



Environment, Climate Change and Sustainable Development

COURSE CODE: SGB24UC102VC

Value Added Course
For FYUG Programmes
Self Learning Material



**SREENARAYANAGURU
OPEN UNIVERSITY**

SREENARAYANAGURU OPEN UNIVERSITY

The State University for Education, Training and Research in Blended Format, Kerala



Vision

To increase access of potential learners of all categories to higher education, research and training, and ensure equity through delivery of high quality processes and outcomes fostering inclusive educational empowerment for social advancement.

Mission

To be benchmarked as a model for conservation and dissemination of knowledge and skill on blended and virtual mode in education, training and research for normal, continuing, and adult learners.

Pathway

Access and Quality define Equity.



Environment, Climate Change and Sustainable Development

Course Code: SGB24UC102VC

Semester - IV

**Value Added Course
For FYUG Programmes (Honours)
Self Learning Material
(With Model Question Paper Sets)**



**SREENARAYANAGURU
OPEN UNIVERSITY**

SREENARAYANAGURU OPEN UNIVERSITY

The State University for Education, Training and Research in Blended Format, Kerala



SREENARAYANAGURU
OPEN UNIVERSITY

ENVIRONMENT, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Course Code: SGB24UC102VC

Semester- IV

Skill Enhancement Course

For FYUG Programmes (Honours)

Academic Committee

Dr. Sabu Joseph
Dr. A. Krishnakumar
Dr. Ayona Jaydev
Dr. K. Anoop Krishnan
Dr. Salom Gnana Thanga K.

Development of the Content

Dr. I.G. Shibi
Dr. Sanitha K.K.
Dr. Anfal M.

Review

Dr. K. Anoop Krishnan

Edit

Dr. K. Anoop Krishnan

Linguistics

Dr. Anas Thayyil Padinharayil

Scrutiny

Dr. Sanitha K.K.
Dr. Anfal M.

Cover Design

Jobin J.

Co-ordination

Director, MDDC :

Dr. I.G. Shibi

Asst. Director, MDDC :

Dr. Sajeekumar G.

Coordinator, Development:

Dr. Anfal M.

Coordinator, Distribution:

Dr. Sanitha K.K.



Scan this QR Code for reading the SLM
on a digital device.

Edition
March 2026

Copyright
© Sreenarayanaguru Open University

ISBN 978-81-996670-9-9



All rights reserved. No part of this work may be reproduced in any form, by mimeograph or any other means, without permission in writing from Sreenarayanaguru Open University. Printed and published on behalf of Sreenarayanaguru Open University by Registrar, SGOU, Kollam.

www.sgou.ac.in



Visit and Subscribe our Social Media Platforms

Message from Vice Chancellor

Dear Learner,

It is with great pleasure that I welcome you to the Four Year UG Programme offered by Sreenarayanaguru Open University.

Established in September 2020, our university aims to provide high-quality higher education through open and distance learning. Our guiding principle, 'access and quality define equity', shapes our approach to education. We are committed to maintaining the highest standards in our academic offerings.

Our university proudly bears the name of Sreenarayanaguru, a prominent Renaissance thinker of modern India. His philosophy of social reform and educational empowerment serves as a constant reminder of our dedication to excellence in all our academic pursuits.

It gives me immense pleasure to introduce the course Environment, Climate Change and Sustainable Development as a core component of the Fourth Semester under the FYUG Programme, designed to equip learners with a comprehensive understanding of environmental systems, climate change challenges, and the principles of sustainable development; in the context of increasing ecological concerns and global climate uncertainties, this course seeks to promote environmental awareness, critical thinking, and responsible citizenship by highlighting the interconnections between human activities and environmental consequences, while encouraging sustainable practices and innovative solutions to contemporary issues, and as a value-added university core course, it reflects our commitment to nurturing environmentally conscious graduates who can contribute effectively to building a sustainable future.

Our teaching methodology combines three key elements: Self Learning Material, Classroom Counselling, and Virtual modes. This blended approach aims to provide a rich and engaging learning experience, overcoming the limitations often associated with distance education. We are confident that this programme will enhance your understanding of statistical methods in business contexts, preparing you for various career paths and further academic pursuits.

Our learner support services are always available to address any concerns you may have during your time with us. We encourage you to reach out with any questions or feedback regarding the programme.

We wish you success in your academic journey with Sreenarayanaguru Open University.

Best regards,



Dr. Jagathy Raj V.P.
Vice Chancellor

01-03-2026

Contents

Block 01	Environment and Natural Resources	1
Unit 1	Environment	2
Unit 2	Renewable and Non-renewable Resources	29
Unit 3	Major Threats to Natural Resources	60
Block 02	Environmental Mitigation and Sustainable Development	92
Unit 1	Solutions to Contemporary Environmental Threats	93
Unit 2	Movements for Protection of Environment	113
Unit 3	UN Sustainable Development Goals	125
Model Question Paper Sets		155

BLOCK - 01

Environment and Natural Resources

Unit 1

Environment

Learning Outcomes

By the end of the unit, the learner will :

- ▶ gain an awareness about the natural systems, various processes vital for supporting life and their interconnectivity
- ▶ recognize the importance of biodiversity and natural resource conservation
- ▶ grasp multidisciplinary perspectives needed to address environmental challenges
- ▶ comprehend weather-climate differences and climate change threats

Prerequisites

Could you get on a journey down memory lane, where the most enchanting and cherished moments of your school and college days were painted with the vibrant hues of nature? Visualise yourself, carefree and barefoot, frolicking in open grassy play- grounds or seeking refuge beneath the sprawling canopies of lush green trees. Remember the thrill of climbing different trees, perching on branches, and reaching for the sun-kissed fruits that dangled within arm's reach. The joy of sharing these treasures with friends and siblings created bonds that echoed the harmony of nature itself. During festive seasons like Onam, the air was filled with excitement as you and your childhood companions scoured the surroundings, plucking flowers of every hue to create vibrant athappookalams, each petal a testament to the beauty of the earth.

Recall those moments of escape from the scorching sunlight, finding solace beneath the cool, green shadows cast by ancient trees. The symphony of birds, soaring through the sky and serenading with melodious tunes, created a soundtrack to your outdoor adventures. The coolness of a natural pond or the refreshing spray from a cascading waterfall provided a respite from the ordinary, a touch of nature's magic. Those were the days when the Earth was our playground, and every step was a dance with the wonders of the environment.

Yet, as we fast-forward to the present, the landscape of our cities is rapidly transforming. Mother Nature, once the canvas upon which our childhood memories were painted, is now overshadowed by towering concrete structures and multi-storied buildings. The urgent need to protect our environment and preserve nature's blessings is undeniable.

As responsible citizens of our nations, it becomes paramount for us to understand the significance of nature and recognize the detrimental impact of modern life on our natural surroundings. Let us cherish these memories, not merely as remnants of the past but as a clarion call to safeguard the environment for future generations. In this self-study material, we unravel the importance of nature, urging each of us to become stewards of our planet and champions for the preservation of its precious blessings.

Key Words

Ecosystems, Biodiversity, Sustainability, Ecology, Multidisciplinary, Pollution, Eutrophication, Conservation, Climate

Discussion

Weather and Climate

Weather:

- ▶ Weather refers to the atmospheric conditions at a specific place and time, typically over a short period ranging from minutes to days.
- ▶ It includes variables such as temperature, humidity, precipitation, wind speed and direction, cloud cover, and atmospheric pressure.
- ▶ Weather conditions can change rapidly and are often unpredictable due to the dynamic nature of the atmosphere.
- ▶ Examples of weather phenomena include rain showers, thunderstorms, snowfall, heatwaves, and cold fronts.

Climate:

- ▶ Climate refers to the long-term patterns and averages of weather conditions observed in a particular region over a period of years, decades, centuries, or even millennia. It encompasses the average temperature, precipitation, humidity, wind patterns, and other atmospheric characteristics of a region.



- ▶ Climate provides a broader perspective on the typical weather conditions experienced in a given area and helps define its overall climate classification (e.g., tropical, arid, temperate, polar).
- ▶ Climate change refers to shifts in these long-term patterns, such as alterations in average temperature or precipitation levels over decades or centuries, often attributed to natural variability and human activities.

1.1.1 Definition of Environmental Studies

Our state Kerala is blessed with lush greenery, serene backwaters, and rich biodiversity. However, in recent years, issues like pollution, deforestation, loss of wetlands etc. have emerged as major environmental concerns in the state. For example, the backwaters and lakes of Kerala which support a thriving ecosystem of fishes, birds and flora, are under threat from factors like water pollution and encroachments. Many unique species found here like the crimson, marsh, glider, dragon fly, etc. are on the verge of extinction.

Similarly, the Western Ghats which nurture dense forests and rare medicinal plants are also facing loss of green cover due to human activities, as the dense forest area have been reduced by 19.5% and open forest area decreased by 33.2%) This indicates the complex interconnection between various elements of nature and how human actions like urbanization, industrialization and pollution can impact the environment. It shows that to protect Kerala's natural beauty, biodiversity and ecological balance, a holistic understanding is needed of how humans, flora, fauna, land, water and air interact with each other.



Fig 1.1.1 Crimon Mars Gliders

The field of Environmental Studies aims to provide a holistic perspective by analyzing the complex interplay between human society and the natural world. By integrating disciplines such as ecology, biology, sociology, and economics, it strives to comprehend the intricate relationships within nature and equip us to handle emerging ecological challenges judiciously.

Just as seen in regions like Kerala, the core objective is to develop sustainable models that preserve fragile ecosystems while simultaneously supporting local livelihoods and economic growth.

1.1.1.1 The Scope of Environmental Studies

To understand how these pieces fit together, it is helpful to view Environmental Studies as a bridge between the physical components of our planet and the academic disciplines we use to manage them.

1. Major Components of the Environment

Environmental studies typically categorizes the world into four overlapping spheres:

- **Atmosphere:** The gaseous envelope (air) surrounding the earth.
- **Hydrosphere:** All water bodies, including oceans, rivers, and groundwater.
- **Lithosphere:** The outer crust of the earth (soil and rock).
- **Biosphere:** The "living shell" where all biological organisms interact with the other three components.

2. Key Interdisciplinary Lenses

Because environmental issues are rarely

just biological or just economic, the field relies on several pillars:

- **Natural Sciences (Ecology & Biology):** These provide the data on how species interact and how ecosystems function.
- **Social Sciences (Sociology & Ethics):** These analyze human behavior, cultural impacts, and the moral obligation to protect nature.
- **Economics:** This discipline focuses on "Sustainable Development"- finding ways to grow wealth without depleting natural capital.
- **Policy & Law:** This translates scientific and social needs into enforceable protections for the environment.

1.1.2 Natural Systems

Earth's natural systems are interconnected, working together like a symphony. Ocean currents, forests, and other systems play their part in the dance of life, weaving together air, water, soil, and living things into balance and diversity. These systems showcase Earth's elegance and complexity. The intricate bonds between mountain ranges, butterfly wings, and everything in between. They remind us that humans are but one part of Earth's fabric, reliant on natural rhythms. Through harmony and interconnectedness, Earth's systems speak of the beauty of evolution and inspire awe at the grandeur of life.

Biodiversity: In nature one can see many types of animals, birds, fish etc, not one category. There exists Species diversity for instance, a tropical rainforest is home to a vast array of species including trees, plants, insects, birds, mammals, reptiles, and amphibians.



Even dogs come in different types or breeds, each with its own special traits and characteristics. Biodiversity is not just about the number of species; it is the total complexity of life, categorized into three primary types:

1. Genetic Diversity

This refers to the variety of genes within a single species. This internal variation allows populations to adapt to changing environments and resist diseases.

- **Example:** Within a single species of rice, there are thousands of genetic varieties, each with different traits like drought resistance or grain color. Similarly, the subtle genetic differences among individuals in a human population or a pack of wolves represent genetic diversity.

2. Species Diversity

This describes the variety of different species found within a specific region or across the globe. It is the most common way people think of biodiversity.

- **Example:** The distinction between the African elephant and the Indian elephant. While they share a common ancestry, they are distinct species with different physical traits and habitats.

3. Ecosystem Diversity

This encompasses the variety of habitats, biological communities, and ecological processes in a particular area. It considers how species interact with their physical environment.

- **Example:** A single country like India contains vast ecosystem diversity, ranging from the Western Ghats' rainforests

and Himalayan alpine meadows to the Thar Desert and the Sundarbans' mangrove wetlands

The biodiversity of the Sahya Mountains, also known as the Western Ghats, is exceptionally rich and diverse. These mountains run parallel to the western coast of India, stretching across the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu. Here are some key points regarding the biodiversity of the Sahya Mountains:

Flora: The Western Ghats are recognized as one of the world's biodiversity hotspots, harboring thousands of plant species, many of which are endemic to the region. It is estimated that the Western Ghats are home to around 5,000 species of flowering plants, including many rare and endangered species.

Endemism: The Western Ghats have a high degree of endemism, meaning many species found here are unique to this region and are not found anywhere else in the world. This includes various species of trees, shrubs, herbs, and other plant life.

Fauna: The Sahya Mountains are also home to a diverse array of fauna. They support a rich variety of mammals, birds, reptiles, amphibians, and insects. Some notable species found here include the Bengal tiger, Indian elephant, Indian gaur (also known as the Indian bison), lion-tailed macaque, Nilgiri langur, Malabar giant squirrel, and various species of snakes and birds.

Protected Areas: The Western Ghats contain numerous protected areas - including national parks, wildlife sanctuaries, and biosphere reserves - aimed at conserving the region's unique biodiversity. These areas provide crucial habitats for many species and

serve as vital centers for scientific research. Key examples of these protected zones include:

- Silent Valley National Park
- Bandipur and Mudumalai National Parks
- Periyar Tiger Reserve
- Eravikulam National Park
- Agasthyamala Biosphere Reserve

By safeguarding these landscapes, we ensure the survival of endemic species that are found nowhere else on Earth.

The Amazon rainforest contains incredibly diverse species around 40,000 identified plant species and hundreds of mammals like jaguars, sloths, river dolphins and monkeys. This immense variety of genetically distinct plants, animals and habitats encompasses the concept of biodiversity.

Formally, biodiversity refers to the richness and variability of life forms on Earth across ecosystems at genetic, species, and habitat levels. High biodiversity is a hallmark of ecological complexity, interdependency, and resilience.

Preserving this diversity is crucial for several fundamental biological processes:

- **Evolutionary Progress:** It allows for continued genetic evolution.
- **Ecological Balance:** It maintains the delicate balance within food chains.
- **Resilience:** It provides ecosystems with the flexibility to withstand or "bounce back" from perturbations, such as disease outbreaks or climate fluctuations.

Conversely, declining biodiversity directly decreases the supply of ecosystem services—such as pollination, water purification, and carbon sequestration—that are essential for human welfare.



Fig 1.1.2 Amazon Rainforest



Fig 1.1.2 Biodiversity Museum, Vallakkadavu, Thiruvananthapuram,

Kerala is home to incredible biodiversity, with 5 national parks and 17 wildlife sanctuaries protecting habitats for a wide variety of flora and fauna. The parks and sanctuaries harbor over 30 species of mammals, including endangered species like tigers, Nilgiri tahrs, and Asian elephants. Hundreds of bird species can be spotted across sanctuaries like Thattekad and Peppara. Reptiles like snakes and lizards also thrive thanks to conservation efforts. Beyond the sanctuaries, Kerala contains diverse landscapes from grasslands to rainforests, supporting thousands of plant varieties and animal species. Though some wildlife populations face threats, new conservation initiatives aim to preserve Kerala's cherished natural heritage for future generations. The abundance and uniqueness of life make Kerala one of India's most captivating ecological destinations.

Ecosystem Services

Nature provides a vast array of benefits that underpin the quality of human life. These services are categorized into four primary types:

- ▶ **Provisioning Services:** These are the "products" obtained from ecosystems.
 - **Raw Materials & Energy:** Timber from forests, minerals, and fossil fuels.
 - **Medicinal Resources:** Approximately 25% of modern medicines contain active compounds derived from plants.
- **Basic Necessities:** Provision of food, fresh water, and soil for agriculture.
- ▶ **Regulating Services:** Benefits obtained from the regulation of ecosystem processes.
 - Examples include climate regulation, carbon sequestration, and the natural purification of air and water.
- ▶ **Supporting Services:** Services necessary for the production of all other ecosystem services.

- These include nutrient cycling, primary production, and the formation of topsoil.
- Cultural Services: Non-material benefits people obtain from ecosystems.
- These include spiritual enrichment, intellectual development, recreation, and aesthetic values.

While these services are essential, many resources - specifically groundwater, topsoil, and oil - are currently being consumed faster than their natural replenishment rates. To ensure these systems continue supporting life, it is vital to manage them within their regenerative capacities. Handled sustainably, these natural resources remain the foundation of human welfare.

In a forest ecosystem, diverse species ranging from trees, orchids, insects, and squirrels to mushrooms, interact with their non-living surroundings of soil, rainfall and temperature. Dynamic relationships within interconnected community members like predation of insects by birds enable the smooth functioning and productivity of the system. However, disruptions to components through human activities like deforestation, pollution or invasive species can be hugely detrimental to the balance of these complex ecosystems.

1.1.3 Scope of Environmental Studies

The drying of the Aral Sea, deforestation of Borneo's ancient rainforests, and bleaching of the Great Barrier Reef, for instance, showcase the devastating environmental impacts of human activities. Yet the growth of renewable energy, local community based conservation efforts, and global agreements affirm that solutions exist if we act collectively. Within these opposing narratives lies the essence of

environmental studies assessing humankind's relationship with nature, and analyzing causes of degradation, while catalyzing environmental action.

Environmental studies encompass scientific inquiry interwoven with social science and humanities scholarship to evaluate ecosystems, conservation strategies, climate change mitigation policies, energy transitions and sustainability frameworks. The field confronts issues like pollution, declining biodiversity, and resource depletion that threaten ecological balance. However, it also reveals opportunities for innovation, behavior change, and building resilient systems through global cooperation and local initiatives instilling optimism for a livable future.

Beyond technical analysis, environmental studies awaken a personal commitment to safeguarding the beauty, diversity and sustainability of the natural world. Much like conservation biologists moved to action after witnessing the declining health of beloved ecosystems, or communities mobilizing to protect local wetlands and forests, environmental consciousness stems from emotional affinity towards nature. It manifests as a call to action to curb excesses, nurture what sustains us, and mutually coexist with all life forms that enrich our planet. Just as ecological balance enables conditions for life to thrive, environmental studies brings hope by guiding humankind's collective responsibility towards sustainable living.

1.1.4 Understanding Environmental Processes

Consider a forest stream's gentle watering of fertile soil, enabling diverse trees and vegetation to seed, sprout and blossom on its banks. Such regenerative environmental pro-



cesses cycling water, carbon and nutrients sustain the forests, grasslands and aquatic ecosystems that harbour life. Yet today, excessive emissions and resource extraction overload nature's equilibrium. Understanding environmental processes awakens us to both the nuanced balance that allows birds, bees and bacteria to thrive, as well as the fragility stemming from ecological overshoot.

Beyond intellectual curiosity lives an emotional affinity with the natural systems that sustain us. As environmental education reveals the relationships between human actions and environmental consequences, it brings deeper resonance with the living fabric of our planet. We begin to comprehend our embeddedness within nature, not apart from it. This shifted perspective compels compassionate conservation of ecosystems through everyday stewardship actions. For only by knowing the land we inhabit, may we learn to nurture our shared home.

By understanding environmental processes, we find not only answers but also inspi-

ration a reminder of the awe-inspiring complexity and boundless resilience of the natural world.

Water Cycle: The flowing of water from ocean to air, to land, and back to the seas in rainfall and runoff highlights the interconnected water cycle that continuously purifies and redistributes Earth's fixed water supply. Understanding this recycling enables informed groundwater and watershed conservation efforts.

Carbon Cycle: Similarly, carbon flows between rocks, ocean, plants, soil and living organisms in a balanced cycle. However excessive carbon dioxide emissions from activities like deforestation and burning fossil fuels overload this equilibrium, contributing to climate change threats. Hence curbing carbon imbalances requires tracking its intricate environmental pathways through air, land and seas.

Nutrient Cycles: Cycling of nutrients like nitrogen and phosphorus also showcase ele-

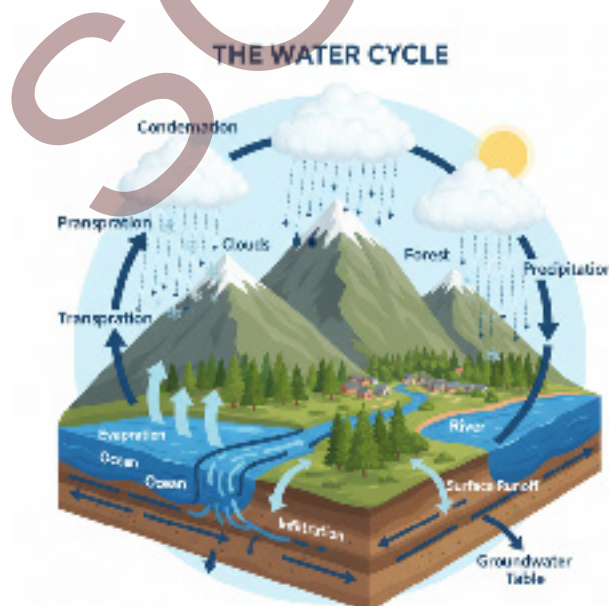


Fig1.1.4 A representative image of the water cycle

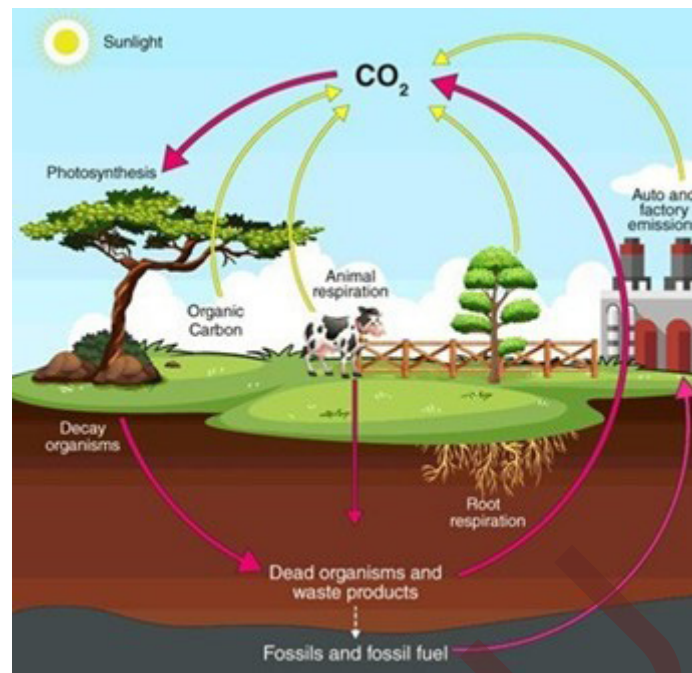


Fig 1.1.5 Diagram of Carbon Cycle

gant natural binding, processing and release in soils, vegetation and water bodies. Optimizing applications in agriculture while minimizing leaching can nurture this cycling of growth enablers and avoid issues like algal blooms in beloved lakes.

Water Management in Arid Regions: Studying ecosystems in arid regions involves understanding water scarcity issues, the impact on biodiversity, and the development of sustainable water management strategies.



Fig. 1.1.6 A community-managed check dam built on a stream passing through Pransla village in Gujarat

Water is precious in arid regions with little rainfall. In the semi-arid villages of Gujarat, India, the communities came together to better manage their limited water resources through voluntary labour. They constructed check dams, desilted ponds, and built barriers to capture rainwater runoff and allow it to percolate into the ground. This boosted groundwater levels, soil moisture, and well water availability. With more reliable access to water, farmers diversified their crops beyond traditional options like cotton and groundnuts. They now grow wheat, garlic, legumes and vegetables as well. Higher agricultural productivity has increased incomes. The success of these community-driven projects highlights how villages can work collectively to make the most of scarce rainfall in very dry areas. The structures built require continued maintenance, but with livelihoods improved, communities are motivated to upkeep them. Similar participatory approaches to water harvesting and conservation could be replicated elsewhere to help arid regions become more resilient.

(<https://www.downtoearth.org.in/news/water/community-driven-management-systems-offer-new-options-to-these-semi-arid-gujarat-villages-86425>)

Impact of Deforestation on the Carbon Cycle: The carbon cycle is the biogeochemical cycle by which carbon is exchanged between the biosphere, geosphere, hydrosphere and atmosphere of the Earth. A crucial part of this cycle involves carbon storage and sequestration by terrestrial sinks like forests. The Amazon rainforest, home to over half the planet's remaining tropical rainforests that sequester atmospheric CO₂ through photosynthesis, plays a vital role. However, rampant deforestation from clearing and burning trees releases stored carbon back into the atmosphere. This land use change in the Amazon is now a major anthropogenic source of CO₂ emissions, contributing to rising atmospheric greenhouse gas levels that drive climate change.

Deforestation and land clearing activities from agriculture, logging etc. have removed vast swathes of tropical rainforest coverage that would otherwise be absorbing CO₂. With less forest area and fewer trees left standing, the Amazon basin's photosynthetic capacity to fix CO₂ declines. The rapidly shrinking capacity

of this critical carbon sink poses huge risks to mitigation efforts against climate change on a global scale. As forests disappear, the planet loses an ecosystem intrinsically linked with regulating the Earth's carbon climate system. Preserving tropical rainforests like the Amazon through conservation is thus essential to curb emissions from forest destruction and protect their irreplaceable carbon storage and sequestration services.

Agricultural Nutrient Management: The intensive use of chemical fertilizers in agriculture has greatly boosted crop yields but also comes at an environmental cost. Excess inorganic nitrogen and phosphorus applied on farms generate substantial nutrient runoff that makes its way into ground and surface waters. When reaching rivers, lakes and coastal zones, this agricultural runoff spurs eutrophication and algae blooms, creating aquatic "dead zones" devoid of oxygen that threaten ecosystems and biodiversity. Carefully investigating nutrient cycles across agricultural landscapes provides insights into developing improved nutrient management strategies.



In the Amazon forest, the study found fires produced about 1.5 billion tonnes of CO² a year, with forest growth removing 0.5 bn tonnes. The 1 billion tonnes left in the atmosphere is equivalent to the annual emissions of Japan. (Source: theguardian.com)

Assessing fertilizer inputs, crop uptake ratios, nutrient accumulation in soils, and loss pathways via runoff and leaching enables quantifying farm-level nutrient balances. This understanding then aids in optimizing fertilizer application rates to crop needs based on soil fertility testing. Combining synthetic fertilizers with organic nutrient sources like cover crops and compost in integrated soil fertility management programs also help minimize external inputs. These practices reduce nutrient losses off farmlands and maintain the quality of surrounding waters. Managing agricultural nutrient flows sustainably boosts efficiency while curbing downstream pollution threats, underscoring how ecological knowledge aids synergies between food production and environmental health.

This way, the scope of Natural Systems within Environmental Studies encompasses

the study of ecosystems, biodiversity, and natural resources, along with a deep understanding of essential environmental processes like the water, carbon and nutrient cycles. This knowledge powers sustainable resource management while addressing ecological challenges.

1.1.5 Multidisciplinary approach

From oil spills poisoning ocean life to deforestation eliminating critical habitats, environmental challenges highlight the interconnectedness of natural systems. Consider the catastrophic impacts of invasive species establishing in new ecosystems or the compounding effects of climate change accelerating desertification. Examining such issues demands a holistic, collaborative approach.

Environmental Studies embraces this mul-



Fig 1.1.7 Nitrogen fertilizer being applied to a maize field in Iowa, United States

interdisciplinary perspective, drawing upon diverse fields to comprehensively understand and tackle environmental challenges.

a. Biology and Biodiversity

Wander through lush Western Ghat jungles and you might see a giant squirrel scurrying up a tall teak or through backwaters in Kerala and you glimpse the Green chromide (*Karimeen*) gliding through swirling tides. Such creatures dwell comfortably in Kerala's bound-

tiful habitats, yet alter these havens and their fate hangs in precarious balance. Each creature fits nature like a glove: the squirrel's strong claws grip bark; the fish's streamlined shape cuts water. Yet if vines choke the woods, the squirrel loses its home. If we pollute the backwaters, the *karimeen* die or must painfully migrate from waters they've always known.

Biology decodes nature's hidden connections preserving vibrant biodiversity balances. Studying interwoven food webs, tracking spe-



Fig 1.1.8 The widely-poached Asian brown tortoise in a Nagaland zoo. After a population decline, the zoo started captive breeding of the species. (Source: Deccan Herald)

Wildlife Protection Act, 1972

India is home to diverse flora and fauna found in forests, grasslands, and other natural habitats. However, due to anthropogenic interference such as hunting, exploitation, and habitat destruction, many species of animals, birds, and plants began to decline and faced threats to their survival. If this continued, several species would disappear from India, disturbing the balance of nature.

Therefore, to control over-exploitation and protect wildlife, the Government of India enacted the Wildlife Protection Act in 1972. Wildlife includes uncultivated animals, birds, plants, and trees. The Act provides rules and measures for their protection. It directs state governments to establish national parks and wildlife sanctuaries. National parks offer strict protection to wildlife, while wildlife sanctuaries also protect animals and birds but allow certain regulated human activities.

The law prohibits hunting, catching, or killing rare animals and birds, making it an offence punishable by law. It classifies animals, birds, and plants into schedules that determine their level of protection—ranging from high protection to those that can be hunted with special permits. A National Board for Wildlife, chaired by the Prime Minister, advises the government on wildlife protection policies. Additionally, the law has played a key role in tiger conservation through initiatives like Project Tiger, launched in 1973, which has helped increase tiger populations.

cies movements, and analysing their adaptation to fast changing climates help experts safeguard ecological resilience. Mapping trophic links enables better protection when habitats shift. Monitoring biodiversity provides early warnings to intervene for endangered plants and animals. Thus, biology equips us to not only understand but thoughtfully conserve a region's dazzling natural heritage for generations to come.

b. Environmental chemistry

The rivers of Kerala, once pristine, now suffer from industrial effluents and plastic waste. As we gaze upon filmy waters, consider how environmental chemistry protects what we cherish. This field analyses chemical pollutants in nature, augmenting our power to preserve beauty. Environmental chemists

reveal hidden truths by examining air, water, and soil. Understanding pollutants requires careful study - unraveling their composition, behavior, and toxicity. This involves investigating their chemical reactions. With this knowledge, we can trace pollution to its sources and track its movement through the environment.

New research reveals mangroves and salt marshes store remarkably high levels of carbon, doubly more than prior estimates. These coastal habitats substantially reduce greenhouse gas impacts. The University of Gothenburg study underscores the vital role such ecosystems play in climate change mitigation. (Source: eurekaalert.org)

Mercury has value in medicine yet harms life when concentrated up food chains. Pes-





Fig 1.1.9 Mangroves in Munroe Island, Kerala

pesticides boost crops but also damage ecosystems. Environmental chemists study these toxins how they move, transform, and impact the living world. This knowledge leads to protective rules and clean-up methods, sustaining nature's web of life. From climate change to plastics, environmental chemistry measures key problems and solutions. The science informs policy and action to safeguard the health and beauty of the Earth. For the land we inherit, the children to come, we must thoughtfully build capacity in this field.

c. Physics for Environment Protection

Farms in southern India bake under intense heatwaves. Once fertile lands now lie barren

without farming. Physics provides insight into stabilizing such climate shifts and preventing more harm. By studying Earth's atmosphere and energy flows, physicists reveal what drives weather patterns, monsoons, and melting ice. This sheds light on both human impacts shifting storms and seas, and nature's delicate balances. Physics maps the carbon cycle and quantifies the complex processes, like sunlight piercing through haze, that sustain Earth's harmony. From advancing clean energy to predicting disasters, physics enables responsible stewardship of our shared planet. To build resilience against increasing climate disruptions, we must foster an appreciation of physics across all communities

Quantum Computing and Climate Change

Our world is getting warmer every year due to climate change. This is happening because certain gases like carbon dioxide are trapping heat from the sun. Many of these gases are produced from the use of oil, coal and gas to run our cars, trains, factories and homes. To reduce climate change, we need to cut these emissions. But it is hard to quickly change most cars, trains, factories and homes to stop using these fuels. Even when trying to switch to cleaner energies like solar and wind power, it takes a lot of complex calculations to figure out the best way forward.

This is where quantum computers can help. Normal computers have limitations in how

fast they can process complex problems with lots of possible solutions. But quantum computers work very differently and can try out many solutions all at the same time. This allows them to solve problems much faster. For example, quantum computers could calculate the most efficient way to capture carbon emissions at factories and store them safely underground. They could also design better clean energy systems like smart electricity grids between cities and optimize wind farm sites. In transportation, quantum computing could figure out how to make lighter vehicles that go further on a single charge. It could also plan transportation networks and shipping routes to have the lowest environmental impact.

Quantum computing has started helping in some areas but the technology is still new. As bigger and more powerful quantum computers are built, they are expected to help tackle climate change in many more ways.

1.1.6 Social Sciences and the Environment

a. Anthropology and Nature

The San, known as the world's most ancient race, are an indigenous tribe who have roamed southern Africa for over 20,000 years. They hunt wildlife like kudu antelope but gather plant foods most days, plucking berries or digging up roots. The land provides plenty, yet the San are careful not to take the excess. They rotate hunting areas so animals can recover and spread seeds as they go. At night around the fire, San children listen as elders share ancient tales about the connectedness of all beings animal, plant, and human. Their stories teach that if you care for nature then nature will care for you in return. But if you disrespect the animals, the rainfall might cease as punishment. The gods above made a pact with the first San peoples to watch over the land together.

Studying tribes like the San, anthropologists uncover wisdom used for a very long time to sustain life in harmony with the wild. Modern generations can learn a simpler, more joyful way to live from San's model. We, too, can form a friendship pact with the living

Earth, turning daily habits into small acts of gratitude through gentle gathering, mindful hunting, and rotating spaces of use to enable regeneration. We might discover that nature can provide all we need if only we befriend her first as our ancestor, our nurturer, and our life long companion.



Fig 1.1.10 The San People

b. Sociology and Environmental Protection

In recent years, many around the world have protested, asking governments and companies for stronger climate action. Sociologists study



Fig 1.1.11 Climate protesters marching in Brussels, Belgium in 2018

these movements to understand views on our duty to the Earth. Surveys conducted after protests show that most people feel policymakers do not adequately protect the future rights of young people. Many express moral shock that ongoing pollution unjustly disrupts the global climate that we all share. Others emphasize a spiritual role as stewards who care for nature. Overall, protesters view humans as guardians, not masters, of nature

However, some groups oppose reforms aimed at limiting corporate environmental damage. Studies examine the values underlying this resistance to change. Findings show climate scepticism often links more to politics than facts. Many prioritize personal over collective well-being. Yet as floods, fires and shortages grow, public opinion increasingly supports green regulations. Facing calamities teaches societies that ecology supports economy and community resilience too.

Sociologists believe supportive cultural mindsets and economic policies can enable sustainability. Grassroot networks pioneer

local renewable energy, food cooperatives and green housing, showing people power for change. If stewardship becomes a shared duty between generations, lifestyles and systems can nurture the earth for all life. Our ties with nature reflect our ties to each other.

c. The Green Economy

Typically, economic progress has come with some tradeoffs against environmental quality. But what if economic development could improve environmental sustainability? The green economy concept represents a shift toward viewing environmental goals as aligned with, rather than opposed to economic prosperity. This paradigm sees conservation, renewable resources and clean technologies not as burdensome costs but as prudent long-term investments. Beyond risk mitigation, sustainability targets like carbon neutrality and circular supply chains can spur innovation, competitiveness, job creation and other economic goods. Policy reforms and subsidies to support renewable energy, regenerative agriculture, eco- tourism and other green market



Fig 1.1.12 A Forest walkaway in Zuhoui Park, China. The 19 km-long elevated footpath in a forest offers people a good place to spend their leisure time

segments redirect investment, consumption and workforce skills toward environmentally sound outcomes.

The green economy thus introduces new metrics and incentives around ecological principles to transform how we produce, distribute and trade goods and services. It measures economic progress not just through GDP and income, but factors like resource efficiency, pollution control and nature preservation. It aims to promote prosperity while respecting planetary boundaries. This transition brings challenges around stranded assets, job transitions, competitiveness, and the feasibility of shifting consumer values. And tensions persist over balancing public good regulations

versus market-driven solutions. However, the underlying recognition is that the health of the environment and the health of the economy are intrinsically bound.

Politics: Developing Green Policies

Big environmental problems face India terrible air pollution in cities like Delhi, plastic rubbish everywhere that won't rot away, and meeting the country's huge need for energy by burning fossil fuels like coal. Coming up with green policies is really important but also hard politically. For example, eliminating subsidies that keep fuel prices low provokes public anger, promoting renewable energy clashes with the powerful coal industry. Banning certain

A Green Economy Model by CIAL Kerala

The Cochin International Airport in Kerala has become the world's first fully solar-powered airport. Giant solar panels spread over 45 acres generate 50,000 to 60,000 units of clean electricity daily – enough to meet all the airport's energy needs. In 2018, the United Nations awarded Cochin Airport the prestigious 'Champions of the Earth' prize for its pioneering solar initiatives. Such trailblazing projects demonstrate that a green future is possible today with existing technology.



Fig 1.1.13 Aerial view of the solar farm operated by Cochin International Airport Limited

But the airport hasn't stopped innovating for sustainability. Solar panels now also double up as shaded covers for vegetable cultivation using run-off water. Floating solar panels were installed on the airport's golf course lakes too. In just one year, Cochin Airport's solar energy capacity has doubled to over 50 megawatts. This avoids nearly 2 million tons of carbon emissions annually equivalent to the oxygen produced by growing 46 lakhsaplings for a decade!

Cochin Airport proves that waiting for futuristic tech is no excuse for climate inaction. With imagination and commitment, we already have all the tools required for a sustainable world today whether solar farms on runways or green roofs atop buildings. The future is as bright as the tropical Sun shining above India's pioneering solar airport.

plastics upsets small businesses. But politics is central to making environmental progress happen. As Mahatma Gandhi said, the Earth gives enough to meet every person's needs but not endless greedy wants. Politics shapes the rules, taxes and spending on interests like sustainability. It determines whether we act out of need or greed; self-interest or greater good; short term gains or long term planetary health.

Political scientists study how different government systems and ideologies impact policy making on issues like air, plastic and clean en-

ergy. India's democracy allows green movements to influence politics but vested interests still dominate decisions. Understanding what drives and blocks politicians is key to turning public concern into real world action. So grassroots activism and media coverage must shape incentives as well as propose workable solutions.

Moving forward requires politicians looking beyond narrow self-interest and citizens demanding accountability to future generations. With rising environmental awakening



Fig 1.1.14 'Mana Foresta' in Bangalore is the first ever vertical forest housing in India, and it is what the company calls a balance between comfort, convenience and nature

Vertical Forest is an innovative architectural concept that involves constructing high-rise buildings in urban areas with vegetation covering much of their exterior facades. Developed by Italian architect Stefano Boeri, the first Vertical Forest buildings were constructed in Milan featuring trees, shrubs, and plants of different varieties planted across balconies and terraces up and down the towers. The key goals of Vertical Forest are to improve air quality, reduce energy costs, decrease urban heat impacts, create habitat for birds and insects, and promote the well-being benefits of natural surroundings in cities. Careful botanic planning and maintenance are needed to ensure the greenery can thrive at different altitudes and exposures on the complex structures. The concept aims to seamlessly integrate forests and ecosystems into dense city spaces through creative building design. The governments and policymakers should come up with innovative ideas like Vertical Forest that fulfil our journey towards developing green policies.

globally, we've reached a critical juncture. The coming years may determine whether politics accelerates efforts to tackle issues threatening life on Earth or obstructs them. We all have a role to play.

Psychology: Shifting Mindsets to Protect the Planet

India faces huge environmental troubles from terrible city air pollution to rivers choked with plastic waste. Yet the people react very differently. Some people wear masks while

others casually burn rubbish in the open. Green activists get arrested trying to stop deforestation but neighbours stay passive. Psychology helps explain these opposites. Take air pollution for instance. Doctors all agree Delhi's smog is dangerous, especially for kids. But many residents still burn garbage outside. The science makes people uncomfortable since it doesn't match their own actions making the problem worse. Blaming the government comes easier than admitting our personal role.

The way people think shapes how they re-

act to climate change. The psychologist Sarah Thomas found two mindset types believing intelligence is fixed or can grow with learning. “Fixed mindsets” feel too small to solve big problems. “Growth mindsets” see potential through step-by-step progress. Facing environmental crisis can seem hopeless. Challenges look too massive for one person’s actions. But a “growth mindset” believes small daily choices cumulatively drive big transformations. As the British natural historian Attenborough said: “The problem is immense, but we already have the knowledge and skills to halt and reverse it. We need to re-examine our relationship with nature, working with it instead of against it, to restore our planet to its former glory.”

Lots of advertising pressures us to over-consume without worrying about the planet. Companies spend billions convincing us buying more brings happiness. They promote myths like convenience matters most, or an item’s cheap price means throwaway value.

But convenience has hidden downsides like pollution and waste too. Price doesn’t show the wider value of public goods like clean air or nature. Lasting happiness comes from beyond materialistic possessions.

