows in Himalayan forests; collection is labor-intensive, contributing to its high price.

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10 Protected Area Network of India

- Protected Area (PA) has been **defined in the Wildlife (Protection) Act, 1972**. Protected Areas under WPA 1972 include **national parks(NP), wildlife sanctuaries (WLS), conservation reserves (CnRs) and community reserves (CmR)**.

TYPES OF PROTECTED AREAS

Difference between National Park and Wildlife sanctuary

Feature	National Park	Wildlife Sanctuary
Purpose	Protect ecosystems and biodiversity	Protect specific species and their habitats
Human Activity	Strictly prohibited	Limited activities like grazing may be allowed by the chief wildlife warden
Boundaries	Clearly defined and strictly regulated. Can be altered only on approval by NBWL.	Not always well-defined or strictly regulated. Can be altered only on approval by NBWL. A WLS can be larger than NP in terms of area.
Conversion	National Park can not be converted into a wildlife sanctuary.	Wildlife sanctuary can be converted into a National Park.
Declaration	By State and Central Government both.	By state and Central Government both.

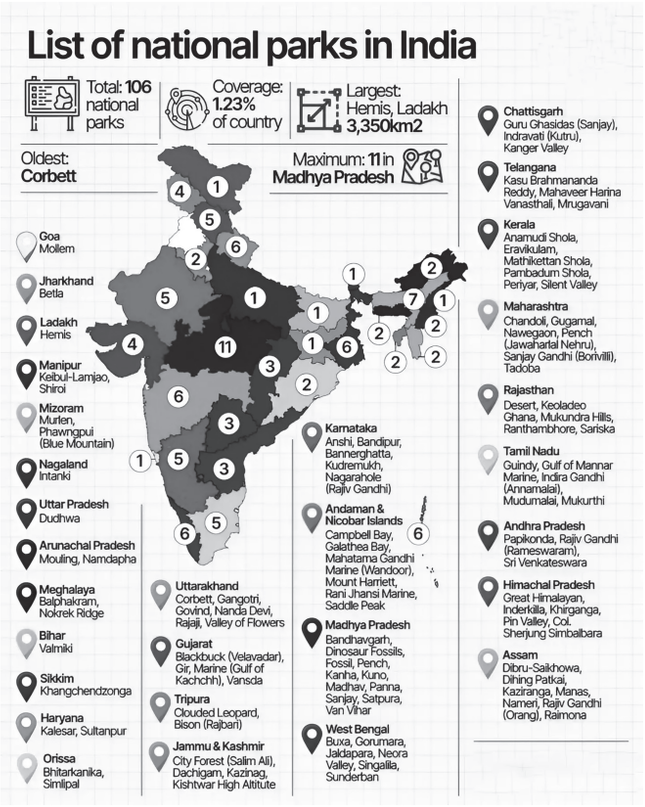
In addition to National Parks and Wildlife sanctuaries, WPA 1972 also recognises protected areas like community reserves and conservation reserves.

NATIONAL PARKS OF INDIA

There are 106 existing national parks in India covering an area of 44,402.95 km2, which is 1.35% of the geographical area of the country (National Wildlife Database)

Facts about India's National Parks

- **Largest National Park in India:** Hemis NP (Ladakh) UT of Ladakh
- **Smallest National Park in India:** South Button Island NP Andaman & Nicobar
- **State with largest % of area under National Parks:** Sikkim (25.14%)
- **State with smallest % of area under National Parks:** Telangana (0.02%)
- **Punjab** is the only Indian state that does not have a national park. UTs of Delhi, Puducherry, Chandigarh, Dadra and Nagar Haveli, and Lakshadweep also do not have a national park.



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STATE WISE LIST OF NATIONAL PARKS

Andaman & Nicobar Island (9)

1. Mahatma Gandhi Marine (Wandoor) NP

- Located in **South Andaman**.
- Most of the coral reefs in the park are **fringing reefs**.

2. Campbell Bay & Galathea Bay NP

- **Part of the Great Nicobar BR.**
- Galathea NP - **southernmost NP of India.**
- **Vegetation:** Tropical evergreen & semi-evergreen forests.
- **Major Fauna:** Giant robber crab, megapode, Nicobar pigeon and turtle species (Hawksbill, Olive Ridley, Leatherback, Malayan box and Giant Leatherback).

3. Mount Manipur (Harriet) NP

- **Third-highest peak in the A&N archipelago**, located near Port Blair in **South Andaman**.
- Previously known as Mount Harriet, **renamed** in honour of Manipur's freedom fighters who were imprisoned there.
- **Vegetation:** Tropical evergreen, hilltop tropical evergreen and littoral forests.
- **Major Fauna: Butterfly hotspot.**

4. Rani Jhansi Marine NP

- **Location:** Ritchie's Archipelago, **South Andaman.** It lies in the vicinity of Button Islands.
- **Vegetation:** Mangroves and evergreen forests.
- **Major Terrestrial Fauna:** Spotted deer, water lizards and monitor lizards, **fruit-eating bats**.
- **Major Marine Fauna:** Dugongs, dolphins, sea turtles, blue whales and corals.

5. Saddle Peak NP

- **The highest point of A&N Islands.**
- **Major Fauna:** Andaman wild pig, Andaman imperial pigeon, dolphins, whales and saltwater crocodile

6. Others

- **North Button** Island NP, **Middle Button** Island NP, **South Button** Island NP

Arunachal Pradesh(2)

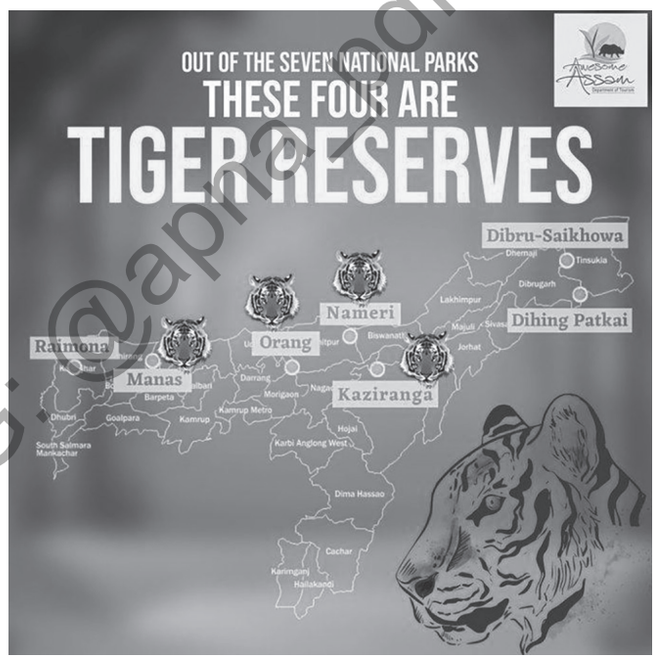
1. Mouling NP

- Named after Mouling Peak. **Mouling NP and Dibang WLS are located within Dihang-Dibang BR**.
- **Vegetation:** Tropical forests (at lower altitudes) to moist temperate forests (at higher altitudes).
- **Fauna:** clouded leopard, takin, red panda, capped langur, macaque, and several bird species.

2. Namdapha NP (also a TR) (UPSC-2015)

- **Location:** Between the **Dapha bum range** of the Mishmi Hills and the Patkai range, crossed by the **Noa Dihing River** which originates at Chaukan Pass, the **largest protected area in the Eastern Himalaya biodiversity hotspot**.
- **Vegetation:** Evergreen to temperate broadleaf forest.
- **It is the only park in the World to have the four Feline species of big cat, namely:** Tiger, Leopard, Snow Leopard and Clouded Leopard.
- It is famous for the **critically endangered Namdapha flying squirrel** which is endemic to the park.
- **Primates:** Stump-tailed macaque, slow loris, Western Hoolock gibbon **(the only 'ape' species found in India)**, capped langur, Assamese macaque and rhesus macaque.

Assam (7)



1. Nameri NP(TR)

- **Location:** Foothills of the Eastern Himalayas & Kameng River flows along its southern boundary. Its northern boundary is shared with the Pakke TR. It has **two core areas: Nameri NP & Sonai-Rupai WLS**.
- **Fauna:** Pygmy Hog, Royal Bengal Tiger, Indian Bison, Asiatic Elephant, Clouded Leopard, Wild Dog, Black Bear, Sambar and hog deer.

2. Raimona NP

- **Location:** Along the Himalayan foothills **together with Buxa TR of West Bengal and Phipsoo WLS and Jigme Singye Wangchuck NP of Bhutan**.
- Bounded by the **Sankosh River** on the west, the **Saralbhanga River** on the east, the Indo-Bhutan border on the north, and Ripu RF on the south.
- **Non-human Primates: Golden langur (EN) (endemic to the region; named as the mascot of Bodoland region)**.

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- **Major Avifauna:** White-bellied heron, Oriental darter, lesser adjutant, Bengal florican, hill myna.

3. Orang NP (TR)

- Lies on the **bank of the Brahmaputra River. Pachanoi River, Belsiri River and Dhanshiri River** border the park.
- The park, formed of alluvial flood plains, is an integral part of the **Indo-Burma hotspot of biodiversity**.
- **Vegetation:** Moist deciduous forest, swamp forest, wet alluvial and savannah grassland.

4. Dihing Patkai NP

- **Location:** Foothills of Patkai Hills & Dihing River flows through it.
- Also called **Jeypore Rainforest**, it harbours the largest stretch of lowland rainforests in India.
- **Fauna:** Chinese pangolin, flying fox, wild pig, sambar, barking deer, gaur, serow and Malayan giant squirrels.
- It has the **highest concentration of the White Winged Wood Duck (EN)**

5. Dibru-Saikhowa NP (also a BR)

- Bounded by the **Brahmaputra and Lohit Rivers** in the north and the Dibru River in the south.
- It is **famous for Feral horses**.
- **Vegetation:** Wet evergreen and semi-evergreen, deciduous, littoral and swamp forests.

6. Kaziranga NP (also a TR)

- Lies in the **Eastern Himalayan biodiversity hotspot** and the **Brahmaputra River** flows through the park.
- Hosting **2/3rd of the world's one-horned rhinoceroses**, it is a World Heritage Site, recognized as an **Important Bird Area** by BirdLife International.
- **Major Flora:** Speargrass, **elephant grass**, common reed, cotton tree, and elephant apple.
- **Major Fauna:** One-horned rhinoceros (VU), Royal Bengal Tiger, Asian elephant, wild water buffalo (EN) and swamp deer are collectively known as the '**Big Five' of Kaziranga**.

7. Manas NP (also a TR, ER,BR)

- **UNESCO Natural World Heritage site** located on the Himalayan Foothills, contiguous with the Royal Manas NP (Bhutan). **Manas River** passes through it.
- **Bhabar-terai region** with riverine succession makes it one of the richest areas of biodiversity.
- **Major Avifauna:** It has the **world's largest population of the endangered Bengal florican**. Other major bird species include great hornbills, pelicans, eagles, and herons.

Bihar(1)

1. Valmiki NP (TR, WLS)

- **Location:** Foothill ranges of Siwaliks at the Indo-Nepal border. **River Gandak** forms its western boundary. It is the **only NP in Bihar**.
- **The Harha-Masan River system** originates from the Valmiki NP and forms the Burhi Gandak River down south.
- **Vegetation:** Moist deciduous, semi-evergreen, freshwater swamps, alluvial grasslands, savannah and wetlands.
- **Major Fauna:** Bengal tiger, rhinoceros, Indian flying fox, black bear, sloth bear, leopard, barking deer, spotted deer, hog deer, sambar, clouded Leopard, Indian gaur.
- **'Tharu',** a scheduled tribe, is the dominant community

Chhattisgarh (3)

1. Sanjay (Guru Ghasidas) NP, Sanjay-Dubri TR

- **Location:** Chhattisgarh and Madhya Pradesh, it is **named after Guru Ghasidas of the Satnami sect**. Lies in the Narmada Valley and is a **part of the Sanjay-Dubri TR**.

2. Indravati NP (TR)

- It derives its name from the **Indravati River** that forms its **northern boundary**. It is **home to one of the last remaining populations of the wild water buffalo (EN)**.
- **Major Fauna:** Gaur, blackbuck, chausingha, sambar, chital, Indian muntjac, tigers, pangolins, rhesus monkeys.
- **Major Avifauna:** Common (Bastar) hill myna (LC).
- **Major Reptilian Fauna:** Freshwater crocodile.

3. Kanger Valley NP

- Home to the Bastar **Hill myna (LC)**, It derives its name from the **Kanger River** which flows through it. It has **limestone caves**.
- **Major Reptilian Fauna:** Freshwater crocodile

Goa (1)

1. Mollem NP and Bhagwan Mahaveer Sanctuary

- Located in the Western Ghats in Goa. **National Highway 4A** divides the park into two parts. It is home to waterfalls, such as **Dudhsagar Falls (on the Mandovi River**; it is Goa's tallest waterfall and India's 5th tallest) and **Tambdi Falls**.
- It is known for it's Leopards, Elephants, Deer & Gaur population.
- Home to a community of **nomadic buffalo herders** known as the **Dhangar**.

Gujarat (4)

1. Blackbuck (Velavadar) NP

- It is **bordered by the Gulf of Khambha**t on the south.
- **Vegetation:** Savanna grassland.
- **Major Fauna:** Blackbucks (LC), hyenas, jungle cats.

