Environmental Economics

COURSE CODE: M23EC04DE

Postgraduate Programme in Economics
Discipline Specific Elective Course
Self Learning Material

SREENARAYANAGURU
OPEN UNIVERSITY

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

SREENARAYANAGURU OPEN UNIVERSITY

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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

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Pathway

Access and Quality define Equity.

Environmental Economics

Course Code: M23EC04DE

Semester - III

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MESSAGE FROM VICE CHANCELLOR

Dear learner,

I extend my heartfelt greetings and profound enthusiasm as I warmly welcome you to Sreenarayanaguru Open University. Established in September 2020 as a state-led endeavour to promote higher education through open and distance learning modes, our institution was shaped by the guiding principle that access and quality are the cornerstones of equity. We have firmly resolved to uphold the highest standards of education, setting the benchmark and charting the course.

The courses offered by the Sreenarayanaguru Open University aim to strike a quality balance, ensuring students are equipped for both personal growth and professional excellence. The University embraces the widely acclaimed "blended format," a practical framework that harmoniously integrates Self-Learning Materials, Classroom Counseling, and Virtual modes, fostering a dynamic and enriching experience for both learners and instructors.

The University aims to offer you an engaging and thought-provoking educational journey. The postgraduate programme in Economics builds on the undergraduate programme by covering more advanced theories and practical applications. The course material aims to spark learners' interest by using real-life examples and combining academic content with empirical evidence, making it relevant and unique. The Self-Learning Material has been meticulously crafted, incorporating relevant examples to facilitate better comprehension.

Rest assured, the university's student support services will be at your disposal throughout your academic journey, readily available to address any concerns or grievances you may encounter. We encourage you to reach out to us freely regarding any matter about your academic programme. It is our sincere wish that you achieve the utmost success.

Regards,
Dr. Jagathy Raj V.P.

01-01-2025

Contents

Part - I

Block 01	**Economy and Environment**	**1**
Unit 1	Economy, Ecology, and the Environment	2
Unit 2	Natural Resources	16
Unit 3	Environmental Economics and Sustainability	30
Unit 4	Impact of Climate Change	62
Block 02	**Sustainable Development**	**84**
Unit 1	Environmental Sustainability	85
Unit 2	Theories of Resource Use and Environmental Accounting	99
Unit 3	Sustainable Development Goals: India and Kerala	122
Unit 4	Global Environmental Issues	141

Part - II

Block 03	**Environmental Management**	**160**
Unit 1	Valuation of the Environment	161
Unit 2	Environment Valuation Methods	169
Unit 3	Stated Preference Methods and Cost-Benefit Analysis	180
Block 04	**Environmental Management**	**198**
Unit 1	Approaches for Environmental Protection	199
Unit 2	Environmental Regulations and Assessment in India	216
Unit 3	Solid Waste Management: A Case Study from Lucknow City, India	225

BLOCK 1 Economy and Environment

UNIT 1

Economy, Ecology, and the Environment

Learning Outcomes

After completing this unit, the learner will be able to:

- understand economic principles underlying environmental issues
- learn the principles of ecological economics
- analyse the distinction between resource economics and environmental economics
- integrate economic, ecological, and social perspectives

Background

The interconnected fields of Environmental Economics, Ecological Economics, and Resource Economics have changed in response to the growing awareness of the complicated relationships between economic growth, environmental degradation, and human well-being. As the global economy has expanded, so too has the exploitation of natural resources, pollution, and climate change, underlining the urgent need for a more sustainable and equitable approach to development. These fields collectively seek to explain the economic causes and consequences of environmental problems, with a view to developing innovative policies and solutions that harmonise economic, social, and environmental objectives. By examining the complex interplay between human economic activity and the natural environment, Environmental Economics, Ecological Economics, and Resource Economics address a range of emerging issues, including climate change, sustainable development, natural resource management, and environmental valuation, ultimately providing a framework for creating a more sustainable, equitable, and resilient future for all.

Keywords

Environmental Economics, Ecological Economics, Resource Economics

Discussion

1.1.1 Environment and Economy

- Through interdisciplinary approach enviornmental challenges can be addressed

Addressing environmental challenges requires an interdisciplinary approach. Effective management of the biosphere demands the integration of various fields, including biology, economics, physics, geology, and engineering. Only through a unified approach to environmental issues can we identify both preventive and corrective measures. Social sciences, such as economics, sociology, and anthropology, provide valuable tools for effective environmental planning and management. As Professor Larry Ruff highlights, "We will make little real progress in solving pollution problems until we recognise it for what it primarily is - an economic problem." He argues that solutions based solely on technological, political, legal, and ethical perspectives will fall short because they overlook the core economic nature of pollution. This multidisciplinary connection between environmental issues and economic principles has led many economists to advocate for an integrated study of Economics and Ecology.

- Economic theory focuses on what, how and for whom to produce

Economic theory focuses on the fundamental questions of what to produce, how to produce, and for whom to produce, aiming to allocate scarce resources efficiently to maximise human well-being. In the past, when natural resources were abundant, environmental concerns were mainly social in nature. However, as environmental goods have become increasingly scarce, economists have applied economic theories to environmental issues. The exploitation of these resources has turned them into economic goods, altering the supply-demand relationship. The demand for environmental quality has surged, while the supply of clean air, water, and other resources has dwindled, highlighting the economic dimensions of environmental degradation.

1.1.2 Environmental Economics

- Environmental economics for sustainability

Environmental economics is a field of study that uses economic principles to understand how people interact with the environment. It looks at how people use and manage natural resources, and how their actions affect the environment. To do this, environmental economics draws on ideas from many areas of economics, such as microeconomics and macroeconomics, as well as from natural sciences like environmental science. It tries to explain why people make certain choices about the

environment, and how economic systems and policies can be changed to reduce harm to the environment. The goal is to find a balance between what people want and need, and what the environment can sustain. By understanding the economic side of environmental issues, we can develop solutions that work for both people and the planet.

1.1.2.1 Scope of Environmental Economics

Environmental economics is a field of study that tries to understand complex environmental issues. Because these issues involve many different factors, environmental economics draws on ideas from several social sciences, such as economics and sociology, and natural sciences, like biology and chemistry. When environmental economics first emerged in the 1960s, it incorporated a wide range of economic theories and perspectives. Today, environmental economists use many economic concepts and tools to analyse environmental problems. These tools include ideas like marginalism, which looks at the value of small changes, and cost-benefit analysis, which compares the pros and cons of different choices. They also consider concepts like externalities, which are unintended consequences of economic activities, and social welfare, which refers to the overall well-being of society. By applying these economic concepts and tools, environmental economists can better understand environmental problems and develop effective solutions.

- Economic tools analyse and solve environmental problems

Environmental economics is an area of interest that focuses on the economic relationships between people and the environment. One of the main challenges in environmental economics is that many environmental resources, such as clean air and water, do not have a market price. This means that people do not pay a direct price for using these resources, and as a result, they are often overused or exploited. Environmental problems usually arise because markets for these resources do not exist or do not work properly. For example, people may not pay for the negative impacts of pollution, such as dirty air and water, because there is no market price for these costs. Environmental economics seeks to understand the economic value of these non-market goods and services, such as the benefits of preserving natural habitats or the costs of climate change. By putting a value on these resources, environmental economists can help develop policies and solutions that promote sustainable use of the environment and protect natural resources for future generations.

- Valuing environmental resources economically

- Economics for environmental sustainability

Environmental economics is a discipline that examines the relationship between economic activities and the environment. For a long time, humans have been using the environment's resources without thinking about the consequences, assuming that they would never run out. However, we now realise that environmental resources, such as clean air and water, are limited and can be depleted. This is where economics comes in, as it is the study of how to allocate limited resources in the best way possible. Economics plays a crucial role in solving environmental problems because it helps us understand the trade-offs involved in protecting the environment. In other words, if we want to preserve more environmental resources, we may have to give up some other things we value, such as economic growth or consumer goods. This means that there is a balance to be struck between environmental protection and other economic goals. By using economic principles, we can make informed decisions about how to manage our environmental resources in a way that is sustainable and equitable.

1.1.2.2 Difference between Traditional Economics and Environmental Economics

The main idea of environmental economics is that the environment and economy are closely connected and rely on each other. Changes in one can affect the other.

- Economics ignores environmental impact

Traditional economics does not usually consider how the economy and environment are connected, and it doesn't try to understand how economic decisions affect the environment, or how the environment affects the economy.

- Markets fail for environmental goods

Environmental goods, like clean air and beautiful landscapes, are special because many people can enjoy them at the same time without using them up. This means that markets, where people buy and sell things, do not work well for these kinds of goods. In fact, markets often do not exist for environmental goods such as clean air and biodiversity.. This is different from regular goods like clothes, cars, and books, which have markets where people can buy and sell them.

- Traditional Economics ignores externalities while considering costs

When people make or use things, like goods and services, it can sometimes hurt or affect others in ways they didn't intend. This is called an 'externality'. Environmental economics looks at these externalities, especially when they harm the

environment. Traditional economics does not usually consider these externalities.

- Time matters in economics

Time is very important in environmental economics. Traditional economics helps figure out the best way to use resources to make goods and services, but it only looks at one moment in time. It assumes that using resources today won't affect our ability to use them tomorrow. But with environmental resources, like fossil fuels or prawns, using them up today can cause problems for future generations. Some decisions we make about the environment cannot be undone and can have a big impact on the future.

Traditional Economics	Environmental Economics
1. It does not deal with the inter-relationship and interactions between the environment and economic activities.	1. A nascent sub-discipline of economics that deals with the inter-relationship and interactions between the environment and economic activities.
2. Deals with private goods that are bought and sold in markets.	2. Deals with public or collective goods for which either no markets exists or the markets are imperfect.
3. Does not take into account externalities associated with the actions of individuals, groups of individuals and organisations.	3. Takes into account the externalities associated with the actions of individuals, groups of individuals and organisations.
4. Time-related decisions such as allocations of resources over time and inter-generational equity do not receive much attention.	4. Time-related decisions and inter-generational equity receive high attention.
5. Often does not consider the limited capacity of environment to provide inputs for production and absorb wastes produced in the process of production.	5. Limited capacity of the environment is explicitly considered.

Source: Lesser et al. (1997)

- The environment has limited capacity

Traditional economics does not consider the fact that the environment has limits to how much it can provide and absorb. The environment can only give us so many resources and handle so much waste. Environmental economics, on the other hand, recognises these limits and takes them into account when making decisions. It doesn't ignore the fact that the environment has a limited capacity to support human activities.

1.1.3 Ecological Economics

- Ecological economics deals with how human activities affect environment

Ecological economics is a branch of economics that acknowledges the limits of the environment and how human activities affect it. It is a field that combines ideas from many different subjects to understand how ecosystems and economic systems interact. Ecological economics tries to find ways to make the world sustainable, both environmentally and economically. It looks at how human activities impact the environment and emphasises the need to understand how ecosystems work in order to solve economic and environmental problems.

1.1.3.1 Core Concepts of Ecological Economics

Ecological economics is a broad field that is harder to describe because it combines ideas from many areas, including biology, ecology, engineering, and philosophy. Unlike environmental economics, which focuses mainly on economic solutions to environmental problems, ecological economics takes a more holistic approach, considering the complex relationships between humans, the economy, and the natural world. As a result, ecological economists have diverse viewpoints and strategies, making it a rich and multidisciplinary field.

Ecological economists agree on three key ideas:

1. The economy is part of the larger ecosystem.
2. Sustainability should be measured by how well we protect the environment, not just by economic growth.
3. To understand environmental issues, we need to combine insights from many fields, including economics, ecology, biology, and more.

1.1.3.2 Environmental Economics and Ecological Economics

- Ecological vs environmental economics

Environmental economics often involves economists applying their field's principles to environmental issues. Conversely, ecological economics typically involves ecologists broadening their focus to include human society and the economy. A key difference is that ecological economics is highly multidisciplinary, welcoming researchers from diverse fields interested in the intersection of environment and society, unlike environmental economics, which remains a subfield of economics. However, rather than focusing on their historical differences, it is more relevant to examine how each field currently approaches and tackles environmental problems.