Rethinking these assumptions of consumer culture brings psychological benefits: (a) Empowerment Controlling consumption gives a sense of empowerment against marketing tactics. Just refusing a plastic straw makes an impact. We regain agency over voices telling us to buy unneeded things. (b) Knowledge Understanding how products get made builds concern over waste. (c) Community Sustainability groups have an open culture focused on shared goals around responsible living, not profit first mentalities. Working towards common aims connects people.

In this way, climate psychology matters. Those skeptical of individual impact have a “fixed mindset”, unable to see their role creating change through example whether using

Climate change will harm children’s mental health: The American Psychological Association’s report

The American Psychological Association’s and Eco America’s 2023 report “Mental Health and our Changing Climate: Children and Youth Report” says that the climate crisis negatively impacts children’s mental health in many ways. Wildfires, floods, and heatwaves traumatize kids directly. Extreme weather also displaces families, destroys homes and communities, and disrupts schooling – all damaging to wellbeing. Moreover, worsening air pollution from events like wildfires increase risks for developmental issues and mental health conditions. A hotter planet also breeds anxiety, depression and stress about the future. Children feel angry at leaders failing to address threats to their lifetime prospects.

Adults must listen to climate concerns without dismissal, have age-appropriate conversations, and provide outlets for impactful action. Attending protests can empower kids to see themselves as part of vital causes. Doctors should ask about climate feelings, limit news exposure if causing anxiety, and supply appropriate resources. Climate change interlinks environmental and mental health. We must support youth facing ecological unraveling that threatens emotional wellness well-being and development.

voice or changing habits. Small committed groups can shift wider norms. Growth mindsets can inspire the authorities to take actions. The task is huge but within reach if we support each other towards planet-protecting choices.

Need for an Interdisciplinary Approach

Thus, solving today's environmental crisis requires a perspective that connects the dots between complex systems. Laws and policies should integrate ecological science to understand planetary boundaries, while still adapting based on sociological feedback from citizens to promote fair, inclusive outcomes. At the same time, shifting cultural narratives and social perceptions can empower both grass root lifestyle changes and the political will needed for wider transformation. Together, the insights from interconnected disciplines within the social sciences spanning psychology, sociology, anthropology and more provide navigation tools for charting a path towards sustainability in a world inherently defined by interwoven systems across societies, economies, and environments. By elevating our vantage point to see these myriad interdependencies clearly, a web of solutions can emerge.

Scientists, policymakers, economists, sociologists, and experts from various fields bring unique perspectives and methodologies to the table, enriching the understanding of environmental problems and enhancing the effectiveness of solutions. For instance, scientists provide insights into ecological processes, economists analyze the cost-effectiveness of environmental policies, sociologists study human behavior and societal responses to environmental change, and policymakers navigate the complex landscape of governance and regulation. By fostering interdisciplinary collaboration, environmental studies harnesses the collective wisdom and expertise needed

to address pressing environmental challenges comprehensively and sustainably.

1.1.7 Concepts of climate and weather

For thousand of years, the Earth's atmosphere remained relatively stable, but today, maintaining its balance poses challenges. Dangerous materials are rapidly increasing in the atmosphere. Since the Industrial Revolution (late 18th to early 19th centuries), human activities such as transportation, agriculture, fossil fuel usage, waste disposal, deforestation, power generation, land use changes, biomass burning, and industrial processes have contributed significantly to the change.

It's April in Mumbai and you awake before dawn without need for an alarm, the humidity already announcing the coming heat. Stepping onto your balcony you feel the air thick and still, promising another blistering day ahead. Yet the forecast shows likelihood of relief a major thunderstorm rolling in by early afternoon as moisture gathers from the Arabian Sea.

Shift instead to Leh, high in the arid Trans-Himalayan valley, where the July air remains crisp and bone dry. The morning sun sears with intensity rivalling noontime anywhere, its penetrating light bearing down on brown rolling peaks dotted with green where glacier-fed streams cut through. By late afternoon, patches of azure appear as the monsoon takes aim, soon unleashing its deluge upon the parched land.

Beyond lived experience, what scientifically differs weather from climate? Weather describes atmospheric conditions at a specific place and time temperature, rain, wind and more. Highly localized and transient, weather



Weather and Climate

As climate chaos accelerates, enhancing our conceptual comprehension grows ever more critical. Weather and climate remain distinct disciplines: meteorology focuses hourly atmospheric dynamics driving weather, while climatology studies how these system interactions manifest over decades as regional and global climate trends. Public confusion between weather and climate thrives however. Politicians leverage seasonal cold snaps to claim climate change a hoax, neglecting to differentiate between isolated weather fluctuations and the inevitable rise of global average temperatures. No singular hot or wet summer proves long-term climate shift alone, but only multidecadal trend analysis.

changes by the hour and day as air masses collide, frontal boundaries shift, and storms erupt or fade. Climate represents weather patterns over decades, the long-term averages and extremes of meteorological variables in a region. While weather dictates your outfit today, climate influences entire landscapes over generations from tundra to rainforest to desert.

United Kingdom enjoys a temperate maritime climate, despite highly variable weather on any given day. Compare the arid climate of Egypt's Nile Valley, with minimal rainfall but year-round sunshine. Local weather events bring the odd thunderstorm or sandstorm, but the regional climatic norms enable agriculture and settlement dependent on the great river. Beyond geography, climate also shifts temporally according to natural cycles so London once experienced a "Little Ice Age" and Egypt a "green Sahara" period.

Weather's unpredictable variability makes daily experience exciting but planning difficult. By charting climatic norms and extremes, we grasp expected conditions for travel, infrastructure, urban design and farming over long periods. So climate change now threatens systems balanced finely across centuries by incremental natural shifts, with rapid temperature and precipitation transformations that outpace ecosystem and social adaptation.

Equally, media grabs public attention via extreme weather events like floods and heatwaves, while the slow burn cascading consequences of creeping drought or sea level rise gather less reaction. Landmark political moments have emerged after public weather trauma - the great Mississippi floods of 1927 prompted shifts in US flood control policy for example. So perhaps witnessing this century's unprecedented weather extremes may finally spur commensurate climate action.

The statement you provided explains the intricate relationship between seemingly unrelated events, such as a butterfly flapping its wings in Brazil and the formation of a tornado in Texas. This concept originates from chaos theory, which suggests that small changes in initial conditions can lead to significant and unpredictable outcomes in complex systems like weather patterns. The butterfly effect illustrates how interconnected our world is, emphasizing that even minor actions can have far-reaching consequences across time and space.

Furthermore, the statement underscores the dynamic nature of weather variability against the backdrop of shifting climatic norms. Weather patterns are influenced by broader changes in climate, and understanding these interactions is crucial for navigating our rapidly transforming environments. By grasping

The wisdom of an ancient Native American proverb reminds us: “We do not inherit the Earth from our ancestors, we borrow it from our children.” This saying holds profound truth today, highlighting how our actions impact not only the present but also the well-being of future generations. It’s clear that human activities and their effects on the environment shape conditions for years to come. We must consider how our choices today, particularly regarding Earth’s climate, will shape the world our children and grandchildren inherit.

In the past, Mark Twain humorously remarked, “Everyone talks about the weather, but no one does anything about it.” However, this statement is no longer accurate. Human activities are altering the Earth’s climate, which in turn influences local, regional, and global weather patterns. Scientists emphasize that while climate is what we anticipate over time, weather is the day-to-day reality. Climate change occurs as the long-term average weather shifts in specific areas, regions, or across the entire planet. Understanding these dynamics is crucial for addressing the challenges posed by climate change and safeguarding the planet for future generations.

the complexities of atmospheric systems as a dynamic interplay across spatial and temporal scales, we gain valuable insights into the behaviour of weather systems and the impacts of climate change.

Ultimately, this understanding extends beyond mere academic interest; it has practical implications for daily life and public policy. Recognizing the interconnectedness of at-

mospheric systems allows us to make more informed decisions, whether it’s planning for extreme weather events, managing natural resources sustainably, or crafting policies to mitigate the effects of climate change. In essence, appreciating the complexity of weather and climate dynamics provides us with a lens through which we can navigate and respond to the challenges of our ever-changing world.



Recap

- ▶ Earth's natural systems work in harmony through processes like nutrient and water cycling
- ▶ Biodiversity provides ecosystem services essential for human welfare
- ▶ Natural resources like water, soil, forests support quality human life
- ▶ Environmental studies integrates science, social sciences to address ecological issues
- ▶ Understanding environmental processes like carbon cycle enables sustainability
- ▶ Biology analyzes biodiversity and food webs to protect ecological resilience
- ▶ Environmental chemistry studies movement of toxins and pollution
- ▶ Physics quantifies Earth's energy flows and climate change drivers
- ▶ Social sciences evaluate behavioral and policy dimensions around environment
- ▶ Interdisciplinary collaboration needed for effective eco-solutions
- ▶ Weather describes short-term atmospheric conditions
- ▶ Weather changes due to temperature, precipitation, and wind,
- ▶ Experiences over hours to days.
- ▶ Weather is characterized by its dynamic and often unpredictable nature,
- ▶ Reflects the immediate state of the atmosphere.
- ▶ Climate long term weather patterns and averages
- ▶ Climate influenced by natural variations and human actions.
- ▶ Human emissions are altering regional climates and ecosystems

Objective Questions

1. What does biodiversity refer to?
2. Which gas do trees take in during photosynthesis?
3. What field analyzes toxins and pollution?
4. What concept aims for sustainability with prosperity?
5. What variable is changing due to fossil fuel use?
6. What recycles water through the environment?

7. What shift is disrupting balanced ecosystems?
8. Which field studies energy flows on Earth?
9. What approach is needed to solve eco-challenges?

Answers

- | | |
|------------------------------------|----------------------|
| 1. Richness of life forms on earth | 6. Water cycle |
| 2. Carbon dioxide | 7. Climate change |
| 3. Environmental chemistry | 8. Physics |
| 4. Green economy | 9. Interdisciplinary |
| 5. Temperature | |

Assignments

1. Explain why preserving biodiversity is important with examples of how declining biodiversity can impact human welfare.
2. Discuss how environmental chemistry helps analyze and address pollution issues through examples of studying contaminants like mercury.
3. Analyze the shifts in economic thinking underlying the green economy paradigm and how it aims to balance prosperity with sustainability.
4. Assess the role of interdisciplinary collaboration in enhancing the understanding of environmental problems and effectiveness of solutions.
5. Evaluate how transformations in climatic patterns due to human activities are
6. disrupting balanced ecosystems using specific evidence.
7. Differentiate between the concepts of weather and climate using illustrative examples contrasting their characteristic features.



Suggested Reading

1. Dickinson, G., & Murphy, K. (2007). *Ecosystems: Routledge introductions to environment*. Routledge.
2. Guha, R. (2000). *Environmentalism: A global history*. Longman.
3. Leopold, A. (1949). *A Sand County almanac and sketches here and there*. Oxford University Press. (Focus on "The Land Ethic").
4. United Nations Environment Programme. (2021). *Making peace with nature: A scientific blueprint to tackle the climate, biodiversity and pollution emergencies*. <https://www.unep.org/resources/making-peace-nature>
5. World Wide Fund for Nature. (2024). *Living planet report 2024: A system in peril*. WWF International.

Reference

1. Bharucha, E. (2021). *Textbook of environmental studies for undergraduate courses* (3rd ed.). Universities Press.
2. Cunningham, W. P., & Cunningham, M. A. (2020). *Principles of environmental science: Inquiry and applications* (9th ed.). McGraw-Hill Education.
3. Miller, G. T., & Spoolman, S. (2018). *Environmental science* (16th ed.). Cengage Learning.
4. Odum, E. P., & Barrett, G. W. (2005). *Fundamentals of ecology* (5th ed.). Cengage Learning.
5. Wright, R. T., & Boorse, D. F. (2017). *Environmental science: Toward a sustainable future* (13th ed.). Pearson.

Unit 2

Renewable and Non-renewable Resources

Learning Outcomes

By the end of the unit, the learner will be able to:

- ▶ distinguish between renewable resources and non-renewable resources
- ▶ classify energy sources like hydropower and biomass as renewable, understanding their ability to sustainably generate power over time.
- ▶ explore the environmental benefits of renewable resources, contrasting them with the environmental impacts of non-renewable resources like nuclear and fossil fuels.
- ▶ assess the long-term sustainability of various energy sources, considering factors such as resource availability, environmental impact, and technological advancements.

Prerequisites

Imagine a lush forest teeming with life, where sunlight filters through the canopy, nourishing the plants below. In this vibrant ecosystem, myriad plant and animal species thrive in harmony. Monkeys swing from branch to branch, colourful birds flit among the foliage, and frogs croak near babbling streams. Rivers flow steadily, providing water for drinking, irrigation, and hydropower. Birds chirp, insects buzz, and the ecosystem hums with vitality.

The rainforest is a prime example of renewable resources at work. Sunlight fuels photosynthesis, enabling plants to grow and produce oxygen. Rivers and streams, fed by rainfall, sustain a delicate balance of aquatic life while providing essential resources for human communities downstream. Fields of golden wheat, lush green vineyards, and rows of leafy vegetables stretching towards the horizon are nature's common sights. Farmers toil under the sun, cultivating crops that nourish billions around the world. These agricultural landscapes exemplify renewable resources in action. Sunlight, rainwater, and fertile soil combine to support the growth of crops year after year. Through sustainable farming practices, farmers can ensure the longevity of these vital resources for future generations. This ecosystem represents renewable resources, constantly replenished by natural processes.



In contrast, picture a vast desert landscape stretching as far as the eye can see, where oil rigs pump tirelessly, extracting fossil fuels buried deep beneath the earth's surface. The landscape bears the scars of mining operations, with polluted air and contaminated water sources. This stark scene epitomizes the exploitation of non-renewable resources, finite treasures extracted at great cost to the environment. Picture a rugged mountain scape marred by open-pit mines and slag heaps, where heavy machinery gouges the earth to extract precious metals and minerals. Toxic runoff seeps into nearby waterways, contaminating aquatic habitats and endangering the health of surrounding communities. The once-pristine wilderness is now marred by pollution and ecological devastation. This scene serves as a stark reminder of the consequences of exploiting non-renewable resources. While mining operations may yield valuable resources in the short term, they exact a heavy toll on the environment and future generations.

The juxtaposition of renewable and non-renewable resources highlights the importance of sustainable resource management. By prioritizing renewable energy sources and adopting eco-friendly practices, we can mitigate environmental degradation and build a more resilient and equitable future for all. Resources are the lifeblood of human civilization, providing the raw materials and energy necessary for survival, growth, and progress. They encompass everything from air and water to minerals, fuels, and agricultural products. Without resources, society as we know it would grind to a halt.

Keywords

Renewable Resources, Non-Renewable Resources, Sustainability, Fossil Fuels, Bioenergy, Geothermal Energy, Environmental Impact

Discussion

1.2.1 Concepts and major types of natural resources

You pay for everything you purchase from the market. What are the things that you get from nature without paying? They are natural products. Common examples of natural resources include air, sunlight, water, soil, stone, plants, animals and fossil fuels. Natural resources can be defined as the resources that exist (on the planet) independent of human actions. The five most important natural resources are:

1. **Air:** Clean air is important for all the plants, animals and humans to survive on this planet.
2. **Water:** 71% of the Earth is covered in water and only 2 % of that is fresh water.
3. **Soil:** Soil is composed of various particles and nutrients. It helps plants to grow.
4. **Iron:** It is made from ores and is used to build strong weapons, instruments and buildings
5. **Forests:** Forests provide clean air and preserve the ecology of the world.

Resources, such as sunlight, wind, water, biomass, and geothermal energy, have the remarkable ability to replenish themselves over time. For instance, solar energy is inexhaustible as long as the sun continues to shine, and wind power relies on the perpetual movement of air currents. These resources offer a sustainable alternative to finite fossil fuels and minerals. Resources encompass any material or substance that fulfils human needs and desires. They can be classified into two broad categories: renewable and non-renewable resources. Renewable resources are those that can be naturally replenished through ongoing processes, while non-renewable resources are finite and irreplaceable.

Fossil fuels like coal, oil, and natural gas,

formed over millions of years from organic matter, are prime examples of non-renewable resources. Once extracted and burned for energy, they cannot be replaced within a human timescale. Similarly, minerals such as iron, copper, and gold are finite deposits that cannot be replenished once depleted. Non-renewable resources, are thus finite and exhaustible.

Understanding the distinction between renewable and non-renewable resources is paramount for fostering sustainable development and environmental conservation. By harnessing renewable resources responsibly and minimizing reliance on non-renewable ones, we can pave the way for a more equitable, prosperous, and environmentally sustainable future.

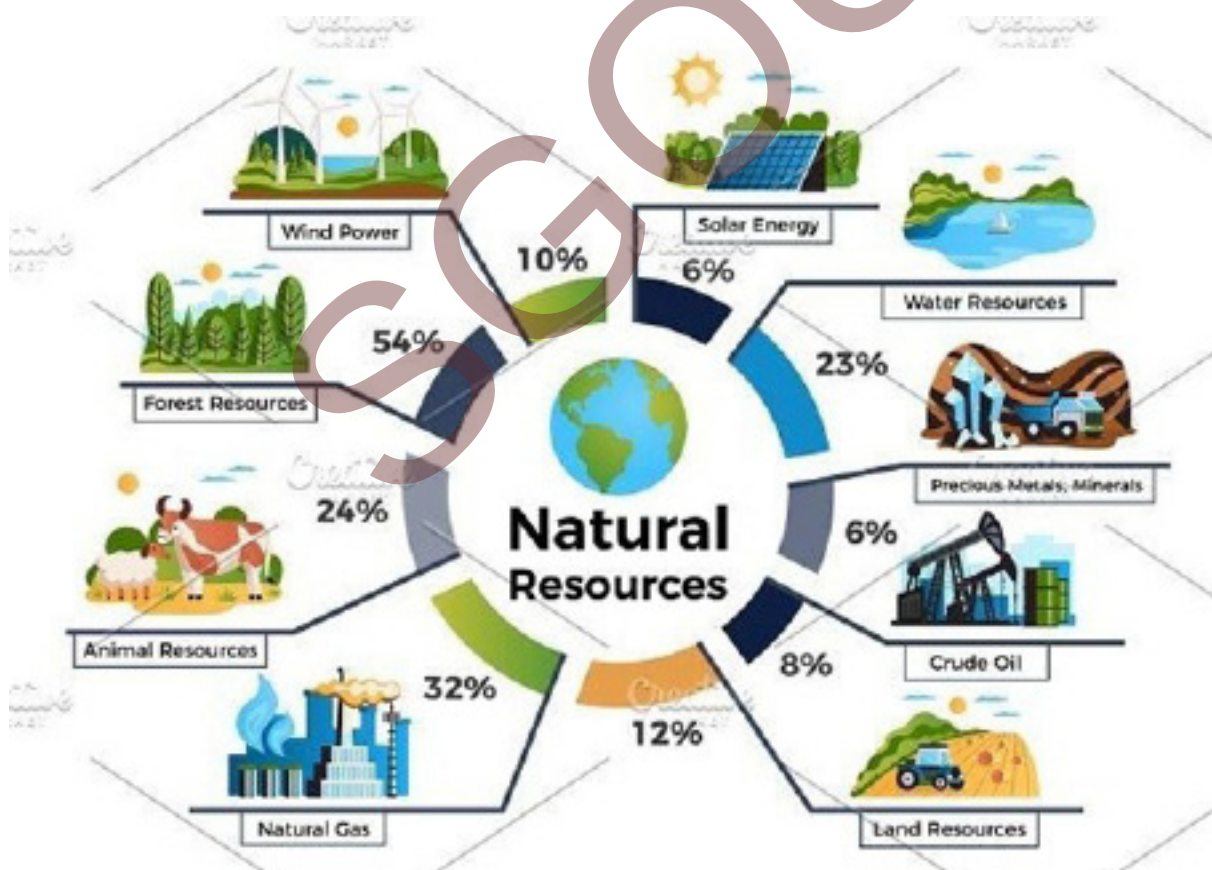


Fig 1.2.1 Natural Resources

Basis of Difference	Renewable Resources	Non-Renewable Resources
Definition	Resources that are available in abundant or infinite quantity and can be replenished naturally over time.	Resources that are limited in quantity and cannot be easily replenished once exhausted.
Availability	Available continuously or can be renewed within a short period.	Available in fixed amounts; their supply may run out in the future.
Exhaustibility	Generally not exhausted if used wisely and sustainably.	Can get exhausted due to overuse and cannot be replaced quickly.
Time for Formation	Formed or replenished within a short span of time through natural processes.	Take millions of years to form and cannot be regenerated within a human lifetime.
Environmental Impact	Usually environment-friendly and cause less pollution.	Often cause pollution and environmental degradation when used.
Examples	Forests, wind, water, solar energy, wildlife.	Coal, petroleum, natural gas, minerals.

1.2.2 Importance of Natural Resources

Natural resources are very important for the survival and development of mankind on this Earth. The importance of natural resources in human life is mentioned below:

1. They provide us with air to breathe.
2. Land for cultivation and growing food products.
3. Sunlight gives us solar energy, which is an important alternative source of energy.
4. Oil and natural gas give us fuel which are used in many industries and vehicles.
5. Minerals which are used as fuel and raw materials, like coal, iron ore, etc.
6. Valuable materials like gold and diamonds which are used for the jewellery industry and in many mechanical equipment.
7. Forest provides us with food, timber,

fuel, and it is a shelter for many living organisms.

8. Natural resources help in industrialization and urbanization.
9. Dams which are built on rivers prevent flood, provide proper irrigation, development of fishing industry and electricity generation.

1.2.3 Threats to Natural Resources

The major threats to natural resources are:

1. Overpopulation
2. Over exploitation
3. Climate change
4. Environmental Pollution

1.2.4 Conservation of Natural Resources

Conservation of natural resources is a procedure of protection and skillful management

to preserve the resources provided by nature. The methods that can be used to conserve the natural resources are mentioned below:

1. Reduce, reuse and recycle. The 3R should always be followed.
2. We should take part as volunteers in cleaning up our community.
3. Water should not be wasted, and rainwater should be harvested for future use.
4. Ponds and lakes should be preserved in a clean state, and maintenance activities should occur more regularly.
5. Dams and water reservoirs should be built. (This could have negative implications as well)
6. Deforestation should be stopped.
7. Natural resources should be used more efficiently.
8. Public awareness of the importance of natural resource conservation should be developed.
9. Use of alternative forms of energy Need to be encouraged.
10. Controlled plantation of trees which is suitable to the particular ecology needs to be studied and implemented.
11. Pollution should be controlled by using electric vehicles and alternative forms of energy.
12. Laws on the preservation of natural resources should be strictly implemented.

1.2.5 Renewable Resources

1.2.5.1 Solar Energy

Imagine a solar panel on a rooftop converting sunlight into electricity. This process relies on the continuous and abundant energy provided by the sun, making solar power a renewable resource. Solar energy is derived from the sun's radiation. It is harnessed through technologies like solar panels to generate electricity or for direct heating purposes. Solar energy, a prolific and sustainable source, is captured through technologies like photovoltaic cells or solar thermal systems. Its low environmental impact and scalability make it a key player in reducing dependence on fos-

Did you know that the amount of solar energy reaching the Earth's surface in just one hour is equivalent to the total global energy consumption for an entire year? According to data from the International Energy Agency (IEA), the world's total primary energy supply in 2020 was approximately 168,000 terawatt-hours (TWh). In contrast, the solar energy reaching the Earth's surface is estimated to be around 173,000 terawatts (TW) per hour.

This staggering statistic underscores the immense potential of solar energy as a clean and abundant renewable resource. With advancements in solar technology and increased deployment of solar panels, harnessing even a fraction of this solar energy could significantly reduce reliance on fossil fuels, mitigate climate change, and transition toward a more sustainable energy future. By tapping into this vast and virtually limitless source of energy, countries around the world have the opportunity to accelerate the transition to clean energy systems, create green jobs, and improve energy access for communities worldwide.





Fig 1.2.2 Solar Panel

sil fuels. In India, solar energy is harnessed in large-scale solar parks, rooftop installations, and for applications like solar water heaters. Examples: Solar water heaters, solar cookers, and solar-powered vehicles.

1.2.5.1.1 Advantages of consumption by Solar energy

1. Unlimited supply,
2. Does not produce air, water, thermal, and noise pollution,
3. No danger of large-scale disasters,
4. Conserves earth's resources and
5. Technology is available for immediate use.

1.2.5.1.2 Disadvantages

1. Solar cells are more expensive.
2. They cannot completely replace the conventional fuels.

1.2.6 Wind Energy

Picture a vast wind farm with spinning

turbines harnessing the wind's energy. The wind constantly renews itself, allowing these turbines to generate electricity continuously. Wind energy is generated by harnessing the power of the wind through wind turbines. The kinetic energy of the wind is converted into electrical energy. Harnessing the kinetic energy from the wind, wind energy utilizes turbines to generate electricity. With advantages such as cleanliness, low greenhouse gas emissions, and long-term cost-effectiveness, wind energy has seen widespread use in India. Wind farms are prominent in states like Tamil Nadu and Karnataka, contributing significantly to the country's renewable energy mix.

Windmills, iconic symbols of renewable energy, have evolved from simple mechanical devices to sophisticated turbines harnessing the power of the wind. Their working principle revolves around converting wind energy into mechanical or electrical energy through the rotation of blades. Modern windmills, known as wind turbines, feature large rotor blades mounted on a horizontal or vertical axis. As the wind blows, it causes the blades to rotate, driving the turbine's generator and producing

electricity. This renewable energy source has found widespread applications, primarily in electricity generation but historically also in tasks like water pumping and grain milling.

While windmills offer numerous advantages, they also present challenges. One significant advantage is their renewable nature: wind is an abundant resource that produces no greenhouse gas emissions during power generation, aligning with sustainability goals. Moreover, wind energy has low operating costs once the infrastructure is in place, making it economically viable in the long run. However, wind

energy's intermittent nature poses challenges for grid stability and reliability. Additionally, the visual impact and noise generated by wind turbines can be contentious, especially in densely populated areas. Balancing the benefits of wind energy with environmental and social considerations remains an ongoing challenge in its widespread adoption.

Examples: Small-scale wind turbines for residential use and wind-powered water pumps in rural areas showcase the versatility of wind energy.

Some Famous Wind Power Plants

- Muppandal Wind Farm (Tamil Nadu, India): One of the largest onshore wind farms in India and among the biggest in Asia.
- Jaisalmer Wind Park (Rajasthan, India): One of India's largest wind power projects, contributing significantly to renewable energy generation.
- Alta Wind Energy Centre (California, USA): One of the largest onshore wind farms in the world.
- Gansu Wind Farm (China): Also known as the Jiuquan Wind Power Base, it is one of the largest wind power projects globally.
- Walney Offshore Wind Farm (United Kingdom): One of the world's largest offshore wind farms

One significant scientific piece of information about wind energy is its remarkable growth and potential as a renewable energy source. According to recent statistics:

As of 2021, wind energy is one of the fastest-growing renewable energy sources worldwide, with a global installed capacity of over 743 gigawatts (GW). In 2020 alone, the global wind power capacity increased by 93 GW, representing a 10% growth compared to the previous year. The leading countries in wind energy capacity include China, the United States, Germany, India, and Spain, with China alone accounting for nearly half of the world's installed wind capacity.

Wind energy is becoming increasingly cost-competitive with traditional fossil fuels. The



levelized cost of electricity (LCOE) from wind power has significantly decreased over the past decade, making wind farms a viable and attractive investment for utilities and energy developers. Offshore wind energy, which involves wind turbines installed in bodies of water, such as oceans and seas, is experiencing rapid growth and has the potential to become a major contributor to global electricity generation. The United Kingdom, Germany, and China are among the leaders in offshore wind capacity.

Wind energy contributes to reducing greenhouse gas emissions and mitigating climate change. According to the International Energy Agency (IEA), wind power avoided around

1.1 billion tons of CO₂ emissions globally in 2020, equivalent to taking 240 million cars off the road. These statistics underscore the significant role of wind energy in the global transition to clean, renewable sources of electricity and highlight its potential to contribute to sustainable energy systems and mitigate the impacts of climate change.



Fig 1.2.3 Wind Mill

1.2.6.1 Merits and demerits of Wind Energy

1. The generation period is low (5 months). This is because of the seasonal availability of a reasonably useful wind.
2. Power generation starts immediately after commissioning the plant.
3. Power is cost free; generation is cheaper and recurring cost is less.
4. Installation cost is heavy, and the maintenance of machinery is also expensive.
5. This is a pollution free and environ-

ment friendly generation of power.

6. A wind power plant is also a source of income. A wind power generator of 200 kw/250 kw, generates at an average of six to seven lakh units every year.

1.2.7 Hydropower

Imagine standing atop a massive concrete structure, overlooking a vast expanse of water held back by the sheer force of engineering prowess. Below, a river rushes with purpose, its currents harnessed by the imposing presence of a dam. This scene embodies the essence of human ingenuity intertwined with the power of nature. At the heart of this engineering marvel lies the concept of hydropower, a renewable energy source that capitalizes on the kinetic energy of flowing water to generate electricity. As the river cascades downhill, its potential energy transforms into mechanical energy as it churns massive turbines housed within the dam's bowels.

The turbines whirl to life, spinning with formidable force as water surges through their colossal blades. This mechanical energy is then converted into electrical energy through electromagnetic induction, where rotating

magnets induce currents in conductive coils to generate electricity. The electricity is then transmitted through power lines to homes, businesses, and industries. Hydropower represents a harmonious balance between human innovation and nature. By harnessing the renewable energy of flowing water, it provides a clean and sustainable alternative to fossil fuels and helps reduce environmental pollution and climate change.

Moreover, hydropower projects often provide ancillary benefits to surrounding communities and ecosystems. Reservoirs formed by dams serve as vital water sources for irrigation, flood control, and recreational activities, enhancing the resilience and well-being of local populations. In addition, the regulated flow of water can support aquatic habitats and biodiversity, creating thriving ecosystems amidst the concrete structures of human development.

However, it's essential to recognize that hydropower projects are not without their challenges and controversies. Large-scale dams can disrupt natural river ecosystems, fragmenting habitats and altering sediment transport patterns. They may also displace communities and inundate valuable agricul-

Renewable Energy Generation

1. Solar Energy

Sunlight → Solar panels absorb sunlight → Conversion into electrical energy (solar cells) → Electricity flows through inverter → Used in homes/industries or stored in batteries

2. Wind Energy

Wind blows → Wind turns turbine blades → Turbine spins generator → Mechanical energy converts to electrical energy → Electricity transmitted through power lines → Used by consumers



3. Hydropower (Water Energy)

Flowing water stored in dam/reservoir → Water released through turbines → Turbines rotate → Generator converts mechanical energy to electrical energy → Electricity transmitted through power lines → Supplied to homes and industries

Hydroelectric energy is a significant source of renewable energy globally, including in India and Kerala. Here's a scientifically valid piece of information related to hydro energy in India:

In India, hydroelectric power contributes a substantial portion of the country's total electricity generation capacity. As of [2021], India's total installed hydroelectric capacity stood at [~46.61 gigawatts (GW)]. Hydroelectric power plants accounted for about [13%] of India's total electricity generation capacity. Kerala, known for its abundant rivers and rainfall, also harnesses hydroelectric energy. The state has several hydroelectric power projects, including the Idukki Hydroelectric Project, which is one of the largest hydroelectric projects in Kerala.

tural land, raising questions about social equity and environmental justice. The vision of a dam harnessing the power of a river to generate electricity encapsulates the transformative potential of renewable energy technologies. Through sustainable practices and careful stewardship of natural resources, we can harness the power of nature to build a brighter and more sustainable future for generations to come. Hydropower thus utilizes the energy from flowing or falling water to generate electricity. Dams and turbines are commonly used in hydropower plants.

Utilizing the energy from flowing or falling water, hydropower, with its reliable and efficient nature, involves components like dams and turbines. In India, large hydropower projects such as the Bhakra Nangal Dam and Idukki provide substantial electricity. Additionally, smaller run-of-river projects contribute to rural electrification with minimal environmental impact.

1.2.8 Geothermal Energy

Are you aware of the underground reservoir of heat beneath the Earth's surface? This reservoir is like a giant, simmering pot of water, continuously heated by the Earth's core. Now, imagine a series of pipes extending deep into this reservoir, tapping into the natural warmth below. As these pipes reach down, they encounter the hot rocks and steam rising from beneath the Earth's crust, which can be harnessed to produce geothermal energy for generating electricity and providing heat.

This heat is harnessed and brought to the surface through a process called geothermal energy extraction. Above ground, there's a facility with turbines and generators. The hot steam and water from below are directed to these turbines, where they spin and generate electricity. Just like the steam in a kettle powers a locomotive's engine, the steam from the Earth powers these turbines, producing clean,



Fig 1.2.4 Idukki Dam

renewable energy. Geothermal energy, tapping into the Earth's interior heat, utilizes hot water reservoirs or steam.

The energy generated can be used to power homes, businesses, and entire cities, providing a sustainable alternative to traditional fossil fuels. Geothermal energy is a remarkable illustration of how we can tap into the Earth's natural resources to create power while minimizing environmental impact. As long as the Earth's heat persists, geothermal energy can be continuously utilized. But Geothermal energy has several advantages, including its low carbon footprint, reliability, and ability to provide baseload power. However, challenges such as

site-specific limitations, high initial development costs, and potential environmental impacts need to be addressed for wider adoption and sustainable utilization of geothermal resources globally.

Known for its continuous and reliable nature, geothermal energy has applications in power plants, spas, and heating. India has geothermal power plants in Puga Valley, Ladakh, and ongoing exploration for more potential in the Himalayan region.

Examples: Ground-source heat pumps for residential heating and direct use applications, like geothermal spas, are other examples.

As of [2021], geothermal power plants worldwide have an installed capacity of approximately [14.9 GW], with geothermal energy contributing to about [0.3%] of global electricity generation. Geothermal energy harnesses the heat stored beneath the Earth's surface, typically from volcanic activity or natural heat flow from the Earth's core. It's utilized for electricity generation, heating, and cooling purposes in various regions around the world.

One fascinating aspect of geothermal energy is its versatility. It can be harnessed through different technologies, including dry steam power plants, flash steam power plants, and bi-

nary cycle power plants, depending on the temperature and accessibility of the geothermal resource. Countries like Iceland, the United States, the Philippines, and Kenya are among the leaders in geothermal energy production, utilizing their geothermal resources to generate electricity and provide heating for homes and industries.

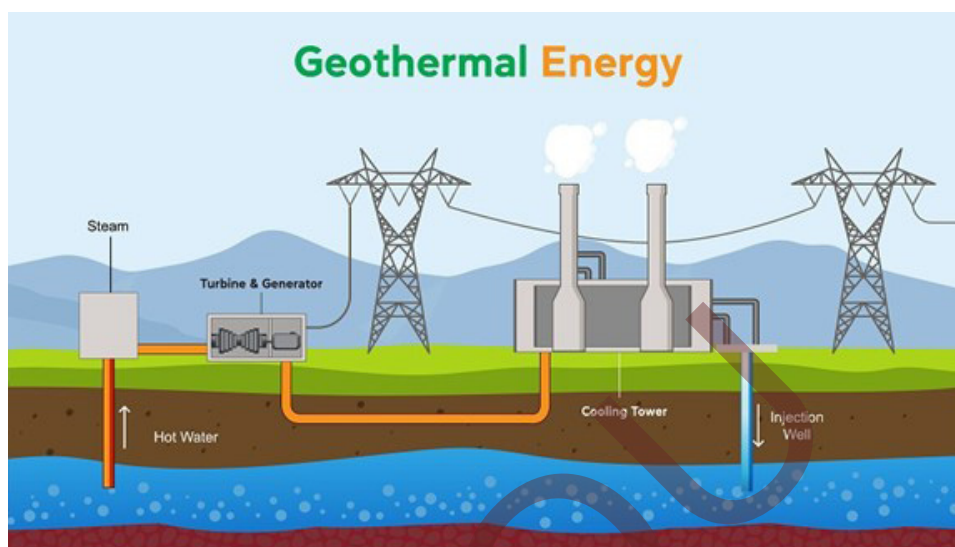


Fig 1.2.5 Geothermal Station

1.2.9 Bioenergy

Let us consider a big factory surrounded by farms and fields. It's a biomass plant, and it's special because it turns leftover plants and organic trash into energy. As long as there are plants and organic stuff, this plant can keep making energy in a sustainable way. Here's how it works: Farmers bring in leftover crops like cornstalks and straw, while trucks drop off wood chips and other waste. All this stuff gets chopped up and sorted. Then, the chopped-up bits go into big boilers that burn them up, creating a lot of heat and steam. This steam spins turbines, which are like big fans, and they generate electricity. This electricity goes to homes and businesses nearby through power lines. The best part? Unlike fossil fuels, which run out and harm the environment, biomass energy uses things that keep growing, like plants. So, it's good for the environment and helps

farmers too, by giving them extra income.

In short, the biomass plant is like a magic factory that turns trash into treasure, helping power our world in a sustainable way. Bioenergy involves energy production using organic materials, such as wood, agricultural residues, and organic waste. Derived from organic materials, bioenergy encompasses biofuels, biogas, and biomass. Its advantage lies in utilizing waste materials, reducing reliance on fossil fuels. In India, bioenergy finds application in biomass power plants, biogas production from agricultural waste, and biofuels for transportation, addressing both energy needs and waste management.

Examples: Biogas from anaerobic digestion of organic waste and biofuels derived from crops like sugarcane or corn are part of the biomass energy spectrum.

From Waste to Power: Växjö's Bioenergy Transformation

In Sweden, the city of Växjö has become a leading example of how bioenergy can revolutionize a community's energy landscape. Växjö, located in the southern part of the country, has successfully transitioned to nearly 90% renewable energy, with a significant portion coming from bioenergy sources. One of the key players in Växjö's bioenergy success story is the local energy company, Växjö Energi. The company has spearheaded numerous initiatives to utilize biomass and waste to generate heat and electricity for the city.

One notable project is the Växjö Energy Park, a combined heat and power plant that utilizes locally sourced wood chips and forestry residues as fuel. The plant not only supplies heat and electricity to thousands of homes and businesses in Växjö but also serves as a model of efficiency and sustainability. Another innovative endeavor is the biogas production facility in Växjö, which converts organic waste from households, industries, and agriculture into biogas for use as a renewable fuel in vehicles and for heating purposes.

The success of Växjö's bioenergy initiatives can be attributed to strong collaboration between the public and private sectors, as well as active engagement from the local community. The city's commitment to sustainability and environmental stewardship has earned it international recognition as a green city and a model for others to follow. Växjö's story demonstrates how bioenergy can play a crucial role in reducing carbon emissions, promoting energy independence, and fostering economic growth at the local level. By harnessing the power of biomass and waste, communities like Växjö are paving the way towards a more sustainable future for generations to come.

1.2.10 Nuclear energy

Element Uranium is like a treasure chest, hiding a powerful force called nuclear energy. Inside uranium atoms, there are tiny particles called neutrons in its nucleus, the centre core of atoms. When a fast moving outside neutron bumps into a uranium atom, it can split the atom apart, releasing a tremendous amount of energy in the process. This splitting is called nuclear fission. When lots of uranium atoms are splitting apart all at once, like a chain reaction it creates an enormous amount of heat, which we can use to make steam. The steam then spins turbines, just like wind pushes the blades of a windmill, generating electricity. This is how we use nuclear energy to create electricity. It's like unlocking the energy hid-

den deep inside the uranium atoms to power homes, schools, hospitals, and cities.

Nuclear energy is powerful and can generate a lot of electricity without releasing harmful greenhouse gases like those produced by burning fossil fuels. However, we have to be careful with nuclear energy because if not managed properly, it can be dangerous. That's why scientists and engineers work hard to ensure that nuclear power plants are safe and secure. India, like many other countries, has recognized the potential of nuclear energy to meet its growing electricity demands while reducing reliance on fossil fuels.

Nuclear power plants in India, such as the Tarapur Atomic Power Station, Rajas-



than Atomic Power Station, and Kaiga Generating Station, contribute significantly to the country's electricity generation capacity. These plants use nuclear fission to produce heat, which is then converted into electricity through turbines and generators.

By generating electricity without burning fossil fuels, nuclear power helps India reduce its carbon emissions and combat climate change. This is particularly important as India works to meet its commitments under the Paris Agreement and transition to a more sustainable energy mix. Nuclear energy contributes to India's energy security by diversifying its energy sources. With a growing population and economy, India needs reliable and affordable electricity to support economic growth and improve living standards. Nuclear power provides a stable and continuous source of electricity, helping to meet these energy demands.

India has a robust nuclear research and development program aimed at advancing nuclear technology, improving safety standards, and developing innovative reactor designs. Institutions like the Bhabha Atomic Research Centre (BARC) play a crucial role in nuclear research, education, and training. India actively participates in international collaborations and partnerships to promote peaceful

uses of nuclear energy, enhance nuclear safety and security, and strengthen non-proliferation efforts. Collaborative initiatives with countries like the United States, France, Russia, and Canada have facilitated technology transfers, knowledge sharing, and capacity building in the nuclear sector.

