IAS MIND

Belief is Experience

GENERAL STUDIES · PRELIMS SERIES

Environment & Ecology

MINDMAPS FOR PRELIMS

13 chapters · Concept to current status · Diagrams & tables

Updated to November 2026 · UPSC · State PCS

BELIEF IS EXPERIENCE · @IASMIND2026

Contents

01	Environment & Sustainable Development	3
02	Institutions, Laws & Ideas	10
03	Ecology & Ecosystems	14
04	Biodiversity & its Conservation	20
05	Greenhouse Effect & Climate Change	25
06	The Ozone Layer	29
07	Forests & Land	31
08	Protected Areas of India	33
09	Saving India's Wildlife	37
10	Energy Resources	40
11	Environmental Pollution	43
12	Water & the Ganga	46
13	People, Days, Awards & Treaties	48

> Every section opens with a short narrative that links it to what came before. Its branches then move in a fixed order — **Concept**, **Key facts**, **Explained**, **Points of precision** and **Current status (2026)** — and every line is a complete statement. Figures and events are current to November 2026.

What Surrounds Us

Environment · The global environmental movement

CHAPTER OUTLINE

1 Environment → 2 Global journey 1972–2015 → 3 Sustainable development → 4 SDGs → 5 India's green law → 6 Green farming → 7 Nature's cycles → 8 Air & degradation

1 ENVIRONMENT *Pari + Aavaran*

Every story of ecology begins with one simple question — what surrounds us? Not just the trees and rivers we can see, but the invisible threads that tie air to water, soil to seed, and people to all of them. On these threads rests the whole science of ecology.

Concept

- The Hindi word "paryavaran" joins **pari** (around) and **aavaran** (cover) — the cover that surrounds us on all sides.
- Environment is the **sum total of conditions** — land, water, air, plants, animals — that surround a living being at a given time.
- In its fullest sense, environment is an **interacting system of physical, biological and cultural elements** that are interlinked.

Key facts

- **Abiotic (physical)** — land, water, air, soil, rocks, minerals, climate; they set the stage.
- **Biotic** — plants, animals, humans and micro-organisms; they are the actors on that stage.
- **Geomorphological** features (mountains, plains, valleys) are also counted as environment.
- Common threefold division: **physical, biological and cultural** environment.
- The **cultural** environment — religion, morals, customs, law, behaviour — is what humans build from their contact with nature.

Explained

- Environment is not a list of objects but a web of **interactions** — a forest is trees **plus** the way they shade soil, hold rain and feed animals.
- Because every part is linked, damage travels: cutting a hillside forest causes erosion, silted rivers and floods far downstream.
- It can be studied at micro (a pond), macro (a biome), regional and global scales.
- This idea of linkage is the root of **ecology** and of every environmental law.

Points of precision

- **Habitat** is the actual **place** where an organism lives; **environment** is the whole set of conditions around it, of which habitat is a part.
- An **ecosystem** is the living community **plus** its physical environment working as one unit.
- "**Environmental degradation**" means an overall decline in the quality of environmental attributes — caused by nature or by humans.
- The natural environment is not always "clean" — volcanoes, dust storms and forest fires also pollute.

FOUR TERMS DISTINGUISHED

- **Habitat** = address (where it lives).
- **Niche** = profession (what role it plays).
- **Environment** = everything around, plus the interactions.
- **Ecosystem** = community + environment as one functioning unit.

2 THE GLOBAL ENVIRONMENTAL MOVEMENT *1962 – 2015*

Before the 1960s, smoke from chimneys was a sign of progress. Then a marine biologist wrote about birds dying from pesticides, and the world began to ask whether growth itself had a cost. Within ten years, nations met in Stockholm; within thirty, in Rio and Johannesburg. Every international environmental framework of today rests on this journey.

Concept

- Modern environmentalism grew in three waves: **awareness (1960s)**, **institutions (1970s)** and **global agreements (1990s onward)**.
- Each summit built on the last — Stockholm gave UNEP, Brundtland gave the definition, Rio gave the treaties, and Rio+20 gave the SDGs.

Key facts

- **1962** — **Rachel Carson**'s *Silent Spring* exposed how **DDT** killed birds and set off the global environmental movement.
- **1972 (5–16 June)** — **UN Conference on the Human Environment, Stockholm** — the first global environment summit.
- Stockholm created **UNEP** (HQ **Nairobi**) and gave us **World Environment Day — 5 June** (first held in 1973, theme "Only One Earth").
- **1972** — the **Club of Rome** published *The Limits to Growth* (Meadows and others): endless growth on a finite planet must hit limits.
- **1987** — **Brundtland Report**, *Our Common Future*, defined sustainable development.
- **1992 (June)** — **Rio Earth Summit (UNCED)**, Rio de Janeiro.
- **1997** — **Rio+5 / Earth Summit+5**, a special UN General Assembly session in **New York**.
- **2002** — **Rio+10**: **World Summit on Sustainable Development (WSSD), Johannesburg**.
- **2012 (20–22 June)** — **Rio+20**: **UN Conference on Sustainable Development**, Rio; outcome "**The Future We Want**".
- **2015 (Sept)** — **2030 Agenda** with 17 SDGs adopted in New York; **Paris Agreement** in December.

Explained

- At Stockholm, **Indira Gandhi** — the only head of government other than the host to attend — argued that "**poverty is the greatest polluter**", linking environment with development.
- Rio 1992 produced five documents: the **Rio Declaration** (27 principles), **Agenda 21**, the **Forest Principles**, and two treaties opened for signature — **UNFCCC** and **CBD**.
- The **UNCCD** (desertification) was a Rio follow-up, adopted in 1994.
- Rio+20 did not create new treaties; it launched the process for the **SDGs** and set up the **High-Level Political Forum (HLPF)**.

Points of precision

- **Earth Summit + 5** was held in **1997** at **New York**.
- "Rio+20" is the short name for the **UN Conference on Sustainable Development (2012)**.
- The SDGs trace back to **Rio+20 (2012)**; the 1972 think-tank report was *The Limits to Growth*.
- The concept of "**Limits to Growth**" is linked with the **Club of Rome**.
- *Silent Spring* (1962) is by **Rachel Carson** — she also wrote *The Sea Around Us*.

The Global Journey, 1962–2015

Rio Earth Summit & the GEF · Agenda 21

MILESTONES OF THE GLOBAL ENVIRONMENTAL MOVEMENT

Year	Event	Place	Gave us
1962	Silent Spring (Rachel Carson)	USA	Global awareness; DDT bans
1972	UN Conf. on the Human Environment	Stockholm	UNEP; World Environment Day (5 June)
1972	The Limits to Growth	Club of Rome	Idea of planetary limits
1987	Brundtland Report	WCED	Definition of sustainable development
1992	Earth Summit (UNCED)	Rio de Janeiro	Agenda 21, Rio Declaration, UNFCCC, CBD, Forest Principles
1997	Earth Summit +5	New York	Review of Agenda 21
2002	WSSD (Rio+10)	Johannesburg	Johannesburg Plan of Implementation
2012	UNCSD (Rio+20)	Rio de Janeiro	"The Future We Want"; SDG process; HLPF
2015	UN Summit	New York	2030 Agenda, 17 SDGs

3 RIO EARTH SUMMIT & THE GEF

UNCED, 3–14 June 1992

Rio was the moment the world tried to bind environment and development into one bargain: the South would grow cleanly, and the North would help pay for it. Promises need a purse, so alongside the treaties came a permanent fund.

Concept

- **UNCED** (United Nations Conference on Environment and Development), popularly the **Earth Summit**, met at **Rio de Janeiro, 3–14 June 1992**, with about **180 countries**.
- Its aim was a global framework that **balances environmental protection with economic development**.

Key facts

- Issues on the table: climate change, global warming, environmental protection and sustainable development.
- Outcomes: **Agenda 21**, the **Rio Declaration** (27 principles), the **UNFCCC**, the **CBD** and the **Forest Principles** (non-binding).
- The Rio Declaration carries the principle of **Common But Differentiated Responsibilities (CBDR)** — Principle 7.
- The **CBD** has three aims: **conservation** of biodiversity, **sustainable use** of its components, and **fair and equitable sharing of benefits** from genetic resources.

Explained

- The **GEF (Global Environment Facility)** began in **October 1991** as a **pilot fund of the World Bank, UNDP and UNEP**; at Rio it became a **permanent, independent** financial mechanism. **HQ: Washington, D.C.**
- It is the financial mechanism for five conventions — **CBD, UNFCCC, UNCCD, Stockholm (POPs)** and **Minamata (mercury)**.
- Funds it manages: **GEF Trust Fund** (core grants and blended finance), **Least Developed Countries Fund (LDCF)** (National Adaptation Programmes of Action), **Special Climate Change Fund (SCCF)** (adaptation, technology transfer, diversification), **Global Biodiversity Framework Fund (GBFF)** (Kunming-Montreal targets) and the **Small Grants Programme (SGP)** for local communities and NGOs.

Points of precision

- The GEF is **not** a mechanism for the Ramsar Convention or CITES.
- Rio+5 met at **New York, 23–27 June 1997**; Rio+10 at **Johannesburg, 26 Aug–4 Sept 2002**.
- The **Partnership for Action on Green Economy (PAGE)** was launched in **2013** in response to the call made at Rio+20.

4 AGENDA 21

Rio 1992

Rio needed a programme of action for the new century. It came as a comprehensive plan named after its own time-frame — the twenty-first century.

Concept

- **Agenda 21** is a comprehensive, **non-binding** global action plan for sustainable development in the **21st century**, adopted at **Rio 1992**.

Key facts

- Focus areas: **survey and conservation of biodiversity**, **poverty alleviation** in developing countries, **population control**, **food and clean water**, **social security** and **transfer of resources and capital**.
- It has **40 chapters** in four sections — social & economic, conservation of resources, role of major groups, means of implementation.
- It asks governments, the UN and local bodies to act together.
- "**Local Agenda 21**" carries the plan to city and village level.

Points of precision

- Agenda 21 concerns **environment and sustainable development** in the 21st century.
- It **originated at Rio (1992)**; Johannesburg (2002) reviewed it.
- Being non-binding, it is an action **plan**, not a treaty.

Sustainable Development & the SDGs

Sustainable development · SDGs — the 2030 Agenda

5 SUSTAINABLE DEVELOPMENT *Our Common Future, 1987*

Once we see how tightly everything is linked, a hard question follows: how do we grow — build roads, farms and factories — without breaking those links? In 1987 a UN commission gave the answer a name that still guides every policy.

Concept
- Development that **meets the needs of the present without compromising** the ability of future generations to meet their own needs.
- Defined in *Our Common Future* — the **Brundtland Report (1987)** of the **World Commission on Environment and Development (WCED)**, chaired by **Gro Harlem Brundtland** of Norway.

Key facts
- Its foundation is **inter-generational equity** — today's generation holds the Earth in trust for tomorrow's.
- It also needs **intra-generational equity** — fairness between rich and poor living today.
- Three pillars: **economic, social, environmental** (people, planet, prosperity).
- It needs biodiversity conservation, pollution control and **poverty reduction**.
- Progress is judged by **ecological, economic, social and cultural** indicators together.

Explained
- The Brundtland definition has two key ideas: the concept of **needs** (especially the essential needs of the world's poor, to which overriding priority is given) and the idea of **limitations** imposed by technology and social organisation on the environment's ability to meet present and future needs.
- The poor often over-use forests and soils because they have no other choice — so ending poverty is itself an environmental policy.
- Sustainability does not mean "no growth"; it means growth that **does not eat its own capital** — the forests, soils, water and air.
- Planning it needs data on population, resources, living standards and technology, gathered by **remote sensing, GIS** and statistics.

Points of precision
- Saving energy and resources for the future **without sacrificing** present comfort is the essence of **sustainable development**.
- The concept is intertwined with **inter-generational equity**.
- The aim of **sustainable tourism** is to meet tourists' needs while **maintaining cultural integrity and ecological processes**.
- **Net Zero** means remaining emissions are **balanced by removals** (forests, carbon capture); India's target is **2070**.

6 SDGS — THE 2030 AGENDA *adopted September 2015*

An idea needs targets to become action. The world first tried eight Millennium Development Goals in 2000. When they ended in 2015, nations returned with a far bigger promise — seventeen linked goals, to be met by 2030.

Concept
- The SDGs are **17 goals with 169 targets** adopted by all **193 UN members** in **Sept 2015** under the 2030 Agenda, "Transforming our World".
- Motto: "**Leave No One Behind**"; grouped as the **5 Ps** — People, Planet, Prosperity, Peace, Partnership.

Key facts
- They replaced the **8 MDGs (2000–2015)**, which were mainly for poor countries; SDGs apply to **every** country.
- The process was launched at **Rio+20 (2012)**.
- In India **NITI Aayog** is the nodal body; **MoSPI** frames the **National Indicator Framework**.
- NITI Aayog's **SDG India Index** (since **Dec 2018**) ranks States and UTs — the first government-led sub-national SDG index in the world.

Explained
- The goals are interlinked — clean energy (SDG 7) helps climate action (SDG 13) and health (SDG 3).
- The index turns the goals into a race among states — **competitive and cooperative federalism**.

Points of precision
- Goal numbers: **SDG 10** Reduced Inequalities · **SDG 13** Climate Action · **SDG 14** Life Below Water · **SDG 15** Life on Land.
- The target year for all SDGs is **2030**.

Current status (2026)
- **UN SDG Index 2026** (SDSN, released at the Hamburg Sustainability Conference, June 2026): India **94th of 167** — its best ever — score **68.3** (99th in 2025; 112th in 2015).
- **Finland** first, then Sweden and Denmark; India still trails Bhutan, Maldives, Nepal and Sri Lanka.
- Only **~33%** of India's targets are on track; **SDG 2 (Zero Hunger)** is the biggest gap; globally no goal is on track.
- **SDG India Index 2023–24** (4th edition): India **71** (66 in 2020–21, 57 in 2018); **Kerala & Uttarakhand** top with **79**; 113 indicators.

THE 17 GOALS IN ORDER

No.	Goal	No.	Goal
1	No Poverty	10	Reduced Inequalities
2	Zero Hunger	11	Sustainable Cities and Communities
3	Good Health and Well-being	12	Responsible Consumption and Production
4	Quality Education	13	Climate Action
5	Gender Equality	14	Life Below Water
6	Clean Water and Sanitation	15	Life on Land
7	Affordable and Clean Energy	16	Peace, Justice and Strong Institutions
8	Decent Work and Economic Growth	17	Partnerships for the Goals
9	Industry, Innovation and Infrastructure		

Principles & Measures of Sustainability

Principles of sustainable development · Shades and models of ...

7 PRINCIPLES OF SUSTAINABLE DEVELOPMENT *from Rio to Indian courts*

A definition alone cannot settle a dispute between a factory and a village. So the concept was broken into working rules — principles that judges, planners and treaty-makers can actually apply. India's Supreme Court made several of them part of the law of the land.

Concept

- Sustainable development rests on a small set of principles drawn mainly from the **Rio Declaration (1992)**.
- Indian courts treat them as part of **Article 21** (right to life) and **Articles 48A and 51A(g)** (State and citizens' duty to protect the environment).

Key facts

- **Precautionary principle** (Rio Principle 15) — where there is a threat of serious or irreversible damage, lack of full scientific certainty is **no excuse** for postponing protection.
- **Polluter pays** (Principle 16) — the polluter bears the cost of pollution and of restoring the damage.
- **CBDR–RC** (Principle 7) — all states share the duty, but those who polluted more historically and have more capacity must do more.
- **Inter-generational equity** (Principle 3) and **intra-generational equity** (Principle 5 — eradicating poverty).
- **Public participation** and access to information (Principle 10); **Environmental Impact Assessment** (Principle 17).
- **Public trust doctrine** — the State holds natural resources (rivers, forests, seashores) **in trust** for the public and cannot hand them over for private use.

Explained

- **Vellore Citizens' Welfare Forum v. Union of India (1996)** — the Supreme Court held that the **precautionary principle and polluter-pays principle** are part of India's environmental law; tanneries in Tamil Nadu were ordered to pay.
- **M.C. Mehta v. Kamal Nath (1997)** — applied the **public trust doctrine** to the Beas river (Span Motel case).
- **M.C. Mehta v. Union of India (1986)**, the **Oleum gas leak** case — laid down **absolute liability** for hazardous industries, stricter than the English rule of strict liability.
- **Indian Council for Enviro-Legal Action (1996)** — polluting chemical units at Bichhri (Rajasthan) made to pay for restoration.

Points of precision

- Article **48A** (Directive Principle) and **51A(g)** (Fundamental Duty) were both added by the **42nd Amendment, 1976**.
- Absolute liability allows **no exceptions**; strict liability (Rylands v. Fletcher) allows some.
- The **Bhopal Gas Leak (Processing of Claims) Act, 1985** and the **Public Liability Insurance Act, 1991** both grew out of the Bhopal disaster.

8 SHADES AND MODELS OF SUSTAINABILITY

Not everyone agrees how much nature can be traded for wealth. That disagreement gives two schools of thought — and, from them, new models of how an economy should run.

Concept

- **Weak sustainability** — natural capital can be **replaced** by man-made capital, as long as total capital does not fall.
- **Strong sustainability** — some natural capital (ozone layer, climate stability, biodiversity) is **critical** and cannot be substituted at any price.

Key facts

- **Circular economy** — **"reduce, reuse, recycle"** (and refurbish, remanufacture); waste from one process becomes input for another, unlike the linear "take–make–dispose" economy.
- **Green economy** (UNEP) — growth in income and jobs driven by investment that **cuts carbon and pollution**, improves resource efficiency and **prevents loss of biodiversity**.
- **Blue economy** — sustainable use of ocean resources for growth, livelihoods and ocean health.
- **Extended Producer Responsibility (EPR)** — the producer stays responsible for a product after it is discarded (plastic, e-waste, batteries, tyres, used oil).
- **Triple bottom line** — business success measured by **people, planet and profit**.

Explained

- The **"3Rs"** follow a hierarchy — reducing comes first, recycling last; disposal in landfill is the least preferred option.
- **Decoupling** means breaking the link between economic growth and resource use or emissions.
- The **"Rebound effect"** (**Jevons paradox**, from *The Coal Question*, 1865) — efficiency can increase total use because the resource becomes cheaper.

Current status (2026)

- **Mission LiFE** (Lifestyle for Environment) — idea put forward by India at **COP26, Glasgow (2021)**; launched on **20 Oct 2022 at Ekta Nagar (Kevadia), Gujarat** with the UN Secretary-General; seven themes — save energy, save water, say no to single-use plastic, sustainable food systems, reduce waste, healthy lifestyles, reduce e-waste.
- **Green Credit Programme** — notified **12 Oct 2023** under the EPA; a market-based reward for voluntary green actions (tree plantation first, then water, waste, mangroves).
- The **Carbon Credit Trading Scheme (2023)** under the **Energy Conservation Act** sets up India's domestic carbon market; the **Bureau of Energy Efficiency** is the administrator.

9 MEASURING SUSTAINABLE PROGRESS

What is not measured is not managed. GDP counts a felled forest as income and ignores the lost forest. So economists and ecologists built new yardsticks.

Concept

- **Green GDP** — GDP adjusted for the **depletion of natural resources** and the **cost of environmental damage**.
- India's **MoSPI** publishes **EnviStats** and **natural-resource accounts** under the UN **System of Environmental-Economic Accounting (SEEA)**.

Key facts

- **Ecological footprint** — area of productive land and water needed to supply what a population consumes and absorb its wastes (Global Footprint Network).
- **Earth Overshoot Day** — the date each year when humanity's demand exceeds what Earth can regenerate in that year.
- **Planetary boundaries** (Johan Rockström, **Stockholm Resilience Centre, 2009**) — nine Earth-system limits; climate change, biosphere integrity, land-system change, freshwater, biogeochemical flows (N, P), novel entities, ozone, aerosols, ocean acidification.
- **Environmental Performance Index (EPI)** — Yale and Columbia universities; India ranks near the **bottom** (**176th of 180** in 2024).
- **Human Development Index (HDI)** — UNDP, since **1990**, built on health, education and income; the **planetary-pressures adjusted HDI** discounts it for CO_2 and material footprint.
- **Genuine Progress Indicator (GPI)** and **Gross National Happiness (Bhutan)** are other alternatives to GDP.

Points of precision

- A **carbon footprint** is the total greenhouse gas emitted (in CO_2-equivalent) by a person, product or activity.
- A **water footprint** counts **green** (rainwater), **blue** (surface and groundwater) and **grey** (water needed to dilute pollution) water.
- The **Planetary Health Check 2025** reported **seven of nine** boundaries crossed, with **ocean acidification** newly crossed.

India's Green Law

The Environment (Protection) Act, 1986 · National Green Tribunal

10 THE ENVIRONMENT (PROTECTION) ACT, 1986

India's umbrella law

Global commitments demand national law. India's turning point was tragic: the Bhopal gas leak of December 1984. Within eighteen months Parliament passed a single law broad enough to cover every gap — the Environment (Protection) Act.

Concept
- The EPA is an **umbrella law** that lets the Centre take **all measures** needed to protect and improve the environment.
- It was passed under **Article 253** (laws to implement international agreements — here, the Stockholm decisions).

Key facts
- Enacted **23 May 1986**; in force **19 November 1986**.
- It followed the **Bhopal Gas Tragedy (2–3 Dec 1984)** — methyl isocyanate leak from Union Carbide.
- The Centre can **set emission and discharge standards**, restrict industries in certain areas, and lay down safeguards for hazardous substances.
- Most green rules are issued under it — EIA notification, Coastal Regulation Zone, waste rules, Ecomark.
- The **Department of Environment** came in **1980**; the **Ministry of Environment & Forests** in **1985**; renamed **MoEFCC** in **2014**.

Explained
- "Umbrella" means it fills the gaps left by the Water Act (1974) and Air Act (1981) and ties the system together.
- It also lays down how the **public participates** in environmental protection.

Points of precision
- The EPA is also called an **umbrella Act**.
- Its powers include setting **standards for emission/discharge of pollutants** and the requirement of **public participation**.
- The Ministry of Environment was set up in **1985**.

Current status (2026)
- The **Jan Vishwas (Amendment of Provisions) Act, 2023 decriminalised** EPA offences — jail terms replaced by **monetary penalties** imposed by an **Adjudicating Officer** (new Sections 15–15D).
- The **Environment Protection (Manner of Holding Inquiry and Imposition of Penalty) Rules, 2024** were notified on **4 Nov 2024**; penalties go to the **Environment Protection Fund**.
- Appeals against the Adjudicating Officer lie with the **NGT**.
- Recent rules under the EPA include the **End-of-Life Vehicles Rules (2025)**, **Environment Audit Rules (2025)** and **Environment (Protection) Fund Rules (2026)**.

11 NATIONAL GREEN TRIBUNAL

NGT Act, 2010

Laws are only as strong as the courts that enforce them. Green cases were piling up in the High Courts and the Supreme Court, so India built a special court with judges and scientists sitting side by side.

Concept
- The NGT is a **statutory** body for the **effective and expeditious disposal** of cases on environmental protection and forest conservation, including **relief and compensation** for damage.
- It rests on the **right to a healthy environment** read into **Article 21** (right to life).

Key facts
- Created by the **NGT Act, 2010**; set up on **18 October 2010**.
- India became the **third country** (after Australia and New Zealand) with a specialised environmental tribunal.
- **Principal bench: New Delhi**; zonal benches at **Bhopal, Pune, Kolkata and Chennai**.
- It has a Chairperson, **judicial members** and **expert members** (scientists).
- It hears cases under seven laws — Water Act, Water Cess Act, Air Act, EPA, Forest Conservation Act, Public Liability Insurance Act and **Biological Diversity Act**.
- It does **not** hear cases under the **Wildlife (Protection) Act** or the Indian Forest Act.
- Appeals against NGT orders go to the **Supreme Court** within **90 days**.

Explained
- It is **not bound by the Code of Civil Procedure, 1908**; it follows the **principles of natural justice**.
- It applies the **sustainable development, precautionary** and **polluter-pays** principles.
- It tries to decide cases within **six months**.

Points of precision
- Both are statutory: the NGT under the **NGT Act, 2010**; the **CPCB** under the **Water Act** (constituted **Sept 1974**).
- The NGT Act was enacted in consonance with **Article 21**.

Current status (2026)
- **Justice Prakash Shrivastava**, former Chief Justice of the Calcutta High Court, has been **Chairperson since August 2023**.
- The first Chairperson was **Justice L.S. Panta** (2010).

Green Farming

Sustainable, conservation & organic farming · Biogeochemical cycles · The carbon cycle

I2 SUSTAINABLE, CONSERVATION & ORGANIC FARMING

Hunger is India's hardest SDG — so the test of sustainability begins in the field. The Green Revolution filled granaries, but heavy chemicals and repeated tilling tired the soil. Three answers emerged: farm sustainably, conserve the soil, and go organic.

Concept
- **Sustainable agriculture** uses land so the environment is protected and soil quality is kept up over the long term.
- **Conservation agriculture** protects soil, prevents erosion and uses resources efficiently at low cost.
- **Organic farming** grows food **without synthetic fertilisers and pesticides**, using manure, compost, crop rotation and natural pest control.

Key facts
- Eco-friendly practices: **mixed cropping, organic manure, nitrogen-fixing plants** and pest-resistant varieties.
- Conservation agriculture rests on **minimum tillage, crop-residue cover, crop diversification** and **crop rotation**.
- About **30%** of the soil surface should stay covered with crop residue.
- Overuse of chemicals causes ecological imbalance, poorer soils, falling fertility and health damage.

Explained
- Legumes host **Rhizobium** bacteria that fix air nitrogen in the soil — a natural fertiliser.
- Residue cover holds moisture and stops erosion; leaving it in the field also cuts **stubble burning**, a cause of north India's winter smog.
- Crop rotation is preferred to continuous mono-cropping, which drains the same nutrients year after year.

Points of precision
- **Sikkim** became **India's first fully organic state** (declared **January 2016**) — and the **world's first** 100% organic state; it won the FAO-backed **Future Policy Gold Award (2018)**.
- The **National Programme for Organic Production (NPOP, 2001)** runs under the **Ministry of Commerce & Industry** — not the Agriculture Ministry.
- **APEDA** is the **secretariat** for NPOP.
- Domestic schemes: **Paramparagat Krishi Vikas Yojana (PKVY, 2015)** and **MOVCDNER** for the North-East.

Current status (2026)
- The **8th edition of NPOP** was launched on **9–10 January 2025**; organic **grower groups** got legal status and **TraceNet 2.0** improves traceability.
- Certified organic area reached about **7.3 million hectares (2023–24)** — **Madhya Pradesh** leads, then Maharashtra and Rajasthan.
- Target: organic exports of **₹20,000 crore** in three years.

I3 BIOGEOCHEMICAL CYCLES

Why can soil feed crops for thousands of years without running out? Because nature never throws anything away. Every atom used by a living being is returned to the air, water or soil and used again. These endless loops are the biogeochemical cycles.

Concept
- The word joins **bio** (life), **geo** (earth) and **chemical** (elements) — elements moving between life and earth.
- They are pathways by which nutrients circulate between **living** beings and the **non-living** air, water and soil.

Key facts
- **Gaseous cycles** — reservoir in the **atmosphere or oceans**; **fast**; e.g. water, carbon, nitrogen, oxygen.
- **Sedimentary cycles** — reservoir in the **Earth's crust, rocks and soil**; **slow**; e.g. **phosphorus, sulphur**.

Explained
- Gaseous cycles balance themselves well because the air mixes quickly.
- Sedimentary cycles depend on slow weathering of rock, so phosphorus is easily lost and often **limits plant growth**.