- Ecological economics study of relation between ecosystems and economic systems

Defining ecological economics is challenging. One prominent Ecological economics is the "the study of the relationships between ecosystems and economic systems in the broadest sense." The central concern is the long-term health of the entire ecosystem, including humans. Malte Faber, in a 2007 lecture, suggested that ecological economists are defined by their interest in 'nature, justice, and time.' He posits that the economy should be seen as part of nature, that justice should be a core principle, and that conventional economics simplifies the concept of time.

- Ecological economics focus a societial decisions on enviorment

Ecological economics often focuses on what society should do, rather than just describing what society actually does. A major difference between ecological and conventional economics is how they view 'value,' which affects how we make social decisions about the environment.

- Assign value based on energy usage

Traditional economists think something is valuable to society if people individually think it is valuable. Ecological economists look at value from a more physical perspective. For example, some might measure the 'value' of something by how much energy it took to make it. So, if you are comparing a typewriter and a computer, they had ask: Which one uses more energy to produce? The one that uses less energy would be considered 'better.' This idea comes from ecological theories about ecosystems trying to use the least amount of energy possible. These ecological economists believe that using less energy to create goods and services should be a major goal of government policy.

- Value depends on scarcity and human preferences

However, environmental economists disagree with this 'energy theory of value.' They argue that many things are scarce, not just energy, like land and skilled labour. They say that determining the value of something only by its energy content is too simplistic. Environmental economists believe that a thing's value comes from a mix of scarce resources (including energy) and how much people want it. Basically, they think you cannot boil down value to just one physical measurement.

- Rethinking economic growth models

Some ecological economists believe that economic growth is not a good thing. They also think that traditional economics wrongly teaches that growth is always good. This difference comes from a misunderstanding of what "growth" really means. Things like better technology, education, and even population increases have caused economic growth. But, growing economically does not have to mean harming the environment. We can consume things like art and literature (aesthetic goods) instead of only using material goods like steel and cars.

1.1.4 Resource Economics

- Environmental and resource interconnected

Environmental economics examines issues like pollution and lack of environmental protection, which are often caused by market failures. On the other hand, resource economics examines how we utilise natural resources, such as renewable resources like fish and non-renewable resources like oil. It also considers things like mountains, forests, and wildlife as natural resources, even if we do not use them directly, because they have value and importance for our planet.

1.1.4.1 Environmental and Resource Economics

- Market failure harms the environment

Environmental economics typically focuses on situations where the market does not do a good job of protecting the environment. This can happen for many reasons, resulting in too much pollution and not enough preservation of natural areas like parks. Some of these problems need to be addressed right away, while others, like climate change, are longer-term issues that require planning for the future. For instance, deciding how much air pollution is acceptable in a city like London is usually considered a short-term problem that needs to be solved quickly, rather than a long-term issue that can be dealt with later.

- Time shapes resource management

Resource economics is concerned with how things change and develop over time. Time plays a crucial role in understanding how to manage resources that can be replenished, such as forests, and those that cannot, like oil. For instance, if we cut down trees in a forest at a slow enough pace, the forest can regrow, allowing us to continue harvesting wood indefinitely. This concept of time helps us make informed decisions about how to use and conserve our resources for future generations.

- Economics meets environmental reality

Environmental and resource economics are closely related fields that often overlap. For example, managing fisheries to prevent overfishing involves understanding both economic market failures, such as when too many fishermen have access to the same waters, and ecological dynamics, like how fish populations grow and regenerate. Similarly, addressing global warming and preserving natural environments are areas where environmental and resource economics converge. These issues often involve thinking about how our actions today will affect the future. However, environmental damage is often an unintended consequence of economic activities that have other primary goals. For instance, when natural habitats are converted for human use, it can lead to the loss of species.

1.1.5 Interlinkages between the Economy and the Environment

- Environment services needed tobe recognised with their economic value

Addressing environmental issues demands an interdisciplinary approach, combining insights from economics, biology, physics, geology, and engineering. The interconnectedness of economics and ecology is rooted in their shared origin from the Greek word 'Oikos,' emphasising the importance of managing resources. Pollution is fundamentally an economic problem, involving resource allocation and cost-benefit trade-offs. The environment provides essential functions, including supplying resources, absorbing waste, and sustaining life. Recognising the economic value of environmental services is crucial to prevent resource mismanagement and environmental crises. Ultimately, sustainable economic development requires integrating ecological considerations into economic activities and using economic mechanisms to manage environmental resources effectively.

The relationship between economics and the environment is complex and interconnected. Economic activities, such as production and consumption, can harm the environment through resource depletion and waste generation. Conversely,

a degraded environment can hinder economic activity, highlighting the need for harmony between economic growth and environmental sustainability. To achieve this balance, a shift towards an 'ecological reorientation' of economic policy is necessary, recognising the environment's vital role in providing resources and supporting economic activity.

1.1.5.1 Different Perspectives Regarding the Interaction of Environment and the Economy

(a) Neo-Malthusian Pessimistic Perspective

- Growth has environmental limits

Some experts, mostly biologists and ecologists, believe that the Earth has a limited capacity to support human life and economic growth. They argue that the planet's resources and ability to absorb waste are finite, and therefore, economic growth cannot continue indefinitely. According to this view, modern industrial society has severely damaged the environment, making ecological and economic collapse inevitable. Reports like 'The Limits to Growth' and books like 'The Population Bomb' have predicted dire consequences, such as global economic collapse, widespread misery and starvation, due to overpopulation, resource depletion, and environmental degradation. Many prominent environmentalists, including Lester Brown, Bill McKibben, Norman Myers, and Vandana Shiva, share this perspective, warning that the Earth's ecological limits must be respected to avoid catastrophic consequences.

(b) Cornucopian Optimistic Perspective

- Innovation supports sustainable growth

This group of experts, including technologists, agricultural scientists, and economists, disagrees with the idea that the world is running out of resources and that collapse is inevitable. They believe that market forces and entrepreneurship will drive innovation and the discovery of new energy sources, minerals, and other commodities. Additionally, advances in agricultural science have made it possible to increase the production of natural resources, such as fish, crops, and forests, through the use of technology and sustainable management practices. For example, fish farming can increase sustainable catches, while crop yields can be improved through the use of balanced fertilisers, pest control, and efficient water management. Even forests can be restored and made more productive through careful management. Overall, this group believes that the Earth's ability to support life can be increased through human innovation and ingenuity.

(c) The Middle Path

- Balancing growth with sustainability

We take a balanced approach, inspired by India's great thinkers, that avoids the extremes of two opposing views. On one hand, we do not believe that economic growth can continue indefinitely, as some technocrats and economists think. On the other hand, we don't think that the limits to growth are absolute, as some ecologists argue. Instead, we believe that these limits can be flexible and can be extended through technological advancements and innovative policies. We are optimistic that the 21st century will bring about a better quality of life for people while reducing humanity's impact on the environment. This view aligns with the principles of sustainable development, which aim to balance economic, social, and environmental needs for a brighter future.

(d) Materials Balance Perspective

- The economy interacts with the environment

In this perspective, the economy is seen as an open system that interacts with the environment. Environmental economics uses the laws of thermodynamics to understand how the economy and environment are connected. The material balance model, based on these laws, shows how the economy uses materials from the environment, transforms them into products, and then releases waste back into the environment. For example, the economy extracts non-renewable resources like fossil fuels and harvests products from renewable resources like forests and fisheries. These materials then go through a series of changes, eventually becoming waste that is partially recycled or returned to the environment. This process highlights the interconnectedness of the economy and environment, and how human activities impact the natural world.

- Entropy affects economic systems

When materials enter the economic system, they are not destroyed, but they do change form and become less useful. They start in a state of low entropy, meaning they are organised and useful, but end up in a state of high entropy, meaning they are disorganised and useless. Think of it like a cup of coffee: when it is freshly brewed, it is hot and useful, but as it cools down, it becomes less useful and eventually ends up as waste. This concept of entropy helps us understand that no matter how hard we try, we cannot recycle materials perfectly - there is always some waste left over. By looking at the economy from a materials balance perspective, we can see how human activities impact the environment and how environmental quality affects the economy's ability to function efficiently.

Summarised Overview

Environmental economics examines the interaction between human economic activity and the natural environment, recognising that the economy is an open system that relies on the environment for resources and waste absorption. This field draws on concepts from economics, environmental science, and ecology to understand how economic decisions affect the environment and vice versa. In contrast, ecological economics takes a more multidisciplinary approach, incorporating insights from ecology, economics, and social sciences to analyse the relationships between ecosystems and economic systems. While environmental economics focuses on market failures and externalities, ecological economics emphasises the need to consider the long-term health of ecosystems and the limits of natural resources.

There are differing perspectives on the relationship between economic growth and environmental sustainability. The neo-Malthusian pessimistic view holds that the Earth's resources are finite and that economic growth cannot continue indefinitely, while the cornucopian optimistic perspective argues that technological innovation and entrepreneurship can drive sustainable growth. A more balanced approach recognises that economic growth has environmental limits, but that these limits can be extended through technological advancements and innovative policies.

The materials balance perspective highlights the interconnectedness of the economy and environment, showing how materials are extracted, transformed, and eventually become waste. This perspective also emphasises the concept of entropy, which helps us understand that materials cannot be perfectly recycled and that waste is an inevitable by-product of economic activity. By considering these different perspectives and approaches, we can gain a deeper understanding of the complex relationships between the economy and environment, and develop more effective strategies for achieving sustainable development.

Assignments

1. What is the primary focus of environmental economics, and how does it differ from traditional economics?
2. Compare and contrast the neo-Malthusian pessimistic perspective with the cornucopian optimistic perspective on the relationship between economic growth and environmental sustainability.
3. Explain the concept of entropy in the context of the materials balance perspective
4. Explain the differences between environmental economics and ecological economics?.
5. Discuss the difference between Ecological economics and Resource economics

Reference

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2. Tietenberg T. (2004) (6th Edition) *Environmental and Natural Resource Economics,* Pearson. Education, Delhi.
3. Hussen,A. M (1999), *Principles of Environmental Economics* , Routledge, London.

Suggested Reading

1. Bromerly D.W. (Ed.) (1995). *Handbook of Environmental Economics.* Blackwell, London.
2. Fisher.A.C. (1981), *Resource and Environmental Economics.* Cambridge University Press, Cambridge.

Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

UNIT 2

Natural Resources

Learning Outcomes

After completing this unit, the learner will be able to:

- understand the material balance approach
- learn about the criteria for natural resource use
- comprehend the principles of uncertainty and irreversibility
- understand the concepts of intergenerational equity and intragenerational equity

Background

In the era of rapid industrialisation, urbanisation, and population growth, the needs of people are increasing daily. However, resources to meet these demands are becoming scarcer. Not only is there a problem of scarce resources, but people also follow a 'use and throw' principle in their daily lives, leading to increased waste. This waste is often dumped into rivers, hills, and other areas, creating serious environmental and health issues. This situation raises another problem, the lack of sustainability in resource use. The ultimate result of this unsustainable consumption is the unpredictability of environmental changes, such as extreme weather events. These challenges require a shift in how we approach resource management and policymaking.

In today's society, where income inequality, poverty, and social disparities are widespread, understanding the importance of equitable access to economic resources and environmental sustainability is crucial. It is essential to find a balance between human needs, environmental protection, and social justice. Moving forward, we must integrate the environmentally friendly principles into policies, business practices, and everyday decisions to ensure a sustainable and equitable future for all.