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2. Gir NP and WLS

- Gir NP (Sasan Gir) is near Talala Gir. Today, it is the **only area in Asia where Asiatic lions occur**. Kamleshwar Dam on **Hiran River** is called **'the lifeline of Gir'**.

3. Marine NP (Gulf of Kachchh)

- **Major Fauna:** Corals, sea turtles such as green sea turtles (EN), olive ridleys (VU) and leatherbacks (VU), dugongs (sea cow; VU), Indo-Pacific humpback dolphins.

4. Vansda (Bansda) NP

- Located on the b**anks of the Ambika River** in the Western Ghats.
- **Major Fauna:** Indian leopard, rhesus macaque, small Indian civet, chausingha, Indian (Malabar) giant squirrel.

Haryana (2)

1. Kalesar NP

- **Location:** Shivalik foothills. It is contiguous to Rajaji NP (Uttarakhand) and Simbalbara NP (Himachal Pradesh). It is bounded by the **Yamuna River** to the east.

2. Sultanpur NP

- It is a **Ramsar Site** located 15 km from Gurugram, the park is famous for **migratory birds**.

Himachal Pradesh (5)

1. Great Himalayan NP

- **Location:** the **Kullu Valley** (formed by Beas River).
- **It is at the junction of the world's two major biogeographic realms:** the Indomalayan realm to the south and the Palearctic realm to the north.
- It is a **UNESCO World Heritage Site**.
- **Vegetation:** Ranges from temperate to subalpine.
- **Major Flora:** Spruces, horse chestnuts, alpine meadows.
- **Major Fauna:** Bharal (blue sheep), snow leopard (VU), Himalayan brown bear,

2. Khirganga NP

- It is flanked by the **Great Himalayan NP and Pin Valley NP**.
- **Vegetation:** Dry alpine and scrub.

3. Pin Valley NP

- **Location:** within the Cold Desert BR in the Himalayan region. Pin River is a tributary of Spiti River

4. Others

- **Inderkilla NP; Simbalbara (Col. Sher Jung) NP**

Jammu & Kashmir (4)

1. City Forest (Salim Ali) NP

- **Major Fauna:** Kashmiri stag (hangul) (CR), musk deer (EN), Himalayan black bear.
- **Major Avifauna:** Paradise flycatcher, Himalayan monal, and Himalayan snowcock.

Salim Ali (1896-1987): Salim Ali, an Indian ornithologist, was the first Indian to conduct systematic bird surveys across India. He was a key figure behind the Bombay Natural History Society and the creation of the Bharatpur BS (Keoladeo NP).

2. Dachigam NP

- **Location:** Zabarwan Range of Western Himalayas.
- **Vegetation:** Coniferous forest, alpine pastures, meadows, and scrub vegetation.

3. Kishtwar NP

- Bounded to the north by the Rinnay River, south by the Kibar Nala catchment, east by the main divide of the Great Himalayas, and west by the Marwah River.
- **Vegetation:** Conifer forests, alpine scrub, and meadows.
- **Major Fauna:** Snow Leopards, Himalayan snowcock.

4. Kazinag NP

- Kazinag National Park is a national park in Baramulla city of the Baramulla district in the Indian union territory of Jammu and Kashmir notified under Wild Life Protection Act 1972. It is part of a proposal for a trans-Karakoram peace park with Pakistan.

Ladakh (1)

1. Hemis NP

- **Location:** Within the Palearctic realm. It is the **only NP in India that is to the north of the Greater Himalayas**.
- Bounded on the north by the Indus River, and on the south by the Zanskar Range.
- It is the **2nd largest contiguous protected area, after the Nanda Devi BR** and is famous for snow leopards. It is the o**nly refuge in India for the Shapu (Ladakhi Urial)**.

Jharkhand (1)

1. Betla NP

- **Location:** Chota Nagpur Plateau. North Koel River (a tributary of Son River) flows through the park.
- **Betla NP = Palamu TR + Mahuadanr Wolf Sanctuary**
- **Vegetation:** Bamboo and sal forests.

Karnataka (5)

1. Anshi NP and Dandeli-Anshi TR (Kali TR)

- Located on the banks of Kali River in the Western Ghats. It is a **part of the Dandeli WLS**.
- Anshi NP and Dandeli WLS were together granted the status of Project Tiger TR and were declared as 'Anshi-Dandeli TR' (which is now renamed as **Kali TR**).

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- **Vegetation:** Deciduous forest & montane rainforest.
- **Major Flora:** True cinnamon, bamboo, eucalyptus.
- **Major Fauna:** Elephant (EN), Bengal tiger (EN), black panther (a black color variant of leopard; VU), wild boars, bonnet macaque, Malabar civet, Malabar giant squirrel.
- **Major Avifauna:** Adjutant stork, great hornbill.

2. Bandipur NP, TR (UPSC-2012)

- Together with Nagarhole NP, Mudumalai NP (TN) and Wayanad WLS (Kerala), it is **part of the Nilgiri BR**.
- Kabini River **(a tributary of the Cauvery River) s**eparates the park from Nagarhole NP.
- **Vegetation:** Dry & moist deciduous forests, and shrubs.

3. Nagarahole (Rajiv Gandhi) NP, TR

- **Location:** foothills of Western Ghats.
- It is recognized as an **Important Bird Area**.
- **Jenu Kurubas** (honey-collecting tribe) live in this park.
- **Vegetation:** Moist & dry deciduous forests, swamp forests, and bamboo

4. Bannerghatta NP

- It is **part of a wildlife corridor for elephants** which connects Biligirirangana Hills and Sathyamangalam forest.
- **Vegetation:** Moist deciduous forest and scrubland.
- A portion of the NP is converted into Bannerghatta Biological Park.

5. Kudremukh NP

- Located in the **Western Ghats**
- The park is named after the **Kudremukh Peak**, which is the third-highest peak in Karnataka and is characterized by its distinctive horse-shaped outline **("Kudremukh" translates to "horse face" in the local language)**.

Andhra Pradesh (3)

1. Papikonda NP

- **Location: Papi Hills of Eastern Ghats.** It is an **Important Bird and Biodiversity Area.**
- **Major Fauna:** Bengal tiger, leopard, hyena, Indian gaur, sloth bear, spotted deer (chital), sambar, barking deer(or Indian muntjac), four-horned antelope (chausingha), kanchu mekha (an endemic dwarf goat).
- **Major Avifauna:** Common peacock, red jungle fowl.
- **Major Reptiles:** Indian golden gecko, monitor lizard.
- The NP has a **population of both Rhesus macaque** (normally found north of Godavari) **and Bonnet macaque** (usually found south of Godavari).

2. Rajiv Gandhi (Rameswaram) NP

- **Location:** Rameswaram of Kadapa district. It lies on the north bank of the Penna
- **Major Avifauna:** Little egrets, parakeets.
- **Major Amphibian Fauna:** Bullfrog.
- **Major Reptilian Fauna:** Burrowing snakes (Russell, earth boa, John and boa).

3. Sri Venkateswara NP

- **Location:** Part of the **Seshachalam Hills BR**. It spreads over the Seshachalam Hills and the Tirumala Hills of Eastern Ghats.
- **Major Flora:** Red Sanders.
- **Major Fauna:** Slender loris, leopard, sloth bear, mouse deer, Chausingha, Indian giant squirrel.

Kerala (6)

1. Anamudi Shola NP

- **Location:** Western Ghats, Anamudi (2695 m)
- Surrounded by **Mathikettan Shola NP, Eravikulam NP, Pambadum Shola NP, Chinnar WLS**, and the Kurinjimala WLS. (All are part of Munnar Wildlife Division).
- **Major Fauna:** Lion-tailed macaques, Nilgiri tahr (EN), Nilgiri marten (VU), gaur, muntjac, giant grizzled squirrel (NT), flying squirrels, Nilgiri langur (VU).

Sholas

Tropical montane forests in the Western Ghats, separated by rolling grasslands in high altitudes.

House a dense patch of stunted trees with the presence of lichen, mosses, and climbers.

2. Periyar NP(TR, ER)

- It forms the **major watershed of two important rivers of Kerala, the Periyar and the Pamba**. It is located in the Cardamom Hills of the Western Ghats.
- It **surrounds the Periyar Lake** which became a reservoir in 1895 after the **Mullaperiyar Dam** (built at the confluence of the Mullayar and Periyar rivers in Kerala but is operated and maintained by Tamil Nadu) **was erected**.

3. Silent Valley NP

- Silent Valley NP is located in the **Nilgiri Hills** in the Malappuram district, Kerala, and Nilgiris district of Tamil Nadu. The park lies within the Nilgiri BR
- **Bhavani River** (a tributary of the Kaveri River) and **Kunthipuzha River** (a tributary of Bharathapuzha River) originate in the vicinity of the park. The **Kadalundi River** also originates in this park.

4. Others: Eravikulam NP, Mathikettan Shola NP, Pambadum Shola NP

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Madhya Pradesh (11)

1. Bandhavgarh NP (TR)

- **Location:** At **Vindhya Range. India's first white tiger** was captured here in 1951. The density of the tiger population at Bandhavgarh is one of the highest in India.
- **Vegetation:** Moist and mixed deciduous forests.
- **Major Fauna:** Bengal tiger, elephant, leopard, sambar, barking deer, Indian wolf, striped hyena, nilgai.
- **Major Avifauna:** Indian grey hornbill, lesser adjutant stork, lesser spotted eagle, Bonelli's eagle.
- The **Indian bison was reintroduced from Kanha**.

2. Dinosaur (Ashmadha) Fossils NP

- **Location: Narmada Valley.**
- Dinosaur egg fossils and fossilized trees dating back 60 million years were discovered at the site.

3. Indira Priyadarshini Pench NP, TR

- **Location: Satpura Range. Pench River** flows through the park dividing it into two halves.
- Pench TR straddles across Madhya Pradesh and Maharashtra. It comprises the Indira Priyadarshini Pench NP (MP) and the Jawahar Nehru Pench NP (Maharashtra).
- **Collarwali ('The One With a Collar')**, the first tigress in the park fitted with a radio collar recently died.
- Pench NP was the inspiration for **Rudyard Kipling's 'The Jungle Book'**.

4. Kanha NP, TR [UPSC-2020]

- **Location:** Maikal Range of Satpuras. It is the largest NP of Madhya Pradesh and Central India.
- The present-day Kanha area is divided into two protected areas, **Hallon and Banjar**.
- **Tribes displaced from the region:** The **Baiga tribe** (a semi-nomadic tribe of Central India) lost their forest rights & were not properly compensated.

5. Madhav NP

- **Sakhya Sagar and Madhav Sagar** are two important reservoirs within the park built by Madho Rao Scindia. Sakhya Sagar has been designated as a Ramsar site since 2022.
- **Vegetation:** Dry deciduous forests and grasslands.
- **Major Fauna:** Chinkara (Indian gazelle), chital, nilgai, sambar, chausingha (four-horned antelope).

6. Mandla Plant Fossil NP

- **Location:** Narmada Valley. It has **plant fossils** that existed in India between 40-150 million years ago.

7. Panna NP, TR

- Panna NP along with Ken Gharial WLS, form a significant part of the **catchment area of the Ken River** which runs through the park.
- In the Ken WLS, **gharials** (fish-eating freshwater crocodiles) are bred in captivity and then released.
- **Vegetation:** Fragmented deciduous forests.
- **Major Fauna:** Tiger, leopard, chital, chinkara, sambar.
- In 2012, no tigers were left in the reserve. A tiger each from Bandhavgarh NP and Kanha NP were translocated to Panna TR

8. Kuno NP

- Located in Vindhyan hills in the Sheopur district.
- It derives its name from the Kuno River that flows through the national park.
- **Flora:** The park's diverse ecosystems include dry deciduous forests, grasslands, and riverine habitats.
- **Fauna:** Bengal tigers, leopards, Indian wolves, sloth bears, and various ungulates like chital, sambar, and nilgai.In September 2022, Kuno became the site for the reintroduction of cheetahs in India, with eight individuals translocated from Namibia.

9. Sanjay NP, Sanjay-Dubri TR

- It is already covered under Chhattisgarh.

10. Satpura NP, TR

- It was **India's first reserve forest**, located in the Satpura Range. It has the Dhoopgarh peak (1,350 m) and the level plains of Churna.
- **Pachmarhi** is the closest city to the park.

11. Van Vihar NP

- It is located in **Bhopal**. It has the status of an NP but is **developed and managed as a zoological park**.
- **Captive Fauna:** Bengal tiger, Asiatic lion, mugger crocodile, gharial, spotted deer (chital), sambar, blackbuck

Maharashtra (6)

1. Gugamal NP (Melghat TR)

- **Location:** Amravati region. **Tapi River and Gawilgarh Hills** (of Satpura Range) form its northern boundary.
- **Gugamal NP is part of Melghat TR**. It is one of seven protected areas in the Melghat TR.
- **The TR is a catchment of five major rivers:** Khandu, Khapra, Sipna, Gadga and Dolar (all tributaries of Tapti).

2. Nawegaon NP

- Dr Salim Ali Bird Sanctuary, Navegaon is home to almost 60% of bird species found in the entire Maharashtra.
- **Navegaon Nagzira TR = Nawegaon NP + Nagzira WLS + Koka WLS**.