Points of precision
- The cycling of elements within an ecosystem constitutes a **biogeochemical cycle**.
- Phosphorus has **no gaseous phase** — its cycle is the classic sedimentary cycle.

I4 THE CARBON CYCLE

Carbon is the backbone of every living cell — and today the most talked-about element on Earth. Follow its journey from air to leaf, from leaf to animal, and back to air, and you will understand both how life works and why the climate is changing.

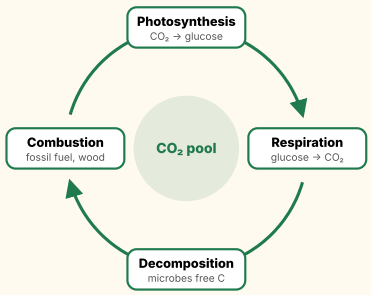
Concept
- The continuous movement of carbon between the atmosphere, oceans, living beings, soils and rocks.
- The concept was first given by **Lavoisier and Priestley** and was popularised by **Humphry Davy**.

Key facts
- Carbon occurs as graphite, diamond, CO_2, carbonates, hydrogen carbonates and minerals; in plants as glucose, starch, cellulose, sucrose.
- **Photosynthesis** takes CO_2 **out** of the air; **respiration, decomposition, combustion** and **volcanoes** put it **back**.

Explained
- Huge stores lie in **oceans, rocks, soils and fossil fuels** — the carbon sinks and reservoirs.
- When release outpaces absorption, CO_2 builds up — the bridge to **global warming**.

Points of precision
- Much of the extra CO_2 released by human activity does not stay in the lower atmosphere because **phytoplankton in the oceans** absorb it through photosynthesis.
- The ocean is the **largest active carbon sink** on Earth.

DIAGRAM · The carbon cycle



Nature's Recycling

The water cycle · Atmosphere & degradation

15 THE WATER CYCLE

If carbon is life's backbone, water is its blood. The same water the dinosaurs drank still circulates today — lifted by the sun, carried by winds, dropped as rain and gathered again in rivers and seas.

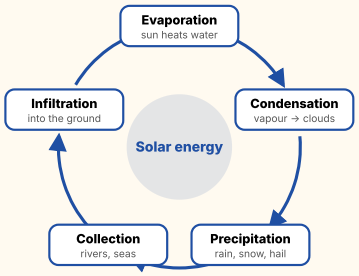
Concept
- The endless movement of water from one form and place to another, **driven by solar radiation**.

Key facts
- **Evaporation** → **transpiration** (from leaves) → **condensation** (clouds) → **precipitation** (rain, snow, hail) → **collection, runoff and infiltration**.
- **Atmospheric humidity** decides the amount of precipitation.

Explained
- The sun lifts water up; **gravity** brings it down and pulls it through rivers to the sea.
- Forests feed the cycle through transpiration — cutting them reduces local rainfall.

Points of precision
- **Solar radiation** is the prime driver of the water cycle.

DIAGRAM · The water cycle



16 ATMOSPHERE & DEGRADATION

Both cycles meet in the thin blanket of air around the Earth. Its mix of gases has stayed stable for ages — but one small number, carbon dioxide, is now rising every year.

Concept
- The **atmosphere** is the envelope of gases held to the Earth by **gravity**.
- **Weathering** is the breaking and decay of rocks **in situ** — the first step in soil formation.

Key facts
- Dry air: nitrogen **78.08%**, oxygen **20.95%**, argon **0.93%**, CO_2 **~0.04%**.
- Forests balance O_2 and CO_2.
- Degradation can be **natural** (floods, quakes) or **man-made** (deforestation, pollution).

Current status (2026)
- CO_2 at **Mauna Loa** (the "Keeling Curve", since 1958) peaked at about **432 ppm in May 2026** — a record, up 1.8 ppm on 2025.
- Pre-industrial CO_2 was about **280 ppm** — today's level is over **50%** higher.

DRY AIR BY VOLUME

Gas	Share
Nitrogen	78.08%
Oxygen	20.95%
Argon	0.93%
Carbon dioxide	~0.04% (≈432 ppm, 2026)
Neon	0.0018%
Helium	0.0005%
Krypton	0.0001%
Hydrogen	0.00005%
Xenon	0.000009%

Who Guards the Environment in India

India's environmental institutions

CHAPTER OUTLINE

1 Indian institutions → 2 WMO & UNEP → 3 Global bodies → 4 NGOs → 5 Green laws → 6 Labels & ideas → 7 Books & thinkers

1 INDIA'S ENVIRONMENTAL INSTITUTIONS

survey · research · regulation · justice

Laws need hands to carry them out. Over a century India built a family of institutions — some to count plants and animals, some to research, some to regulate polluters and some to judge disputes. Knowing which body does what, and where it sits, is the backbone of this subject.

Concept

- Most bodies work under the **Ministry of Environment, Forest and Climate Change (MoEFCC)**; a few sit under other ministries (CGWB under **Jal Shakti**, NEERI under **CSIR**).
- They fall into four groups: **survey** (BSI, ZSI, FSI), **research and training** (FRI, ICFRE, WII, NEERI), **regulation** (CPCB, NTCA, NBA, CZA, WCCB, NCZMA) and **adjudication** (NGT).

Key facts

- **Dehradun** is home to the **FRI (1906)**, **FSI (1981)**, **WII (1982)** and **ICFRE (1986)**.
- **Kolkata** hosts the two oldest surveys — **BSI (1890)** and **ZSI (1916)**.
- **NBA** sits at **Chennai**; **NEERI** at **Nagpur**; **CGWB** at **Faridabad**; most others in **New Delhi**.
- **FSI** publishes the biennial **India State of Forest Report (ISFR)**; **WII** runs the **All India Tiger Estimation** with the NTCA.

Explained

- **NTCA (2006)** and **WCCB (2007)** were created by the **Wildlife (Protection) Amendment Act, 2006**.
- **CZA (1992)** came from the **1991 amendment** to the WPA and recognises and regulates zoos.
- **CAMPA** began as an ad hoc body on Supreme Court orders (**2009**) and became statutory under the **Compensatory Afforestation Fund Act, 2016**.
- **NEAA (1997)** heard appeals against environmental clearances; it was **replaced by the NGT** in 2010.
- **State Biodiversity Boards** and local **Biodiversity Management Committees** (which keep **People's Biodiversity Registers**) work under the **Biological Diversity Act, 2002**.

Points of precision

- The **CPCB** is a statutory body under the **Water Act, 1974**, and was later given powers under the **Air Act, 1981**.
- The **National Botanical Research Institute** is at **Lucknow**; the **Rain Forest Research Institute** is at **Jorhat (Assam)**; the **Arid Forest Research Institute** at **Jodhpur**.
- The **National Centre for Polar and Ocean Research (NCPOR)**, India's Antarctic study centre, is at **Vasco da Gama, Goa**.
- **IndARC** is India's first underwater moored observatory in the **Arctic** (Kongsfjorden, Svalbard, 2014).

ENVIRONMENTAL INSTITUTIONS OF INDIA

Institution	Set up	HQ	Main role
Botanical Survey of India (BSI)	1890	Kolkata	Plant survey, taxonomy
Forest Research Institute (FRI)	1906	Dehradun	Forestry research & education
Zoological Survey of India (ZSI)	1916	Kolkata	Animal survey, taxonomy
NEERI (CSIR)	1958	Nagpur	Environmental engineering research
Central Ground Water Board (CGWB)	1970	Faridabad	Groundwater survey & management
Central Pollution Control Board (CPCB)	1974	New Delhi	Prevention & control of pollution
Forest Survey of India (FSI)	1981	Dehradun	Forest cover assessment (ISFR)
Wildlife Institute of India (WII)	1982	Dehradun	Wildlife research & training
ICFRE	1986 (autonomous 1991)	Dehradun	Apex forestry research body
Central Zoo Authority (CZA)	1992	New Delhi	Recognition & regulation of zoos
National Environment Appellate Authority	1997	New Delhi	Clearance appeals (now NGT)
National Biodiversity Authority (NBA)	2003	Chennai	Access & benefit-sharing of bio-resources
National Tiger Conservation Authority	2006	New Delhi	Tiger conservation
Wildlife Crime Control Bureau (WCCB)	2007	New Delhi	Wildlife crime & illegal trade
CAMPA	2009 (statutory 2016)	New Delhi	Compensatory afforestation funds
National Green Tribunal (NGT)	2010	New Delhi	Environmental justice
National Mission for Clean Ganga (NMCG)	2011	New Delhi	Ganga rejuvenation
NMSHE	2014	New Delhi	Himalayan ecosystem & climate

The Global Architecture

WMO and UNEP · Environmental NGOs

2 WMO AND UNEP

Weather and pollution do not stop at borders. Two UN bodies became the world's eyes on the sky and its voice on the environment — one counting rain and heat since the nineteenth century, the other born of Stockholm.

Concept

- The **World Meteorological Organization (WMO)** is the UN's specialised agency for weather, climate and water; **HQ Geneva**.
- The **UN Environment Programme (UNEP)** is the **leading global environmental authority** — it sets the agenda and carries the **environmental dimension of the SDGs**; **HQ Nairobi**.

Key facts

- WMO began as the **International Meteorological Organization (IMO) in 1873**; became the WMO on **23 March 1950**; a UN specialised agency in **1951**.
- **World Meteorological Day — 23 March** — marks the 1950 founding.
- UNEP was set up on **5 June 1972** after Stockholm; its **India office (New Delhi) opened in 2016**; nodal ministry: MoEFCC.
- UNEP reports: **Emissions Gap Report**, **Global Environment Outlook (GEO)**, **Frontiers Report**, **Foresight Report**, **Adaptation Gap Report**.
- UNEP gives the **Champions of the Earth** award — successor to the **Global 500 Roll of Honour** (1987–2003).

Explained

- UNEP hosts the secretariats of the **CBD, CITES, CMS, Minamata, Vienna Convention and Montreal Protocol**, and the Basel–Rotterdam–Stockholm conventions.
- The **UN Environment Assembly (UNEA)**, of all 193 UN members, is UNEP's governing body; **UNEA-5.2 (2022)** launched the talks on a global **plastics treaty**.
- WMO and UNEP together set up the **IPCC (1988)**; WMO also co-sponsors the **ozone assessments** with UNEP.

Points of precision

- WMO is a **specialised agency**; UNEP is a **programme** of the UN, not a specialised agency.
- WMO publishes the **State of the Global Climate** and the **Greenhouse Gas Bulletin**; the **Ozone Secretariat** sits with UNEP in Nairobi.

GLOBAL ENVIRONMENTAL INSTITUTIONS AND THEIR SEATS

Body	Abbr.	Year	Headquarters
UN Educational, Scientific & Cultural Org.	UNESCO	1945	Paris
International Union for Conservation of Nature	IUCN	1948	Gland, Switzerland
World Meteorological Organization	WMO	1950	Geneva
International Atomic Energy Agency	IAEA	1957	Vienna
International Maritime Organization	IMO	1958	London
World Wide Fund for Nature	WWF	1961	Gland, Switzerland
UN Development Programme	UNDP	1965	New York
Ramsar Convention Secretariat	—	1971	Gland (hosted by IUCN)
UN Environment Programme	UNEP	1972	Nairobi
Convention on Migratory Species	CMS	1979	Bonn
Intergovernmental Panel on Climate Change	IPCC	1988	Geneva
Ozone Secretariat	—	1991	Nairobi
Global Environment Facility	GEF	1991	Washington, D.C.
UN Framework Convention on Climate Change	UNFCCC	1992	Bonn
Convention on Biological Diversity	CBD	1992	Montreal
UN Convention to Combat Desertification	UNCCD	1994	Bonn
International Solar Alliance	ISA	2015	Gurugram, India
Global Green Growth Institute	GGGI	2010	Seoul

3 ENVIRONMENTAL NGOS

Many of the turning points in Indian conservation began outside government — a natural history society cataloguing birds, a think-tank measuring Delhi's smog, a campaign group chaining itself to whaling ships abroad.

Key facts

- **BNHS (1883, Mumbai)** — India's oldest conservation NGO; **Salim Ali** worked with it; it is BirdLife International's partner in India.
- **TERI (1974, New Delhi)** — energy and sustainability research; hosts the **World Sustainable Development Summit**.
- **CSE (1980, New Delhi)** — founded by **Anil Agarwal**; publishes *Down To Earth*; campaigned for CNG in Delhi.
- **SACON (1990, Coimbatore)** — named after Salim Ali; ornithology research.
- **ATREE (1996, Bengaluru)**; **Wildlife Trust of India (1998, Noida)**; **Sulabh International (1970, New Delhi)**, founded by **Bindeshwar Pathak** for sanitation.

Explained

- **Greenpeace (1971)** began in **Vancouver**; its international HQ is in **Amsterdam**; ship *Rainbow Warrior*.
- **WWF (1961)**, HQ **Gland**, logo the **giant panda**; publishes the **Living Planet Report** and runs **Earth Hour**.
- **TRAFFIC** (wildlife-trade monitoring) is a joint body of **WWF and IUCN**.
- **BirdLife International (1922)**, Cambridge, UK, identifies **Important Bird and Biodiversity Areas (IBAs)**.

Points of precision

- The **International Whaling Commission (1946)** sits at **Impington, near Cambridge, UK**; it imposed the commercial whaling moratorium (1986).
- **Friends of the Earth (1969)** and **Greenpeace** are both headquartered in **Amsterdam**.
- The **Wildlife Conservation Society (1895, New York)** is the oldest of the global NGOs listed here.

Voices Outside Government

Major environmental Acts

NGOS AT A GLANCE

NGO	Year	HQ	Known for
Bombay Natural History Society (BNHS)	1883	Mumbai	Bird studies; Salim Ali
Sulabh International	1970	New Delhi	Sanitation, low-cost toilets
The Energy & Resources Institute (TERI)	1974	New Delhi	Energy, sustainability
Centre for Science & Environment (CSE)	1980	New Delhi	Down To Earth; clean air
SACON	1990	Coimbatore	Ornithology
ATREE	1996	Bengaluru	Ecology research
Wildlife Trust of India	1998	Noida	Wildlife rescue
Wildlife Conservation Society	1895	New York	Field conservation
BirdLife International	1922	Cambridge, UK	Important Bird Areas
International Whaling Commission	1946	Impington, UK	Whaling moratorium
The Nature Conservancy	1951	Arlington, USA	Land protection
WWF	1961	Gland	Living Planet Report; Earth Hour
Friends of the Earth Intl.	1969	Amsterdam	Grassroots network
Greenpeace International	1971	Amsterdam	Direct-action campaigns
Conservation International	1987	Virginia, USA	Biodiversity hotspots

4 MAJOR ENVIRONMENTAL ACTS

India's green laws were written in waves — first to manage forests for timber, then after Stockholm to save wildlife and clean water and air, then after Bhopal to cover everything else, and lately to reconcile protection with ease of doing business.

Concept

- Before 1976 "forests" and "wild animals and birds" were in the **State List**; the **42nd Amendment (1976)** moved them to the **Concurrent List** (entries **17A and 17B**).
- Several laws (Water, Air, EPA) were made by Parliament to give effect to **Stockholm (1972)** decisions.

Key facts

- **Indian Forest Act, 1927** — reserved, protected and village forests; transit of forest produce.
- **Wildlife (Protection) Act, 1972** — sanctuaries, national parks, hunting ban, schedules of species.
- **Water (Prevention and Control of Pollution) Act, 1974** — India's **first** pollution-control law; created the CPCB and SPCBs.
- **Forest (Conservation) Act, 1980** — Centre's **prior approval** needed to divert forest land.
- **Air (Prevention and Control of Pollution) Act, 1981**; **Environment (Protection) Act, 1986**.
- **Public Liability Insurance Act, 1991**; **National Environment Tribunal Act, 1995**; **NEAA Act, 1997**.
- **Energy Conservation Act, 2001** (BEE); **Biological Diversity Act, 2002**; **Disaster Management Act, 2005**.
- **Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006**; **NGT Act, 2010**; **Compensatory Afforestation Fund Act, 2016**.

Explained

- The **Wild Life (Protection) Amendment Act, 2022** cut the schedules from **six to four** — **I** (highest protection), **II** (lesser protection), **III** (plants), **IV** (specimens listed in **CITES** appendices) — and removed the vermin schedule.
- The **Forest (Conservation) Amendment Act, 2023** renamed the law the **Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980** and exempted some land, such as strategic linear projects within **100 km of international borders**.
- The **Biological Diversity (Amendment) Act, 2023** decriminalised offences and eased rules for **AYUSH practitioners** and codified traditional medicine.
- The **Energy Conservation (Amendment) Act, 2022** enabled a **carbon credit trading scheme**.

Points of precision

- The **Water Act (1974)** came **before** the Air Act (1981) — it is the oldest anti-pollution statute.
- The **Atomic Energy Act, 1962** is also counted among environment-related laws.
- The **Water Cess Act, 1977** let SPCBs collect a cess on water used by industries.

Current status (2026)

- The **Jan Vishwas Act, 2023** replaced jail with penalties under the **Water, Air and EPA** laws; the **Jan Vishwas (Amendment of Provisions) Bill, 2025** proposed further decriminalisation.
- Waste is now governed by the **Solid Waste Management Rules, 2026** (in force **1 April 2026**) and the **Construction & Demolition Waste Rules, 2025**.

TIMELINE OF ENVIRONMENTAL LAWS

Year	Act	Year	Act
1927	Indian Forest Act	1995	National Environment Tribunal Act
1962	Atomic Energy Act	1997	NEAA Act
1972	Wildlife (Protection) Act	2001	Energy Conservation Act
1974	Water Act	2002	Biological Diversity Act
1977	Water Cess Act	2005	Disaster Management Act
1980	Forest (Conservation) Act	2006	Forest Rights Act
1981	Air Act	2010	National Green Tribunal Act
1986	Environment (Protection) Act	2016	Compensatory Afforestation Fund Act
1991	Public Liability Insurance Act	2022–23	WPA, FCA, BD, EC amendments; Jan Vishwas

Labels, Terms & Thinkers

Green labels and key terms

5 GREEN LABELS AND KEY TERMS

A shopper cannot test a soap for its effect on rivers. Labels do that work for her — and because labels can also mislead, the world coined a word for false green claims.

Key facts

- **Ecomark** — India's eco-labelling scheme since **1991**, launched by the Environment Ministry; marks consumer goods that harm the environment least; logo: an **earthen pot (matka)**; linked with the **BIS** for standards.
- The **Ecomark Rules, 2024**, notified under the EPA, revamped the scheme; the **CPCB** administers it.
- **BEE star label** — energy efficiency of appliances; **AGMARK** — agricultural produce (Directorate of Marketing & Inspection); **ISI mark** — BIS for industrial goods.
- **FSC** (Forest Stewardship Council) certifies timber from responsibly managed forests.

Explained

- **Greenwashing** — a misleading effort to make a company, product or service look more eco-friendly than it is; a false or exaggerated green claim.
- India's **Guidelines for Prevention and Regulation of Greenwashing and Environmental Claims (Oct 2024)** were issued by the **CCPA** under the Consumer Protection Act.
- **Masanobu Fukuoka** of Japan, author of *The One-Straw Revolution*, is the best-known pioneer of **natural farming** ("do-nothing farming").
- The **Global Alliance for Climate-Smart Agriculture (GACSA)** was launched on **23 Sept 2014** at the **UN Climate Summit, New York**; it is **voluntary** and creates **no binding obligations**.

Points of precision

- "**Ecology is permanent economy**" was the slogan of the **Chipko movement** (Sunderlal Bahuguna).
- *The Limits to Growth* (1972, Club of Rome) used a computer model called **World3**.
- **World Environment Day** (5 June) was declared by the UN General Assembly in 1972; first observed in **1973** with the slogan "**Only One Earth**".

BOOKS THAT SHAPED ENVIRONMENTAL THOUGHT

Book	Author	Book	Author
Man and Nature (1864)	George Perkins Marsh	The Coal Question (1865)	W. S. Jevons
Civilization and Climate	Ellsworth Huntington	The Pulse of Asia	Ellsworth Huntington
A Sand County Almanac	Aldo Leopold	Road to Survival	William Vogt
Our Plundered Planet	H. F. Osborn	Under the Sea-Wind	Rachel Carson
The Sea Around Us	Rachel Carson	The Edge of the Sea	Rachel Carson
Silent Spring (1962)	Rachel Carson	The Population Bomb	Paul R. Ehrlich
The Tragedy of the Commons	Garrett Hardin	The Closing Circle	Barry Commoner
Only One Earth	Barbara Ward & René Dubos	A Blueprint for Survival	Edward Goldsmith & others
Small Is Beautiful	E. F. Schumacher	The Arrogance of Humanism	David Ehrenfeld
Gaia: A New Look at Life on Earth	James Lovelock	Overshoot	William R. Catton Jr.
The End of Nature	Bill McKibben	Eaarth	Bill McKibben
The Diversity of Life	E. O. Wilson	The Future of Life	E. O. Wilson
The Creation	E. O. Wilson	Half-Earth	E. O. Wilson
Something New Under the Sun	J. R. McNeill	The Unquiet Woods	Ramachandra Guha
This Fissured Land	Madhav Gadgil & R. Guha	Ecology and Equity	Madhav Gadgil & R. Guha
Environmentalism: A Global History	Ramachandra Guha	Green Development	W. M. Adams
This Changes Everything	Naomi Klein	The Sixth Extinction	Elizabeth Kolbert
The Great Derangement	Amitav Ghosh	The Nutmeg's Curse	Amitav Ghosh
The Uninhabitable Earth	David Wallace-Wells	The One-Straw Revolution	Masanobu Fukuoka

The Science of the Household

Ecology · Ecosystem and biosphere · Producers, consumers and decomposers

CHAPTER OUTLINE

1 Ecology & ecosystem → 2 Food & energy → 3 Populations & niches → 4 Succession → 5 Services & footprint → 6 Water worlds → 7 Biomes → 8 Nutrient cycles

1 ECOLOGY *oikos + logos*

Nature is one large household, and every living being is a member of it. Ecology is the study of how the members of this household live together — who feeds whom, who shelters whom, and how all of them depend on air, water and soil.

Concept
- **Ecology** is the branch of biology that studies the **reciprocal relationships** between living communities and their environment.
- The word comes from Greek **oikos** (home, dwelling) and **logos** (study).

Key facts
- **Ernst Haeckel** (German biologist) coined "**Oecologie**" in **1866** in his book *Generelle Morphologie der Organismen*.
- Modern ecology also covers **humans and society** and their interaction with the physical environment.
- **Autecology** studies a single species; **synecology** studies whole communities.

Points of precision
- The study of the composition, organisation and development of communities and their environment is **synecology (community ecology)**.
- Ecology is **not** a synonym of ecosystem — one is a science, the other a unit of nature.

2 ECOSYSTEM AND BIOSPHERE *Tansley, 1935*

To study the household, ecologists needed a unit — a piece of nature small enough to observe yet complete in itself. That unit, where living and non-living parts work as one machine, is the ecosystem.

Concept
- An **ecosystem** is a **functional unit** of nature in which **biotic and abiotic components** interact.
- The term was coined by British ecologist **Arthur George Tansley** in **1935**.
- The **biosphere** is the life-supporting layer of soil, rock, water and air — the **largest ecosystem** on Earth.

Key facts
- Every ecosystem has four basic parts: **abiotic substances, producers, consumers and decomposers**.
- Abiotic parts: light, temperature, air, water, soil, minerals and inorganic substances.
- It is an **open system** — energy and matter flow in and out continuously.
- Its size is not fixed: from a **drop of water** (micro-ecosystem) to an **ocean** (macro-ecosystem); the **Earth** itself is one vast ecosystem.
- Features: occupies a definite area, is a functional unit, has its own **productivity**, and is studied over **time and space**.
- The **ocean (marine) ecosystem** is the **most stable** — salinity, dissolved oxygen, light and temperature stay relatively constant.

Explained
- **Natural ecosystems** — forest, grassland, desert, pond, lake, river, ocean.
- **Artificial (man-made)** — crop field, paddy field, garden, aquarium, spacecraft.
- **Terrestrial** — forest, grassland, desert, mountain, lowland, semi-arid; **aquatic** — freshwater (pond, lake, stream) and marine/saline (salt lake, estuary, ocean).
- The biosphere is open for **energy** but almost **closed for matter** — nutrients must be recycled within it.

Points of precision
- Levels of organisation: **organism → population → community → ecosystem → landscape → biome → biosphere**.
- A **population** is a group of the **same species**; a **community** is populations of **two or more species** living together.
- **Cropland** is a biome created by human activity; grasslands and rainforests are natural biomes.

3 PRODUCERS, CONSUMERS AND DECOMPOSERS

Every ecosystem runs on sunlight, but only green plants can catch it. Everything else — the deer, the tiger, the mushroom on a fallen log — lives on what the plants have made. That simple dependence divides the living world into three trades.

Concept
- **Autotrophs** make their own food by **photosynthesis** (green plants, algae, cyanobacteria) or **chemosynthesis** (some bacteria); they are the **primary producers**.
- **Heterotrophs** depend on others for food — **consumers** and **decomposers**.

Key facts
- Producers occupy the **first trophic level**; chlorophyll lets them turn **solar energy into chemical energy**.
- Main producers: **phytoplankton** in the sea, **rooted plants** in shallow water, **grasses** in grasslands, **crops** on farmland.
- Consumers: **primary** (herbivores), **secondary** (eat herbivores), **tertiary**, and the **apex** consumer at the top.
- **Decomposers** — **bacteria and fungi** (also flagellates); earthworms, insect larvae, snails and slugs are **detritivores** that help decay.
- Production at the autotroph level is **primary productivity**; at the heterotroph level, **secondary productivity**.

Explained
- A human is a **primary consumer** when eating vegetables and a **secondary consumer** when eating meat — an **omnivore** can sit at more than one level.
- Decomposers turn dead organic matter into simple **inorganic** nutrients that return to soil — without them, nutrients would stay locked in corpses.
- **Gross primary productivity (GPP)** is total photosynthesis; **net primary productivity (NPP) = GPP − respiration** — the food actually available to consumers.

Points of precision
- Green plants capture only about **1–2%** of the sunlight falling on them for photosynthesis.
- Productivity of ecosystems in decreasing order: **mangroves/estuaries and tropical rainforests > grasslands > lakes > open oceans**; open oceans and deserts have the lowest productivity per unit area.
- **Lichens** — a symbiosis of an **alga and a fungus** — are **pioneers** that begin succession on bare rock.

Who Eats Whom

Food chain, food web and energy flow · Ecological pyramids and biomagnification · Population growth and limits · Habita...

4 FOOD CHAIN, FOOD WEB AND ENERGY FLOW

Lindeman, 1942

Energy enters with sunlight and leaves as heat. In between it passes from mouth to mouth, and at every step most of it is lost. That loss decides how many tigers a forest can feed.

Concept
- A **food chain** is the sequence of organisms through which energy flows; a **food web** is the network of interlinked food chains.
- Energy flow is **unidirectional**: Sun → producers → primary → secondary → tertiary consumers.

Key facts
- Grassland chain: **grass → grasshopper → frog → snake** (producer, primary, secondary, tertiary consumer).
- Marine chain: **diatoms → crustaceans → herrings**.
- **Grazing food chain** starts with living plants; **detritus food chain** starts with dead organic matter — in forests most energy flows through detritus.
- **Lindeman's 10% law (1942)** — only about **10%** of energy passes to the next trophic level; ~90% is lost in respiration, movement and heat.
- Illustrative energy: producers 100% → primary 10% → secondary 1% → tertiary 0.1%.

Explained
- Because energy shrinks at each step, food chains rarely exceed **four or five** links and the **apex carnivore gets the least** energy.
- A food web makes an ecosystem **stable** — if one prey falls, predators switch to another.
- A food chain links **different species**; it is never found within a single species' population.