While nuclear energy offers significant benefits, it also poses unique challenges, particularly related to safety, security, and waste management. The Fukushima Daiichi nuclear disaster in Japan and the Chernobyl disaster in Ukraine serve as reminders of the importance of stringent safety regulations and continuous monitoring of nuclear facilities. In India, safety and security measures are paramount in the operation of nuclear power plants. The Atomic Energy Regulatory Board (AERB) regulates and oversees nuclear safety standards, ensuring that nuclear facilities operate safely and securely.

Nuclear energy thus plays a crucial role in India's energy landscape, offering a low-carbon alternative to fossil fuels and contributing to energy security and economic development. However, it requires careful management, robust regulations, and ongoing research to address safety and security concerns and maximize its potential benefits.

The Chernobyl catastrophe, 1986

On April 26, 1986, in the early hours of the morning, reactor number 4 at the Chernobyl Nuclear Power Plant in Pripyat, Ukraine, experienced a catastrophic explosion during a safety test gone wrong. The explosion, followed by a series of fires, released a massive amount of radioactive material into the atmosphere, creating one of the worst nuclear disasters in history.

As news of the explosion spread, panic and confusion gripped the surrounding area. Within hours, thousands of residents were evacuated from the nearby city of Pripyat, leaving behind their homes, belongings, and livelihoods. In the days and weeks that followed,

emergency workers known as liquidators risked their lives to contain the radiation and prevent further contamination. Many of these brave individuals were exposed to dangerously high levels of radiation, suffering from acute radiation sickness and long-term health consequences. The effects of the Chernobyl disaster were far-reaching and devastating. Entire communities were displaced, ecosystems were contaminated, and the health of millions of people was put at risk. The true human toll of the disaster may never be fully known, as the long-term health effects of radiation exposure continue to affect survivors and their descendants to this day.

The Chernobyl disaster serves as a sobering reminder of the potential dangers associated with nuclear energy, including the risk of accidents, environmental contamination, and human suffering. While nuclear power has the potential to provide clean and reliable energy, it requires strict safety measures, rigorous oversight, and transparency to prevent future catastrophes and protect the well-being of people and the planet.

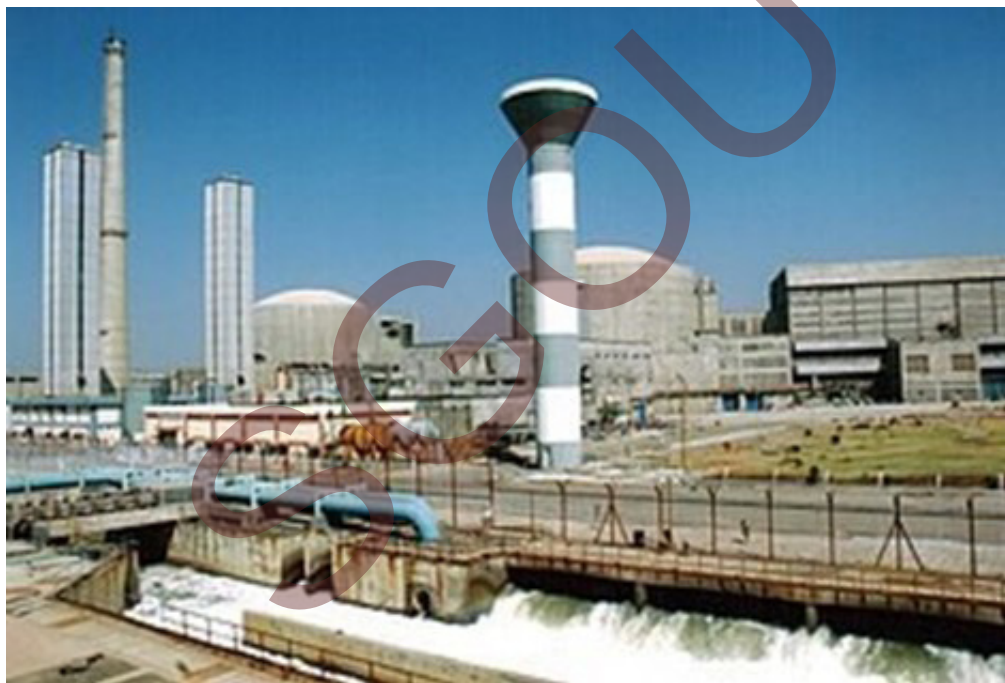


Fig 1.2.6 The Tarapur Power Plant: India's first Nuclear Power station

1.2.11 Hydrogen Energy

Hydrogen is the most abundant element in the universe, though it is typically found bonded to other elements such as oxygen in water (H_2O), or carbon in hydrocarbons. It can be produced from a variety of renewable resources, including water and biomass, mak-

ing it a potentially sustainable fuel source. Functioning as a clean energy carrier, hydrogen possesses immense potential for long-term storage, addressing the intermittent nature of some renewable sources. Hydrogen is an energy carrier that can transform our fossil-fuel dependent economy into a hydrogen economy, which can provide an emis-

sions-free transportation fuel. An alternative fuel must be technically feasible, economically viable, easily convertible to another energy form when combusted, be safe to use, and be harmless to the environment.

Hydrogen gas can be used in traditional gasoline-powered internal combustion engines (ICE) with minimal conversions. However, vehicles with polymer electrolyte membrane (PEM) fuel cells provide a greater efficiency. Hydrogen gas combusts with oxygen to produce water vapour. Even the production of hydrogen gas can be emission-free with the use of renewable energy sources. The current price of hydrogen varies depending on production methods and geographic location but generally ranges from \$10 to \$16 per kilogram. This cost is higher than gasoline on a per-mile basis. For instance, in fuel cell vehicles like the Honda Clarity Fuel Cell, which can travel approximately 68 miles per kilogram of hydrogen, the cost per mile is higher compared to gasoline-powered vehicles.

The price of hydrogen is influenced by several factors including production, transportation, and distribution costs, as well as the availability of infrastructure. Ongoing research and development efforts are essential to improving the efficiency of hydrogen production methods and reducing costs associated with its distribution and utilization.

While the current cost of hydrogen may be prohibitive for widespread adoption, advancements in technology, economies of scale, and supportive policies can help drive down costs and make hydrogen a more economically feasible fuel option in the future. It is important to continue research and implementation efforts toward a hydrogen economy to realize its full potential as a clean and sustainable energy solution.

The current focus is directed toward hydrogen being a clean alternative fuel that produces insignificant greenhouse gas emissions. If hydrogen is the next transportation fuel, the primary energy source used to produce the vast amounts of hydrogen will not necessarily be a renewable, clean source. The U.S. Department of Energy has recently funded a research project to produce hydrogen from coal at large scale facilities, with carbon sequestration in mind. Is this the wrong approach? Should there be more focus on other forms of energy that produce no greenhouse gas emissions? If the damage to the environment is interpreted into a monetary cost, the promotion of energy sources such as wind and solar may prove to be a more economical approach.

The transition toward a hydrogen economy, where hydrogen is extensively used in various transportation sectors, requires significant research and development efforts. Currently, one of the most economical methods of hydrogen production in the US is through steam reformation of natural gas. However, this process is non-renewable and emits greenhouse gases, highlighting the need for more sustainable alternatives.

Electrolysis of water presents a potentially sustainable method for hydrogen production, but its viability depends on the source of electricity used. Currently, less than 5% of electricity in the US is generated from renewable sources such as solar, wind, and hydro. Increased investment in renewable energy infrastructure is crucial to support the widespread adoption of electrolysis as a sustainable hydrogen production method.

While nuclear power may be considered a low-carbon energy source, concerns regarding nuclear waste management persist. The disposal of radioactive waste generated by

nuclear power plants poses significant environmental and safety challenges, underscoring the need for comprehensive solutions and stringent regulatory measures.

In summary, advancing towards a hydrogen economy requires prioritizing sustainable methods of hydrogen production and transitioning to renewable energy sources to power these processes. Additionally, addressing the environmental impacts associated with energy production, including nuclear waste management, is essential for achieving a truly sustainable energy future.

A rapid shift toward renewable energy sources is required before this proposed hydrogen economy can prove itself. The transport of hydrogen through underground pipes seems to be the most economical when demand grows enough to require a large centralized facility. However, in places of low population density, this method may not be economically feasible. The project mentioned earlier may become an option for individuals to produce their own hydrogen gas at home, with solar panels lining their roof. A drastic change is needed to slow down the effects of our fossil fuel dependent society. Conservation can indeed help, but the lifestyles we are accustomed to require certain energy demands. Transportation is a necessary part of our current world and the switch to a hydrogen economy can provide a sustainable solution.

Fuel cells are electrochemical devices that convert the chemical energy of a fuel, such as hydrogen, directly into electricity through an oxidation-reduction reaction. The oxidation of hydrogen (reaction with oxygen) in fuel cells provides a clean and efficient means of extracting energy from hydrogen while producing water vapour as the only emission. This makes fuel cells a promising technology for various applications, including transportation, sta-

tionary power generation, and portable electronics. As research and development efforts continue, improvements in fuel cell efficiency, durability, and cost-effectiveness are expected to further enhance the viability of hydrogen energy as a sustainable energy solution. Thus hydrogen energy, generated through hydrogen fuel cells, stands out for its versatility and the ability to be derived from various sources, including renewables. In India, the applications of hydrogen energy are multifaceted.

One noteworthy application is the adoption of hydrogen fuel cell vehicles, representing a leap towards sustainable and zero-emission transportation. These vehicles utilize hydrogen to generate electricity, emitting only water vapor as a byproduct, contributing significantly to reducing air pollution and greenhouse gas emissions in urban environments. Unlike batteries, which have limited energy storage capacity, hydrogen fuel cells can continuously generate electricity as long as they are supplied with hydrogen and oxygen. This feature is particularly beneficial for extended space missions where reliable power is essential.

India is actively pursuing the integration of hydrogen energy with renewables. This involves using excess electricity generated from renewable sources, such as wind or solar, to produce hydrogen through electrolysis. The stored hydrogen can then be used during periods of low renewable energy production, creating a more stable and reliable energy supply. The country is also engaging in pilot projects for green hydrogen production. Green hydrogen is produced using renewable energy sources, ensuring that the entire process, from generation to utilization, is environmentally sustainable. These projects serve as crucial steps towards establishing a hydrogen economy, fostering innovation, and reducing dependency on conventional fossil fuels.



Hydrogen Fuel Cells

NASA's Space Shuttle programmes rely on advanced technology to propel astronauts and cargo into space. A critical component of the Space Shuttle's power system is its fuel cells, which generate electricity to power the spacecraft during missions. The Space Shuttle's fuel cells use liquid hydrogen and liquid oxygen stored in separate tanks onboard the spacecraft.

One of the most memorable moments involving the Space Shuttle's fuel cells occurred during the Apollo 13 mission in 1970. After an oxygen tank explosion crippled the spacecraft, leaving the crew stranded in space, the fuel cells played a crucial role in providing essential power for life support systems and navigation. The crew's safe return to Earth is attributed in part to the reliability of the fuel cell technology onboard the spacecraft.

The success of NASA's Space Shuttle program and its innovative use of hydrogen fuel cells have inspired advancements in fuel cell technology for terrestrial applications. Today, fuel cells are being used in a variety of industries, including transportation, stationary power generation, and portable electronics, offering a clean and efficient alternative to traditional combustion engines and batteries. The story of hydrogen fuel cells in the Space Shuttle program highlights the importance of innovation, reliability, and sustainability in space exploration and technology development. It serves as a testament to the remarkable capabilities of hydrogen fuel cells and their potential to revolutionize energy systems both on Earth and beyond.

1.2.12 Ocean Energy

Wind blowing over the surface of the ocean transfers energy to the water, creating ripples and small waves. As the wind continues to blow and energy is transferred to the water, these waves grow in size and energy. Ocean waves are thus the result of the interaction between wind, water, and the Earth's surface. They are the continuous motion of water particles that travel across the surface of the ocean. Several factors contribute to the formation of ocean waves, including wind speed, wind duration, and the distance over which the wind blows. Ocean energy, tapping into the immense power of ocean currents, waves, and temperature differences, presents a promising frontier for sustainable energy production. Two key technologies in this realm are Ocean Thermal En-

ergy Conversion (OTEC) and wave energy harnessing.

Ocean Thermal Energy Conversion (OTEC)

India, particularly in the Andaman and Nicobar Islands, is actively exploring OTEC projects. OTEC leverages temperature differences in ocean water to generate electricity. Warm surface water and cold deep-sea water are used to drive a heat engine, producing a continuous and predictable source of power. This technology has the potential to provide clean and reliable electricity for remote island regions.

1.2.13 Wave Energy

Research initiatives in India are focused

on harnessing the power of waves along the coastline. Wave energy, driven by the kinetic energy of ocean waves, can be captured using various technologies. This form of ocean energy offers a predictable and high-density source of power. If successfully harnessed, it can contribute significantly to the country's electricity generation, reducing reliance on conventional sources.

1.2.14 Tidal Energy

When turbines beneath the ocean's surface harness the ebb and flow of tides, tidal energy is driven by the gravitational forces of the moon and the sun. This is a perpetually renewable resource. Tidal energy captures the rise and fall of tides using technologies like tidal stream systems or tidal range systems. With predictable tidal patterns, minimal environmental impact, and high energy density, tidal energy holds promise. In India, pilot projects in the Gulf of Kutch and Gulf of Cambay explore the potential for large-scale tidal power generation. Wave energy, which captures the energy from ocean waves, is related to tidal energy in utilizing the power of the ocean.

1.2.15 Non-Renewable Resources

Non-renewable resources are natural resources that are finite in supply and cannot be replaced on a human timescale. These resources have been formed over millions of years through geological processes and are typically extracted from the Earth's crust. Non-renewable resources include fossil fuels such as coal, oil, and natural gas, as well as minerals and metals like uranium, copper, and iron ore.

1.2.15.1 Fossil Fuels

Imagine a vast landscape dotted with towering rigs and heavy machinery, where the earth's crust is pierced to access hidden treasures buried deep within. This is the realm of fossil fuel extraction—a world of coal mines and oil wells where humanity's insatiable thirst for energy meets the harsh reality of finite resources. In this industrial tableau, coal mines delve deep into the earth's bowels, while oil wells puncture the surface, tapping into ancient reservoirs of black gold. These fossil fuels, formed over millions of years from the decayed remains of prehistoric plants and



Fig 1.2.7 Tidal Energy Station

animals, represent a bounty of energy locked within the earth's crust.

Fossil fuels are thus organic compounds derived from the remains of ancient plants and animals that have undergone geological processes over millions of years. These fuels include coal, oil (petroleum), and natural gas, and they have been the primary source of energy for human civilization for centuries.

Coal: About 85 per cent of the world's commercial energy comes from coal, oil, and natural gas. These are called fossil fuels since they have formed from the fossilized remains of prehistoric plants and animals.

Coal is made up of organic material which has escaped from oxidation in the carbon cycle. It is an altered residue of plants and trees of older forests, which have been buried under sediments, and they were subjected to a set of geological processes and transformations. Coal is a combustible black or brownish-black sedimentary rock composed mostly of carbon and hydrocarbons. Coal is mined from underground or surface mines and is burned to generate electricity, heat buildings, and produce steel.

Coal is burned to create heat to turn water into steam. The steam is then used to rotate turbines which will rotate the dynamos to generate electricity. It is also converted into another useable form called coke. It is a charcoal-like solid which is an essential raw material used in the production of iron and steel.

Coal occurs in sedimentary basins as coal seams or layers. There are four types of coal occurring in the order of decreasing carbon content, volatiles and moisture, as

- a. Anthracite
- b. Bituminous coal

- c. Sub-bituminous coal and
- d. Lignite.

Peat is partially decayed plant matter found in recent swamp deposits. Peat and wood are the basic materials before the formation of lignite. Anthracite is a rare form but is the hardest variety of coal. It also contains more carbon and produces more heat than the other varieties. Bituminous coal is the most commonly used coal by industries. It contains more carbon and produces more heat than either lignite or sub-bituminous coal. It is also suitable for making coke.

Coal contains some sulphur compounds. The sulphur content may be very low ($< 1\%$) or medium ($1-3\%$) and high ($> 3\%$).

Coal is mainly used in thermal power plants. While using it, the one having low sulphur will cause less air pollution. The production of thermal power depends on the ash-content of the coal used. The higher the ash content, the lower the efficiency of the boiler and furnaces. Use of coal also generates solid wastes and ashes. For every megawatt of energy produced by a thermal plant, about one acre of land is needed to dump the wastes (ash). Coal-based thermal plant pollute the atmosphere by gaseous emissions of sulphur-dioxide and nitrogen oxide, and produce tremendous amount of solid wastes, fly ash and bottom ash.

Coal mining, transport, washing, processing, shipping, combustion and final disposal of ash may lead to potentially adverse environmental effects like aesthetic degradation, noise pollution, dust pollution and the release of trace elements into water, soil and air. Coal is a non-renewable form of energy, the use of which is to be done very economically. Global coal reserves are estimated to be approximately 1.1 trillion short tons. Major coal-producing



Fig 1.2.8 Coal Mining

countries include China, India, and the United States. Coal remains a significant source of electricity generation, accounting for over 40% of global electricity production.

Oil (Petroleum): The next major source of energy comes from oil. The oil that is derived from rocks is called Petroleum. (Petro means rock, oleum means oil). Petroleum furnishes about 40 per cent of the commercial energy used in the world. It provides most of the energy used for transportation and other activities of the population.

In general, Petroleum and natural gas (methane) are hydrocarbons. They are fossil fuels formed from organic material, free from complete decomposition after burial. Petroleum is a complex mixture of hydrocarbons containing N, S and O.

The major source for oil and gas is the fine grained, organic rich sediments that are buried to a depth of 500 m or below stagnant oceanic waters. These might have experienced a thrust due to an increase in pressure and heat. The water is deficient in oxygen. Various geological and biological (bacteria) processes have promoted the chemical transformation

of these organic materials into hydrocarbons. They tend to migrate through the porous sediments called reservoir rocks.

Like coal, oil also contains some impurities that can cause air pollution. But refineries can remove many of these pollutants when they process the petroleum.

Petroleum is extracted from oil wells through drilling and then refined into various products such as gasoline, diesel, jet fuel, and plastics. Proven global oil reserves stand at approximately

1.7 trillion barrels. Top oil-producing countries include the United States, Saudi Arabia, and Russia. Global oil consumption reached around 100 million barrels per day in recent years.

Natural Gas: Natural gas is the most convenient fossil fuel. It causes little or no air pollution. Natural gas is a clean source of energy because it is refined naturally during its formation within the earth and does not require further refining. In addition, it can be compressed into a liquid and transported long distances through pipelines. Natural gas accounts



Fig 1.2.9 Oil Refining

for about 21 per cent of the commercial energy used in the world. Millions of people use natural gas to heat their homes, cook their meals, and dry their laundry.

Typical gas consists of hydrocarbons, having a very low boiling point. Methane, the first member of the paraffin series makes up 85 % of the typical gas. It is extracted through drilling and is used for heating, cooking, electricity generation, and as a feedstock for the production of chemicals and fertilizers. Global proven reserves of natural gas are estimated at about 7,000 trillion cubic feet. Leading natural gas producers include the United States, Russia, and Iran. Global natural gas consumption has been steadily increasing, reaching over 3.9 trillion cubic meters in recent years.

Once extracted from their subterranean confines, these fossil fuels are transported to power plants, refineries, and factories, where they are burned to produce heat, electricity,

and fuel. It's a process as old as the Industrial Revolution itself—a relentless cycle of extraction, combustion, and consumption that has fueled human progress for centuries. But therein lies the paradox of fossil fuels. While they have powered the engines of modernity and fueled unprecedented economic growth, they come with a steep price. Once burned, fossil fuels release vast quantities of carbon dioxide and other greenhouse gases into the atmosphere, driving climate change and exacerbating environmental degradation.

Moreover, the very essence of fossil fuels carbon-rich hydrocarbons means that they are finite resources. Unlike renewable energy sources such as sunlight and wind, which are constantly replenished by natural processes, fossil fuels exist in limited quantities. Once extracted and burned, they cannot be replaced within a human timeframe, consigning future generations to a world deprived of these invaluable resources.



Fig 1.2.10 Compressed Natural Gas

The consequences of this finite nature are manifold. As demand for energy continues to soar, fossil fuel reserves dwindle, leading to increased extraction efforts in ever-more remote and environmentally sensitive areas. This relentless pursuit of finite resources exacts a heavy toll on the environment, causing habitat destruction, air and water pollution, and irreversible ecological damage. Furthermore, the geopolitical implications of fossil fuel dependency loom large on the global stage. Nations vie for control over dwindling reserves, leading to conflicts, instability, and geopolitical tensions. The specter of resource scarcity looms large, casting a shadow over the prospects for peace and prosperity in an increasingly interconnected world.

The image of a coal mine or an oil well extracting fossil fuels from the earth serves as a stark reminder of humanity's precarious dependence on finite resources. As we confront the urgent challenges of climate change, environmental degradation, and energy security, the imperative to transition towards renewable energy sources has never been more pressing. Only by embracing sustainable alternatives can we forge a path towards a brighter, more resilient future for generations to come.

1.2.16 Non-renewable metal and mineral sources

Non-renewable metal and mineral resources are valuable natural commodities that play a crucial role in various aspects of human civilization. These resources, formed over geological timescales, are finite in nature and cannot be replaced within a human lifetime. They encompass a wide range of elements and compounds extracted from the Earth's crust, including metals like iron, copper, and aluminum, as well as minerals such as coal, oil, and natural gas.

The extraction and utilization of non-renewable metal and mineral resources have driven advancements in technology, infrastructure, manufacturing, and energy production. From the construction of buildings and infrastructure to the manufacturing of electronics and transportation vehicles, non-renewable resources form the foundation of modern society's development and progress.

However, the finite nature of these resources poses significant challenges and considerations for sustainable resource management. As demand for metals and minerals continues

to rise with population growth and economic development, there is a growing need to balance resource extraction with environmental conservation, social responsibility, and long-term resource sustainability.

Moreover, the extraction and processing of non-renewable resources often have environmental, social, and economic impacts, including habitat destruction, air and water pollution, greenhouse gas emissions, and socioeconomic inequalities. These challenges underscore the importance of adopting responsible and sustainable practices in resource extraction, utilization, and recycling to minimize negative impacts and ensure the equitable distribution of benefits.

In summary, non-renewable metal and mineral resources are essential components of human civilization, providing the raw materials necessary for industrial and technological advancement. However, their finite nature and associated challenges necessitate careful stewardship and proactive measures to promote resource conservation, environmental protection, and sustainable development for present and future generations.

Impact of Depletion of Non-Renewable Resources on Key Sectors

a. Infrastructure and Construction

With the depletion of resources like iron ore, which is essential for steel production, the construction industry would struggle to build infrastructure such as buildings, bridges, roads, and railways. Without steel, construction projects would become more expensive, and alternative materials may need to be developed, leading to delays and limitations in infrastructure development.

b. Manufacturing and Electronics

The manufacturing sector relies heavily on non-renewable resources like copper, which is crucial for electrical wiring, electronics, and machinery. Without copper, manufacturing industries would face challenges in producing electronics, appliances, and industrial equipment, leading to disruptions in supply chains and reduced productivity.

c. Transportation

Non-renewable resources such as petroleum are essential for fueling vehicles, airplanes, ships, and other modes of transportation. Depletion of petroleum reserves would severely impact global transportation systems, leading to fuel shortages, increased transportation costs, and disruptions in trade and logistics.

d. Energy Production

Uranium, a non-renewable resource used in nuclear power plants, plays a significant role in electricity generation. Without uranium, there would be a reduction in available energy sources, potentially leading to energy shortages, increased reliance on fossil fuels, and higher greenhouse gas emissions.

Economic and Social Impacts

The depletion of non-renewable metal and mineral resources would have profound economic implications, leading to job losses, reduced economic growth, and increased poverty. Social unrest and geopolitical tensions may arise as nations compete for dwindling resources, exacerbating inequalities and conflicts over resource extraction and distribution.

Environmental Degradation

Table 1.2.1 Difference between Renewable and Non renewable Resources

Basis	Renewable Resources	Non-Renewable Resources
Definition	Natural resources that can overcome depletion due to consumption and can be replenished naturally.	Resources that do not renew themselves sufficiently for sustainable economic extraction in meaningful human time-frames.
Limit	Unlimited	Limited
Effect on Environment	Mostly their usage is environmentally friendly.	Mostly harmful to the environment.
Restrictions	Convenient to use	There are restrictions in using these.
Cost	Freely available in nature	Expensive

The extraction and depletion of non-renewable resources often result in environmental degradation, habitat destruction, air and water pollution, and climate change. Continued exploitation of finite resources can lead to irreversible damage to ecosystems, loss of biodiversity, and disruptions in natural processes essential for human survival.

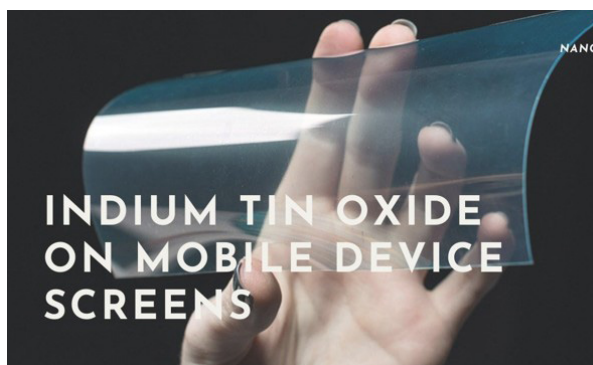
In summary, the exhaustion of non-renewable metal and mineral resources would pose

significant challenges to human civilization, including disruptions in infrastructure, manufacturing, transportation, energy production, and socioeconomic stability. It underscores the importance of sustainable resource management, conservation efforts, and the development of alternative technologies to mitigate the impacts of resource depletion and ensure the long-term viability of human civilization on Earth.

Several metals are facing depletion due to increasing demand, limited reserves, and challenges in extraction and processing. Some of the metals experiencing fast depletion include:

1. Indium

Indium is a rare metal used in the production of flat-panel displays, solar cells, and semiconductors. The demand for indium has increased significantly with the growth of electronic devices and renewable energy technologies. Indium is primarily sourced as a byproduct of zinc mining, and its supply is limited, leading to concerns about future



2. Rare Earth Elements

Rare earth elements, including neodymium, dysprosium, and praseodymium, are essential for the production of high-tech devices, magnets, and renewable energy technologies. China dominates the production of rare earth elements, leading to concerns about supply security and geopolitical tensions. Recycling and diversification of rare earth element sources are critical for mitigating supply risks.

3. Cobalt

Cobalt is a key component of lithium-ion batteries used in electric vehicles, smartphones, and laptops. The majority of the world's cobalt supply comes from the Democratic Republic of Congo, where concerns about labour practices and environmental impact exist. Increasing demand for electric vehicles and energy storage systems has led to concerns about cobalt supply constraints.

4. Lithium

Lithium is essential for rechargeable lithium-ion batteries used in electric vehicles, energy storage systems, and consumer electronics. Lithium reserves are concentrated in a few countries, including Chile, Australia, and Argentina. As the demand for electric vehicles and renewable energy storage grows, concerns about lithium supply and extraction methods have emerged.



Efforts to address the depletion of these metals include recycling initiatives, exploration for new reserves, and research into alternative materials and technologies. Sustainable resource management and diversification of supply sources are essential for ensuring the availability of critical metals for future generations.

Recap

- ▶ Energy sources are classified based on renewability and availability.
- ▶ Renewable resources replenish naturally, contributing to sustainability.
- ▶ Non-renewable resources are finite and diminish over time.
- ▶ Solar energy harnesses sunlight for power generation.
- ▶ Wind energy utilizes the kinetic energy of moving air.
- ▶ Hydropower generates electricity from flowing water.
- ▶ Bioenergy derives from organic materials like biomass.
- ▶ Tidal energy captures the power of ocean tides.
- ▶ Geothermal energy utilizes heat from beneath the Earth's surface.
- ▶ Ocean energy encompasses various renewable forms like wave and thermal energy.
- ▶ Nuclear energy is derived from the nucleus of atoms.
- ▶ Hydrogen energy holds promise for clean and versatile fuel applications.
- ▶ Environmental impacts of energy sources vary, influencing sustainability.
- ▶ Renewable resources contribute to reduced greenhouse gas emissions.
- ▶ Non-renewable resources pose challenges due to depletion and pollution.
- ▶ Sustainability involves balancing resource use with environmental conservation.
- ▶ Integration of renewable energy sources promotes energy diversity and resilience.

Objective Questions

1. Differentiate between renewable and non-renewable resources.
2. What are the defining characteristics of renewable resources?
3. Provide an example of a renewable energy source derived from sunlight.
4. Name a non-renewable resource commonly used in electricity generation.
5. Define the concept of non-renewable resources.
6. Identify a renewable energy source extracted from wind.
7. Give an example of a non-renewable resource extracted from fossilized remains.
8. Describe the classification criteria for renewable resources.

9. Name a renewable energy source derived from water flow.
10. What is a common form of renewable energy derived from organic matter?
11. Explain the primary energy source used in nuclear power plants.
12. Provide an example of a renewable resource extracted from the earth's internal heat.
13. Define ocean energy and provide an example.
14. Name a renewable resource derived from the gravitational pull of the moon.
15. Identify a potential renewable energy source derived from hydrogen.
16. What are the primary environmental benefits of renewable resources?
17. Describe the environmental impacts associated with non-renewable resources.
18. Provide an example of a renewable resource derived from the movement of ocean currents.
19. Name a form of renewable energy derived from biomass combustion.
20. Define geothermal energy and its sources.
21. Name a renewable energy source derived from the kinetic energy of waves.
22. Describe the potential applications of hydrogen energy.
23. What are the key considerations in the classification of energy sources?
24. Identify a renewable resource extracted from the natural motion of air.
25. Explain the concept of ocean thermal energy conversion (OTEC)

Answers

1. Renewability and replenishment.
2. Ability to replenish over time.
3. Solar energy.
4. Coal.
5. Finite and exhaustible resources.
6. Wind energy.
7. Coal.
8. Replenishment capacity.
9. Hydropower.

10. Bioenergy.
11. Uranium.
12. Geothermal energy.
13. Energy from oceanic sources; tidal energy.
14. Tidal energy.
15. Hydrogen.
16. Reduced greenhouse gas emissions.
17. Air and water pollution, habitat destruction.
18. Ocean currents; ocean thermal energy.
19. Biomass combustion.
20. Heat from within the Earth's crust.
21. Wave energy.
22. Transportation, electricity generation.
23. Renewability, environmental impact, availability.
24. Wind energy.
25. Utilization of temperature differences in ocean water for energy conversion.

Self-assessment Questions

1. Explain the key difference between renewable and non-renewable resources, providing examples of each type.
2. Describe the process of harnessing solar energy for power generation and discuss its environmental benefits compared to traditional energy sources.
3. Discuss the environmental impacts associated with the extraction and combustion of fossil fuels, highlighting the importance of transitioning to renewable energy sources.
4. How do wind turbines convert the kinetic energy of wind into electricity, and what are some advantages and limitations of wind energy?
5. Explain the role of hydropower in electricity generation, including its potential environmental impacts and considerations for sustainable hydropower projects.
6. Define bioenergy and discuss its potential as a renewable energy source, considering factors such as feedstock availability, conversion technologies, and sustainability.

7. Describe the process of harnessing tidal energy and evaluate its potential as a reliable and predictable source of renewable energy.
8. Discuss the sources of geothermal energy and explain how geothermal power plants utilize heat from the Earth's interior to generate electricity.
9. Explain the concept of ocean wave energy and analyze the challenges and opportunities associated with harnessing wave power for electricity generation.
10. What is ocean thermal energy conversion (OTEC), and how does it utilize temperature differences in seawater to generate electricity?
11. Describe the primary fuel source used in nuclear power plants, the process of nuclear fission, and the associated environmental and safety concerns.
12. Discuss the production methods and potential applications of hydrogen energy, including its use as a fuel for transportation and energy storage.
13. Evaluate the environmental impacts of non-renewable resources such as coal, oil, and natural gas, considering factors such as air and water pollution, habitat destruction, and greenhouse gas emissions.
14. Define sustainability in the context of energy resources and discuss the importance of transitioning to renewable energy sources for long-term environmental and economic sustainability.
15. Explain how the integration of renewable energy sources such as solar, wind, and hydropower contributes to energy resilience and diversity, reducing dependence on fossil fuels and enhancing overall energy security.
16. Discuss the significance of renewable energy sources in mitigating climate change and reducing greenhouse gas emissions, providing examples of effective renewable energy policies and initiatives implemented globally.
17. Analyze the environmental, economic, and social impacts of non-renewable resource extraction and utilization, considering factors such as air and water pollution, habitat destruction, energy security, and geopolitical tensions.
18. Evaluate the potential of renewable energy technologies, such as solar photovoltaic systems and wind turbines, to meet future energy demand while ensuring sustainability and environmental integrity on a global scale.
19. Compare and contrast the advantages and disadvantages of different renewable energy sources, including solar, wind, hydropower, biomass, and geothermal energy, in terms of resource availability, scalability, reliability, and environmental impact.
20. Assess the role of government policies, incentives, and regulatory frameworks in promoting the development and adoption of renewable energy technologies, highlighting successful case studies and lessons learned from various countries.

Reference

1. Abbasi, S. A., & Abbasi, N. (2010). *Renewable energy sources and their environmental impact*. PHI Learning.
2. Hinrichs, R. A., & Kleinbach, M. H. (2012). *Energy: Its use and the environment* (5th ed.). Cengage Learning.
3. Kaltschmitt, M., Streicher, W., & Wiese, A. (Eds.). (2007). *Renewable energy: Technology, economics and environment*. Springer.
4. Smil, V. (2017). *Energy and civilization: A history*. MIT Press.
5. Twidell, J., & Weir, T. (2015). *Renewable energy resources* (3rd ed.). Routledge.

Suggested Reading

1. International Energy Agency. (2023). *Renewables 2023: Analysis and forecast to 2028*. <https://www.iea.org/reports/renewables-2023>
2. Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. *Energy & Environmental Science*, 2(2), 148–173.
3. Lovins, A. B. (1976). Energy strategy: The road not taken? *Foreign Affairs*, 55(1), 65–96.
4. National Research Council. (2010). *Hidden costs of energy: Unpriced consequences of energy production and use*. The National Academies Press.
5. World Resources Institute. (2022). *World resources report: A guide to the global environment*. Oxford University Press.

Unit 3

Major Threats to Natural Resources

Learning Outcomes

By the end of the unit, the learner will be able to:

- ▶ understand the threats to forest resources, including overexploitation, deforestation, and the ecological impacts of mining and dam construction.
- ▶ recognise the challenges affecting water resources, including overexploitation, pollution, and the consequences of waterlogging, floods, and drought.
- ▶ explore the complexities surrounding land and mineral resources, including land degradation, soil erosion, and the environmental effects of mineral extraction and utilization.
- ▶ analyse the interplay between human activities and natural processes in the degradation of natural resources, emphasising the need for sustainable management.

Prerequisites

In the heart of the Western Ghats, nestled amidst the misty mountains and verdant valleys, lies the village of Kudremukh in Karnataka, India. This region, renowned for its rich biodiversity and pristine landscapes, has been a focal point in the struggle between conservation and development. For decades, Kudremukh has been home to diverse flora and fauna, including the elusive Malabar giant squirrel and the endangered lion-tailed macaque. However, the area also harboured vast reserves of iron ore, sparking the interest of mining companies seeking lucrative profits.

In the 1980s, plans were set in motion to establish an open-cast iron ore mine in the heart of the Kudremukh National Park, threatening to devastate the fragile ecosystem and displace local communities. Among those affected were the indigenous tribes whose lives and livelihoods were intricately woven into the fabric of the forest. As bulldozers loomed on the horizon, a grassroots movement emerged, led by environmental activists, local communities, and concerned citizens. They rallied together, staging protests, organizing awareness campaigns, and petitioning government authorities to halt the mining operations.

One of the movement's prominent voices was Ramachandra Guha, a renowned environmental historian, who eloquently articulated the ecological significance of the Western

Ghats and the imperative to protect its fragile ecosystems. In a landmark 2002 decision, the Supreme Court of India ordered the closure of the Kudremukh iron ore mine, citing irreparable environmental and wildlife damage. The ruling marked a turning point in India's conservation efforts, setting a precedent for protecting ecologically sensitive areas. Today, Kudremukh stands as a testament to the power of community activism and the importance of safeguarding our natural heritage. Its forests echo with wildlife calls, a testament to nature's resilience and the enduring spirit of those who fought to preserve it.

Key Words

Deforestation, Water pollution, Land degradation, Soil erosion, Desertification, Mineral extraction, Environmental degradation, Desalinization

Discussion

1.3.1 Forests in India

Forests are more than just clusters of trees; they are dynamic environments teeming with life and offering myriad benefits essential to both humans and the planet. In a lush forest, where sunlight filters through the canopy, amidst tranquillity lies a wealth of resources waiting to be discovered. Forests serve as vital reservoirs of biodiversity, housing countless plant and animal species, many of which are found nowhere else on Earth. From towering hardwoods to delicate ferns, each organism plays a unique role in maintaining the delicate balance of the ecosystem.

Beyond their ecological significance, forests provide a wide range of benefits essential to human well-being. Timber harvested from mature trees forms the backbone of countless industries, supplying wood for construction, furniture, paper, and fuel. Yet, the forest offers more than just timber. Medicinal plants found within its depths have been used for centuries by indigenous communities to treat ailments and cure diseases. The forest also acts as a

natural carbon sink, absorbing greenhouse gases and mitigating climate change on a global scale.

Moreover, forests play a crucial role in regulating local and regional climates by influencing rainfall patterns, temperature, and humidity. They help prevent soil erosion, filter water, and provide habitats for pollinators essential for agriculture. As you go deeper into the forest, each rustling leaf and chirping bird tells a story of interconnectedness and interdependence. It is a reminder of our responsibility to cherish and protect this invaluable resource for generations to come. Forests are important renewable resources. The Forest varies in composition and diversity and can contribute substantially to a country's economic development. Forests in India are highly diverse in composition, with long evolutionary and geological histories, occurring under diverse climatic conditions.

1.3.2 Threats to the Forest Ecosystem

Forests are among the most biodiverse and valuable terrestrial ecosystems on the planet.



However, maintaining forests and their biodiversity is both complex and sensitive. Natural and anthropogenic activities impact forest ecosystems, making it increasingly difficult. Unregulated logging has penetrated deep into the heart of the forest, leaving a trail of destruction and despair. As chainsaws roar and heavy machinery rumbles through the undergrowth, the once-pristine forest echoes with the sounds of devastation. Tall trees, some centuries old, crash to the forest floor, disrupting the delicate balance of the ecosystem. With each tree felled, habitats are destroyed, and biodiversity dwindles, pushing vulnerable species to the brink of extinction.

In the midst of the chaos, indigenous communities, who have called the forest home for generations, find their way of life threatened. They rely on the forest for food, medicine, and spiritual sustenance, but the relentless march of logging operations threatens to sever their connection to the land. As logging roads carve through previously untouched wilderness, the forest becomes increasingly vulnerable to encroachment and exploitation. Poachers capitalize on the newfound access, decimating populations of rare and endangered species for profit.

Moreover, the loss of forest cover aggravates soil erosion, disrupts water cycles, and contributes to climate change. Once lush landscapes turn barren, rivers run dry, and the very foundation of life begins to crumble. The fate of the forest hangs in the balance, a battleground where the forces of destruction and preservation clash. In this critical moment, the choices we make will shape the destiny of one of Earth's most precious ecosystems. Will we heed the call to action and safeguard the forest for future generations, or will we stand by as it fades into memory? The answer lies in our hands.

1.3.3 Over-exploitation

Over 72% of species are threatened by over-exploitation and 62% by agriculture out of the 9,000 species listed on the International Union for the Conservation of Nature's Red List of Threatened Species. Overharvesting wild species is putting more species on an extinction pathway than any other threat. The expansion and intensification of agriculture (the production of food, fodder, fibre and fuel crops; livestock; aquaculture; and the cultivation of trees) is the second-largest driver of biodiversity loss. Hunting threatens more than 1,600 species, including many large carnivores such as tigers and snow leopards. Unsustainable logging is driving the decline of more than 4,000 species, such as Australia's Leadbeater's possum, while more than 1,000 species, including southern bluefin tuna, are losing out to overfishing. Land change for crop farming and timber plantations imperils more than 5,300 species, including the far eastern curlew, while the northern hairy-nosed wombat is among more than 2,400 species affected by livestock farming and aquaculture.

1.3.4 Timber extraction

Timber extraction, driven by the insatiable demand for wood products, has led to widespread deforestation and degradation of forest ecosystems worldwide. As industries expand and urbanization accelerates, forests bear the brunt of this relentless pursuit of timber resources. The consequences of timber extraction reverberate throughout forest ecosystems, disrupting the delicate balance of biodiversity and ecosystem services. Clear-cutting and selective logging practices not only result in the loss of valuable habitat for countless plant and animal species but also diminish forests' capacity to sequester carbon and regulate local climates.

Furthermore, the social impact of timber extraction is deeply felt by indigenous and local communities who depend on forests for their livelihoods and cultural identity. For centuries, tribal people have lived in harmony with the land, relying on traditional knowledge and sustainable practices to meet their needs. However, the onslaught of commercial logging operations has marginalized these communities, displacing them from their ancestral lands and eroding their way of life. Moreover, the environmental consequences of timber extraction extend beyond the forest ecosystem. Soil erosion, water pollution, and biodiversity loss are just a few of the cascading effects that threaten the health and resilience of entire landscapes.