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3. Jawaharlal Nehru Pench NP, TR

- Spread across Madhya Pradesh and Maharashtra. It comprises the Indira Priyadarshini Pench NP (MP) and the Jawahar Nehru Pench NP (Maharashtra).
- **Major Fauna:** Royal Bengal tiger, leopard, sloth bear, gaur, four-horned antelope.

4. Chandoli NP (Sahyadri TR, Koyna WLS)

- Sahyadri TR = Chandoli NP + Koyna WLS.
- **Location:** Sahyadri Range of the Western Ghats.
- Koyna WLS has two reservoirs along the Koyna River, Shivsagar Lake and Koyna Reservoir.

5. Sanjay Gandhi (Borivilli) NP

- **Location:** Mumbai. 2400-year-old Kanheri caves sculpted out of a massive basalt lie within the park. It served the Buddhist centers of education.

6. Tadoba NP (Tadoba Andhari TR, Andheri WLS)

- **Maharashtra's oldest and largest NP. Tadoba Lake and Erai Reservoir** are the major wetlands in the reserve. Erai Reservoir offers a good habitat for mugger crocodiles (marsh crocodiles).
- **Tadoba Andhari TR = Tadoba NP + Andhari WLS**
- **Vegetation:** Dry deciduous forest.
- **Major Flora:** Teak, tendu.
- **Major Fauna:** Tigers, leopards, sloth bears, Indian wild dogs, and herbivores like gaur and deer. It also shelters over 195 bird species, including crested serpent eagles and paradise flycatchers, along with reptiles like pythons and marsh crocodiles.

Manipur (2)

1. Keibul-Lamjao NP (UPSC-2015)

- **Only floating park in the world**. It is an **integral part of Loktak Lake (a Ramsar site)**.
- Characterized by floating decomposed plant materials locally called **phumdis**.
- Declared a NP to preserve the natural refuge of brow-antlered deer (also called **sangai**, dancing deer & Manipurs's Eld's deer).

2. Shirui National Park:

- **Famous for Shirui Lily**,The local name of the flower is **Kashong Timrawon**.

Meghalaya (2)

1. Balphakram NP

- **Location:** Garo Hills in Meghalaya, close to the Indo-Bangladesh border.
- **Major Fauna:** Barking deer, Asian golden cat, tiger, marbled cat, wild water buffalo, red panda, elephant.

2. Nokrek Ridge NP

- **Location:** close to Tura Peak in West Garo Hills. It forms the core area of the Nokrek BR.
- **Important Bird Area**. All important rivers of the Garo Hills region rise from the Nokrek Range, of which the **Simsang River** (known as Someshwari in Bangladesh) is most prominent.
- **Vegetation:** Evergreen, semi-evergreen and deciduous.
- **Major Fauna:** Red panda, Asian elephant, stump-tailed macaque, pig-tailed macaque, hoolock gibbon.

Mizoram (2)

1. Murlen NP

- **Location:** Close to the Chin Hills of Myanmar. It is to the south of Lengteng WLS.
- **Vegetation:** Semi-evergreen and sub-montane forests.
- **Major Fauna:** Tiger, leopard, Malayan giant squirrel, Himalayan black bear, serow, hoolock gibbon.
- **Major Avifauna:** Mrs. Hume's pheasant (NT), the state bird of Mizoram and hill myna

2. Phawngpui Blue Mountain NP

- It covers the entire **Phawngpui Mountain or Blue Mountain** (2,157 m), the highest peak of Mizoram.
- **Major Fauna:** Slow loris, tiger, leopard, serow, goral.
- Mrs. Hume's pheasant (NT), the state bird of Mizoram

Nagaland (1):

1. Ntanki National Park (Intanki National Park)

Odisha (2)

1. Bhitarkanika NP (Ramsar Site)

- It is the **second RS of Odisha** after Chilika Lake. **Gahirmatha Marine Sanctuary separates the NP from the Bay of Bengal**. It is inundated by the rivers **Brahmani, Baitarani & Dhamra**.
- It hosts many mangrove species and is the **second-largest mangrove ecosystem in India**.
- **Major Fauna:** Saltwater (Estuarine) Crocodile (LC).

2. Simlipal NP(TR,BR)

- **Location:** Eastern Ghats and is listed in the UNESCO World Network of BRs.
- **Mayurbhanj ER** = Similipal TR + Hadgarh + Kuldiha WLS.
- **Vegetation:** moist and dry deciduous forests, and grasslands.
- **Major Fauna:** Bengal tigers, wild elephants, gaurs (Indian bison), chausingha.

Rajasthan (5)

1. Desert NP

- **Location:** It is spread over two districts. It is one of the natural habitats of the Great Indian Bustard **(UPSC 2020)**

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- **Vegetation:** Open grassland, thorny bushes, and dunes.
- **Major Flora:** Patches of sewan grass and aak shrub.
- **Major Avifauna:** Great Indian bustard (CR), eagles, harriers, falcons, buzzards, and vultures.
- **Major Fauna:** Chinkara or Indian Gazelle, desert fox

2. Mukundra Hills NP (TR)

- Previously known as **Darrah WLS**, located within the **Kathiawar-Gir dry deciduous forests ecoregion**.
- Like Sita Mata WLS, Mukundara Hills NP was one of the places that were considered for the reintroduction of the Asiatic lion.
- **Major Fauna:** Bengal tiger, Indian wolf, leopard, chital, sambar, wild boar, sloth bear and chinkara, Mugger crocodile and gharial.

3. Keoladeo Ghana NP (RS)

- Formerly known as **Bharatpur BS**, it is a **freshwater swamp**. It gets flooded during the monsoon.
- A famous **avifauna sanctuary** that hosts thousands of birds, especially during the winter season. It is a **Ramsar Site** and a **UNESCO World Heritage Site**.
- It is the **only regular wintering** area in India for the Siberian crane (CR).
- **Major Avifauna:** Migratory waterfowl, sarus crane (large non-migratory crane found in parts of India).
- **Major Fauna:** Blackbuck, hog deer, chital deer, sambar.

4. Ranthambore NP, TR

- It is bounded to the north by the **Banas River** and to the south by the **Chambal River**.
- **Major Fauna:** Bengal Tiger, leopard, nilgai, sambar, Mugger crocodile.

5. Sariska NP, TR

- Part of the Aravalli Range and the Kathiawar-Gir dry deciduous forests ecoregion. It is **rich in mineral resources**, such as copper.
- **Vegetation:** Arid forests, dry deciduous forests, scrub-thorn and grasslands.
- **Major Fauna:** Bengal tiger, Indian leopard, golden jackal, chital, sambar deer, nilgai, rhesus macaque.

Sikkim (1)

1. Khangchendzonga NP (BR)

- The park gets its name from the mountain **Kanchenjunga, the third-highest peak in the world**.
- It is the first and only **"Mixed Heritage" site in India**. It is also included in the **UNESCO Man and the Biosphere Programme**.
- **Vegetation:** Temperate broadleaf and mixed forests.
- **Fauna:** snow leopard, red panda, Himalayan blue sheep, serow, goral, takin

Tamil Nadu (5)

1. Annamalai (Indira Gandhi) NP (TR, WLS)

- **Location:** in the **Anaimalai Hills**.
- **Vegetation:** Wet evergreen forest to shola grassland.
- **Major Fauna:** Bengal tiger, Indian elephant, Indian leopard, Nilgiri tahr, lion-tailed macaque, gaur, Nilgiri langur.
- **Threats:** Tea and coffee plantations and tourism.

2. Guindy NP

- **Guindy Snake Park** and **IIT Madras** are located at the periphery of Guindy NP. The Madras Crocodile Bank Trust is only 30 km away from Guindy NP.
- **Vegetation:** Tropical dry evergreen forest, dry evergreen scrub, and thorn forest.
- **Major Fauna:** Blackbucks (flagship species of the park), chital, jackals, etc.

3. Gulf of Mannar Marine NP

- Consists of 21 small islands (islets) and adjacent coral reefs. It is the **core area of the Gulf of Mannar BR**.
- Includes marine components such as coral reefs, seaweed, seagrasses, salt marshes, and mangroves.
- **Major Marine Fauna:** Dugong (Sea Cow), Green turtles, Olive Ridley turtles. Dugong (VU), a marine mammal, is the flagship mammal of the park.

4. Mudumalai NP, TR, WLS

- **Location:** north-western side of the Nilgiri Hills (Blue Mountains), in Nilgiri district. It shares its boundaries with the states of Karnataka and Kerala.
- **Vegetation:** Tropical moist deciduous, dry deciduous, and dry thorn forests.
- **Major Fauna:** Indian elephant, Bengal tiger, leopard, bonnet macaque, sloth bear, Indian giant squirrel, Indian white-rumped vulture (CR) and India Vulture (CR).

5. Mukurthi NP

- **Location: Within Nilgiri BR**. The NP was created to protect its keystone species, the **Nilgiri tahr (EN)**.
- **Vegetation:** Montane grasslands and shrublands interspersed with sholas.

Telangana (3)

1. Kasu Brahmananda Reddy National Park (KBR Park)

- **Location:** Located in Hyderabad,
- **Flora and Fauna:** This urban park is known for its greenery and biodiversity, including peacocks, butterflies, and various bird species.

2. Mahavir Harina Vanasthali National Park

- Situated near Hyderabad, it is named after Lord Mahavir.
- **Fauna:** It is known for its population of blackbucks and other wildlife.

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3. Mrugavani National Park

- Located near Chilkur in Hyderabad,
- **Fauna:** this park is home to various mammals like Spotted Deer (Chital),Indian Hare,wild boar,porcupine,junglecat

Tripura (2)

1. Bison (Rajbari) NP

- NP in the **Trishna WLS**, established to restore the natural living habitat of **India Bison**.
- **Gumti River** originating from the Gumti WLS (in Tripura), separates the Sipahijala WLS (Clouded Leopard NP) from Trishna WLS (Bison NP).
- **Rudrasagar Lake** (RS) is located between the Sipahijala WLS and the Trishna WLS.

2. Clouded Leopard NP

- **Part of the Sipahijala WLS**. Sipahijala WLS is a **woodland with an artificial lake** and natural botanical and zoological gardens.
- Sipahijala WLS is famous for **clouded leopards (VU)**.

Uttarakhand (6)

1. Gangotri NP

- **Location:** Upper catchment of Bhagirathi River.
- The park area forms a **continuity between Govind NP and Kedarnath WLS**. The **Gaumukh glacier**, the origin of the river Ganges is located inside the park.
- **Habitat:** Coniferous forests, alpine meadows, and glaciers.
- **Vegetation:** Pine, deodar, fir, and rhododendrons.
- **Major Fauna:** Snow leopard, Asian black bear, brown bear, musk deer, blue sheep, Himalayan tahr.

2. Govind Pashu Vihar NP and WLS

- The **Snow Leopard Project** is being managed at this sanctuary.
- **Vegetation:** Himalayan broadleaf forests, conifer forests, alpine shrubs, and meadows.
- **Flora:** Pine, Deodar, cedar, oak, maple, walnut, horse chestnut, hazel and rhododendron.
- **Major Fauna:** Snow Leopard (VU), leopard, musk deer, Himalayan tahr, steppe eagle, bearded vulture.

3. Jim Corbett NP, Corbett TR

- **Oldest NP in India (1936)** and is located in **Nainital**.
- The park was the **first NP to come under the Project Tiger initiative**.
- Corbett TR's core area is formed by Jim Corbett NP, while the buffer contains Sonanadi WLS.
- **Ramganga, Sonanadi, and Kosi** are the major rivers flowing through the NP, and Ramganga Reservoir is located within the NP.
- **Vegetation:** Dense, moist deciduous forests, marshy depressions, and grasslands.
- **Major Fauna:** Bengal tigers, elephants, leopards, Himalayan black bears, Himalayan goral, rhesus macaque. Local crocodiles and gharials were saved from extinction by captive breeding programs that subsequently released crocodiles into the Ramganga River.
- **Threats:** Invasive weeds, and poaching.
- Corbett NP is **one of the thirteen protected areas covered by the Worldwide Fund For Nature** under their Terai Arc Landscape Program.

4. Rajaji NP, TR

- **Location:** Spreads over the Shivalik ranges and the Indo-Gangetic plains. The Ganga and Son Rivers flow through the park.
- The park is at the north-western limit of distribution for both elephants and tigers in India.
- **Major Fauna:** Elephants, Bengal tiger, sloth bear, black bear, Indian langur, Indian porcupine.

5. Nanda Devi BR, NP

- India's second BR and it is **under UNESCO's Man & Biosphere Programme**. Its core area is **formed by Nanda Devi NP and Valley of Flowers NP**.
- The Nanda Devi NP is situated around the peak of Nanda Devi (7816 m). It is a **UNESCO World Heritage Site**.

6. Valley of Flowers NP

- It is a high-altitude Himalayan valley in the **transition zone between Zanskar and Great Himalayas**.
- It is known for its meadows of endemic alpine flowers. NPs lies completely in the **Temperate alpine zone** **[UPSC 2019]**
- Both the Valley of Flowers NP and the Nanda Devi NP form the **core area of Nanda Devi BR**.

West Bengal (6)

1. Buxa NP, TR

- Lies in the **Gangetic Plains**. Its northern boundary runs along the Indo-Bhutan border.
- **Vegetation:** Evergreen and semi-evergreen, moist and dry deciduous, savannah and grasslands.
- **Major Fauna:** Bengal tiger, Asian elephant, gaur, sambar deer, clouded leopard, Indian leopard.