Points of precision
- **Decomposers** draw dead matter from **every** trophic level.
- Matter **cycles**; energy **flows** and does not cycle.

5 ECOLOGICAL PYRAMIDS AND BIOMAGNIFICATION

Draw the trophic levels as stacked bars and a shape appears. Usually it is a pyramid — but not always, and the exceptions are where the interesting questions lie.

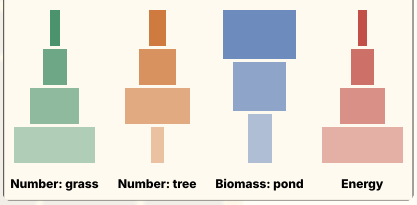
Concept
- An **ecological pyramid** shows **numbers, biomass or energy** at successive trophic levels; producers form the base, apex carnivores the top.
- Pyramids were introduced by **Charles Elton (1927)**.

Key facts
- **Pyramid of numbers** — upright in a grassland; **inverted** for a single large tree carrying many insects and birds (and in a parasitic chain).
- **Pyramid of biomass** — upright on land; **inverted in ponds and seas**, where a small standing crop of fast-growing phytoplankton supports a larger mass of zooplankton and fish.
- **Pyramid of energy** — **always upright**, because energy is lost at every level.

Explained
- **Biomagnification** — persistent chemicals (DDT, mercury, PCBs) **increase in concentration** at each higher trophic level; they sit in **fat** and are hard to excrete.
- **Bioaccumulation** is the build-up of a chemical **within one organism** over its lifetime; biomagnification is the increase **across the food chain**.
- DDT thinned the eggshells of fish-eating birds — the story told in *Silent Spring*; mercury in fish caused **Minamata disease** in Japan.

Points of precision
- A pollutant that biomagnifies must be **persistent, fat-soluble and biologically active**; water-soluble substances are excreted and do not magnify.
- In a DDT-contaminated grassland chain the **highest concentration** is found at the **top** carnivore.

DIAGRAM · Ecological pyramids



6 POPULATION GROWTH AND LIMITS

Left alone, any species could fill the Earth — a pair of houseflies in one summer could bury a city. It never happens, because the environment pushes back. The tug-of-war between a species' urge to multiply and nature's resistance shapes every population.

Concept
- **Biotic potential (r)** — the maximum reproductive capacity of a species when there is no environmental resistance.
- **Carrying capacity (K)** — the maximum population that the available resources can sustain over the long term.

Key facts
- With unlimited resources growth is **exponential (J-shaped)**; with limited resources it is **logistic (S-shaped)**, levelling off at K.
- **r-strategists** — many small offspring, little care, short life (insects, rodents, weeds).
- **K-strategists** — few large offspring, long care, long life (elephants, whales, humans).
- A population above K damages its habitat and may **crash**.

Explained
- **Environmental resistance** — food shortage, disease, predators, competition — brings the growth rate down as numbers rise.
- Human pressure beyond carrying capacity is the root of many environmental problems.

7 HABITAT, NICHE AND ECOLOGICAL LAWS

Two birds may live in the same tree yet never compete — one eats insects from the bark, the other seeds from the cones. Where an animal lives is its address; how it makes a living is its profession.

Concept
- **Habitat** — the actual place where an organism lives (its **address**).
- **Ecological niche** — its **role and position**: what it eats, when it is active, how it uses resources (its **profession**); "**place + role**".

Key facts
- **Joseph Grinnell** introduced the term "niche" in **1917** (linked with micro-habitat); **Charles Elton (1927)** stressed the functional role; **G. E. Hutchinson (1957)** described it as an n-dimensional space.
- **Gause's competitive exclusion principle** — two species with **identical niches cannot coexist** for long; one eliminates the other.
- **Liebig's law of the minimum** — growth is limited by the **scarcest** essential resource.
- **Shelford's law of tolerance** — each species survives only within a **range** of a factor, with a minimum and maximum.

Points of precision
- Two species can share a habitat **if** their niches differ — resource partitioning, as in MacArthur's warblers.
- **Stenothermal** species tolerate a narrow temperature range; **eurythermal** a wide one (likewise steno-/eury-haline for salinity).

Populations, Niches & Limits

Special roles of species · Ecological succession · Ecotone, edge effect and ideas in ecology

INTERACTIONS BETWEEN SPECIES

Interaction	Species A	Species B	Example
Mutualism	+	+	Lichen (alga + fungus); Rhizobium and legumes; fig and fig wasp; mycorrhiza
Commensalism	+	0	Orchid (epiphyte) on a mango tree; barnacles on a whale; cattle egret and cattle
Parasitism	+	–	Cuscuta on host plants; tapeworm; ticks; cuckoo (brood parasite)
Predation	+	–	Tiger and deer; insectivorous pitcher plant
Competition	–	–	Flamingo and fish for zooplankton
Amensalism	0	–	Penicillium mould inhibiting bacteria; black walnut toxins

8 SPECIAL ROLES OF SPECIES

Key facts

- **Keystone species** — has an effect **far larger than its numbers** on the persistence of many other species (sea otter, fig trees, elephants, tiger as top predator).
- **Flagship species** — a charismatic animal used to win public support (tiger, panda, elephant).
- **Umbrella species** — protecting its large range protects many others (tiger, elephant).
- **Indicator species** — reveals the health of an environment: **lichens** vanish where **SO_2** is high; **Gangetic dolphin** indicates river health; frogs and mayflies indicate water quality.
- **Foundation species** — builds the habitat itself (corals, kelp).
- **Invasive alien species** — introduced species that spread and harm natives: **Lantana, Parthenium (congress grass), water hyacinth, Prosopis juliflora**, African catfish.

Points of precision

- The **fig tree and fig wasp** have **co-evolved** — each fig species has its own wasp, the only insect that can pollinate it.
- Some species of **fungi** form **mycorrhiza** — a symbiosis with plant roots that helps absorb phosphorus and water.
- The **Himalayan hekistotherms** (e.g. alpine plants) grow in extremely cold conditions.

9 ECOLOGICAL SUCCESSION

Leave a bare rock for a thousand years and it becomes a forest. First come lichens that crack the stone, then mosses, grasses, shrubs and finally trees. Each community prepares the ground for the next and is then replaced by it.

Concept

- **Ecological succession** — the gradual, orderly change in communities of an area over time until a stable **climax community** develops.
- The whole series of communities in one area is a **sere**; each stage is a **seral stage**.

Key facts

- **Primary succession** — begins where no life existed (bare rock, cooled lava, new sand dune); slow, may take thousands of years.
- **Secondary succession** — begins where life was destroyed (after fire, flood, abandoned farm); faster, because soil remains.
- Stages: **nudation → invasion/migration → ecesis → aggregation → competition → reaction → stabilisation (climax)**.
- Seres by habitat: **hydrosere** (water), **xerosere** (dry), **lithosere** (bare rock), **psammosere** (sand), **halosere** (saline).

Explained

- **Pioneer species** — the first colonisers: **lichens** on rock, phytoplankton in water.
- As succession advances, **biomass, species diversity, soil depth and humus increase**; food webs become more complex.
- Succession driven by the community itself is **autogenic**; by outside forces (floods, fire), **allogenic**.

Points of precision

- **Frederic E. Clements** (USA) proposed the **monoclimax (climatic climax) theory** in **1916** — one climax per climatic region.
- **Tansley** proposed the **polyclimax** theory — several climaxes controlled by soil, topography and fire.

10 ECOTONE, EDGE EFFECT AND IDEAS IN ECOLOGY

Concept

- An **ecotone** is the **transition zone** between two ecosystems or communities — narrow or wide; examples: **mangroves, estuaries, marshes**, forest–grassland borders.
- It has features of both neighbours, so it is often **richer in species** than either; it is also called a **zone of tension**.

Key facts

- **Edge effect** — the greater **number and density of species** in an ecotone; species found mainly there are **edge species**.
- **Ecological transition** — term used first in **1976** by American cultural anthropologist **John W. Bennett** (*The Ecological Transition: Cultural Anthropology and Human Adaptation*) for the changing relationship between human society and the physical environment.
- **Deep ecology** — coined by Norwegian philosopher **Arne Naess** in **1973** ("The Shallow and the Deep, Long-Range Ecology Movement"); rejects **anthropocentrism** and values nature for its own sake.

Explained

- **Eco-Sensitive Zones (ESZs)** are notified by the **MoEFCC under the Environment (Protection) Act, 1986** around protected areas as **shock absorbers**.
- Inside an ESZ some activities are **prohibited** (commercial mining, polluting industries), some **regulated** (felling, hotels) and some **permitted** (farming, rainwater harvesting) — it is **not** a total ban.
- The 2011 guidelines allow an ESZ of **up to 10 km** around a protected area; in 2022–23 the Supreme Court first required, then relaxed, a **minimum 1 km** ESZ.

Points of precision

- ESZs are declared under the **EPA**, not the Wildlife (Protection) Act.
- **Eucalyptus** is called ecologically unfriendly — it draws heavily on water and can lower the local water table; it is native to **Australia**.

What Nature Gives Us

Ecosystem services · Ecological footprint and the cost of carbon · Freshwater habitats · Marine zones and ...

11 ECOSYSTEM SERVICES

Millennium Ecosystem Assessment, 2001–05

> *A forest gives timber we can sell — but it also gives clean water, pollinators and cooler air that no market prices. Ecologists began to count these free gifts so that decision-makers would stop treating them as worthless.*

Concept

- **Ecosystem services** are the benefits people obtain from ecosystems.
- The **Millennium Ecosystem Assessment (MEA)**, started in **2001** at the call of UN Secretary-General **Kofi Annan** and published in **2005**, assessed how ecosystem change affects human well-being.

Key facts

- **Provisioning** — food, water, timber, fibre, medicines.
- **Regulating** — climate, floods, disease, water purification.
- **Supporting** — nutrient cycling, soil formation, **pollination**, primary production.
- **Cultural** — spiritual, educational, recreational, aesthetic.
- Some lists add **preserving services** — keeping diversity for future options.

Explained

- Supporting services underpin all others; their loss is felt slowly but widely.
- The MEA found that about **60%** of the services it examined were being **degraded or used unsustainably**.
- Its successor-like global body is **IPBES (2012)** — "the IPCC for biodiversity".

12 ECOLOGICAL FOOTPRINT AND THE COST OF CARBON

Concept

- **Ecological footprint** — the area of biologically productive land and water needed to supply what a person or population consumes and to absorb its wastes, including **carbon emissions**.
- It is measured in **global hectares (gha)** and compared with the Earth's **biocapacity**.

Key facts

- Wasteful use of water, energy and resources **enlarges** the footprint.
- It indicates the minimum land needed to fully support one person's life.
- **Social cost of carbon** — the estimated long-term economic damage caused by emitting **one extra tonne of CO_2** in a given year.

13 FRESHWATER HABITATS

> *Still water and running water are two different worlds. A pond warms, stratifies and grows green; a mountain stream stays cold, fast and full of oxygen. Each zone from shore to floor holds its own community.*

Concept

- **Lentic** habitats — **still or standing** water with no gravity-driven current: lakes, ponds, swamps, reservoirs, pools.
- **Lotic** habitats — water **flowing** in one direction down a gradient: rivers, streams, brooks, channels.

Key facts

- Lotic water usually has **higher dissolved oxygen** because it is constantly mixed with air.
- Lake zones: **littoral** (shallow edge, light to the bottom, rooted plants, frogs, small fish) → **limnetic** (open sunlit water, plankton, free-swimming fish) → **profundal** (deep, dark, cold; decomposers dominate) → **benthic** (bottom mud and sediment).

Explained

- **Thermal stratification** in deep lakes: warm **epilimnion** above, a sharp temperature drop in the **thermocline (metalimnion)**, cold **hypolimnion** below.
- In temperate lakes the layers mix in spring and autumn (**overturn**), carrying oxygen down and nutrients up.

DIAGRAM · Zones of a lake

Littoral	shallow edge; light reaches bottom; rooted plants
Limnetic	open sunlit water; plankton, fish
Profundal	deep, dark, cold; decomposers
Benthic	bottom mud and sediment

14 MARINE ZONES AND UPWELLING

Key facts

- The ocean has **pelagic** (open water) and **benthic** (floor) realms.
- **Epipelagic/photic (0–200 m)** — sunlit; most photosynthesis and biodiversity (fish, dolphins, turtles).
- **Mesopelagic (200–1,000 m)** — the "**twilight zone**".
- **Bathypelagic (1,000–4,000 m)** — the "**midnight zone**"; dark, high pressure, ~4°C.
- **Abyssopelagic (4,000–6,000 m)** and **hadopelagic (>6,000 m)** — trenches such as the **Mariana Trench**.
- Floor zones: **intertidal/littoral** (between tides), **sublittoral** over the continental shelf (0–200 m), then **bathyal, abyssal and hadal**.

Explained

- **Upwelling** brings **cold, dense, nutrient-rich** water from the deep to the surface, replacing warm nutrient-poor water — productivity soars.
- Upwelling coasts (Peru, California, Namibia, Somalia) host the world's richest fisheries; a weak upwelling off Peru marks **El Niño**.

DIAGRAM · Ocean zones by depth

Epipelagic / photic · 0–200 m	sunlit; most photosynthesis and life
Mesopelagic · 200–1,000 m	"twilight zone"; dim light
Bathypelagic · 1,000–4,000 m	"midnight zone"; dark, ~4°C
Abyssopelagic · 4,000–6,000 m	abyssal plains; no sunlight
Hadopelagic · > 6,000 m	trenches, e.g. Mariana

Water Worlds

Coral reefs · Biomes · The nitrogen cycle

15 CORAL REEFS

rainforests of the sea

A coral reef is built by animals smaller than a fingernail. Each polyp lays down limestone and shelters a tiny alga that feeds it sunlight-made sugar. Over thousands of years their skeletons pile into reefs that can be seen from space.

Concept

- Reefs form from the **calcium carbonate skeletons of coral polyps**, living in **symbiosis** with algae called **zooxanthellae**.
- They grow in **warm (≈20–29°C), clear, shallow, saline, sunlit** tropical water, roughly between **25°N and 25°S**.

Key facts

- Types: **fringing** (attached to the coast), **barrier** (separated by a lagoon) and **atolls** (ring-shaped around a lagoon).
- The **Great Barrier Reef** (Australia) is the largest reef system on Earth.
- About **19%** of the world's reef area lies with **Australia** and **17%** with **Indonesia**; Australia, Indonesia and the Philippines together hold over a third.
- Reefs host **more animal phyla** than tropical rainforests.
- India's reefs: **Gulf of Kutch, Gulf of Mannar, Andaman & Nicobar, Lakshadweep** (mainly **atolls**).

Explained

- **Coral bleaching** — stressed corals expel zooxanthellae and turn white; the main trigger is **rising sea temperature** (global warming); **ocean acidification** weakens skeletons.
- Reefs protect coasts from waves, support fisheries and tourism, and yield medicines.
- The **Gulf of Mannar** biosphere reserve combines estuaries, seagrass beds, reefs, salt marshes and mangroves.

Points of precision

- Coral reefs are **absent** off the mouths of large rivers (fresh, muddy water) — e.g. the Ganga–Brahmaputra delta has none.
- The **Coral Triangle** (Indonesia–Philippines–Papua New Guinea region) is the world's richest marine biodiversity zone.
- The world is in its **fourth global bleaching event**, declared by NOAA in **2024**, the largest on record.

16 BIOMES

Climb from the equator to the pole, or from a valley floor to a Himalayan peak, and the vegetation changes in the same order. Climate paints the Earth in broad belts of life called biomes.

Concept

- A **biome** is the **largest recognisable assemblage** of plants and animals on land, controlled mainly by **climate** (temperature and rainfall).
- **Natural vegetation** is the truest index of a region's climate.

Key facts

- **Tropical rainforest** — the **densest and tallest** vegetation, evergreen, highest biodiversity; most productive land ecosystem; called the "**lungs of the planet**".
- **Tropical deciduous (monsoon) forest** — sheds leaves in the dry season; teak and sal.
- **Savanna** — tropical grassland with scattered trees; East Africa's savanna is the "**land of big game**".
- **Temperate grasslands** — **steppes** (Eurasia), **prairies** (N. America), **pampas** (Argentina), **veld** (S. Africa), **downs** (Australia), **canterbury** (New Zealand).
- **Hot desert** — rainfall below 25 cm; **taiga (boreal coniferous)** — the largest forest biome; **tundra** — treeless, permafrost, mosses and lichens.
- The **open ocean** is the largest ecosystem by area on Earth.

Explained

- Rainforest soils are **poor** — nutrients sit in the living biomass and are recycled fast; cleared land soon turns infertile ("**deserts covered by trees**").
- The Amazon is often credited with about **20%** of the world's oxygen, but its **net** contribution is near zero — the forest uses almost as much as it produces.
- Tundra and boreal regions are warming fastest — the **tundra** is among the first ecosystems hit by global warming.

Points of precision

- Plant groups by heat need: **megatherms** (high heat all year — tropical), **mesotherms** (moderate heat), **microtherms** (low heat — temperate), **hekistotherms** (very cold — alpine and polar).
- **Xerophytes** suit dry places; **hydrophytes** water; **halophytes** salty soil (mangroves); **mesophytes** moderate conditions.
- Mangroves have **pneumatophores** (breathing roots) and **vivipary** (seeds germinate on the tree).

17 THE NITROGEN CYCLE

Nitrogen makes up most of the air, yet plants starve for it — they cannot use the gas directly. A handful of microbes and the occasional lightning bolt unlock it, and the whole living world depends on them.

Concept

- Nitrogen is essential for **proteins and nucleic acids**; the atmosphere (**~78%** N_2) is its reservoir, so it is a **gaseous cycle**.

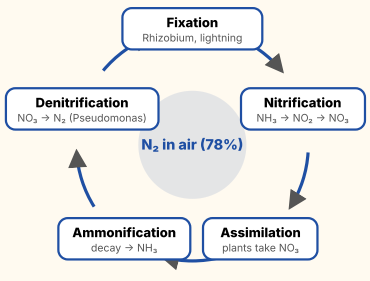
Key facts

- **Nitrogen fixation** — N_2 → ammonia: by **Rhizobium** (in legume root nodules), **Azotobacter, Clostridium, cyanobacteria (Anabaena, Nostoc)**, by **lightning** and by industry (**Haber–Bosch**).
- **Nitrification** — ammonia → nitrite (**Nitrosomonas**) → nitrate (**Nitrobacter**).
- **Assimilation** — plants absorb nitrates; animals get nitrogen by eating plants.
- **Ammonification** — decomposers turn dead matter back into ammonia.
- **Denitrification** — nitrates → N_2 gas by **Pseudomonas**, mostly in waterlogged soil.

Explained

- **Azolla** (a water fern hosting Anabaena) and **blue-green algae** are biofertilisers for paddy.
- Excess nitrate runs off into lakes and causes **eutrophication**; nitrous oxide (N_2O) is a potent greenhouse gas.

DIAGRAM · The nitrogen cycle



Nutrient Cycles

Phosphorus, sulphur and oxygen cycles

18 PHOSPHORUS, SULPHUR AND OXYGEN CYCLES

Key facts

- **Phosphorus** — a **sedimentary** cycle with **no gaseous phase**; reservoir in rocks (phosphates); released by weathering; bones, ATP and DNA need it; lost to deep ocean sediments.
- **Sulphur** — mostly sedimentary, with a small gaseous phase (SO_2 from volcanoes and fuel burning, H_2S from decay); part of amino acids.
- **Oxygen** — released by photosynthesis, used in respiration and combustion; tied closely to the carbon cycle.

Explained

- Phosphorus is often the **limiting nutrient** for plant growth in fresh water; phosphate detergents trigger algal blooms.
- Seabirds return phosphorus to land through **guano**.

Points of precision

- **Gypsum** (calcium sulphate) supplies **calcium and sulphur** to soil and reclaims **alkaline (sodic)** soils.
- Gaseous cycles: water, carbon, nitrogen, oxygen; sedimentary: phosphorus, sulphur, calcium, iron.

The Variety of Life

Biodiversity · Value of biodiversity and causes of loss · Biodiversity hotspots

CHAPTER OUTLINE

1 Biodiversity → 2 Hotspots → 3 Conservation → 4 Biosphere reserves → 5 IUCN & species → 6 Wetlands & Ramsar → 7 Global bodies & treaties

1 BIODIVERSITY

Dasmann 1968 · Rosen 1985

The previous chapter showed how an ecosystem works. But no two forests, ponds or reefs are alike — each holds its own mix of genes, species and habitats. That variety is the insurance policy of life: the more of it there is, the better nature survives shocks.

Concept

- **Biodiversity** is the **variability among living organisms** from all sources — terrestrial, marine and other aquatic ecosystems — including diversity **within species, between species and of ecosystems** (CBD definition).
- **Raymond F. Dasmann** first used "biological diversity" in *A Different Kind of Country* (**1968**); **W. G. Rosen** shortened it to "**biodiversity**" (1985); **E. O. Wilson** popularised it.

Key facts

- Three levels: **genetic** (within a species — e.g. thousands of rice varieties), **species** (between species) and **ecosystem/community** diversity.
- **R. H. Whittaker** divided diversity into **alpha** (within one community), **beta** (turnover between communities along a gradient) and **gamma** (whole landscape or region).
- Its most important role is to **maintain ecosystem stability**.
- **International Day for Biological Diversity — 22 May** (adoption of the CBD text, 1992).
- India's first **National Centre for Marine Biodiversity (NCMB)** is at **Jamnagar, Gujarat** (2011).

Explained

- Biodiversity **increases from the poles to the equator** — tropical rainforests (roughly **10°N–10°S**) are richest, thanks to steady heat, rain and long evolutionary time.
- On mountains it **falls with altitude** as temperature drops; valleys are richer than peaks.
- Cold-blooded groups such as **butterflies** are far more diverse in the tropics.
- Indices used to measure it: **Shannon–Wiener** and **Simpson** indices.

Points of precision

- India has about **2.4%** of the world's land but **7–8%** of recorded species — about **1.04 lakh animal** and **55,000+ plant** species.
- Biodiversity is richer in **tropical** than temperate regions and in **lower** than higher latitudes.

2 VALUE OF BIODIVERSITY AND CAUSES OF LOSS

We eat, breathe and heal because of other species. Yet species are now vanishing hundreds of times faster than the natural rate — mostly because we are taking away the places they live.

Key facts

- Services: **soil formation**, erosion control, **waste recycling**, **pollination**, food, **medicines**, better crop varieties, livestock, water conservation, **climate regulation**, nutrient cycling, ecotourism, cultural and aesthetic value.
- Causes of loss: **habitat loss and fragmentation (the biggest cause)**, over-exploitation, **invasive alien species**, deforestation, industrialisation, mining, poaching, trafficking, pollution, **climate change** and urbanisation.
- Paul Ehrlich's "**rivet popper**" idea: each lost species is a rivet pulled from an aeroplane wing.

Explained

- **Taxol**, an anti-cancer drug, comes from the **Himalayan yew (Taxus)** — a species now threatened by over-harvesting.
- **Diclofenac**, a pain-killer given to cattle, killed over **95%** of India's *Gyps* vultures; its veterinary use was banned in **2006**.
- **Prosopis juliflora** is called a threat because it is an aggressive **invasive** that dries out land and crowds out native plants.

Points of precision

- The Jatayu **Conservation Breeding Centre** for vultures is at **Pinjore, Haryana**.
- The **Vulture Action Plan 2020–25** also banned **ketoprofen and aceclofenac** for veterinary use.

3 BIODIVERSITY HOTSPOTS

Norman Myers, 1988

Conservation money is scarce, so it must go where it saves the most. In 1988 Norman Myers pointed out that a handful of regions hold a huge share of the world's unique species — and are being destroyed fastest.

Concept

- A **hotspot** is a biogeographic region with **exceptional species richness**, a **high share of endemic species** and **severe threat** to its habitat.
- The concept came from **Norman Myers (1988)**; **Conservation International** adopted and expanded it.

Key facts

- Criteria: at least **1,500 endemic vascular plant species** (over 0.5% of the world total) and loss of at least **70%** of original native vegetation.
- There are **36** hotspots, covering only about **2.4%** of Earth's land but holding over half of the world's endemic plants.
- The **North American Coastal Plain** became the **36th** hotspot in **2016**.
- Hotspots are **not limited to the tropics** — the Mediterranean, California, Caucasus and Japan are hotspots.

Explained

- India shares **four**: **Himalaya**, **Western Ghats & Sri Lanka**, **Indo-Burma** (North-East India) and **Sundaland** (**Nicobar Islands**).
- The **Western Ghats** are rich in endemic **amphibians**; the **lion-tailed macaque** lives in the Ghats of Kerala, Tamil Nadu and Karnataka.
- In India the **red panda** is found in **Sikkim, Arunachal Pradesh and Darjeeling (West Bengal)**; the **slow loris** in the forests of the **North-East**.

Points of precision

- The Andaman Islands fall in **Indo-Burma**; the **Nicobar** Islands fall in **Sundaland**.
- The **Critical Ecosystem Partnership Fund (CEPF)** finances civil-society work in hotspots.

Hotspots & Megadiverse Nations

Megadiverse countries · Methods of conservation · Biosphere reserves

THE 36 HOTSPOTS OF THE WORLD

Region	Hotspots
Asia–Pacific (14)	Himalaya · Indo-Burma · Western Ghats & Sri Lanka · Sundaland · Mountains of SW China · Japan · Philippines · Wallacea · East Melanesian Islands · New Caledonia · New Zealand · Polynesia–Micronesia · Forests of East Australia · Southwest Australia
Africa (8)	Cape Floristic Region · Succulent Karoo · Maputaland–Pondoland–Albany · Coastal Forests of Eastern Africa · Eastern Afromontane · Guinean Forests of West Africa · Horn of Africa · Madagascar & Indian Ocean Islands
Europe & Central Asia (4)	Mediterranean Basin · Caucasus · Irano-Anatolian · Mountains of Central Asia
Americas (10)	Atlantic Forest · Cerrado · Tropical Andes · Tumbes–Chocó–Magdalena · Chilean Winter Rainfall–Valdivian Forests · Mesoamerica · Caribbean Islands · Madrean Pine–Oak Woodlands · California Floristic Province · North American Coastal Plain

4 MEGADIVERSE COUNTRIES

Concept
- **17 megadiverse countries** together hold about **70%** of the Earth's species.
- Criteria: at least **5,000 endemic plants** and a **marine coastline**.

Key facts
- Australia, Brazil, China, Colombia, DR Congo, Ecuador, **India**, Indonesia, Madagascar, Malaysia, Mexico, Papua New Guinea, Peru, Philippines, South Africa, USA, Venezuela.
- The **Like-Minded Megadiverse Countries** group was formed by the **Cancún Declaration (2002)** to press for benefit-sharing rights.

5 METHODS OF CONSERVATION

There are two ways to save a species: protect it where it lives, or take it somewhere safe. The first keeps the whole web of life intact; the second is a lifeboat when the home itself is burning.

Concept
- **In-situ** — conservation **within the natural habitat**: national parks, sanctuaries, biosphere reserves, tiger reserves, community and conservation reserves, **sacred groves**.
- **Ex-situ** — conservation **outside the natural habitat**: botanical gardens, zoos, **gene banks**, seed banks, **cryopreservation (−196°C, liquid nitrogen)**, tissue culture, aquaria.