1.3.5 Deforestation

Deforestation, a grave form of environmental degradation, poses a significant threat to the planet's ecological balance and biodiversity. This phenomenon transcends geographical boundaries, manifesting as a global assault on forested landscapes that continues unabated. Forests, covering more than a quarter of the Earth's land area, are not merely repositories of timber; they are multifaceted ecosystems with profound social, ecological, and climatic functions.

At the heart of the forest lies a wealth of biodiversity, encompassing diverse plant and animal species that together form the intricate web of life. From towering trees to microscopic organisms, each component plays a vital role in sustaining ecosystem health and resilience. Moreover, forests act as crucial carbon sinks, absorbing vast quantities of atmospheric carbon dioxide through photosynthesis. By sequestering carbon, forests help mitigate the impacts of climate change, stabilizing global temperatures and regulating weather patterns on a planetary scale.

However, the relentless march of deforestation is driven by various human activities, each contributing to the gradual clearance of forested lands. From large-scale commercial logging operations to slash-and-burn agriculture, the methods employed in deforestation vary widely but share a common outcome: the irreversible loss of forest cover and biodiversity. Commercial agriculture, particularly the expansion of monoculture plantations for crops such as palm oil and soybeans, and cattle grazing, is a significant driver of deforestation in tropical regions. In addition, urbanization, infrastructure development, and illegal logging exacerbate the degradation of forested ecosystems, fragmenting habitats and diminishing the resilience of forest landscapes.

As forests vanish at an alarming rate, the consequences reverberate far beyond their borders, affecting ecosystems, communities, and the global climate system. To combat deforestation effectively, concerted efforts are needed to promote sustainable land-use practices, enforce conservation measures, and empower local communities to steward their natural heritage. Only through collective action and a shared commitment to environmental stewardship can we halt the devastating tide of deforestation and safeguard our planet's forests for generations to come.

1. Deforestation, the clearance of forests by human activities, occurs through various destructive practices:
2. Reckless and ruthless cutting of trees: Logging operations, both legal and illegal, involve the indiscriminate felling of trees for timber, paper, and other wood products. This uncontrolled extraction leads to the rapid depletion of forest cover and biodiversity loss.



3. Forest fires set by farmers: In many regions, farmers use slash-and-burn techniques to clear land for agriculture. These intentionally set fires, often set during dry seasons, can quickly spiral out of control, engulfing vast swaths of forest and causing irreparable damage to ecosystems.

Air pollution: Industrial activities and the burning of fossil fuels contribute to air pollution, which indirectly impacts forests by depositing harmful pollutants onto foliage and soil. This pollution can weaken trees, making them more susceptible to disease and infestation.

In summary, deforestation is primarily driven by human activities that prioritize short-term economic gains over long-term environmental sustainability. By addressing the root causes of deforestation and implementing measures to promote sustainable land management and conservation, we can mitigate its devastating impacts on forests and the planet.

1.3.6 Mining

Mining is the process of extracting valuable minerals, metals, and other geological materials from the Earth's crust. It encompasses a range of activities, from exploration and extraction to processing and transportation of minerals. Mining plays a crucial role in meeting global demand for raw materials used in industries such as construction, manufacturing, energy production, and technology. The mining process begins with exploration, during which geologists and engineers identify potential mineral deposits through geological surveys, satellite imagery, and drilling. Once a viable deposit is discovered, mining operations begin, typically using open-pit or underground methods.

In open-pit mining, large holes or pits are excavated to access the ore body, which is then extracted using heavy machinery, such as excavators, trucks, and conveyor belts. This method is commonly used to extract minerals near the surface, such as coal, iron ore, and copper. Alternatively, underground mining involves tunnelling into the Earth to access deeper mineral deposits. Miners use specialized equipment and techniques to extract ores from underground tunnels and shafts, ensuring safety and efficiency in challenging environments.

After extraction, the mined ore undergoes processing to separate the valuable minerals from the surrounding rock and impurities. This process may involve crushing, grinding, sorting, and chemical treatments to concentrate the desired minerals into a usable form. Once processed, the minerals are transported to refineries, smelters, or manufacturing facilities for further processing. The final products, such as metals, alloys, and industrial minerals, are then used in a wide range of applications, from construction materials to electronic components.

While mining contributes to economic development and provides essential raw materials for modern society, it also poses significant environmental and social challenges. Mining operations can lead to habitat destruction, soil and water pollution, deforestation, and the displacement of local communities. Moreover, the extraction and processing of minerals consume vast amounts of energy and water, contributing to greenhouse gas emissions and resource depletion.

To address these challenges, sustainable mining practices aim to minimize environmental impacts, promote responsible resource management, and ensure the well-being of affected communities. This includes imple-

menting environmental mitigation measures, adopting efficient technologies, restoring mined areas, and engaging in transparent and inclusive stakeholder dialogue. Through responsible mining practices, the industry can balance the needsof society, the economy, and the environment, ensuring the long-term sustainability of mineralresources.

1.3.6.1 Major effects of mining operations on forests

- ▶ Mining from shallow deposits is done by surface mining, while that from deep deposits is done by sub-surface mining. It leads to land degradation and loss of topsoil. It isestimated that about eighty thousand hectares of land are under stress from mining activities in India
- ▶ Mining dries up perennial water sources, such as springs and streams, in mountainous areas.
- ▶ Mining and other associated activities remove vegetation and the underlying soil mantle, resulting in the destruction of topography and landscape in the area. Large scale deforestation has been reported in Mussorie and Dehradun valleys due to indiscriminate mining.
- ▶ The forest area has declined at an average rate of 33%, and the increase in non-forest area from mining activities has created relatively unstable zones, leading to landslides.
- ▶ Indiscriminate mining in Goa's forests since 1961 has destroyed more than 50,000 ha of forest

land. Coal mining in Jharia, Raniganj and Singrauli areas has caused extensive deforestation in Jharkhand.

- ▶ Mining of magnetite and soapstone has destroyed 14 ha of forest on the hilly slopes of Khirakot, Kosi Valley, and Almora.
- ▶ Mining of radioactive minerals in Kerala, Tamil Nadu and Karnataka is posing similar threats of deforestation.
- ▶ The rich forests of the Western Ghats are also facing the same threat from mining projects to excavate copper, chromite, bauxite, and magnetite.

1.3.7 Effects of dams on forests and tribal people

Dams are large structures built across rivers or streams to regulate water flow, store water, and generate hydroelectric power. They are constructed from concrete, earth, or rock and typically include a reservoir, an intake structure, a spillway, and an outlet. The primary purpose of dams is to store water for various uses, including irrigation, drinking water supply, flood control, and hydropower generation. By impounding water, dams can control river flow and reduce the risk of flooding during periods of heavy rainfall or snowmelt.

Hydropower generation is another significant function of dams. Water stored behind the dam is released through turbines, which convert the kinetic energy of flowing water into electricity. Hydropower is a renewable energy source that provides clean and sustainable electricity, reducing dependence on fossil fuels and lowering greenhouse gas emissions. Dams also play a crucial role in water resource

management, particularly in arid and semi-arid regions where water is scarce. They enable the storage and distribution of water for agricultural irrigation, municipal water supply, and industrial uses, helping to support human populations and economic development.

However, the construction and operation of dams can have significant environmental and social impacts. Large-scale dams can disrupt natural river ecosystems, alter water flow patterns, and disrupt fish migration routes, leading to biodiversity loss and degradation of aquatic habitats. Dams can also have profound social consequences, particularly for communities living downstream or in areas affected by reservoir inundation. Displacement of communities, loss of agricultural land, and changes in traditional livelihoods are common issues associated with dam construction, often leading to social conflict and economic displacement. Additionally, the reservoirs created by dams can submerge forests, archaeological sites, and cultural heritage sites, resulting in the loss of valuable cultural and historical roots.

Pandit Jawaharlal Nehru referred to dam and valley projects as “Temples of modern India”. These big dams and river valley projects have multi-purpose uses. However, these dams also destroy forests. They are responsible for the degradation of catchment areas, the loss of flora and fauna, the increase in water-borne diseases, the disturbance of forest ecosystems, and the rehabilitation and resettlement of tribal peoples. India has more than 1,550 large dams, the largest number in Maharashtra (more than 600), followed by Gujarat (more than 250) and Madhya Pradesh (130).

1.3.8 Environmental Impact of Large Dams

Large dams have resulted in extensive forest degradation due to reservoir submergence,

as well as the dereservation and clearance of forest land for the resettlement of ousters. Both forests and good farmland have been appropriated by reservoirs, canals, and other infrastructure connected with river valley projects. Rivers and the ecosystems they support are unique. Irreparable environmental damage is caused by the construction of large-scale dams. Some of these are considered here.

1. Change in downstream morphology and water quality

- a. Rivers provide energy for several vital processes such as transport of nitrogen, organic matter and nutrient-rich silt, oxygen enrichment, and enrichment of nutrients in bottom sediments in downstream entries, deltas and coastal areas, upon which the health of the fish is dependent. Any water management scheme that reduces runoff by more than 25% will have negative effects on coastal and estuarine fisheries, thereby depleting fish catches.
- b. Dams trap the sediment eroded from soils and rocks by the river. Clear water below the dam then seeks to recapture its lost sediment, eroding the soil on the bed and banks downstream from the dam. Loss of sediment is particularly important on river deltas, as it exacerbates coastal erosion. Increased sediment flow also adversely affects the dam's capacity for hydro power generation.
- c. Flowing water undergoes rapid thermal, chemical and physical changes. Deterioration of water quality is said to increase with retention time due to loss of dissolved oxygen.

2. Loss of forest and biodiversity

The most dramatic ecological effect of a

dam project is the flooding of vast areas of forested wetlands, cultivated land, and wildlife habitat. It is estimated that approximately 40,000 sq km. have been flooded by such dams worldwide.

Good forest cover is essential for mitigating soil erosion. Yet, reservoir catchment areas often experience rapid deforestation, leading to landslides, increased runoff, and, ultimately, siltation, which ironically threatens the viability of river valley projects. High siltation rates have dramatically reduced the life expectancy to the point of unsuitability for agriculture.

3. Salinity and pollution

Dams cause substantial evaporation losses, leading to increased salinity that can reach dangerous levels. Reductions in water and sediment flows caused by dams negatively affect downstream ecosystems and agricultural fertility. Delta areas are subject to seawater ingress. Reduced water flow in many rivers has also increased pollution levels, rendering river water unusable for humans and animals.

4. Earthquakes

Large dams built along fault lines or in geologically unstable regions can trigger earthquakes due to the pressure exerted by the weight of the reservoir and the dam, which, in turn, can destroy the dam and cause widespread flooding. This danger was evidenced by a devastating earthquake at Koyanagar near the Koyna dam reservoir in Maharashtra in 1967. Although India has already experienced dam-induced earthquakes, the government is pushing ahead with its plans to build the Tehu dam in a seismically sensitive region, the Garhwal Himalayas, in the face of opposition by experts and local people and despite the warning sign of a major earthquake in the region in 1992.

5. Design / Construction problems

Dams may fail even in the absence of tremor due to poor construction, as in the case of the Machu dam (Gujarat), which collapsed in 1979, resulting in widespread flooding and fatalities. Large dams and their reservoirs disrupt local ecosystems in multiple ways, and quantifying their economic costs and benefits is difficult. As in the case of forests, biodiversity loss is not accounted for in cost-benefit analyses.

6. Resettlement

People who lose their homes and lands due to large-scale development projects are referred to as environmental refugees. Displacement occurs very easily because it involves the tribals to a large extent. These tribes are largely illiterate and unaware of their rights. They are forced to move around without considering the economic and psychological impacts of such action on them. Hence, displacement takes place without the affected population's knowledge, who have no sense of participation in the project and receive no share of the benefits. This problem of displacement is compounded by the fact that even land records of the displaced population are not up to date, and hence there is no guarantee that the benefits will reach the right person. The resettlement process can have profound social, economic, and cultural impacts on affected communities.

- a. **Displacement:** Communities residing in the vicinity of dam construction sites may be forcibly displaced from their homes, agricultural land, and ancestral territories. Forced displacement can result in the loss of homes, livelihoods, social networks, and cultural heritage, leading to psychological distress and trauma among affected populations.



- b. Loss of Livelihoods:** Many communities dependent on agriculture, fishing, and other natural resources face the loss of their primary livelihoods due to dam construction. Traditional occupations and practices may no longer be viable in resettlement areas, leading to economic hardship and food insecurity.
 - c. Social Disruption:** Resettlement often disrupts social cohesion and community dynamics, as families and communities are dispersed and relocated to unfamiliar environments. Social networks and support systems may be fractured, exacerbating feelings of isolation and vulnerability among resettled populations.
 - d. Access to Services:** Resettled communities may experience challenges in accessing basic services such as healthcare, education, clean water, and sanitation in their new locations. Infrastructure development in resettlement areas may lag, leaving communities underserved and marginalized.
 - e. Cultural Impact:** Dams and reservoirs can inundate sacred sites, cultural heritage and ancestral lands of indigenous peoples and local communities. Loss of cultural identity, spiritual connections, and traditional knowledge may result from displacement and disruption of cultural practices.
 - f. Compensation and Rehabilitation:** Adequate compensation, resettlement assistance, and rehabilitation measures are essential to mitigate the negative impacts of dam-induced resettlement. However, disputes over compensation, lack of consultation, and inadequate resettlement planning often lead to grievances and social unrest among affected communities.
- In summary, the resettlement of people due to dam construction represents a complex and challenging process that requires careful planning, consultation, and implementation. Recognising the rights and needs of affected communities, ensuring meaningful participation and consultation, and prioritising social equity and justice are essential to responsible dam development and resettlement policies.

In *Budhini a novel*, the author Sarah Joseph brings to light the harsh realities faced by Budhini Mehjan and others like her, whose lives are upended by the relentless march of progress and so-called civilization. Budhini's story, set against the backdrop of the inauguration of the Panchet Dam, underscores the toll exacted on the poor and marginalized in the name of development.

As Budhini returns to her native village of Karbona after the dam's inauguration, she is ostracised and excommunicated by tribal elders for marrying an outsider. Cut off from her community and livelihood, Budhini's plight epitomizes the injustices faced by those at the fringes of society, forced into debt and destitution.

Joseph's narrative paints a poignant picture of Budhini's struggle, shedding light on

the exploitation and dispossession experienced by marginalized communities. However, despite its noble intentions, the novel's stylized portrayal of Santal life and romanticized ideology may leave readers feeling disconnected and disillusioned.

"Budhini: A Novel" serves as a powerful reminder of the human cost of progress and the need for empathy and social justice in the face of adversity. Yet, while the novel's themes resonate deeply, its execution falls short of capturing the complexity and depth of Budhini's story.

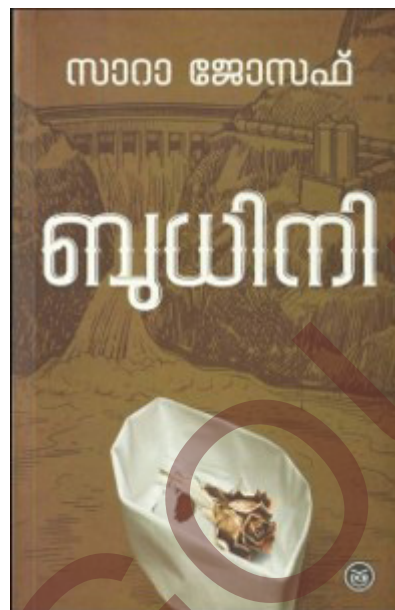


Fig 1.3.1 Budhini: Novel by Sarah Joseph

1.3.9 Water Resources

Water, the elixir of life, flows through the veins of our world, nourishing ecosystems, sustaining communities, and shaping civilizations. From the majestic rivers that carve through rugged landscapes to the tranquil lakes nestled amidst lush greenery, water holds the key to our existence. When you are standing on the banks of a mighty river, feeling the rush of water as it surges forward with unstoppable force, each ripple, each eddy, tells a story of resilience and adaptation, of life finding a way even in the harshest of environments.

But water is not just a source of sustenance; it's a source of wonder and awe. Dive beneath

the surface and discover a hidden world teeming with vibrant colours, exotic creatures, and untold mysteries. From the playful dance of dolphins in the ocean depths to the graceful glide of swans across tranquil ponds, water beckons us to explore its depths and unlock its secrets. Yet, amid the beauty and abundance, water also reminds us of our responsibility as stewards of the Earth. With climate change threatening to disrupt delicate water cycles and pollution choking our rivers and streams, the need to protect and preserve our water resources has never been more urgent.

1.3.9.1 Global distribution of water

What is the source of drinking water in your

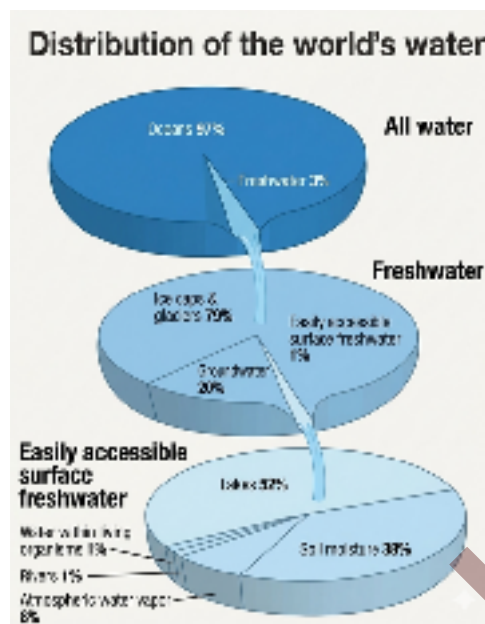


Fig 1.3.2 Global Distribution of Water

Table 1.3.1 Global Distribution of Water

Distribution	Abundance in Percentage
Oceans and Seas	97.4
Ice Caps and Glaciers	1.98
Groundwater and Soil water	0.599
Lakes	0.007
Atmosphere	0.001
Rivers	0.0001

house? Some of you may be using well water, river water, pond water, or pipeline water. Earth's water is (almost) everywhere in the air and clouds, in rivers, oceans, ice, plants, and in living organisms. The distribution of water on the Earth's surface is extremely uneven.

Of the world's total water supply of about 332.5 million cubic miles of water on earth, over 97% is saline water and is confined in the open ocean and seas. The remaining 3% is fresh water on land, and the bulk of it is stored in snow-covered continents and mountain regions as ice caps and glaciers. The remaining

fresh water on land, like groundwater (0.6%), lakes (0.007), water vapour in the atmosphere (0.001) and river water (0.0001%), is very small in abundance compared to the total water on earth.

If we consider the freshwater on land alone, of the total freshwater, over 79% is locked up in the ice and glaciers. Another 20% of freshwater is groundwater occurring within the earth. However, the easily accessible surface freshwater constitutes only 1%.

Among the easily accessible fresh water on

land, a major portion is in lakes (52%), followed by soil moisture (38%), water vapour in the atmosphere (8%), living organisms (1%) and rivers (1%). The important thing to realise is that the volume of water in the river is very small (0.0001%) compared to the total volume of water on the globe. Hence, river water must be used very judiciously when planning sustainable river water management projects.

1.3.10 Water resource types

The world's water exists in nature in different forms and locations: in the air, on the surface, below the ground and in the oceans.

a. Saltwater– 97%

As you are aware, the majority of water on Earth is salty! Chloride and sodium are the most abundant ions found in saltwater. Other ions or elements, particularly in the oceans, include magnesium, sulphur, calcium, potassium, and many more. These ions form salt, giving oceans, seas, and some lakes their salty or saline characteristics. Humans cannot use saltwater directly. Before humans can use saltwater for drinking or irrigation, it must be desalinated to remove the salts. Desalination is costly and energy-intensive, but in extremely dry regions, this process can provide people with much-needed freshwater.

b. Surface water

Surface water is any body of water found on the Earth's surface, including both saltwater and freshwater. In a terrestrial context, it refers specifically to water that does not penetrate the ground, collecting instead in rivers, lakes, ponds, and wetlands. It is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, and evapotranspiration. Natural input to any

surface water system is precipitation within its watershed. The total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands, and artificial reservoirs; the permeability of the soil beneath these storage bodies; the runoff characteristics of the watershed; the timing of precipitation; and local evaporation rates. All these factors also affect the proportions of water loss.

c. Lakes

A lake is a large body of relatively still water localized in a basin that is surrounded by land, apart from any river or other outlet that serves to feed or drain the lake. Scientifically, they are often distinguished from ponds by their depth; a lake is typically deep enough to have a light-compensated zone (aphotic zone) where sunlight cannot reach the bottom, preventing rooted plants from growing across the entire basin. Lakes form where water runs off from rain and snow accumulates. In some places, lakes form where groundwater seeps to the surface. Lakes come in a variety of shapes and sizes, and can contain salty or fresh water. The Earth's oldest and largest lake, Lake Baikal in Siberia, has a depth of over 1,500 m (1 mile)! Freshwater lakes are highly valued for recreation and water supply.

d. Estuary

An estuary is a body of water where fresh water and salt water meet. An estuary is a partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and through it, into the open sea. Normally, estuaries serve as transition zones between river and marine environments. All estuaries have a free connection, either continuous or intermittent. They tend to be very rich in organisms. Rivers, before they are diluted



by the enormous body of ocean water, have generally high concentrations of many chemical elements needed by plants and animals to build their tissues.

e. Rivers

Rivers form where water flows downhill, due to gravity, making a journey from the tops of mountains to the sea. Many different plant and animal species can be found along rivers. Although rivers make up a small proportion of Earth's water resources, they have and continue to be an important resource for humans, serving as transit systems for exploration and the transport of goods, as sources of power, as sites of recreation, and as sources of freshwater.

f. Groundwater

Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that flows within aquifers below the water table. Sometimes it is useful to distinguish between groundwater closely associated with surface water and deep groundwater in an aquifer (sometimes called "fossil water"). The natural input to groundwater is seepage from surface water. The natural outputs from groundwater are springs and seepage to the oceans. Water from rain trickles downward through the soil until it reaches material that is already saturated with water. Depending on the depth of this area and how fast the water has filtered through the soil, groundwater can be days to thousands of years old. Places where groundwater collects are called aquifers. Aquifers can be quite large – the Great Artesian Basin in Australia is one of the deepest and largest in the world, covering 1.7 million square kilometres (660,000 square miles) or 23% of the Australian Continent. Humans rely heavily on groundwater for drinking, farming, and other uses, but overuse, pollution, and sea level rise threaten this precious resource.

g. Frozen water

Frozen water is found as a persistent body of dense ice in water bodies, otherwise called glaciers. Glacier runoff is considered surface water, and glacial ice is the largest reservoir of fresh water. The Himalayas, often called "The Roof of the World," contain some of the most extensive and rugged high-altitude regions on Earth, as well as the largest areas of glaciers and permafrost outside the poles. Ten of Asia's largest rivers flow from there, and more than a billion people's livelihoods depend on them. To complicate matters, temperatures there are rising more rapidly than the global average.

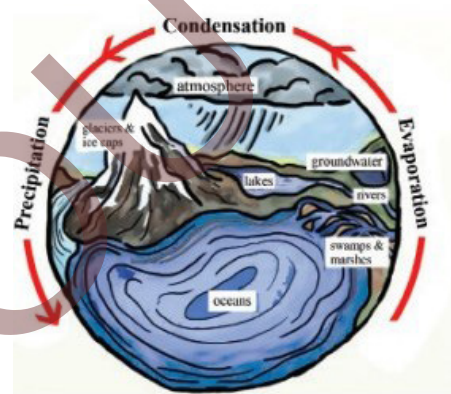


Fig 1.3.3 Water moves between these reservoirs through processes that transfer energy across the globe

h. Ice

Most of the freshwater on Earth is frozen. So much of our water is frozen that if all of it melted at once, the sea would rise about 6 meters (20 feet)! Ice is made of freshwater, even when it floats in oceans and seas. This is because saltwater freezes at much lower temperatures than freshwater, and very cold saltwater is so dense that it sinks away from the surface where freezing takes place. Ice is found at the north and south poles as ice caps, as glaciers on high mountains and at high latitudes, and in regions with permanent snow

and permafrost (frozen soils). Approximately 90% of the Earth's ice is in Antarctica.

1.3.11 Water availability and water use

1. Drinking water and domestic use (household)

It is estimated that 8% of the world's water use is for domestic purposes. These include drinking water, bathing, cooking, toilet flushing, cleaning, laundry and gardening. Drinking water is water that is of sufficiently high quality so that it can be consumed without risk of immediate or long-term harm. Such water is commonly called potable water.

2. Agriculture

It is estimated that 70% of the world's water is used for irrigation, with 15–35% of irrigation withdrawals being unsustainable. To avoid a global water crisis, farmers will have to increase productivity to meet growing food demands, while industry and cities find ways to use water more efficiently. The changing landscape of agriculture significantly affects the flow of fresh water.

3. Industries

It is estimated that 22% of the world's water is used in industry. Major industrial users include hydroelectric dams, thermoelectric power plants that use water for cooling, ore and oil refineries that use water in chemical processes, and manufacturing plants that use water as a solvent. Water withdrawal can be very high in certain industries, but consumption is generally much lower than in agriculture.

4. Environment

Water use in the environment is also very

small, but the percentage of total water use is increasing. Environmental water use includes watering natural or artificial wetlands, artificial lakes intended to create wildlife habitat, fish ladders, and water releases from reservoirs timed to help fish spawn or restore more natural flow regimes. Environmental use is non-consumptive but may reduce water availability for other users at specific times and places.

5. Recreation

Recreational water use is mostly tied to lakes, dams, rivers or oceans. If a water reservoir is kept fuller than it would otherwise be for recreational use, the water retained could be categorised as recreational use. Examples are anglers, water skiers, nature enthusiasts and swimmers. Recreational usage is usually non-consumptive. However, recreational use may reduce water availability for other users at certain times and places.

1.3.12 Water scarcity

You might have seen people searching for water in drought-prone areas. Water scarcity or watershortage is the lack of fresh water resources to meet the standard water demand. Two types of water scarcity have been defined: physical and economic. Physical water scarcity occurs when there is not enough water to meet all demands, including those needed for ecosystems to function effectively. Arid areas (for example, Central and West Asia, and North Africa) often suffer from physical water scarcity. On the other hand, economic water scarcity is caused by a lack of investment in infrastructure or technology to draw water from rivers, aquifers, or other water sources, or by insufficient human capacity to meet water demand. Much of Sub-Saharan Africa is characterised by economic water scarcity.



Climate change, such as altered weather patterns (including droughts or floods), deforestation, increased water pollution, and the wasteful use of water, can also cause an insufficient water supply. Scarcity varies over time as a result of natural hydrological variability, but varies even more so as a function of prevailing economic policy, planning and management approaches. Scarcity can be expected to intensify with most forms of economic development, but, if correctly identified, many of its causes can be predicted, avoided or mitigated.

1.3.13 Threats to water sources

Threats are conditions that could affect people's health if the water were used for drinking, cooking, or general hygiene; they can be either quality or quantity issues. Threats to your drinking water system may be either man-made or naturally occurring. Threats to our drinking water sources can be considered as groundwater threats or surface water threats.

1.3.13.1 Groundwater Threats

Groundwater, a vital resource beneath the Earth's surface, faces numerous threats that endanger its availability and quality. These threats stem from human activities, environmental changes, and unsustainable water management practices, posing significant challenges to global water security. Many human activities can negatively affect both groundwater quality and quantity. Some key threats to groundwater include waste disposal, resource extraction, agricultural practices, and urbanisation.

a. Over-Extraction of Water

Excessive groundwater pumping for agriculture, industry, and domestic use has led to the depletion of aquifers, causing water levels to decline and wells to run dry. Over-extraction

exacerbates water scarcity, particularly in regions reliant on groundwater as a primary water source.

b. Waste Disposal

The best-known source of groundwater contamination is waste disposal sites (landfills). Septic systems are another potential source of groundwater contamination. If septic systems are improperly installed or maintained, bacteria, viruses, nitrate, phosphorus, chlorides, and the organic solvents found in many household cleaners, as well as products sold to "clean" septic systems, can all make their way into groundwater.

c. Mineral Resource Extraction

As mines intersect aquifers and collect water, they interfere with groundwater storage and can lower water levels in wells. Drainage from mining degrades water quality as it infiltrates aquifers or discharges into streams. Increased concentrations of iron, manganese, sulphate, and dissolved solids in well water can result in severe health problems.

d. Agriculture

Common agricultural practices such as fertilising and applying pesticides are under increased scrutiny after groundwater samples revealed nitrates and, in some cases, pesticides. The most prevalent problem is the presence of high nitrate levels from overapplication of manure and fertiliser. Nitrate is especially harmful to babies, interfering with the blood's ability to transport oxygen, which causes the baby to suffocate ("blue baby" disease).

e. Urbanization

Many human activities and land-use practices that proliferate with urbanisation can negatively affect groundwater. Even cemeteries, for example, can contaminate groundwater.

ter. Soils that have been covered with impervious surfaces—roofs, parking lots, or streets obviously cannot absorb precipitation. As a result, much of the water from rain and snowmelt goes directly into streams and is never available to recharge groundwater. Large concentrations of people can also lead to overpumping of aquifers. This can result in significant aquifer drawdown, which, in turn, reduces streamflow. Intensive pumping in coastal areas can draw saltwater into aquifers and wells. With increased population comes industrialisation and an increase in the number and variety of industrial activities, many of which can contaminate groundwater.

f. Saltwater Intrusion

In coastal areas, overpumping of groundwater can induce saltwater intrusion, in which seawater from the ocean infiltrates freshwater aquifers. This phenomenon jeopardizes the availability of potable water supplies and compromises agricultural productivity, particularly in regions dependent on groundwater for irrigation.

g. Natural Contamination

The natural constituents of water that may affect its suitability for drinking and other purposes, most commonly found in groundwater, are dissolved solids, calcium carbonate, and iron. Concentrations of chlorides and nitrates can also restrict the use of water. These constituents enter water by leaching from rocks as water moves through them. Hardness is a property of water, usually measured by the concentration of calcium carbonate, which increases the amount of soap needed to produce lather. Corrosive groundwater is common. Corrosibility involves many factors, including high acidity and low concentrations of calcium carbonate.

1.3.13.2 Surface Water Threats

Because surface water (rivers, streams, ponds, lakes, reservoirs, and springs) is, by its nature, more “visible,” most people have more experience with this water source. Surface waters are often recreational areas that offer opportunities for swimming, boating, fishing, and camping. Most of us have pleasant memories and experiences related to these water habitats and view them as a wonder of nature, representing crisp, clear, clean water. Surface waters can be contaminated by pollution from point or nonpoint sources.

Types of Groundwater Contamination Sources

► Point Source

- Contamination originating from a single and identifiable source.
- Examples: Permitted discharge from a factory or a sewage treatment plant.

► Nonpoint Sources

- Contamination that originates from multiple and unidentifiable sources.
- Examples: Fertilizers and herbicides from agricultural lands, as well as sedimentation.

Water pollution

Water pollution, a pervasive environmental issue, arises when harmful substances contaminate water bodies, compromising their quality and posing significant threats to ecosystems and human health. The sources of water pollution are diverse and include:

- Domestic Sewage:** Wastewater from homes and businesses, containing

various pollutants and pathogens, is discharged into water bodies, contributing to contamination.

- b. Industrial Waste:** Industries release large quantities of pollutants, including chemicals, heavy metals, and toxins, into freshwater sources during manufacturing processes and operations.
- c. Agricultural Pollution:** Runoff from agricultural lands carries sediments, fertilizers, pesticides, and animal waste into water bodies, leading to nutrient imbalances and ecological disruption.
- d. Urban Runoff:** Stormwater runoff from urban areas carries pollutants such as oil, grease, heavy metals, and litter into water bodies, contaminating them and degrading water quality.
- e. Plastic Pollution:** The widespread use and improper disposal of plastic products result in plastic debris entering waterways, posing threats to marine life, ecosystems, and human health through bioaccumulation and ingestion.
- f. Thermal Pollution:** Discharge of heated water from industrial processes and power plants into water bodies raises water temperatures, disrupting aquatic ecosystems, altering habitat suitability, and affecting the distribution of species.
- g. Acid Rain:** Atmospheric pollutants, particularly sulfur dioxide and nitrogen oxides, combine with rainwater to form acid rain, which acidifies water bodies, harms aquatic life, and damages ecosystems, soils, and infrastructure.

h. Pharmaceutical and Personal Care Products (PPCPs): Residues from pharmaceuticals, cosmetics, and personal care products enter water bodies through wastewater effluent, posing risks to aquatic organisms and potentially affecting human health through exposure to trace amounts of chemicals.

i. Microplastics: Microscopic plastic particles, resulting from the breakdown of larger plastic items or intentionally manufactured for certain applications, contaminate water bodies worldwide, posing threats to marine life and ecosystems.

j. Heavy Metals: Industrial discharges, mining activities, and agricultural runoff introduce heavy metals such as lead, mercury, cadmium, and arsenic into water bodies, posing toxicological risks to organisms and accumulating in food chains.

The consequences of water pollution are far-reaching, encompassing:

Human Health Impact: Waterborne diseases such as cholera, jaundice, and typhoid are prevalent where water pollution is rampant, posing significant risks to public health and well-being.

Ecological Damage: Aquatic life, including fish, plankton, and seabirds, suffers dire consequences from water pollution, leading to habitat degradation, biodiversity loss, and ecosystem imbalance.

Artificial Eutrophication: Excessive nutrient input, primarily phosphates and nitrates from pollution sources, disrupts natural nutrient cycles and promotes algal growth, deplet-

ing oxygen levels and causing eutrophication in lakes and canals.

Addressing the multifaceted challenges of water pollution requires holistic approaches that encompass pollution prevention, sustainable resource management, and strengthened regulatory measures. By fostering awareness, promoting responsible behaviour, and implementing effective pollution control measures, society can strive to safeguard water resources and ensure their availability and quality for future generations.

1.3.14 Waterlogging

Waterlogging is the saturation of soil with water. Soil may be regarded as waterlogged when it is nearly saturated with water much of the time, such that its air phase is restricted and anaerobic conditions prevail. In extreme cases of prolonged waterlogging, anaerobiosis occurs, the roots of mesophytes suffer, and a subsurface reducing atmosphere supports processes such as denitrification, methanogenesis, and the reduction of iron and manganese oxides. In agriculture, various crops need air (specifically, oxygen) at varying depths in the soil. Waterlogging of the soil stops air from getting in.

Waterlogging in agricultural lands can manifest in various forms, each categorized based on distinct factors:

a. Based on Causes:

- **Natural:** Waterlogging can occur naturally in areas such as swamps and valley bottoms where water naturally accumulates due to geological features and landscape characteristics.
- **Human-Induced:** Activities such as improper land drainage, over-irriga-

tion, and land levelling for agriculture can lead to human-induced waterlogging, exacerbating the problem.

b. Based on Permanence:

i. **Temporary:** Temporary waterlogging occurs seasonally or intermittently, lasting from a few days to several months, typically in response to heavy rainfall or temporary changes in water table levels.

- **Monsoon Floodplains:** Agricultural fields in tropical regions that become saturated during peak rainy seasons but dry out sufficiently for a second crop cycle in winter.
- **Depressional Wetlands (Vernal Pools):** Shallow natural depressions that collect water during spring snowmelt or heavy storms but evaporate completely by mid-summer.
- **Poorly Drained Urban Lawns:** Low-lying residential areas where water pools for 48–72 hours after an intense thunderstorm before eventually infiltrating.

ii. **Permanent:** Permanent waterlogging persists throughout the year, with saturated soil conditions prevailing continuously, posing significant challenges for agricultural productivity and land use.

- **Peat Bogs and Fens:** Ecosystems where the water table is at or near the surface year-round, leading to the accumulation of organic matter (peat) due to anaerobic conditions.
- **Mangrove Swamps:** Coastal areas where the soil remains submerged or saturated by daily tidal cycles, sup-



porting only specialized salt-tolerant vegetation.

- **Seepage Zones:** Areas at the base of hills or slopes where groundwater continuously discharges to the surface, keeping the soil perpetually "spongy" and unfit for standard construction or farming.

c. Based on Source of Water:

- **Rainfed:** Rainfed waterlogging occurs primarily due to excess rainfall, where inadequate drainage systems or impermeable soils result in water accumulation on agricultural lands.
- **Irrigated Agriculture:** Waterlogging in irrigated agriculture arises from excessive water application for irrigation purposes, leading to water accumulation and soil saturation beyond the capacity of natural drainage systems.

d. Based on Location:

- **Agricultural Lands:** Waterlogging affects cultivated lands predominantly, impacting crop growth, soil fertility, and overall agricultural productivity.
- **Other Utility Lands:** Beyond agricultural areas, waterlogging can also occur in built-up and urban areas, posing challenges for infrastructure, construction, and urban planning due to water accumulation and soil saturation.

Understanding the various types and factors contributing to waterlogging is essential for implementing effective mitigation strategies and land management practices aimed at minimizing its adverse impacts on agricultural productivity and environmental sustainabil-

ity. Through proper drainage design, land-use planning, and water management techniques, the detrimental effects of waterlogging can be mitigated, ensuring sustainable utilization of agricultural lands and improved resilience to changing environmental conditions.

1.3.15 Floods

A flood is a natural event that can have far-reaching effects on people and the environment. A flood is caused by heavy rainfall that makes rivers / oceans overflow their banks and can happen at any time of year. However, they can happen very quickly when heavy rain falls over a short period. These 'flash floods' occur with little or no warning and cause the biggest loss of human life compared to any other type of flooding. The worst flooding may occur when storms, spring tides and low atmospheric pressure coincide.

Floodwater can seriously disrupt public and personal transport by cutting off roads and railway lines, as well as communication links when telephone lines are damaged. Floods disrupt normal drainage systems in cities, leading to sewage spills that pose a serious health hazard, along with standing water and wet materials in the home. Bacteria, mould and viruses cause diseases, trigger allergic reactions, and continue to damage materials long after a flood. Floods can distribute large amounts of water and suspended sediment over vast areas, restocking valuable soil nutrients to agricultural lands. In contrast, soil can be eroded by large amounts of fast-flowing water, ruining crops, destroying agricultural land/buildings, and drowning farm animals.

The major types of floods are:

- a. Flash Floods
- b. Single event floods
- c. Multiple event floods



Fig 1.3.4 Maharashtra Flooding, July 2005

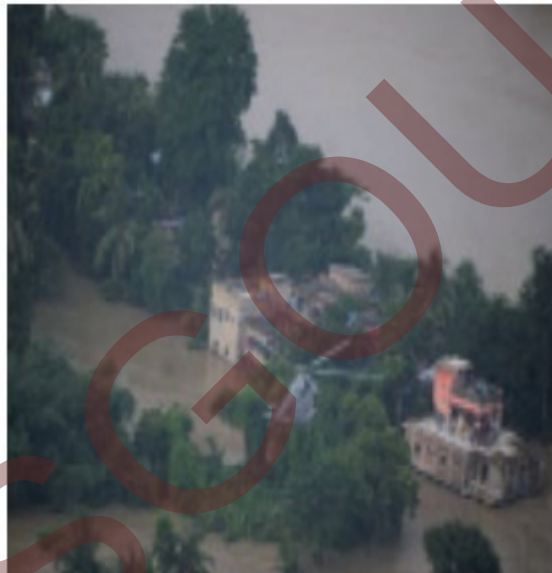


Fig 1.3.5 Flooding in West Bengal, August 2021

- d. Seasonal floods
- e. Coastal floods
- f. Estuarine floods
- g. Floods caused by Dam failures
- h. Floods due to the sudden melting of snow and glaciers

They are floods of great volume and short duration. These result from cloud bursts on relatively small and widely dispersed streams. These unpredictable heavy rainfalls or slow-moving thunderstorms may create flash floods.

Flash floods are frequently associated with violent, short-duration convectional storms.

A single-event flood is the most common type of flooding. It is caused by widespread, prolonged rainfall lasting 2 to 3 days. These are associated with cyclonic disturbances, such as storms and depressions.

The Kerala floods of 2018 were one of the most devastating natural disasters in the history of the state. Triggered by unusually heavy rainfall during the monsoon season, the floods wreaked havoc across the region, resulting in widespread destruction, loss of lives, and displacement of thousands of people. The heavy rainfall, which began in late May and continued into August, caused rivers and reservoirs to overflow, leading to massive flooding in various parts of Kerala. The incessant downpour resulted in landslides, collapsed bridges, submerged roads, and inundated homes and farmlands.

The floodwaters inundated numerous towns and cities, including the state capital Thiruvananthapuram, Kochi, and Kozhikode, causing extensive damage to infrastructure, public utilities, and agricultural fields. Thousands of homes were destroyed or damaged, leaving countless families homeless and in desperate need of assistance. The rescue and relief operations during the Kerala floods were massive, involving the deployment of the Indian Army, Navy, Air Force, and various disaster response teams. Helicopters were used to airlift stranded individuals from rooftops and isolated areas, while boats and makeshift rafts were employed to evacuate people from flooded villages and remote regions.

Successive weather disturbances cause multiple-event floods. Floods in the Indo-Gangetic plains are of this type. crop damage, and a general water shortage. Droughts are the second-most costly weather events after hurricanes.