2. Gorumara NP

- **Location:** in the Eastern Himalayas Terai belt. The major river of the park is the **Jaldhaka River**, a tributary of the Brahmaputra.
- **Vegetation:** Rolling forests and riverine grasslands known as Duars and moist deciduous forests.
- **Major Fauna: Indian rhinoceros,** gaur, **Asian elephant**, sloth bear, chital, sambar deer, barking deer, hog deer.

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3. **Jaldapara NP**
   - **Location:** banks of the Torsa River at the foothills of the Eastern Himalayas.
   - **Largest population of the Indian one-horned rhinoceros after Kaziranga NP** in Assam.
   - It is located near Chilapata Forests which is an elephant corridor between **Jaldapara and Buxa** TR while Gorumara NP is known for its population of Indian rhinoceros.
   - **Vegetation:** Mainly savannah with tall elephant grasses.
   - **Major Fauna:** Indian rhinoceros, leopards, elephants, sambar, barking deer, spotted deer, hog deer, gaur.
4. **Neora Valley NP**
   - **Location:** Himalayas in Kalimpong.
   - **Vegetation:** Himalayan broadleaf forests.
   - **Major Flora:** Rhododendron, bamboo, oak, ferns, sal.
   - **Major Fauna:** Red Panda, Indian leopard, black bear, sloth bear, golden cat, barking deer, Himalayan flying squirrel, thar.
5. **Singalila NP**
   - **Location:** Singalila Ridge in Darjeeling.
   - **Vegetation:** Coniferous, broadleaf, and mixed forests.
   - **Major Fauna:** Red panda, yellow-throated marten, pangolin, Himalayan black bear, clouded leopard, takin.
6. **Sunderban NP(TR, Ramsar Site ,BR)**
   - **Largest delta and mangrove forest in the world**. Sundarbans NP is a part of the Sundarbans on the Ganges Delta and is adjacent to the Sundarban Reserve Forest in Bangladesh. Bound on the west by river Muriganga and on the east by rivers Haribhanga and Raimangal.
   - It is also a B**R, TR, Ramsar Site and a UNESCO World Heritage Site**.
   - Eco-geography of this area is dependent on the tidal effect. The tidal action deposits silt back on the channels, raising the bed and forming new islands and creeks.
   - **Vegetation:** Mangrove forests (Sundarbans has achieved its name from the Sundari mangrove tree).
   - **Major Fauna:** Royal Bengal Tiger, saltwater crocodile, river terrapin, olive ridley turtle, Ganges River dolphin, hawksbill turtle, mangrove horseshoe crab.

WILD LIFE SANCTUARIES OF INDIA

There are 573 existing wildlife sanctuaries in India covering an area of 123,762.56 km2, which is 3.76% of the geographical area of the country (National Wildlife Database).

Andaman & Nicobar Islands

1. **Barren Island WLS:** Barren Island is the **only active volcano in India**.
2. **Narcondam Island WLS:** Narcondam Island is a **dormant volcano**.

Andhra Pradesh

1. **Coringa WLS:** It is a part of the Godavari estuary (delta), Mangroves, and dry deciduous tropical vegetation with Fauna Including estuarine crocodile (saltwater crocodile; LC).
2. **Gundla Brahmeswaram WLS:** Located on the periphery of Nagarjunasagar-Srisailam TR in the Nallamala Hills.
3. **Kolleru WLS (BS):** Natural eutrophic lake situated between the river basins of the Godavari and the Krishna.
4. **Krishna WLS: mangrove wetland located in the Krishna delta.**
5. **Pulicat Lake WLS (BS):** Located in Andhra Pradesh and Tamil Nadu, India's second largest brackish-water ecosystem after Chilka Lake in Odisha.
6. **Rollapadu WLS (BS):** Established to protect Great Indian Bustard (CR) and Lesser Florican (EN).
7. **Sri Lankamalleswara WLS: Located in the southern** part of the **Nallamala Hills**. The WLS is known for **Jerdon's courser bird (CR)**.
8. **Sri Penusila Narasimha WLS:** It comprises a unique forest type viz. the **dry evergreen forests**. Such vegetation is unique to the Coromandel Coast (Tamil Nadu, Puducherry and Andhra Pradesh)

Arunachal Pradesh

- **Kamlang TR, WLS:** Named after the **Kamlang River**, which flows through it. It is located between the **Lohit River & Namdapha NP**.
- **Dibang WLS:** It is located **within Dihang-Dibang BR**.

Assam

1. **Chakrasila WLS:** North bank of the Brahmaputra River, an Important protected habitat for golden langur (EN) after Manas NP.
2. **Deepor Beel WLS (Ramsar Site): Permanent freshwater lake** in a former channel of the Brahmaputra River.
3. **Hollongapar Gibbon WLS:** Contains **India's only apes – the hoolock gibbons (EN)**, and North-eastern India's only nocturnal primate – the Bengal slow loris (VU).
4. **Pobitora WLS:** Pobitora (Mini Kaziranga) has exceeded its rhino-bearing capacity. Under the **Indian Rhino Vision 2020 (IRV 2020)** several rhinos were translocated from Pobitora and re-introduced into the Manas NP.

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5. **Barnadi WLS** (established to protect the Hispid hare (EN) and Pygmy hog (EN) on Himalayan foothills bordering Bhutan);
6. **Burachapari WLS** (south bank of the Brahmaputra River, habitat for the Bengal florican (CR));
7. **Garampani WLS**
8. **Lawkhowa WLS** (between Kaziranga NP and Orang NP, ideal habitat for Indian rhinoceros (VU) and Asiatic water buffaloes (EN));
9. **Marat Longri WLS** (important component of Dhansiri-Lungding ER);
10. **Nambor WLS** (on the periphery of the Mikir Hills)
11. **Nambor-Doigrung WLS** (along with Garampani WLS, Nambor WLS is a part of the Kaziranga-Karbi Anglong ER);
12. **Pani-Dihing WLS** (BS)
13. **Sonai Rupai WLS** (west of Pakke TR and Nameri NP);
14. **Amchang WLS, Barail WLS, East Karbi Anglong WLS**.

Bihar

1. **Kaimur WLS:** Eastern part of the Vindhyan Scrap Lands. It is Bihar's largest WLS and is a tiger corridor
2. **Kanwar Jheel WLS (BS) (Ramsar Site):** Asia's **largest freshwater oxbow lake**.
3. **Vikramshila Gangetic Dolphin WLS:** Protected area for **India's national aquatic animal – Gangetic Dolphins (EN)**.
4. **Barela Jheel Salim Ali Bird WLS**
5. **Kusheshwar Asthan Bird WLS** (Close to the right bank of River Kosi (Sorrow of Bihar) and Kanwar Lake);

Chattisgarh

1. **Badalkhol WLS:** Located in Ramgarh Hills, It is a tiger corridor between Achanakmar TR (Chhattisgarh) & Palamau TR (Jharkhand).
2. **Bhairamgarh WLS:** Indravati River (a tributary of Godavari) separates Indravati NP from Bhairamgarh WLS.
3. **Bhoramdev WLS:** Tiger corridor in Maikal Hills between Kanha TR (Madhya Pradesh) and Achanakmar TR (Chhattisgarh).
4. **Others: Pamed Wild Buffalo WLS; ; Sarangarh-Gomardha WLS; Barnawapara WLS**

Goa

1. **Dr. Salim Ali Bird (Chorao) WLS:** Estuarine mangrove habitat located on Chorao Island along the Mandovi River.
2. **Mhadei WLS (IBA):** Mhadei River passes through the Mhadei WLS and meets the sea at Panaji

Gujarat

1. **Barda WLS:** It was a p**revious range of Asiatic lions**.
2. **Gaga (Great Indian Bustard) WLS:** Established to protect Great Indian Bustard (CR). Along with Kutch Bustard Sanctuary, Gaga WLS is one of two great Indian bustard sanctuaries in Gujarat.
3. **Girnar WLS:** In Girnar Hills; famous for Asiatic lions (EN).
4. **Jessore Sloth Bear WLS:** At Gujarat-Rajasthan border for the protection of sloth bear (VU). The Banas River separates Jessore Sloth Bear WLS from Balaram Ambaji WLS.
5. **Kutch (Lala-Parjan) Great Indian Bustard WLS:** Established to protect the Great Indian Bustard (CR) (locally called Ghorad).
6. **Kutch Desert WLS:** It is a **shallow seasonal saline wetland** in the Great Rann of Kutch. Fossils of dinosaurs, crocodiles, and whales have been recovered from here.
7. **Nal Sarovar Bird WLS (BS) (Ramsar Site): Natural freshwater lake** (a relict sea) located in the Thar Desert. It is the largest wetland BS in Gujarat. **Lifeline for the Indian Wild Ass (NT) & blackbuck (LC)**.
8. **Narayan Sarovar Chinkara WLS:** Its flagship species is Chinkara (LC).
9. **Shoolpaneswar (Dhumkhal) WLS:** Common boundary with Madhya Pradesh and Maharashtra. Tapti River separates Shoolpaneswar WLS from Purna WLS.
10. **Thol Lake WLS** (man-made reservoir) , **Wild Ass WLS** (one of the last places where Indian wild ass (NT) can be spotted), **Khijadiya Bird WLS (BS), Mitiyala WLS**

Himachal Pradesh

1. **Dhauladhar WLS Location:** In the Lesser Himalayas, it lies between Dalhousie (near Ravi River) and Kullu-Manali Valley (Beas River). Ravi River flows along the fringes of the Dhauladhar range. Hanuman Tibba (5,982 m) is its highest peak.
2. **Pong Dam Lake WLS (BS) (Ramsar Site):** Also called **Maharana Pratap Sagar**, it was created on the Beas River. Pong Dam and Gobindsagar Reservoir (on the Sutlej River) are the two most important fishing reservoirs in the Himalayan foothills of Himachal Pradesh.

Jammu & Kashmir

1. **Gulmarg WLS: Located on the** foothills of Pir Panjal Range.
2. **Hokersar/ Hokera WLS (Ramsar Site):** Natural perennial wetland contiguous to the Jhelum basin. It is an important migratory bird area.
3. **Tral WLS:** Created to conserve **hangul (Kashmir Stag; CR**) and acts as **a buffer around Dachigam NP and Overa-Aru WLS**.

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4. **Rajparian (Daksum) WLS:** It is disturbed due to excessive grazing by **nomadic Bakarwals**. The Bakarwal are nomads of the Pir Panjal and Himalayan mountains. They are **transhumants**.

Ladakh

1. **Changthang WLS (Ramsar Site):** It has one of the highest lakes on earth, **Tso Moriri** (4595 m).
2. **Karakoram (Nubra Shyok) WLS: Location:** High-altitude WLS located in the easternmost reaches of the Karakoram range. It is one of the few places with a migratory population of the chiru/Tibetan antelope (NT).

Jharkhand

1. **Mahuadar Wolf WLS:** Located along the Jharkhand-Chhattisgarh border. It is a breeding ground for Indian Wolf.
2. **Palkot WLS:** Located in contiguous with the Koel River Valley forests, Saranda-Singhbhum Range forests, and Dalma WLS.
3. **Dalma WLS:** It is an important elephant corridor in the Dalma Hills.
4. **Gautam Budha WLS:** It covers the Lower Gangetic Plains (moist deciduous forests) and Chota Nagpur (dry deciduous forests).
5. Parasnath WLS (in Parasnath Hills (Chota Nagpur Plateau));
6. Udhwa Lake Bird Sanctuary (only BS of Jharkhand state);

Karnataka

1. **Bhimgad WLS:** Located in the Western Ghats and is the only known **breeding area of Wroughton's free-tailed bat** (CR). It is contiguous to Madei WLS (Goa), Bhagwan Mahaveer WLS Mollem NP (Goa), and Dandeli WLS (Karnataka).
2. **Brahmagiri WLS:** Western Ghats and is contiguous with the Aralam WLS of Kerala.
3. **Cauvery WLS:** Contiguous with BR Hill TR (Karnataka), Sathyamangalam TR (TN), and Dharmapuri forest (TN).**Hogenakal Falls and Mekedatu** are important locations of the WLS.
4. **Ranganathittu WLS (BS)/ Pakshi Kashi of Karnataka: Largest BS in the state**, It receives thousands of migratory birds from Siberia, Latin America, and parts of north India during winter.
5. **Ramadevara Betta WLS (Vulture Sanctuary): India's first vulture sanctuary**.
6. Talakaveri WLS (source of the river Kaveri, located on Brahmagiri hills).
7. Kamasandra WLS (located at trijunction of Karnataka, Andhra Pradesh & Tamil Nadu)

Kerala

1. **Chinnar WLS:** Integral part of the protected forests straddling the Kerala-Tamil Nadu border in the Anaimalai Hills. The **rare Albino gaur** (Manjampatti white bison) is found only in Indira Gandhi WLS and Chinnar WLS.
2. **Idukki WLS:** It is cradled by the **Cheruthoni River and Periyar River**. Cardamom Hills lies between Mathikettan NP and Idukki WLS.
3. **Malabar WLS:** Part of Nilgiri BR and Wayanad ER.
4. **Kurinjimala WLS:** Protects the **core habitat of the endangered Neelakurinji plant (blossom only once in 12 years)**. The WLS is contiguous to the Chinnar WLS, Eravikulam NP, Anamudi NP, Pampadum Shola NP, and the proposed Palani Hills NP.
5. **Neyyar WLS:** It is the drainage basin of **Neyyar River and Neyyar Dam**. It is a **part of the Agasthyamala BR**.
6. **Peechi-Vazhani WLS:** It consists of **Palappilli-Nelliyampathi forests**, including the area of Chimmony WLS.
7. **Wayanad WLS: Integral part of the Nilgiri BR**. It is bounded by **Nagarhole NP, Bandipur NP** (Karnataka) and **Mudumalai NP**. It is a major elephant and tiger corridor.