Key facts
- **Sacred groves** — patches of forest protected by communities for religious reasons: **Kavu (Kerala), Devrai (Maharashtra), Orans (Rajasthan), Law Kyntang (Meghalaya), Sarna (Jharkhand)**.
- India's **National Bureau of Plant Genetic Resources (NBPGR)**, New Delhi, runs the national gene bank; the **Svalbard Global Seed Vault (Norway)** is the world's "doomsday" seed bank.
- The Government of India set up the **National Afforestation and Eco-development Board** in **1992**.

Explained
- In-situ protects **evolutionary processes**; ex-situ protects **genetic material** and allows captive breeding and reintroduction (e.g. the cheetah, gharial, vultures).
- A **seed bank** is a form of ex-situ conservation; a national park is in-situ.

Points of precision
- Most of India's wildlife conservation areas were set up under the **Wildlife (Protection) Act, 1972**.
- A **botanical garden** is **not** an in-situ site even if it grows native plants.

6 BIOSPHERE RESERVES *UNESCO Man and the Biosphere, 1971*

A national park keeps people out; a biosphere reserve keeps them in. Its aim is to prove that people and wild nature can share a landscape — with a strictly protected heart and a working, living edge.

Concept
- Biosphere reserves conserve **biodiversity and genetic diversity** together with the **traditional lifestyles** of local people.
- They get international recognition under UNESCO's **Man and the Biosphere (MAB)** programme (**1971**); India's national programme began in **1986**.

Key facts
- **Core zone** — strictly protected; no human activity except monitoring; must be legally protected (often a national park or sanctuary).
- **Buffer zone** — surrounds the core; research, education, training and eco-friendly use.
- **Transition zone** — outermost; local villages, farming and sustainable economic activity.
- India has **18** biosphere reserves; **13** are in UNESCO's **World Network of Biosphere Reserves (WNBR)**.
- **First**: **Nilgiri (1986)** — Tamil Nadu, Kerala, Karnataka; **largest**: **Great Rann of Kutch**; **most recent**: **Panna (2011)**.

Explained
- Biosphere reserves are notified by the Centre as an **executive scheme**; they have **no separate law**.
- **Cold Desert (Himachal Pradesh)** joined the WNBR on **27 Sept 2025** at the 5th World Congress of Biosphere Reserves, **Hangzhou** — India's 13th.
- The WNBR has about **785 sites in 142 countries** (2025).

Points of precision
- Not in the UNESCO network: **Manas, Dihang-Dibang, Great Rann of Kutch, Dibru-Saikhowa, Seshachalam**.
- Spread over **three states**: Nilgiri. Two states: **Achanakmar-Amarkantak** (MP–Chhattisgarh) and **Agasthyamala** (Kerala–Tamil Nadu).
- Agasthyamala includes **Neyyar, Peppara and Shenduruney** sanctuaries and **Kalakad-Mundanthurai** Tiger Reserve.

Saving Life: In-situ & Ex-situ

IUCN and the Red List

THE 18 BIOSPHERE RESERVES OF INDIA

Biosphere reserve	State	Year	UNESCO
Nilgiri	TN, Kerala, Karnataka	1986	2000
Nanda Devi	Uttarakhand	1988	2004
Nokrek	Meghalaya	1988	2009
Gulf of Mannar	Tamil Nadu	1989	2001
Sundarban	West Bengal	1989	2001
Manas	Assam	1989	—
Similipal	Odisha	1994	2009
Dibru-Saikhowa	Assam	1997	—
Dihang-Dibang	Arunachal Pradesh	1998	—
Pachmarhi	Madhya Pradesh	1999	2009
Khangchendzonga	Sikkim	2000	2018
Agasthyamala	Kerala, Tamil Nadu	2001	2016
Achanakmar-Amarkantak	MP, Chhattisgarh	2005	2012
Great Rann of Kutch	Gujarat	2008	—
Cold Desert	Himachal Pradesh	2009	2025
Seshachalam Hills	Andhra Pradesh	2010	—
Panna	Madhya Pradesh	2011	2020
Great Nicobar	Andaman & Nicobar	1989	2013

7 IUCN AND THE RED LIST *Gland, 1948*

To save species you must first know which are slipping away. A union of governments and NGOs took on that task and built a global register of the threatened — a barometer of the health of life on Earth.

Concept
- The **International Union for Conservation of Nature (IUCN)**, founded **1948**, HQ **Gland, Switzerland**, is a union of **governments and NGOs**.
- It is **not a UN organ**; it holds **observer status** at the UN General Assembly.
- Its **Red List of Threatened Species** (the "**Barometer of Life**") assesses extinction risk worldwide; the printed version is the **Red Data Book**.

Key facts
- **Nine categories**: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), **Vulnerable (VU), Endangered (EN), Critically Endangered (CR)**, Extinct in the Wild (EW), Extinct (EX).
- **VU, EN and CR** together form the "**threatened**" group.
- IUCN also defines the six **protected-area categories** (Ia strict nature reserve to VI sustainable use) and runs the **Green Status of Species** and the **Red List of Ecosystems**.
- IUCN runs thousands of field projects worldwide.

Explained
- A species is judged on **population decline, range size, small population** and **probability of extinction** (criteria A–E).
- The **Botanical Survey of India** publishes India's plant Red Data Book; the **ZSI** covers animals.

Current status (2026)
- The **IUCN World Conservation Congress** met at **Abu Dhabi in October 2025**.
- The Red List now covers over **1.7 lakh species**, of which roughly **48,000** are threatened.

SOME THREATENED SPECIES OF INDIA

Species	IUCN	Where in India	Note
Great Indian Bustard	CR	Rajasthan (Desert NP), Gujarat	Power lines a major killer; captive breeding at Sam
Jerdon's Courser	CR	Sri Lankamalleswara WLS, Andhra Pradesh	Rediscovered 1986
Gharial	CR	Chambal, Girwa, Gandak	Fish-eating crocodile
Pygmy Hog	EN	Manas, Assam	World's smallest wild pig
Ganges River Dolphin	EN	Ganga–Brahmaputra system	National Aquatic Animal
Asian Elephant	EN	Western Ghats, NE, central India	National Heritage Animal
Red Panda	EN	Sikkim, Arunachal, Darjeeling	State animal of Sikkim
Lion-tailed Macaque	EN	Western Ghats	Endemic
Dugong (sea cow)	VU	Gulf of Mannar, Palk Bay, Kutch, A&N	Grazes on sea-grass; Schedule I
Snow Leopard	VU	Himalaya, Ladakh	718 counted in SPAI (2024)
Nilgiri Tahr	EN	Western Ghats (Eravikulam)	State animal of Tamil Nadu
Sangai deer	EN	Keibul Lamjao, Manipur	Lives on floating phumdis

Wetlands & the Ramsar Convention

Wetlands · Ramsar Convention

8 WETLANDS

Between land and water lies a world that is neither — marshes, mangroves, lakes and floodplains. Long treated as wasteland to be drained, wetlands turn out to be among the hardest-working ecosystems on Earth.

Concept

- **Wetlands** are areas where **water is the primary factor** controlling the environment and its life — a **transition (ecotone)** between land and water.
- They include marshes, fens, **peatlands**, lakes, rivers, mangroves, tidal flats and **marine water up to 6 m deep at low tide**.

Key facts

- Permanently or seasonally waterlogged; **natural** (lakes, rivers) or **man-made** (ponds, reservoirs, **paddy fields**).
- Functions: nutrient cycling, **sediment trapping**, **water purification**, absorbing heavy metals, **flood control**, reducing river siltation, groundwater recharge, carbon storage.
- Called the "**kidneys of the Earth**" (they filter water) and "**biological supermarkets**" (they are so rich in life).
- Wetland plants have **aerenchyma** — tissue with large air spaces for buoyancy and gas exchange.

Explained

- **Peatlands** store about twice as much carbon as all the world's forests although they cover about 3% of land.
- India regulates wetlands under the **Wetlands (Conservation and Management) Rules, 2017** (EPA); State **Wetland Authorities** notify and manage them.
- The **National Plan for Conservation of Aquatic Ecosystems (NPCA, 2015)** merged the earlier lake and wetland programmes; **Amrit Dharohar (2023)** promotes Ramsar sites.

9 RAMSAR CONVENTION *2 Feb 1971, Ramsar, Iran*

Concept

- An intergovernmental treaty for the **conservation and wise use of wetlands**, adopted at **Ramsar, Iran, on 2 February 1971**; in force **21 Dec 1975**; for India from **1 Feb 1982**.
- It is **not** part of the UN system; its secretariat at **Gland** is hosted by IUCN.

Key facts

- **World Wetlands Day — 2 February**.
- First Ramsar site in the world: **Cobourg Peninsula, Australia (1974)**.
- India's first: **Chilika Lake (Odisha)** and **Keoladeo National Park (Rajasthan)**, both **1981**.
- **Montreux Record** (set up at **COP4, Montreux, 1990**) lists Ramsar sites whose ecological character is changing; India's entries: **Keoladeo** and **Loktak**. **Chilika** was listed in **1993** and **removed in 2002** after restoration.
- International Organisation Partners: **BirdLife, IUCN, IWMI, Wetlands International, WWF, Wildfowl & Wetlands Trust**.

Current status (2026)

- India has **103 Ramsar sites** (15 Oct 2026), covering over **13.87 lakh ha** — **first in Asia**, **third in the world** after the **UK and Mexico**; up from 26 in 2014.
- **Tamil Nadu (20)** leads, then **Uttar Pradesh (14)**.
- **100th: Jai Prakash Narayan Bird Sanctuary (Surha Tal, Ballia, UP)**, June 2026; **101st: Glaw Lake** (Kamlang Tiger Reserve) — Arunachal's first; **102nd: Sukhna Wetland (Chandigarh)**; **103rd: Sauj Jheel (UP)**.
- **Ramsar COP15, Victoria Falls, Zimbabwe (July 2025)** adopted the **5th Strategic Plan 2025–2034** and the **Victoria Falls Declaration**; **COP16** will be in **Panama (2028)**.

Points of precision

- **Largest** Indian Ramsar site: **Sundarban Wetland** (West Bengal, ~4.23 lakh ha); **smallest**: **Vembannur Wetland Complex** (Tamil Nadu, ~20 ha), just below **Renuka** (Himachal).
- Chhattisgarh, Sikkim, Jharkhand and Arunachal received their **first** sites in 2025–26.

RAMSAR SITES OF INDIA — STATE-WISE (103)

State/UT	Sites
Tamil Nadu (20)	Point Calimere · Koonthankulam · Chitrangudi · Karikili · Pichavaram Mangrove · Pallikaranai Marsh · Gulf of Mannar · Vembannur · Vellode · Udhayamarthandapuram · Vedanthangal · Suchindram-Theroor · Vaduvur · Kanjirankulam · Karaivetti · Longwood Shola · Kazhuveli · Nanjarayan · Sakkarakottai · Therthangal
Uttar Pradesh (14)	Upper Ganga (Brijghat–Narora) · Nawabganj · Parvati Arga · Saman · Samaspur · Sandi · Sarsai Nawar · Sur Sarovar · Haiderpur · Bakhira · Patna Bird Sanctuary · Shekha Jheel · Surha Tal (JP Narayan) · Sauj Jheel
Punjab (6) + Chandigarh (1)	Harike · Kanjli · Ropar · Beas Conservation Reserve · Keshopur-Miani · Nangal · Sukhna (Chandigarh)
Bihar (6)	Kanwar Lake (Kabartal) · Nagi · Nakti · Gokul Reservoir · Udaipur Lake · Gogabil
Odisha (6)	Chilika · Bhitarkanika Mangroves · Satkosia Gorge · Tampara · Hirakud · Ansupa
Gujarat (5)	Nalsarovar · Wadhvana · Thol · Khijadia · Chhari-Dhand
Madhya Pradesh (5)	Bhoj Wetland · Sirpur · Sakhya Sagar · Yashwant Sagar · Tawa Reservoir
Rajasthan (5)	Keoladeo · Sambhar · Menar · Khichan · Siliserh
Jammu & Kashmir (5)	Wular · Surinsar-Mansar · Hokera · Hygam · Shallabug
Karnataka (4)	Ranganathittu · Ankasamudra · Aghanashini Estuary · Magadi Kere
Himachal (3) · Kerala (3) · Maharashtra (3)	Pong Dam, Chandertal, Renuka · Ashtamudi, Sasthamkotta, Vembanad-Kol · Nandur Madhameshwar, Lonar, Thane Creek
Ladakh (2) · Haryana (2) · West Bengal (2)	Tso Moriri, Tso Kar · Sultanpur, Bhindawas · East Kolkata Wetlands, Sundarban
One site each	AP: Kolleru · Arunachal: Glaw · Assam: Deepor Beel · Chhattisgarh: Kopra · Goa: Nanda · Jharkhand: Udhwa · Manipur: Loktak · Mizoram: Pala · Sikkim: Khecheopalri · Tripura: Rudrasagar · Uttarakhand: Asan

Global Bodies & Biodiversity Treaties

Networks, initiatives and India's biodiversity law · CBD and its offspri...

10 NETWORKS, INITIATIVES AND INDIA'S BIODIVERSITY LAW

Biodiversity crosses borders, and so must its defenders — bird networks, trade monitors, forest-carbon schemes and economists who put a price on nature's services.

Key facts

- **BirdLife International** — founded **1922, London** (as the International Committee for Bird Protection); HQ **Cambridge, UK**; the IUCN **Red List authority for birds**; maps **Important Bird and Biodiversity Areas (IBAs)**; magazine *World Birdwatch*.
- **TRAFFIC** (Trade Records Analysis of Flora and Fauna in Commerce) — **1976**, HQ **Cambridge, UK**; an NGO allied with **WWF and IUCN**; ensures wildlife trade does not threaten nature. It is **not** a UN body.
- **Wetlands International** — founded **1937**, global body **1996**; HQ **Wageningen, Netherlands**.
- **CEBPOL** (Centre for Biodiversity Policy and Law) — **Chennai, Nov 2010**, under the NBA, an **India–Norway** collaboration.

Explained

- **UN-REDD (2008)** — **FAO, UNDP and UNEP** together; **REDD** = Reducing Emissions from Deforestation and forest Degradation.
- The "**+**" adds **conservation of forest carbon stocks, sustainable management of forests and enhancement of carbon stocks**.
- **TEEB** (The Economics of Ecosystems and Biodiversity) — launched **2007** by **Germany and the European Commission**, hosted by **UNEP**; aims at "**making nature's values visible**" to decision-makers.

Points of precision

- The **Biological Diversity Act, 2002** was born out of India's obligations under the **CBD**; it set up a **three-tier** structure — **NBA (Chennai)**, **State Biodiversity Boards**, **Biodiversity Management Committees** (People's Biodiversity Registers).
- The NBA checks **biopiracy**; foreigners need its approval to access Indian bio-resources, and **IPR applications** based on them need its prior approval.
- **Sea buckthorn** ("**Leh berry**", "**Ladakh gold**") — a thorny cold-desert shrub; fixes nitrogen, binds soil, rich in vitamins.
- *Tomorrow's Biodiversity* (2000) is by **Vandana Shiva**.

11 CBD AND ITS OFFSPRING

Rio 1992 → Kunming-Montreal 2022

Concept

- The **Convention on Biological Diversity (CBD)** — opened at **Rio 1992**, in force **29 Dec 1993**; secretariat **Montreal**; three aims: **conservation, sustainable use, fair and equitable benefit-sharing**.
- The **USA** is the only major country that has **not ratified** it.

Key facts

- **Cartagena Protocol on Biosafety** — adopted **29 Jan 2000**, in force **11 Sept 2003**; safe handling and transboundary movement of **Living Modified Organisms (LMOs)**; uses the **Advance Informed Agreement (AIA)** procedure. India is a party; MoEFCC implements.
- **Nagoya–Kuala Lumpur Supplementary Protocol (2010)** — **liability and redress** for damage from LMOs.
- **Nagoya Protocol (2010; in force 2014)** — **Access and Benefit-Sharing (ABS)** of genetic resources.
- **Aichi Biodiversity Targets (2010)** — 20 targets for 2011–2020; none fully met.
- **Kunming–Montreal Global Biodiversity Framework (KMGBF)** — **COP15, Montreal, Dec 2022**; **4 goals, 23 targets** for 2030, including "**30 × 30**" (protect 30% of land and sea), restore 30% of degraded ecosystems, halve food waste and nutrient loss.

Current status (2026)

- **COP16, Cali (Colombia), 2024** set up the **Cali Fund** for sharing benefits from **Digital Sequence Information (DSI)** and a subsidiary body for **Indigenous peoples**.
- **COP17, Yerevan (Armenia), 19–30 Oct 2026**, theme "**Taking Action for Nature**", held the **first global review** of KMGBF progress.
- India updated its **National Biodiversity Strategy and Action Plan (NBSAP)** in 2024 with **23 national targets** mirroring the KMGBF.

12 OTHER WILDLIFE AND OCEAN TREATIES

Key facts

- **CITES** (Washington Convention) — signed **1973**, in force **1975**; secretariat **Geneva**; regulates **international trade** in wild species; **legally binding** but does not replace national laws. **Appendix I** — trade banned except in exceptional cases; **II** — trade controlled by permits; **III** — listed by one country seeking help.
- **CMS (Bonn Convention, 1979)** — migratory species; India hosted **COP13 at Gandhinagar (2020)**; **COP14, Samarkand (2024)**.
- **World Heritage Convention (1972, UNESCO)** — cultural and natural heritage.
- **UNCLOS (1982)** — law of the sea, maritime zones.
- **BBNJ / High Seas Treaty** (adopted **2023**, under UNCLOS) — **entered into force on 17 Jan 2026**; India **signed in 2024**, ratification pending.

Points of precision

- CITES CoP20 met at **Samarkand, Uzbekistan (Nov–Dec 2025)**.
- Correct chronological order: **Ramsar (1971) → World Heritage (1972) → CITES (1973) → CMS (1979) → UNCLOS (1982) → Montreal (1987) → CBD (1992)**.

BIODIVERSITY AGREEMENTS AT A GLANCE

Agreement	Year	Purpose
Ramsar Convention	1971	Wetlands — conservation and wise use
World Heritage Convention	1972	Cultural and natural heritage
CITES	1973	Trade in endangered fauna and flora
CMS (Bonn)	1979	Migratory species
UNCLOS	1982	Maritime zones and resources
Montreal Protocol	1987	Ozone-depleting substances
CBD	1992	Biodiversity, sustainable use, benefit-sharing
Cartagena Protocol	2000	Biosafety of LMOs
Nagoya Protocol	2010	Access and benefit-sharing
Nagoya–Kuala Lumpur Suppl. Protocol	2010	Liability and redress for LMO damage
Kunming–Montreal GBF	2022	23 targets for 2030; 30×30
BBNJ (High Seas) Agreement	2023 (in force 2026)	Marine biodiversity beyond national jurisdiction

A Blanket Around the Earth

The greenhouse effect · Methane and crop-residue burning · Climate change and global war…

CHAPTER OUTLINE

1 Greenhouse effect → 2 Global warming → 3 Mitigation tools → 4 UNFCCC & Kyoto → 5 Paris & after → 6 COP timeline → 7 India's response → 8 Carbon vocabulary

1 THE GREENHOUSE EFFECT *Fourier, 1824*

Sunlight passes easily through the air, warms the ground, and the ground glows back in infrared. Certain gases catch that outgoing heat and send part of it back down. Without this blanket the Earth would freeze; with too thick a blanket, it overheats. The whole climate story turns on how thick we make it.

Concept
- Solar radiation arrives as **UV, visible and infrared**; most harmful UV is absorbed by the **ozone layer**.
- The warmed surface re-emits **long-wave infrared**; greenhouse gases **absorb and re-radiate** it, keeping the lower atmosphere warm — the **greenhouse effect**.
- Without it, Earth's average surface temperature would be about **−18°C** instead of about **+15°C**.

Key facts
- First proposed by French mathematician **Joseph Fourier (1824)**; **John Tyndall** (1859) measured heat absorption by gases; **Svante Arrhenius** (1896) linked CO_2 to temperature.
- Greenhouse gases: **water vapour, CO_2, CH_4, N_2O, O_3, CFCs, HCFCs, HFCs, SF_6, NF_3**.
- **Not** direct greenhouse gases: **O_2, N_2, H_2, argon**, and NO_2, SO_2 (which act indirectly).
- Share of radiative forcing among long-lived gases: **CO_2 ~66%**, **CH_4 ~16%**, CFCs ~9%, **N_2O ~6%**, HCFCs ~2%.
- **Water vapour** is the **most abundant** greenhouse gas, but it responds to temperature rather than driving it.

Explained
- **Global Warming Potential (GWP)** compares heat trapped by a gas to CO_2 over 100 years: **CH_4 ≈ 27–30**, **N_2O ≈ 273**, **SF_6 ≈ 25,000** — SF_6 is the most potent gas assessed by the IPCC.
- **Carbon fertilisation** — higher CO_2 can boost plant growth under some conditions, though heat and water stress limit the gain.
- **Aerosols** (sulphates) **cool** the Earth by reflecting sunlight; **black carbon** warms it.

Points of precision
- The natural greenhouse effect is **essential** to life; the problem is the **enhanced** greenhouse effect caused by humans.
- CO_2 stays for centuries; methane only about **12 years** — cutting methane gives the fastest cooling.

2 METHANE AND CROP-RESIDUE BURNING

Key facts
- **Methane** ("**marsh gas**") — human sources: **paddy fields**, **coal mining**, **ruminant livestock (enteric fermentation)**, landfills; natural sources: **wetlands**, **termites**, oceans, **methane hydrates**.
- Paddy fields release both **CH_4** (from waterlogged soil) and **N_2O** (from fertilisers).
- **Methane hydrate** — ice-like solid of methane trapped in water molecules under **low temperature and high pressure**: Arctic, Antarctic, continental margins, deep ocean floor.
- Burning **rice, wheat and sugarcane** residue releases **CO_2, CO, CH_4, SO_2, NOx, black carbon, organic carbon, VOCs, non-methane hydrocarbons, ozone, particulate matter and aerosols**.

Explained
- Thawing permafrost and warming seas could release hydrates — a dangerous **positive feedback**.
- **Alternate wetting and drying** and **direct-seeded rice** cut methane from paddy; the **Global Methane Pledge (COP26, 2021)** aims to cut methane 30% by 2030 — **India has not joined** it.

3 CLIMATE CHANGE AND GLOBAL WARMING

For ten thousand years a stable climate let farming and cities flourish. In just over a century of burning coal and oil, the thermometer has climbed more than a degree — and every fraction of that degree is now being felt in heatwaves, floods and melting ice.

Concept
- **Climate change** — long-term shifts in temperatures and weather patterns.
- **Global warming** — the long-term rise in the average temperature of Earth's surface air and oceans; the world has warmed by **more than 1.1°C** since pre-industrial times (1850–1900).

Key facts
- Causes: rising **greenhouse gases**, **fossil fuel** burning, growing vehicles, **deforestation** (fewer sinks), industrialisation, pollution.
- Impacts: **glacier retreat**, shrinking **polar ice**, **sea-level rise**, droughts, floods, storms, **cyclones**, **coral bleaching**, spread of **vector-borne diseases**, falling farm output, food insecurity, biodiversity loss, **climate refugees**, conflict.
- On farms: hotter soils lose moisture, **salinity rises**, yields swing and fall.

Explained
- **Milankovitch theory** — long-term climate cycles (ice ages) are driven by changes in Earth's orbit: **eccentricity** (~100,000 years), **obliquity/tilt** (~41,000 years) and **precession** (~26,000 years); named after Serbian scientist **Milutin Milankovitch**.
- Today's warming is far **too fast** to be explained by orbital cycles or the Sun — the IPCC calls human influence "**unequivocal**" (AR6, 2021).
- Feedbacks speed it up: melting ice lowers **albedo**, permafrost releases methane, warmer air holds more water vapour.

Current status (2026)
- **2024** was the **warmest year on record** — about **1.55°C** above pre-industrial (WMO) — the first calendar year above 1.5°C; **2015–2025** are the eleven warmest years on record.
- CO_2 at Mauna Loa peaked near **432 ppm (May 2026)**.
- The **IPCC** (chair **Jim Skea** since 2023) is in its **seventh assessment cycle**; a **Special Report on Climate Change and Cities** is due in 2027.

4 CLIMATE-SMART AGRICULTURE

Concept
- An approach that **raises farm productivity**, builds **resilience (adaptation)** and **cuts or removes emissions (mitigation)** at the same time.

Key facts
- Practices: **drought-tolerant varieties**, **drip and sprinkler irrigation**, **zero/conservation tillage**, **agroforestry**, precision farming and weather-based advisories.
- India's **Climate-Smart Villages** are part of **CCAFS** (Climate Change, Agriculture and Food Security), a programme of **CGIAR**.
- The **National Innovations in Climate Resilient Agriculture (NICRA, 2011)** of ICAR tests resilient practices in vulnerable districts.

Pulling Carbon Back

Carbon sequestration, capture and net zero · The colours of carbon and carbon accounting · UNFCCC and the...

5 CARBON SEQUESTRATION, CAPTURE AND NET ZERO

Cutting emissions is only half the job. The other half is to take carbon back out of the air — by growing forests and soils, or by catching CO_2 at the chimney and burying it deep underground.

Concept
- **Carbon sequestration** — long-term storage of carbon in **vegetation, soils, geological formations or oceans**.
- **Carbon capture (CCS/CCUS)** — trapping CO_2 at **large point sources** (power plants, cement, steel) before it escapes, then storing or using it.
- **Net zero** — **not** zero emissions, but a **balance** between greenhouse gases emitted and those removed.

Key facts
- Geological storage sites: **unmineable coal seams**, **depleted oil and gas fields**, **deep saline aquifers**.
- **Enhanced rock weathering** — spreading crushed **basalt** on farmland to absorb CO_2; **ocean alkalinity enhancement** raises the sea's CO_2 uptake.
- **Direct air capture** pulls CO_2 straight from ambient air.
- Net-zero years: **India 2070**, **China 2060**, most developed countries **2050** — the 2050 date is tied to the **1.5°C** goal.

Explained
- **Enhanced oil recovery** pumps CO_2 into oil fields to push out more oil — it stores carbon but also produces fossil fuel.
- Forest sinks are reversible: a fire or felling releases the carbon again.

6 THE COLOURS OF CARBON AND CARBON ACCOUNTING

Key facts
- **Blue carbon** — stored by **coastal and marine ecosystems**: **mangroves, sea-grass meadows, salt marshes**.
- **Green carbon** — stored by **land ecosystems**: forests, vegetation, soils.
- **Black carbon** — **soot** from incomplete burning of diesel, biomass and wood; a **short-lived climate pollutant (SLCP)**; darkens snow and speeds glacier melt.
- **Brown carbon** — light-absorbing organic aerosols, chiefly from burning **biomass** (forest fires, crop residue).
- **Grey carbon** — unabated emissions from **industry** (cement) and fossil power.

Explained
- **Carbon footprint** — total greenhouse gases caused directly and indirectly by a person, event, organisation or product.
- **Carbon tax** — a charge on fuels by their emissions; a **Pigouvian** tax on pollution.
- **Common Carbon Metric** — UNEP **Sustainable Buildings and Climate Initiative** method for measuring building emissions.
- **GHG Protocol** — the global accounting standard set by the **World Resources Institute (WRI)** and the **World Business Council for Sustainable Development (WBCSD)**; Scope 1 (direct), 2 (purchased energy), 3 (value chain).

Points of precision
- The **Forest Carbon Partnership Facility (FCPF, 2008)** — managed by the **World Bank**; supports REDD+ through a **Readiness Fund** and a **Carbon Fund**.
- **Global Climate Change Alliance (GCCA, 2007)** — an **EU** initiative for vulnerable countries; became **GCCA+** after Paris.
- **Climate Action Tracker (2009)** — by **Climate Analytics** and the **NewClimate Institute**; rates national pledges against Paris goals.
- **The Climate Group (2003)** runs **EP100** (energy productivity) and **RE100**, and the **Under2 Coalition**; **Mahindra & Mahindra** was the first Indian firm in EP100.
- **Earth Hour** (WWF) began in **Sydney, 2007**; lights off for an hour, **8:30–9:30 pm, last Saturday of March**.