Keywords

Material Balance, Natural Resources, Renewable Resources, Non-Renewable Resources, Uncertainty, Irreversibility, Intergenerational Equity, Intragenerational Equity

Discussion

1.2.1 Material Balance Approach

- Materials Balance Model helps us understand how the economy and the environment are connected

Material Balance Models were developed by Alen Kneese and R.V. Ayres. This model explains the relationship between the economy and the environment. These models are based on the first and second laws of thermodynamics. The First Law of Thermodynamics is essentially a restatement of the law of conservation of energy, which asserts that energy cannot be created or destroyed. It can only be transferred or converted from one form to another. The Second Law of Thermodynamics states that in any energy transfer or transformation, the total entropy of an isolated system will either increase or remain constant; it will never decrease. This principle essentially describes the irreversibility of natural processes. The Materials Balance Model helps us understand how the economy and the environment are connected. It shows how everything is linked in a cycle of making things, using things, and dealing with the waste left behind.

- The environment has limited assimilation capacity

An economy has three main functions: production, consumption, and distribution. Production is when businesses create goods using raw materials, while consumption happens when people buy and use those goods and services. Distribution refers to how these goods and services are delivered from businesses to consumers. All of these activities are closely connected to nature, as nature provides the raw materials needed for both production and consumption. However, after goods are made and used, waste is often created. For example, factories might produce trash, smoke, or chemicals that pollute the air, water, and land. This pollution can harm animals, such as fish, cause health problems for people, and even damage buildings. The environment can naturally handle certain types of waste, like cleaning the air or water. However, if too much waste is created, the environment may not be able to keep up, leading to

serious problems. Two famous economists, Ayres and Kneese, argue that in order to protect the environment, we must ensure that the materials we use are transformed into useful products and that no unnecessary waste is produced. The environment should be able to manage the waste without being harmed. This concept can be explained with the help of the figure:

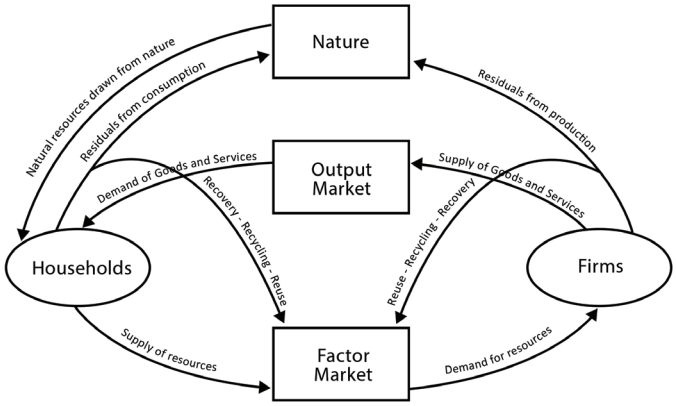

Fig.1.2.1 The Material Balance Model

Figure 1.2.1 illustrates that the environment supplies all forms of resources, both renewable and non-renewable, and also serves as a sink for waste disposal. Households and firms are connected to the environment, and they are interdependent. Both households and firms rely on nature for resources. In turn, they return waste from consumption and production activities to nature. As mentioned earlier, nature can assimilate all types of waste, but this ability is limited. As long as the Earth is not overwhelmed by excessive waste, it can manage natural waste. However, when the amount of waste exceeds the Earth's capacity to handle it, environmental damage begins to occur. There is a natural cycle in the use and reuse of resources by humans, but Earth is unable to properly process man-made or artificial waste. These human-made wastes are accumulating around us, leading to increasing environmental harm. Not all the waste being produced can be cleaned up by the Earth. If the Earth can still absorb and clean the pollution caused by waste, there would not be any environmental issues. But now, the Earth has reached its saturation point and is unable to clean up many types of waste, which results in significant global environmental problems.

- The economy and environment are interconnected

1.2.2 Natural Resources

- Materials and substances formed without human intervention

Natural resources refer to materials and substances that exist in the natural environment and are formed without human intervention. These resources come from Earth and its ecosystems. If humans cultivate or create something, such as crops grown by farmers, it is not considered a natural resource. Natural resources can be either finite or renewable. Examples of finite resources, which were formed millions of years ago, include fossil fuels, minerals, and certain landforms. On the other hand, renewable resources are replenished naturally and include sunlight, wind, and water.

1.2.2.1 Types of Natural Resources

- Resources are divided into living, non-living, replenishable, and non-replenishable

We can find different types of natural resources on Earth, and it is difficult for scientists to list them all. Instead, they categorise natural resources based on their characteristics. They are mainly divided into the following categories:

- Abiotic resources
- Biotic resources
- Renewable resources
- Non-renewable resources

Abiotic Resources

Abiotic resources are non-living natural resources that come from the Earth's physical environment. These include things like water, minerals, air, and sunlight. They do not originate from living organisms and are essential for supporting life on Earth.

Biotic Resources

Biotic resources are natural resources that come from living organisms or once-living matter. These include plants, animals, forests, and other organic materials. They play a crucial role in ecosystems and are vital for food, shelter, and various other human needs.

Renewable Resources

Renewable resources are natural resources that can be replenished or regenerated over time through natural processes. They can be used repeatedly without being permanently

depleted. Examples of renewable resources include sunlight, wind, water, and biomass.

Non-Renewable Resources

Non-renewable resources are natural resources that cannot be replenished or regenerated on a human time scale, and once they are used up, they are gone for a very long time. Examples include fossil fuels like coal, oil, natural gas, and minerals.

1.2.2.2 Problem of Natural Resources

Natural resources are being used unevenly around the world, which negatively impacts human life. Therefore, we must adopt sustainable practices to protect our planet for future generations. These practices involve balancing human needs with environmental protection. Let us discuss the importance of natural resources.

1. Unequal Consumption of Natural Resources

- Consumption of natural resources is high in developed countries

Developed countries like the USA and Europe use far more natural resources per person than developing countries like India and China. While developing countries have larger populations, the consumption of resources per person in developed countries is 50 times higher. These countries also produce most of the world's pollution, such as waste and greenhouse gases. For example, the USA has only 4% of the world's population but uses about 25% of the world's resources. Developed countries consume more food and waste a lot of food and packaging materials. The production of animal-based foods (like meat) requires much more land than growing plants, so countries with diets high in meat need more land for raising animals.

2. Pressures on Land

- Pressure on natural resources leads to their depletion

The land is an important resource used for growing food, raising animals, building industries, and creating cities. Today, the world faces problems with a large population and industrial growth. This growing population leads to the destruction of wild lands like forests and wetlands. Land is under pressure mainly due to its overuse. Scientists believe that at least 10% of the land and water in each ecosystem should be kept as wilderness to protect nature. Forests are valuable because they help maintain oxygen levels, remove carbon dioxide,

control water flow, prevent soil erosion, and provide important resources like food, fuel, timber, and medicinal plants. However, forests are disappearing quickly, and this loss has long-term consequences that are more harmful than the short-term benefits of converting forests into other uses.

3. Water Scarcity

Water scarcity is a growing issue worldwide, affecting both developed and developing countries. Water scarcity refers to the lack of sufficient available water resources to meet the demands of a population or area. India, with the largest population in the world and an agrarian economy, faces significant challenges in this regard. In the agriculture sector, which uses about 80% of the country's freshwater resources, there is a heavy reliance on irrigation. The problem is compounded not only by high consumption but also by pollution, climate change, and rapid urbanization, which worsen these conditions. A notable example is the Chennai Water Crisis of 2019. Chennai, one of India's major metropolitan cities, faced an extreme water shortage due to a severe drought. The city's four main reservoirs ran dry, leaving millions of people without access to clean drinking water. The crisis was further exacerbated by poor water management, rapid population growth, and climate change. This event highlighted the growing vulnerability of urban centres to water scarcity.

- Pollution and high consumption lead to its scarcity

4. Resource Depletion

Non-renewable resources like fossil fuels, minerals, and metals cannot be replaced within a human lifetime. Overusing these resources is causing them to run out, leading to energy shortages and economic problems. As countries, especially industrial ones, use more of these resources, they are being used up faster. This depletion also harms the environment, causing damage like habitat loss from mining and drilling and pollution that contributes to climate change. Additionally, the scarcity of these resources can raise prices and cause conflicts between countries trying to access the remaining supplies.

- Scarcity of resources leads to a rise in prices

5. Soil Degradation

Over-farming, deforestation, and the use of harmful chemicals are causing soil erosion and reducing soil fertility. As a result, the land becomes less productive, affecting agriculture and the ability to grow enough food. This leads to food insecurity and can hurt local economies that rely on farming.

6. Loss of Biodiversity

- Loss of biodiversity makes the ecosystem vulnerable

The destruction of natural habitats and pollution has caused the loss of many plant and animal species. This weakens ecosystems, making it harder for nature to provide essential services like pollination, which helps crops grow, and water filtration, which keeps water clean. The loss of biodiversity makes ecosystems less stable and more vulnerable to environmental changes.

1.2.2.3 Criteria of Natural Resource Use

When we use natural resources like water, land, or forests, it is important to follow certain guidelines to make sure we do not harm the environment or run out of these resources. We need to think about how our actions today will affect future generations. Here are the key ideas for using resources responsibly:

1. Sustainability

Sustainability means using resources in a way that meets our needs today without taking away the chance for future generations to meet their needs. We need to think about the long-term impact of our actions on the environment and resources. For example, if we cut down trees in a forest, we must make sure to plant new ones so that the forest can continue to grow and provide benefits in the future.

2. Efficiency

Efficiency means using resources wisely so that we can get the most out of them without wasting too much. This involves being smart about how we use things like water, energy, or food. When we use resources efficiently, we reduce waste and help preserve them for the future. For example, using energy-saving light bulbs or electric cars helps reduce the amount of energy we use, which helps reduce pollution and conserve resources like fossil fuels.

3. Equity

Equity means ensuring that everyone has fair access to resources and opportunities. It is about making sure that all people, regardless of their background, can access clean water, energy, education, and other important resources. For instance, it is important to make sure everyone, including poor

communities, has access to clean drinking water and energy, so that no one is left behind in using these resources.

4. Conservation

Protect nature and ecosystems so that they do not get destroyed. We need to make sure those plants, animals, and natural places are preserved for the future.

5. Consider Environmental Impact

The environmental consequences of resource extraction and use should be considered to avoid or minimise negative impacts, such as pollution, habitat destruction, and climate change. For instance, mining operations should implement measures to reduce air and water pollution and rehabilitate land after resource extraction.

6. Biodiversity Protection

- Sustainability, efficacy, and equity are the major criteria while using natural resources

The use of natural resources should consider the impact on biodiversity. Overexploitation of resources can threaten species, disrupt ecosystems, and decrease the resilience of nature. Protecting biodiversity is critical for maintaining the balance of ecosystems and their ability to provide essential services. For instance, sustainable fishing practices include setting catch limits to avoid overfishing and allowing fish populations to regenerate.

7. Integrated Approach

When using natural resources, an integrated approach means considering environmental, social, and economic factors together. This involves balancing resource extraction with protecting ecosystems and ensuring human well-being. For instance, urban planning should consider natural resources like water and land, ensuring that cities grow in a way that preserves ecosystems and provides green spaces for residents.

1.2.3 Principles of Uncertainty and Irreversibility

Environmental economics deals with the efficient management of environmental resources. Most of the policies aim to reduce pollution or mitigate climate change. However, these objectives are often not fully achieved due to the uncertainty surrounding environmental problems, which makes policy implementation more complicated.

Uncertainty refers to the lack of complete knowledge or predictability about future environmental outcomes. In environmental economics, uncertainty is a key factor because we cannot always predict how ecosystems, climate change, or human actions will evolve over time.

Types of Uncertainty

1. **Environmental Uncertainty**: Refers to the unknowns about how ecosystems, species, and environmental processes will respond to human activities. For example, we don't know the exact impact of a specific level of carbon emissions on the climate over the next 50 years.
2. **Economic Uncertainty:** Involves the unpredictability of economic outcomes. For example, how a change in environmental policy (like a carbon tax) will affect economic growth, employment, and innovation is uncertain.