Madhya Pradesh

1. **Bori WLS:** Located in the foothills of the **Satpura Range**. It is bounded by Satpura NP and Tawa River (tributary of Narmada). The sanctuary, **together with Satpura NP and Pachmarhi WLS, forms Pachmarhi BR**.
2. **Ken Gharial WLS:** Panna NP along with Ken Gharial WLS form a significant part of the catchment area of the Ken River (a tributary of Yamuna). In the Ken Gharial WLS, **fish-eating freshwater crocodiles (CR) are bred in captivity and then released**.
3. **National Chambal Gharial WLS:** Located on the Chambal River near the tripoint of Rajasthan, Madhya Pradesh, and Uttar Pradesh. It is a **tri-state protected area** for the Gharial (CR), red-crowned roof turtle (CR), and Ganges river dolphin (flagship species; EN). It is listed as an Important Bird Area. **(UPSC-2017)**
4. **Noradehi WLS:** It is the **largest WLS of Madhya Pradesh**, spread over the southern area of the **Vindhya Range** in which Bandhavgarh NP and Panna NP are also located.
5. **Pachmarhi WLS: Pachmarhi BR is situated in the Satpura Range. It includes three wildlife conservation units:** Bori WLS, Pachmarhi WLS & Satpura NP.
6. **Kuno WLS:** Cheetahs from Namibia were released here as part of cheetah reintroduction in India.
7. **Panna (Gangau) WLS** (Panna TR = Panna NP + Gangau WLS + Ken Gharial WLS);

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8. **Panpatha WLS** (Bandhavgarh TR = Bandhavgarh NP + Panpatha WLS);
9. **Sailana or Kharmour WLS** (BS) (home to the 'Kharmour' bird, a very rare species);
10. **Son Gharial WLS** (natural habitat of Gharial and marsh crocodile.

Maharashtra

1. **Great Indian Bustard WLS:** Also known as **Jawaharlal Nehru Bustard Sanctuary**. The land is **drought-prone and semi-arid**.
2. **Koyna WLS:** Important Bird Area located in the Western Ghats. Sahyadri TR **lies between Koyna WLS and Chandoli NP**.
3. **Lonar WLS (Ramsar Site):** It is a saline-alkaline lake located in Buldhana district. It is a 56,000-year-old crater created by a meteor impact during the Pleistocene Epoch (2.58 million to 11,700 years ago).
4. **Nandur Madhameshwar WLS (BS) (Ramsar Site):** It is located in Nashik at the confluence of the Godavari and Kadwa Rivers. It is Maharashtra's first Ramsar site.
5. Amba Barwa WLS (Melghat TR = Gugamal NP + Melghat WLS, Narnala WLS & Amba Barwa WLS);
6. Bhimashankar WLS (habitat of Indian (Malabar) Giant Squirrel (LC), the state animal of Maharashtra);
7. Chaprala WLS (Pranhita River flows along its western boundary, serves as a link between the Tadoba TR (Maharashtra) and the Indravati TR (Chhattisgarh));

Haryana

1. Morni Hills (Khol-Hi-Raitan) WLS & Bir Shikargarh WLS; Chhilchhila Lake WLS (Seonthi Reserve Forest); Khaparwas WLS (BS)

Manipur

1. Bunning WLS; Khongjaingamba Ching; Thinungei BS (first BS of Manipur); Yangoupokpi Lokchao (along the Indo-Myanmar border); Zeilad WLS

Meghalaya

1. Narpuh WLS (Jaintia Hills); Nongkhyllem WLS; Siju Bird WLS(banks of Simsang River)

Mizoram

1. Khawnglung WLS (Lushai Hills); Lengteng WLS (Lushai Hills); Ngengpui WLS (Mizo Hills); Tawi WLS (Lushai Hills); Thorangtlang WLS; Tokalo WLS

Nagaland

1. Fakim WLS (Naga Hills); Puliebadze WLS; Rangapahar WLS

Odisha

1. **Gahirmatha Marine WLS:** World's largest nesting beach for Olive Ridley Sea Turtles (VU). Dhamra River mouth in the north to Brahmani River mouth in the south.
2. **Chilika Lake RS & Nalbana BS:** Chilika Lake is an ephemeral (not permanent) brackish water lagoon. It is a shallow bar-built estuary fringed by the Eastern Ghats. It is located at the mouth of the Daya River. It is the largest coastal lagoon in India and the largest brackish water lagoon in Asia. In 1981, Chilika Lake was designated India's first Ramsar Site. The Irrawaddy dolphin (EN) is the flagship species of Chilika Lake. Chilika is home to the only known population of Irrawaddy dolphins in India. Chilika is the largest wintering ground for migratory birds on the Indian subcontinent. Birds from as far as the Caspian Sea, Lake Baikal, and Aral Sea come here.
3. **Nalbana BS:** Core area of Ramsar wetlands of Chilika Lake. It hosts thousands of migratory birds. The island disappears during monsoon due to inundation, only to emerge again in post-monsoon.
4. Lakhari Valley WLS (Rushikulya River flows through the region;
5. Nandankanan WLS (captive breeding of Asiatic lions, tigers and crocodiles);
6. Satkosia Gorge WLS (Saktosia TR = Satkosia Gorge WLS + Baisipalli WLS);

Punjab

1. **Abohar WLS:** Located close to the intersection of Haryana, Rajasthan & Punjab. It spreads over the private land inhabited by the Bishnoi community.
2. **Harike Lake WLS (Ramsar Site):** Large wetland formed after constructing the headworks across the Sutlej river.
3. **Nangal WLS (Ramsar Site):** Located on Shivalik foothills. It occupies a human-made reservoir constructed as part of the Bhakra-Nangal Project. Here, Indian and Chinese Prime Ministers formalized the 'Five Principles of Peaceful Coexistence' in 1954.

Rajasthan

1. **Bhensrodgarh WLS; Mukundara Hills (Darrah) WLS (consists of three wildlife sanctuaries:** Darrah WLS, Chambal WLS, and Jawahar Sagar WLS);
2. Jaisamand WLS; Jamwa Ramgarh WLS (man-made lake);
3. Jawahar Sagar WLS; Kailadevi WLS (extension of the Ranthambore NP);
4. Mount Abu WLS (located in the Aravalli range);
5. National Chambal WLS (located on the Chambal River near the tripoint of Rajasthan, Madhya Pradesh, and Uttar Pradesh);
6. Ramgarh Vishdhari WLS;
7. Sawaimadhopur WLS (part of Ranthambore TR);
8. Sawai Man Singh WLS (part of Ranthambore TR);

Telangana

1. **Eturnagaram WLS:** Part of the Dandakaranya forests. The Godavari River passes through the sanctuary. It is

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inhabited by the Koya Tribes. The biennial Sammakka Saralamma Jatara (Medaram Jatara) is held in the WLS.

2. **Others:** Kinnerasani WLS; Lanja Madugu Siwaram WLS (right bank of the Godavari River); Manjeera Crocodile WLS; Pranahita WLS (located on the bank of Pranahita River); Pakhal WLS; Pocharam WLS.

Tripura

1. Sepahijala WLS (Clouded Leopard NP is located here);
2. Trishna WLS (Bison/Rajbari NP is located in the Trishna WLS);
3. Gumti WLS; Rowa WLS.

Tamil Nadu

1. **Cauvery North WLS:** Forms the vital link to the Male Mahadeshwara Hills (Karnataka), Biligiri Ranganathaswamy Hills (Karnataka), Sathyamangalam WLS (Tamil Nadu) and Nilgiri BR.
2. Cauvery South WLS (Grizzled giant squirrel, four-horned antelope, and lesser fish eagle are exclusively dependent on the Cauvery river and its riverine forest ecosystem);
3. Kadavur Slender Loris WLS (India's first slender loris sanctuary);
4. Megamalai WLS (buffer to Periyar TR and Srivilliputhur Grizzled Squirrel WLS);
5. Koonthankulam-Kudankulam WLS (IBA);
6. Melaselvanoor-Keelaselvanoor WLS (BS);

Uttar Pradesh

1. **Bakhira WLS:** Natural floodplain wetland, The Rapti River flows through it. It provides a wintering ground for a number of migratory birds.
2. **Jai Prakash Narayan (Surhatal) Bird WLS:** Near the confluence of Ghaghara and Ganges Rivers.
3. **Katerniaghat WLS:** It provides connectivity between the tiger habitats of Dudhwa NP (Uttar Pradesh) and Bardia NP (Nepal).
4. **Kishanpur WLS:** The Sarda River (known as Kali River before it reaches the plains; it flows along the Indo-Nepal Border) separates Kishanpur WLS from the Dudhwa NP.
5. National Chambal Gharial WLS (tripoint of Rajasthan, Madhya Pradesh, and Uttar Pradesh);
6. Nawabganj Bird WLS (Ramsar Site) (also known as Shahid Chandra Shekhar Azad BS);
7. Parvati Aranga WLS (Ramsar Site) (ox-bow lake formed by the Ghaghara River);
8. Saman Bird WLS (Ramsar Site) (seasonal oxbow lake on the Ganges floodplain);
9. Sandi Birds WLS (Ramsar Site, freshwater marsh designated as an Important Bird Area by BirdLife International);
10. Shekha Bird WLS (perennial lake);
11. Sur Sarovar Bird WLS (right bank of Yamuna River);

Uttarakhand

1. **Kedarnath WLS:** It has been set up for conserving the musk deer (EN). It stretches from Gaurikund to Kedarnath mountain. Mandakini River flows through the WLS.
2. **Askot WLS:** set up for conserving the musk deer (EN). **[UPSC-2020]**
3. **Nandhaur WLS:** Jim Corbett TR lies between Rajaji TR and Nandhaur WLS. Nandhaur WLS is a part of the Shivalik ER.

West Bengal

1. **Chapramari WLS:** It is contiguous with Gorumara NP. They lie between Teesta and Jaldhaka Rivers.
2. **Mahananda WLS:** It is located on the foothills of the Himalayas in the Darjeeling district, between the Teesta and Mahananda Rivers (a small tributary of Ganga).
3. **Others:** Lothian Island WLS; Raiganj Bird WLS; Sajnakhali WLS; Senchal WLS; West Sunderban WLS (Part of larger Sundarbans region).

Chandigarh

1. **City Bird WLS: It is also known as Parrot BS as it is primarily a habitat of parrots.**
2. **Sukhna Lake WLS**

Puducherry

1. **Oussudu WLS (BS) (spreads in Puducherry and Tamil Nadu)**

Lakshadweep

1. **Pitti (Bird Island) WLS (uninhabited coral islet in Lakshadweep)**

TIGER RESERVES

- In 1973, with an aim to protect tigers from extinction, India launched Project Tiger in Jim Corbett National Park of Uttarakhand. A network of tiger reserves was gradually established based on a core-buffer strategy.
- All the tiger reserves are governed by the **Project Tiger (1973), a Centrally Sponsored Scheme of MoEFCC, and administered by the National Tiger Conservation Authority.**

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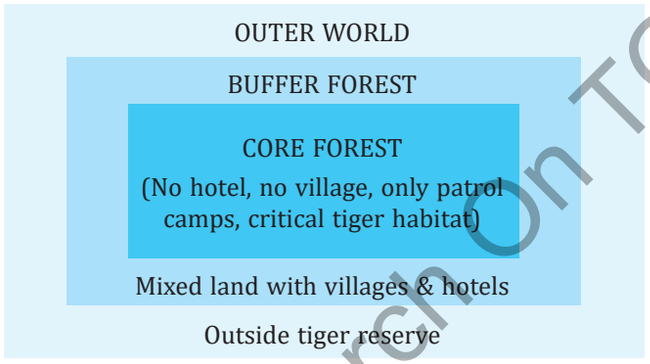
NTCA (National Tiger Conservation Authority)

- The National Tiger Conservation Authority (NTCA) is a statutory body under the Ministry of Environment, Forest and Climate Change. **It was established in 2005 under the Wildlife Protection Act, 1972** to oversees the implementation of Project Tiger.
- No alteration in the boundaries of a tiger reserve shall be made except on a recommendation of the NTCA and the approval of the NBWL(National Board for Wild Life)
- No State Government cannot de-notify a tiger reserve, except in public interest with the approval of the NTCA and National Board for Wild Life.

Core- Buffer strategy for tiger reserves

- In this strategy, the whole tiger reserve area is divided into core forest and buffer forest. As per this strategy, the central part of the forest was marked as core forest.
  - It is a critical tiger habitat thus put in the core forest category, making it undisturbed from human intervention.