7 UNFCCC AND THE KYOTO PROTOCOL

Rio gave the world a climate treaty with a goal but no numbers. Kyoto supplied the numbers — binding cuts for rich countries only — and with them a set of markets to make cutting cheaper.

Concept
- The **UNFCCC** came out of **Rio 1992**; in force **21 March 1994**; secretariat **Bonn**.
- Aim: stabilise greenhouse gas concentrations at a level that prevents **dangerous anthropogenic interference** with the climate system.
- The **COP** is its supreme body, meeting yearly; **COP1, Berlin (1995)** adopted the **Berlin Mandate**.

Key facts
- Countries are grouped as **Annex I** (industrialised and economies in transition), **Annex II** (rich countries that must pay) and **non-Annex I** (developing, including India).
- **Kyoto Protocol** — adopted **11 Dec 1997** (COP3), in force **16 Feb 2005**; **legally binding** cuts for Annex I based on **CBDR–RC**; first period 2008–12 (average **5.2%** below 1990).
- Six gases covered: **CO_2, CH_4, N_2O, HFCs, PFCs, SF_6** (NF_3 added for the second period).
- **Doha Amendment (2012)** set a second period **2013–2020**.

Explained
- Three market mechanisms: **International Emissions Trading** (trade spare units), **Clean Development Mechanism** (Annex I invests in developing countries for **CERs**) and **Joint Implementation** (between Annex I countries, for **ERUs**).
- The **CDM (Article 12)** brings finance and technology to developing countries; the price of a carbon credit is set by the **market**.
- The USA never ratified Kyoto; Canada withdrew in 2011.

8 PARIS AGREEMENT AND CLIMATE FINANCE *COP21, 12 Dec 2015*

Concept
- A **legally binding** treaty adopted at **COP21, Paris, 12 Dec 2015**; in force **4 Nov 2016**.
- Goal: hold warming **well below 2°C** and pursue efforts to limit it to **1.5°C** above pre-industrial levels.
- Every country sets its own targets — **Nationally Determined Contributions (NDCs)** — updated every **five years** with rising ambition (**ratchet**).

Key facts
- **Global Stocktake** every five years (first concluded at **COP28, 2023**).
- **Article 6** — carbon markets and cooperation; its rules were completed at **COP29, Baku (2024)**.
- **Article 7** — the **Global Goal on Adaptation**; **Article 8** — loss and damage; **Article 9** — finance from developed countries.
- **Green Climate Fund** — agreed at **COP16, Cancún (2010)**; HQ **Songdo, South Korea**; linked to the goal of **$100 billion a year by 2020**.
- **NCQG (COP29, Baku)** — at least **$300 billion a year by 2035** for developing countries, with a call to scale up to **$1.3 trillion**.
- **Loss and Damage Fund** — agreed at **COP27, Sharm el-Sheikh (2022)**, operationalised at **COP28, Dubai**.

Points of precision
- The **USA** left Paris in 2020, rejoined in 2021, and announced withdrawal again in **January 2025**.
- INDCs became NDCs once a country ratified the agreement.

Fifty Years of Climate Diplomacy

COP30 Belém and the road to Antalya · National Action Plan on Climate Change

TIMELINE OF CLIMATE NEGOTIATIONS

Year	Event	Outcome
1972	Stockholm Conference	Foundation of global environmental governance; UNEP
1979	First World Climate Conference (Geneva)	First major scientific–policy meeting on climate
1988	IPCC set up by WMO and UNEP	Scientific assessment of climate change
1990	IPCC First Assessment Report	Call for a climate treaty; INC talks 1990–91
1992	Rio Earth Summit	UNFCCC opened for signature
1994	UNFCCC in force	21 March 1994
1995	COP1, Berlin	Berlin Mandate
1997	COP3, Kyoto	Kyoto Protocol adopted
2001	COP7, Marrakesh	Marrakesh Accords — Kyoto rule-book
2005	Kyoto in force	16 February 2005
2007	COP13, Bali	Bali Road Map / Action Plan
2009	COP15, Copenhagen	Copenhagen Accord; below 2°C
2010	COP16, Cancún	Green Climate Fund
2011	COP17, Durban	Durban Platform for a new deal for all
2012	COP18, Doha	Doha Amendment — Kyoto 2013–20
2013	COP19, Warsaw	Warsaw Mechanism on Loss & Damage; REDD+ framework
2014	COP20, Lima	Lima Call for Climate Action
2015	COP21, Paris	Paris Agreement
2016	COP22, Marrakesh	Paris rule-book talks
2021	COP26, Glasgow	Glasgow Pact; coal "phase-down"; India's Panchamrit
2022	COP27, Sharm el-Sheikh	Loss and Damage Fund agreed
2023	COP28, Dubai	First Global Stocktake; "transition away from fossil fuels"
2024	COP29, Baku	NCQG $300 bn; Article 6 rules
2025	COP30, Belém	Global Mutirão; tripling adaptation finance; Belém Mission to 1.5
2026	COP31, Antalya (Türkiye)	9–20 Nov 2026; Australia leads negotiations

9 COP30 BELÉM AND THE ROAD TO ANTALYA

10–22 Nov 2025, Brazil

Thirty years after the first COP, the talks went to the edge of the Amazon. Brazil called its package a "mutirão" — an Indigenous word for a community working together.

Key facts

- The first COP in the **Amazon**, presided by **André Corrêa do Lago**.
- Main decision: the "**Global Mutirão**" — calls to **triple adaptation finance by 2035** (from 2025 levels), launches the **Belém Mission to 1.5** and a **Global Implementation Accelerator**, and a dialogue on **trade measures**.
- Adopted indicators for the **Global Goal on Adaptation**, a **Just Transition mechanism**, the **Belém Gender Action Plan**, and the **Baku-to-Belém Roadmap** towards **$1.3 trillion** a year.
- Brazil launched the **Tropical Forests Forever Facility (TFFF)** to pay countries for standing forests.

Explained

- The final text carried **no roadmap to move away from fossil fuels**, despite pressure from the EU and others.
- India backed the package, stressing **CBDR–RC** and finance from developed countries.

Current status (2026)

COP31 meets at **Antalya, Türkiye, 9–20 Nov 2026**, under a shared arrangement: **Türkiye hosts and presides**, **Australia leads the negotiations**, and the **pre-COP** is in the Pacific.

10 NATIONAL ACTION PLAN ON CLIMATE CHANGE

30 June 2008

India is the third-largest emitter in total but among the lowest per person. Its policy walks a line between climate justice — the rich polluted first — and the fact that India itself is among the most exposed countries to heat, floods and failing monsoons.

Concept

The **NAPCC** was released on **30 June 2008** by the PM's Council on Climate Change; it rests on **eight national missions**.

Key facts

- 1 **National Solar Mission** · 2 **Enhanced Energy Efficiency** · 3 **Sustainable Habitat** · 4 **Water** · 5 **Sustaining the Himalayan Ecosystem** · 6 **Green India** · 7 **Sustainable Agriculture** · 8 **Strategic Knowledge for Climate Change**.
- States prepare **State Action Plans on Climate Change (SAPCCs)**.
- Proposed new missions: **wind, health, coastal resources, waste-to-energy** (and a revised Himalayan mission).

Explained

- **PAT (Perform, Achieve and Trade)** under the energy-efficiency mission trades energy-saving certificates among industries.
- The **National Adaptation Fund for Climate Change (2015)** funds state adaptation projects through **NABARD**.

India's Climate Response

India's targets

11 INDIA'S TARGETS

Key facts

- **Panchamrit (COP26, Glasgow, 2021)**: **500 GW** non-fossil capacity by 2030; **50%** of energy needs from renewables by 2030; cut **1 billion tonnes** of projected emissions by 2030; reduce emissions intensity by **45%** (over 2005) by 2030; **net zero by 2070**.
- **Updated NDC (Aug 2022)**: **45%** intensity cut and **50%** non-fossil installed capacity by 2030; an additional carbon sink of **2.5–3 billion tonnes** through forests; mass movement for **LiFE**.
- **Long-Term Low-Emission Development Strategy (LT-LEDS)** submitted at **COP27 (Nov 2022)**.

Current status (2026)

- **NDC 3.0 (2031–2035)** — approved by the Cabinet in **March 2026** and submitted to the UNFCCC on **24 April 2026**: **47%** cut in emissions intensity of GDP by **2035** (over 2005), **60%** of installed power capacity from **non-fossil** sources by 2035, and an additional sink of **3.5–4 billion tonnes CO_2e**.
- India reached **50% non-fossil capacity in June 2025** — five years early; non-fossil capacity crossed **300 GW** in July 2026.
- The **Carbon Credit Trading Scheme (2023)** sets emission-intensity targets for energy-intensive sectors; the **Bureau of Energy Efficiency** administers it and the **Grid Controller of India** keeps the registry.

Points of precision

- India's per-capita emissions are about **one-third** of the world average.
- The emissions-intensity target is **economy-wide**, not an absolute cap.

Earth's Sunscreen

Ozone and the ozone layer · Ultraviolet radiation and its effects · Ozone depletion

CHAPTER OUTLINE

1 Ozone & the layer → 2 Depletion & the hole → 3 UV and its harm → 4 Vienna & Montreal → 5 Kigali & India

1 OZONE AND THE OZONE LAYER

The same gas is a poison at street level and a shield twenty kilometres up. Where ozone sits decides whether it hurts us or protects us — and for half a century we were quietly destroying the good ozone while making more of the bad.

Concept

- **Ozone (O_3)** is a **triatomic** form of oxygen found in trace amounts; it was discovered by German scientist **Christian Friedrich Schönbein** in **1839**.
- In the **stratosphere** it is a **life-saver** that absorbs harmful UV; near the ground (**troposphere**) it is a harmful **secondary pollutant**.

Key facts

- Formed by **UV radiation**: UV splits O_2 into two O atoms; each O joins an O_2 to make **O_3** — a continuous photochemical cycle.
- The **ozone layer** lies in the **stratosphere** between about **10–50 km**, densest at **15–30 km**; about **90%** of all ozone is stratospheric, **10%** tropospheric.
- Discovered in **1913** by French physicists **Charles Fabry and Henri Buisson**.
- Measured in **Dobson Units (DU)** — **1 DU = 0.01 mm** of pure ozone at standard temperature and pressure; the global average is about **300 DU**.
- An "**ozone hole**" is an area where the column falls below **220 DU**.

Explained

- Ozone is **made mostly over the tropics** (strong sunlight) and carried towards the **poles** by stratospheric winds; so the layer is often **thicker at high latitudes** and **thinner at the equator**.
- Thickness varies with **latitude, season and time of day**; in the northern hemisphere it is usually thickest in **spring**.
- **Ground-level ozone** forms when **NOx and VOCs** react in sunlight — a key part of **photochemical smog**; it harms lungs and crops.

2 ULTRAVIOLET RADIATION AND ITS EFFECTS

Key facts

- **UV-A (315–400 nm)** — reaches the surface largely unfiltered; penetrates deep skin layers, causes **ageing**.
- **UV-B (280–315 nm)** — mostly absorbed by ozone; causes **sunburn, skin cancer and DNA damage**; it is the band that **increases when ozone thins**.
- **UV-C (100–280 nm)** — most lethal; **completely absorbed** by oxygen and ozone; never reaches the ground.

Explained

- Thinner ozone means more UV-B: **skin cancers** (melanoma and others), **cataracts**, snow blindness (photokeratitis), **weakened immunity**, **genetic mutations**.
- It slows plant growth, lowers crop yields and harms **phytoplankton** — the base of ocean food chains.

3 OZONE DEPLETION

CFCs looked like miracle chemicals — non-toxic, non-flammable, perfect for fridges and sprays. Their very stability was the problem: they drifted untouched up to the stratosphere, where sunlight finally broke them and set loose chlorine that ate ozone by the thousand molecules.

Concept

- **Ozone depletion** — the long-term thinning of stratospheric ozone that lets more UV reach the surface; the main culprits are **chlorofluorocarbons (CFCs)**.
- A **British Antarctic Survey** team (Farman, Gardiner and Shanklin) reported the **Antarctic ozone hole** in **1985**; NASA's **TOMS** satellite data confirmed it.

Key facts

- **CFCs** — made of **chlorine, fluorine and carbon**; colourless, odourless, **unreactive, non-flammable**, easily liquefied; atmospheric life **~80–100 years**; also greenhouse gases.
- Uses: **refrigerators, ACs, aerosol sprays, solvents, foam-blowing**, cosmetics propellants, cleaning electronic circuits.
- **Freon (CFC-12)** has been replaced in fridges by ozone-friendly coolants.
- Other **ozone-depleting substances (ODS)**: **halons** (fire extinguishers; halon-1211, 1301), **carbon tetrachloride**, **methyl chloroform**, **methyl bromide** (fumigant), **HCFCs**, trichloroethylene and **nitrous oxide**.

Explained

- In the stratosphere **UV breaks CFCs** and frees **chlorine atoms**; one chlorine atom can destroy **tens of thousands** of ozone molecules in a catalytic chain ($Cl + O_3 \rightarrow ClO + O_2$).
- **Bromine** (from halons) is even more destructive per atom.
- In the Antarctic winter the **polar vortex** isolates very cold air; **polar stratospheric clouds (PSCs)** form, and their **nitric acid trihydrate** surfaces convert stable chlorine into active forms; with spring sunlight, ozone collapses — hence the hole appears in **September–October**.
- The hole is **largest over Antarctica**; the Arctic is warmer and its vortex weaker.

Points of precision

- **N_2O** is now the largest ozone-depleting emission still **not controlled** by the Montreal Protocol.
- An "**ozone halo**" over the **Tibetan Plateau** — low ozone in the centre, higher at the edges — was reported in **2005** by a team under **G. W. Kent Moore** (University of Toronto).

Current status (2026)

- The **2025 Antarctic ozone hole** was small and short-lived — the **fifth smallest since 1992** — and **closed on 1 Dec 2025**, the earliest since 2019.
- The Protocol has phased out **over 99%** of controlled ODS; the layer should return to **1980 levels** by about **2040** (most of the world), **2045** (Arctic) and **2066** (Antarctic).
- The next WMO–UNEP **Scientific Assessment of Ozone Depletion** is due in **2026**.

The Most Successful Treaty

Vienna Convention and Montreal Protocol · Kigali Amendment and India

4 VIENNA CONVENTION AND MONTREAL PROTOCOL

Diplomacy rarely moves faster than science, but here it did. Within two years of the ozone-hole alarm, the world signed binding phase-outs — and nearly every country on Earth has kept to them.

Concept

- **Vienna Convention for the Protection of the Ozone Layer** — adopted **22 March 1985**, in force **22 Sept 1988**; a **framework** for cooperation, research and data exchange; it set **no binding phase-out targets**.
- **Montreal Protocol on Substances that Deplete the Ozone Layer** — signed **16 Sept 1987**, in force **1 Jan 1989**; **legally binding** phase-out of nearly **100** man-made ODS.

Key facts

- Controlled substances: **CFCs, HCFCs, halons, carbon tetrachloride, methyl chloroform, methyl bromide**, and (since Kigali) **HFCs**.
- In **2009** the Vienna Convention and Montreal Protocol became the **first treaties in UN history** to achieve **universal ratification**.
- **World Ozone Day — 16 September** (declared by the UN General Assembly in **1994**).
- Its **Multilateral Fund (1990)** pays developing countries' costs of switching; the **Ozone Secretariat** sits with **UNEP in Nairobi**.

Explained

- It works on **CBDR**: developing (**Article 5**) countries got **later deadlines** and finance.
- By removing ODS, which are also greenhouse gases, the Protocol has done more to slow warming than Kyoto.

OZONE TREATIES AND AMENDMENTS

Year	Instrument	Place	What it did
1985	Vienna Convention	Vienna	Framework: cooperation, research, monitoring
1987	Montreal Protocol	Montreal	Binding phase-out of ODS
1990	London Amendment	London	More substances; Multilateral Fund
1992	Copenhagen Amendment	Copenhagen	HCFCs, methyl bromide controls
1997	Montreal Amendment	Montreal	Licensing system for ODS trade
1999	Beijing Amendment	Beijing	HCFC production; bromochloromethane
2016	Kigali Amendment	Kigali, Rwanda	Phase-down of HFCs (in force 1 Jan 2019)

5 KIGALI AMENDMENT AND INDIA

Concept

- **HFCs** do **not** harm ozone but are **powerful greenhouse gases**; the **Kigali Amendment (2016)** phases them down by over **80%** by the late 2040s — avoiding up to about **0.4°C** of warming by 2100.

Key facts

- India **ratified Kigali in August 2021**; it is in the **Group 2** timetable — **freeze in 2028** (baseline 2024–26), then cuts of **10% (2032), 20% (2037), 30% (2042), 85% (2047)**.
- India phased out **CFCs, CTC and halons** ahead of the 2010 deadline; **HCFC-141b** was phased out by **1 Jan 2020**; HCFCs are being phased out fully by **2030**.
- Law: **Ozone Depleting Substances (Regulation and Control) Rules, 2000** under the EPA; the MoEFCC's **Ozone Cell** is the nodal unit.
- **India Cooling Action Plan (March 2019)** — India was among the **first countries** with a long-term cooling plan: cut cooling demand **20–25%** and refrigerant demand **25–30%** by **2037–38**.

Points of precision

- HFCs were **promoted** under Montreal as CFC substitutes and later **controlled** for climate reasons.
- Natural refrigerants (ammonia, CO_2, hydrocarbons like propane R-290) and **HFOs** are low-GWP alternatives.

India's Green Mantle

Forest types of India · Mangroves · Services of forests and causes of deforestation

CHAPTER OUTLINE

1 Forest types → 2 Mangroves → 3 Forest services & loss → 4 Forest status 2023 → 5 Policy & law → 6 Desertification → 7 Institutions & days

1 FOREST TYPES OF INDIA

rainfall decides the forest

Travel from the soaked Western Ghats to the Thar, or from the Sundarbans up to the Himalayan snowline, and the forest changes with every step. Rainfall and altitude are the two brushes that paint India's forests.

Concept

- **H. G. Champion and S. K. Seth (1968)** classified India's forests into **16 type groups** and about **200 types**; the broad classes follow **rainfall, temperature and altitude**.

Key facts

- **Tropical wet evergreen** — rainfall **over 200 cm**; **Western Ghats, North-East (Arunachal, Mizoram), Andaman & Nicobar**; **rosewood, ebony, mahogany, rubber**; the **highest plant diversity**, tall multi-storeyed canopy, **lianas** and epiphytes.
- **Tropical moist deciduous — 100–200 cm**; **teak** (dominant), **sal**, bamboo, sheesham, sandalwood, shisham.
- **Tropical dry deciduous — 70–100 cm**; teak, tendu, palas, amaltas; much cleared for farming.
- **Tropical thorn / desert vegetation** — below **50–70 cm**; Rajasthan, Gujarat; **acacia, babool, khejri**, cacti; long roots, thick fleshy leaves.
- **Tropical dry evergreen — Coromandel coast (eastern Deccan)**; rain mainly from the **north-east monsoon**.
- **Montane** forests change with height: wet temperate (oak, chestnut) → **coniferous** (pine, deodar, fir, spruce — Himachal, J&K) → alpine scrub and meadows.
- **Mangrove / tidal** forests in deltas and estuaries.

Explained

- Tropical **monsoon (deciduous) forests** are India's most widespread type; they shed leaves in the dry season to save water.
- Tropical **rainforests** lie mostly between **10°N and 10°S**; they hold over **200 tree species per hectare** and the highest biomass of any biome.
- Deciduous monsoon forests reach their greatest extent in **Asia** (India, Myanmar, Thailand).

Points of precision

- Ecological zones matched with vegetation: **south-western Ghats — moist forests**; **Terai–Duar — broadleaf forests and grasslands**; **Rann of Kutch — grasslands**; **eastern Deccan — dry evergreen**; **Silent Valley — tropical evergreen**; **Himachal — coniferous**; **Sundarbans — mangroves**; **Rajasthan — dry deciduous and thorn**.

2 MANGROVES

Concept

- **Mangroves** are **salt-tolerant (halophytic)** trees and shrubs of the **inter-tidal zone** in tropical and subtropical coasts.

Key facts

- Adaptations: **pneumatophores** (breathing roots), **stilt/prop roots**, **vivipary** (seeds germinate on the parent tree), salt-excreting leaves.
- India's mangrove cover: about **4,992 sq km** (ISFR 2023) — about **0.15%** of the country.
- **West Bengal (Sundarbans)** has the largest share, followed by **Gujarat** and the **Andaman & Nicobar** Islands.
- The **Sundarbans** is the world's largest mangrove forest (India–Bangladesh) and the only **mangrove tiger** habitat.

Explained

- They protect coasts from **cyclones and tsunamis**, trap sediment, nurse fish and store large amounts of **blue carbon**.
- **MISHTI (2023)** — Mangrove Initiative for Shoreline Habitats & Tangible Incomes — to plant mangroves over about 540 sq km; India also joined the **Mangrove Alliance for Climate (COP27)**.

MAIN MANGROVE SITES OF INDIA

State/UT	Mangrove areas
West Bengal	Sundarbans
Odisha	Bhitarkanika, Mahanadi delta, Subarnarekha, Devi estuary, Dhamra
Andhra Pradesh	Coringa, Godavari and Krishna deltas
Tamil Nadu	Pichavaram, Muthupet, Pulicat
Kerala	Kannur, Kasaragod, Kochi–Vembanad
Karnataka	Kundapura, Honnavar, Karwar, Mangaluru
Goa	Mandovi and Zuari estuaries, Chorao Island (Salim Ali Bird Sanctuary)
Maharashtra	Mumbai, Thane, Vasai, Vaitarna, Kundalika, Ratnagiri, Devgad, Vijaydurg, Malvan
Gujarat	Gulf of Kutch, Gulf of Khambhat, south Gujarat coast
Andaman & Nicobar	North and Middle Andaman creeks

3 SERVICES OF FORESTS AND CAUSES OF DEFORESTATION

A forest is a factory that makes water, soil, oxygen and medicine — and asks for nothing in return. Most of what destroys it comes from our hunger for land, roads, dams and timber.

Key facts

- **Provisioning**: timber, fruits, **resins**, rubber, **medicines and alkaloids**, fodder, fuelwood, minor forest produce.
- **Regulating and protective**: soil and water conservation, shade, **noise reduction**, **flood and drought control**, temperature regulation, **O_2–CO_2 balance**, carbon cycling.
- **Cultural**: spiritual, educational, cultural and literary value.
- Causes of loss: **industrialisation, urbanisation, farm expansion**, roads, **river-valley projects**, commercial logging, **forest fires**, **overgrazing**, **shifting cultivation (jhum)** and land-use planning that ignores sustainability.

Explained

- Effects: **drying of Himalayan springs**, **soil erosion**, biodiversity loss and ecological imbalance.
- **Jhum** (slash-and-burn) is mainly practised in the **North-East**; shorter fallow cycles have made it destructive.
- The **National Disaster Management Authority** lists **forest fires** among disasters; FSI issues near-real-time fire alerts.

What Forests Give & Why We Lose Them

India State of Forest Report 2023 · Forest policy and program...

4 INDIA STATE OF FOREST REPORT 2023

FSI, released Dec 2024

Concept

- The **Forest Survey of India (Dehradun)** publishes the **ISFR every two years** using satellite data and field inventory.
- **Forest cover** — all land over **1 hectare** with **tree canopy density above 10%**, irrespective of ownership or legal status.
- **Tree cover** — tree patches **smaller than 1 ha** outside recorded forests.

Key facts

- **Forest + tree cover: 8,27,357 sq km = 25.17%** of India (first time above 25%).
- **Forest cover 7,15,343 sq km (21.76%)**; **tree cover 1,12,014 sq km (3.41%)**.
- Net gain since 2021: **1,445 sq km** (forest **156**, tree **1,289**).
- Canopy classes: **very dense (≥70%) 3.04%**, **moderately dense (40–70%) 9.33%**, **open (10–40%) 9.34%** of the country; below 10% is **scrub**.
- Largest forest cover (area): **Madhya Pradesh > Arunachal Pradesh > Chhattisgarh**; largest forest + tree cover: **MP > Arunachal > Maharashtra**.
- Highest forest cover (% of area): **Lakshadweep (91.33%) > Mizoram (85.34%) > Andaman & Nicobar (81.62%)**.
- **19** states/UTs have over 33% of their area under forest.
- Forest **carbon stock: 7,285.5 million tonnes**; bamboo-bearing area **1,54,670 sq km**; mangroves **4,992 sq km**.

Explained

- Forest cover in the **North-East** continued to **decline**; tree cover is growing mostly through **agroforestry**.
- India has already added an extra carbon sink of about **2.29 billion tonnes** over 2005 against its NDC target of 2.5–3 billion.

Points of precision

- The national goal of **33%** forest/tree cover is **not** yet met — India stands at about **25%**.
- Since 2003, canopy density of **70% and above** is classified as **very dense forest**.

5 FOREST POLICY AND PROGRAMMES

> *Colonial policy saw forests as timber mines; independent India slowly learned to see them as homes, watersheds and carbon banks — and to bring the people who live in them into their care.*

Key facts

- **National Forest Policy, 1952** — classified forests as **protection, national, village forests and tree lands**; set the **one-third** goal.
- **National Forest Policy, 1988** — **environmental stability** first; **33%** of land under forest or tree cover (**two-thirds in hills**); **social forestry**, people's participation, afforestation of wastelands, timber substitutes and alternative fuels.
- **Joint Forest Management (1990)** — villages and forest departments manage forests together and share benefits.
- **Forest Rights Act, 2006** — recognises individual and **community forest rights** of tribals and forest dwellers; Gram Sabha central; defines "**critical wildlife habitat**".
- The **Baigas** of Madhya Pradesh were the **first** community to get **habitat rights** under the FRA (2015–16).

Explained

- **Green India Mission (GIM)** — one of the eight NAPCC missions; improve **5 Mha** of forest and increase cover on another 5 Mha; a revised plan (2025) focuses on the **Aravallis, Western Ghats, Himalaya and mangroves**.
- **CAMPA funds** — money paid for diverting forest land is used for **compensatory afforestation**; **90%** goes to states under the **CAF Act, 2016**.
- **Nagar Van Yojana (2020)** — urban forests; **Van Mahotsav** (first week of July) was started by **K. M. Munshi in 1950**.
- **Ek Ped Maa Ke Naam** (June 2024) — mass tree-planting campaign; **Aravalli Green Wall Project (2023)** — a 5 km green belt across four states.

Points of precision

- **Green Credit Programme** — tree plantation on degraded forest land was the first activity notified for credits.
- The **Van (Sanrakshan Evam Samvardhan) Adhiniyam** (2023 amendment) applies to recorded forests and land recorded as forest after **25 Oct 1980**.

6 DESERTIFICATION AND THE UNCCD

Concept

- The **UNCCD** is the **only legally binding** treaty linking environment and development to **sustainable land management**; it grew out of Rio, was adopted in **1994**, entered into force in **1996**; secretariat **Bonn**.
- India **signed on 14 Oct 1994** and **ratified on 17 Dec 1996**; nodal ministry MoEFCC.