- Lack of complete knowledge or predictability about future environmental outcomes

3. **Technological Uncertainty:** We do not know when or how technological advancements will occur. Will renewable energy technologies become cheaper and more efficient, or will fossil fuel use remain dominant?
4. **Policy Uncertainty:** Governments may change policies over time, leading to unpredictability. This could affect investments in renewable energy or environmental protection.

Irreversibility refers to the idea that certain environmental changes cannot be undone or reversed once they occur. Once a resource is depleted, a species is extinct, or an ecosystem is destroyed, the damage cannot be repaired.

Types of Irreversibility

1. **Ecological Irreversibility:** The destruction or damage to ecosystems or biodiversity that cannot be repaired. For example, the extinction of a species or the destruction of a coral reef.
2. **Resource Irreversibility:** Over-exploitation of natural resources (such as fossil fuels or water) may lead to their depletion. Once they are used up, they cannot be replenished within human time scales.

- Certain environmental changes cannot be undone

3. **Climate Irreversibility:** Emissions of greenhouse gases that lead to irreversible climate changes. For instance, once carbon is released into the atmosphere, it stays there for hundreds or even thousands of years, causing long-term warming and impacts.

1.2.4 Inter generational Equity and Intra generational Equity

Intergenerational equity deals with the distribution of resources and opportunities across different generations. It emphasises the need to consider and protect the interests of future generations, ensuring that they have access to the same opportunities and resources that the current generation enjoys. On the other hand, Intra generational equity refers to the fair distribution of resources and opportunities within a single generation. It aims to ensure that everyone in a society, regardless of their age, gender, race, or background, has their needs met and their rights respected. This principle focuses on equality within the current generation.

1.2.4.1 Inter generational Equity

Inter generational equity refers to fairness between generations. It emphasises the importance of ensuring that future generations have the same opportunities, resources, and well-being as the current generation. It considers sustainability and environmental justice and also ensures that the actions of today do not deplete resources or cause harm to future generations. Key principles of inter-generational equity includes the following.

1. Sustainable Resource Use

Resources such as fossil fuels, forests, and water are finite. If the current generation overuses these resources or degrades the environment without considering future generations, it could leave them with significantly fewer opportunities. Inter-generational equity requires us to manage resources sustainably, ensuring they remain available for future generations. For example, deforestation today might provide immediate economic benefits, but it can lead to a loss of biodiversity, soil erosion, and climate change, making it difficult for future generations to thrive.

2. Climate Change

- Inter-generational equity refers to fairness between generations

The current generation's activities are emitting greenhouse gases at an unprecedented rate, contributing to global warming, which could have devastating effects on future generations. Ensuring inter-generational equity involves taking immediate action to reduce emissions and transition to cleaner energy sources. An example of such action is the Paris Agreement (2015): This international treaty aims to limit global warming

to well below 2°C above pre-industrial levels, recognising the need to balance the current generation's development with the protection of future generations' well-being.

3. Protecting Ecosystems for Future Generations

In addition to resources, ecosystems also need protection for future generations. Loss of biodiversity, depletion of fish stocks, or pollution of oceans not only harms present-day society but also limits the ability of future generations to meet their needs. For instance, overfishing can deplete fish populations today, but it risks leaving future generations without an important food source. Inter-generational equity requires the current generation to regulate fishing and ensure that sustainable practices are in place.

4. Equitable Distribution of Future Benefits and Costs

- Inter-generational equity also ensures that the actions of today do not deplete resources or cause harm to future generations.

Another key principle of inter-generational equity is ensuring that future generations inherit a world that is not overburdened with debt, environmental destruction, or social inequalities. For example, excessive national debt or environmental degradation may constrain future generations' ability to improve their standard of living. The focus of inter-generational equity here is on long-term sustainability, ensuring that future generations are not unfairly burdened by today's decisions.

1.2.4.2 Intra generational Equity

Intra generational equity refers to fairness within the present generation, focusing on the equitable distribution of resources and opportunities among all individuals in that same generation. This concept emphasises that all people, regardless of age, gender, race, social status, or wealth, should have equal access to the resources, opportunities, and benefits provided by society. In essence, it represents the idea of social justice within the current generation. The main concepts of intra-generational equity are:

1. **Fair Distribution of Wealth and Resources:** Fair distribution of wealth and resources means ensuring equal access to education, healthcare, employment, and basic services like food, water, and housing. For example, in a society where a large portion of the population lacks access to quality education or healthcare, intra-generational equity demands that resources be distributed in a way that uplifts marginalised or disadvantaged communities.

2. **Eliminating Social Inequality:** Intra-generational equity is essential for addressing gender, racial, or class-based inequalities. For instance, women may not have equal access to economic resources, political power, or decision-making as men in some societies. Intra-generational equity calls for the removal of such barriers to ensure fairness and equality. For example, in India, caste-based inequality (discrimination based on caste) and gender disparities in access to education and employment opportunities can be addressed by focusing on intra-generational equity.

- Fairness within the present generation, focusing on the equitable distribution of resources

3. **Reducing Poverty and Inequality:** One of the keys aims of intra-generational equity is to address poverty and inequality. If economic growth benefits only a small portion of the population while leaving others in poverty, intra-generational equity demands the redistribution of resources to correct this imbalance.

Summarised Overview

The Material Balance Approach, developed by Alen Kneese and R.V. Ayres, helps us understand the flow of materials and energy between the economy and the environment. The model explains that the environment has an assimilation capacity, meaning it can absorb and process waste. However, if the waste produced exceeds the environment's assimilation capacity, it leads to environmental damage.

Natural resources are essential to both the economy and the environment. These resources can be finite (non-renewable) or renewable. The uneven consumption of these resources across the globe has resulted in environmental stress, particularly due to excessive use in developed nations. Key problems include land degradation, water scarcity, resource depletion, soil erosion, and the loss of biodiversity. Sustainable practices, such as efficient resource use and conservation, are necessary to ensure that resources remain available for future generations.

In environmental economics, uncertainty refers to the unpredictability of future environmental outcomes, which complicates policy-making. These uncertainties relate to environmental, economic, technological, and policy changes. Irreversibility refers to the fact that some environmental changes cannot be undone once they occur, such as species extinction or the impacts of climate change. These principles highlight the need for caution and sustainability in managing natural resources.

Equity refers to fairness in the distribution of resources. Intra-generational equity focuses on ensuring the fair distribution of resources within the current generation, addressing issues like poverty, inequality, and social injustice. Inter-generational equity, on the other hand, emphasizes the need to protect resources and opportunities for future generations, ensuring that today's actions do not harm their ability to meet their needs.

Assignments

1. Explain the Material Balance Approach.
2. Discuss the significance of natural resources for both the economy and the environment.
3. What do the concepts of uncertainty and irreversibility mean in environmental economics?
4. Explain the concepts of intra-generational equity and inter-generational equity.

Reference

1. Tietenberg, T. (2004) (6th Edition) *Environmental and Natural Resource Economics*, Pearson. Education, Delhi.
2. Jonathan M. Harris and Brian Roach (2017) *Environmental and Natural resource* Economics: A Contemporary Approach, 4th Edition, Routledge.

Suggested Reading

1. Fishes. A.C. (1981), *Resource and Environmental Economics.* Cambridge University Press, Cambridge
2. Jeroen. C.J M. van den Bergh (1999), *Handbook of Environmental and Resource Economics,* Edward Elgar Publishing Ltd., U.K.

Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

UNIT 3

Environmental Economics and Sustainability

Learning Outcomes

After completing this unit, the learner will be able to:

- understand the role of property rights in environmental protection
- analyse the concept of pollution rights
- identify the concept of spillover costs
- assess the importance of sustainability

Background

Today, we live in an era of climate change, where every day the climate situation is getting worse, leading to severe climate effects. Environmental resources, such as land, water, and forests, are being depleted, and many animals are at risk of losing their lives. To protect our environment, we must manage these resources carefully, and one way to do this is through property rights. Industrial pollution is another major issue we face today. It harms our air, water, and land, and if this continues, climate change will only get worse. Therefore, governments need to control pollution by making and enforcing laws. This is where pollution rights come in. Here, governments allow companies to pay for the right to pollute, but set limits to reduce overall pollution.

Some resources, like clean air and water, are collectively consumed by the public. Since no one controls them directly, they can easily get overused or depleted, leading to economic and environmental losses. These are called externalities. They are unseen costs or benefits that affect others, even if they are not directly involved. Understanding externalities helps us make fair decisions about who should pay for environmental damage. We must use natural resources carefully, considering their long-term impact. Sustainably using resources means making sure we do not deplete them for future generations. This helps maintain high environmental quality, which is essential for a healthy environment and good quality of life. Poor environmental quality, on the other hand, can lead to health problems and damage to the planet. Governments play a key role in creating rules and policies to protect our natural resources. Just like we keep track of money in a bank account, we should also track the health of our environment to understand its value and how our actions affect it. By doing so, we can protect the environment for future generations.

Keywords

Environmental Economics, Natural Resources, Property Rights, Collective Consumption, Sustainability, Environmental Quality, Environmental Accounting, Externalities, Spill Over Effect, Ozone layer.

Discussion

1.3.1 Environmental Economics

Environmental economics studies the economic impacts of environmental policies, focusing on issues like air pollution, water quality, waste management, and global warming. It is concerned with balancing economic growth and environmental protection. The central concept of environmental economics is market failure. Common forms of market failure include externalities, non-excludability, and non-rivalry. A market failure occurs when the free market does not allocate resources efficiently, leading to suboptimal outcomes for society. For example, businesses may not account for environmental costs (such as pollution), which harm the environment and public health. In such cases, resources can be redistributed in a way that benefits at least one person without making others worse off. Environmental economics focuses on using economic tools to address environmental problems, often emphasising market-based solutions (like pricing mechanisms) to ensure the efficient allocation of resources. In the words of D.W. Pearce, "Environmental Economics brings the discipline of economic analysis to environmental issues such as pollution, the rate of use of renewable and non-renewable natural resources, conservation of living species and resources, and the choice of policy to achieve environmental ends."

- Environmental economics focuses on the economic impacts of environmental policies

1.3.1.1 Subject Matter of Environmental Economics

Environmental economics examines different views on the relationship between economic growth, natural resource scarcity, and environmental issues. The major points covered under this heading are:

- Natural Resources Scarcity Approach
- Economic Growth and Environment
- Population Growth and Environmental Crisis
- Impact of Climate Change

1. Natural Resources Scarcity Approach

- Natural resources are finite, and overusing these resources may eventually cause them to run out

This approach states that natural resources are finite, and as the human population increases and economic activities expand, these resources may eventually run out or become harder to access. Classical economists like Malthus argued that population growth would always outpace the growth of food supply, leading to scarcity and hardship. If the population keeps increasing, economic development will slow down due to limited resources. J.S. Mill extended this idea to non-renewable mineral resources, like coal and metals, noting that as these resources are depleted, the cost of production will rise. Essentially, the scarcity of these resources would make economic progress more difficult over time. Classical economists considered the environment a free good. They assumed that resources were abundant and that the productivity of nature was limited. However, society has overused these resources, leading to environmental degradation. In Ricardo's view, as high-quality resources are exploited, the remaining resources (which are of lower quality) will become more expensive to us.

2. Economic Growth and Environment

- Economic growth activities lead to environmental degradation

Economists like Galbraith, Mishan, Boulding, Nordhaus, and Commoner have expressed concern about how economic growth leads to pollution, wasteful consumption, and environmental degradation. They argue that economic growth often results in the production of goods that do not contribute to human happiness but instead harm the environment. These economists believe we should reconsider the goals of economic growth. While growth is usually seen as good, it has caused pollution, wasted natural resources, and failed to solve important social problems. They argue that growth may not be as beneficial as it seems, especially when it harms the environment and people's well-being. E.J. Mishan in his book 'The Costs of Economic Growth', says that economic growth puts pressure on people and society, and this pressure increases over time. He believes that the idea of constant growth can cause social problems instead of providing lasting benefits. Another environmentalist, Lester Brown, emphasises that the costs of economic growth often outweigh the benefits. He points out specific negative consequences of growth, such as the rapid depletion of natural resources, urban issues like congestion and noise pollution, and rural problems like strip mining and deforestation.