Distinction Between Critical Tiger Habitat (CTH) and Critical Wildlife Habitat (CWH)

Feature	Critical Tiger Habitat (CTH)	Critical Wildlife Habitat (CWH)
Definition	Areas within tiger reserves crucial for tiger conservation under the Wildlife Protection Act, 1972.	Areas in protected areas identified for wildlife conservation under the Forest Rights Act, 2006.
Legal Framework	Governed by the Wildlife Protection Act, 1972.	Governed by the Forest Rights Act, 2006.
Rights of Communities	Requires settlement or relocation of forest-dwelling communities without affecting their rights.	Rights can only be modified or curtailed with informed **consent of Gram Sabha** and after due process.
Authority Responsible	National Tiger Conservation Authority **(NTCA).**	Ministry of Environment, Forest, and Climate Change **(MoEFCC).**

TIGER RESERVES IN INDIA (57) [UPSC-2012]

India is home to over 70% of the world's tiger population and boasts of 57 protected areas dedicated to the conservation of tigers.

- **Largest Tiger Reserves in India (by Core Area):** Nagarjunsagar Srisailam TR (Andhra Pradesh)(UPSC-2020)
- **Largest Tiger Reserves in India (by Total Area):** Nagarjunsagar Srisailam TR (Andhra Pradesh)
- **Smallest TR in India :** The Bor Tiger Reserve in Maharashtra.
- The Jim Corbett National Park in Uttarakhand has the highest tiger density in India.

Map shows 54 Tiger reserves of India. Newer Tiger reserves of Dholpur–Karauli@(2023), Guru Ghasidas–Tamor Pingla (2023) and Ratapani@(2024) are not given in the image.

Andhra Pradesh

1. Nagarjunasagar Srisailam TR:

- **Largest TR in India.** It spreads over **Andhra Pradesh and Telangana.**
- It is located inside the **Nallamala Hills & the Krishna River** cuts through the reserve. **Srisailam**

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Reservoir and Nagarjuna Sagar Reservoir lie within the reserve.

- **Largest area Under "Critical Tiger Habitat".**

Arunachal Pradesh

1. **Kamlang and Namdapha TR : Already Covered in National Park Section**
2. **Pakke (Pakhui) TR:** **[UPSC-2019]**
   - Lies in the **foothills of the Eastern Himalayas.** It is bounded by the **Kameng River** in the west and north and by the **Pakke River** in the east. To the south, the sanctuary adjoins Assam's Nameri NP and to the west, it is bounded by Eaglenest WLS and Sessa Orchid Sanctuary.
   - It is known for its **Hornbill Nest Adoption Programme**

Assam

1. **Manas TR, Orang TR, Nameri TR, Kaziranga** TR-details of these have been covered above under National Parks.

Bihar

1. **Valmiki TR**

Chhattisgarh

1. **Indravati TR, Achanakmar TR, Udanti-Sitanadi TR: It comprises Sitanadi WLS and Udanti WLS.**
2. **Guru Ghasidas Tamor Pingla TR**
   - Adopting a landscape approach it ensures ecological connectivity with neighbouring tiger reserves like Sanjay Dubri (Madhya Pradesh), Bandhavgarh (Madhya Pradesh), and Palamau (Jharkhand).

Jharkhand

1. **Palamu TR**
   - It is **one of the nine original TRs in India.**
   - It forms part **of Betla NP and Palamu WLS. The North Koel River runs** through it.

Karnataka

Name	Features
Bandipur TR	It is part of the Nilgiri Biosphere Reserve and is renowned for its Bengal tiger population, Asian elephants, leopards, and diverse flora and fauna.
Nagarahole TR (Rajiv Gandhi)	It is located in the foothills of Western Ghats. It is recognized as an Important Bird Area.
Biligiri Ranganatha Temple TR	It is the starting point of Eastern Ghats. The Biligiri Ranganatha Hills (BR Hills) connect the Eastern Ghats and Western Ghats and facilitate gene flow between populations of species in these areas.Major fauna over here includes -Wild elephants, tiger, gaur, sambhar, chital.
Dandeli-Anshi TR	Anshi National Park and Dandeli Wildlife Sanctuary were together granted the status of Project Tiger Tiger Reserve, and were declared as 'Anshi-Dandeli Tiger Reserve' (which is now renamed as Kali Tiger Reserve).
Bhadra TR	Lies to the east of Kudremukh National Park. It is surrounded by scenic hills, including the Baba Budangiri hills. Tiger, leopard, Malabar civets, **Malabar giant squirrel,** spotted deer, bonnet macaque, **lion-tailed macaque (EN)** etc are the main fauna found here.

Kerala

- **Periyar TR**
  - The Periyar Tiger Reserve in Kerala is the best-maintained of all tiger reserves in the country, according to the 5th cycle of Management Effectiveness Evaluation (MEE). It is located in the western ghats, and is traversed by the Periyar and Pamba rivers. The fauna includes Elephants, Wild Pigs, Sambar, Gaur, Mouse Deer, Dole or Barking Deer, Indian Wild Dog and Tiger.
- **Parambikulam TR**
  - **Location:** Sungam range of hills between Anaimalai Hills (TN) and Nelliampathy Hills (Kerala).
  - **Vegetation:** Evergreen, moist deciduous, and sholas.
  - **Major Fauna:** Lion-tailed macaques, Nilgiri tahr, Nilgiri langurs, Nilgiri marten, small Travancore flying squirrel.

Madhya Pradesh

1. **Bandhavgarh TR, Kanha TR, Panna TR, Pench TR, Sanjay-Dubri TR ,Satpura TR**
   - Already covered under National Parks.
2. **Damoh Tiger Reserve: The central government has issued a notification approving the proposal to merge the Noradehi Sanctuary with the Rani Durgavati Sanctuary of the Damoh district, creating a vast tiger reserve spanning 2,300 square kilometres.**
3. **Ratapani TR (added in Dec 2024)**
   - situated near the Vindhya hills, and encompasses the Bhimbetka Rock Shelter.It is 57th TR of India.

Maharashtra

1. **Melghat TR, Navegaon-Nagzira TR, Pench TR, Sahyadri TR, Tadoba-Andhari TR**

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2. **Bor TR/ WLS**
   - It includes the drainage basin of the Bor Dam.
   - **Vegetation:** Dry deciduous forests.
   - **Major Fauna:** Bengal tiger, Indian leopard, Indian bison, blue bull, chital, barking deer, mouse deer.

Mizoram

1. **Dampa TR**
   - It is located in the **Lushai Hills (Mizo Hills).**
   - Though no tiger was found in the reserve in the 2022 tiger census.
   - It has **one of the highest clouded leopard (VU)** populations in South & South East Asia.

Rajasthan

1. **Mukundra Hills TR, Ranthambore TR, Sariska TR**
2. **Ramgarh Vishdhari TR**
   - It acts as a **buffer for Ranthambore NP.**
   - It will link **Ranthambore TR & Mukundra Hills TR**.
   - The government is making efforts to strengthen the prey base by transferring chital (spotted deer) from Ghana BS (Karauli) to Mukundra Hills TR, Keoladeo NP, and Ramgarh Vishdhari TR.
3. **Dholpur-Karauli TR**
   - Rajasthan's 5th and India's 55th tiger reserve, approved in August 2023.
   - The reserve encompasses diverse habitats that support a variety of wildlife, including tigers, leopards, hyenas, and multiple deer species.

Odisha

1. **Simlipal TR**
   - It is part of the Eastern Ghats and features dense forests, grasslands, and stunning waterfalls like Barehipani and Joranda.
   - It is **home to a significant population of Bengal tigers, along with leopards, elephants, gaurs, and various deer species.**
   - It **also hosts a wide variety of bird species, reptiles, and endemic flora. It is also a UNESCO-recognized Biosphere Reserve**
2. **Satkosia TR**
   - It encompasses Satkosia Gorge WLS and the Baisipalli WLS.
   - The TR is located where the **Mahanadi River** passes through a long gorge in the Eastern Ghats.
   - The area is also a **part of the Mahanadi ER.**

Tamil Nadu

Name	Features
Anamalai TR **Mudumalai TR**	• Features discussed above under National Parks
Sathyamangalam TR, WLS (UPSC 2017)	• It is located in the **Eastern Ghats.** • Sathyamangalam TR = **Sathyamangalam + Hasanur Forest Divisions.** • It is a wildlife corridor in the Nilgiris BR between the Western Ghats and the Eastern Ghats and a **genetic link between BR Hills WLS, Mudumalai NP and Bandipur NP.**
Kalakad-Mundanthurai TR	• It forms **part of the Agasthyamalai BR.** • Agasthyamalai Hill Range is the **core zone of the TR.** • **Major Fauna:** Tiger, leopard, elephant, gaur, sambar, chital, Nilgiri tahr, mouse deer, lion-tailed macaque.
Srivilliputhur-Megamalai TR	• Created by **combining Srivilliputhur Grizzled Giant Squirrel Sanctuary and Megamalai WLS.** • Biggest beneficiary is the dying **Vaigai River** (that drains to the Palk Strait). The formation of TR has kept the rivers perennial in the region. • It is a **part of the Brahmagiri-Nilgiris-Eastern Ghats ER.**

Telangana

1. **Kawal TR**
   - The **Godavari River** flows along its southern boundary.
   - **Major Fauna:** Tiger, leopard, gaur, cheetah, sambar, nilgai, barking deer, Chausingha, sloth bear
2. **Amrabad TR, WLS**
   - **Earlier, part of Nagarjunasagar-Srisailam TR,** but post-bifurcation, the northern part of the reserve is vested with Telangana state and renamed as Amrabad TR.
   - It is **India's second-largest TR,** next only to Nagarjunasagar Srisailam TR.
   - **Chenchu tribe:** It is a hunter-gatherer community, designated as a Scheduled Tribe in Andhra Pradesh, Telangana, Karnataka, and Odisha.

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Uttar Pradesh

1. Amangarh TR

- It forms an **extension of and buffer to Jim Corbett NP.**
- After the state of Uttarakhand was carved out of Uttar Pradesh, Jim Corbett went to Uttarakhand and Amangarh remained in Uttar Pradesh.

2. Dudhwa TR, NP

- It is located in the **Terai belt (Indo-Nepal border).**
- **Dudhwa TR = Dudhwa NP + Kishanpur WLS + Katarniaghat WLS.**
- The **Sharda River** (Kali or Mahakali River) separates Dudhwa NP from Kishanpur WLS. The **Ghaghara River** separates Dudhwa NP from Katarniaghat WLS. Indian rhinoceros (VU) was **reintroduced** into Dudhwa from Pobitora Sanctuary (Assam). Black-crested bulbul (LC) was spotted after several years.

3. Pilibhit TR

- It lies in the **Terai belt (on the Indo-Nepal border).** Sharda Sagar Dam is on the east and **River Sharda** (a tributary of River Ghaghara) is on the northeast.

4. Ranipur TR, WLS

- It is 54th TR in India.
- Ranipur WLS has no tigers of its own, but it is frequented by tigers from the nearby Panna TR. Ranipur WLS is an **important corridor for the movement of tigers.**

Uttarakhand

1. Jim Corbett TR, Rajaji TR

West Bengal

1. Buxa TR, Sunderbans TR

ELEPHANT RESERVES OF INDIA

- India has the **largest number of wild Asian elephants** in the world, estimated at 29,964 according to the **2017 census,** about 55% of the species' global population.
- They range in 33 Elephant Reserves spread over 10 elephant landscapes in 14 states, covering about 80,000 sq km of forests across India.
- The 'home range' of an elephant herd can vary from an average of about 250 sq km (in Rajaji NP) to over 3500 sq km (in the highly fragmented landscapes of West Bengal).