Seasonal floods are those that occur during different seasons. Floods occur in some parts during the summer monsoon and in others during the winter monsoon. The southern half of the Indian Peninsula experiences floods mostly during the winter season.

Coastal floods occur due to the action of high tides and waves. Storm surges can create extensive floods along a coast. Hurricanes and tropical storms can produce heavy rains or drive ocean water onto the land. Beaches and coastal houses can be swept away by the water. Coastal flooding can also be produced by killer sea waves called tsunamis.

A drought is an event of prolonged shortages in the water supply, whether atmospheric (below-average precipitation), surface water, or groundwater. A drought can last for months or years, or sometimes it can be declared as drought after as few as 15 days. It can have a substantial impact on the ecosystem and agriculture of the affected region and harm the local economy. Annual dry seasons in the tropics significantly increase the likelihood of drought and subsequent bushfires. Periods of heat can significantly worsen drought conditions by hastening the evaporation of water vapour.

1.3.16.1 Types of droughts

1. Meteorological drought occurs when there is a prolonged time with less than average precipitation. Meteorological drought usually precedes the other kinds of drought.

1.3.16 Drought

A drought is a period when an area or region experiences below-normal precipitation. The lack of adequate precipitation, either rain or snow, can cause reduced soil moisture or groundwater, diminished stream flow,

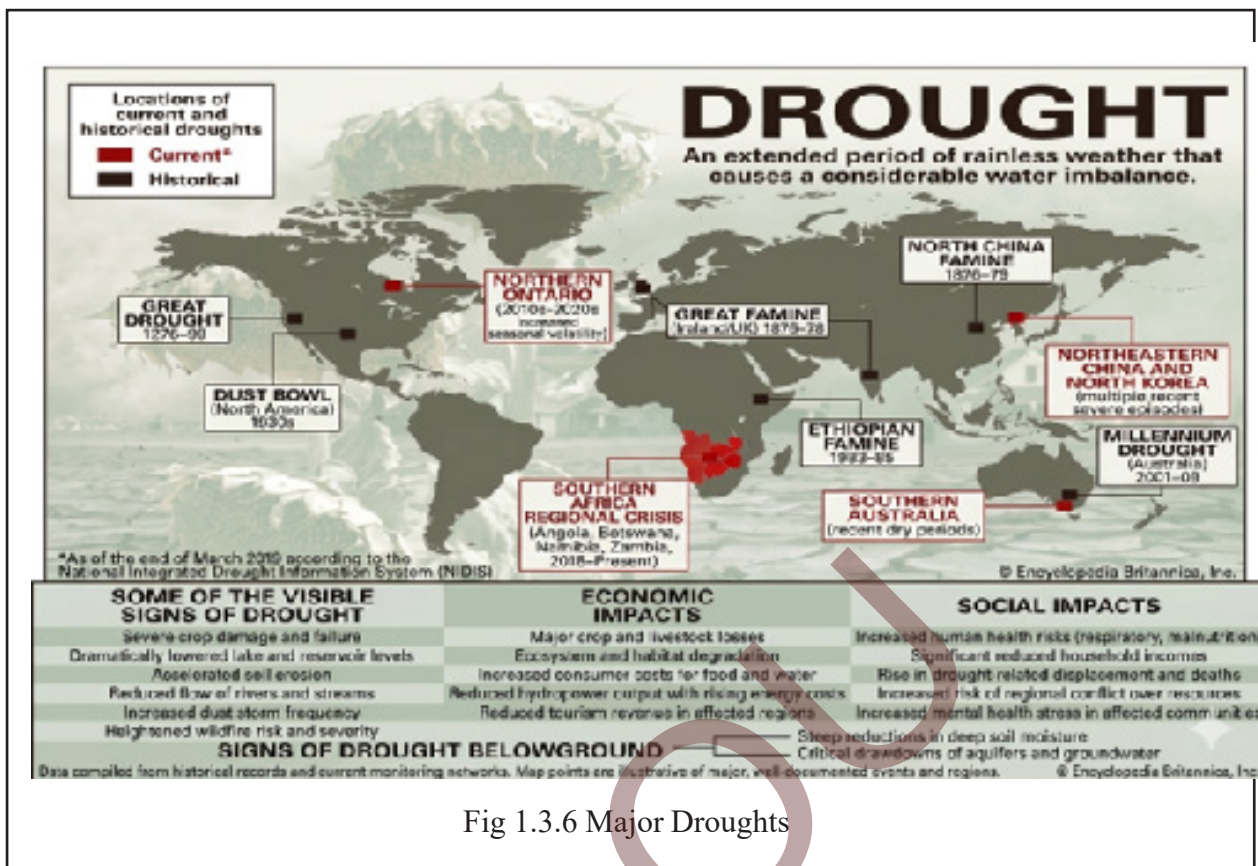


Fig 1.3.6 Major Droughts

- Agricultural droughts affect crop production or the ecology of the range. This condition can also arise independently of changes in precipitation levels when either increased irrigation or soil conditions and erosion triggered by poorly planned agricultural endeavours cause a shortfall in water available to the crops.
- Hydrological drought is brought about when the water reserves available in sources such as aquifers, lakes and reservoirs fall below a locally significant threshold. Hydrological drought tends to show up more slowly because it involves stored water that is used but not replenished.

1.3.17 Land and Mineral Resources

1.3.17.1 Land resources

Landforms such as hills, valleys, plains, river basins and wetlands include different resource-generating areas that the people living in them depend on. It is an essential natural resource, both for the survival and prosperity of humanity and for the maintenance of all terrestrial ecosystems. Land is a major resource for agricultural development worldwide. Over millennia, people have become increasingly skilled at exploiting land resources for their own ends. The limits on these resources are finite, while human demands on them are not. Increased demand, or pressure on land resources, shows up as declining crop production, degradation of land quality and quantity, and competition for land. Attention should

now be focused on the role of humankind as stewards rather than exploiters, charged with safeguarding the rights of unborn generations and conserving land as the basis of the global ecosystem.

1.3.17.2 Land degradation

Has anybody thought of how land degradation happens? Land degradation is a process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land. It is viewed as any change or disturbance to the land that is perceived as undesirable. Natural hazards are excluded as causes; however, human activities can indirectly affect phenomena such as floods and bushfires. This is considered an important topic of the 21st century due to the implications of land degradation for agricultural productivity, the environment, and food security. It is estimated that up to 4% of the world's agricultural land is seriously degraded.

According to the Special Report on Climate Change and Land of the Intergovernmental Panel on Climate Change, "About a quarter of the Earth's ice-free land area is subject to human-induced degradation (medium confidence). Soil erosion from agricultural fields is estimated to be currently 10 to 20 times (no tillage) to more than 100 times (conventional tillage) higher than the soil formation rate (medium confidence)." The United Nations estimate that about 30% of land is degraded worldwide, and about 12 million hectares of productive land, which roughly equals the size of Greece, is degraded every year. This happens because people exploit the land without protecting it. The United Nations Sustainable Development Goal 15 targets the restoration of degraded land and soil and the achievement of a land degradation-neutral world by 2030.

Agriculture, deforestation, and climate change are the main causes of land degradation, a global issue. Land clearing, including clear-cutting and deforestation; agricultural soil nutrient depletion due to inefficient farming methods; livestock overgrazing and overdrafting; inappropriate irrigation; urban sprawl; commercial development; vehicle off-roading; quarrying for stone, sand, ore, and minerals; and increase in field size due to economies of scale.

1.3.18 Man-induced landslides

Human-induced landslides (HIL) refer to landslide events directly triggered or partially aggravated by anthropogenic factors, such as topographic modification, changes in water circulation, land-use changes, and ageing infrastructure. Human-induced landslides usually occur on cut slopes due to excavation, which can cause many fatalities and severe destruction.

- ▶ Landslides are aggravated by human activities, such as:
- ▶ Deforestation, cultivation and construction.
- ▶ Vibrations from machinery or traffic.
- ▶ Blasting and mining.
- ▶ Earthwork (e.g., by altering the shape of a slope, or imposing new loads); in shallow soils, the removal of deep-rooted vegetation that binds colluvium to bedrock.
- ▶ Logging and urbanisation change the amount of water infiltrating the soil.
- ▶ Temporal variation in land use



Fig 1.3.7 Landslide in Idukki, Kerala, on August 2020

and land cover (LU/LC): It includes human abandonment of farming areas, e.g., due to economic and social transformations that occurred in Europe after the Second World War. Land degradation and extreme rainfall can increase the frequency of erosion and landslide phenomena.

1.3.19 Soil erosion

What is soil erosion? When will it happen? Soil erosion is a major worldwide threat to agro- ecosystem sustainability and land productivity. More than 36 billion tons of fertile soil are lost from global agricultural systems each year due to soil erosion. Erosion is a serious problem for productive agricultural land and water quality. Controlling the sediment must be an integral part of any soil management system to improve water and soil quality. Eroded topsoil can be transported by wind or water into streams and other waterways. Sediment is a product of land erosion and derives

largely from sheet and rill erosion from up-land areas, and to a lesser degree, from cyclic erosion activity in gullies and drainage ways.

1.13.19.1 Types of Erosion

- ▶ Sheet erosion (water) is almost invisible. Lighter-coloured soils indicate that, over the years, erosion has taken its toll.
- ▶ Wind erosion is highly visible. Although it is a problem, water erosion is generally much more severe.
- ▶ Rill erosion occurs during heavy rains, when small rills form over an entire hillside, making farming difficult.
- ▶ Gully erosion makes gullies, some of them huge, impossible to cross with farm machinery.
- ▶ Ephemeral erosion occurs in natural depressions. It differs from gully erosion in that the area can be crossed by farm equipment.

1.3.20 Desertification

Do you know what Desertification is? Desertification basically implies the degradation, deterioration, and impoverishment of the world's dryland regions. It is defined as the reduction or destruction of the biological potential of land, leading to the development of desert conditions. In other words, it refers to a loss of land productivity. This, however, does not mean that deserts are expanding. In this context, it is necessary to focus on the fact that desertification is inherently adverse. The problem is global in scale, affecting nearly one-fourth of the world's land area. It can take place anywhere; however, fertile land near existing deserts is often particularly vulnerable to desertification. Desertification is essentially the result of human activities rather than natural factors.

1.3.20.1 Causes of Desertification

1. **Over-cultivation-** most countries need to cultivate commercial or cash crops. This displaces traditional agriculture to marginal lands. The marginal lands, which were previously unused, either decline in productivity or remain stagnant at a basic production level. Natural events such as droughts and famines lead to the process of deterioration and degradation.
2. **Over-grazing-** low livestock prices tempt producers to rear as many as possible. The cattle overgraze the green land. This leads to the removal of vegetation cover and its nutrients. The loose soil particles, which basically contain the fertile characteristics, are blown away by the wind. This makes the land look like a desert. In other words, overgrazing over a period of time leads to desert-like conditions.
3. **Over irrigation-** The irrigation schemes meant for the supply of water are important, and hence they require adequate planning. Inefficient irrigation schemes result in waterlogging of crops and consequent soil salination. The saline soil brings up the salts to the surface, and continued evaporation makes the soil unfit for cultivation. Subsequently, this causes desertification.
4. **Deforestation-** This is one of the significant causes of desertification. Forests are cleared for various purposes: the cultivation of cash crops, human settlement, and to create space for increased cattle, among others. This process is called deforestation. As a result, top-quality or fertile soil is exposed to the forces of nature. Subsequently, it gets washed away. Thus, deforestation results in desertification.
5. **Mining operation-** Mining operations result in the disposal of rejects in fertile land. These mining rejects lead to total erosion of soil, further resulting in desert-like conditions.
6. **Growth of population-** A large increase in population is taking place in many parts of the world. This puts severe pressure on land, leading to desertification. In other words, human encroachment on land will lead to desertification.

1.3.20.2 Consequences of desertification

What are the consequences of desertification? Desertification is a severe problem because it leads to the exploitation of land, one of the most important natural resources. This problem is especially grave in the developing countries. Moreover, the seriousness of the problem increases because the negative consequences are irreversible.

1. Productivity of the land is almost eliminated, or it reaches the lowest level.
2. The productivity of land is vital for the survival of humanity. If a particular area of land becomes dry, the living conditions of the people in that area become miserable.
3. Once a land becomes a dry land or has desert-like conditions, the result is a loss of productivity or a loss of important means of survival. It means the drylands are incapable of producing food resources.
4. Desertification also leads to the drying up of the water resources; it destroys the natural resources of the environment.
5. There is also an adverse effect on the biotic and abiotic components of the environment.
6. The desert-like conditions created due to desertification seriously affect human beings. It leads to less productive or relatively infertile land. All these factors basically create miserable living conditions or poverty for the people. Desertification is a serious problem because its consequences cannot be reversed.

1.3.2.1 Mineral resources

Use of Minerals

The Earth's resources have been used by all cultures throughout history. The earliest uses of the earth's resources involved water, salt and simple tools made from rocks. The quantities of various mineral resources used by societies vary widely but generally correspond per capita to the nation's degree of development and standard of living.

The use of minerals depends upon their deposits. Some countries are rich in mineral deposits, while others have no deposits. The greatest use of minerals depends on their properties. Minerals are used in almost all industries. Gold, silver and platinum are used in the jewellery industry. Copper is used in the coin industry and in the production of pipes and wire. Silicon obtained from quartz is used in the computer industry. Aluminium is light, strong, and durable, so it is used in the aircraft, shipping, and automotive industries.

Exploitation of Mineral Resources

Exploitation of minerals refers to the use of mineral resources for economic growth. Exploitation of mineral resources at a mindless pace to meet the growing needs of modern civilisation has resulted in numerous environmental problems. Although the exploitation of minerals began slowly during the Industrial Revolution in Western countries, in the 20th century it increased exponentially, especially of fossil fuels, to meet growing energy needs. Today, about 80% of the world's energy consumption is sustained by the extraction of fossil fuels, which consist of oil, coal, and gas.

1.3.22 Environmental effects of mineral extraction

Mineral extraction and its subsequent use can have significant adverse environmental



impacts, with effects varying depending on factors such as mining techniques, ore quality, climate, and the scale of operations. Some of the major environmental effects associated with mining and processing operations include:

1. **Degradation of Land:** Mining activities often result in the physical alteration and degradation of land surfaces, leading to habitat destruction and loss of biodiversity.
2. **Pollution of Surface and Groundwater Resources:** Contaminants from mining operations can leach into surface water bodies and groundwater aquifers, polluting these vital resources and jeopardising ecosystems and human health.
3. **Impact on Vegetation Growth:** Mineral extraction processes can disrupt soil chemistry and nutrient balances, inhibiting the growth of vegetation and contributing to habitat degradation.
4. **Surface Water Pollution and Groundwater Contamination:** Runoff from mining sites can carry pollutants into nearby water sources, causing surface water pollution and groundwater contamination, posing risks to aquatic life and public health.
5. **Air Pollution:** Emissions from mining activities, including dust, particulate matter, and gases such as sulfur dioxide and nitrogen oxides, can contribute to air pollution, affecting air quality and human health in surrounding areas.
6. **Deforestation:** Mining operations often entail the clearing of forests and vegetation to access mineral deposits, leading to deforestation and habitat loss for various plant and animal species.
7. **Rehabilitation of Affected Areas:** After mining activities cease, the rehabilitation of disturbed land areas is essential to restore ecosystems, mitigate environmental impacts, and support sustainable land use practices.
8. **Rapid Depletion of High-Grade Minerals:** Extraction of high-grade mineral deposits can lead to their rapid depletion, necessitating sustainable resource management practices to ensure long-term availability.
9. **Forced Migration:** Mining operations may necessitate the relocation of communities and indigenous populations, leading to social disruption, loss of cultural heritage, and challenges in resettlement and livelihoods.
10. **Wastage of Upper Soil Layer and Vegetation:** The removal of overburden and vegetation during mining operations can result in the wastage of upper soil layers, affecting soil fertility and nutrient cycling processes.
11. **Soil Erosion and Oil Depletion:** Mining activities can exacerbate soil erosion and contribute to the depletion of soil resources, impairing agricultural productivity and ecosystem stability.

12. Ozone Depletion: Certain mining processes and emissions may release ozone-depleting substances, contributing to the depletion of the ozone layer and exacerbating environmental concerns.

13. Environmental Pollution: Mining activities can generate various forms of environmental pollution, including noise pollution, light pollution, and thermal pollution, impacting surrounding ecosystems and human well-being.

14. Natural Hazards: Mining operations may increase the risk of natural hazards such as landslides, subsidence, and seismic events, posing safety hazards to workers and nearby communities.

Addressing these environmental challenges requires implementing sustainable mining practices, adopting technologies to minimise environmental impacts, promoting ecosystem restoration and rehabilitation, and fostering stakeholder engagement and collaboration to ensure responsible resource management and environmental stewardship.

Recap

- ▶ Over-exploitation: Unsustainable use of natural resources.
- ▶ Timber Extraction: Removal of trees for commercial purposes.
- ▶ Deforestation: Clearing forests for agriculture, urbanization, or logging.
- ▶ Mining in Forest Areas: Extracting minerals from forested regions.
- ▶ Dams and Their Effects: Altering ecosystems and displacing communities.
- ▶ Resettlement of People: Forced relocation due to resource development projects.
- ▶ Overexploitation of Surface and Groundwater: Depletion of water sources beyond sustainable levels.
- ▶ Water Pollution: Contamination of water bodies by chemicals, sewage, or waste.
- ▶ Water Logging: Saturation of soil with excess water, hindering plant growth.
- ▶ Floods: Overflowing of water onto land, causing damage and displacement.
- ▶ Drought: Prolonged periods of low precipitation, leading to water scarcity.
- ▶ Land Degradation: Deterioration of land quality due to human activities.
- ▶ Man-Induced Landslides: Slope instability caused by deforestation or construction.
- ▶ Soil Erosion: Loss of topsoil due to water or wind, reducing fertility.
- ▶ Desertification: Expansion of arid areas due to soil degradation and climate change.-

Objective Questions

1. Define over-exploitation in two words.
2. State the primary ecological impact of deforestation.
3. Briefly describe the overall impact of mining.
4. Identify a major cause of water pollution.
5. What is the core result of land degradation?
6. List two primary water resource threats.
7. How do dams primarily affect local ecosystems?
8. What is the general outcome of mineral extraction?
9. Define water logging simply.
10. What is the functional definition of desertification?
11. Define soil erosion in its simplest form.
12. What is the main social impact of resettlement?
13. Define forest exploitation.
14. State a major consequence of timber extraction.
15. What is a primary tangible impact of floods?
16. Define drought based on resource availability.
17. How does agriculture typically contaminate water?
18. What characterizes surface water pollution?
19. Define groundwater depletion.
20. What does mineral resource extraction involve?
21. Define soil degradation.
22. What is the mechanical cause of landslides?
23. What makes industrial waste harmful?
24. Define habitat destruction.
25. Identify the broad cause of deforestation.

Answers

1. Unsustainable use
2. Habitat loss
3. Environmental damage
4. Industrial discharge
5. Soil quality decline
6. Scarcity, pollution
7. Habitat alteration
8. Environmental harm
9. Water accumulation
10. Land degradation
11. Soil loss
12. Social disruption
13. Resource depletion
14. Biodiversity loss
15. Property damage
16. Water shortage
17. Agricultural runoff
18. Contaminants in water
19. Groundwater decline
20. Resource extraction
21. Soil quality decline
22. Slope instability
23. Toxic chemicals
24. Ecosystem destruction
25. Human activities

Self Assessment Questions

1. Define deforestation.
2. What are the causes of water pollution?
3. Explain the concept of land degradation.
4. How do dams affect river ecosystems?
5. Describe the process of soil erosion.



6. What are the impacts of mining on the environment?
7. Define waterlogging.
8. Discuss the consequences of over-exploitation of natural resources.
9. Explain the term "desertification".
10. What are the effects of industrial waste on water bodies?

Assignments

1. Discuss the various human activities contributing to deforestation and their ecological impacts.
2. Explain the sources and types of pollutants responsible for water pollution, along with their effects on aquatic ecosystems and human health.
3. Describe the factors contributing to land degradation and its consequences for agriculture, biodiversity, and human settlements.
4. Analyze the ecological and social implications of large-scale dam construction, including impacts on river ecosystems and local communities.
5. Discuss the mechanisms and consequences of soil erosion, highlighting its effects on agricultural productivity and land stability.
6. Explore the environmental, social, and economic impacts of mining activities, including habitat destruction, water pollution, and displacement of communities.
7. Evaluate the causes and consequences of water logging in agricultural lands, including its effects on soil fertility and crop yields.
8. Assess the significance of sustainable resource management practices in mitigating over-exploitation of natural resources and conserving biodiversity.
9. Examine the processes and impacts of desertification, emphasizing its causes, geographical distribution, and measures for prevention and mitigation.
10. Investigate the challenges posed by industrial waste pollution to water bodies, including contamination sources, regulatory frameworks, and remediation strategies.

Reference

1. Diamond, J. (2005). *Collapse: How societies choose to fail or succeed*. Viking Press.
2. Gleick, P. H. (2014). *The world's water volume 8: The report on freshwater resources*. Island Press.
3. Primack, R. B. (2014). *Essentials of conservation biology* (6th ed.). Sinauer Associates.
4. Raven, P. H., Berg, L. R., & Hassenzahl, D. M. (2012). *Environment* (8th ed.). John Wiley & Sons.
5. Wilson, E. O. (2002). *The future of life*. Alfred A. Knopf.

Suggested Reading

1. Dirzo, R., et al. (2014). Defaunation in the Anthropocene. *Science*, 345(6195), 401–406.
2. Food and Agriculture Organization of the United Nations. (2020). *Global forest resources assessment 2020: Main report*. <https://doi.org/10.4060/ca9825en>
3. Hardin, G. (1968). The tragedy of the commons. *Science*, 162(3859), 1243–1248.
4. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services*. IPBES Secretariat.
5. Rockström, J., et al. (2009). A safe operating space for humanity. *Nature*, 461(7263), 472–475.

BLOCK - 02

Environmental Mitigation and Sustainable Development

Unit 1

Solutions to Contemporary Environmental Threats

Learning Outcomes

The components in this unit are aligned to the following learning outcomes:

- ▶ understand forest conservation strategies: reforestation, afforestation, social forestry, and agroforestry, for mitigating environmental threats.
- ▶ gain practical knowledge in water resource conservation: wastewater treatment, rainwater harvesting, groundwater recharge, watershed management, and Coastal Regulation Zone compliance.
- ▶ demonstrate proficiency in solid waste management: sanitary disposal, awareness of plastics and microplastics impact, e-waste management, and application of 3Rs principles.
- ▶ analyze the interconnection of environmental threats and solutions, evaluating the effectiveness of conservation strategies and waste management practices.

Prerequisites

Imagine you're on a hike through a lush forest, surrounded by towering trees and vibrant wildlife. As you walk, you notice the sound of running water nearby, leading you to a pristine stream flowing through the trees. The air is fresh, and the environment feels untouched by human hands.

But beneath this picturesque scene lies a hidden truth: our forests, waterways, and land are facing unprecedented threats due to human activity. Deforestation, pollution, and improper waste management are endangering the delicate balance of nature.

Before delving into solutions, it's crucial to understand the gravity of these threats and the interconnectedness of our actions with the environment. From the forest canopy to the depths of the ocean, every aspect of nature plays a vital role in sustaining life on Earth.

With this foundational understanding, we can embark on a journey to explore practical solutions to these contemporary environmental threats. From reforestation and afforestation



tion to innovative water management techniques and responsible waste disposal practices, each strategy holds the potential to restore and protect our natural world.

As we delve deeper into these topics, we'll learn about the importance of conserving forest resources through practices such as social forestry and agroforestry. We'll uncover the significance of treating and reusing wastewater, harvesting rainwater, and preserving coastal ecosystems through watershed management and adherence to Coastal Regulation Zones.

Moreover, we'll examine the critical issue of solid waste management and raise awareness of the impact of plastics and microplastics on the environment. From understanding the basics of e-waste management to embracing the zero-waste principles of Reduce, Reuse, and Recycle (3Rs), we'll explore tangible ways to minimise our ecological footprint.

By the end of our journey, we'll not only grasp the importance of these conservation strategies but also feel empowered to act in safeguarding our planet for future generations. Together, we can make a difference in combating contemporary environmental threats and preserving the beauty and diversity of our natural world.

Keywords

Afforestation, Rainwater harvesting, Watershed management, Sanitary landfill, Microplastics, 3Rs (Reduce-Reuse-Recycle), E-waste

Discussion

2.1.1 Conservation Strategies for Forest Resources

Conservation is the preservation and protection of natural assets for future generations. It incorporates maintaining a variety of species, traits, and biological systems, as well as elements of the climate, such as nutrient cycling. Some of the conservation measures practised in India and other parts of the world are as follows:

1. Increase in area of forest plantation: Planting of trees can be made in vacant or unused lands and waste, degraded and margin-

al lands, especially on roadside, along railway tracts, on contours and on land not suited for agricultural production. Planting trees outside forest areas will reduce pressure on forests for timber, fodder, and fuelwood. In addition, the deforested areas need to be reforested.

2. Developing alternative sources and promoting substitutes: It has become necessary to find alternative fuels as well as raw materials to manufacture paper, sports goods, packing cases, furniture and beams used in buildings. Research is underway to

develop alternative sources; in some cases, plastics and composite materials have successfully replaced timber.

3. Increase the area of forest permanently reserved for timber production: The most serious impediment to sustainable forest management is the lack of dedicated forests specifically set aside for timber production.
4. Developing a reliable mechanism of information base and regular monitoring: Knowledge of how much forest, where it is, and what it is comprised of seems to be straightforward. However, surprisingly, this most basic information is not always available. It is not possible to properly manage a forest ecosystem without first understanding it. Remote sensing technologies enable and make affordable identifying hotspots of deforestation.
5. Establishing an effective system of fighting forest fires.
6. Strictly enforcing laws to deal with unauthorised cutting of trees.
7. Promoting agro-forestry and social forestry: Agroforestry is the interaction of agriculture and trees, including the agricultural use of trees. This comprises trees on farms and in agricultural landscapes, farming in forests and along forest margins and tree-crop production, including cocoa, coffee, rubber and oil palm. Rural people partly meet their

needs for firewood and small timber by growing fast-growing trees within the limits of their village, along footpaths, roadsides, railway tracks, side roads, canals, and streams, and at field boundaries and in empty spaces. Social forestry aims to meet the needs of local people for fuel, fodder, fruits, timber, and other requirements.

8. Participatory forest management and rights: All stakeholders with an interest in the fate of the forest should be involved in planning, management and benefit sharing. The balance of rights can be strongly tilted toward society through publicly owned, strictly protected areas. As of now, much of the world's tropical forests are state-owned, but community participation in forest ownership and management needs to be encouraged. Moreover, the rights of indigenous forest dwellers and others who depend on intact forests must be upheld by recognising the traditional laws of indigenous peoples as indigenous rights. This will address conflicts between customary and statutory laws and regulations related to forest ownership and the use of natural resources, while ensuring the conservation of forest resources. Keeping this in view, various state governments in India have been implementing the Joint Forest Management Program after its successful implementation in West Bengal and Haryana in the 1970's.



2.1.1.1 Reforestation

The Intergovernmental Panel on Climate Change (IPCC) defines reforestation as the establishment of a forest cover in a location where forests were recently cleared, usually to use the land for activities such as agriculture or mining. Reforestation is also important for several other reasons, including the fact that

1.6 billion people worldwide rely on forests for their livelihoods. Additionally, forests have been shown to have benefits related

to anti-erosion, flood control, water security, soil protection/production and the maintenance of biodiversity.

2.1.1.2 Afforestation

Afforestation stands for the establishment of forests where previously there have been none, or where forests have been missing for a long time. The IPCC Guidelines define afforestation as the “planting of new forests on lands which, historically, have not contained forests.”



Fig 2.1.1 M. R. Hari, a land restoration consultant, grows 400- Tree Forest in 3 cents of land

Table 2.1.1 Difference Afforestation and Reforestation

Afforestation	Reforestation
Afforestation is the construction of a completely new forest in unused land, where no forest existed.	Involves using body language, facial expressions, gestures, posture, tone of voice, etc.
Afforestation is meant for growing trees in new areas.	Reforestation is done in an area where a forest was destroyed.
Here, only one sapling is needed to plant for a single tree	Here, two saplings are planted to eliminate each chopped down tree.
It is done to increase forest areas and to eliminate the effects of deforestation.	It is done to eradicate the negative impacts of burning forests for cultivation.
Afforestation may lead to the destruction of the grassland ecosystem.	Reforestation needs more labour and, thus, is found to be costly.

2.1.1.3 Social Forestry

Social forestry is forestry outside conventional forests that primarily aims to provide a continuous flow of goods and services to meet local people's needs. Social forestry was first recognised as an important component of forestry development in the Interim Report of the National Commission on Agriculture, 1976, and later in the National Forest Policy, 1988. The objective is to organise local communities in their struggle for socio-economic development and to integrate economic gains into the distribution of their benefits to rural society. It includes raising wind breaks on dry farmlands, planting trees along roadsides, planting in village common lands and waste lands, along railway lines and canal banks, on common community lands such as religious places, educational areas, and panchayat lands, etc.

Benefits of social forestry

- ▶ Fuel, fodder, timber, supplementary food and income from surplus forest products and tree-derived resources for rural people.
- ▶ It can form villagers into a well-knit community and increase social cohesion
- ▶ Reclamation of waste lands and degraded lands along with soil conservation and green cover.
- ▶ Protection of agricultural fields from winds and dust storms.
- ▶ Check desertification.

2.1.1.4 Agroforestry

Agroforestry is the management and inte-

gration of trees, crops and/or livestock on the same plot of land. It combines agriculture and forestry by planting viable tree shelterbelts along agricultural land. It is a dynamic, ecologically based, natural resource management system that diversifies and sustains production to increase social, economic, and environmental benefits for land users. Agroforestry is derived from ecological concepts and emphasises the interactions among different plant species. It results in higher overall yields and reduced operational costs.

Benefits of agroforestry

- ▶ Maintains soil organic matter and biological activity at levels satisfactory for soil fertility.
- ▶ Controls runoff and soil erosion and maintains the required soil moisture.
- ▶ Maintains more favourable soil physical properties than agriculture, through organic matter maintenance and the effects of tree roots.
- ▶ Promotes more closed nutrient cycling than agriculture and hence leads to more efficient use of nutrients.
- ▶ Nitrogen-fixing trees and shrubs can substantially increase nitrogen inputs to agroforestry systems.
- ▶ Decomposition of trees and pruning can substantially contribute to the maintenance of soil fertility.
- ▶ Helps in income diversification, thereby reducing the agricultural dependency of farmers.



Table 2.1.2 Distinction between Social Forestry and Agroforestry

Social Forestry	Agroforestry
Social forestry is a plantation made on lands outside conventional forest areas for the benefit of rural and urban communities, with objectives to supply fuel wood, to divert cow dung from village hearths to village fields, small timber for housing and agricultural implements and fodder for cattle of the rural population, protection of agriculture by creation of diverse ecosystem and arresting wind and water erosion, provide raw material for village cottage industries and improve scenic value in rural and urban areas.	Agroforestry is a sustainable land management system that increases the overall production, combines agricultural crops, tree crops and forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population.
It is the forestry of the people, by the people and for the people.	It is a system which is rather localized in its concept for managing the unit of land for maximising production of agricultural crop and forest trees complementary with each other.
Planting of trees on massive scales is done on vacant land, community land, roadside, railway track and even degraded reserve forests. Helps to eradicate poverty especially among landless and marginal rural people by providing them job potential.	Agroforestry is practiced mostly in farmers' field/own land.
Mainly trees and shrubs are to be used to harvest multiple products.	It involves integration of two or more than two components in the same unit of land.
Social forestry is primarily a government-based programme that aims at increasing the forest area by rehabilitating wastelands while producing biomass both for industrial and local uses.	Agroforestry involves the rural awakening towards self-sufficiency by producing maximum biomass per unit area, fulfilling needs of food, fodder, fuel wood etc.

2.1.2 Conservation and management of water resources

Water conservation and management encompass the policies, strategies, and activities aimed at managing water as a sustainable resource, protecting the water environment, and meeting current and future human demand. Population, household size, growth and afflu-

ence all affect how much water is used. Though blessed with large rivers like the Ganga, the Yamuna, the Godavari, the Narmada, and others, India's socio-economic development has contributed to declining water resources. Rising population, industrialisation, urbanisation, and the modernisation of agriculture are among the main reasons for water shortages in many parts of the country. As a result, most

of our prominent rivers, especially the smaller ones, have become toxic with waste products and pollution. The supply of water is fixed by nature. But water consumption has increased significantly. This has led to a water scarcity, especially in the poorest countries. Therefore, rational use of water is essential.

2.1.2.1 Various methods of water conservation need to be adopted:

1. Traditional water harvesting system- traditional systems are usually suited to the local conditions. Different areas have their own systems of collecting and sharing water. Pat, Johad, Saza Kuva, Talab, and Paar are examples of traditional Indian water-harvesting systems.
2. Watershed management- A watershed is a land area that sheds water into a particular region. It is the study of the relevant characteristics of a watershed, aimed at the sustainable distribution of its resources, and the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within the watershed boundary. Features of watersheds that agencies seek to manage include water supply, water quality, drainage, storm-water runoff, water rights and the overall planning and utilisation of watersheds.
3. Pani Panchayat- It is a voluntary activity of farmers which regulates the adequate supply of water from the river to the crop fields to ensure its optimum use.
4. Percolation Ponds- They help in reducing water shortage. They use check dams and tap rainwater.
5. Trapping spring water- This is a new solution to conserve and harvest water.
6. Roof- top rainwater harvesting. In this system, the rainwater falling on a building's roof or terrace is to be collected into a well or tank below.
7. Reclamation of wastewater- Waste water reclamation involves the treatment or processing of wastewater to a quality level acceptable for reuse. Wastewater reuse may be direct or indirect. Direct wastewater reuse involves a direct link between reclamation and processing. Indirect reuse occurs when reclaimed water is discharged into a stream, impoundment, or aquifer, where it is diluted and mixed with freshwater before reuse.
8. Groundwater recharging- Artificial recharge can be done through the injection of water through wells. This method is often applied to recharge deep aquifers where application of water to the land surface is not effective at recharging these aquifers.

2.1.3 Coastal Regulation Zone(CRZ)

Under Section 3 of the Environment Protection Act, 1986 of India, the Coastal Regulation Zone (CRZ) notification was issued in February 1991 for the first time, for the regulation of activities in the coastal area by the Ministry of Environment and Forests, MoEF



(currently MoEFCC)

As per the 1991 notification, the coastal land up to 500m from the High Tide Line (HTL) and a stage of 100m along the banks of creeks, lagoons, estuaries, backwaters, and rivers subject to tidal fluctuations is called the Coastal Regulation Zone (CRZ). The above notification covers only the intertidal zone and the land part of the coastal area. It does not include the ocean part—the notification-imposed restriction on the setting up and expansion of industries in the said CRZ. The CRZ along the country has been placed in four categories, viz., CRZ-I, CRZ-II, CRZ-III and CRZ-IV.

Amendments to the 1991 notification were made in 2003, 2011, and 2019.

Under the 1991 Notification, the coastal area has been classified as CRZ-1, CRZ-2, CRZ-3, and CRZ-4. The same were retained for CRZ in the 2003 notifications as well.

- ▶ CRZ-1: These are ecologically sensitive areas essential in maintaining the ecosystem of the coast. They lie between the low and high tide lines. Exploration of natural gas and extraction of salt are permitted in CRZ-1.
- ▶ CRZ-2: These areas are urban areas located in the coastal areas. Under the Coastal Regulation Zone (CRZ) Notification 2019, the floor space index (FSI) norms have been de-frozen.
- ▶ CRZ-3: Rural and urban localities which fall outside the 1 and 2. Only certain activities related to agriculture and some public facilities are allowed in this zone.
- ▶ CRZ-4: This lies in the aquat-

ic area up to territorial limits. Fishing and allied activities are permitted in this zone. No Solid waste should be let off in this zone. This zone was changed from the 1991 notification, which covered coastal stretches in the islands of Andaman & Nicobar and Lakshadweep.

2.1.3.1 Coastal regulation zone notification - 2019

The CRZ notification 2019 was issued to replace the 2011 notification and to develop the coastal regions of the country sustainably, on scientific principles, keeping in view current global problems of climate change and sea level rise.

One important development was the division of CRZ-I into IA and IB. The CRZ-IA covers 11 ecologically sensitive areas, including mangroves, coral reefs, dunes, salt marshes, national parks, and seagrass beds. The CRZ-I B covers the intertidal zone. i.e. the area between Low Tide Line and High Tide Line.

CRZ-II shall constitute the developed land areas (urban areas) upto or close to the shoreline, within the existing municipal limits or in other existing legally designated urban areas, which are substantially built-up with a ratio of built-up plots to that of total plots being more than 50 per cent and have been provided with drainage and approach roads and other infrastructural facilities, such as water supply, sewerage mains, etc.

CRZ-III: Land areas that are relatively undisturbed (i.e., rural areas) and those which do not fall under CRZ-II, shall constitute CRZ-III. This shall be further classified into the following categories:

CRZ-III A: densely populated areas, where the population density is more than 2161 per square kilometre as per 2011 census base shall be designated as CRZ-III A and in this, area upto 50 meters from the HTL on the landward side shall be earmarked as the 'No Development Zone (NDZ)', provided the CZMP as per this notification, framed with due consultative process, have been approved, failing which, a NDZ of 200 meters shall continue to apply.

CRZ-III B: All other CRZ-III areas with population density of less than 2161 per square kilometre, as per the 2011 census base, shall be designated as CRZ-III B and in this, the area up to 200 meters from the HTL on the landward side shall be earmarked as the 'No Development Zone (NDZ)'. Land area up to 50 meters from the HTL, or the width of the creek, whichever is less, along the tidal influenced water bodies in the CRZ III, shall also be earmarked as the NDZ in CRZ III.

CRZ- IV shall constitute the water area and shall be further classified as CRZ- IVA: The water area and the seabed area between the Low Tide Line up to 12 nautical miles on the seaward side shall constitute CRZ-IV A. The CRZ- IVB shall include the water area and the bed area between LTL at the bank of the tidal influenced water body to the LTL on the opposite side of the bank, extending from the mouth of the water body at the sea up to the influence of tide, i.e., salinity of five parts per thousand (ppt) during the driest season of the year.

The notification of 2019 also promotes the development of tourism infrastructure in the coastal areas. One of the important features of the 2019 notifications is the streamlining of the coastal regulation zone clearing procedure. The Ministry of Environment, Forest and Climate Change will oversee the matter of CRZ clearance only for CRZ-I; i.e., the ecologically vulnerable areas and CRZ IV (area

between low tide line and 12 nautical miles seaward) areas, while for the other two categories, namely CRZ-III and CRZ-II (urban areas), the power of clearance has been designated at the State level. The notification also proposes a 20-meter no-development zone for all islands. The ecologically vulnerable areas identified under the Environment Protection Act, 1986, are to be managed in partnership with coastal communities and fisher folks. To address pollution in coastal areas, the regulation requires the development of treatment facilities in CRZ-IB areas.

2.1.4 Segregation and Management of Solid Waste

Imagine waking up on a serene Saturday morning, ready to embrace the weekend. But as you step out of your house, instead of crisp air and chirping birds, you're greeted by a disheartening sight - piles of garbage strewn across the neighbourhood. Plastic bags flutter in the wind, food scraps mingle with discarded bottles, and the stench of decay hangs heavy in the air. This scene is all too familiar in many communities worldwide, where managing solid waste has become an increasingly pressing issue. The way we handle our waste has profound implications for the environment, public health, and overall quality of life. Amidst this challenge, the concept of segregation emerges as a beacon of hope, offering a simple yet powerful solution to mitigate the impact of our waste.

Segregation of solid waste involves sorting different types of waste materials at the source, typically at households or businesses, into categories such as organic, recyclable, and non-recyclable. It's like organizing a chaotic jigsaw puzzle, where each piece - be it a plastic bottle, a banana peel, or a newspaper - finds its rightful place. Instead of tossing



everything into a single bin, families separate their kitchen scraps for composting, rinse out recyclable containers, and properly dispose of hazardous materials, such as batteries. This small act of segregation sets off a chain reaction, streamlining the waste management process and paving the way for more sustainable practices.

But segregation is just the first step in the journey towards effective waste management. Once waste is sorted, it must be handled and processed to minimise its environmental impact. From recycling facilities that transform old newspapers into new paper products to composting sites where organic waste decomposes into nutrient-rich soil, each component of the waste management infrastructure plays a crucial role in closing the loop on our consumption habits. In our daily lives, the choices we make - from the products we buy to how we dispose of them - ripple outwards, shaping the collective footprint we leave on the planet. By embracing the principles of segregation and responsible waste management, we not only lighten the burden on our environment but also foster a culture of sustainability that future generations can inherit.

Solid waste refers to the range of garbage materials arising from plant, animal, and human activities that are discarded as unwanted and useless. Solid waste is generated from industrial, residential, and commercial activities in a given area. The effective measures for managing solid waste are called the Solid Waste Management system or processes.

2.1.4.1 Functional Elements of the Waste Management System

There are six functional components of the waste management system, as outlined below:

1. Waste generation: This encompasses

any activity involved in identifying materials that are no longer usable and are either gathered for systematic disposal or thrown away.