3. Population Growth and Environmental Crisis

Population growth raises the environmental crisis, according to Malthus. He believed that the population increases in a geometric progression (1, 2, 4, 8, etc.), while the food supply increases in an arithmetic progression (1, 2, 3, 4, etc.). In this view, the population would eventually outgrow the ability of farmland to provide sustenance, leading to deprivation, suffering, and malnourishment. This idea is known as the Malthusian Population Trap, which suggests that population growth surpasses available resources, causing a crisis due to insufficient resources. Another perspective comes from Neo-Classical Economists. These economists extended Malthus's ideas by describing the situation as a vicious circle. They argue that rapid population growth leads to poverty and a lower status for family members, particularly women and children. The rapid increase in population causes scarcity of land and housing, forcing many people to settle in ecologically sensitive areas, and resulting in environmental damage. Additionally, the over-exploitation of natural resources (such as deforestation for farming) worsens the environmental crisis.

- Population growth leads to over-exploitation of natural resources

4. Impact of Climate Change

Economists have studied how climate change impacts various aspects of life, such as agriculture, wildlife, human life, and water resources. This analysis helps us understand the broader economic consequences of climate change and its potential to disrupt ecosystems and human activities. In short, climate change has a wide-ranging impact, and economists have explored its effects on critical environmental and societal systems.

1.3.2 Property Rights

Property rights refer to a bundle of entitlements that define the owner's rights, privileges, and limitations for the use of a resource. These legal entitlements determine what an owner can and cannot do with a resource. Property rights are essential for ensuring that resources are used efficiently and sustainably. The nature of property rights can vary in different economic systems. In a capitalist system, individuals or private entities typically own resources, meaning they have the right to use or sell them as they see fit. In contrast, in a centrally planned or socialist economy, the state (government) owns most resources, and individuals may have limited rights to use them based on government regulations. Whether property rights belong to an

- What an owner can and cannot do with a resource

individual or the government depends on the economic system in place. An efficient property rights structure has three main characteristics:

1. Exclusivity

2. Transferability

3. Enforceability

1. Exclusivity

Exclusivity means that the owner of a resource gets all the benefits and takes on all the costs associated with that resource. When the resource is used well, the owner benefits, but if it's overused or not managed properly, the owner faces the costs. Imagine you have a garden where you grow vegetables. If you take care of it take water it, remove weeds, and make sure the soil stays healthy, you get the benefit of eating the vegetables you grow. But if you ignore the garden and it gets overrun with weeds or the soil becomes unhealthy, the garden won't produce as many vegetables, and you lose out. Suppose a company owns a forest, they have to make sure they take care of it (not cut down too many trees too quickly) to ensure it can keep providing timber for many years.

- Get all the rewards or bear all the costs of using something

2. Transferability

Transferability means the owner of a resource can sell, lease, or give away their rights to the resource to someone else. This ensures that the resource goes to the person who values it the most. Let us say you own a bicycle, but you do not need it anymore. You can sell it to someone else who needs it. This is transferability. In the case of pollution, countries or companies can sell 'pollution permits.' Imagine if one company finds a way to pollute less and has extra 'permission' to pollute. They can sell that 'permission' to another company that needs it to keep producing, helping the environment by making sure the overall pollution stays low.

- You can sell or give away your rights to the resource

3. Enforceability

Enforceability in property rights refers to the ability to legally protect and defend one's rights over a resource. It ensures that the owner can take action if someone violates their rights, and it helps maintain order and accountability in the management

- Your rights to the resource are safe from being taken by others

of environmental resources. Suppose a factory is emitting pollutants beyond the legally allowed limits, local authorities or affected parties can enforce the regulation through fines or legal action. This enforces the owner's responsibility to manage pollution levels.

The lack of property rights leads to inefficiencies, meaning that some individuals or groups may take advantage of the situation and exploit these resources without regard for sustainability or fairness. For instance, people may steal intellectual property, misuse public resources, or overuse shared resources like the environment, leading to problems such as over-fishing and deforestation. The overexploitation of natural resources can result in long-term environmental damage. The lack of proper property rights gives rise to many problems, including

- **Opportunism:** Without clear property rights, people may exploit common resources. For example, it is easy to copy music or movies without paying for them, taking advantage of the lack of ownership protection.
- **Misuse of Resources:** People may misuse or harm public spaces, like littering or spilling oil in waterways, because no one owns or is responsible for maintaining these resources.
- **Over-Use:** Without ownership, resources may be overused. Examples include environmental depletion, overfishing, and traffic congestion. The absence of ownership rights leads to the exhaustion of resources, which negatively affects everyone in the long run.

- Lack of property rights leads to inefficiencies

One way to solve the problem of overusing resources is for the government to give people or groups the right to own certain resources. This means they would have control over those resources and could protect them from being misused or overused. A famous economist named Ronald Coase said that when ownership rights are clear, people are more likely to take care of the resources because they know they own them. If someone damages the resource, the owner can take legal action (like suing) to stop them or get compensated. For example, if property rights were given to things like clean air or water, the owners could protect these resources from things like pollution. They could even sue companies or individuals who pollute the environment, helping to reduce harmful activities.

- Give people the legal right to own certain resources

1.3.3 Pollution Rights

Pollution rights are permits that allow companies (like factories, power plants, or other industries) to produce a certain amount of pollution. Companies are given these rights to either keep for themselves or sell to other companies. This creates a market where pollution is managed and traded. For instance, Delhi faces severe air pollution levels, especially during the winter months. The government set up measures like the Graded Response Action Plan (GRAP) to reduce emissions from industries, vehicles, and power plants. In some cases, industries were asked to reduce their emissions, and pollution rights (like permits) were introduced to ensure that companies had an incentive to follow the rules. Additionally, industries in places like industrial zones in and around Delhi could be given limits on pollution. If they reduce their emissions, they could sell their surplus permits to other companies that are struggling to meet the standards. This market-based approach helps balance economic growth with environmental protection.

- Permission to produce a certain amount of pollution

This idea was first used in the USA in 1990, under the Clean Air Act, to help reduce the pollution caused by power stations, especially pollution like sulphur dioxide. The government set a target for how much pollution the power stations should reduce. Power stations were given a set number of pollution permits based on how much they were already polluting. They could only pollute up to the amount allowed by their permits. Now, if a power station could reduce pollution at a low cost, it could sell its extra permits to other power stations that found it more expensive to reduce pollution. This creates a market for pollution rights, which means companies can make money by selling their unused permits.

- Pollution rights first used in the USA

Pollution rights can be a good solution for controlling pollution because they work through a market-based system, providing companies with a financial incentive to reduce their pollution. Companies that can reduce their emissions at a low cost can sell any extra permits they don't use, creating a competitive market that encourages pollution reduction. Additionally, pollution rights are cheap and simple for the government to manage, as they don't need to track the exact costs each company incurs for pollution control. The government issues permits and allows companies to trade them as needed. Finally, this system can lead to lower prices for consumers. If companies make extra money by selling permits, they may

- Pollution rights work through a market-based system

pass on those savings to consumers in the form of reduced prices for goods or services.

Pollution rights can be helpful in reducing pollution, but they also come with some problems and negative effects. They are:

1. Does not Stop Pollution Completely

- Pollution rights not forcefully implemented

Pollution rights only limit how much pollution a company can produce, but they do not force companies to stop polluting altogether. As long as they have enough permits, they can keep polluting. For example, imagine a factory that makes cars. The government gives it a permit that allows it to release a certain amount of pollution. As long as the factory stays within that limit, it can continue polluting. If the factory wants to pollute more, it can buy extra pollution permits from another company that doesn't use all of theirs. This means the factory can still pollute as long as it has enough permits. So, while the factory might reduce its pollution a little to save money, it does not have to stop completely. The system does not force them to stop polluting entirely; it just limits how much they can pollute.

2. Possible Price Increases

- The cost of buying additional permits may raise the price of the product

If companies need to buy extra pollution rights to continue operating, they may raise the prices of their products or services to cover the cost of these additional permits. This can lead to higher prices for consumers. For example, let us say a power plant needs more permits to keep running, so it buys them from another company. Buying these extra permits costs money. To make up for the cost, the power plant might raise the price of electricity. As a result, consumers would end up paying higher electricity bills. So, the pollution rights could cause prices to go up for consumers, making everyday goods and services more expensive.

3. Reward the Biggest Polluters

In some cases, the pollution rights system can reward the companies that pollute the most. For example, companies that have been polluting for a long time might receive more permits based on their current pollution levels, even though they are causing the most harm to the environment. Let us say Company 'A' has been polluting a lot, but the government gives it pollution permits based on how much it is polluting right now. Because Company A has polluted a lot in the past, it

receives more permits to pollute. Now, Company B, which has been polluting less, gets fewer permits. But because Company A has so many extra permits, it can sell its unused permits to Company B. So, even though Company A is the worst polluter, it can still make money by selling its extra pollution rights. This means that companies that pollute the most get more permits to sell, which can be unfair, because they are the ones causing the most damage to the environment.

- More polluting companies receive more permits to pollute

1.3.4 Collectively Consumed Goods and Services

Collective consumption refers to the goods and services that are shared by many people at the same time. The key characteristic of collective consumption is that everyone benefits from these goods or services, regardless of whether they contribute financially or not. These services often involve state intervention, regulation, or direct provision because they impact social equality or are difficult to manage privately. Examples include:

- Public housing: The government provides homes for those who cannot afford them, with costs often partially subsidised by taxes.
- Public transport: Like buses or trains, where everyone uses the service and the costs are shared by taxpayers.
- Healthcare and education: These are essential services that the state often provides, making them available to everyone, particularly those who cannot afford private alternatives.

- Consumption of goods and services that are shared by many people at the same time

In collective consumption, the state plays an important role because these services often need to be subsidised, regulated, or directly managed to ensure equal access for all citizens. The key characteristics of collective consumption are described in more detail below.

1. Non-excludable

No excludability means that once a good or service is made available, it is nearly impossible to exclude people from using it, even if they haven't paid for it. For instance, a public park is a great example of a non-excludable good. Anyone can enter and use the park, regardless of whether they contribute financially (like paying taxes) toward its maintenance or not. Similarly, things like clean air and street lighting are also non-excludable. Once they are provided, they are available to everyone.

- People cannot be excluded from the consumption of goods

2. Non-rivalrous

- The amount of consumption cannot be reduced by others

Nonrivalrous means that one person's use or consumption of a good or service does not reduce the availability of that good or service for others. For instance, public television broadcasts are non-rivalrous. If one person is watching a program, it does not prevent someone else from watching the same program at the same time. Similarly, things like public roads (not congested) and street lighting is non-rivalrous; one person's use of the road or light does not affect another person's ability to use it.

While collectively consumed goods and services offer many benefits, such as greater social equality and accessibility, there are also some demerits or challenges associated with them. These include:

1. Free Rider Problem

- People get benefits from these goods or services without paying for it

Since collectively consumed goods are non-excludable, the free-rider problem arises. This means that people can benefit from these goods or services without directly contributing to their cost, such as through taxes or other means. For example, public transportation is a collectively consumed good. People can use the service (like buses or trains) without necessarily paying taxes that help fund the transportation system. As a result, some people get the benefits of the service without contributing financially to it. These people are called free riders. This free-rider problem can lead to inefficiencies. Since individuals do not have to pay directly for the service, they have less incentive to help maintain or improve the system. Over time, this could lead to underfunding of important services like public transportation, making them worse for everyone. People paying taxes end up shouldering a bigger share of the costs, which can feel unfair.