East-Central Landscape (WB – Jharkhand –Orissa)	• **Mayurjharna ER – West Bengal, Odisha** • Singhbhum ER – Jharkhand (comprises of Dalma WLS) • Mahanadi ER – Odisha (Satkosia TR = Satkoshia Gorge WLS + Baisipalli WLS) • Sambalpur ER – Odisha • Baitami (Brahmani-Baitarani) ER – Odisha • South Orissa ER – Odisha • Lemru ER – Chhattisgarh • Badalkhol-Tamorpingla Elephant Reserve – Chhattisgarh (constitutes Badalkhol WLS and forests between Badalkhol WLS and Guru Ghasidas NP.)
Kameng-Sonitpur Landscape (Arunachal – Assam)	• **Kameng Elephant Reserve – Arunachal Pradesh** • Sonitpur Elephant Reserve – Assam & Arunachal Pradesh (southern extension of Kameng ER, The Nameri TR, and Sonai Rupai WLS are a part of this reserve)
Eastern-South Bank Landscape (Assam – Arunachal)	• Dihing-Patkai ER – Assam (Dihing Patkai NP is a part of Dehing Patkai ER) • South Arunachal Elephant Reserve – Arunachal Pradesh (Namdapha TR is a part of this ER.
Kaziranga-Karbi Anglong-Intanki Landscape	• Kaziranga-Karbi Anglong ER – Assam (Kaziranga TR, Nambor-Doigrung WLS, Garampani WLS, Nambor WLS are a part of this ER) • Dhansiri-Lungding ER – Assam • **Intanki ER – Nagaland** • Singphan ER – Nagaland
North Bengal-Greater Manas Landscape	• Chirang-Ripu ER – Assam (part of the buffer zone of Manas TR. These forests have the largest known population of the endangered Golden Langur (EN)) • Eastern Dooars ER – West Bengal
Meghalaya Landscape	• Garo Hills ER – Meghalaya (consists of Nokrek NP, Balpakram NP and Siju WLS and the surrounding Reserved Forests) • Khasi Hills ER – Meghalaya
Brahmagiri-Nilgiri-Eastern Ghat Landscape	• Mysore ER – Karnataka (integral part of Muttodi (Bhadra TR) – Brahmagiri – Nagarholle TR – Bandipur TR Corridor, Nagarhole TR and Bandipur TR are a part of the Nilgiri BR) • Wayanad ER – Kerala (Wayanad WLS and Aralam WLS are a part of the Nilgiri BR) • Nilgiri ER – Tamil Nadu (consists of the entire Nilgiri BR of Tamil Nadu) • Rayala ER – Andhra Pradesh • Nilambur ER – Kerala (Salient Valley NP, New Amarambalam WLS are a part of this ER • Coimbatore ER – Tamil Nadu
Annamalai-Nelliyampathy Landscape (TN – Kerala)	• Anamudi ER and Anamalai ER are separated from Nilgiris by Palakkad Gap. • Anamalai ER – Tamil Nadu, Kerela

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Periyar-Agasthyamalai Landscape (Kerala – Tamil Nadu) (UPSC-2019)	• Periyar ER – Kerala (Periyar NP and WLS was declared as an Periyar ER) • Srivilliputhur ER • Agasthyamalai ER (Agasthyamalai ER is also a BR. It includes Shendurney WLS, Peppara WLS, Neyyar WLS, and Kalakkad Mundanthurai TR)
North-Western Landscape (Uttarakhand – Uttar Pradesh)	• Shivalik ER – Uttarakhand (It constitutes Jim Corbett TR, Rajaji TR, Sonanadi WLS, DehraDun forests and other Shivalik forest divisions sprawling in Garhwal and Kumaon hills) • Uttar Pradesh ER – Uttar Pradesh • Terai ER – Uttar Pradesh (include Dudhwa TR, Pilibhit TR and areas of Kishanpur and Katarniaghat WLS)

Ramsar Sites

Ramsar Sites are wetlands designated as internationally important under the Ramsar Convention 1971 , an international convention for the conservation and sustainable use of wetlands. Their conservation is based on the 'wise-use' principle.

- **The Cobourg Peninsula in Australia was the world's first Ramsar site, identified in 1974.**
- **The United Kingdom has the most Ramsar sites in the world with 175.**
- **Bolivia has the largest area with 148,000 square km under the Convention protection.**

Ramsar Sites of India (85- by Dec 2024)

- **State with highest no. of sites:** Tamil Nadu

Andhra Pradesh (1)	**Kolleru** Lake
Assam (1)	**Deepor** Beel
Bihar (3)	**Kanwar** (Kabar) Taal, Nagi Bird Sanctuary, Nakti Bird Sanctuary
Goa (1)	Nanda Lake
Gujrat (4)	Khijadia WLS; Nalsarovar BS; **Thol** Lake; and Wadhvana Wetland
Haryana (2)	Bhindawas WLS and Sultanpur NP
Himachal Pradesh (3)	Chandra Taal; **Pong Dam Lake; and Renuka Lake [UPSC 2018, 2022]**
Karnataka (4)	Aghanashini Estuary, Ankasamudra Bird Conservation Reserve, Mgadi Kere Conservation reserve, Ranganathituu BS
Kerala (3)	Ashtamudi Wetland; Sasthamkotta Lake and Vembanad-Kol Wetland (Longest Lake in India)
Madhya Pradesh (5)	Bhoj Wetland; Sakhya Sagar; Sirpur wetland; and Yashwant Sagar, Tawa Reservoir
Maharashtra (3)	Lonar Lake (Impact Crater Lake); Nandur Madhameshwar and Thane Creek (Flamingo Sanctuary)
Manipur (1)	Loktak Lake
Mizoram (1)	Pala Wetland
Odisha (6)	Chilika Lake; Ansupa Lake; Bhitarkanika Mangroves; Hirakud Reservoir; Satkosia Gorge and Tampara Lake.
Punjab (6)	Beas CnR; Harike Wetland; Kanjli Wetland; Keshopur-Miani CmR; Nangal WLS and Ropar Wetland
Rajasthan (2)	Keoladeo National Park and Sambhar Lake
Tamil Nadu (18-maximum)	Chitrangudi BS; Gulf of Mannar Marine BR; Kanjirankulam BS; Karaivetti BS; Karikili BS; Kazhhuvelli BS; Koonthankulam BS; longwood Shola RF; Nanjaryan BS; Pallikaranai Marsh Reserve Forest; Pichavaram Mangrove; Point Calimere WLS & BS; Suchindram Theroor Wetland Complex; Udhayamarthandapuram BS; Vaduvur BS; Vedanthangal BS; Vellode BS and Vembannur Wetland Complex
Tripura (1)	Rudrasagar Lake **[UPSC 2022]**
UT of JK (5)	Hokera Wetland **[UPSC 2022];** Hygam Wetland CnR; Shallbugh Wetland CnR; Surinsar-Mansar Lakes and Wular Lake
UT of Ladakh (2)	Tso Kar (High Altitude Ramsar Site) and Tsomoriri (High Altitude Ramsar Site)
Uttar Pradesh (10)	Bakhira WLS; Haiderpur Wetland; Nawabganj BS; Parvati Arga BS; Saman BS; Samaspur BS; Sandi BS; Sarsai Nawar Jheel; Sur Sarovar (Keetham Lake) and Upper Ganga River (Brijghat to Narora)
Uttarakhand (1)	Asan Barrage
West Bengal (2)	East Kolkata Wetlands and Sundarban Wetland (Largest Ramsar Site in India)

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Largest, Smallest and Oldest Ramsar Sites in India

	Ramsar site	State	Area(km2)
Largest	**Sundarban Wetland**	West Bengal	4230
Smallest	**Renuka Lake**	HP	0.2
	Vembannur Wetland Complex	TN	0.2
Oldest	**Chilika**	Odisha	1981
	Keoladeo Ghana	Rajasthan	1981

BIOSPHERE RESERVES (UPSC-2014)

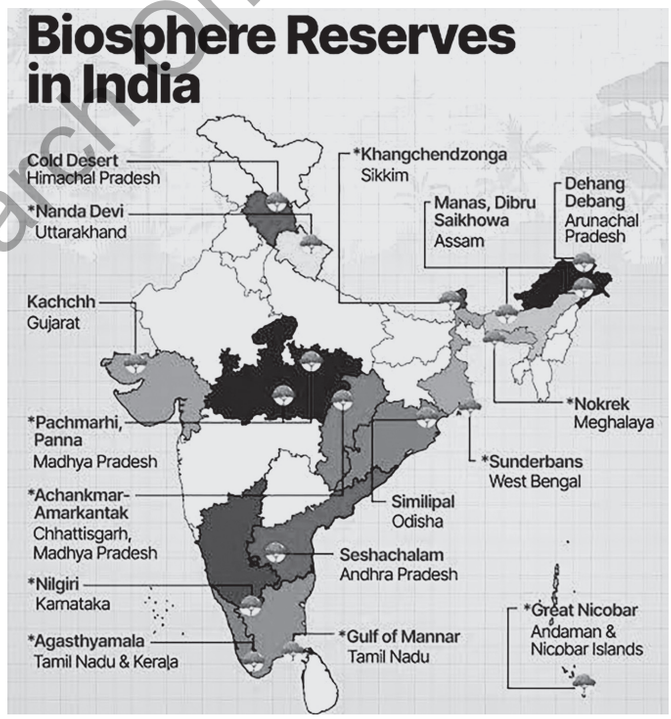
- A Biosphere Reserve is a designated area that promotes the balanced relationship between humans and nature by integrating conservation, sustainable use of natural resources, and scientific research.
- It is based on the principle of zonation and is divided into the following three zones as follows:

Features	Core Zone	Buffer Zone	Transition Zone
Definition	Central, strictly protected area of a biosphere reserve.	Surrounds the core zone, and serves as a buffer for activities compatible with conservation.	Outer zone where sustainable human activities are promoted.
Primary Function	Conservation of biodiversity and ecosystems.	Research, education, and limited activities that support conservation.	Development, sustainable resource use, and community engagement.
Human Activity	Prohibited or minimal (e.g., scientific monitoring).	Regulated activities like tourism, research, and education.	Extensive human activity, including agriculture, settlements, and industries.

- Biosphere reserves are sites established by countries and recognized under UNESCO's Man and the Biosphere (MAB) Programme to promote sustainable development based on local community efforts and sound science.
- The World Network of Biosphere Reserves currently consists of 738 sites in 134 countries, including 22 transboundary sites.
- Spain has the most biosphere reserves (BRs) in the world, with 53 properties

Biosphere Reserves of India

Presently, there are **18 notified biosphere reserves in India (12 of them are recognized by UNESCO's MAB)**



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Cold Desert, Himachal Pradesh	• It includes **Pin Valley National Park, Chandratal, Sarchu and Kibber** Wildlife Sanctuaries. • Major Fauna: Snow Leopard (VU), Himalayan Ibex (also referred to as Siberian Ibex – LC).
Nanda Devi, Uttrakhand (UNESCO's MAB)	• **Nanda Devi NP + Valley of Flowers NP.** • Major Fauna: Snow Leopard (VU), Musk Deer (EN), Bharal Or Blue Sheep (LC), etc.
Khangchendzog, Sikkim (UNESCO's MAB)	• **Transboundary biodiversity hotspot** conservation area. It includes the **third-highest mountain peak in the world, Kanchenjunga** (8,586 m). • The **Khangchendzonga NP, which comprises the core area of the KBR,** was inscribed as **India's first "Mixed World Heritage Site".** • **Major Fauna:** Red Panda (EN), Snow Leopard (VU), Musk Deer (EN), Great Tibetan Sheep(Argali) etc.
Dehang-Debang, Arunachal Pradesh	• The **Mouling NP and the Dibang WLS** are located fully or partly within this biosphere reserve. The terrain is rugged, with an altitudinal range of 750 to 3000 m at the highest point, the **Mouling Peak.** • **Major Fauna:** Takin (VU), Red Panda (EN).
Manas, Assam	• Manas BR = **Manas National Park.** It is contiguous with the **Royal Manas National Park** in Bhutan. Manas is famous for its population of the Wild Water Buffalo (EN). • **Rare and endemic wildlife:** Assam Roofed Turtle (EN), Hispid Hare (EN), Golden Langur (EN) and Pygmy Hog (EN). • **The grassland biomes inhabits:** Pygmy Hog, Rhinoceros (re-introduced in 2007), elephants, Bengal florican (CR), etc.
Dibru-Saikhowa, Assam	• Dibru-Saikhowa BR = **Dibru-Saikhowa National Park.** • **Major Fauna:** Bengal Tiger, Clouded Leopard (VU), Gangetic Dolphin (EN), etc.
Nokrek, Meghalaya (UNESCO's MAB)	Nokrek (1,412 m) is the highest peak of the Garo hills. **Vegetation:** Evergreen, semi-evergreen & deciduous. **Key Fauna:** Red Panda (EN), Hoolock Gibbons (EN), Red Giant Flying Squirrel (LC), etc.
Panna, Madhya Pradesh (UNESCO's MAB)	• Panna Biosphere Reserve = **Panna TR.** • **Fauna:** Tiger (EN), Chital (LC), Chinkara (LC), Sambar (VU). • Latest Site to be add in **UNESCO's MAB**
Pachmarhi, Madhya Pradesh (UNESCO's MAB)	• Pachmarhi BR **(Satpura NP + Bori WLS + Pachmarhi WLS)** lies in the centre of the Satpura Range. The highest peak is the **Dhoopgarh** (1,352 m). **Gonds** are the major tribes.
Achanakmar-Amarkantak, Madhya Pradesh, Chhattisgarh (UNESCO's MAB)	• It extends across the states of **Madhya Pradesh and Chhattisgarh. Maikal hills** together with eastern **Vindhyas** and **Satpuras** lie within the reserve. • **Major Fauna:** Four Horned Antelope (Chausingha (VU)), Indian Wild Dog (EN), etc. • **Vegetation:** moist deciduous and dry deciduous forests.
Kachchh, Gujarat (Largest Area)	• The Great Rann of Kutch is a salt marsh in the Thar Desert. • Great Rann of Kutch BR = **Kachchh Desert Sanctuary (in Great Rann of Kutch) + Wild Ass Sanctuary (in Little Rann of Kutch), Narayan Sarovar Sanctuary + Kutch Bustard Sanctuary + Banni Grasslands Reserve.** • Major Fauna: Great Indian Bustard (CR), Indian Wild Ass (NT), etc.