2. On-site handling, storage, and processing: Storage is a system for keeping materials after they have been discarded and before collection and final disposal. This relates to activities at the point of waste generation, which facilitate easier collection. Improved storage facilities include:

- Small containers: household containers, plastic bins, *etc.*
- Large containers: communal bins, oil drums, *etc.*
- Shallow pits

3. Waste collection: This includes activities such as placing waste collection bins, collecting waste from those bins, and accumulating trash in the location where the collection vehicles are emptied. Although the collection phase involves transportation, this is typically not the main stage of waste transportation. Any collection system should be carefully planned to prevent storage facilities from becoming overloaded. Collection intervals and volumes of collected waste must be estimated carefully.

4. Waste transfer and transport: These are the activities involved in moving waste from the local waste collection locations to the regional waste disposal site in large waste transport vehicles. This is the stage when solid waste is transported to the final disposal site. There are various modes of transport available, and the chosen method depends on local availability and the vol-

ume of waste to be transported. The types of transportation can be divided into three categories:

- Human-powered: open handcart, handcart with bins, wheelbarrow, tri-cycle
- Animal-powered: donkey-drawn cart
- Motorised tractor and trailer, standard truck, tipper-truck

5. Waste processing and recovery: This refers to the facilities, equipment, and techniques employed to recover reusable or recyclable materials from the waste stream and to improve the effectiveness of other functional elements

of waste management.

6. Disposal: This is the final stage of waste management. It involves the activities aimed at the systematic disposal of waste materials in locations such as landfills or waste-to-energy facilities. This includes safe disposal, where associated risks are minimised. There are four main methods for the disposal of solid waste:

- Land application: burial or land filling
- Composting
- Burning or incineration
- Recycling (resource recovery)

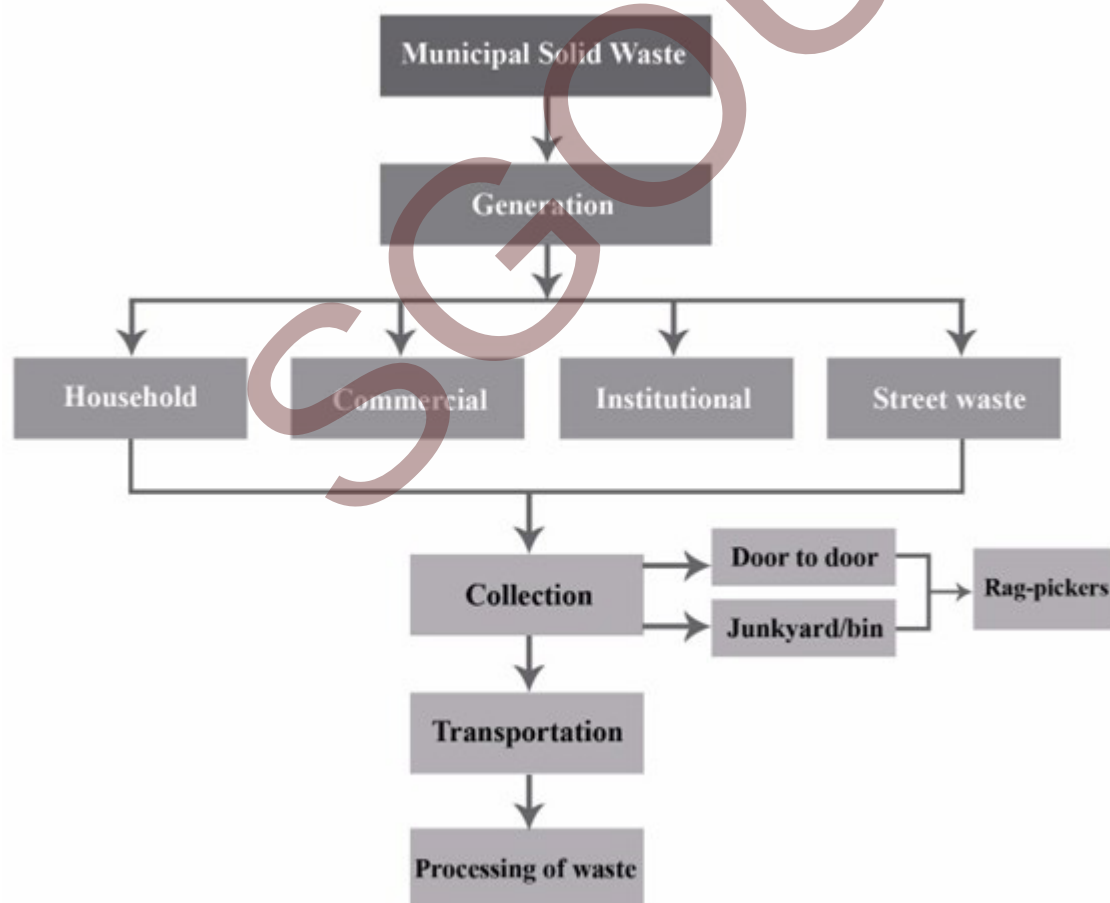


Fig 2.1.2 Flowchart representing the processes involved in solid waste management

2.1.4.2 On-site disposal

On-site disposal is the handling of waste at the site of its production. These may be adapted for the particular site and situation in question.

a. Communal pit disposal

The simplest solid waste management system is one in which consumers dispose of waste directly into a communal pit. The size of this pit will depend on the number of people it serves. The recommended size or dimension is six cubic metres per fifty people. The pit should be fenced off to prevent small children from falling in and should generally not be more than 100 m from the dwellings. Ideally, waste should be covered with a thin layer of soil at least weekly to minimise flies and other pests.

b. Family pit disposal

Family pits may provide a better long-term option where there is adequate space. These should be fairly shallow (up to 1 m deep), and families should be encouraged to regularly cover waste to prevent soil from sweeping or ash from firewood used for cooking. This method is best suited for families with large plots and for those with organic food waste as the main component of domestic refuse.

c. Communal bins

Communal bins or containers are designed to collect waste. Here, it will not be dispersed by wind or animals, and it can easily be removed for transportation and disposal. Plastic containers are generally inappropriate because the wind may blow them over, they can be easily removed, and they may be desirable for alternative uses. A popular solution is to provide an oil drum cut in half. The bases of these should be perforated to allow liquid to

pass out and to prevent their use for other purposes. A lid and handles can be provided if necessary.

2.1.4.2 Off-site disposal options

The technology choices are general options for off-site final waste disposal.

a. Landfilling

Once solid waste is transported off-site, it is normally taken to fill a site. Here, the waste is placed in a large (pit/ trench) in the ground, which is backfilled with excavated soil each day waste is tipped. Ideally, about 0.5 m of soil should cover the deposited refuse at the end of each day to prevent animals from digging it up and flies from breeding.

The location of landfill sites should be determined through consultation with local authorities and the affected population. Sites should preferably be fenced.

b. Incineration

Burning, or incineration, is often used to dispose of combustible waste. This takes place off-site or a considerable distance downwind of dwellings. Burning refuse within dwelling areas may create a significant smoke or fire hazard, especially if several fires are lit simultaneously. Burning may be used to reduce waste volume and may be appropriate where there is limited space for burial or landfill. Waste should be ignited within pits and covered with soil once incinerated, in the same manner as land filling.

c. Composting

Simple composting of vegetables and other organic waste can be applied in many situations. Where people have their own gardens or vegetable plots, organic waste can be



Fig 2.1.3 Flowchart representing the processes involved in solid waste management in Urban areas

dug into the soil to add humus and fibre. This makes the waste perfectly safe and supports plant growth. Properly managed composting requires careful monitoring of decomposing waste to control moisture and chemical levels and to promote microbial activity. This is designed to produce compost that is safe to handle and acts as a good fertiliser. Such systems require considerable knowledge and experience and are best managed centrally. In general, they are unlikely to be appropriate in emergencies.

d. Recycling

Complex recycling systems are unlikely to be appropriate, but recycling some waste items may be possible on occasion. Plastic bags, containers, tins, and glass are often automatically recycled because they are likely to be scarce commodities in many situations. In most developing countries, there exists a strong tradition of recycling, leading to lower volumes of waste than in many more developed societies.

2.1.5 Zero Waste

Isn't it good if there were no waste at all? How can we do that?

“Zero Waste” is a philosophy of eliminating the generation of materials that have no viable end-of-use management options. Zero Waste is an ethical, economical, efficient, and visionary goal that guides people in changing their lifestyles and practices to sustain natural cycles, where all discarded materials are designed to become resources for others to use. Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste, conserve and recover all resources, and not burn or bury them. A zero-waste approach conserves natural resources and reduces pollution from extraction, manufacturing and disposal. Reducing and reusing means fewer products are made, as people buy less and products are designed to last. Recycling keeps waste out of landfills and incinerators and pro-

Zero waste programs include all the following strategies:

- Reusing discards
- Reducing consumption and discards
- The principle of producer accountability (including extended producer responsibility strategies)
- Comprehensive recycling
- Comprehensive composting or bio-digestion of organic materials
- Citizen participation and worker rights
- A ban on waste incineration and illegal dumping
- The systematic reduction of landfilling over time
- Effective policies, regulations, incentives, and financing structures to support these systems

vides manufacturers with recycled materials instead of raw materials to make new goods. Effective zero-waste programmes also include people from various fields, such as waste worker cooperatives/ local neighbourhood groups/ universities, and governments.

2.1.6 Plastics and microplastics in the environment

Look around you and find different types of plastics. Are you able to categorise those plastics?

Plastic is an umbrella term that encompasses a wide range of materials made of semi-synthetic or synthetic organic compounds. They are long chains of polymers comprised of linked repeated units, named “monomers”. The International Union of Pure and Applied Chemistry (IUPAC) defines plastics as “polymeric materials that may contain

other substances to improve performance and/or reduce costs. Due to their ease of manufacture, low cost, impermeability, and resistance to chemicals, temperature, and light, plastics are used in a wide range of products and have replaced many other materials, such as wood, paper, stone, leather, metal, glass, and ceramic. In the modern world, plastics can be found in components ranging from stationery items to space ships. The smaller particles, frequently classified as <5mm, are known as microplastics and are colloquially referred to as “mermaid’s tears” due to their size and the vast array of colours they exhibit. Microplastics come from a variety of sources, including larger plastic debris that breaks down into smaller pieces. In addition, microbeads, a type of microplastic, are very tiny pieces of manufactured polyethylene plastic that are added as exfoliants to health and beauty products, such as some cleansers and toothpastes. They have become a growing concern for scientists and

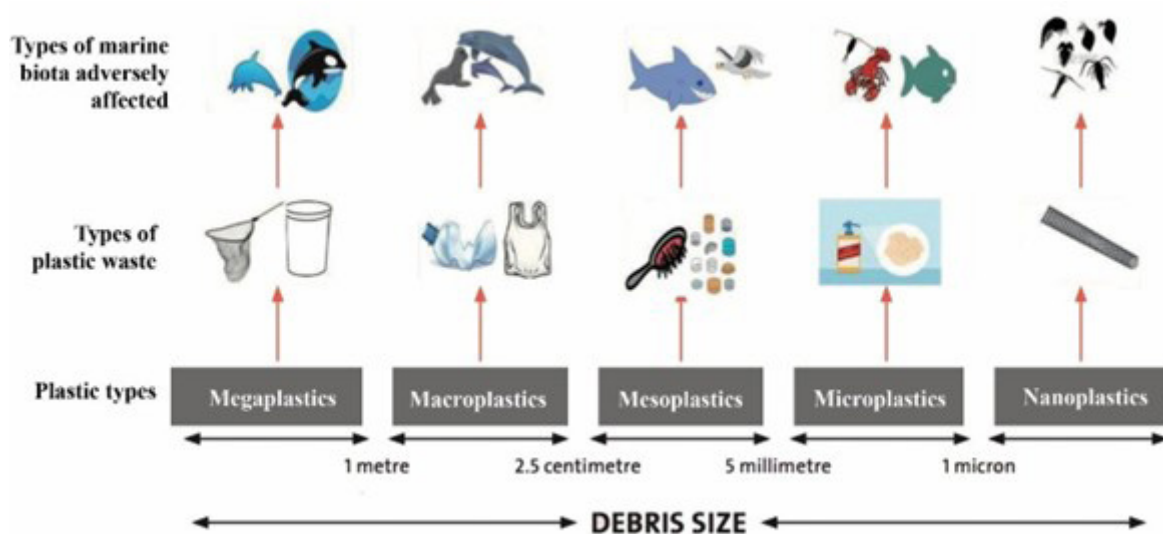


Fig 2.1.4 Classification of plastics in the environment

the general public because they pose a threat to the environment. These tiny particles easily pass through water filtration systems and end up in the ocean and the Great Lakes, posing a potential threat to aquatic life. The health effects of microplastics are yet to be fully understood.

Microplastics may be classified as primary or secondary, depending on their source.

Primary microplastics are deliberately manufactured in the millimetric or submillimetric size. They can be found in numerous household items, including personal hygiene products such as facial cleansers, toothpaste, and exfoliating creams. These products are of special concern, as it has been estimated that approximately 6% of all liquid skin-cleaning products sold in the EU, Switzerland and Norway contain microplastics, of which more than 93% consist of polyethylene (PE). Another key source of primary microplastics is the raw materials used to manufacture plastic items. Inadequate handling, accidental loss, runoff from processing facilities, and production pro-

cess residues can lead to the accumulation of primary microplastics. Microplastics are also used, to a lesser extent, in medicine, namely as drug carriers. After their use, microplastics are discharged in domestic wastewater and may reach the environment.

Secondary microplastics result from the breakdown of larger plastic particles. When exposed to the elements, physical, chemical, and biological processes can reduce the structural integrity of these plastics, leading to fragmentation. However, this breakdown can also occur before these materials enter the environment, as is the case with synthetic fibres from clothes released during washing cycles or the wear-and-tear of car tyres, which generate minute polymeric fragments.

Microplastics have been identified across the globe, including in remote locations, in the Arctic and the Antarctic, and throughout the water column from the surface to the depths (benthos). Microplastics are also found in rivers and lakes, in agricultural soils and sediments, and even in the atmosphere, both in-

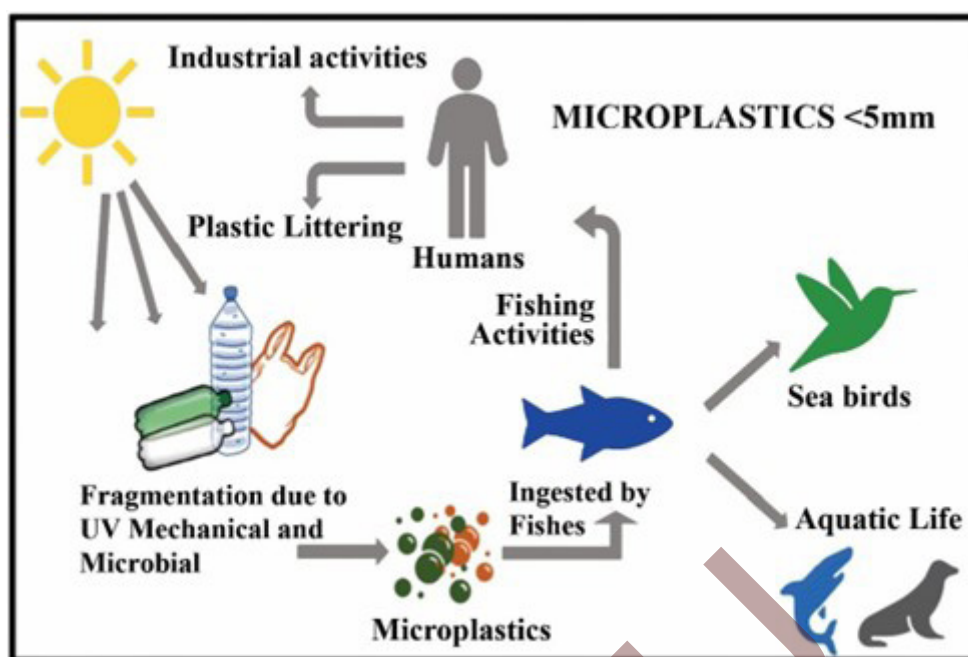


Fig 2.1.5 Fate of microplastics in the environment

doors and outdoors. Once in the environment, plastics can degrade through abiotic and/or biotic processes.

2.1.7 Effects of plastics

The interaction of organisms with plastic debris results in a wide range of consequences, both direct and indirect, including the potential for sub-lethal effects, which may be of considerable concern. Broadly, the presence of larger plastic materials in the ocean may result in entanglement and ingestion, potential creation of new habitats, and dispersal via rafting, including transport of invasive species. Entanglement and ingestion frequently cause harm or death. The gathered data appear to suggest that entanglement is far more fatal (79% of all cases) than ingestion (4% of all cases).

Although increased awareness and research focus have led to significant advances in understanding microplastic behaviour in the environment, much remains undetermined about

accurately forecasting exposure scenarios and predicting exposure hotspots. Owing to their small size, microplastics may be ingested by multiple organisms, including plankton and higher organisms such as mammals, birds, and fish. Although the exact mechanisms of toxicity of these materials are still not understood, the effects are potentially due to either (1) ingestion-induced stress such as physical blockage, energy expenditure; (2) leakage of chemicals, such as additives, from plastics and; (3) exposure to contaminants adsorbed (and subsequently released) by micro plastics such as persistent organic pollutants (POPs). The direct consequences of ingesting microplastics include obstruction of the digestive tract and internal injury, frequently leading to reduced food consumption and concomitant decreased nutrition. This potentially results in starvation and death. In air-breathing organisms, microplastics have been reported to lodge in gills, which may result in reduced respiration rates.

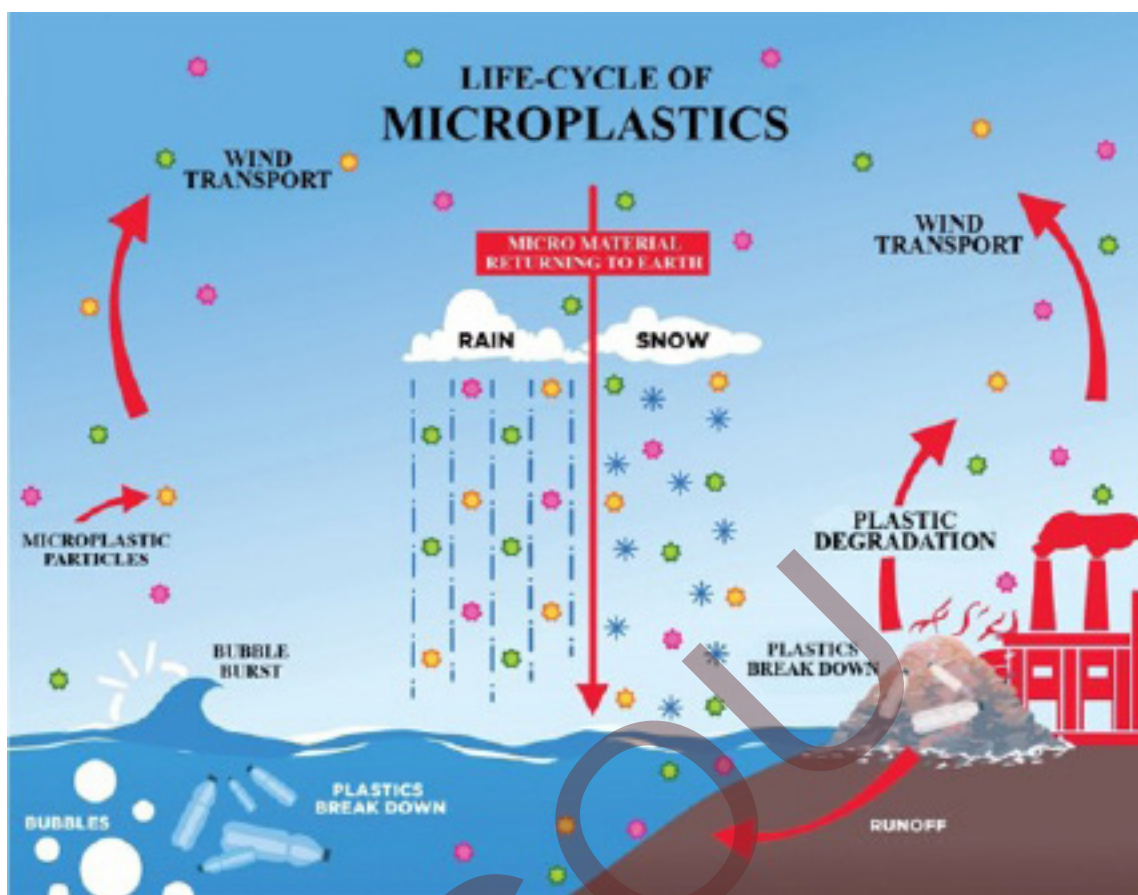


Fig 2.1.6 Lifecycle of microplastics in the environment

Activities to ensure hygienic, cleaner and healthier surroundings, better sanitation, waste disposal at the source of generation, promotion of organic farming, prevention of dumping garbage in the water bodies, zero pesticide cultivation and pure and pollution free water bodies, are all on the move for the cause of greener and cleaner Kerala under the stewardship of Hygienic Waste Management and Agricultural Development Karmasenas. Organic vegetable farming in all households, promoting paddy cultivation in barren lands, rooftop vegetable cultivation, and planting

saplings are the focal points emphasised and encouraged by the Sujalam Suphalam projects. In addition, the Hygiene Waste Management Sub-Mission envisions promoting biogas plants, decentralised waste disposal on the Thumboormoozhy model, dispensing with plastic and e-waste at the block level, and effective disposal of hospital waste. Moreover, centralised waste-disposal management utilising modern technologies will be implemented in the urban cities of Trivandrum, Kochi, and Kozhikode.

Recap

- ▶ Forests are vital for ecological balance.
- ▶ Reforestation restores previously existing forests.
- ▶ Afforestation creates forests in new areas.
- ▶ Social forestry involves community participation.
- ▶ Agroforestry integrates trees with crops.
- ▶ Water conservation is essential for survival.
- ▶ Wastewater treatment removes contaminants from water.
- ▶ Rainwater harvesting collects runoff for future use.
- ▶ Groundwater recharge replenishes underground aquifers.
- ▶ Watershed management ensures sustainable water use.
- ▶ Coastal Regulation Zones protect marine ecosystems.
- ▶ Solid waste management prevents environmental pollution.
- ▶ Sanitary landfills provide safe waste disposal.
- ▶ Plastics cause long-term soil and water damage.
- ▶ Microplastics are tiny, toxic plastic particles.
- ▶ E-waste contains hazardous electronic components.
- ▶ The 3Rs reduce the burden on landfills.
- ▶ Source segregation is key to waste management.
- ▶ Organic farming reduces chemical runoff.
- ▶ Decentralized waste disposal empowers local communities.

Objective Questions

1. What term describes planting trees on land not previously forested?
2. Which process removes contaminants from used water?
3. What is the practice of growing trees and crops together?
4. What does the "C" stand for in CRZ?
5. What are plastic particles smaller than 5mm called?
6. Which "R" emphasizes using an item multiple times?

7. What type of landfill prevents leachate from leaking?
8. What is the collection of rain from rooftops called?
9. Which waste category includes old computers and phones?
10. What management unit covers a whole drainage basin?

Answers

- | | |
|------------------|---------------|
| 1. Afforestation | 6. Reuse |
| 2. Treatment | 7. Sanitary |
| 3. Agroforestry | 8. Harvesting |
| 4. Coastal | 9. E-waste |
| 5. Microplastics | 10. Watershed |

Assignments

1. Compare and contrast the objectives of reforestation and afforestation.
2. Discuss the importance of Social Forestry in rural development.
3. Explain the different stages involved in municipal wastewater treatment.
4. Describe the design and benefits of a modern rainwater harvesting system.
5. Why is the enforcement of Coastal Regulation Zone (CRZ) rules critical for ecology?
6. Evaluate the impact of microplastics on the marine food chain.
7. Outline a comprehensive strategy for managing urban electronic waste.
8. Explain how the "3Rs" principle contributes to a circular economy.
9. Discuss the role of watershed management in preventing soil erosion and drought.
10. Analyze the environmental hazards associated with traditional open dumping vs. sanitary landfills.

Reference

1. Davis, M. L., & Cornwell, D. A. (2013). *Introduction to environmental engineering* (5th ed.). McGraw-Hill.
2. Hawken, P. (Ed.). (2017). *Drawdown: The most comprehensive plan ever proposed to reverse global warming*. Penguin Books.
3. Masters, G. M., & Ela, W. P. (2008). *Introduction to environmental engineering and science* (3rd ed.). Pearson.
4. McDonough, W., & Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. North Point Press.
5. Stahel, W. R. (2019). *The circular economy: A user's guide*. Routledge.

Suggested Reading

1. Ellen MacArthur Foundation. (2013). *Towards the circular economy: Economic and business rationale for an accelerated transition*. <https://www.ellenmacarthurfoundation.org/publications>
2. Gumbira-Sa'id, E. (2021). Solid waste management and the 3Rs. In *Sustainability science and technology* (pp. 45–60). CRC Press.
3. United States Environmental Protection Agency. (2021). *National recycling strategy: Part one of a series on building a circular economy for all*. <https://www.epa.gov/recycling/national-recycling-strategy>
4. World Bank. (2022). *What a waste 2.0: A global snapshot of solid waste management to 2050*. <https://datatopics.worldbank.org/what-a-waste/>
5. World Health Organization. (2022). *Compendium of WHO guidance on health and environment*. WHO.

Unit 2

Movements for Protection of Environment

Learning Outcomes

The components in this unit are aligned to the following learning outcomes:

- ▶ understand the historical significance of Indian environmental movements: Chipko movement, Narmada Bachao Andolan, and their impact on policy and consciousness.
- ▶ explore contemporary conservation initiatives: Swachh Bharat Abhiyan, Haritha Keralam Mission, assessing their objectives and contributions to sustainable development.
- ▶ evaluate role of eco-clubs and nature clubs: fostering environmental awareness, grassroots activism, potential for positive change.
- ▶ analyze evolution of environmental activism in India: identifying challenges, successes, lessons from past and current movements.

Prerequisites

Imagine yourself stepping into a time machine, journeying back to a time when communities in India banded together to protect their natural surroundings. Picture the serene hills of the Himalayas, where villagers embraced trees to prevent their felling, giving birth to the iconic Chipko movement. Visualize the mighty Narmada River, where people stood up against large-scale dam projects, igniting the Narmada Bachao Andolan, a symbol of grassroots environmental activism.

Now, fast forward to the present day. As you step out of the time machine, you're greeted by bustling streets adorned with posters promoting cleanliness and hygiene. You learn about Swachh Bharat Abhiyan, a nationwide campaign aiming to ensure a cleaner and healthier environment for all. You witness the lush landscapes of Kerala, where the Haritha Keralam Mission is in full swing, fostering sustainable development through afforestation and waste management initiatives.

But the journey doesn't end there. You join a group of enthusiastic individuals gathered in a cozy corner of a park, discussing ways to protect the environment. Here, you discover the vital role of eco-clubs and nature clubs in raising awareness, organising clean-up drives, and advocating eco-friendly practices within communities.



With this captivating introduction, you're ready to dive deeper into the world of environmental movements and conservation activities in India. As you explore the past and present efforts to protect our planet, you'll uncover inspiring stories, learn valuable lessons, and perhaps even find your own role in the ongoing journey towards a greener, more sustainable future.

Keywords

Chipko Movement, Narmada Bachao Andolan, Sustainability, Swachh Bharat Abhiyan, Haritha Keralam, Eco-clubs, Grassroots Activism

Discussion

2.2.1 Movements for Protection of Environment

The major environmental movements in India during the period up to 2000 are the following.

1. Chipko Movement
2. Save Silent Valley Movement
3. Jungle Bachao Andholan
4. Appiko Movement
5. Narmada Bachao Andholan (NBA)

2.2.1.1 Chipko Movement

What is meant by Chipko, the name of the movement? 'Chipko' comes from the word

'embrace', as the villagers hugged the trees and encircled them to prevent them from being hacked down. The Chipko movement or Chipko Andolan, was a forest conservation movement in India. It began in 1973 in Khumtung (at the foothills of the Himalayas), Mizoram, which was then part of Uttar Pradesh, and later became a rallying point for many lat-

er environmental movements worldwide. It created a precedent for starting nonviolent protest in India. However, it was Sunderlal Bahuguna, a Gandhian activist, who gave the movement a proper direction and its success meant that the world immediately took notice of this non-violent movement, which was to inspire in time many similar eco-groups by helping to slow down the rapid deforestation, expose vested interests, increase social awareness and the need to save trees, increase ecological awareness, and demonstrate the viability of people's power. He used the slogan "Ecology is the permanent economy". Above all, it stirred up India's existing civil society, which began to address the issues of tribal and marginalised people. The Chipko Andolan, or the Chipko movement, was a movement that practised methods of Satyagraha, in which both male and female activists from Uttarakhand played vital roles, including Gaura Devi, Suraksha Devi, Sudesha Devi, Bachni Devi, Chandi Prasad Bhatt, Virushka Devi, and others. And it is true that the movement's support came mainly from the womenfolk.

In 1987, the Chipko movement was awarded [the Right Livelihood Award](#) "by Sunderlal Bahuguna for its dedication to the conserva-

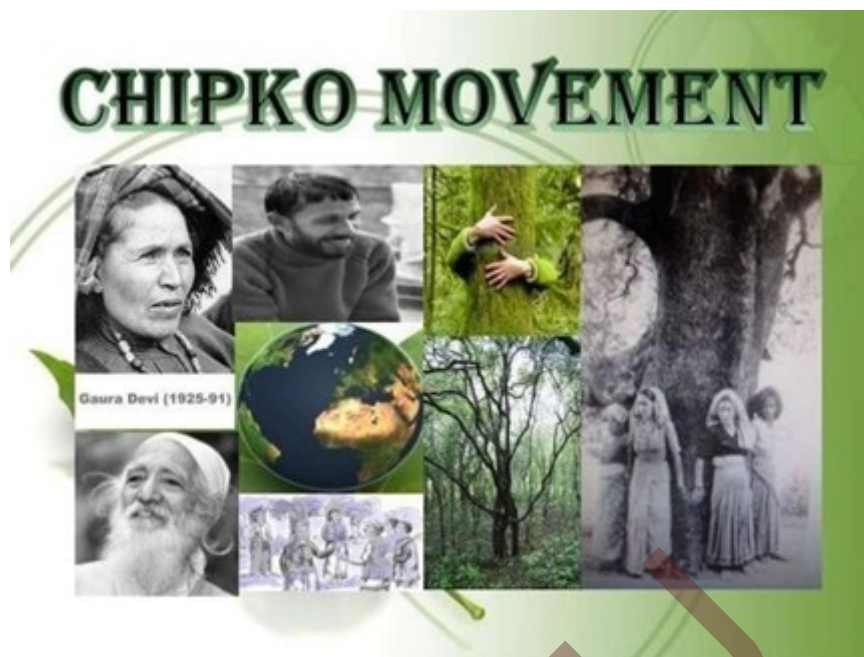


Fig 2.2.1 Chipko Movement

tion, restoration and ecologically-sound use of India's natural resourcesl.

Women's participation in the Chipko agitation was a very novel aspect of the movement. The forest contractors of the region usually doubled up as suppliers of alcohol to men.

Women held sustained agitations against the habit of alcoholism and broadened the agenda of the movement to cover other social issues. The movement achieved a victory when the government issued a 15-year ban on the felling of trees in the Himalayan regions in 1980, under then Prime Minister Indira Gandhi, until the green cover was fully restored. One of the prominent Chipko leaders, Gandhian Sunderlal Bahuguna, took a 5,000-kilometre (3,000-mile) trans-Himalayan foot march in 1981–83, spreading the Chipko message to a far greater area. Gradually, women set up cooperatives to guard local forests, and organized fodder production at rates conducive to local environment. Next, they joined hands with land rotation schemes for fodder

collection, helped replant degraded land, and established nurseries stocked with species they selected.

The Chipko Movement was a major success against those who wanted to cut down a large number of trees for personal gain. The movement succeeded in creating a trigger for other people and communities in India to come forward to protest and protect the trees. Soon the movement became a national phenomenon and became one of the biggest ecological movements.

2.2.1.2 Narmada Bachao Andolan

Narmada Bachao Andolan (NBA) is an Indian social movement spearheaded by native tribals (adivasis), farmers, environmentalists, and human rights activists against several large dam projects across the Narmada River, which flows through the states of Gujarat, Madhya Pradesh, and Maharashtra. Sardar Sarovar Dam in Gujarat is one of the biggest dams on the river and was one of the first fo-

cal points of the movement. It is part of the Narmada Dam Project, whose main aim is to provide irrigation and electricity to people of the above states. The mode of campaign under NBA includes court actions, hunger strikes, rallies and gathering support from notable film and art personalities. The NBA, with its leading spokespersons Medha Patkar and Baba Amte, received the Right Livelihood Award in 1991.

Narmada is India's largest west-flowing river, which supports a wide variety of people with distinctive cultures and traditions, ranging from the indigenous (tribal) people inhabiting the jungles to a large portion of the rural population. Narmada Bachao Andolan is the most powerful mass movement, started in 1985, against the construction of a huge dam on the Narmada River. As part of the Narmada Dam Project, the plan was to build over 3,000 large and small dams along the river. The

proposed Sardar Sarovar Dam and Narmada Sagar were to displace more than 250,000 people. The big fight of the Save the Narmada Movement was over the resettlement or rehabilitation of these people. According to Narmada Bachao Andolan, the dams force the displacement of about a million people and affect many more, largely poor peasants and tribals. They also cause immense ecological damage by inundating forests, including prime habitats of rare species. The movement was heavily criticised by many people who saw it as an obstruction to economic development, as the project was considered essential for providing water access to a large number of people.

According to one NBA partner, the campaign against the construction of dams on the Narmada River symbolises a global struggle for social and environmental justice. At the same time, the NBA itself is a sym-



Fig 2.2.2 Narmada Bachao Andolan

bol. Though the movement started to save the rights of the indigenous population but the focus of the NBA shifted towards rehabilitation and resettlement. But even so, the World Bank's exit, the Harsud Rally, and other notable successes occurred between 1990 and 1993. Its influence has diminished since then, largely because people now believe that the Sardar Sarovar Project (SSP) will move on regardless of what, given the Indian government's will to support it. Notwithstanding this, Medha Patkar and the NBA continue to challenge the SSP.

2.2.1.3 Haritha Keralam Mission

Kerala, the southern tip of the Indian Peninsula, has been immensely blessed by Nature, with its rich and varied flora and fauna, lush green forests, enthralling waterfalls, mighty mountains, virgin beaches and breathtaking backwaters. The expanse of greenery and abundance of water bodies stand as the hallmark of this land. Depletion of water resources, unscientific methods of solid waste management, air pollution, dumping garbage and chemical effluents into water bodies, loss of grass cover, abuse of agricultural land, and deforestation are some of the threats the State is confronted with. With a vision to bestow an eco-friendly land, rich in greenery and serenity, on posterity, the Government of Kerala has launched a people-centric endeavour, Mission Haritha Keralam, under the umbrella project NavaKerala Mission.

Mission Haritha Kerala aims to promote an eco-friendly environment, sustainable development of natural resources, effective solid waste management, rejuvenation of water reserves, sanitation and social hygiene, promotion of organic cultivation, zero-pesticide food products, healthy foods, propagation

of organic farming, protection of biodiversity, and so on. Environmental sustainability is framed within a biocentric approach, which places humans within the broader context of their natural environment.



Haritha Keralam Mission is one of the well-designed and impactful programmes under the Government of Kerala's overall development banner. It encompasses three other Missions: Hygienic Waste Management for effective waste disposal; Jala Samirdhi for water conservation; and Sujalam Suphalam for agricultural development, implemented through Local Self-Government bodies in a people-centric mode under the Water Resources, Local Self-Government, and the Agricultural Department, respectively.

Though Kerala receives twice the national average rainfall, it is not capitalised, as the bulk of the rainwater flows into the sea within 48 to 72 hours of rainfall. As such, it is a pressing necessity to harvest rainwater and replenish groundwater. Recognising the magnitude of this issue, the Haritha Keralam Mission is taking vital steps to preserve water bodies across the state.

The Water Conservation Sub-Mission emphasises instilling a new culture of water conservation in the State by rejuvenating existing water bodies and cleansing and protecting them with pure, pristine water, from village ponds to large reservoirs, to tackle water woes. The message of the 3Rs approach to the use of water (Reduce, Reserve and Recycle) has to be imprinted in the minds of citizens,

with active participation from voluntary organisations, youth associations, students, social and philanthropic organisations, discerning groups, and people from all walks of life. Local self-governing institutions are the premier bodies for making this venture a success. It is envisaged to revitalise and safeguard the existing wells, ponds, springs, canals, and streams across this land in the first phase. In the second phase, rivers, reservoirs, lakes, backwaters and other larger water bodies will be cleaned and protected. The reunification of streams and rivers, the revival of dead rivers with enhanced free-flowing water, is aimed at this stage. Spreading the message of conserving water sources, judicious use of wells, water recharge, and rainwater harvesting is also aimed at this stage

Activities to ensure hygienic, cleaner and healthier surroundings, better sanitation, waste disposal at the source of generation, promotion of organic farming, prevention of dumping garbage in the water bodies, zero pesticide cultivation and pure and pollution free water bodies, are all on the move for the cause of greener and cleaner Kerala under the stewardship of Hygienic Waste Management and Agricultural Development Karmasenas. Organic vegetable farming in all households, promoting paddy cultivation in barren lands, rooftop vegetable cultivation, and planting saplings are the focal points emphasised and encouraged by the SujalamSuphalam projects. In addition, the Hygiene Waste Management Sub Mission envisions promoting biogas plants, decentralised waste disposal management on the Thumboormoozhy model, dispensing plastic and e-waste on a Block-level basis, and effective disposal of hospital waste. Moreover, centralised waste-disposal management with modern technologies will be implemented in the cities of Trivandrum, Kochi, and Kozhikode.

2.2.2 Environmental Conservation Activities

The term "conservation" refers to the safeguarding, maintenance, management, or restoration of natural areas and the ecological communities that live there. A natural resource must be carefully managed to prevent its extinction. Conservation works in two ways. It is a way of life that counters the reckless commercial and corporate activities and is intended to protect nature by safeguarding essential resources. Conservation safeguards ecosystems by using natural resources sustainably. For instance, sustainable logging techniques are often used in forest conservation to reduce deforestation. To preserve the forest, it would need to be protected against development as a whole or in parts.

Environmental conservation is the process of protecting the environment from species extinction and ecosystem collapse, which are largely driven by pollution and human activity. Given that we are all reliant on one another for survival, conservation is essential for preserving and assisting both animals and trees. We can breathe more easily because trees can transform the carbon dioxide produced by industry into oxygen. Despite their distinct meanings, the terms environmental conservation and preservation are sometimes used synonymously. The proper management of the environment and its resources for both present and future uses is referred to as conservation.

2.2.2.1 Swachh Bharat Abhiyan

The Swachh Bharat Abhiyan is the most significant cleanliness campaign by the Government of India. Prime Minister Narendra Modi led a cleanliness pledge at India Gate in 2019, which was joined by about 30 lakh government employees across the country.

He also flagged off a walkathon at Rajpath. While leading the mass movement for cleanliness, the Prime Minister exhorted people to fulfil Mahatma Gandhi's dream of a clean and hygienic India. He gave the mantra of 'Won't mess up, won't let.' Shri Narendra Modi also invited nine people to join the cleanliness drive and asked each of them to bring in nine more people to the initiative.

By inviting people to participate in the drive, the Swachhta Abhiyan has turned into a National Movement. The objectives of Swachh Bharat Abhiyan are:

- ▶ To promote cleanliness and hygiene holistically.
- ▶ To reduce the incidence of open defecation.
- ▶ To bring improvement in the quality of life in rural areas.
- ▶ To encourage the concept of sustainable sanitation practices.
- ▶ To create awareness about health and hygiene.

The National Tricolour appears on the bridge of Mahatma Gandhi's glasses, which are part of the logo. It represents the entire country coming together to realise Mahatma Gandhi's goal of creating a clean India.

People from different sections of society have come forward to join this mass movement for cleanliness. From government officials to jawans, Bollywood actors to the sportspersons, industrialists to spiritual leaders have lined up for the noble work. Millions of people across the country have been joining day after day the cleanliness initiatives of government departments, NGOs, and local community centres to make India clean. Or-

ganising frequent cleanliness campaigns to spread awareness about hygiene through plays and music is also being widely carried out across the nation.

Swachh Bharat Abhiyan has become 'Jan Andolan,' receiving tremendous support from the people. Citizens, too, have turned out in large numbers and pledged to a cleaner, neater India. Taking the broom to sweep the streets, cleaning up garbage, focusing on sanitation, and maintaining a hygienic environment have become practices after the launch of the Swachh Bharat Abhiyan. People have started taking part and helping spread the message of Cleanliness is next to Godliness.

2.2.2.2 Eco club

Eco is an abbreviation for ecology, the study of the relationships between living things and their environments. An eco-club is a group that works to improve environmental conditions. They offer programs and activities to encourage others to reduce pollution, plant trees and more. Eco club activities can help the teacher to meet the objectives of Environmental Education, which are to create awareness and sensitivity among individuals and social groups to the total environment and its allied factors.