2. Overconsumption and Congestion

- Overconsumption leads to the depletion of resources

Since collectively consumed goods are often non-rivalrous, many people can use them without directly affecting others' ability to do the same. However, when too many people use the service or goods, it can lead to overconsumption and congestion. For example, public transportation systems can become overcrowded, or public parks can be overused, which reduces the overall experience for everyone. When too many people use these services at once, the quality of the service goes down, and it becomes less enjoyable or efficient. If

overconsumption is not properly managed, it may put a strain on the system, requiring higher taxes or fees to maintain or improve the service. This could unfairly burden the population, especially those who rely on these services the most.

3. Inefficiency in Provision

The public sector's provision of goods and services can sometimes be less efficient than the private sector. This is because of bureaucratic processes, lack of competition, and sometimes government inefficiencies. For example, public education or healthcare systems, although providing universal access to everyone, might not always offer the same level of quality or efficiency as private alternatives, especially if the funding is insufficient or not properly managed. This inefficiency can result in poor service quality, delays, and less innovation. In comparison, privately funded services benefit from market competition, which can encourage constant improvements to meet customer demands.

- Public efficiency is less than the private

4. Lack of Personal Choice and Customisation

When goods and services are provided collectively, they are usually designed to meet the needs of the general population, which means they may not consider individual preferences or specific needs. For example, in public healthcare systems, people might have limited choices when it comes to selecting their healthcare providers or treatment options. This contrasts with private systems, where individuals can choose based on their own personal preferences or specific needs. The lack of customisation in public services can lead to dissatisfaction, especially for people who have unique needs or preferences. Public services may struggle to cater to niche demands or offer the personalised experience that private providers can.

- Public goods may not consider individual preferences

5. Inequality in Access and Quality

Although the goal of collective consumption is to make goods and services available to everyone, there can still be disparities in access or quality, especially in larger or more economically diverse societies. For example, public schools are meant to be available to all children, but the quality of education can vary widely depending on the region, city, or neighbourhood. This often reflects local wealth and the amount of funding available, with wealthier areas being able to provide better resources and facilities. The implication is that while these services are

- Collective consumption raises the problem of inequality and quality

supposed to be available for all, some communities end up with higher-quality services than others. This creates inequalities in the benefits people receive from collectively consumed goods, even though the aim is universal access.

1.3.5 Sustainability

- Meeting the needs of the present without compromising the ability of future generations

The concept of sustainability is centred around the idea of meeting the needs of the present without compromising the ability of future generations to meet their own needs. This idea, was most notably defined by the UN World Commission on Environment and Development as: 'sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' Sustainability focuses on balancing three main pillars: economic, environmental, and social, also known informally as profits, planet, and people.

1. Environmental Dimension

- The environmental dimension ensures the safeguarding of natural resources and ecological integrity

The environmental dimension of sustainability focuses on safeguarding natural resources and ensuring ecological integrity. Key concerns under this dimension include climate change, biodiversity loss, pollution, and ecosystem degradation. Awareness around environmental issues began to grow in the 1960s and 1970s, especially with the rise of concerns such as pollution, deforestation, and the depletion of natural resources. The Brundtland Report of 1987 emphasized that environmental protection and development are inseparable, calling for a development path that sustains both human progress and the planet's health. Protecting natural ecosystems and reducing environmental harm are essential for ensuring a sustainable future for all.

2. Economic Dimension

- The economic dimension focuses on balancing economic growth with environmental protection

The economic dimension of sustainability is centred on balancing economic growth with environmental protection. While economic development can improve social welfare, such as reducing hunger and poverty, it can also contribute to environmental degradation if not managed sustainably. The challenge lies in decoupling economic growth from environmental harm. This requires finding ways to foster economic development while minimising negative impacts on the environment. The Brundtland Report highlighted the

interconnectedness of poverty and environmental degradation, underscoring that sustainable economic development is critical for both developing and industrialised nations. Achieving this balance is vital to ensuring long-term economic prosperity without compromising the planet's resources.

3. Social Dimension

- Social Dimension ensuring equity between the rich and the poor

Social sustainability aims to ensure that individuals and communities have access to essential needs and opportunities for health, education, and participation in society. While less clearly defined than the environmental and economic dimensions, social sustainability is grounded in principles of fairness, equality, human rights, and empowerment. A key component of social sustainability is social justice, ensuring equity between rich and poor, both within and between nations. Additionally, it stresses intergenerational equity, which means making sure future generations have access to the same opportunities and resources. For Indigenous communities, sustainability often extends beyond these dimensions, emphasising spiritual values, community-based governance, and a deep connection to place. The goal of social sustainability is to create communities where people can thrive in a fair, inclusive, and just society.

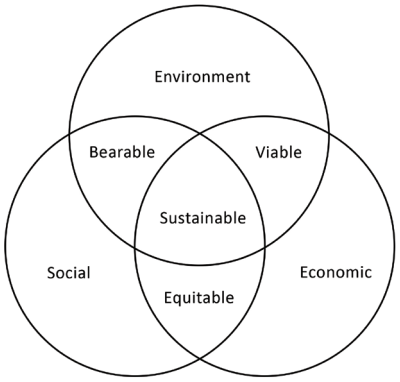

Fig.1.3.1 Environmental and Economic Dimensions of Sustainability

- Weak sustainability suggests that human-made capital can replace natural capital

The relationship between the environmental and economic dimensions of sustainability is a subject of ongoing debate. In academic circles, this relationship is often explored through the concepts of weak and strong sustainability. Weak sustainability suggests that human-made capital, such as technology and infrastructure, can replace natural capital, or the environmental resources that support life. For instance, technologies that reduce pollution or increase resource efficiency might be seen as ways to offset the environmental damage caused by economic growth.

- Strong sustainability suggests that human-made capital cannot replace natural capital

On the other hand, strong sustainability posits that nature provides essential services and functions that technology cannot replace. These services, such as biodiversity, pollination, fertile soils, clean air, clean water, and climate regulation, are fundamental to life on Earth. Without these natural systems, it would be impossible to maintain the planet's ecological balance, and their loss could be irreversible. Therefore, strong sustainability emphasises the preservation of ecological integrity above economic gains.

Weak sustainability, while popular in policy and business circles, has faced criticism for failing to ensure the long-term protection of the environment. In particular, it has been criticised for neglecting the fundamental role nature plays in supporting economic systems. In 2020, the World Economic Forum highlighted that $44 trillion of global economic value, more than half of the world's GDP, depends on nature. Loss of natural resources, such as deforestation or climate change, directly threatens this economic value. Key sectors, including construction, agriculture, and food production, are especially vulnerable to environmental degradation.

Trade-offs

Balancing the three dimensions of sustainability viz,environmental, social, and economic often involves trade-offs. These trade-offs arise because each dimension can sometimes conflict with the others. For example, economic growth may lead to environmental degradation, or efforts to protect the environment might limit economic development. The challenge lies in finding ways to integrate, balance, and reconcile these dimensions effectively.

- Trade-off relation between the economic, social, and environmental dimensions

Some critics argue that the United Nations Sustainable Development Goals (SDGs) are unrealistic because they aim for universal human well-being while ignoring the physical limits of Earth's ecosystems. The fundamental conflict between human desires for prosperity and the finite capacity of the planet poses a significant challenge to achieving truly sustainable development. Balancing these competing priorities requires careful consideration of ecological integrity, social justice, and long-term economic viability.

1.3.6 Biodiversity

Biodiversity refers to the variety and abundance of living organisms found in a particular geographical area. This

includes different species of plants, animals, microorganisms, the genetic variation they possess, and the ecosystems they create. It encompasses the diversity within and between species, as well as the diversity across the ecosystems they inhabit.

1.3.6.1 Importance of Biodiversity

Biodiversity has significantly contributed to the development of human culture, and in return, human communities have played a crucial role in shaping biodiversity at the genetic, species, and ecological levels. Biodiversity is essential in several ways as follows.

1. Ecological Role

- Biodiversity plays important role in preserving ecosystem and food web, protecting from climate change

Different species perform a variety of functions in ecosystems. Each organism not only meets its own needs but also contributes to the overall health of the environment. Species capture, store, and utilise energy, produce and decompose organic matter, participate in water and nutrient cycles, fix gases in the atmosphere, and help regulate the climate. These functions contribute to soil formation, pollution reduction, and the protection of land, water, and air resources. Therefore, biodiversity is vital for maintaining ecosystem functions and stability.

2. Food Web Maintenance

Biodiversity helps sustain food webs. The greater the diversity in an ecosystem, the more complex the food webs become, offering many food sources for different species. This leads to greater species survival and results in more stable food chains and ecosystems.

3. Scientific Role

Biodiversity is essential for scientific research, education, and monitoring. It facilitates the discovery of new genetic materials through gene pools and aids in understanding the functioning of life and the role each species plays in sustaining ecosystems, which includes humans.

4. Ecosystem Services: Biodiversity is the foundation of all ecosystem services on Earth.

- **Provisioning Services:** Biodiversity provides essential resources such as food (cereals, fish), fibers for clothing

(cotton, wool), fuelwood, and medicinal products (like neem and tulsi).

- **Regulating Services:** Biodiversity helps regulate both local and global climates, manage levels of gases like oxygen and carbon dioxide, maintain freshwater quality by slowing runoff, and act as carbon sinks, absorbing carbon from the atmosphere. In this way, biodiversity plays a crucial role in regulating life processes on Earth.
- **Supporting Services:** Biodiversity supports vital processes like pollination, nutrient cycling, and greenhouse gas reduction through carbon sequestration.
- **Social and Cultural Services:** Biodiversity provides aesthetic value, recreational opportunities, and inspiration for art and design. It encourages tourism, especially ecotourism, and many cultures have evolved in harmony with the biologically diverse environments around them, highlighting its social importance. Some notable services provided by biodiversity include recreation and relaxation, tourism, and spiritual experiences.

- Ecosystem Services - Provisioning, Regulating, Supporting , Social and Cultural Service

5. Protecting from Climate Change

- **Ecosystem Resilience:** Biodiversity helps maintain ecosystem resilience, especially during extreme weather events like storms, floods, and sea level rise. Ecosystems with a variety of species that perform similar functions are more resilient to environmental changes.
- **Natural Hazard Mitigation:** Biodiversity contributes to protecting ecosystems from natural disasters. For example, mangrove forests act as natural barriers against tsunamis and provide livelihoods to communities, but they are at risk due to rising sea levels.
- **Marine Ecosystems:** Coral reefs are also vulnerable to climate change, especially with rising sea temperatures. Coral bleaching and death can affect marine life and fisheries. Additionally, increased sea surface temperatures can reduce fish productivity, impacting marine ecosystems.
- **Freshwater Resources:** Climate change is expected to affect freshwater ecosystems through changes in flow regimes and temperature, which can disrupt the balance between human use of water resources (like hydropower generation) and maintaining ecological functions.

1.3.6.2 Biodiversity Loss

Biodiversity loss refers to the rapid and ongoing decline in the variety of life forms on Earth. It includes the extinction of species and the reduction in genetic, species, and ecosystem diversity. This loss is primarily driven by human activities. The major causes of biodiversity loss are :

1.Habitat Loss and Fragmentation

- Natural habitats are being destroyed or broken into smaller patches

Natural habitats are being destroyed or broken into smaller patches due to activities like agriculture, urbanization, infrastructure development, and mining. In the Western Ghats, large-scale deforestation for tea and coffee plantations, along with expanding human settlements, has fragmented critical forest areas. This fragmentation poses a serious threat to species like the Lion-tailed macaque, which depend on continuous forest canopy for their survival. Similarly, in the Sundarbans, mangrove forests are rapidly declining due to aquaculture, rising sea levels, and human encroachment. This degradation endangers the iconic Bengal tiger and disturbs the delicate balance of the estuarine ecosystem, which supports a wide variety of biodiversity. These examples highlight how habitat loss and fragmentation are major drivers of biodiversity decline in India.