Key facts

- **Desertification** — land degradation in **arid, semi-arid and dry sub-humid** areas from climate variation and human activity.
- **World Day to Combat Desertification and Drought — 17 June**.
- India hosted **UNCCD COP14** at **Greater Noida (2019)**; target to **restore 26 Mha** of degraded land by **2030** (also its **Bonn Challenge** pledge); **land degradation neutrality** by 2030.
- ISRO's **Desertification and Land Degradation Atlas** puts about **97.85 Mha (~29.7%)** of India under degradation (2018–19).

Current status (2026)

- **UNCCD COP16, Riyadh (Dec 2024)** focused on drought resilience; **COP17** met at **Ulaanbaatar, Mongolia (17–28 Aug 2026)**.

7 FOREST INSTITUTIONS AND DAYS

Key facts

- **FRI, Dehradun** — began **5 June 1906** as the **Imperial Forest Research Institute**; under **ICFRE**; **deemed university (Dec 1991)**.
- **Indian Institute of Forest Management (IIFM), Bhopal (1982)** — first under the Agriculture Ministry, now MoEFCC.
- **Central Agroforestry Research Institute (CAFRI), Jhansi** — under **ICAR**.
- **NTCA** — set up **Dec 2005** to reorganise Project Tiger; statutory under the WPA (2006); chaired by the **Union Environment Minister**.
- **Animal Welfare Board of India** — **19 March 1962**, under **Section 4** of the **Prevention of Cruelty to Animals Act, 1960**.
- **National Ganga River Basin Authority** — **20 Feb 2009**, under the **EPA**, chaired by the **Prime Minister**.
- **Project Elephant** — centrally sponsored scheme, **February 1992**: protect elephants, habitats and **corridors**, reduce conflict, welfare of captive elephants.

Points of precision

- **International Day of Forests — 21 March** (declared by the UN General Assembly in **2012**); **World Wildlife Day — 3 March**; **Wildlife Week — 2–8 October**; **World Environment Day — 5 June**.
- Chronology: **WPA 1972 → Project Tiger 1973 → Water Act 1974 → FCA 1980 → Air Act 1981 → EPA 1986 → Project Elephant 1992 → BD Act 2002**.
- **WWF** — 1961, Gland, logo the **giant panda**.

Homes Kept Wild

Protected areas · National parks — records and stories

CHAPTER OUTLINE

1 Protected areas → 2 National parks → 3 Park list → 4 Rivers & species → 5 Sanctuaries → 6 Bird sanctuaries

1 PROTECTED AREAS *Wildlife (Protection) Act, 1972*

Laws and lists mean little unless wild animals have somewhere to live. India's answer has been a network of protected areas — strict refuges at the core, softer zones around them, and community-run reserves where people and wildlife share the land.

Concept

- **Protected areas (PAs)** are the main tool of **in-situ** conservation; under the **WPA, 1972** India has **four** legal categories: **national parks, wildlife sanctuaries, conservation reserves and community reserves**.
- **Marine protected areas** are national parks or sanctuaries in coastal and marine waters.

Key facts

- **Wildlife sanctuary** — declared by the **State** (Sec. 18); some rights (grazing, collection) can be allowed by the Chief Wildlife Warden.
- **National park** — stricter; **no grazing or private rights**; boundaries fixed by law; can be declared by the **State or the Centre** (Sec. 35).
- **Conservation reserve** and **community reserve** — added by the **2002 amendment** (Sec. 36A, 36C); they buffer and connect PAs on government or community land.
- A sanctuary can be **upgraded** to a national park; a park **cannot be downgraded** to a sanctuary.
- Most PAs are surrounded by **dense forest**; some (deserts, grasslands, wetlands) are not.

Explained

- Changes to a national park's or sanctuary's boundary need the advice of the **National Board for Wildlife (NBWL)**, chaired by the **Prime Minister**.
- **Tiger reserves** are notified under **Sec. 38V** on NTCA advice; **elephant reserves** and **biosphere reserves** are administrative (no WPA status).
- The **Third National Wildlife Action Plan (2017–2031)** is the first to include **climate change** and to stress landscape-level conservation.

Current status (2026)

- India has about **1,134 PAs** covering **1,87,163 sq km (~5.69%)** of its area: **106 national parks**, **574 sanctuaries**, **145 conservation reserves**, **310 community reserves**.
- **Similipal** (Odisha) was notified as a **national park in 2025**.

2 NATIONAL PARKS — RECORDS AND STORIES

Key facts

- **Oldest/first**: **Jim Corbett** (Uttarakhand), set up **1936** as **Hailey National Park**; renamed **Ramganga NP (1954)** and **Corbett (1956)**; first under **Project Tiger (1973)**. The **Ramganga** flows through it; the **Kosi** marks its east.
- **Largest**: **Hemis (Ladakh)** — also the **highest-altitude** park; snow leopard country. **Smallest**: **South Button Island** (Andaman).
- **First marine park**: **Gulf of Kutch (1980–82)**, Gujarat.
- **Keibul Lamjao (Manipur)** — the world's **only floating national park**, on **phumdis** (floating mats of vegetation and soil) in the south-west of **Loktak Lake**; home of the **Sangai** (brow-antlered deer).
- **Valley of Flowers** (Chamoli, Uttarakhand) — temperate-alpine, where the **Zanskar** range and the eastern and western Himalaya meet; with **Nanda Devi** forms a **World Heritage Site**; Brahma Kamal is Uttarakhand's state flower.
- States with most parks: **Madhya Pradesh** and **Andaman & Nicobar** (about 9–11 each by different counts).

Points of precision

- **Phawngpui** (Mizoram) is the "**Blue Mountain**" national park.
- **Top Slip** is part of the **Anamalai (Indira Gandhi) National Park/Tiger Reserve**, Tamil Nadu.
- **Desert National Park** spans **Jaisalmer and Barmer** (two districts); it has human settlements inside and protects the **Great Indian Bustard**.
- **Kanha** (MP) is famous for the hard-ground **barasingha**, rescued from near extinction; **Dachigam** for the **hangul** (Kashmir stag).

National Parks State by State

NATIONAL PARKS OF INDIA

State/UT	National parks (year)
Andaman & Nicobar	Campbell Bay (1992) · Galathea Bay (1992) · Mahatma Gandhi Marine (1983) · Mount Harriet (1987) · Rani Jhansi Marine (1996) · Saddle Peak (1987)
Andhra Pradesh	Papikonda (2008) · Rajiv Gandhi/Rameswaram (2005) · Sri Venkateswara (1989)
Arunachal Pradesh	Mouling (1986) · Namdapha (1983)
Assam	Kaziranga (1974) · Manas (1990) · Nameri (1998) · Orang (1999) · Dibru-Saikhowa (1999) · Dehing Patkai (2021) · Raimona (2021)
Bihar	Valmiki (1989)
Chhattisgarh	Guru Ghasidas/Sanjay (1981) · Indravati (1982) · Kanger Valley (1982)
Goa	Mollem (1992)
Gujarat	Gir (1975) · Vansda (1979) · Marine NP, Gulf of Kutch (1982) · Blackbuck/Velavadar (1976)
Haryana	Kalesar (2003) · Sultanpur (1989)
Himachal Pradesh	Great Himalayan (1984) · Inderkilla (2010) · Khirganga (2010) · Pin Valley (1987) · Simbalbara (2010)
Jharkhand	Betla (1986)
Karnataka	Anshi/Kali (1987) · Bandipur (1974) · Bannerghatta (1974) · Kudremukh (1987) · Nagarhole (1988)
Kerala	Anamudi Shola (2003) · Eravikulam (1978) · Mathikettan Shola (2003) · Pampadum Shola (2003) · Periyar (1982) · Silent Valley (1984)
Madhya Pradesh	Bandhavgarh (1968) · Dinosaur Fossil (2011) · Mandla Fossil (1983) · Pench (1975) · Kanha (1955) · Kuno (2018) · Madhav (1959) · Panna (1981) · Sanjay (1981) · Satpura (1981) · Van Vihar (1979)
Maharashtra	Chandoli (2004) · Gugamal (1975) · Navegaon (1975) · Pench/Jawaharlal Nehru (1975) · Sanjay Gandhi (1983) · Tadoba (1955)
Manipur	Keibul Lamjao (1977) · Shirui (1982)
Meghalaya	Balpakram (1986) · Nokrek (1997)
Mizoram	Murlen (2003) · Phawngpui/Blue Mountain (1997)
Nagaland	Intanki/Ntangki (1993)
Odisha	Bhitarkanika (1998) · Similipal (2025)
Rajasthan	Desert (1992) · Keoladeo Ghana (1981) · Mukundra Hills (2006) · Ranthambore (1980) · Sariska (1992)
Sikkim	Khangchendzonga (1977)
Tamil Nadu	Guindy (1976) · Gulf of Mannar Marine (1980) · Indira Gandhi/Anamalai (1989) · Mudumalai (1990) · Mukurthi (1990)
Telangana	Kasu Brahmananda Reddy (1994) · Mahavir Harina Vanasthali (1994) · Mrugavani (1994)
Tripura	Clouded Leopard (2007) · Bison/Rajbari (2007)
Uttar Pradesh	Dudhwa (1977)
Uttarakhand	Jim Corbett (1936) · Gangotri (1989) · Govind Pashu Vihar (1990) · Nanda Devi (1982) · Rajaji (1983) · Valley of Flowers (1982)
West Bengal	Buxa (1992) · Gorumara (1992) · Jaldapara (2014) · Neora Valley (1986) · Singalila (1986) · Sundarbans (1984)
Jammu & Kashmir	City Forest/Salim Ali (1992) · Dachigam (1981) · Kazinag (2000) · Kishtwar High Altitude (1981)
Ladakh	Hemis (1981)

SIGNATURE SPECIES AND WHERE TO SEE THEM

Species	Protected area	State
Indian wild ass (khur)	Indian Wild Ass Sanctuary, Little Rann of Kutch	Gujarat
One-horned rhinoceros	Kaziranga NP (also Pobitora, Orang, Manas; Jaldapara, Gorumara; Dudhwa)	Assam, WB, UP
Asian elephant	Periyar NP & Tiger Reserve	Kerala
Asiatic lion	Gir NP & Sanctuary	Gujarat
Great Indian Bustard	Desert NP	Rajasthan
Royal Bengal tiger (mangrove)	Sundarbans NP	West Bengal
Olive ridley turtle	Gahirmatha Marine Sanctuary (also Rushikulya, Devi mouths)	Odisha
Ganges river dolphin	Vikramshila Gangetic Dolphin Sanctuary	Bihar
Vultures	Ramadevarabetta Vulture Sanctuary	Karnataka
Sloth bear	Daroji Sloth Bear Sanctuary (also Jessore, Gujarat)	Karnataka
Sangai (brow-antlered deer)	Keibul Lamjao NP	Manipur
Barasingha (hard-ground swamp deer)	Kanha NP	Madhya Pradesh
Jerdon's courser	Sri Lankamalleswara Sanctuary	Andhra Pradesh
Gharial	National Chambal Sanctuary	MP, Rajasthan, UP
Grizzled giant squirrel	Srivilliputhur Sanctuary	Tamil Nadu
Clouded leopard	Clouded Leopard NP	Tripura
Snow leopard	Hemis NP	Ladakh
Hoolock gibbon (India's only ape)	Hoollongapar Gibbon Sanctuary	Assam
Golden langur	Chakrashila Sanctuary, Raimona NP	Assam
Hangul (Kashmir stag)	Dachigam NP	Jammu & Kashmir
Nilgiri tahr	Eravikulam NP	Kerala
Red panda	Khangchendzonga NP (also Singalila, Neora Valley)	Sikkim, WB
Musk deer	Askot Sanctuary (also Kedarnath)	Uttarakhand
Indian wolf	Mahuadanr Wolf Sanctuary	Jharkhand
Pitcher plant	Baghmara Pitcher Plant Sanctuary	Meghalaya

Parks, Rivers & Their Signature Species

Wildlife sanctuaries

RIVERS THAT RUN THROUGH THE PARKS

National park	River(s)	National park	River(s)
Corbett (UK)	Ramganga (Kosi on the east)	Kaziranga (Assam)	Brahmaputra, Diphlu, Mora Diphlu
Manas (Assam)	Manas	Orang (Assam)	Brahmaputra
Dibru-Saikhowa (Assam)	Brahmaputra, Lohit	Namdapha (Arunachal)	Noa-Dihing
Silent Valley (Kerala)	Kunthipuzha	Periyar (Kerala)	Periyar
Panna (MP)	Ken	Kanha (MP)	Banjar, Halon
Pench (MP–MH)	Pench	Bandhavgarh (MP)	Charanganga
Satpura (MP)	Denwa	Dudhwa (UP)	Suheli, Mohana
Ranthambore (Raj.)	Banas, Chambal (nearby)	Keoladeo (Raj.)	Gambhir, Banganga
Mollem (Goa)	Mandovi system	Nagarhole (Kar.)	Kabini
Bandipur (Kar.)	Kabini, Moyar	Great Himalayan (HP)	Tirthan, Sainj
Hemis (Ladakh)	Indus tributaries	Dachigam (J&K)	Dachigam Nallah
Similipal (Odisha)	Budhabalanga, Khairi	Indravati (CG)	Indravati
Kanger Valley (CG)	Kanger	Valmiki (Bihar)	Gandak
Sundarbans (WB)	Ganga distributaries, Matla	Khangchendzonga (Sikkim)	Teesta system

3 WILDLIFE SANCTUARIES

Sanctuaries are the most numerous of India's protected areas — from vast salt deserts in Kutch to a two-square-kilometre patch kept for a single bird.

Key facts

- India has about **574** sanctuaries (MoEFCC).
- **Largest**: **Kutch Desert Wildlife Sanctuary**, Gujarat (~7,506 sq km); **smallest**: **Kutch Bustard (Lala Parjan) Sanctuary**, Gujarat (~2 sq km).
- Most sanctuaries: **Andaman & Nicobar (96)** among UTs; **Maharashtra (49)** among states.
- Notable: **Chandra Prabha** (Chandauli, UP — once proposed for Asiatic lions), **Karera** (MP, for the Great Indian Bustard, since de-notified), **Askot** (Uttarakhand, musk deer), **Periyar** (Kerala, elephants), **Pakke** (Arunachal), **Gomarda** (Chhattisgarh), **Bhimbandh** (Bihar), **Bondla** (Goa), **Ushakothi** (Odisha), **Chinnar** (Kerala, grizzled giant squirrel and star tortoise).
- The **National Chambal Sanctuary** spans **Rajasthan, MP and UP** — the best place to see **gharials** in the wild.

Points of precision

- **Asan Conservation Reserve** is in **Dehradun, Uttarakhand** — the state's first Ramsar site.
- **Bakhira** Bird Sanctuary is in **Sant Kabir Nagar, UP**; **Sur Sarovar (Keetham Lake)** near **Agra** is a man-made reservoir.
- **Khijadiya** (near **Jamnagar**, Gujarat) mixes freshwater and saline habitats; **Bhindawas** (Jhajjar) is Haryana's largest wetland.
- The first **marine sanctuary** in India was in the **Gulf of Kutch**.

MAJOR SANCTUARIES STATE-WISE

State/UT	Sanctuaries
Andhra Pradesh	Coringa · Kambalakonda · Kaundinya (elephants) · Kolleru · Krishna · Rollapadu (GIB) · Nelapattu · Pulicat Lake
Arunachal	Eaglenest · Pakke · Dibang · Kamlang · Itanagar · Sessa Orchid
Assam	Pobitora · Chakrashila · Deepor Beel · Hoollongapar Gibbon · Panidihing · Sonai Rupai · Bornadi
Bihar	Bhimbandh · Kaimur · Gautam Buddha · Rajgir · Valmiki · Vikramshila Dolphin · Kanwar Lake · Nagi Dam · Nakti Dam
Chhattisgarh	Achanakmar · Barnawapara · Bhairamgarh · Bhoramdev · Sitanadi · Udanti · Tamor Pingla
Goa	Bhagwan Mahavir · Bondla · Cotigao · Mhadei · Netravali · Dr Salim Ali Bird Sanctuary
Gujarat	Gir · Wild Ass · Kutch Desert · Nalsarovar · Marine Sanctuary (Gulf of Kutch) · Narayan Sarovar Chinkara · Jessore Sloth Bear
Haryana	Kalesar · Bhindawas · Khaparwas · Nahar
Himachal Pradesh	Chail · Chandratal · Churdhar · Dhauladhar · Kibber · Kalatop-Khajjiar · Pong Dam Lake · Renuka Ji
Jharkhand	Dalma · Hazaribagh · Koderma · Lawalong · Mahuadanr Wolf · Palamau · Udhwa Lake
Karnataka	Dandeli · Bhadra · Cauvery · Ranganathittu · Daroji Sloth Bear · Ramadevarabetta Vulture
Kerala	Wayanad · Periyar · Chinnar · Neyyar · Peppara · Shendurney · Idukki
Madhya Pradesh	National Chambal · Ken Gharial · Nauradehi · Bori · Gandhi Sagar · Pachmarhi · Ratapani · Ghatigaon · Sailana · Sardarpur (florican)
Maharashtra	Bhimashankar · Koyna · Radhanagari · Karnala · Nandur Madhameshwar
Manipur · Meghalaya	Yangoupokpi-Lokchao · Nongkhyllem · Siju · Baghmara Pitcher Plant
Mizoram · Nagaland	Dampa · Khawnglung · Lengteng · Ngengpui · Tawi · Fakim · Puliebadze · Rangapahar
Odisha	Bhitarkanika · Gahirmatha Marine · Chilika (Nalabana) · Satkosia Gorge · Debrigarh · Nandankanan
Punjab	Harike · Abohar (blackbuck) · Nangal · Kathlaur-Kushlian · Takhni-Rehmapur
Rajasthan	Tal Chhapar (blackbuck) · Sariska · Kumbhalgarh · Mount Abu · National Chambal · Sita Mata · Desert
Sikkim	Barsey Rhododendron · Fambong Lho · Kitam · Kyongnosla Alpine · Pangolakha
Tamil Nadu	Point Calimere · Mudumalai · Sathyamangalam · Srivilliputhur · Cauvery North & South · Vedanthangal · Kalakad
Telangana	Kawal · Amrabad · Eturnagaram · Kinnerasani · Manjira (crocodile) · Pakhal
Tripura	Sepahijala · Trishna · Gumti · Rowa
Uttar Pradesh	Katarniaghat · Kishanpur · Hastinapur · National Chambal · Kaimur · Sohagibarwa · Ranipur · Bakhira · Sandi · Samaspur · Okhla
Uttarakhand	Kedarnath · Binsar · Askot · Govind · Sonanadi · Nandhaur · Mussoorie
West Bengal	Buxa · Chapramari · Haliday Island · Jore Pokhri Salamander · Ballavpur · Bethuadahari · Raiganj (Kulik)

Where the Birds Gather

MAJOR BIRD SANCTUARIES

Bird sanctuary	State	Note
Vedanthangal	Tamil Nadu	One of India's oldest water-bird refuges; Ramsar
Koonthankulam	Tamil Nadu	Breeding of migratory birds; Ramsar
Point Calimere	Tamil Nadu	Coastal birds, flamingos; Ramsar
Vellode · Vaduvur · Udhayamarthandapuram · Kanjirankulam · Karikili	Tamil Nadu	Water-bird wetlands; Ramsar
Ranganathittu	Karnataka	River islands in the Kaveri
Gudavi · Attiveri · Magadi Kere	Karnataka	Lakes for resident and migrant birds
Dr Salim Ali (Chorao Island)	Goa	Mangrove bird habitat
Nalsarovar · Thol · Khijadiya	Gujarat	Migratory water-birds; Ramsar
Porbandar	Gujarat	Urban wetland
Sultanpur · Bhindawas	Haryana	Migratory birds; Ramsar
Keoladeo Ghana	Rajasthan	World Heritage and Ramsar; Siberian crane once wintered here
Nalabana (Chilika)	Odisha	Migratory water-birds
Harike	Punjab	Confluence of the Sutlej and Beas
Nangal	Punjab	Reservoir habitat
Samaspur (Raebareli) · Sandi (Hardoi) · Saman (Mainpuri)	Uttar Pradesh	Water-birds; Ramsar
Sur Sarovar · Bakhira · Okhla	Uttar Pradesh	Near Agra; natural wetland; on the Yamuna
Deepor Beel · Panidihing	Assam	Near Guwahati; Brahmaputra valley
Kumarakom · Mangalavanam	Kerala	Vembanad lake; Kochi mangroves
Udhwa Lake	Jharkhand	State's main bird sanctuary
Nagi · Nakti · Kanwar Lake	Bihar	Jamui reservoirs; Begusarai wetland — Ramsar
Nandur Madhameshwar · Karnala	Maharashtra	Godavari wetland (Ramsar); forest birds of Raigad
Siju · Kitam	Meghalaya · Sikkim	Cave and forest birds
Raiganj (Kulik)	West Bengal	Breeding colony of Asian openbill storks

Project Tiger

Project Tiger and the NTCA

CHAPTER OUTLINE

1 Project Tiger → 2 Tiger reserves → 3 Elephants → 4 Other species projects → 5 Wildlife law & crime

1 PROJECT TIGER AND THE NTCA — 1 April 1973

By 1972 India's tigers had fallen to under 2,000 — a census shock that shook the government into action. Fifty years on, India holds about three-quarters of the world's wild tigers, and the tiger has become the umbrella under which whole forests are saved.

Concept

- **Project Tiger** was launched on **1 April 1973** by PM **Indira Gandhi** at **Jim Corbett National Park** (then in UP) with **9 reserves**.
- It is a **centrally sponsored scheme** of the MoEFCC, run by the **National Tiger Conservation Authority (NTCA)**.

Key facts

- **NTCA** — constituted in **Dec 2005** on the Tiger Task Force's advice; statutory under the **WPA amendment of 2006**; chaired by the **Union Environment Minister**.
- A tiger reserve has a **core (critical tiger habitat)** kept inviolate and a **buffer** for coexistence.
- **M-STrIPES** (Monitoring System for Tigers — Intensive Protection and Ecological Status), developed by **NTCA and WII** in **2010**: a field protocol plus software for patrolling and monitoring.
- **International Tiger Day — 29 July**, fixed at the **St. Petersburg Tiger Summit (2010)**, where the 13 tiger-range countries set the **TX2** goal of doubling wild tigers by 2022.
- **Management Effectiveness Evaluation (MEE)** grades every reserve; **CA|TS** (Conservation Assured Tiger Standards) accredits well-run reserves.

Explained

- The **All India Tiger Estimation** is held every **four years** by NTCA and WII using **camera traps** and capture–recapture; the 2018 round entered the **Guinness World Records** as the largest camera-trap survey.
- Nearly **30%** of India's tigers live **outside** tiger reserves — corridors matter.
- The **International Big Cat Alliance (IBCA)** was launched at **Mysuru on 9 April 2023** (50 years of Project Tiger) for seven big cats; it is headquartered in India.

Current status (2026)

- **AITE 2022**: about **3,682** tigers (range 3,167–3,925) — roughly **75%** of the world's wild tigers; **MP (785) > Karnataka (563) > Uttarakhand (560) > Maharashtra (444)**; **Corbett** has the most tigers of any reserve.
- The **2026 estimation cycle** is under way.
- **58** tiger reserves: newest **Madhav (MP, March 2025)**, before it **Ratapani (MP, Dec 2024)**, **Guru Ghasidas–Tamor Pingla (Chhattisgarh, Nov 2024)**, **Dholpur–Karauli (Rajasthan, 2023)**.

Points of precision

- **Largest** reserve: **Nagarjunsagar–Srisailam** (Andhra Pradesh–Telangana); **smallest**: **Orang** (Assam) by total area, **Bor** (Maharashtra) by core.
- **Madhya Pradesh** has the most reserves (**9**) and is the "**Tiger State**".
- **Sariska** (Rajasthan) lost all its tigers by 2004 and was restocked from **Ranthambore** in 2008 — the first tiger relocation in the world.
- **Pench** is a tiger reserve in **both MP and Maharashtra**; **Sundarban** is the only **mangrove** tiger habitat.

THE 58 TIGER RESERVES (STATE-WISE)

State	Tiger reserves	No.
Madhya Pradesh	Kanha · Bandhavgarh · Panna · Pench · Satpura · Sanjay–Dubri · Veerangana Durgavati · Ratapani · Madhav	9
Maharashtra	Melghat · Tadoba–Andhari · Pench · Sahyadri · Bor · Navegaon–Nagzira	6
Karnataka	Bandipur · Bhadra · Biligiri Ranganatha Temple · Kali · Nagarhole	5
Rajasthan	Ranthambore · Sariska · Mukundra Hills · Ramgarh Vishdhari · Dholpur–Karauli	5
Tamil Nadu	Kalakad–Mundanthurai · Anamalai · Mudumalai · Sathyamangalam · Srivilliputhur–Megamalai	5
Assam	Kaziranga · Manas · Nameri · Orang	4
Chhattisgarh	Achanakmar · Indravati · Udanti–Sitanadi · Guru Ghasidas–Tamor Pingla	4
Arunachal Pradesh	Namdapha · Pakke · Kamlang	3
Uttar Pradesh	Dudhwa · Pilibhit · Ranipur	3
Kerala · Odisha · Telangana	Periyar, Parambikulam · Similipal, Satkosia · Amrabad, Kawal	2 each
Uttarakhand · West Bengal	Corbett, Rajaji · Buxa, Sundarban	2 each
AP · Bihar · Jharkhand · Mizoram	Nagarjunsagar–Srisailam · Valmiki · Palamau · Dampa	1 each

Gentle Giants

Project Elephant · Big cats beyond the tiger · Other flagship programmes

2 PROJECT ELEPHANT *February 1992*

> *An elephant needs a whole landscape, not a park. Herds walk hundreds of kilometres along old routes that now cross railways, canals and farms — so saving elephants means saving the paths between forests as much as the forests themselves.*

Concept

- **Project Elephant** — a **centrally sponsored scheme** launched in **February 1992**: protect elephants, their **habitats and corridors**, reduce **human–elephant conflict**, and look after **captive elephants**.
- In 2023 Project Tiger and Project Elephant were merged into one scheme, "**Project Tiger and Elephant**", under the NTCA's umbrella division.

Key facts

- A herd is led by the **oldest female (matriarch)**; gestation is the longest of any land mammal — up to about **22 months**; cows can calve until about **60** years.
- The **Asian elephant** is **Endangered** (IUCN), in **Schedule I** of the WPA and **CITES Appendix I**; declared India's **National Heritage Animal (2010)**.
- Main habitat: **moist deciduous** forests; ranges: **north-west (Uttarakhand–Bijnor)**, **North-East**, **east-central**, and **south (Western and Eastern Ghats)**.
- **World Elephant Day — 12 August**; **Gaj Yatra** is the national awareness campaign; **MIKE** (CITES) monitors illegal killing.

Current status (2026)

- The first **DNA-based** count — **SAIEE 2021–25** (WII, released **Oct 2025**) — estimated **22,446** wild elephants.
- **Karnataka (6,013) > Assam (4,159) > Tamil Nadu (3,136) > Kerala (2,785)**; the **Western Ghats** hold about **11,934**.
- Central India and the Eastern Ghats hold under 10% of elephants but account for about **45%** of human deaths from conflict.
- India has **33 elephant reserves** and about **150** identified corridors.

Points of precision

- The 2025 figure is a **new baseline** from a new method; the 2017 direct count (~27,312) is **not** strictly comparable.
- Elephant reserves are notified by states on the Centre's advice — they have **no separate status** under the WPA.