Eco Clubs play an important role in fostering environmental awareness among future generations.

The activities under the scheme include:

- ▶ Motivate the students to keep their surroundings green and clean by undertaking the planting of trees.
- ▶ Promote the ethos of conservation of water by minimising the use of water.
- ▶ Motivate students to imbibe habits





Fig 2.2.3 Eco club of National Green Corps

and lifestyle for minimum waste generation, source separation of waste and disposing of the waste at the nearest storage point.

- ▶ Educate students to create awareness amongst the public and sanitary workers, to stop the indiscriminate burning of waste, which causes respiratory diseases.
- ▶ Sensitise the students to minimise the use of plastic bags, not to throw them in public places as they choke drains and sewers, cause waterlogging and provide breeding ground for mosquitoes.
- ▶ Organise tree plantation programmes, awareness programmes such as quizzes, essays, painting competitions, rallies, nukkad natak, *etc.*, regarding various environmental issues and educate children about the reuse of waste material and the preparation of products out of waste
- ▶ Organise Nature Trail in Wildlife Sanctuaries/Parks/Forest areas to know about the biodiversity

An eco club, or green club, is a voluntary group that promotes student participation in learning about and improving their environment. Students and young people can organize themselves into a green club to learn more about this topic and to act to better their immediate environment.

2.2.2.3 Nature Club

It is said that nature is the best teacher. It teaches us about the survival of the fittest and nourishes us in all aspects. Nature has endowed us with incredible assets, such as biodiversity and natural resources. The conservation of these assets has become the need of the times. It is our responsibility to leave this planet in a better state for future generations than we found it. Nature Club is a dedicated program that raises awareness among students, faculty, and staff about nature and related issues. Nature club is a gathering of nature lovers to promote, monitor, and operate environmental and sustainable activities in society, starting on college campuses, with the novel objectives of facilitating skill development for environmental protection, promoting environmental awareness among all sections

of society, and spreading environmental education among students. The various objectives of the nature club are:

- ▶ To sensitise, motivate and educate students and staff about environmental conservation.
- ▶ To create awareness among society about the environment and related issues.
- ▶ Organising activities to reduce pollution in the district.
- ▶ Encouraging efforts to protect and conserve biodiversity in the vicinity.
- ▶ Executing small-scale projects within

the campus.

- ▶ Contributing to environmental awareness and conservation drives in collaboration with regional nature clubs and institutes.

The Nature Club conducts various activities throughout the year, such as observing Plantation Day, Vermicomposting of biodegradable waste, maintenance of Butterfly Garden, Herbal Garden, and nature trail. The nature club allows most of the students to break free from their daily routine and experience life in the simplicity and splendour of Mother Earth.

Recap

- ▶ Environmental movements in India protect natural resources.
- ▶ The Chipko movement began in the Himalayas.
- ▶ Villagers hugged trees to prevent felling.
- ▶ Sunderlal Bahuguna was a key leader.
- ▶ It highlighted the link between forests and livelihoods.
- ▶ Narmada Bachao Andolan opposed large dam projects.
- ▶ Medha Patkar led the Narmada resistance.
- ▶ It focused on tribal displacement and rehabilitation.
- ▶ The movement questioned the "development" model.
- ▶ Swachh Bharat Abhiyan aims for a clean India.
- ▶ It focuses on eliminating open defecation.
- ▶ Solid waste management is a core objective.
- ▶ Haritha Keralam Mission is a Kerala initiative.
- ▶ It integrates waste management and organic farming.

- ▶ Water conservation is a priority for the mission.
- ▶ Eco-clubs foster environmental awareness in schools.
- ▶ Nature clubs promote hands-on conservation activities.
- ▶ Student participation drives grassroots change.
- ▶ Vermicomposting helps manage campus biodegradable waste.
- ▶ Awareness leads to long-term sustainable habits.

Objective Questions

1. Which movement is famous for the act of hugging trees?
2. Who was the prominent female leader of Narmada Bachao Andolan?
3. In which mountain range did the Chipko movement start?
4. What is the national campaign for cleanliness launched in 2014?
5. Which Kerala mission focuses on "Green-Clean Kerala"?
6. Which river project was the focus of the Bachao Andolan?
7. What type of club is formed in schools to protect nature?
8. Who led the Chipko movement alongside Chandi Prasad Bhatt?
9. What is the process of using worms to compost waste called?
10. What term describes local-level social or political campaigning?

Answers

- | | |
|--------------------|------------------------------|
| 1. Chipko | 6. Narmada |
| 2. Medha Patkar | 7. Eco-club (or Nature club) |
| 3. Himalayas | 8. Sunderlal Bahuguna |
| 4. Swachh Bharat | 9. Vermicomposting |
| 5. Haritha Keralam | 10. Grassroots |

Assignments

1. Analyze the role of women in the success of the Chipko movement.
2. Discuss the social and environmental concerns raised by the Narmada Bachao Andolan.
3. Evaluate the impact of Swachh Bharat Abhiyan on public health and hygiene in India.
4. Explain the three main pillars of the Haritha Keralam Mission.
5. How do Eco-clubs in educational institutions contribute to environmental policy change?
6. Compare the strategies used by historical movements versus contemporary government missions.
7. Describe the concept of "Ecofeminism" in the context of Indian environmentalism.
8. Assess the effectiveness of the "Thumboormoozhy model" in waste management.
9. Discuss how the Narmada movement shifted the global perspective on large dams.
10. Propose a plan for a "Nature Club" to reduce plastic footprints on a college campus.

Reference

1. Gadgil, M., & Guha, R. (1995). *Ecology and equity: The use and abuse of nature in contemporary India*. Penguin Books.
2. Mallick, K. (2021). *Environmental movements of India: Chipko, Narmada Bachao Andolan, Navdanya*. Routledge.
3. Martínez-Alier, J. (2002). *The environmentalism of the poor: A study of ecological conflicts and valuation*. Edward Elgar Publishing.
4. Shiva, V. (1988). *Staying alive: Women, ecology and survival in India*. Kali for Women.
5. Speth, J. G. (2004). *Red sky at morning: America and the crisis of the global environment*. Yale University Press.



Suggested Reading

1. Baviskar, A. (1995). *In the belly of the river: Tribal conflicts over development in the Narmada Valley*. Oxford University Press.
2. Government of India. (2014). *Guidelines for Swachh Bharat Mission (Gramin)*. Ministry of Drinking Water and Sanitation.
3. Mishra, A. (1993). *Aaj bhi khare hain talab* [Ponds are still relevant today]. Gandhi Peace Foundation.
4. Ramesh, M. (2018). *The climate solution: India's climate-change crisis and what we can do about it*. Hachette India.
5. Sujit, K. (2021). Haritha Keralam Mission: A model for sustainable development in Kerala. *Journal of Coastal Conservation*, 25(4), 1–12.

Unit 3

UN Sustainable Development Goals

Learning Outcomes

The content of the Unit is aligned with the following learning outcomes:

- ▶ Define sustainable development and its core pillars.
- ▶ Identify the 17 UN Sustainable Development Goals (SDGs).
- ▶ Explain major international climate agreements like the Paris Agreement.
- ▶ Understand the mechanisms of carbon credits and emissions trading.

Prerequisites

Sustainable development emerged as a global priority following the 1987 Brundtland Commission Report, which defined it as meeting present needs without compromising future generations. It moves away from purely economic metrics, instead focusing on a balanced "triple bottom line" of environmental health, social equity, and economic viability. This framework acknowledges that human prosperity is inextricably linked to the preservation of the Earth's natural systems.

In response to escalating crises like climate change and ozone depletion, the international community established various legal frameworks and goals. These range from the Millennium Development Goals to the current 2030 Agenda for Sustainable Development, alongside landmark treaties like the Kyoto Protocol and the Paris Agreement. These initiatives provide a structured roadmap for nations to reduce carbon footprints, transition to clean energy, and ensure a livable planet through global cooperation and market-based solutions.

Keywords

Sustainable Development, SDGs, Brundtland Report, Kyoto Protocol, Paris Agreement, Carbon Credits, Greenhouse Gases.



Discussion

2.3.1 Sustainable Development

The concept of sustainable development was described by the 1987 Brundtland Commission Report as –development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is a way for people to use resources without depleting them. There are four dimensions to sustainable development – society, environment, culture and economy – which are intertwined, not separate. Sustainability is a paradigm for thinking about the future in which environmental, societal and economic considerations are balanced in the pursuit of an improved quality of life. For example, a prosperous society relies on a healthy environment to provide its citizens with food and resources, safe drinking water, and clean air. Sustainability is most often defined as meeting the needs of the present without compromising the ability of future generations to meet their needs. It has three main pillars:

Economic, environmental, and social. These three pillars are informally referred to as people, planet and profits. Sustainable development encourages us to conserve and enhance our resource base by gradually changing the ways we develop and use technologies. These include social progress and equality, environmental protection, conservation of natural resources and stable economic growth.

The main features of sustainable development are:

- ▶ It respects and cares for all kinds of life forms.
- ▶ It improves the quality of human life.

- ▶ It minimises the depletion of natural resources.
- ▶ It enables the communities to care for their own environment.

2.3.1.1 Principles of sustainable development

Sustainable development (SD) is a leading issue in contemporary development discourse. It is an approach to development that takes the environmental dimension into account and originated in debates and environmental movements in the 1970s and 1980s on the connection between the environment and economic development. The approach seeks to reconcile human needs with the environment's capacity to cope with the consequences of the economic system, so that these needs can be met not only in the present but also for future generations. It holds that the wealth of nations does not rest solely on their economic wealth but also on the smooth development and protection of environmental resources.

The major principle of the concept is that natural resources should be used in a manner that does not eliminate or degrade them, or otherwise diminish their usefulness to future generations. However, the concept has been criticised as vague and unattainable, and has been introduced by developed countries to protect capitalism and impede the development of other countries. Others believed that implementing sustainable development would mean a return to pre-modern lifestyles.

The principles of sustainable development are as follows:

- I. Conservation of the ecosystem.
- II. Development of a sustainable society.

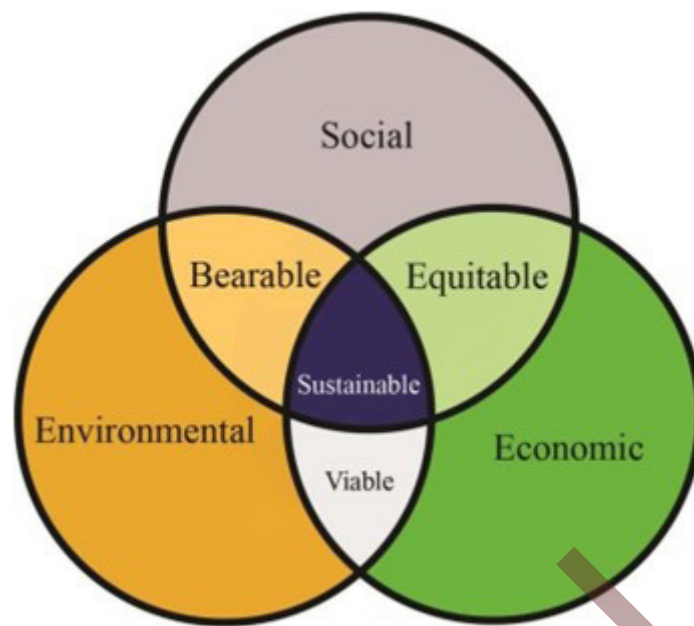


Fig 2.3.1 A diagram of sustainable development with different factors overlap

- III. Conservation of biodiversity.
- IV. Control of population growth.
- V. Development of human resources.
- VI. Promotion of public participation.

2.3.2 Examples of Sustainable Development

1. **Wind Energy:** People have utilised the power of the wind for millennia, dating back to the first recorded wind-mill in Persia between 500 and 900 AD. Fast-forward to the 21st century, and in many localities wind-generated energy has become either competitive with or less expensive than coal-generated electricity. Wind turbines are a great solution for power generation due to their low cost and small land footprint. Other land uses, such as farming, conservation and recreation, can happen simultaneously with wind power generation. As the price of wind power technology continues to drop and energy storage and transmission infrastructure improves, wind energy can significantly supplement or replace entire grid systems.
2. **Solar Energy:** From rooftop solar panels to massive solar farms that can attain the same generating capacity as a conventional power plant, it is clear that there is a renewable energy revolution happening in the world — and it is powered by the sun. A solar farm can reduce emissions by 94% compared to a coal power plant. It also eliminates noxious pollutants like sulphur dioxide, nitrogen oxides, and mercury, which are major contributors to air pollution responsible for millions of premature deaths every year. Solar technology is becoming cheaper and is now cost-competitive with, or even less costly than, conventional power generation in many parts of the world.
3. **Crop Rotation:** Crop rotation, in contrast, is defined as the successive planting of different crops on the same

land to improve soil fertility and help control insects and diseases. This way of farming is not a new practice, but rather a more ancient way of farming chemical-free, whilst maximising the long-term growth potential of the land.

4. **Water-efficient fixtures:** Many countries in the world are becoming water-stressed, and we are beginning to understand that water is not as unlimited as we once believed. In most buildings around the world, essential water use, such as showering, handwashing, and sewage conveyance, is unavoidable. However, the amount of water used for these essential services can be drastically reduced by more than 50% with the use of water-saving fittings and fixtures. Some examples of water-efficient fixtures include low-flow taps and shower heads, dual-flush toilets, and toilet stops. These fixtures can be retrofitted easily and affordably into existing buildings or specified for new building projects.
5. **Green Spaces:** Green spaces such as parks, wetlands, lakes, forests, or other ecosystems are fundamental to sustainably developed urban areas. These areas are essential for cooling cities while trees produce oxygen and filter out air pollution.

Well-designed green spaces also play a critical role in providing safer routes for those commuting on foot or by bicycle and safer spaces for physical activity and recreation. According to the World Health Organisation, "recent estimates show that physical inactivity, linked to poor walkability and lack of access to recreational areas, accounts for 3.3% of global deaths." Thus, having access to green spaces can improve

health and well-being and even aid in the treatment of mental illness.

These examples are only a few of the many types of sustainable development that have the potential to perpetuate positive global change. The world is at a crossroads, where we now have the power to shift global development toward greater sustainability before it is too late. As such, changes to the regulations and incentives that govern development are needed. This will make sustainable development not only the best and most affordable option, but also the most obvious choice.

2.3.3 Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The Sustainable Development Goals (SDGs) or Global Goals are a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all". The SDGs were adopted in 2015 by the United Nations General Assembly and are intended to be achieved by 2030. The SDGs were developed in the Post-2015 Development Agenda as the future global development framework to succeed the Millennium Development Goals, which ended in 2015. The 17 SDGs are: (1) No Poverty, (2) Zero Hunger, (3) Good Health and Well-being, (4) Quality Education, (5) Gender Equality, (6) Clean Water and Sanitation, (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation and Infrastructure, (10) Reducing Inequality, (11) Sustainable Cities and Communities, (12) Responsible Consumption and Production, (13) Climate Action, (14) Life



Fig 2.3.2 Sustainable Development Goals

Below Water, (15) Life On Land, (16) Peace, Justice, and Strong Institutions, (17) Partner-

security and improved nutrition, and promote sustainable agriculture. SDG 2 has eight targets and 14 indicators to measure progress. The five "outcome targets" are: ending hunger and improving access to food; ending all forms of malnutrition; promoting agricultural productivity; sustainable food production systems and resilient agricultural practices; and genetic diversity of seeds, cultivated plants and farmed and domesticated animals; investments, research and technology. The three "means of achieving" targets include: addressing trade restrictions and distortions in world agricultural markets, food commodity markets, and their derivatives.

Goal 1: No Poverty

SDG 1 is to: "End poverty in all its forms everywhere by 2030". The goal has seven targets and 13 indicators to measure progress. The five "outcome targets" are: eradication of extreme poverty; reduction of all poverty by half; implementation of social protection systems; ensuring equal rights to ownership, basic services, technology, and economic resources; and building resilience to environmental, economic, and social disasters. The two targets related to "means of achieving" SDG 1 are mobilization of resources to end poverty, and the establishment of poverty eradication policy frameworks at all levels.

Goal 2: Zero hunger (No hunger)

SDG 2 is to: "End hunger, achieve food

Goal 3: Good health and well-being

SDG 3 is to: "Ensure healthy lives and promote well-being for all at all ages". SDG 3 has 13 targets and 28 indicators to measure progress toward targets. The first nine targets are "outcome targets".

Those are: reduction of maternal mortality; ending all preventable deaths under five years of age; fight communicable diseases; ensure reduction of mortality from non-communicable diseases and promote mental health; prevent and treat substance abuse; reduce road injuries and deaths; grant universal access to sexual and reproductive care, family planning and education; achieve universal health coverage; and reduce illnesses and deaths from hazardous chemicals and pollution.

The four "means to achieve" SDG 3 targets are: implement the WHO Framework Convention on Tobacco Control; support research, development and universal access to affordable vaccines and medicines; increase health financing and support the health workforce in developing countries; and improve early warning systems for global health risks.

Goal 4: Quality education

SDG 4 is to: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". SDG 4 has 10 targets, each measured by 11 indicators. The seven "outcome-oriented targets" are: free primary and secondary education; equal access to quality pre-primary education; affordable technical, vocational and higher education; increased number of people with relevant skills for financial success; elimination of all discrimination in education; universal literacy and numeracy; and education for sustainable development and global citizenship. The three "means of achieving targets" are to build and upgrade inclusive and safe schools; expand higher education scholarships for developing countries; and increase the supply of qualified teachers in developing countries.

Goal 5: Gender equality

SDG 5 is to: "Achieve gender equality and

empower all women and girls". Through the pledge to "Leave No One Behind", countries have committed to fast-track progress for those farthest behind, aiming to grant women and girls equal rights and opportunities to live free without discrimination, including workplace discrimination or any violence. This is to achieve gender equality and empower all women and girls.

Goal 6: Clean water and sanitation

SDG 6 is to: "Ensure availability and sustainable management of water and sanitation for all". The eight targets are measured by 11 indicators. The six "outcome-oriented targets" include: Safe and affordable drinking water; end open defecation and provide access to sanitation and hygiene; improve water quality, wastewater treatment, and safe reuse; increase water-use efficiency; ensure freshwater supplies; implement IWRM; and protect and restore water-related ecosystems. The two "means of achieving" targets are to expand water and sanitation support to developing countries and to support local engagement in water and sanitation management.

Goal 7: Affordable and clean energy

SDG 7 is to: "Ensure access to affordable, reliable, sustainable and modern energy for all". The goal has five targets to be achieved by 2030. Six indicators measure progress towards the targets. Three out of the five targets are "outcome targets": universal access to modern energy, increase the global share of renewable energy, and double the improvement in energy efficiency. The remaining two targets are "means of achieving targets": to promote access to research, technology, and investment in clean energy; and to expand and upgrade energy services for developing countries. In other words, these targets include access to affordable and reliable energy while

increasing the share of renewable energy in the global energy mix. This would involve improving energy efficiency and enhancing international cooperation to facilitate more open access to clean energy technology and more investment in clean energy infrastructure.

Goal 8: Decent work and economic growth

SDG 8 is to: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all". SDG 8 has twelve targets in total to be achieved by 2030. Some targets are for 2030; others are for 2020. The first ten are "outcome targets". These are: sustainable economic growth; diversify, innovate and upgrade for economic productivity; promote policies to support job creation and growing enterprises; improve resource efficiency in consumption and production; full employment and decent work with equal pay; promote youth employment, education and training; end modern slavery, trafficking, and child labour; protect labour rights and promote safe working environments; promote beneficial and sustainable tourism; universal access to banking, insurance and financial services. In addition, there are also two targets for "means of achieving": Increase aid for trade support; develop a global youth employment strategy.

Goal 9: Industry, Innovation and Infrastructure

SDG 9 is to: "Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation". SDG 9 has eight targets, and progress is measured by twelve indicators. The first five targets are "outcome targets": Develop sustainable, resilient, and inclusive infrastructure; promote inclusive and sustainable industrialisation; increase access to financial services and mar-

kets; upgrade all industries and infrastructure for sustainability; enhance research and upgrade industrial technologies. The remaining three targets are "means of achieving" targets: Facilitate sustainable infrastructure development for developing countries; support domestic technology development and industrial diversification; universal access to information and communications technology.

Goal 10: Reduced inequality

SDG 10 is to: "Reduce income inequality within and among countries". The Goal has ten targets to be achieved by 2030. Progress towards targets will be measured by indicators. The first seven targets are "outcome targets": Reduce income inequalities; promote universal social, economic and political inclusion; ensure equal opportunities and end discrimination; adopt fiscal and social policies that promotes equality; improved regulation of global financial markets and institutions; enhanced representation for developing countries in financial institutions; responsible and well-managed migration policies. The other three targets are "means of achievement" targets: Special and differential treatment for developing countries; encourage development assistance and investment in least developed countries; reduce transaction costs for migrant remittances.

Goal 11: Sustainable cities and communities

SDG 11 is to: "Make cities and human settlements inclusive, safe, resilient, and sustainable". SDG 11 has 10 targets to be achieved, and this is being measured with 15 indicators. The seven "outcome targets" include: Safe and affordable housing, affordable and sustainable transport systems; inclusive and sustainable urbanization; protect the



world's cultural and natural heritage; reduce the adverse effects of natural disasters; reduce the environmental impacts of cities; provide access to safe and inclusive green and public spaces. The three "means of achieving" targets include: Strong national and regional development planning; implementing policies for inclusion, resource efficiency, and disaster risk reduction; and supporting least developed countries in sustainable and resilient building.

Goal 12: Responsible consumption and production

SDG 12 is to: "Ensure sustainable consumption and production patterns". The 11 targets of the goal are: implement the 10 Year Framework of Programs on Sustainable Consumption and Production Patterns; achieve the sustainable management and efficient use of natural resources; reducing by half the per capita global food waste at the retail and consumer levels and the reduction of food losses along production and supply chains, including post-harvest losses; achieving the environmentally sound management of chemicals and all wastes throughout their life cycle; reducing waste generation through prevention, reduction, recycling and reuse; encourage companies to adopt sustainable practices; promote public procurement practices that are sustainable; and ensure that people everywhere have the relevant information and awareness for sustainable development. The three "means of achieving" targets are: support developing countries in strengthening their scientific and technological capacity; develop and implement tools to monitor the impacts of sustainable development; and remove market distortions, such as fossil fuel subsidies, that encourage wasteful consumption.

Goal 13: Climate action

SDG 13 is to: "Take urgent action to com-

bat climate change and its impacts by regulating emissions and promoting developments in renewable energy". The targets cover a wide range of issues surrounding climate action. There are five targets in total. The first three targets are "output targets": Strengthen resilience and adaptive capacity to climate-related disasters; integrate climate change measures into policies and planning; build knowledge and capacity to meet climate change. The remaining two targets are "means of achieving" targets: To implement the UN Framework Convention on Climate Change and to promote mechanisms to raise capacity for planning and management. The United Nations Framework Convention on Climate Change (UNFCCC) is the primary international, inter-governmental forum for negotiating the global response to climate change.

Goal 14: Life below water

SDG 14 is to: "Conserve and sustainably use the oceans, seas and marine resources for sustainable development". The first seven targets are "outcome targets": reduce marine pollution; protect and restore ecosystems; reduce ocean acidification; sustainably fish; conserve coastal and marine areas; end subsidies that contribute to overfishing; increase the economic benefits from the sustainable use of marine resources. The last three targets are "means of achieving" targets: to increase scientific knowledge, research, and technology for ocean health; to support small-scale fishers; and to implement and enforce international sea law.

Oceans and fisheries support the global population's economic, social and environmental needs. Oceans are the source of life on the planet and the regulator of the global climate system. They are the world's largest ecosystem, home to nearly a million known

species. Oceans cover more than two-thirds of the Earth's surface and contain 97% of the planet's water. They are essential for making the planet livable. Rainwater, drinking water and climate are all regulated by ocean temperatures and currents. Over 3 billion people depend on marine life for their livelihood. However, there has been a 26 per cent increase in acidification since the Industrial Revolution. Effective strategies to mitigate the adverse effects of increased ocean acidification are needed to advance the sustainable use of oceans.

Goal 15: Life on land

SDG 15 is to: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". The nine "outcome targets" include: Conserve and restore terrestrial and freshwater ecosystems; end deforestation and restore degraded forests; end desertification and restore degraded land; ensure conservation of mountain ecosystems, protect biodiversity and natural habitats; protect access to genetic resources and fair sharing of the benefits; eliminate poaching and trafficking of protected species; prevent invasive alien species on land and in water ecosystems; and integrate ecosystem and biodiversity in governmental planning. The three "means of achieving targets" include: Increasing financial resources to conserve and sustainably use ecosystems and biodiversity; financing and incentivising sustainable forest management; and combating global poaching and trafficking.

Humans depend on the Earth and the ocean to live. This goal aims to secure sustainable livelihoods that will be enjoyed for generations to come. The human diet is composed 80% of plant life, which makes agriculture a

very important economic resource. Plant life provides 80 per cent of the human diet, and we rely on agriculture as an important economic resource. Forests cover 30 per cent of the Earth's surface, provide vital habitats for millions of species, are important sources of clean air and water, and are crucial for combating climate change.

Goal 16: Peace, justice and strong institutions

SDG 16 is to: "Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels". The goal has ten "outcome targets": Reduce violence; protect children from abuse, exploitation, trafficking and violence; promote the rule of law and ensure equal access to justice; combat organized crime and illicit financial and arms flows, substantially reduce corruption and bribery; develop effective, accountable and transparent institutions; ensure responsive, inclusive and representative decision-making; strengthen the participation in global governance; provide universal legal identity; ensure public access to information and protect fundamental freedoms. There are also two "means of achieving targets": Strengthen national institutions to prevent violence and combat crime and terrorism; promote and enforce non-discriminatory laws and policies.

Goal 17: Partnership for the Goals

SDG 17 is to: "Strengthen the means of implementation and revitalise the global partnership for sustainable development". This goal has 19 outcome targets and 24 indicators. Increasing international cooperation is seen as vital to achieving each of the 16 previous goals. Goal 17 is included to ensure that



countries and organisations cooperate instead of competing. Developing multi-stakeholder partnerships to share knowledge, expertise, technology, and financial support is seen as critical to the overall success of the SDGs. The goal encompasses improving north–south and South-South cooperation, and public-private partnerships, which involve civil societies, are specifically mentioned.

Implementation of SDGs

Implementation of the SDGs started worldwide in 2016. This process can also be called "Localizing the SDGs". Individuals, universities, governments, institutions, and organisations of all kinds are working separately toward one or more goals simultaneously. Individual governments must translate the goals into national legislation, develop a plan of action, and establish their own budget. However, they must also be open to and actively seek partners. Coordination at the international level is crucial, making partnerships valuable. The SDGs note that countries with less access to financial resources need partnerships with more well-to-do countries.

Throughout the world, the value of biologically rich natural areas is increasingly being recognised as invaluable. International agreements, such as the World Heritage Convention, aim to protect and support such areas. India is a signatory to the convention and has included several protected Areas as World Heritage sites. These include Manas on the border between Bhutan and India, Kaziranga in Assam, Bharatpur in U.P., Nandadevi in the Himalayas, and the Sunderbans in the Ganges delta in West Bengal. India has also signed the Convention on International Trade in Endangered Species (CITES), which is intended to reduce the utilisation of endangered plants and animals by controlling trade in their products and in the pet trade.

2.3.4 Ozone layer depletion

The Earth's atmosphere is composed of several layers. The lowest layer, the troposphere, extends from Earth's surface to about 6 miles (10 km) in altitude. Most atmospheric ozone is concentrated in a layer in the stratosphere, about 9 to 18 miles (15 to 30 km) above the Earth's surface. Ozone is a molecule that contains three oxygen atoms. At any given time, ozone molecules are constantly formed and destroyed in the stratosphere. The total amount has remained relatively stable during the decades that it has been measured. It has the potential to absorb 97-99% of the harmful ultraviolet radiation from the sun, which can damage life on Earth.

Ozone layer depletion is the thinning of the ozone layer present in the upper atmosphere. This happens when chlorine and bromine atoms in the atmosphere react with ozone, destroying ozone molecules. One chlorine molecule can destroy 100,000 molecules of ozone. It is destroyed more quickly than it is created. Some compounds release chlorine and bromine when exposed to high ultraviolet light, which contributes to ozone layer depletion. Such compounds are known as Ozone Depleting Substances (ODS).

The ozone-depleting substances that contain chlorine include chlorofluorocarbons, carbon tetrachloride, hydrochlorofluorocarbons, and methyl chloroform, whereas the ozone-depleting substances that contain bromine are halons, methyl bromide, and hydrobromofluorocarbons. Chlorofluorocarbons are the most abundant ozone-depleting substances. It is only when the chlorine atom reacts with another molecule that it does not react with ozone.

In the 1970s, concerns about the effects of ozone-depleting substances (ODS) on the

stratospheric ozone layer prompted several countries, including the United States, to ban the use of chlorofluorocarbons (CFCs) as aerosol propellants. However, global production of CFCs and other ODS continued to grow rapidly as new uses were found for these chemicals in refrigeration, fire suppression, foam insulation, and other applications. Some natural processes, such as large volcanic eruptions, can indirectly affect ozone levels. For example, Mt. Pinatubo's 1991 eruption did not increase stratospheric chlorine concentrations, but it did produce large amounts of tiny particles called aerosols (not to be confused with consumer products also known as aerosols). These aerosols increase chlorine's effectiveness at destroying ozone. The stratospheric aerosols create a surface on which CFC-based chlorine can destroy ozone. However, the effect of volcanoes is short-lived.

One example of ozone depletion is the annual ozone "hole" over Antarctica that has occurred during the Antarctic spring since the early 1980s. This is not really a hole in the ozone layer, but rather a large area of the stratosphere with extremely low ozone levels. The Montreal Protocol was proposed in 1987 to stop the use, production and import of ozone-depleting substances and minimise their concentration in the atmosphere to protect the ozone layer of the Earth.

2.3.4.1 Effects of Ozone Layer Depletion

The depletion of the ozone layer has harmful effects on the environment. Let us see the major effects of ozone layer depletion on man and the environment.

Effects on Human Health

Humans will be directly exposed to harmful ultraviolet radiation from the sun due to

ozone layer depletion. This might result in serious health issues among humans, such as skin diseases, cancer, sunburns, cataracts, quick ageing and a weak immune system.

Effects on Animals

Direct exposure to ultraviolet radiation leads to skin and eye cancer in animals.

Effects on the Environment

Strong ultraviolet radiation may reduce plant growth, flowering, and photosynthesis. The forests also have to bear the harmful effects of the ultraviolet rays.

Effects on Marine Life

Planktons are greatly affected by exposure to harmful ultraviolet rays. These are higher in the aquatic food chain. If plankton are destroyed, the organisms in the food chain are also affected.

2.3.5 Major drivers of climate change (greenhouse gases and aerosols)

Higher emissions of greenhouse gases lead to higher atmospheric concentrations. Greenhouse gas concentrations are measured in parts per million, parts per billion, and even parts per trillion. One part per million is equivalent to one drop of water diluted into about 13 gallons of liquid (roughly the fuel tank of a compact car). Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years. All of these gases remain in the atmosphere long enough to become well mixed.

We will discuss some important greenhouse gases in the atmosphere.

1. Water Vapour

The most abundant greenhouse gas overall,



water vapour differs from other greenhouse gases in that changes in its atmospheric concentration are not directly linked to human activities, but rather to the warming caused by the other greenhouse gases emitted. As the atmosphere's temperature rises, more water evaporates from ground storage (rivers, oceans, reservoirs, soil). Because the air is warmer, the absolute humidity can be higher (in essence, the air can 'hold' more water), leading to more water vapour in the atmosphere. As a greenhouse gas, the higher concentration of water vapour results in more thermal IR energy being radiated from the Earth, thus further warming the atmosphere. The warmer atmosphere can then hold more water vapour and so on and so on. This is referred to as a 'positive feedback loop'.

2. Carbon dioxide

Carbon dioxide (CO₂) is the primary greenhouse gas emitted through human activities. Carbon dioxide is naturally present in the atmosphere and forms part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle—both by adding more CO₂ to the atmosphere, and by influencing the ability of natural sinks, like forests and soils, to remove and store CO₂ from the atmosphere. While CO₂ emissions come from a variety of natural sources, human-related emissions are responsible for the increase in atmospheric CO₂ since the Industrial Revolution. The main human activity that emits CO₂ is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation. However, certain industrial processes and land-use changes also emit CO₂. Carbon dioxide is constantly exchanged between the atmosphere, the ocean, and the land surface, as it is produced and absorbed by many microorganisms, plants, and

animals. However, emissions and CO₂ removal by these natural processes tend to balance each other. Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO₂ and other heat-trapping gases to the atmosphere.

3. Methane

Although methane (CH₄) persists in the atmosphere for far less time than carbon dioxide (about a decade), it is much more potent in terms of the greenhouse effect. Human activities emitting methane include leaks from natural gas systems and the raising of livestock. Methane is also emitted by natural sources such as natural wetlands. In addition, natural processes in soil and chemical reactions in the atmosphere help remove CH₄. Methane's atmospheric lifetime is much shorter than that of carbon dioxide (CO₂), but CH₄ is more efficient at trapping radiation than CO₂. The comparative impact of CH₄ is 25 times greater than that of CO₂ over 100 years.

4. Nitrous oxide

Human activities such as agriculture, fuel combustion, wastewater management, and industrial processes are increasing atmospheric N₂O levels. Nitrous oxide is also naturally present in the atmosphere, supports the Earth's nitrogen cycle, and has a variety of natural sources. Nitrous oxide molecules remain in the atmosphere for an average of 114 years before being removed by sinks or destroyed through chemical reactions. The impact of 1 pound of N₂O on atmospheric warming is almost 300 times that of 1 pound of carbon dioxide. Globally, about 40 per cent of total N₂O emissions are from human activities. Nitrogen takes on a variety of chemical forms throughout the nitrogen cycle, including N₂O.

Natural emissions of N_2O are mainly from bacteria breaking down nitrogen in soils and the oceans. Nitrous oxide is removed from the atmosphere when it is absorbed by certain types of bacteria or destroyed by ultraviolet radiation or chemical reactions.

5. Fluorocarbons (FCs)

Unlike many other greenhouse gases, fluorinated gases have no natural sources and are produced only by human activities. They are emitted through their use as substitutes for ozone-depleting substances (e.g., as refrigerants) and through a variety of industrial processes, such as aluminium and semiconductor manufacturing. Many fluorinated gases have very high global warming potentials (GWPs) relative to other greenhouse gases, so small atmospheric concentrations can have disproportionately large effects on global temperatures. They can also have long atmospheric lifetimes—in some cases, lasting thousands of years. Like other long-lived greenhouse gases, most fluorinated gases are well-mixed

in the atmosphere, spreading around the world after they are emitted. Many fluorinated gases are removed from the atmosphere only when they are destroyed by sunlight in the far upper atmosphere. In general, fluorinated gases are the most potent and longest-lasting greenhouse gases emitted by human activities. There are four main categories of fluorinated gases—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphurhexafluoride (SF_6), and nitrogen trifluoride (NF_3).

2.3.6 Greenhouse Effect

The greenhouse effect occurs when certain gases, known as greenhouse gases, accumulate in Earth's atmosphere. These gases, which occur naturally in the atmosphere, include carbon dioxide, methane, nitrogen oxides, and fluorinated gases such as chlorofluorocarbons (CFCs).

The sun's rays heat the Earth's surface. Subsequently, it cools, and the heat radiates

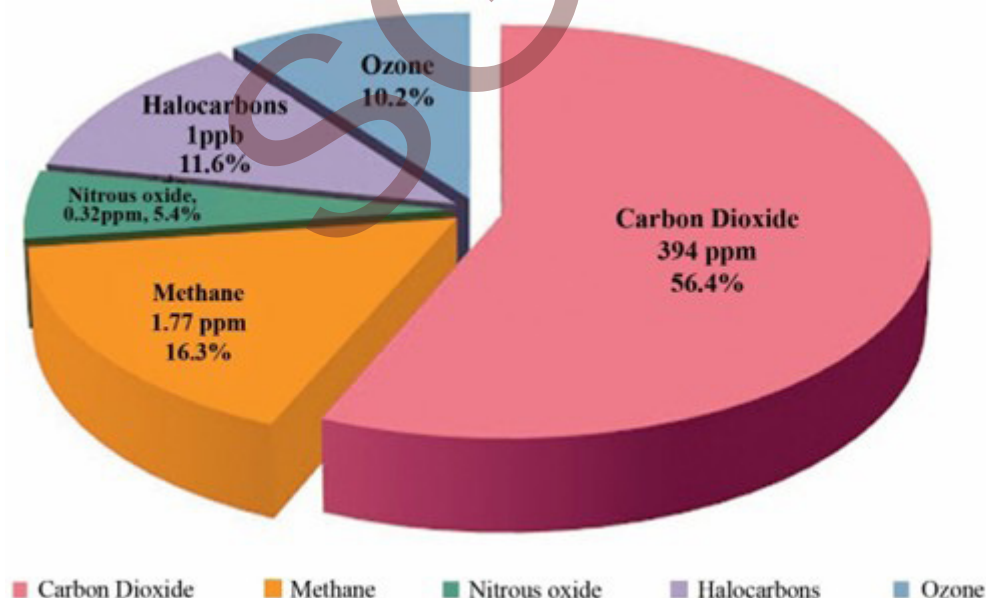


Fig 2.3.3 Concentration of various GHG gases in the atmosphere

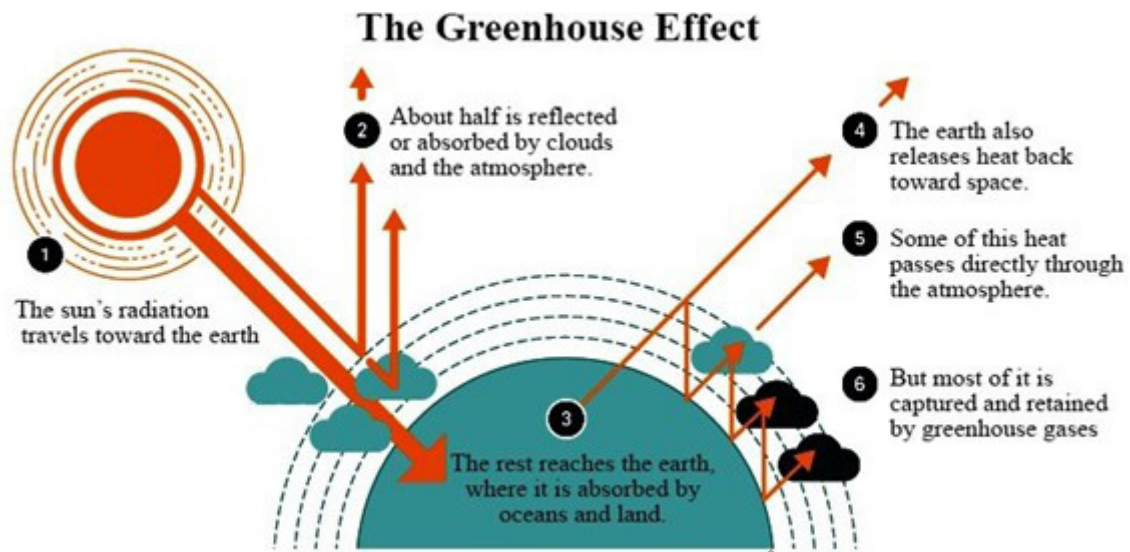


Fig:2.3.4 Greenhouse effect and global warming

from the Earth to the atmosphere. But CO₂ and other heat absorbing gases take a part of the radiated heat and return it to the earth. This process results in the accumulation of extra heat energy at the surface of the earth. In the last few decades, the amount of heat absorbing gases has remarkably increased and as a result the average temperature of the atmosphere has gone up. This phenomenon is called "Green House Effect". It is clear that gases like CO₂, Chlorofluorocarbons, N_xO and CH₄ make a cloud over the earth, which allows the incoming rays of the sun but obstructs the outgoing heat energy from the earth to the atmosphere. There have been numerous warnings in the recent years that the earth's climatic pattern which almost maintained a steady course for centuries has undergone visible changes. This is caused by changes in the composition of global atmosphere which consists of a number of natural and synthetic gases. Any increase in gases which have the ability to absorb infrared radiation reflected will enhance heat - trapping capacity of the earth. In 1961, the English Philosopher John Tyndall proposed that increased concentration of atmospheric

carbon dioxide could raise surface temperature and change the climate.

The concentration of this gas has increased by about 25%. This increase has been caused by various factors. An indiscriminate burning of fossil fuels like coal, oil and natural gases releases huge amounts of gas into the atmosphere. There are more than half a billion vehicles on the road which spew CO₂ and other gases into air. The burning of a large number of oil wells continuously

After the Gulf War, a tremendous amount of carbon dioxide was added to the atmosphere. As far as the Industrial Revolution is concerned, the main culprits are the developed countries. The industrialised countries are responsible for forcing the pace of global warming and climate change. The entire international community, from world leaders to laypeople, is aware of global warming and its dangers. This could destabilize world food security. There may be massive disruption to agriculture and the loss of ecosystems of worldwide importance.