2.Over-exploitation

- The excessive harvesting of natural resources beyond sustainable levels

Over-exploitation refers to the excessive harvesting of natural resources beyond sustainable levels, leading to the depletion of species and ecosystems. In India, overfishing in coastal waters has caused a significant decline in fish stocks, particularly affecting species like Hilsa in the Ganges delta, which are vital to local fishing communities. Similarly, the over-exploitation of sandalwood trees in Karnataka and Tamil Nadu, prized for their fragrant wood, has led to a dramatic decrease in their population, pushing them towards scarcity and endangerment. Additionally, the excessive harvesting of medicinal plants like Nardostachys jatamansi (Jatamansi) in the Himalayan region has placed pressure on this valuable species, pushing it towards the brink of extinction. These examples highlight the destructive impact of over-exploitation on India's biodiversity.

3. Invasive Alien Species

Invasive alien species are non-native species introduced into new ecosystems, where they spread aggressively, outcompete, or harm native species. In India, one such invasive species is

- Non-native species introduced into new ecosystems

Lantana camara, a thorny shrub from South America that has spread across forests in central and southern India, suppressing the growth of native plants and disrupting local ecosystems. Another example is Eichhornia crassipes (water hyacinth), which clogs water bodies like lakes and rivers, reducing oxygen levels and severely harming aquatic life. Additionally, the Clarias gariepinus (African catfish), which was illegally introduced for aquaculture, preys on native fish species and threatens the biodiversity of Indian rivers. These invasive species highlight the serious ecological challenges faced by India due to the introduction of non-native organisms.

4. Co-extinctions

- Extinction of one species leads to the disappearance of other species that depend on it for food, habitat, or pollination

Co-extinctions occur when the extinction of one species leads to the disappearance of other species that depend on it for food, habitat, or pollination. In India, the extinction of large mammals like tigers can disrupt the food web, affecting not only the prey species that are part of the tiger's diet but also scavengers that depend on the remains of the tiger's kills. These examples demonstrate how the loss of one species can have far-reaching consequences for an entire ecosystem. occur when the extinction of one species leads to the disappearance of other species that depend on it for food, habitat, or pollination.

1.3.7 Ozone Layer Depletion

- The ozone layer is a high concentration of ozone (O_3) molecules

The ozone layer is a region of Earth's atmosphere, located about 15 to 35 kilometres above the surface, where there is a high concentration of ozone (O_3) molecules. The ozone layer is very important because it helps protect life on Earth by blocking harmful types of solar radiation, particularly ultraviolet (UV) radiation, which can damage living organisms. Since the 1970s, human activities, particularly the use of chemicals called chlorofluorocarbons (CFCs) and other halocarbons, have caused damage to the ozone layer. When these chemicals reach the stratosphere, they break down ozone molecules by releasing chlorine and bromine, which strip away ozone. This depletion of ozone has led to the formation of ozone holes, especially over the poles (Antarctica and the Arctic), where ozone levels drop drastically, particularly during the spring.

The destruction of the ozone layer is mainly caused by chlorofluorocarbons (CFCs), which are chemicals commonly found in products like aerosol cans, air conditioners, and refrigerators. These chemicals contain chlorine, and when

- Chlorine atoms can destroy ozone molecules

released into the atmosphere, they can cause serious damage to the ozone layer. In the stratosphere, CFCs are broken down by ultraviolet (UV) rays from the Sun, releasing chlorine atoms. These chlorine atoms then react with ozone molecules (O_3), breaking them apart and reducing the amount of ozone in the atmosphere. A single chlorine atom can destroy thousands of ozone molecules, leading to the creation of the ozone hole, especially over Antarctica. This has been a growing problem since the 1970s and continues to be a major environmental issue.

CFCs are particularly harmful because they are very stable and can stay in the atmosphere for 20 to 120 years, meaning they continue to damage the ozone layer for a long time. While the ozone layer can repair itself naturally, this process has been slowed by the on-going use of CFCs. However, the Montreal Protocol, an international treaty signed in 1987, successfully reduced the use of CFCs and other ozone-depleting chemicals, leading to signs of recovery in the ozone layer, particularly over Antarctica. Despite these positive changes, there are concerns that ozone depletion could spread to other parts of the world if CFC emissions are not fully controlled.

The depletion of the ozone layer has several harmful effects on both humans and the environment. When the ozone layer becomes thinner, more harmful ultraviolet (UV) rays from the Sun can reach Earth's surface. These UV rays can cause serious health issues like skin cancer and skin irritation, which in some cases can be fatal. Even a small decrease in the ozone layer, like 1%, can lead to a 5% increase in skin cancer cases. UV rays also affect the eyes, increasing the risk of cataracts, which can lead to vision problems or even blindness.

The damage to the ozone layer also impacts the environment. UV rays can harm aquatic plants and animals, as they can penetrate through water and kill small marine life. If the ozone hole keeps growing, it could lead to a decrease in plant life, which would affect the food supply for the entire planet. Some animals have been found to suffer from sunburn due to increased UV exposure, and certain crops that rely on specific bacteria could also be harmed. However, there's also a positive side, the increased UV light helps animals produce more vitamin D, which is essential for their health.

Governments around the world have been working to reduce the use of harmful chemicals like CFCs, which were primarily

- Depletion of the ozone layer has several harmful effects on both humans and the environment

- Montreal Protocol is an international treaty designed to protect the ozone layer

responsible for ozone depletion. Bans on CFCs, especially in aerosol cans and electrical appliances, have been put in place. These efforts have been successful, and the ozone layer has started to recover. Still, there is more work to be done to reduce dangerous emissions and protect the ozone layer in the long run.

1.3.7.1 Protective Measures

1. **Montreal Protocol:** The Montreal Protocol is an international treaty designed to protect the ozone layer by phasing out the use of ozone-depleting substances (ODS). Signed in 1987, the protocol has been successful in reducing the production and consumption of CFCs and other harmful chemicals. As a result, the ozone layer is showing signs of recovery, and scientists predict that it will return to pre-1980 levels by the middle of this century.
2. **Ban on CFCs and Other ODS:** One of the most significant protective measures has been the global ban on the production and use of CFCs, halons, and other ozone-depleting chemicals. These chemicals have been replaced by safer alternatives such as hydro chlorofluorocarbons (HCFCs) and hydro fluorocarbons (HFCs), though the latter are also being phased out due to their global warming potential.
3. **Promoting Awareness and Education:** Public awareness and education campaigns are crucial for informing people about the importance of the ozone layer and encouraging environmentally friendly practices. For example, avoiding the use of products containing CFCs, using energy-efficient appliances, and encouraging the adoption of sustainable technologies can help protect the ozone layer.
4. **Regulating and Monitoring Chemical Use:** Governments worldwide are enforcing stricter regulations on the production and use of ozone-depleting chemicals. International agencies, such as the United Nations Environment Programme (UNEP), closely monitor global efforts to protect the ozone layer and ensure compliance with international agreements.
5. **Innovation in Technology:** Advancements in technology, such as the development of more efficient and ozone-friendly refrigerants, are playing a key role in reducing ozone depletion. Additionally, innovations

in solar energy, sustainable agriculture, and eco-friendly manufacturing processes contribute to reducing the overall environmental impact.

1.3.8 Environmental Quality

Environmental quality is a measure of how healthy and clean the environment is. It looks at both the natural environment (like air, water, and land) and how it affects the health and well-being of humans, animals, and plants living in it. A healthy environment supports plants and animals, providing them with what they need to survive. It also impacts the health, comfort, and emotions of humans who live in it.

1.3.8.1 Why Protect Environmental Quality

Protecting environmental quality is important for a wide range of reasons, all of which contribute to the well-being of both humans and the planet. Let us discuss the importance of protecting environmental quality one by one:

1. Clean air, water, and soil are essential for people to stay healthy. They help build a healthy community where everyone can thrive.
2. A clean and attractive environment makes life more enjoyable. Having access to beautiful, green spaces for recreation can reduce stress and foster stronger social connections, improving overall community well-being.
3. A community that cares about its environment will attract eco-conscious businesses. These "green" businesses not only contribute to a cleaner environment but also help sustain the local economy by creating jobs and opportunities.
4. Poor environmental decisions, like destroying wetlands or cutting down forests, can increase the risk of natural disasters, such as floods or mudslides. These events can cause significant harm to communities, both in terms of loss of life and property.
5. For protecting Ecosystems. Ecosystems are complex systems where plants, animals, resources, and climate interact. Disrupting ecosystems can have unpredictable consequences, like global warming, the loss of species, and environmental imbalances. For example, global warming has led to the decline of frog populations, which has wide-reaching effects on other species in the ecosystem.
6. Protecting environmental quality is crucial for preserving

- Environmental quality is a measure of how healthy and clean the environment is

- Environmental quality enhances and supports plants and animals, providing them with what they need to survive

the habitats of endangered animals and plants. By maintaining healthy ecosystems, we help protect species that are at risk of disappearing.

7. Living in a community that is both beautiful and well-maintained can increase pride and give residents a sense of ownership. This pride can encourage people to care for their surroundings, both physically and socially, making the community a better place.

1.3.8.2 When Should You Protect Environmental Quality

Environmental quality should be protected all the time, but it's especially important when the environment is threatened, during new developments, in times of crisis, or when the public is paying attention. Some situations are given below:

1. If important areas, like green spaces or wetlands, are at risk of being destroyed or polluted, it is time to act and show the potential consequences of ignoring environmental concerns.
2. If a new development is happening, it's a great opportunity to make sure environmental protection is part of the planning from the start.
3. Whether it is a new commercial, industrial, or housing development, developers can be encouraged through incentives or regulations to use eco-friendly practices in the construction process.
4. When major environmental problems, like water shortages, air pollution, or extreme weather events, occur, people are more likely to pay attention and take action on environmental quality issues.

- Environmental quality should be protected to avoid the threat of environmental disasters

1.3.8.3 Who Should Protect Environmental Quality

Protecting environmental quality is a responsibility that involves many different groups of people. Government officials play a crucial role through policies and regulations, while environmental organisations work to raise awareness and lead advocacy efforts. Community activists and individuals directly impacted by environmental issues, such as farmers or fishermen, also have a vested interest in ensuring that the environment remains healthy. Environmental professionals,

- The collective responsibility of society is to protect environmental quality

including scientists and biologists, provide vital knowledge and expertise, while outdoor enthusiasts, like hikers and birdwatchers, are often passionate about preserving natural spaces. Architects and green developers lead the way in creating sustainable buildings and communities. Businesses, especially those that prioritize environmental responsibility, can be strong allies in promoting environmental quality. Ultimately, everyone, from individuals to large corporations, has a role to play in protecting the environment, as clean air, water, and natural resources are essential to everyone's well-being.

1.3.9 Environmental Accounting

Environmental accounts are a statistical method used to collect and organise information about the environment and the economy in one system. They help measure how the environment contributes to the economy and how the economy impacts the environment. Environmental accounting combines economic data with environmental data, allowing us to better understand the effects of the economy on the environment and the pressures the economy puts on natural resources. These accounts help answer questions such as which industries are responsible for the most pollution, how our patterns of consumption and production affect the environment, and how policies like environmental taxes influence waste or air pollution. They also show how the "environmental economy" (industries and sectors related to protecting or managing the environment) is growing compared to the overall economy.

- It is a collection of environmental data

Environmental accounting organises information clearly and consistently. It brings together details about natural resources such as water, minerals, and land, and human activities like production, consumption, pollution, and waste. This structure allows for easy comparison of different types of information, helping to create accurate estimates and a better understanding of the relationship between the economy and the environment. The system organizes this data into tables and accounts, making it easier to identify trends and indicators across various environmental and economic issues. By using existing data and reformatting it into this integrated framework, environmental accounting provides a coherent view of the impact of human activities on the environment and how environmental factors influence the economy.

- Organises information in a clear and consistent way

1.3.9.1 Importance of Environmental Accounting

As environmental awareness grows globally, environmental accounting has become essential for businesses, helping them track, manage, and reduce their environmental impact. Here are the key reasons why it is important:

1. Growing Environmental Awareness

Public concern about environmental issues is increasing. In response, companies are recognizing the need to monitor their environmental impact and take responsibility for it.