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Similipal, Odisha (UNESCO's MAB)	• It includes the **Mayurbhanj Elephant Reserve (Similipal TR + Hadgarh WLS + Kuldiha WLS).** • **Tribes: Erenga, Kharias, Mankirdias, Ho, Gonda & Munda.** • **Major Fauna:** Royal Bengal Tigers, Wild Elephants (EN), Gaurs (VU – Indian Bison), Chausingha (VU).
Sundarban, West Bengal (UNESCO's MAB)	• Located in the vast Delta of the Ganges, south of Kolkata and **bordering Bangladesh in the east.** It provides habitat for the threatened Royal Bengal Tiger (EN). • Sundarbans BR = **Sundarbans NP + Sajnekhali WLS + Lothian WLS + Haliday WLS.**
Seshachalam, Andhra Pradesh	• The Seshachalam Hills are part of the **Eastern Ghats** (south of the **Panna River**) in southern Andhra Pradesh. • **Tirupati,** a major Hindu pilgrimage town, and **Sri Venkateswara NP** are located in these ranges. • **Major Flora:** rare and endemic plant species like Red Sanders (NT) are of great economic importance. • **Major Reptilian Fauna:** Golden Gecko (LC – Endemic To Tirumala Hills).
Agasthyamala, Karnataka-Tamil Nadu-Kerala (UNESCO's MAB)	• **Agasthyamala BR = Shendurney WLS + Peppara WLS + Neyyar WLS + Kalakad Mundanthurai TR.** The reserve is home to **Kani tribes** from both Tamil Nadu and Kerala. • **Major Fauna:** Nilgiri Tahr (EN)
Nilgiri, Tamil Nadu-Kerala (UNESCO's MAB, First to be included)	• Nilgiris (blue mountain) got their name from the **purplish blue flowers of Neelakurinji (blossoms once in 12 years).** • The Nilgiri Sub-Cluster (UNESCO World Heritage Site) includes the **Mudumalai, Mukurthi, Nagarhole, Bandipur, and Silent Valley national parks, as well as the Aralam, Wayanad, and Sathyamangalam** wildlife sanctuaries. • **Vegetation:** Tropical evergreen forests (western side of Western Ghats), montane sholas and grasslands (at high altitudes), semi-evergreen forests, moist deciduous forests, dry deciduous forests, and thorn forests. • **Major Fauna:** Lion Tailed Macaque (EN), Nilgiri Tahr (EN), Malabar Giant Squirrel (LC), Nilgiri Langur (VU), etc.
Gulf of Mannar, Tamil Nadu (UNESCO's MAB)	• It lies between the west coast of Sri Lanka and the south-eastern tip of India, in the **Coromandel Coast region.** • The chain of low islands and reefs known as **Ram Sethu** (Adam's Bridge), which includes Mannar Island, separates the Gulf of Mannar from Palk Bay, which lies to the north between Sri Lanka and India. • The biosphere reserve comprises islands with estuaries, seagrasses, coral reefs, salt marshes, and mangroves. • **Major Fauna: Dugong** (VU), Olive Ridley turtles (VU), etc.
Great Nicobar, Andaman & Nicobar Island (UNESCO's MAB)	• Great Nicobar BR = **Campbell Bay NP + Galathea NP.** • **Vegetation:** tropical wet evergreen forests. • **Major Fauna:** Dugong (VU), Saltwater Crocodile (LC), etc.

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UNESCO WORLD HERITAGE SITES IN INDIA

- UNESCO World Heritage Sites are globally significant cultural, natural, or mixed landmarks protected under the 1972 UNESCO World Heritage Convention.
- Sites are classified as cultural (e.g., monuments), natural (e.g., ecosystems), or mixed (e.g., cultural and ecological significance).

List of UNESCO World Heritage Sites in India

Name of WH Site (Natural)	State
Great Himalayan NP Conservation Area	Himachal Pradesh
Western Ghats	Maharashtra to Kerala
Nanda Devi and Valley of Flowers NP	Uttarakhand

Sundarbans National Park	West Bengal
Kaziranga National Park	Assam
Keoladeo National Park	Rajasthan
Manas Wildlife Sanctuary	Assam
Name of WH Site (Cultural)	**State**
Agra Fort	Uttar Pradesh
Ajanta Caves	Maharashtra
Ellora Caves	Maharashtra
Taj Mahal	Uttar Pradesh
Group of Monuments at Mahabalipuram	Tamil Nadu
Sun Temple, Konark	Odisha
Churches and Convents of Goa	Goa
Fatehpur Sikri	Uttar Pradesh
Group of Monuments at Hampi	Karnataka
Khajuraho Group of Monuments	Madhya Pradesh
Elephanta Caves	Maharashtra
Great Living Chola Temples	Tamil Nadu
Group of Monuments at Pattadakal	Karnataka
Santiniketan	West Bengal
Buddhist Monuments at Sanchi	Madhya Pradesh
Mountain Railways of India	West Bengal, T.N, H.P
Humayun's Tomb, Delhi	Delhi
Qutub Minar and Monuments, Delhi	Delhi
Mahabodhi Temple Complex at Bodh Gaya	Bihar
Rock Shelters of Bhimbetka	Madhya Pradesh
Champaner-Pavagadh Archaeological Park	Gujarat
Chhatrapati Shivaji Terminus (formerly Victoria Terminus	Maharashtra
Red Fort Complex	Delhi
Jantar Mantar	Jaipur
Hill Forts of Rajasthan	Rajasthan
Rani Ki Vav	Gujarat
Archaeological Site of Nalanda Mahavira at Nalanda	Bihar
The Architectural Work of Le Corbusier, an Outstanding Contribution to the Modern Movement	Chandigarh
Historic City of Ahmedabad	Gujarat

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Victorian Gothic and Art Deco Ensembles of Mumbai	Maharashtra
Jaipur City	Rajasthan
Kakatiya Rudreshwara (Ramappa) Temple	Telangana
Dholavira, a Harappan City	Gujarat
Sacred Ensembles of the Hoysala	Karnataka
Name of WH Site (Mixed)	**State**
Khangchendzonga National Park (first Mixed Heritage site)	Sikkim

BIODIVERSITY HERITAGE SITE (BHS)

- **Well-defined areas that are unique and ecologically fragile ecosystems (terrestrial, coastal, marine, inland waters) having rich biodiversity comprising of any one or more of the following components:**
  - Species richness, High endemism, Presence of rare and threatened species, keystone species, and species of evolutionary significance, Presence of wild ancestors of domestic/cultivated species
- **Section 37 of the Biological Diversity Act, 2002 (BDA):** State Government local bodies may notify areas of biodiversity importance as BHS. Declaration of an area as BHS does not put any restriction on the prevailing practices and usages of the local communities. The purpose of BHS is to enhance the quality of life of the local communities through conservation measures.

List of Biodiversity Heritage Sites (BHS) in India

Name of the BHS Site (47)	State	Importance
Nallur Tamarind Grove	Karnataka	Believed to be a **relic of the Chola Dynasty**
Hogrekan	Karnataka	**Shola Vegetation,** adjoining Bhadra Wildlife Sanctuary and **Yemmedode Tiger Reserve** and serving as "Wildlife Corridor" between **Kudremukha and Bhadra Wildlife Sanctuary.**
University of Agricultural Sciences, GKVK Campus	Karnataka	**Greenest areas in Bengaluru**
Ambaraguda	Karnataka	Revenue land located between **Sharavathi Wildlife Sanctuary** and Someshwara Wildlife Sanctuary.
Glory of Allapalli	Maharashtra	Reserved forest
Tonglu BHS	Darjeeling, West Bengal	**Medicinal** Plant Conservation Areas
Dhotrey BHS under the Darjeeling Forest Division	West Bengal	**Medicinal** Plant Conservation Areas
Dialong Village	Manipur	The **Rongmei tribes** of Dailong and other villages of Tamenglong district were conserving forest in the form of sacred groves known as **"Raengan"**
Ameenpur Lake	Telangana	Urban Wetland
Majuli	Assam	**Largest river island in India,** famous for producing 100 varieties of paddy without application of fertilizers and pesticides.
Ghariyal Rehabilitation Centre, Lucknow	Uttar Pradesh	Conservation and rehabilitation of critically **endangered species of Gharial**
Chilkigarh Kanak Durga	West Bengal	**Sacred Grove**
Khlaw Kur Syiem KmieIng	Meghalaya	**Sacred Grove**
Mandasaru	Odisha	**Mandasaru gorge** is an adobe of 1563 species of plants, animals, and fungi spread over an area of 528 ha.
Purvatali Rai	Goa	**Sacred Grove,** Medicinal Plants

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Naro Hills	Madhya Pradesh	Part of the Vindhya Hills region and a dry deciduous forest. Medicinal Plant including Dillenia pentagyna, Plumbago capensis, Psilotum nudum, Drosera burmanii, Alectra chitrakutensis, Cordia macleodii, Costus speciosus, Strychnos nux-vomica, Plumbago zeylancia etc.
Patalkot	Madhya Pradesh	Patalkot (Sanskrit for "Very Deep") is a valley in the Tamia tehsil of Chhindwara district in Madhya Pradesh, India. Patalkot is 78 km away from Chhindwara district headquarter. This valley is home to a tribal culture and enormous herbal wealth.
Asramam, Kollam	Kerala	BHS hosts a unique diversity of Mangrove species, Harbour Syzygium travancoricum (CR, IUCN List)
Bambarde Myristica Swamps	Maharashtra	Remnants of primaeval forests of the Western Ghats
Ganeshkhind Garden	Maharashtra	Holds a total of 610 germplasms of 49 crops including high economic value plants
Landorkhori	Maharashtra	The natural plantation of **Bori** (Zizyphus jujube) trees is unique and has survived since old ages.
Schistura Hiranyakeshi	Maharashtra	Declared as **Biological Heritage Site in 2021**
Baneswar Shiva Dighi	West Bengal	Offers refuge to Black Softshell Turtle Nilssonia nigricans listed under Appendix I of CITES and extinct in the wild category of IUCN.
Sural Bhatori Monastery	Himachal Pradesh	Sacred Grove
High Altitude Meadow (HUDAN BHATORI)	Himachal Pradesh	Important Horal species recorded in the area
Birch-pine Forest Patch(Nain Gahar)	Himachal Pradesh	Main trees are Himalayan Birch (Betula utilise) and Blue Pine (Pinus wallichiiana)
Baramura Waterfall	Tripura	Highest natural waterfall in Tripura
Unakoti	Tripura	Cultural and religious significance, Called **Angkor Wat of the North-East**
Silachari Caves	Tripura	**Only natural cave of Tripura**
Debbari or Chabimura	Tripura	Chabimura is famous for its panels of rock carvings on the steep mountain wall on the bank of river Gomati. These images date back to 15th-16th centuries AD.
Betlingshib & its surroundings	Tripura	It is the highest peak of Tripura and has the highest floristic diversity in Tripura. **Conservation:** It is habitat for several red listed flora and fauna. It is a medicinal plant conservation area.
Amarkantak	Madhya Pradesh	Situated on the **Maikal Mountain**
Hajong Tortoise Lake	Assam	Lake is a natural habitat of Critically Endangered freshwater 'Black Softshell turtle'
Borjuli Wild Rice Site	Assam	Good population of wild species of rice -Oryza rufipogon.
Arittapatti Biodiversity Heritage Site	Tamil Nadu	Rich biological and historical significance, 3 flagship **Raptor species - Laggar Falcon, Shaheen Falcon, Bonelli's Eagle**
Mahendragiri Hill Biodiversity Heritage Site	Odisha	The ancient temples of **Kunti, Shima, Arjuna and Yudhisthir** at Mahendragiri have been declared as protected monuments **under the Ancient Monument and Archaeological sites and Remains Act 1958 by the State Government.**

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State Horticulture Research and Development Station	West Bengal	Rich Heritage of indigenous germplasm of horticulture and medicinal plants
Namthing Pokhari	West Bengal	Habitat for **Himalayan Newt**
Char Balidanga	West Bengal	-
Amkhoi Wood Fossil Park	West Bengal	Well preserved angiosperm wood fossil representing the existence of a forest dating back to the late Jurassic age.
Haldir Char Island	West Bengal	Mangrove swamp with tidal influence and sustains littoral fauna
Birampur-Baguran Jalpai	West Bengal	-
Tungkyong Dho	Sikkim	Believed to be one of the oldest natural **dho (lake)** directly related to the **Hee-Youngmingmoo clan of Lepcha community in Dzongu.**
Gandhamardan Hill	Odisha	Treasure trove of **medicinal plants.**

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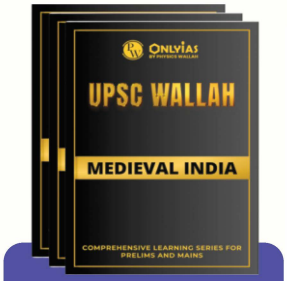

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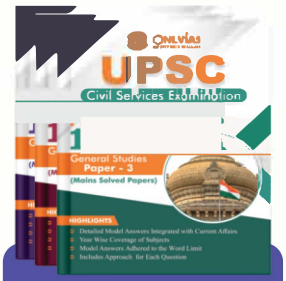

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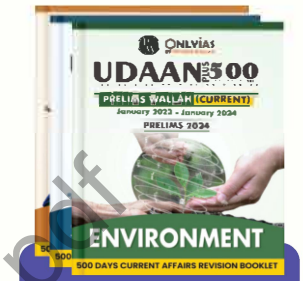

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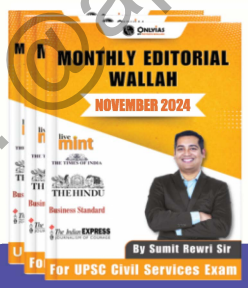

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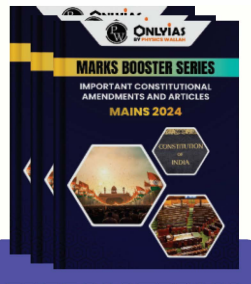

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