2.3.7 Global Warming and Climate Change

Global warming is considered one of the central environmental issues in recent years. It may prove very problematic and disastrous, causing severe harm to the biotic and abiotic components of the environment. Nitrogen and oxygen are the main constituents of the atmosphere, but the proportions of other gases, such as carbon dioxide and carbon monoxide, are steadily increasing. Because of the increasing presence of these gases, global temperatures are rising. In other words, the earth surface is getting warmer and warmer. Sunlight enters the Earth's atmosphere and, after hitting the Earth's surface, is radiated back into the atmosphere. Here, it is absorbed by naturally occurring gases such as carbon dioxide. This absorption process heats the atmosphere, thereby warming the Earth's surface. When gases are present in normal proportions, the warming of the Earth is normal, and their presence is essential to the existence of life on Earth. However, when the proportion of these gases increases, they allow sunlight to reflect back into the atmosphere, resulting in heat generation. Over time, Earth's temperature will gradually increase; this phenomenon is called global warming. Global warming is also known as the greenhouse effect because the phenomenon is very similar to what happens in a greenhouse. The effect of this temperature increase is damaging the environment.

3. The agricultural production will be minimized to a significant extent.
4. Global warming will automatically lead to rise in temperature. According to the Intergovernmental Panel on Climate Change, set up by the United Nations Environment Programme in 1998, the world is already 0.5°C warmer than the pre-industrial period, and this rise in temperature will be an ongoing process.
5. Global warming has a more drastic effect. A rise in temperatures would result in melting in the Polar Regions. This will lead to a rise in sea levels. Even a 5% rise in sea level would displace millions of people in low-lying areas, and several Small Island nations will disappear entirely.
6. Others important effects include global mean surface warming, polar winter surface warming reduction of sea -ice , *etc.*
7. One of the most severe effects of global warming from a human perspective is the creation of "Climate refugees". Climate refugees are people who suffer from climatic conditions such as drought, floods, starvation, and displacement. These climate refugees therefore signify the most visible symbol of global warming.

2.3.7.1 Implications of global warming

1. Global warming can drastically reduce the moisture levels in current fertile zones and turn them subsequently into dry lands and desert.
2. Many countries in the world will suffer from droughts.

2.3.8 Resolutions and treaties on climate change

Resolutions and treaties on climate change represent global efforts to address one of the most pressing challenges of our time: the warming of the planet due to human activities. These agreements aim to mitigate greenhouse



gas emissions, adapt to the impacts of climate change, and foster international cooperation in the transition to a low-carbon future.

One of the landmark agreements in this realm is the Paris Agreement, adopted in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels, with efforts to limit the increase to 1.5 degrees Celsius. It emphasises nationally determined contributions (NDCs), in which each country commits to reducing its greenhouse gas emissions and enhancing its resilience to climate impacts.

Global Temperature Targets: The Paris Agreement aims to limit the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels, while pursuing efforts to limit the increase to 1.5 degrees Celsius. This target is based on scientific assessments of the level of warming that would significantly worsen the impacts of climate change.

Nationally Determined Contributions (NDCs): One of the fundamental aspects of the Paris Agreement is the concept of NDCs. Each participating country is required to submit its own NDC, outlining its climate action plans and commitments to reducing greenhouse gas emissions. Each country determines these contributions based on its individual circumstances, capabilities, and development priorities.

Transparency and Accountability: The Paris Agreement establishes a robust transparency framework to track and monitor countries' progress towards their NDCs. Participating nations are required to regularly report on their emissions and progress towards meeting

their targets, providing transparency and accountability to the global community.

Global Stocktake: The agreement mandates a global stocktake every 5 years to assess collective progress towards its long-term goals. This process allows for the review and enhancement of NDCs over time, ensuring that climate action remains aligned with the latest scientific findings and evolving global circumstances.

Adaptation and Resilience: In addition to mitigation efforts, the Paris Agreement recognizes the importance of adaptation to the impacts of climate change. It calls for enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate-related hazards, particularly in vulnerable and developing countries.

Finance and Support: The agreement includes provisions for financial support from developed countries to assist developing countries in both mitigation and adaptation efforts. This support is crucial for enabling developing countries to transition to low-carbon, climate-resilient pathways and to cope with the impacts of climate change.

Technology Transfer and Capacity Building: The Paris Agreement emphasises the importance of these measures to support climate action in developing countries. It calls for enhancing cooperation on technology development, diffusion, and deployment, as well as building institutional and human capacities to implement climate-related policies and measures effectively.

By addressing these key elements, the Paris Agreement provides a comprehensive framework for global climate action, fostering cooperation and collaboration among nations to

tackle the urgent challenge of climate change.

Another significant treaty is the Kyoto Protocol, adopted in 1997 as an extension of the UNFCCC. The Kyoto Protocol established binding emission-reduction targets for developed countries, known as Annex I parties, for the period 2008-2012. It introduced market-based mechanisms, such as emissions trading and the Clean Development Mechanism (CDM), to facilitate cost-effective emissions reductions.

Emission Reduction Targets: The Kyoto Protocol set legally binding emission reduction targets for developed countries, known as Annex I parties. These targets, established from 2008 to 2012, collectively reduced greenhouse gas emissions by a specified percentage below 1990 levels. Each Annex I country had a specific target based on its historical emissions and its capacity to act.

Flexibility Mechanisms: To facilitate cost-effective emissions reductions, the Kyoto Protocol introduced three market-based mechanisms:

Emissions Trading: This mechanism allows countries to buy and sell emission allowances, providing flexibility for countries to meet their targets by trading surplus allowances or purchasing additional allowances as needed.

Clean Development Mechanism (CDM): The CDM enables developed countries to invest in emission-reduction projects in developing countries as an alternative to costly domestic measures. These projects generate Certified Emission Reductions (CERs), which can be used to meet part of the investing country's emission reduction targets.

Joint Implementation (JI): Similar to the

CDM, JI allows Annex I countries to undertake emission-reduction projects in other Annex I countries and receive emission-reduction units (ERUs) for their efforts.

Commitment Periods and Compliance: The Kyoto Protocol included commitment periods during which Annex I parties were required to meet their emission reduction targets. The initial commitment period was from 2008 to 2012, followed by subsequent commitment periods. Countries were obligated to report their emissions and progress towards meeting their targets, with mechanisms in place to address non-compliance.

Protocol Amendments: Over time, the Kyoto Protocol underwent amendments and revisions to strengthen its effectiveness and address emerging challenges. For example, the Doha Amendment, adopted in 2012, established a second commitment period from 2013 to 2020, with updated emission-reduction targets for participating countries.

Legacy and Lessons Learned: Despite its limitations and challenges, the Kyoto Protocol represents a significant milestone in international efforts to combat climate change. It laid the groundwork for subsequent agreements, including the Paris Agreement, and provided valuable lessons on the importance of global cooperation, equity, and flexibility in addressing climate change.

Transition to the Paris Agreement: While the Kyoto Protocol focused primarily on emission-reduction targets for developed countries, the Paris Agreement adopts a more inclusive and flexible approach, with all countries committing to climate action based on their respective national circumstances and capabilities. The Paris Agreement builds upon the principles of equity and common



but differentiated responsibilities, recognizing the shared but differentiated contributions to global climate action.

By understanding the intricacies of the Kyoto Protocol and its evolution, we can appreciate its role in shaping the international climate change regime and informing future efforts to address this critical global challenge.

Other key agreements include the Montreal Protocol, which addresses ozone-depleting substances, and the Kigali Amendment, which aims to phase down the production and consumption of hydrofluorocarbons (HFCs), potent greenhouse gases used in refrigeration and air conditioning.

The Kigali Amendment

Building on the success of the Montreal Protocol, the Kigali Amendment was adopted in 2016 to phase down hydrofluorocarbons (HFCs), potent greenhouse gases used primarily as substitutes for ODS. While HFCs do not deplete the ozone layer, they have a high global warming potential (GWP) and contribute significantly to climate change when released into the atmosphere.

Objectives of the Kigali Amendment: The Kigali Amendment aims to gradually reduce the production and consumption of HFCs globally, with the ultimate goal of avoiding up to 0.5 degrees Celsius of global warming by the end of the century. By transitioning to more climate-friendly alternatives, such as low-GWP refrigerants and technologies, the amendment seeks to mitigate the impact of HFCs on climate change while safeguarding the ozone layer.

Implementation and Compliance: The Kigali Amendment includes provisions for reporting, monitoring, and compliance to en-

sure that countries adhere to their obligations under the agreement. It provides for financial assistance and technology transfer to support developing countries in phasing down HFCs and transitioning to sustainable alternatives.

Global Cooperation and Partnerships:

As with the Montreal Protocol, the success of the Kigali Amendment relies on strong international cooperation and partnerships among governments, industry stakeholders, and civil society. Collaboration is essential to accelerate the adoption of low-GWP alternatives, promote innovation in refrigeration and air conditioning technologies, and achieve the goals of the amendment in a timely and effective manner.

By addressing the dual challenges of ozone depletion and climate change, the Montreal Protocol and the Kigali Amendment demonstrate the power of international cooperation and collective action in safeguarding the environment and promoting sustainable development. These agreements serve as models for future efforts to address complex global environmental issues and underscore the importance of proactive and inclusive approaches to environmental stewardship.

These resolutions and treaties underscore the collective recognition of the urgent need to combat climate change and safeguard the planet for future generations. While progress has been made, continued efforts and greater ambition are essential to meet the targets set out in these agreements and ensure a sustainable, resilient future for all.

2.3.8.1 G20 Summit

The Group of Twenty (G20) is an international forum comprising 19 countries and the European Union (EU), representing the world's major economies. The G20 members

collectively account for around 80% of global GDP and two-thirds of the world's population. Established in 1999 in response to the financial crises of the late 1990s, the G20 serves as a platform for high-level discussions on global economic governance and coordination.

The primary objective of the G20 is to promote global economic stability, sustainable development, and inclusive growth. The forum facilitates dialogue and cooperation among its members on a wide range of economic, financial, and social issues, including trade, investment, fiscal policy, monetary policy, employment, and development. By fostering consensus and cooperation, the G20 aims to address common challenges and promote shared prosperity.

The G20 holds annual summit meetings, bringing together heads of state or government, finance ministers, central bank governors, and other senior officials from member countries, as well as representatives from international organisations such as the International Monetary Fund (IMF), World Bank, and World Trade Organisation (WTO). The summit meetings provide an opportunity for leaders to discuss pressing global issues, exchange views, and coordinate policy responses.

Each G20 presidency sets the agenda and priorities for its term, focusing on key challenges and opportunities facing the global economy. Past summit meetings have addressed a wide range of topics, including financial regulation, infrastructure investment, digital economy, climate change, energy transition, sustainable development, and global health. The G20 also collaborates with other international organisations and fora to leverage expertise and resources in addressing complex global issues.

Outcomes and Declarations: Summit meetings typically result in communiqués or declarations outlining the outcomes of discussions and agreements reached by G20 leaders. These documents reflect shared principles, commitments, and action plans to address priority areas identified during the summit. While not legally binding, G20 declarations serve as important signals of political will and consensus among member countries, guiding future policy actions and international cooperation efforts.

Shared Principles and Commitments: G20 declarations articulate shared principles and commitments agreed upon by member countries, reflecting their collective vision for addressing global challenges and promoting sustainable development. These principles may include commitments to open and inclusive economic growth, financial stability, poverty reduction, climate action, and global health.

Action Plans and Policy Agendas: G20 declarations often include action plans and policy agendas outlining specific measures and initiatives to achieve the objectives set forth during the summit. These action plans may cover a wide range of areas, including macroeconomic policy coordination, financial regulation, trade facilitation, infrastructure investment, digital transformation, energy transition, and environmental sustainability.

Policy Coordination and Cooperation: G20 declarations emphasise the importance of policy coordination and cooperation among member countries to address common challenges effectively. They reaffirm the G20 leaders' commitment to working together in areas such as monetary policy, fiscal policy, exchange rate management, trade policy, and investment promotion, recognising the inter-



connectedness of the global economy.

Guidance for Future Policy Actions: While G20 declarations are not legally binding, they provide important guidance and signals for future policy actions and international cooperation efforts. Member countries use these declarations to inform their domestic policy-making processes, aligning their policies and priorities with the shared objectives and commitments agreed upon at the summit.

Monitoring and Accountability Mechanisms: G20 declarations often include provisions for monitoring and accountability mechanisms to track progress towards achieving the goals and commitments outlined in the declaration. Member countries may agree to report on their implementation efforts, exchange best practices, conduct peer reviews, and assess the collective impact of G20 initiatives over time.

Engagement with Stakeholders: G20 declarations recognise the importance of engaging with stakeholders beyond government officials, including civil society organisations, private sector representatives, academia, and international organisations. They encourage inclusive dialogue and collaboration to harness the expertise, resources, and perspectives of diverse stakeholders in addressing global challenges.

Adaptability and Flexibility: G20 declarations demonstrate adaptability and flexibility in responding to evolving global dynamics and emerging priorities. They allow for adjustments and refinements to policy approaches and action plans over time, reflecting changes in the economic, social, and environmental landscape.

Overall, G20 declarations serve as import-

ant instruments for promoting dialogue, cooperation, and collective action among member countries, guiding efforts to address complex global challenges and advance sustainable development and inclusive prosperity.

Role in Global Governance: The G20 plays a crucial role in global economic governance, complementing the work of other multilateral institutions such as the United Nations, the IMF, the World Bank, and the WTO. As a forum for major economies, the G20 has the capacity to drive policy coordination, promote financial stability, and catalyze collective action on global challenges. Its inclusive and flexible nature enables constructive dialogue and collaboration among diverse stakeholders, thereby enhancing the effectiveness and legitimacy of global governance arrangements.

Challenges and Criticisms: Despite its importance and potential, the G20 faces challenges and criticisms, including concerns about representativeness, transparency, accountability, and effectiveness. Critics argue that the G20's focus on major economies may marginalize smaller countries and undermine the principles of inclusivity and equity in global governance. Additionally, disagreements among member countries over issues such as trade, climate change, and geopolitical tensions can hinder consensus and cooperation within the G20.

By addressing these challenges and leveraging its strengths, the G20 can play a vital role in shaping the future of global economic governance and advancing sustainable development goals. As the world continues to grapple with complex and interconnected challenges, the G20 remains a critical forum for fostering dialogue, cooperation, and collective action among the world's leading economies.

2.3.8.2 UNFCCC

Historical Context: The UNFCCC was adopted in 1992 at the Earth Summit in Rio de Janeiro, Brazil. It represents a landmark international treaty aimed at addressing the growing threat of climate change by stabilising atmospheric concentrations of greenhouse gases.

Membership and Structure: The UNFCCC has near-universal membership, with 197 countries, including the European Union, as parties to the convention. It operates under the principles of equity, common but differentiated responsibilities, and respective capabilities, recognizing that developed and developing countries have different obligations and capacities to address climate change.

Objectives: The primary objective of the UNFCCC is to prevent dangerous anthropogenic interference with the climate system. To achieve this, the convention sets broad goals, including stabilising greenhouse gas concentrations, promoting sustainable development pathways, and enhancing climate resilience and adaptation efforts.

Key Principles: The UNFCCC is guided by several key principles, including the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC), which acknowledges historical emissions and varying capacities among countries. Other principles include the precautionary principle, intergenerational equity, and the principle of equity and justice.

Conference of the Parties (COP): The COP is the supreme decision-making body of the UNFCCC and meets annually to review the implementation of the convention and negotiate additional agreements. The COP adopts decisions and resolutions, including

protocols, amendments, and guidelines for implementing the convention's provisions.

Kyoto Protocol and Paris Agreement: Two of the most significant outcomes of the UNFCCC process are the Kyoto Protocol and the Paris Agreement. The Kyoto Protocol, adopted in 1997, established legally binding emission reduction targets for developed countries. The Paris Agreement, adopted in 2015, builds upon the UNFCCC's framework and sets out a more ambitious and inclusive approach to climate action, with all countries committing to nationally determined contributions (NDCs).

Subsidiary Bodies and Mechanisms: The UNFCCC includes various subsidiary bodies and mechanisms to support its implementation and enhance international cooperation. These include the Subsidiary Body for Scientific and Technological Advice (SBSTA), the Subsidiary Body for Implementation (SBI), the Adaptation Committee, the Green Climate Fund, and the Technology Mechanism, among others.

Financial Mechanisms and Support: The UNFCCC promotes financial support from developed countries to help developing countries mitigate and adapt to climate change. It established the Green Climate Fund (GCF) to channel financial resources to developing countries and supports initiatives to enhance capacity building, technology transfer, and knowledge sharing.

Enhanced Ambition and Implementation: With the growing urgency of the climate crisis, there is growing recognition of the need for greater ambition and accelerated action to address it. The UNFCCC process provides a platform for countries to ratchet up their climate commitments over time and strengthen their implementation efforts through regular



review and revision of NDCs.

Global Climate Negotiations: The UNFCCC process plays a crucial role in facilitating global climate negotiations and fostering consensus among countries on key issues. It provides a forum for dialogue, negotiation, and collaboration, helping to bridge differences and build momentum towards collective action to address climate change.

Overall, the UNFCCC serves as the cornerstone of international efforts to address climate change, providing a framework for cooperation, coordination, and collective action to safeguard the planet for current and future generations.

2.3.8.3 Copenhagen Accord

Background: The Copenhagen Accord emerged from the 15th Conference of the Parties (COP15) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Copenhagen, Denmark, in December 2009. While the conference did not result in a legally binding agreement, the Copenhagen Accord was a significant political outcome endorsed by a group of key countries.

Key Objectives: The Copenhagen Accord aimed to advance international efforts to address climate change by mobilizing financial resources, enhancing mitigation efforts, and promoting transparency and accountability in climate action. It recognized the urgent need to limit global warming to below 2 degrees Celsius and acknowledged the importance of supporting developing countries in their climate adaptation and mitigation efforts.

Voluntary Emission Reduction Targets: One of the key features of the Copenhagen Accord was the establishment of voluntary

emission reduction targets by both developed and developing countries. Developed countries agreed to implement economy-wide emission reduction targets, while developing countries pledged to take nationally appropriate mitigation actions (NAMAs) in the context of sustainable development.

Financial Support: The Copenhagen Accord included commitments from developed countries to provide financial support to developing countries to help them address climate change. It set a goal of mobilising \$100 billion per year by 2020 from public and private sources to support climate mitigation and adaptation efforts in developing countries.

Fast-Start Finance: As part of the Copenhagen Accord, developed countries pledged to provide \$30 billion in "fast-start finance" from 2010 to 2012 to support immediate climate action in developing countries. This funding was intended to help developing countries build capacity, adapt to the impacts of climate change, and implement low-carbon development projects.

Adaptation and Technology Transfer: The Copenhagen Accord emphasized the importance of supporting adaptation efforts in developing countries, particularly the most vulnerable, to address the impacts of climate change. It also recognised the need for enhanced technology transfer and capacity-building to facilitate the adoption of clean, sustainable technologies in developing countries.

Non-Legally Binding Status: It's important to note that the Copenhagen Accord was not adopted as a legally binding agreement under the UNFCCC process. Instead, it was a political agreement negotiated among a subset of countries participating in the COP15 negoti-

ations. As a result, its implementation and effectiveness depended on the parties' voluntary compliance.

Legacy and Criticisms: The Copenhagen Accord had a mixed legacy and faced criticism from various quarters. While it represented a significant political agreement and helped inject new momentum into international climate negotiations, it also fell short of expectations in some areas, including the level of ambition in emission-reduction targets and the lack of a legally binding framework.

Despite its shortcomings, the Copenhagen Accord continues to shape international climate action and inform subsequent agreements, including the Paris Agreement. It laid the groundwork for key concepts and approaches, such as nationally determined contributions (NDCs) and climate finance, that continue to shape the global climate agenda.

The Copenhagen Accord provided important lessons for future climate negotiations, highlighting the challenges of consensus-building among diverse countries with varying interests and priorities. It underscored the importance of transparency, inclusivity, and political will in advancing international cooperation on climate change.

Overall, while the Copenhagen Accord may not have achieved all its objectives, it served as a stepping stone in the global effort to address climate change and laid the groundwork for more ambitious and inclusive agreements in the years that followed.

2.3.9 Montreal Protocol

The Montreal Protocol was proposed in 1987 to stop the use, production, and import of ozone-depleting substances and to mini-

mise their concentration in the atmosphere to protect the Earth's ozone layer.

Historical Context: The Montreal Protocol is an international environmental treaty designed to protect the Earth's ozone layer by phasing out the production and consumption of ozone-depleting substances (ODS). It was adopted in 1987 in response to growing scientific evidence of the harmful effects of ODS on the ozone layer, which shields the Earth from harmful ultraviolet (UV) radiation.

Global Cooperation: The Montreal Protocol is widely regarded as one of the most successful environmental agreements in history due to its broad participation and effective implementation. It has near-universal membership, with 198 countries and the European Union as parties to the treaty, reflecting the global recognition of the need for collective action to address ozone depletion.

Phasing Out Ozone-Depleting Substances: The Montreal Protocol established a phased approach to phasing out the production and consumption of ODS, such as chlorofluorocarbons (CFCs), halons, and other chemicals used in refrigeration, air conditioning, insulation, solvents, and aerosol propellants. The treaty set specific reduction targets and timetables for the phase-out of these substances, leading to their gradual elimination.

Amendments and Adjustments: Over the years, the Montreal Protocol has undergone several amendments and adjustments to strengthen its effectiveness and address emerging challenges. For example, the London Amendment in 1990 accelerated the phase-out schedule for certain ODS, while the Copenhagen Amendment in 1992 introduced stricter controls on hydrochlorofluorocarbons (HCFCs) and methyl bromide.



Successes and Achievements: The Montreal Protocol has achieved significant reductions in ODS emissions and protection of the ozone layer. According to the World Meteorological Organisation (WMO), the ozone layer is showing signs of recovery, with evidence of a decrease in the atmospheric concentration of ODS and a stabilisation of ozone-depleting chemicals in the atmosphere.

By protecting the ozone layer, the Montreal Protocol has helped prevent millions of cases of skin cancer, cataracts, and other health problems caused by increased UV radiation exposure. It has also helped to safeguard ecosystems and biodiversity, as UV radiation can harm marine life, terrestrial plants, and vulnerable ecosystems.

In addition to its ozone protection benefits, the Montreal Protocol has also had positive co-benefits for climate change mitigation. Many ODS are also potent greenhouse gases, and their phase-out has helped to reduce emissions of these substances, thereby contributing to efforts to combat global warming and climate change.

Implementation Challenges and Compliance: While the Montreal Protocol has been successful overall, it has faced implementation and compliance challenges, particularly in ensuring that all parties fulfil their obligations under the treaty. Efforts to address illegal trade in ODS and to ensure the proper disposal of existing ODS stockpiles remain areas of concern.

As the world transitions to climate-friendly alternatives to ODS, such as hydrofluorocarbons (HFCs), new challenges and opportunities arise for the Montreal Protocol. The Kigali Amendment, adopted in 2016, aims to phase down the production and consumption

of HFCs, which have a high global warming potential, thereby further contributing to climate change mitigation efforts.

The Montreal Protocol remains a shining example of international cooperation and multilateralism in addressing global environmental challenges. Its success demonstrates the effectiveness of collective action and provides valuable lessons for future efforts to address other pressing environmental issues, such as climate change, biodiversity loss, and pollution.

2.3.10.1 Carbon credit and carbon trading

A carbon credit is a tradable permit or certificate that provides the holder of the credit the right to emit one ton of CO₂ or an equivalent of another greenhouse gas. The main goal of creating carbon credits is to reduce CO₂ and other greenhouse gas emissions from industrial activities to mitigate the effects of global warming.

- ▶ Carbon credits were devised as a market-oriented mechanism to reduce greenhouse gas emissions.
- ▶ Companies get a set number of credits, which decline over time. They can sell any excess to another company.
- ▶ Thus, "cap-and-trade" is an incentive to reduce emissions.

Types of credit

- ▶ Voluntary Remissions Reduction (VER): A carbon offset that is exchanged in or over the country or voluntary market for credits.
- ▶ Certified Emissions Reduction

(CER): Emission units (credits) created through a regulatory framework to offset a project's emissions. The main difference between the two is that there is a third-party certifying body that regulates the CER as opposed to the VER.

Carbon trade is the buying and selling of credits that permit a company or other entity to emit a certain amount of carbon dioxide. Carbon credits and carbon trading are authorised by governments to gradually reduce overall carbon emissions and mitigate their contribution to climate change. Carbon trading is also referred to as carbon emissions trading.

- ▶ Carbon trade agreements allow for the sale of credits to emit carbon dioxide between nations as part of an international agreement aimed at gradually reducing total emissions.
- ▶ The carbon trade originated with the Kyoto Protocol, a United Nations treaty that set the goal of reducing global carbon emissions and mitigating climate change starting in 2005.
- ▶ Various countries and territories have started carbon trading programs—for example, in July 2021, China started a national emissions-trading program.
- ▶ Cap and trade, a variation on carbon trade, allows for the sale of emission credits between companies.

These measures are aimed at reducing the effects of global warming, but their effectiveness remains a matter of debate.

Carbon Credit and Carbon Trading were

created as an answer to the need for controlling emissions (global carbon-dioxide emissions in 2016 were about 36 billion metric tonnes), and as an attempt to reduce the emission of greenhouse and harmful gases coming from industrial activity (industries as power, steel, textile, fertilizer *etc.* using all fossil fuels – such as coal, oil and natural gas – that are the major materials responsible for greenhouse gas emissions). The Carbon Credits system was officially formalized in the Kyoto Protocol, while the mechanisms that regulate the Carbon Credits market were established in the Marrakesh Accords. Any government or other regulatory body that is willing to limit carbon dioxide emissions can issue Carbon Credits. Carbon trading follows the principle of an emissions trading (or cap-and-trade) approach, i.e., a market-based approach that provides economic incentives to encourage reductions in the emissions of pollutants. One of the positive aspects of this approach is that organisations can use emissions trading schemes flexibly, choosing the option that best meets policy targets. Example- Company A emits less than its target amount of CO₂; this means that Company A has a surplus of Carbon Credits. Company B, on the other hand, emits more than its target amount of hydrocarbon, so either Company B pays a fine or tries to buy Carbon Credits from another company. At this point, Company A and Company B reach an agreement and trade Carbon Credits: Company A sells its surplus to Company B, earning money and positive feedback, while Company B, by buying Carbon Credits from Company A, avoids paying a fine.

2.3.10.2 The Cap-and-Trade System

This is how carbon trading works: Each nation is awarded a certain number of permits to emit carbon dioxide up to a set limit. If it does not use up all of its permits, it



How Does Emission Trading Work?

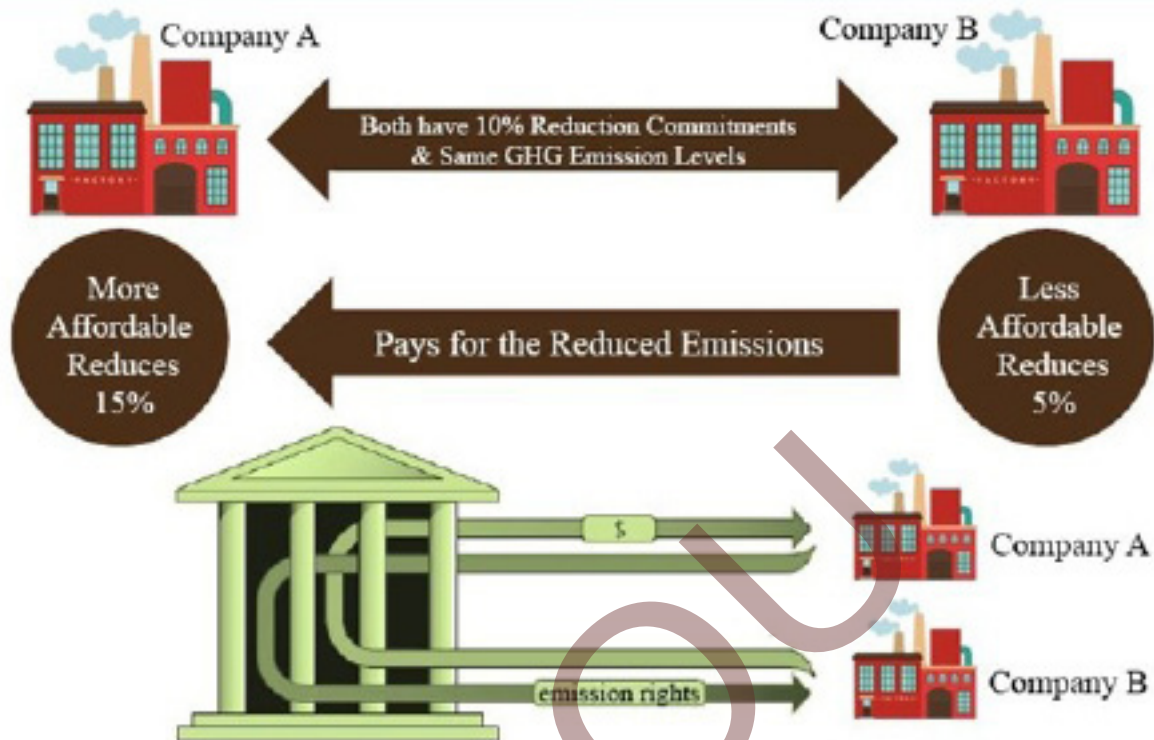


Fig 2.3.5 Carbon credit and carbon trading methods

can sell the unused permits to another nation that wants to emit more carbon dioxide than its permits allow. Every year, a slightly smaller number of new permits is awarded to each nation. A cap-and-trade system is a variant of carbon trading. In this case, the trade, while authorized and regulated by the government, is conducted between companies. Each company is given a maximum carbon pollution allowance. Unused allowances can be sold to other companies. The goal is to ensure that companies in the aggregate do not exceed a baseline level of pollution. The baseline is reduced annually.

Carbon Credits are purchased voluntarily by any country or company interested in lowering its carbon footprint. The Kyoto Protocol divides countries into two groups based

on their level of economic development: industrialised and developing economies. The first group operates in an emissions-trading market, assigning each country an emissions standard to meet. If, for example, a country emits less than its permitted amount of CO₂, it can sell the surplus credits to other countries that do not meet their emissions targets under the Kyoto Protocol. This buying and selling of Carbon Credits is regulated by a legal contract called ERPA (Emission Reduction Purchase Agreement). There is also another mechanism, called the Clean Development Mechanism and specifically addressed to developing countries, that issues Carbon Credits for supporting sustainable development initiatives (those Carbon Credits are called Certified Emission Reduction, or CER).

Carbon credits can be traded on both private and public markets. Current trading rules allow the international transfer of credits. Credit prices are primarily driven by market supply and demand. Due to differences in supply and demand across countries, credit prices fluctuate. The carbon funds provide

small investors with the opportunity to enter the market. Buyers and sellers can also use an exchange platform to trade, which is like a stock exchange for carbon credits. In some cases, though, it may be more economical to pay a fine than to buy Carbon Credits because of their high price.

Recap

- ▶ SDGs encompass 17 global objectives for poverty, inequality, and climate change.
- ▶ International agreements tackle climate change and ozone layer depletion.
- ▶ Montreal Protocol phases out ozone-depleting substances, protecting Earth.
- ▶ Human activities intensify the greenhouse effect, leading to warming.
- ▶ Solutions include emission reduction, renewables, and sustainable land use.
- ▶ G20 Summit coordinates economic policies, including climate action.
- ▶ UNFCCC stabilizes greenhouse gas concentrations to prevent climate interference.
- ▶ Paris Agreement aims to limit warming and enhance resilience.
- ▶ Kyoto Protocol sets emission targets and introduces trading mechanisms.
- ▶ Copenhagen Accord signifies political commitment to combat climate change.
- ▶ Agreements work towards sustainable development and environmental protection.
- ▶ Cooperation is vital for achieving SDGs and addressing global challenges.

Objective Questions

1. What are the UN Sustainable Development Goals (SDGs) aimed at achieving?
2. How many Sustainable Development Goals (SDGs) are there in total?
3. Which international agreement aims to protect the ozone layer?
4. What is the main greenhouse gas responsible for the greenhouse effect?
5. Which treaty established binding emission reduction targets for developed countries?



6. What is the primary objective of the G20 Summit?
7. Which international forum adopted the Paris Agreement in 2015?
8. Which greenhouse gas is targeted for phase-down under the Kigali Amendment?
9. What is the main goal of the Montreal Protocol?
10. Which agreement sets out to limit global warming to well below 2 degrees Celsius above pre-industrial levels?
11. Which international treaty focuses on reducing emissions of hydrofluorocarbons (HFCs)?
12. What mechanism does the Paris Agreement establish for countries to review and enhance their climate commitments?

Answers

1. Sustainability
2. 2. 17
3. Montreal Protocol
4. Carbon dioxide (CO₂)
5. Kyoto Protocol
6. Economic stability
7. UNFCCC
8. Hydrofluorocarbons (HFCs)
9. Ozone protection
10. Paris Agreement
11. Montreal Protocol
12. Global Stocktake

Self-Assessment Questions

1. Define the UN Sustainable Development Goals (SDGs) and explain their significance in global development efforts.
2. List and briefly describe the 17 Sustainable Development Goals (SDGs) established by the United Nations.

3. What are the key principles underlying the SDGs, and how do they contribute to sustainable development?
4. Explain the concept of international agreements in the context of environmental protection. How do they facilitate global cooperation on sustainability?
5. Discuss the importance of the ozone layer and the consequences of its depletion. How does the Montreal Protocol address ozone layer protection?
6. Explain the greenhouse effect and its role in global warming. What are the main sources of greenhouse gas emissions, and how do they contribute to climate change?
7. Describe the Kyoto Protocol and its objectives in mitigating climate change. What were the main provisions and mechanisms introduced by the protocol?
8. What is the Paris Agreement, and how does it differ from the Kyoto Protocol in addressing climate change?
9. Discuss the significance of the Copenhagen Accord in global efforts to combat climate change. What were its main objectives and outcomes?
10. Examine the role of the G20 Summit in addressing climate change and promoting sustainable development. How does it contribute to global climate governance?
11. What is the United Nations Framework Convention on Climate Change (UNFCCC), and what are its primary goals and functions?
12. Describe the main components and achievements of the Montreal Protocol in protecting the ozone layer. How has it contributed to environmental sustainability?
13. Explain the concept of carbon pricing and its role in mitigating greenhouse gas emissions. How does it incentivize emission reductions?
14. Discuss the challenges and opportunities in implementing the Sustainable Development Goals (SDGs) at the national and global levels. How can countries overcome barriers to sustainable development?
15. Examine the role of international cooperation and partnerships in achieving the SDGs and addressing global environmental challenges. How can stakeholders collaborate effectively to promote sustainability?

Reference

1. Dernbach, J. C., & Lewin, S. (2022). *Sustainability and the law: Principles and practice*. Environmental Law Institute.
2. Elliott, J. (2012). *An introduction to sustainable development* (4th ed.). Routledge.
3. Sachs, J. D. (2015). *The age of sustainable development*. Columbia University Press.
4. Strange, T., & Bayley, A. (2008). *Sustainable development: Linking economy, society, environment*. OECD Publishing.
5. Victor, D. G. (2011). *Global warming gridlock: Creating more effective strategies for protecting the planet*. Cambridge University Press.

Suggested Reading

1. Intergovernmental Panel on Climate Change (IPCC). (2023). *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report*. <https://www.ipcc.ch/report/ar6/syr/>
2. United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. <https://sdgs.un.org/2030agenda>
3. United Nations. (2024). *The Sustainable Development Goals report 2024*. <https://unstats.un.org/sdgs/report/2024/>
4. United Nations Framework Convention on Climate Change. (2015). *Adoption of the Paris Agreement*. <https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf>
5. World Meteorological Organization. (2022). *Scientific assessment of ozone depletion: 2022*. UNEP Ozone Secretariat.



SREENARAYANAGURU OPEN UNIVERSITY

QP CODE:

Reg. No :

Name :

Model Question Paper- set-I

FIRST SEMESTER FYUG EXAMINATION

Value Added Course - SGB24UC102VC

Environment, Climate Change and Sustainable Development

(FYUGP)

(CBCS - UG)

2024-25 - Admission Onwards

Time: 1 Hour

Max Marks: 23

SECTION A

Answer any five questions in a word or sentence. Each question carries one mark.

(5x1 = 5 Marks)

1. What is an ecosystem?
2. Define biodiversity.
3. Name any one renewable source of energy.
4. What does the term 'deforestation' mean?
5. Which gas is primarily responsible for the greenhouse effect?
6. What is a sanitary landfill?
7. Expand the term 'SDG'.
8. Name the international agreement that targets ozone layer protection.

SECTION B

Answer any four questions in two or three sentences each. Each question carries two marks.

(4x2 = 8 Marks)

9. Distinguish between weather and climate.
10. State any two characteristics of non-renewable resources.



11. What is rainwater harvesting? Why is it important?
12. Briefly explain the Chipko Movement and its significance.
13. What is meant by the 'triple bottom line' in sustainable development?
14. State any two objectives of the Paris Agreement.

SECTION C

Answer any two questions. Each question carries five marks.

(2x5 = 10 Marks)

15. Explain the importance of biodiversity and describe any two major threats to it.
16. Describe the 3Rs (Reduce, Reuse, Recycle) principle in solid waste management with suitable examples.
17. Discuss the 17 UN Sustainable Development Goals (SDGs) with a focus on their environmental dimensions.

SGOU



SREENARAYANAGURU OPEN UNIVERSITY

QP CODE:

Reg. No :

Name :

Model Question Paper- set-II

FIRST SEMESTER FYUG EXAMINATION

Value Added Course - SGB24UC102VC

Environment, Climate Change and Sustainable Development

(FYUGP)

(CBCS - UG)

2024-25 - Admission Onwards

Time: 1 Hour

Max Marks: 23

SECTION A

Answer any five questions in a word or sentence. Each question carries one mark.

(5x1 = 5 Marks)

1. What is meant by 'climate change'?
2. Give one example of a non-renewable resource.
3. What is afforestation?
4. Name the principle that balances present and future needs in sustainable development.
5. What is e-waste?
6. Which Indian movement is associated with hugging trees to prevent felling?
7. State one goal of the Kyoto Protocol.
8. What are carbon credits?

SECTION B

Answer any four questions in two or three sentences each. Each question carries two marks.

(4x2 = 8 Marks)

9. What is an ecological footprint? How does it relate to sustainability?
10. Differentiate between renewable and non-renewable energy resources with one example each.



11. Briefly describe the Narmada Bachao Andolan and its environmental relevance.
12. What is the role of eco-clubs in promoting environmental awareness?
13. Define 'watershed management' and state its importance.
14. Explain the concept of greenhouse gases and list any two examples.

SECTION C

Answer any two questions. Each question carries five marks.

(2x5 = 10 Marks)

15. Describe the major types of natural resources and explain how over-exploitation affects the environment.
16. Explain the Swachh Bharat Abhiyan and Haritha Keralam Mission as contemporary conservation initiatives in India.
17. Discuss the Brundtland Commission's concept of sustainable development and explain the key principles of the 2030 Agenda.

സർവ്വകലാശാലാഗീതം

വിദ്യായാൽ സ്വതന്ത്രരാകണം
വിശ്വപൗരരായി മാറണം
ഗ്രഹപ്രസാദമായ് വിളങ്ങണം
ഗുരുപ്രകാശമേ നയിക്കണേ

കുതിരുട്ടിൽ നിന്നു ഞങ്ങളെ
സൂര്യവീഥിയിൽ തെളിക്കണം
സ്നേഹദീപ്തിയായ് വിളങ്ങണം
നീതിവൈജയന്തി പാറണം

ശാസ്ത്രവ്യാപ്തിയെന്നുമേകണം
ജാതിഭേദമാകെ മാറണം
ബോധരശ്മിയിൽ തിളങ്ങുവാൻ
ജ്ഞാനകേന്ദ്രമേ ജ്വലിക്കണേ

കുരിപ്പുഴ ശ്രീകുമാർ

SREENARAYANAGURU OPEN UNIVERSITY

Regional Centres

Kozhikode

Govt. Arts and Science College
Meenchantha, Kozhikode,
Kerala, Pin: 673002
Ph: 04952920228
email: rckdirector@sgou.ac.in

Thalassery

Govt. Brennen College
Dharmadam, Thalassery,
Kannur, Pin: 670106
Ph: 04902990494
email: rctdirector@sgou.ac.in

Tripunithura

Govt. College
Tripunithura, Ernakulam,
Kerala, Pin: 682301
Ph: 04842927436
email: rcedirector@sgou.ac.in

Pattambi

Sree Neelakanta Govt. Sanskrit College
Pattambi, Palakkad,
Kerala, Pin: 679303
Ph: 04662912009
email: rcpdirector@sgou.ac.in

**DON'T LET IT
BE TOO LATE**

**SAY
NO
TO
DRUGS**

**LOVE YOURSELF
AND ALWAYS BE
HEALTHY**



SREENARAYANAGURU OPEN UNIVERSITY

The State University for Education, Training and Research in Blended Format, Kerala

Environment, Climate Change and Sustainable Development

COURSE CODE: SGB24UC102VC

SGOU



Sreenarayanaguru Open University

Kollam, Kerala Pin- 691601, email: info@sgou.ac.in, www.sgou.ac.in Ph: +91 474 2966841

ISBN 978-81-996670-9-9



9 788199 667099