ELEPHANT RESERVES OF INDIA

State	Elephant reserves
Assam	Sonitpur · Dehing–Patkai · Kaziranga–Karbi Anglong · Dhansiri–Lungding · Chirang–Ripu
Tamil Nadu	Nilgiri · Coimbatore · Anamalai · Srivilliputhur · Agasthyamalai
Kerala	Wayanad · Nilambur · Anamudi · Periyar
Odisha	Mayurbhanj · Mahanadi · Sambalpur
Karnataka	Mysore · Dandeli
Arunachal Pradesh	Kameng · South Arunachal
Chhattisgarh	Badalkhol–Tamor Pingla · Lemru
Nagaland	Intanki · Singphan
Uttar Pradesh	Uttar Pradesh ER · Terai (2022)
West Bengal	Mayurjharna · Eastern Dooars
Others	Rayala (AP) · Singhbhum (Jharkhand) · Garo Hills (Meghalaya) · Shivalik (Uttarakhand)

3 BIG CATS BEYOND THE TIGER

Key facts

- **Project Cheetah** — launched **17 Sept 2022** at **Kuno NP (MP)**; India's cheetah was declared extinct in **1952**; the world's first **intercontinental** large-carnivore translocation.
- Batches: **8 from Namibia (2022)**, **12 from South Africa (Feb 2023)**, **9 from Botswana (Feb 2026)**; second site **Gandhi Sagar Sanctuary (MP)**; next sites **Nauradehi (MP)** and **Banni grasslands (Gujarat)**.
- **Asiatic lion** — only in the **Gir landscape (Gujarat)**; **Project Lion (2020)**; the **2025** count put lions at about **891** (674 in 2020), many now outside Gir along the coast; **Barda** is being developed as a second home.
- **Snow leopard** — first national count, **SPAI (2024)**: **718**, most in **Ladakh**; **Project Snow Leopard (2009)**; India joined the **GSLEP** (Bishkek Declaration, 2013).
- **Leopard** — about **13,874** (2022), most in **MP**; **clouded leopard** — Tripura's Clouded Leopard NP, Dampa.

Current status (2026)

- Project Cheetah's four-year review (Sept 2026) counted **52** cheetahs — **49 in Kuno, 3 in Gandhi Sagar** — including **32 born in India**.

4 OTHER FLAGSHIP PROGRAMMES

Key facts

- **One-horned rhino** — **Vulnerable**; **Kaziranga** holds about two-thirds of the world's population; **Indian Rhino Vision 2020** spread rhinos to **Manas, Orang, Pobitora**; **National Rhino Conservation Strategy (2019)**; **World Rhino Day — 22 Sept**.
- **Ganges river dolphin** — **National Aquatic Animal (2009)**; **Endangered**; nearly **blind**, hunts by **echolocation**; **Project Dolphin (2020)**; **Vikramshila** (Bihar) is the only dolphin sanctuary; **National Dolphin Day — 5 Oct**. The first survey (released **3 March 2025**) counted **6,327** river dolphins (**6,324 Ganges**, **3 Indus** in the Beas); UP has the most; a second estimation began in **2026**.
- **Great Indian Bustard** — **Critically Endangered**, about 150 left; mainly **Desert NP (Rajasthan)** and Kutch; killed by **power lines**; captive breeding at **Sam and Ramdevra**.
- **Vultures** — *Gyps* populations crashed by over **95%** from **diclofenac**; breeding centres at **Pinjore (Haryana)**, Bhopal, Rajabhatkhawa, Rani (Assam); **Vulture Action Plan 2020–25**.
- **Crocodiles** — **Crocodile Conservation Project (1975)**, with UNDP–FAO help, at **Hyderabad**; **gharial** (fish-eater, **Critically Endangered**, Chambal), **mugger** (marsh crocodile), **saltwater crocodile** (Bhitarkanika — the largest population in India).
- **Olive ridley turtles** — mass nesting (**arribada**) at **Gahirmatha, Rushikulya and Devi** river mouths in Odisha; **Operation Olivia** by the Coast Guard; **TEDs** in trawl nets.

Points of precision

- The **dodo** of Mauritius vanished and the **Calvaria tree** stopped regenerating — the textbook case of **co-extinction**.
- Antelopes have **unbranched, permanent horns**; deer have **branched antlers shed every year**; India's antelopes: **blackbuck, chinkara, nilgai, chousingha** (four-horned) and **Tibetan antelope (chiru)**.
- **Kyasanur Forest Disease (KFD)** — "monkey fever" — is a tick-borne **viral** disease of Karnataka's forests.

The Law That Guards Wildlife

Wildlife (Protection) Act, 1972

5 WILDLIFE (PROTECTION) ACT, 1972

Until 1972, hunting was a sport and most states had their own game laws. A single national law made killing protected animals a crime, created sanctuaries and parks, and built a ladder of protection through its schedules.

Concept

- The **WPA, 1972** protects wild animals, birds and plants, regulates **hunting and trade**, and provides for **protected areas**.
- It was passed under **Article 252** at the request of states (wildlife was then a **State** subject).

Key facts

- After the **2022 amendment** (in force **1 April 2023**) there are **four schedules**: **I** — highest protection; **II** — lesser protection; **III** — protected **plants**; **IV** — specimens in **CITES** appendices.
- The **vermin** schedule was dropped; the Centre can still declare a species vermin for a time and place.
- Creates the **National Board for Wildlife** (chaired by the **PM**) and **State Boards**; the **Chief Wildlife Warden** manages PAs.
- The **2006 amendment** created the **NTCA** and the **Wildlife Crime Control Bureau (WCCB, June 2007)**.
- Protection is given to a species **declared** in a schedule; if a tortoise species is placed in **Schedule I**, it gets the **same protection as the tiger**.

Explained

- The **WCCB** works with police, customs and forests against **organised wildlife crime**; it runs operations like **Operation Wildnet**, **Turtshield** and **Save Kurma**.
- **TRAFFIC India** (WWF) and **WCCB** track trade in pangolins, star tortoises, red sanders and shahtoosh.
- **Animals in Schedule I** include tiger, lion, elephant, rhino, snow leopard, GIB, dugong, gangetic dolphin, pangolin and blackbuck.

Points of precision

- The Act prohibits hunting of **all wild animals** in Schedules I and II except in defined cases (self-defence, scientific, problem animals).
- The **Indian Forest Act (1927)** divided forests into **reserved, protected and village** forests.
- **Shahtoosh** shawls come from the **Tibetan antelope (chiru)**; trade is banned.

Power for a Growing Nation

Energy resources · Solar energy and the International Solar Alliance · Wind, water, earth and ...

CHAPTER OUTLINE

1 Energy basics → 2 Solar & ISA → 3 Wind, water, earth, sea → 4 Nuclear → 5 Bioenergy → 6 Hydrogen → 7 Organic recycling

1 ENERGY RESOURCES

Every function of nature runs on energy, and so does every economy. India must power the lives of 1.4 billion people while keeping its climate promises — which is why the story of energy is now the story of switching from what is buried underground to what falls from the sky.

Concept

- **Renewable** energy is replenished by natural processes — **solar, wind, hydro, tidal, biomass, geothermal**.
- **Non-renewable** energy exists in finite stocks formed over millions of years — **coal, petroleum, natural gas, uranium**; high energy density but polluting.
- **SDG 7** — affordable and clean energy.

Key facts

- **Fossil fuels** are altered remains of ancient plants and organisms; the **Sun** is the ultimate source of the energy they store.
- **Conventional** sources — coal, petroleum, natural gas, **large hydro**, firewood and dung, nuclear.
- **Non-conventional** — solar, wind, tidal, **wave**, **geothermal**, **biogas**, bioenergy, **ocean thermal (OTEC)**, **small hydro**, and **green hydrogen** (an energy **carrier**, not a primary source).
- From the sustainable-development angle, **hydropower** is preferred over coal, oil, gas and nuclear for electricity.

Current status (2026)

- Non-fossil capacity crossed **300 GW** on **31 July 2026** — **solar ~165 GW, wind ~58 GW, hydro ~57 GW, bio-power ~12 GW, nuclear ~8.8 GW** — over **54%** of India's **~552 GW** total.
- A record **55 GW** of non-fossil capacity was added in **2025–26**; India ranks **third** in the world in renewable capacity (after China and the USA).
- Target: **500 GW** non-fossil capacity by **2030**; **60%** of capacity non-fossil by **2035** (NDC 3.0).

Points of precision

- In India **large hydro** (above **25 MW**) was declared renewable in **2019**; **small hydro** (up to 25 MW) is under the **MNRE**.
- India's **highest renewable potential** is in **solar** — often called the "fuel of the future".

2 SOLAR ENERGY AND THE INTERNATIONAL SOLAR ALLIANCE

India receives about 5,000 trillion kWh of sunshine a year — far more than it could ever use. The task has been to make catching it cheap, and in a decade solar went from the most expensive power to among the cheapest.

Concept

- **Solar energy** — electromagnetic energy from the Sun; **inexhaustible** and **non-polluting** in use; the **largest reservoir** of alternative energy; the base of all food chains through photosynthesis.
- **Photovoltaics** — direct conversion of sunlight into electricity in a **solar cell** (mostly **silicon** semiconductors) by the **photovoltaic effect**; **solar thermal** uses heat (cookers, water heaters, concentrated solar power).

Key facts

- Uses: water heaters, cookers, street lights, railway signals, **satellites**, irrigation pumps, solar rickshaws and aircraft, **heliotherapy**.
- **Jawaharlal Nehru National Solar Mission (JNNSM)** — **11 Jan 2010**; target raised in 2015 to **100 GW by 2022**; **Domestic Content Requirement (DCR)** to promote Indian-made cells and modules.
- **PM-KUSUM (2019)** — solar pumps and solar plants for farmers.
- **PM Surya Ghar: Muft Bijli Yojana (Feb 2024)** — rooftop solar for **one crore households**, up to **300 units** of free power a month.
- **Production-Linked Incentive** for high-efficiency modules; **ALMM** lists approved models and manufacturers.

Explained

- **International Solar Alliance (ISA)** — launched by **India (Narendra Modi)** and **France (François Hollande)** on **30 Nov 2015** at **COP21, Paris**; HQ **Gurugram** — the **first** treaty-based international organisation headquartered in India.
- Membership, first meant for countries between the **Tropics of Cancer and Capricorn**, is now open to **all UN members** (2020 amendment).
- "**Towards 1000**" — mobilise **$1 trillion** of solar investment and install **1,000 GW** by **2030**; India also leads "**One Sun One World One Grid (OSOWOG)**".

Points of precision

- Rajasthan and Gujarat lead in solar capacity; **Bhadla Solar Park** (Jodhpur) is among the world's largest.
- **Modhera** (Gujarat) became India's first **24×7 solar-powered village** (2022).

3 WIND, WATER, EARTH AND SEA

Key facts

- **Wind** — kinetic energy turned by turbines; **Gujarat and Tamil Nadu** lead; **Muppandal** (TN) is a major wind farm; **offshore wind** off Gujarat and TN is the next frontier.
- **Hydro** — potential energy of falling water; **pumped storage** projects now store solar power for the night.
- **Geothermal** — heat from the Earth's interior: **Puga Valley (Ladakh)**, **Manikaran (HP)**, **Tattapani (Chhattisgarh)**; India's first geothermal project at **Puga** (ONGC).
- **Tidal** — rise and fall of tides; best sites **Gulf of Khambhat**, **Gulf of Kutch**, **Sundarbans**.
- **Wave energy** — motion of sea waves; a pilot plant once ran at **Vizhinjam** (Kerala).
- **OTEC** — uses the **temperature difference** (at least ~20°C) between warm surface and cold deep water; NIOT is building a plant at **Kavaratti (Lakshadweep)**.

The Atom & the Field

Nuclear energy · Bioenergy and biofuels · Hydrogen — the clean fuel · Turning waste into wealth

4 NUCLEAR ENERGY

Concept
- **Nuclear fission** of uranium-235 (and plutonium) releases enormous heat without CO_2; fuel is limited, so it is usually counted as **non-renewable**.
- Homi **Bhabha's three-stage programme**: **PHWRs** on natural uranium → **fast breeder reactors** on plutonium → **thorium**-based reactors (India has large **monazite** thorium reserves in Kerala sands).

Key facts
- Installed nuclear capacity: about **8.8 GW** (2026); operator **NPCIL**; regulator **AERB**.
- The **Prototype Fast Breeder Reactor** at **Kalpakkam** began core loading in **2024** — the start of stage two.
- The **Nuclear Energy Mission** targets **100 GW by 2047**, including **Bharat Small Modular Reactors**.

Current status (2026)
- The **SHANTI Act, 2025** (Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India) — assent **20 Dec 2025** — **repealed the Atomic Energy Act, 1962** and the **Civil Liability for Nuclear Damage Act, 2010**, allowed **private companies** to build and run reactors, and gave the **AERB statutory status**.

5 BIOENERGY AND BIOFUELS

Biomass is sunlight stored in plants — the same stuff that became coal over millions of years, but harvested fresh every season. Turned into ethanol, diesel or gas, it can replace imported oil and turn farm waste into income.

Concept
- **Biomass** — organic matter from living or recently dead plants and animals used for heat, power or fuels; an **indirect form of solar energy** and **renewable**, unlike fossil fuels formed from ancient biomass.
- Sources: wood, charcoal, **dung cakes**, crop and forest residues (stubble, mustard husk, **bagasse**), sawdust, municipal and industrial organic waste, sewage.

Key facts
- **Ethanol** — a green fuel made from **sugarcane juice, molasses, glucose, mahua flowers**, maize, damaged grain and other starches.
- **Biofuel generations**: **1G** — food crops (sugar, starch, edible oil); **2G** — non-food **lignocellulosic** residues (straw, husk); **3G** — **algae**; **4G** — engineered organisms with carbon capture.
- **Biodiesel** — from vegetable oils, animal fats and **used cooking oil** (RUCO initiative); feedstocks **Jatropha (ratanjot; seed oil 27–40%)**, **Karanj (Pongamia)**, **Mahua, Neem**, sunflower, soybean, palm.
- **Biogas** — **anaerobic** digestion of dung and organic waste; about **55–65% methane** with CO_2; the slurry is a good manure.
- **Gasification** — heats biomass (wood, coconut and groundnut shells, **rice husk**) with little air to make **producer gas / syngas (CO, H_2, CH_4, CO_2)** for heat, power or diesel substitution.

Explained
- **National Policy on Biofuels (2018, amended 2022)** advanced the **20% ethanol blending (E20)** target from 2030 to **2025–26**.
- **PM JI-VAN Yojana (2019)** funds **2G ethanol** plants; **SATAT (2018)** promotes **compressed biogas**; **GOBARdhan** turns cattle dung into gas and manure.
- India launched the **Global Biofuels Alliance** at the **G20 Delhi summit (Sept 2023)**.
- **Algal biofuels** can be grown on sea or land but need high skill and capital.

Current status (2026)
- India reached an average of **20% ethanol blending** in the **2025–26** supply year — five years ahead of the original 2030 goal; **maize** now supplies over a third of ethanol feedstock.
- BIS notified standards for **E22–E30** fuels in May 2026, but no decision has been taken to raise the blend beyond 20%.
- Target for **sustainable aviation fuel**: **1% blending** in international flights by **2027**.

6 HYDROGEN — THE CLEAN FUEL

Concept
- Hydrogen reacts with oxygen (by burning or in a **fuel cell**) and leaves only **water vapour** — no CO_2, no particulates.
- It has the **highest energy per unit mass** of any fuel — about **140–150 kJ per gram**, roughly **three times** petrol, diesel or CNG.

Key facts
- Made by **thermochemical splitting**, **photolysis** (photocatalytic splitting) and **electrolysis** of water, or from natural gas.
- Colours: **grey** (from natural gas, CO_2 released), **blue** (gas + carbon capture), **green** (electrolysis using **renewable** power), **pink** (nuclear power), **turquoise** (methane pyrolysis, solid carbon left).
- Uses: fuel-cell vehicles, **H-CNG** blends, refineries, fertiliser (green ammonia), **green steel**.

Explained
- **National Green Hydrogen Mission** — approved **4 Jan 2023**; outlay about **₹19,744 crore**; aim **5 million tonnes a year by 2030** and to make India a global hub for green hydrogen and its derivatives; **SIGHT** programme for electrolysers.
- India's **Green Hydrogen Standard (2023)** — no more than **2 kg CO_2e per kg** of hydrogen (well-to-gate).

7 TURNING WASTE INTO WEALTH

Key facts
- **Compost** — microbial decay (bacteria, fungi, actinomycetes) of kitchen, leaf and crop waste; takes **3–6 months**; **thermophilic** heat kills pathogens and weed seeds.
- **Vermicompost** — organic waste eaten and excreted by **earthworms** (e.g. *Eisenia fetida*); ready in **1–2 months**; richer and more available **N, P and K** plus useful microbes.
- **Microbial fuel cell (MFC)** — bacteria convert the chemical energy of organic matter (waste-water, biomass) directly into **electricity**; used for waste-water treatment, **bioremediation**, biosensors and hydrogen.
- **Bio-bitumen (bio-asphalt)** — a road binder made from **rice straw (parali)**, lignin, vegetable oils, algae, molasses or starch; renewable, and it cools pavements (less **urban heat island**).

Points of precision
- **NPOP (2001)** — standards and certification for organic produce under the **Ministry of Commerce**; **APEDA** is the secretariat; **8th edition** issued **January 2025**.
- Sources of **biofertilisers**: Rhizobium, Azotobacter, Azospirillum, blue-green algae, **Azolla**, mycorrhiza.
- **Mulching** conserves soil moisture and checks weeds — an essential practice in organic farming.

Fuels of Tomorrow

CONVENTIONAL AND NON-CONVENTIONAL ENERGY

Source	Type	How it works / use
Coal	Conventional, non-renewable	Thermal power
Petroleum	Conventional, non-renewable	Transport fuels
Natural gas	Conventional, non-renewable	Power, fertiliser, cooking
Large hydro	Conventional, renewable	Dams and flowing water
Firewood, dung, residues	Traditional; renewable if sustainable	Household fuel
Nuclear	Conventional; finite fuel	Fission of uranium
Solar	Non-conventional	PV cells, solar thermal
Wind	Non-conventional	Turbines
Tidal · Wave	Non-conventional	Tides · sea waves
Geothermal	Non-conventional	Earth's internal heat
Biogas · Bioenergy	Non-conventional	Anaerobic digestion · biomass and biofuels
OTEC	Non-conventional	Surface–deep water temperature difference
Small hydro	Non-conventional	Plants up to 25 MW
Green hydrogen	Energy carrier	Electrolysis with renewable power

When Matter Is Out of Place

Pollution and pollutants · Air pollution · Air quality standards and programmes

CHAPTER OUTLINE

1 Pollution basics → 2 Air → 3 Air standards → 4 Acid rain → 5 Water → 6 Sea, noise, soil → 7 Plastic, radiation, heat → 8 Waste law → 9 Clean-up & diseases

1 POLLUTION AND POLLUTANTS

Pollution is often described as matter in the wrong place — sewage in a river, smoke in a lung, plastic in a turtle. The same nitrogen that feeds a field poisons a lake; the same ozone that shields us chokes a city. Where and how much decide the harm.

Concept
- **Pollution** — any **undesirable change** in the physical, chemical or biological properties of air, water or land, caused by **pollutants**.
- An environment altered by human activity is an **anthropogenic environment**; most **non-biodegradable** pollutants come from human activity.

Key facts
- By **form**: gaseous, dust, **thermal, noise, radioactive**; by **medium**: air, water, soil; by **origin**: **natural** (volcanoes, forest fires) and **anthropogenic** (industry, farming, transport).
- **Biodegradable** pollutants are broken down by microbes — domestic waste, sewage, paper, wood, **natural rubber**.
- **Non-biodegradable** pollutants persist — **plastics, polythene, DDT, BHC**, pesticides, glass, **synthetic rubber**, heavy metals.

Points of precision
- Biodegradable waste in excess still pollutes — sewage lowers oxygen in rivers.
- A **pollutant** may be natural in origin; it becomes a pollutant when concentration exceeds what the system can absorb.

2 AIR POLLUTION

Concept
- Any undesirable change in the normal composition of air by toxic gases or particles.
- Natural sources: forest fires, volcanoes, decay, natural SO_2 and NOx; human sources: burning **coal, petrol, diesel**, industrial smoke, vehicles, **thermal power plants — fossil-fuel burning is the biggest cause**.

Key facts
- **Primary pollutants** — emitted directly: **CO, CO_2, SO_2, NO, NO_2, $PM_{2.5}$/PM_{10}, VOCs**.
- **Secondary pollutants** — formed in the air: **ground-level O_3, PAN, photochemical smog, H_2SO_4 and HNO_3** (acid rain).
- **Rain and dew** wash smoke and dust out of the air — the atmosphere's natural **scavenger**.
- **Carbon monoxide** — colourless, odourless, from incomplete burning; binds haemoglobin as **carboxyhaemoglobin** with **200–300 times** the affinity of oxygen.
- **Lead** — once added to petrol (**tetraethyl lead**) as an anti-knock agent; lowers children's **IQ**; leaded petrol ended in India in **2000**; now from **smelters and lead paint**.
- Cigarette smoke: **CO, HCN, NOx, formaldehyde, acrolein, benzene, nicotine**.

Explained
- **Photochemical smog** (smoke + fog) — **NOx and hydrocarbons** react in strong sunlight to form **O_3, PAN, formaldehyde, acrolein**; typical of warm, sunny, traffic-heavy cities (Los Angeles type).
- **Classical (London) smog** — **smoke and SO_2** with fog in cold, damp weather; a **reducing** smog (London, 1952).
- **PAN (peroxyacetyl nitrate)** — damages **chloroplasts**, cuts photosynthesis, and is a strong **eye irritant**.
- Smog causes headaches, eye and throat irritation, coughing, poor visibility, accidents, and less sunlight — even lower **vitamin D** (rickets).

Points of precision
- **Fly ash** — fine residue of pulverised coal in thermal plants; mainly **SiO_2, Al_2O_3, CaO** with traces of heavy metals; trapped by **electrostatic precipitators (up to 99%)**, bag filters and scrubbers; reused in **cement (pozzolana), fly-ash bricks, roads and embankments** and as a soil conditioner. The 2021 notification requires **100% utilisation** by thermal plants.
- **Lichens** (alga + fungus) disappear where **SO_2** is high — classic **bio-indicators**.
- Control devices: **bag filters** (particles below ~50 µm), **cyclone separators** (coarse particles), wet scrubbers, ESPs. A "**cyclone divider**" is **not** a pollution-control device.
- **Catalytic converters** use **platinum, palladium, rhodium** to turn **CO → CO_2, NOx → N_2, hydrocarbons → CO_2 + H_2O**; they need **unleaded** fuel.
- **Bharat Stage VI** norms were adopted nationwide from **1 April 2020**, skipping BS-V.

3 AIR QUALITY STANDARDS AND PROGRAMMES

Every winter north India disappears under a grey blanket. Measuring the air honestly — and setting targets against those numbers — was the first step towards clearing it.

Key facts
- **National AQI** — launched by the **CPCB in Oct 2014**: "**One Number, One Colour, One Description**"; **8 pollutants**: **PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, Pb**; CO and O_3 use **8-hour**, others **24-hour** averages.
- AQI bands: **0–50 Good · 51–100 Satisfactory · 101–200 Moderate · 201–300 Poor · 301–400 Very Poor · 401–500 Severe**.
- **NAAQS (2009)** — notified under the **Air Act, 1981**, for **12 pollutants**: the AQI eight plus **benzene, benzo(a)pyrene, arsenic, nickel**.
- **WHO Air Quality Guidelines (22 Sept 2021)** — first revision since 2005: **$PM_{2.5}$ annual 5 µg/m³** (was 10), 24-h **15**; **PM_{10} annual 15**, 24-h **45**; **NO_2 annual 10**, 24-h 25; **SO_2 24-h 40**; **O_3 peak season 60**; **CO 24-h 4 mg/m³**. They are **not binding**.

Explained
- **National Clean Air Programme (NCAP)** — launched **January 2019** for about **130 non-attainment cities**: first a **20–30%** cut in PM by 2024 (base 2017), revised to **up to 40% cut in PM_{10} or meeting the NAAQS by 2025–26**; funded partly by the **15th Finance Commission**; tracked on the **PRANA** portal; cities ranked in **Swachh Vayu Sarvekshan**.
- The **Commission for Air Quality Management (CAQM)** for Delhi-NCR (Ordinance 2020, Act **2021**) enforces the **Graded Response Action Plan (GRAP)** in four stages by AQI.
- **Climate and Clean Air Coalition (CCAC) — 2012**, secretariat with **UNEP**; voluntary; targets **short-lived climate pollutants — methane, black carbon, HFCs, tropospheric ozone**; **India joined in 2019**.

Current status (2026)
- The NCAP's **2026** target is largely **unmet**: of about 130 cities, only around **26** cut PM_{10} by over 40% and only about **14** met the NAAQS (Swachh Vayu Sarvekshan 2026).

Measuring the Air We Breathe

Acid rain · Water pollution · Marine pollution · Noise pollution · Soil and plastic pollution

4 ACID RAIN

Concept

- Normal rain is slightly acidic (**pH ≈ 5.6**) because CO_2 dissolves to form **carbonic acid**; rain more acidic than this — usually below **pH 5** — is **acid rain**.
- **SO_2 and NOx** from fuel burning oxidise to **sulphuric and nitric acid** — the main causes.

Key facts

- Damages **marble and limestone** buildings — "**stone cancer**" (e.g. the **Taj Mahal**, threatened by the Mathura refinery; the **Taj Trapezium Zone** limits polluting industry).
- In soil, **H^+ ions displace K^+, Mg^{2+}, Ca^{2+}** and nutrients are **leached**; soil pH and fertility fall; soil microbes suffer; aluminium is released.
- In water: **fish die**, eggs fail to hatch, **mucus clogs gills**, oxygen uptake and salt balance break down; frogs suffer as mayfly and mosquito larvae vanish.

Points of precision

- Acid rain is a **regional and transboundary** problem — Scandinavia's dead lakes were caused by British and German emissions.
- **Flue-gas desulphurisation (FGD)** units remove SO_2 at coal plants.

5 WATER POLLUTION

A river can clean itself — bacteria eat the waste, the current brings fresh oxygen. Pollution begins when we give it more than it can digest, and the water starts to suffocate.

Concept

- Any physical, chemical, biological or radiological change that makes water harmful to life or unfit for use; even **excess nutrients** pollute.
- **Dissolved oxygen (DO)** is the key indicator; only tolerant species (**tubifex worms**, some insect larvae) live in badly polluted water.

Key facts

- **BOD (biochemical oxygen demand)** — oxygen needed by **microbes** to decompose organic matter in a given volume of water; **more organic load → higher BOD → lower DO**; the standard index of organic pollution.
- **COD (chemical oxygen demand)** — oxygen needed to oxidise **all** organic and inorganic matter chemically; COD is always **higher** than BOD.
- **Eutrophication** — over-enrichment with **nitrogen and phosphorus** (sewage, farm run-off, detergents) causes **algal blooms**; light is cut off, decaying algae use up oxygen, fish die, biodiversity crashes.
- **Arsenic** — mostly **geogenic** (leaches from rocks), worsened by over-pumping; worst in **West Bengal** (first detected **1983**) and the **Ganga–Brahmaputra plains**, and **Bangladesh**; causes **arsenicosis, "blackfoot disease"**, skin lesions and cancers; **rice** absorbs it.
- **Fluoride** — safe up to about **1–1.5 mg/L**; beyond it, **dental and skeletal fluorosis** and "**knock-knee**"; worst in **Rajasthan** and **Telangana**; found in groundwater in most states.
- **Uranium** and **nitrate** are also found above safe limits in parts of India; nitrate causes **blue baby syndrome**.

Explained

- **Bio-toilets** (DRDO) use an **anaerobic** bacterial culture to turn human waste into water, **methane and CO_2**; the effluent is chlorinated before release — used in Indian Railways.
- Water disinfection: **chlorine and bleaching powder**, **chlorine dioxide, chloramine (NH_2Cl)**, **ozone**, **iodine**, **UV rays** (no change in taste or colour) and heat.

6 MARINE POLLUTION

Key facts

- Land-based pollutants: **sewage, farm run-off, pesticides, fertilisers, heavy metals, plastics and microplastics**.
- Oceans absorb about **one-third** of human CO_2; the result is **ocean acidification**, which harms **corals, coccolithophores**, shellfish and plankton larvae.
- Nitrogen run-off creates coastal **dead zones** (hypoxia).

Explained

- **International Maritime Organization (IMO)** — UN specialised agency for shipping safety and ship-source pollution; convention signed **1948 (Geneva)**, in force **1958**; called **IMCO** until 1982; HQ **London**; India a member since **1959**; runs **MARPOL**.
- **SACEP** (South Asia Co-operative Environment Programme) — set up **1982**, HQ **Colombo**; **8 members**: India, Bangladesh, Bhutan, Nepal, Sri Lanka, Pakistan, Afghanistan, Maldives; secretariat of the **South Asian Seas Programme**.

7 NOISE POLLUTION

Key facts

- Sound becomes **noise pollution** when it harms health, mind or environment; measured in **decibels (dB)** — one-tenth of a **bel**, named after **Alexander Graham Bell**; the scale is **logarithmic** (+10 dB = 10 times the intensity).
- Levels: leaves rustling **20 dB** · whisper **30** · quiet office **40** · conversation **60** · truck **80–85** · jet engine **120** · jet landing **150** · rocket **180**.
- **Noise Pollution (Regulation and Control) Rules, 2000** (EPA) — day/night limits: **industrial 75/70 dB**, **commercial 65/55**, **residential 55/45**, **silence zone 50/40**; loudspeakers banned **10 pm–6 am**.

Explained

- A **sonic boom** is the shock wave from an object faster than sound (**~1,235 km/h**); the pilot does not hear it; a **Mach cone** of vapour may form; it can shatter windows, so supersonic flight over towns is restricted.
- **Green muffler** — rows of trees and shrubs along highways and industrial zones to absorb noise.

8 SOIL AND PLASTIC POLLUTION

Key facts

- Causes of soil pollution: industrial waste and **heavy metals**, **excess fertilisers and pesticides**, plastics, **mining** and oil spills.
- Effects: loss of beneficial microbes (nitrifiers), lower fertility and water-holding capacity, toxic residues entering food, run-off polluting rivers and aquifers.
- Excess fertiliser pollutes **soil, water and air** together (nitrate run-off, N_2O emissions).
- Hazardous pesticides in the news: **carbofuran, methyl parathion, phorate, triazophos**.
- **Polythene** is a polymer of **ethylene (C_2H_4)** — stable C–H bonds make it resist microbial breakdown; **chewing gum** contains synthetic polymers (polyisobutylene, polyvinyl acetate) and is a pollutant too.
- **Microbeads** — plastic particles **under 5 mm** (polyethylene, polypropylene, polystyrene) in cosmetics and cleaners; they slip through treatment plants, absorb **POPs** and enter marine food webs.

Explained

- **Plastic Waste Management Rules, 2016** (amended 2021–24): **identified single-use plastic items banned from 1 July 2022**; carry bags must be at least **120 microns** (from Dec 2022); **EPR** for producers and brand owners.
- Global talks on a **plastics treaty** (mandate from **UNEA-5.2, 2022**) failed to conclude at **Busan (2024)** and **Geneva (Aug 2025)**; **INC-5.3 (Feb 2026)** elected a new chair and talks continue.

Noise, Soil, Plastic, Radiation & Heat

Radioactive and thermal pollution · Solid Waste Management Rules, ...

9 RADIOACTIVE AND THERMAL POLLUTION

Key facts

- Sources of radiation: **nuclear plants** (leaks, meltdowns), **weapons tests**, mining of **uranium, thorium, radium**, medical waste, cosmic rays and **radon** from rocks.
- Effects: tissue damage, **mutations**, blood disorders, **cancers**.
- **Chernobyl** — **26 April 1986**, reactor explosion in the then Soviet Union (now **Ukraine**); **Fukushima** (Japan) — after the **2011** tsunami.
- **Bhopal Gas Tragedy** — night of **2–3 Dec 1984**, **Union Carbide India Ltd**; **methyl isocyanate (CH_3NCO)** — colourless, highly toxic, tear-causing; used to make the pesticide **carbaryl (Sevin)**.
- **Thermal pollution** — hot cooling water from **thermal and nuclear power plants** and industries, loss of shade trees and hot urban run-off raise water temperature; **dissolved oxygen falls**, fish suffer **thermal shock**, breeding is disrupted.

Explained

- Remedies for thermal pollution: **cooling towers**, **cooling ponds**, **closed-loop recycling** of cooling water.

10 SOLID WASTE MANAGEMENT RULES, 2026 *in force 1 April 2026*

India's cities produce well over a lakh tonnes of waste every day, much of it still dumped on mountains of garbage. The 2026 rules shift the burden back to where waste is born — the kitchen, the office, the factory.

Concept

- Notified by the **MoEFCC** under the **EPA** in **January 2026**, replacing the **SWM Rules, 2016**; in force **1 April 2026**; apply to **urban and rural** local bodies and all generators.
- Built on the **circular economy**, **EPR** and the **polluter-pays** principle.

Key facts

- **Four-stream segregation at source**: **wet** (green bin), **dry** (blue), **sanitary** (red), **special care / domestic hazardous** (black).
- **Bulk waste generators** — floor area **≥ 20,000 sq m**, or water use **≥ 40,000 litres/day**, or waste **≥ 100 kg/day** — must manage their own waste (**Extended Bulk Waste Generator Responsibility**).
- Ban on littering, dumping and **open burning**; **environmental compensation** for violations.
- Industries must use **refuse-derived fuel (RDF)** — rising from **5% to 15%** over six years.
- **Material Recovery Facilities** recognised; **online portal** (CPCB, SPCBs) tracks waste end-to-end; hill and island bodies may levy **user fees on tourists** and limit tourist inflow.

11 OTHER WASTE RULES AND GLOBAL CHEMICALS TREATIES

Key facts

- **E-Waste (Management) Rules, 2022** — **EPR** with tradable certificates; covers solar panels too.
- **Bio-Medical Waste Management Rules, 2016** — colour codes: **yellow** (anatomical, soiled — incineration), **red** (contaminated plastics — recycling), **white translucent** (sharps), **blue** (glass, metallic implants).
- **Battery Waste Management Rules, 2022**; **Hazardous and Other Wastes Rules, 2016**; **Construction & Demolition Waste Rules, 2025** (from 1 April 2026); **Liquid Waste/used oil** and **tyre** EPR.

Explained

- **Basel Convention (1989)** — transboundary movement of **hazardous waste**; **Ban Amendment** (in force 2019); plastic waste added in 2019.
- **Rotterdam Convention (1998)** — **Prior Informed Consent** for trade in hazardous chemicals and pesticides.
- **Stockholm Convention (2001)** — eliminate **persistent organic pollutants (POPs)** — the "dirty dozen" (DDT, aldrin, dieldrin, PCBs, dioxins...).
- **Minamata Convention (2013, in force 2017)** — **mercury**; India ratified in **2018**.

12 BIOREMEDIATION

Concept

- Using **microbes (bacteria, fungi), algae or plants** to remove, break down or detoxify pollutants in soil, water or air.

Key facts

- **In-situ**: **bioventing** (air and nutrients into unsaturated soil), **biosparging** (air injected below the water table), **biostimulation** (adding N and P), **bioaugmentation** (adding specialised microbes), **phytoremediation** and **phytoextraction** (plants store metals in harvestable parts).
- **Ex-situ**: **composting, bioreactors, landfarming, biopiles**.
- **Oilzapper** — developed by **TERI** with the **Department of Biotechnology**; a mix of **five bacterial strains** on a powder carrier that eat **crude-oil hydrocarbons**, leaving CO_2 and water.

Points of precision

- Heavy metals such as **cadmium and lead cannot be destroyed** by microbes — they can only be immobilised or extracted.
- Genetically engineered "**superbug**" (*Pseudomonas*) for oil spills was developed by **Ananda Mohan Chakrabarty** — the first patented living organism (1980).

POLLUTANTS, DISEASES AND TARGET ORGANS

Pollutant	Disease / effect	Main target
Mercury	Minamata disease (Japan, 1950s)	Nervous system, kidneys
Cadmium	Itai-itai ("ouch-ouch") disease	Kidneys, bones
Nitrate	Blue baby syndrome (methaemoglobinaemia)	Blood oxygen in infants
Fluoride	Dental and skeletal fluorosis; knock-knee	Teeth, bones
Arsenic	Arsenicosis; blackfoot disease	Skin, blood vessels
Lead	Lower IQ; anaemia	Brain, nervous system
Silica dust	Silicosis	Lungs
Asbestos	Asbestosis; mesothelioma	Lungs, pleura
Carbon monoxide	Hypoxia (carboxyhaemoglobin)	Brain, heart
Radon	Lung cancer	Lungs
NO_2 · PM	Respiratory and heart disease	Lungs, heart
Benzene	Leukaemia	Bone marrow
Noise	Hearing loss, stress	Ears, nerves

Every Drop Counts

Water as a resource · Making water safe · Water missions and schemes · Four decades of Ganga cleaning

CHAPTER OUTLINE

1 Water resources → 2 Purification → 3 Water missions → 4 Saving the Ganga → 5 Namami Gange & dolphins

1 WATER AS A RESOURCE

India has about 18% of the world's people but only about 4% of its fresh water. Rivers are polluted, aquifers are being pumped faster than the rain can refill them — so conservation has moved from a slogan to a survival plan.

Concept

- **Biotic resources** come from living things (forests, animals and their products) — **fossil fuels** count as biotic because they formed from organic matter; **pure water is abiotic**.
- Earth's water is vast, but only about **2.5%** is fresh and less than **1%** is easily usable.

Key facts

- **World Water Day — 22 March**; it was proposed at **Rio 1992 (UNCED)**; first observed in **1993**.
- **UN-Water** (2003) coordinates UN work on fresh water, sanitation and water disasters.
- **Rajendra Singh** — "**Waterman of India**"; **Tarun Bharat Sangh (1975)**; revived rivers in Alwar with **johads**; **Ramon Magsaysay (2001)**, **Stockholm Water Prize (2015)**.
- **Sujalam campaign** — Ministry of **Jal Shakti**, **25 Aug 2021** (Azadi Ka Amrit Mahotsav): village waste-water management and **ODF Plus** villages.

Points of precision

- India is the world's **largest user of groundwater**; the CGWB's 2024 assessment put the stage of extraction at about **60%**, with over-exploited blocks concentrated in **Punjab, Haryana, Rajasthan, Delhi**.

2 MAKING WATER SAFE

Key facts

- Disinfection methods: **boiling and heat**, **UV rays**, **chemical oxidation**, **ozone**, **iodine**, **chlorine compounds**, **monochloramine (NH_2Cl)**, **chlorine dioxide (ClO_2)**; **alum** settles suspended particles; some **diatoms** help filtration.
- **Chlorination** — chlorine gas or **bleaching powder** kills bacteria; excess is removed by **dechlorination**.
- **UV treatment** kills microbes without changing **taste, smell or colour**, but it does not remove existing odours or chemicals.

Points of precision

- **Reverse osmosis** removes dissolved salts but wastes water; **activated carbon** removes odour and organics.

3 WATER MISSIONS AND SCHEMES

Key facts

- **National Water Mission** (NAPCC, 2008) — **integrated water resources management**; raise **water-use efficiency by 20%**; conserve water in over-exploited blocks; open water data; basin-level planning; citizen and state participation.
- **National Lake Conservation Plan (June 2001)** — urban lakes; merged with the **National Wetland Conservation Programme** into the **National Plan for Conservation of Aquatic Ecosystems (NPCA)** in **2013**.
- **Hariyali (2003)** — watershed guidelines through **Panchayati Raj** institutions: drinking water, irrigation, fisheries, afforestation, rainwater harvesting.
- **Jal Jeevan Mission (2019)** — tap water to every rural home (**Har Ghar Jal**); **Atal Bhujal Yojana (2019)** — community groundwater management in **7 states**; **Jal Shakti Abhiyan: Catch the Rain**; **Mission Amrit Sarovar (2022) — 75 ponds** in every district.

4 FOUR DECADES OF GANGA CLEANING

The Ganga feeds more than 40 crore people and carries their faith — and much of their sewage. Every decade since 1985 has brought a new plan, a new authority and a larger budget, each learning from the last.

Key facts

- **Ganga Action Plan, Phase I — 1985**; the **Central Ganga Authority** was set up in **February 1985**, renamed the **National River Conservation Authority (NRCA)** in **Sept 1995**, chaired by the **PM**.
- NRCA tasks: intercept and divert drains, build **STPs**, end open defecation on banks, renovate ghats and riverfronts, improve raw water quality, involve and educate the public.
- **GAP Phase II (1993)** brought in tributaries — the **Yamuna Action Plan** (Phase I **1993–2003**, Phase II from **Dec 2004**) and the **Gomti Action Plan**; GAP II was later merged into the **National River Conservation Plan**.
- The Ganga was declared India's **National River** in **Nov 2008**.
- **National Ganga River Basin Authority (NGRBA) — 20 Feb 2009** under **Section 3(3) of the EPA**; chaired by the **PM** (then Manmohan Singh) with Chief Ministers of Ganga states.
- **National Ganga Council (NGC)** replaced the NGRBA by notification of **7 Oct 2016** under the **River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016** (EPA); **chair: PM**, **vice-chair: Union Jal Shakti Minister**; members include the Union ministers of Finance, Housing & Urban Affairs and Environment and the CMs of **Uttarakhand, UP, Bihar, Jharkhand, West Bengal**.

Explained

- The **National Mission for Clean Ganga (NMCG)** — registered as a society in **Aug 2011** — is the implementing arm, now an **authority** under the 2016 Order.
- The **Madhav Chitale Committee (July 2016)** framed guidelines for **desilting** the Ganga.
- Minimum **ecological flows (e-flows)** for the upper Ganga were notified in **Oct 2018**.

Saving the Ganga

Namami Gange and the river dolphin

5 NAMAMI GANGE AND THE RIVER DOLPHIN

Concept

- **Namami Gange** — the integrated Ganga mission announced in the **Union Budget 2014–15**; its pillars are **Nirmal Dhara** (unpolluted flow — municipal sewage, rural sanitation, industrial effluent) and **Aviral Dhara** (continuous flow, e-flows); **Arth Ganga** links the river to the local economy.

Key facts

- **Ganges river dolphin** (*Platanista gangetica*) — a mammal of deep pools, eddies and confluences of the Ganga–Brahmaputra system; **Endangered** since 1996; WWF began its conservation programme in **1997**.
- Declared the **National Aquatic Animal on 5 Oct 2009**; **UP's State Aquatic Animal (Oct 2023)** with the campaign "**Meri Ganga Meri Dolphin**".
- Threats: **dams and barrages** (fragmentation), **gill-net by-catch**, agrochemical run-off, poaching for oil.
- It shares its home with **gharials, muggers**, freshwater turtles and water-birds.

Current status (2026)

- **Namami Gange Mission-II** runs to **2026**; by mid-2026 the programme had created about **4,263 MLD** of sewage-treatment capacity out of **6,610 MLD** sanctioned.
- The first range-wide survey counted **6,327** river dolphins (released **March 2025**); the **second estimation** began at **Bijnor in January 2026**.

People Who Moved the Earth

Environmental movements of India

CHAPTER OUTLINE

1 Movements → 2 Personalities → 3 Thinkers & ideas → 4 Institutes & bodies → 5 Days → 6 Awards → 7 Treaty timeline

1 ENVIRONMENTAL MOVEMENTS OF INDIA

Long before environmental law, villagers hugged trees, blocked loggers and stood in rising dam waters. India's environmentalism was born not in laboratories but in forests and fields, among people whose lives depended on them.

Key facts

- **Bishnoi / Khejarli (1730, Rajasthan)** — **Amrita Devi Bishnoi** and 363 others gave their lives to save **khejri** trees.
- **Chipko (1973, Uttarakhand)** — began at **Mandal/Reni** in Chamoli; **Chandi Prasad Bhatt, Sunderlal Bahuguna, Gaura Devi**; women hugged trees; slogan "**Ecology is permanent economy**".
- **Silent Valley (1970s, Kerala)** — **Kerala Sastra Sahitya Parishad** and others stopped a hydel project; the valley became a national park (1984).
- **Appiko (1983, Karnataka)** — the Western Ghats' Chipko, led by **Pandurang Hegde**.
- **Jungle Bachao (1980s, Singhbhum, Jharkhand)** — tribals resisted replacing **sal** with teak.
- **Narmada Bachao Andolan (from 1985)** — **Medha Patkar, Baba Amte**; displacement by the Sardar Sarovar dam (Gujarat, MP, Maharashtra).
- **Tehri Dam protests (1980s–90s)** — **Sunderlal Bahuguna**.
- **Navdanya (1980s)** — **Vandana Shiva**; seed and biodiversity conservation.
- **Chilika Bachao (1990s, Odisha)** — fishers against aquaculture; **Gandhamardan (1980s)** and **Kashipur (2000s)** — against bauxite mining; **Niyamgiri (2000s)** — **Dongria Kondh** against Vedanta's bauxite mining (Gram Sabhas rejected it, 2013).
- **Maiti (1990s, Uttarakhand)** — **Kalyan Singh Rawat**; brides plant a tree at their wedding.
- **Ganga Bachao (1980s)** — against pollution of the Ganga.

Points of precision

Chipko was **not a single** movement but a series of local protests; it began over **forest rights and livelihoods** (against contractors) and later took on a conservation message; women also fought **alcoholism** within it.

ENVIRONMENTAL PERSONALITIES

Person	Known as / for
Dr Ramdeo Misra	"Father of Indian ecology"; tropical ecology research and teaching
Dr Salim Ali	"Birdman of India"; *The Book of Indian Birds*; BNHS
Dr M. S. Swaminathan	Architect of India's Green Revolution; adapted Mexican dwarf wheat
Dr Norman Borlaug (USA)	High-yield wheat; Nobel Peace Prize 1970
Wangari Maathai (Kenya)	Green Belt Movement; first African woman Nobel Peace laureate (2004)
Rajendra Singh	"Waterman of India"; Tarun Bharat Sangh
Jadav "Molai" Payeng (Assam)	"Forest Man of India"; grew the Molai forest on a Brahmaputra sandbar; Padma Shri 2015
Chewang Norphel (Ladakh)	"Ice Man"; artificial glaciers for irrigation
Mike Pandey	Wildlife film-maker; *Shores of Silence* (whale sharks)
Sunderlal Bahuguna · Chandi Prasad Bhatt	Chipko leaders
Medha Patkar	Narmada Bachao Andolan
Vandana Shiva	Navdanya; *Staying Alive*, *Tomorrow's Biodiversity*
Anil Agarwal	Founder of CSE; *State of India's Environment*
Madhav Gadgil	Western Ghats Ecology Expert Panel (2011)

Ideas & Their Authors

Institutes and other bodies

CONCEPTS AND THE THINKERS BEHIND THEM

Concept	Person	Year
Population and resources	Thomas Robert Malthus	1798
Carrying capacity (logistic growth)	Pierre-François Verhulst	1838
Ecology (term)	Ernst Haeckel	1866
Biosphere (term)	Eduard Suess	1875
Environmental determinism	Friedrich Ratzel	19th century
Ecological succession (study)	H. C. Cowles	1899
Microbial nitrogen fixation	Martinus Beijerinck	1901
Climax community; biomes	Frederic E. Clements	1916
Ecological niche	Joseph Grinnell	1917
Biogeochemistry, biosphere	Vladimir Vernadsky	1920s
Human ecology	Robert E. Park (Chicago School)	1920s
Food chain, food web, pyramids, functional niche	Charles Elton	1927
Competitive exclusion	G. F. Gause	1934
Ecosystem	A. G. Tansley	1935
Trophic levels; 10% law	Raymond Lindeman	1942
Energy concept of the ecosystem	Eugene Odum	1953
Fundamental and realised niche	G. E. Hutchinson	1957
Tragedy of the commons	Garrett Hardin	1968
Gaia hypothesis	James Lovelock	1970s
Deep ecology	Arne Næss	1973
Ecological transition	John W. Bennett	1976
Environmental justice	Robert Bullard	1980s
Ecological modernisation	Joseph Huber	1980s
Biodiversity (term)	Walter G. Rosen	1985
Conservation biology	Michael Soulé & Bruce Wilcox	1985
Sustainable development	Brundtland Commission	1987
Biodiversity hotspots	Norman Myers	1988
Ecological footprint	Mathis Wackernagel & William Rees	1990s

2 INSTITUTES AND OTHER BODIES

Key facts

- **National Institute of Nutrition — Hyderabad**; **National Institute of Ayurveda — Jaipur**; **National Institute of Naturopathy — Pune**.
- **Centre for Ecological Sciences (IISc) — Bengaluru**; **G. B. Pant National Institute of Himalayan Environment — Almora (Kosi-Katarmal)**.
- **Central Arid Zone Research Institute (CAZRI) — Jodhpur**; **Indian Grassland and Fodder Research Institute — Jhansi**; **IARI — New Delhi**.
- **Indian Institute of Ecology and Environment — New Delhi** (5 June 1980); **ENVIS centre on population and environment — IIPS, Mumbai**.
- **INCOIS — Hyderabad (1999)** — ocean information and tsunami warnings.

Explained

- **OPCW** — implements the **Chemical Weapons Convention**; set up **1997**; HQ **The Hague**; Nobel Peace Prize 2013.
- **AGMARK** — quality mark for farm produce by the **Directorate of Marketing and Inspection** (Agriculture Ministry) under the **Agricultural Produce (Grading and Marking) Act, 1937**.
- **UN-Habitat** — UN Human Settlements Programme, **1978**, HQ **Nairobi**; partners include governments, local bodies, the private sector and NGOs.
- **Agenda 21** — non-binding, voluntary UN action plan from **Rio 1992**.

ENVIRONMENTAL DAYS

Date	Day	Date	Day
2 Feb	World Wetlands Day	22 Mar	World Water Day
3 Mar	World Wildlife Day	7 Apr	World Health Day
21 Mar	International Day of Forests	22 Apr	Earth Day (since 1970)
22 May	International Day for Biological Diversity	31 May	World No Tobacco Day
5 Jun	World Environment Day	8 Jun	World Oceans Day
17 Jun	Desertification and Drought Day	11 Jul	World Population Day
26 Jul	Mangrove Ecosystem Conservation Day	29 Jul	International Tiger Day
12 Aug	World Elephant Day	16 Sep	World Ozone Day
22 Sep	World Rhino Day	2–8 Oct	Wildlife Week (India)
First Mon. of Oct	World Habitat Day	4 Oct	World Animal Day
5 Oct	National Ganga River Dolphin Day	31 Oct	World Cities Day
19 Nov	World Toilet Day	21 Nov	World Fisheries Day
2 Dec	National Pollution Control Day (Bhopal)	5 Dec	World Soil Day
11 Dec	International Mountain Day	14 Dec	National Energy Conservation Day

Days to Remember & Honours for the Earth

ENVIRONMENTAL AWARDS

Award	Since	Given by	Note
Tyler Prize for Environmental Achievement	1973	Tyler Prize committee (USC)	A "Green Nobel" for environmental science
Right Livelihood Award	1980	Right Livelihood Foundation	"Alternative Nobel"
UNEP Sasakawa Prize	1984	UNEP	Environment and sustainable development
Global 500 Roll of Honour	1987	UNEP	Ran till 2003; succeeded by Champions of the Earth
Indira Gandhi Paryavaran Puraskar	1987	MoEFCC	Outstanding contribution to environment protection
Goldman Environmental Prize	1989	Goldman Foundation	Grassroots activists; "Green Nobel"
G. D. Birla Award for Scientific Research	1991	K. K. Birla Foundation	Indian scientists; not only environment
Whitley Award	1994	Whitley Fund for Nature	"Green Oscar"
Champions of the Earth	2005	UNEP	UN's top environmental honour
Rajiv Gandhi Environment Award for Clean Technology	—	MoEFCC	Industries adopting clean technology
Amrita Devi Bishnoi Wildlife Protection Award	—	MoEFCC	Courage in protecting wildlife

ENVIRONMENTAL TREATIES AND AGREEMENTS — A TIMELINE

Year	Treaty / outcome	Subject
1946	International Convention for the Regulation of Whaling	Whales; IWC
1959	Antarctic Treaty	Peaceful, scientific use of Antarctica
1963	Partial Test Ban Treaty	No nuclear tests in air, space, under water
1968	African Convention on Nature	Nature and natural resources
1971	Ramsar Convention · Seabed Arms Control Treaty	Wetlands · no nukes on seabed
1972	London Convention · World Heritage · Stockholm Declaration	Dumping at sea · heritage · human environment
1973	CITES · MARPOL	Wildlife trade · ship pollution
1976	Barcelona Convention	Mediterranean Sea
1979	CMS (Bonn) · CLRTAP	Migratory species · transboundary air pollution
1982	UNCLOS · World Charter for Nature	Law of the sea · conservation principles
1985	Vienna Convention · Helsinki Protocol	Ozone layer · sulphur emissions
1987	Montreal Protocol · Brundtland Report	ODS · sustainable development
1988	Sofia Protocol	Nitrogen oxides
1989	Basel Convention	Hazardous waste movement
1991	Bamako · Espoo · Antarctic Environment Protocol (Madrid) · Geneva VOC Protocol	African hazardous waste · transboundary EIA · Antarctica · VOCs
1992	CBD · UNFCCC · Rio Declaration · Agenda 21 · Forest Principles · Helsinki Convention	Rio outcomes · Baltic Sea
1994	UNCCD · Oslo Protocol	Desertification · sulphur
1995	Fish Stocks Agreement · Basel Ban Amendment	Straddling stocks · hazardous waste exports
1996	London Protocol	Stricter ocean dumping rules
1997	Kyoto Protocol	Binding cuts for developed countries
1998	Rotterdam · Aarhus · Heavy Metals and POPs Protocols	Prior informed consent · public participation
1999	Gothenburg Protocol	Acidification, eutrophication, ozone
2000	Cartagena Protocol	Biosafety of LMOs
2001	Stockholm Convention · Marrakesh Accords	POPs · Kyoto rules
2002	Johannesburg Declaration & Plan	Sustainable development
2003	Kyiv Protocol · AEWA	Pollutant registers · migratory water-birds
2010	Nagoya Protocol · Nagoya–KL Supplementary Protocol	ABS · LMO liability
2012	Doha Amendment · "The Future We Want"	Kyoto II · Rio+20
2013	Minamata Convention	Mercury
2015	Paris Agreement · 2030 Agenda	Climate · SDGs
2016	Kigali Amendment	HFC phase-down
2018	Katowice package · Escazú Agreement	Paris rule-book · environmental democracy (Latin America)
2021	Glasgow Climate Pact	1.5°C; coal phase-down
2022	Kunming–Montreal GBF · Sharm el-Sheikh Plan	Biodiversity 2030 · loss and damage fund
2023	UAE Consensus · BBNJ Agreement adopted	Transition from fossil fuels · high seas
2024	Baku NCQG · Cali Fund	Climate finance · DSI benefit-sharing
2025	Belém "Global Mutirão" · Ramsar Victoria Falls Declaration	Adaptation finance · wetlands
2026	BBNJ enters into force (17 Jan) · CBD COP17 Yerevan · COP31 Antalya	High seas · first KMGBF review · climate