2. Reducing Environmental Costs

By measuring the environmental costs of their activities, companies can identify areas where they can reduce waste, pollution, and resource use, resulting in both cost savings and environmental benefits.

3. Meeting Government Regulations

Environmental regulations are becoming more stringent. Environmental accounting helps businesses comply with laws and avoid penalties by providing accurate data on their environmental performance.

- Environmental accounting tracks the environmental impact due to the firm's activities

4. Enhancing Corporate Reputation

Consumers increasingly prefer environmentally responsible companies. A strong sustainability record can improve brand image, increase customer loyalty, and provide a competitive advantage.

5. Assessing and Managing Environmental Risks

Environmental accounting enables businesses to identify potential environmental risks, such as pollution or resource shortages, and take proactive steps to minimize them.

6. Improving Resource Efficiency

By analysing how resources like energy and water are used, businesses can find ways to reduce consumption, save costs, and operate more sustainably.

7. Encouraging Innovation

Tracking environmental impacts often leads to the development of new, greener technologies and processes, driving innovation and long-term competitiveness.

1.3.9.3 Types of Accounts

1.Physical Environmental Accounting

- Physical Environmental Accounting focuses on the quantitative aspects of environmental resources.

Physical Environmental Accounting focuses on the quantitative aspects of environmental resources. The goal is to track and report the physical flows of natural resources and their impacts on the environment. For example, when we monitor the amount of water used in a manufacturing process, measure the emissions of CO_2 produced by an industrial operation, and track how much raw material is consumed and how much waste is generated. The benefits of this accounting are that it helps companies identify areas where resource consumption can be reduced and provides data for sustainability reports and environmental regulations.

2. Natural Resource Accounting

- Natural Resource Accounting focuses on assessing the value of natural resources

Natural Resource Accounting focuses on assessing the value of natural resources and tracking their depletion or degradation over time. For example, estimating the economic value of forests or fisheries and accounting for the depletion of these resources over time, and monitoring the reduction in biodiversity or the degradation of ecosystems due to human activity. The benefits of this accounting are that it helps governments and businesses understand the value of natural capital and make decisions that protect it. It ensures that the depletion of natural resources is factored into economic planning and policy-making, and encourages sustainable practices by accounting for the long-term costs of resource depletion.

3. Environmental Cost Accounting

- Environmental cost accounting focuses on identifying, analysing, and reporting the costs

Environmental cost accounting focuses on identifying, analysing, and reporting the costs associated with environmental impacts and activities. For example, it includes accounting for the cost of treating wastewater or air pollution, and identifying hidden costs caused by inefficiencies, such as excessive water or energy use. The benefits of this type of accounting include identifying ways to reduce environmental costs, demonstrating how pollution and waste affect company expenses, and supporting environmentally friendly and cost-saving decisions.

Environmental accounting plays a crucial role in policy development and evaluation. It helps in formulating clear

- Environmental accounting helps in formulating clear and effective policy frameworks

and effective policy frameworks by organizing information into coherent indicators and aggregates that address the relationship between the economy and the environment. This solid foundation allows policymakers to make informed decisions. Additionally, environmental accounts help evaluate the effectiveness of current policies and also provide insights into how various policy choices impact both the economy and the environment. This can guide future policy decisions to promote sustainable growth.

1.3.10 Externalities

- Economic activities create externalities

Adam Smith introduced the concept of the invisible hand. The invisible hand idea states that if everyone does what's best for them, it will lead to a good outcome for society as a whole, without anyone needing to plan or organise it. For example, if businesses try to make good products that people want, they will make money. This motivates them to work harder, which benefits customers who get better products. However, sometimes this idea does not always work. When people do things that are best for them, it can have either good or bad effects on other people, and those other people do not have a say or control over what happens to them. In this case, externalities occur. Externality refers to when one person's or firm's action affects others who are not directly involved in the action. The effects of externalities can be divided into positive and negative externalities. All economic activities create both negative and positive externalities.

1.3.10.1 Positive Externalities

- Someone's action benefits others without them paying for it

Positive externalities occur when someone's action benefits others without them paying for it. For example, if a company builds a park in a neighbourhood, not only do the people who use the park benefit, but the surrounding community also enjoys cleaner air and a more attractive environment without having to contribute to the cost of the park's creation. In the case of positive externalities, social benefits are greater than private benefits. Social benefits refer to the total benefits that society gains from an activity or decision. This includes both private benefits and external benefits. Private benefits refer to the direct benefits received by individuals or firms involved in the activity, while external benefits refer to the positive effects that affect others who are not directly involved in the activity.

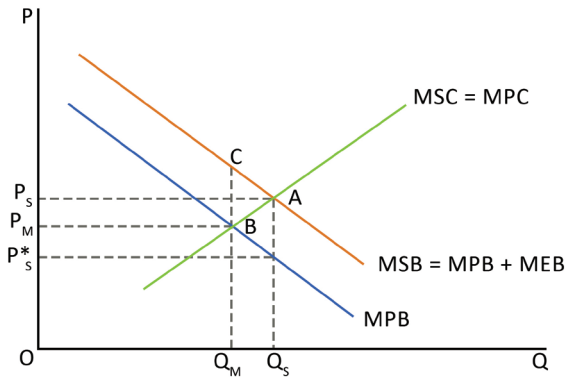

Fig.1.3.2 The Case of Positive Exteranalities with Production

The X-axis represents the quantity of the good or service (in this case, the use of the park). The Y-axis represents the price or marginal benefit/cost. In the figure, the MPB is the Marginal Private Benefit, which denotes the benefit to the people who use the park directly. The MPB curve slopes downward, reflecting the diminishing benefit to users as the quantity of park use increases. The MSB is the Marginal Social Benefit. This represents the total benefit to society from the park, including both the private benefits (MPB) to park users and the external benefits (MEB) to the surrounding community. The MSB curve is parallel and above the MPB because it includes the MEB. MEB denotes the additional benefits that the rest of the community gets from the park, even though they don't directly use it.

The MPC (Marginal Private Cost) is the cost the company or developer incurs when building and maintaining the park. At Point QS, the quantity is consumed at PS price. Point A, where MSB = MSC, is the efficient point. At this point, MSB is greater than MPB, reflecting the full benefits to society. Point B represents the market equilibrium at QM and PM, where MPB = MPC. This is the point that would occur in a competitive market without accounting for the external benefits of the park. At Point C, the deadweight loss triangle is denoted. Deadweight loss is the loss of societal benefit because the market produces too little of the good (the park) compared to what would be optimal for society.

1.3.10.2 Negative Externality

Negative externalities occur when an activity harms others who

are not part of the activity. For example, during production, the factory releases harmful pollutants into the air and water, such as chemical waste or carbon emissions. These pollutants affect the people living in the surrounding area. In this case Social costs is greater than private cost.

- Economic activity harms others who are not part of the activity

Social cost refers to the total cost to society of producing a good or service. It includes both the private cost and the external cost. The private cost is borne by the producer, such as wages, materials, and other production costs and the external costs or negative externalities is that affect third parties who are not directly involved in the production or consumption of the good. Let us explain with the help of figures.

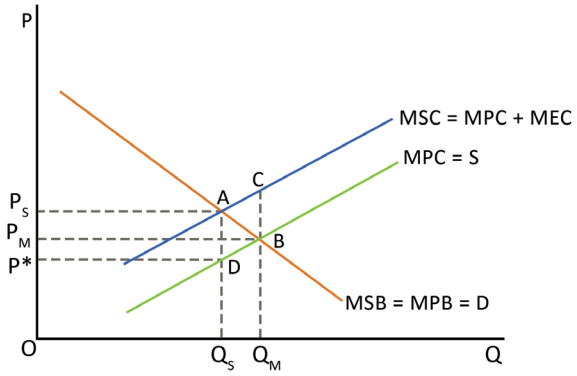

Fig.1.3.3 The Case of Negative Exteranalities with Production

- Negative externalities occur when an activity harms others who are not part of the activity

The X-axis represents the amount of the good being produced or consumed, while the Y-axis shows the price of the good, or the marginal benefit or marginal cost at different levels of quantity. At point A, where MSC = MSB, the amount of sugar produced and the price is socially efficient. This represents the efficient quantity (Q_S) and price (P_S). Point B represents Market Equilibrium without Externalities. Here, MPB = MPC, meaning the sugar factory produces at Q_M and sells sugar at PM, ignoring the harm caused by pollution and the negative externalities. At point C, a triangle ΔABC is formed. This triangle represents Deadweight Loss, which results from overproduction due to negative externalities (pollution). The area ABC shows the lost societal benefit because the market is producing too much sugar (at Q_M) instead of the socially optimal quantity (at Q_S). Point D, represents the point where MSC and MPC intersect in the presence of externalities. This shows how the market should ideally adjust to reflect both private and social costs, reducing overproduction and moving towards the socially efficient quantity.

1.3.12 Spillover Effect

The spillover effect, also known as an externality, refers to the unintended consequences of an action that affect third parties who are not directly involved in the activity. These effects can be either positive or negative and can have significant impacts on the environment, society, and economy. They are:

1. Positive Spillover effect
2. Negative Spillover effect

1.3.12.1 Positive Spillover Effects

Positive spillovers occur when an action benefits others who are not involved in the activity. For example:

- An action benefits others who are not involved in the activity

- **Education:** When one person gets an education, society benefits because educated individuals often contribute more to the economy, improve public health, and raise awareness about important issues like climate change.
- **Public Parks**: A park built in a neighbourhood can improve the quality of life for the surrounding community, providing cleaner air, more recreational spaces, and higher property values, even if only a few people directly use the park.

1.3.12.2 Negative Spillover Effects

Negative spillovers happen when an activity imposes costs on others who are not part of the decision-making process. Examples include:

- An activity imposes costs on others who are not part of the decision-making process.

- **Pollution:** When a factory emits pollutants into the air or water, it can negatively affect the health and well-being of nearby residents or ecosystems, even though they are not involved in the production process.
- **Traffic Congestion:** A new highway or infrastructure project might lead to increased traffic in neighbouring areas, creating noise, air pollution, and accidents, affecting the quality of life for those living nearby.

Summarised Overview

Environmental economics explores the economic effects of environmental policies, focusing on issues like pollution, resource management, and sustainability. Externalities are a key concept in this field, referring to how one person's or firm's actions can impact others not directly involved in the activity. These effects can be either positive (benefits) or negative (harms). The role of property rights is crucial in ensuring resources are used efficiently, with key characteristics such as exclusivity, transferability, and enforceability. Sustainability emphasises meeting present needs without compromising future generations' ability to meet theirs, balancing economic, environmental, and social factors. Environmental accounting combines data on the economy and the environment, helping track how the economy impacts the environment and vice versa. These concepts help in managing both positive and negative externalities effectively for long-term environmental health.

Assignments

1. Explain pollution rights.
2. Discuss the importance of property rights in managing environmental resources.
3. Define spillover costs and explain their impact on the environment and society.
4. Discuss the concept of sustainability and the role of biodiversity in maintaining environmental health.
5. Discuss the importance of the ozone layer in protecting life on Earth.
6. Explain how environmental quality affects human health and well-being.
7. Explain the concept of environmental accounts and their role in measuring the relationship between the economy and the environment.
8. Explain the significance of biodiversity in environmental protection and why it is critical to sustaining life on Earth.
9. Describe the concept of externalities in environmental economics. How do positive and negative externalities affect environmental policy and decision-making?

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Suggested Reading

1. Fisher. A.C. (1981), *Resource and Environmental Economics*. Cambridge University Press, Cambridge.
2. Hanley, N. J.F. Shogren and B. White (1997), *Environmental Economics in Theory and Practice,* McMillan.

Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

UNIT 4 Impact of Climate Change

Learning Outcomes

After completing this unit, the learner will be able to:

- understand global environmental issues with a focus on climate change
- differentiate between positive and normative analysis in the context of climate change
- analyse the economic aspects of global warming and climate change

Background

Climate change is one of the most pressing global challenges of our time. It refers to long-term changes in global or regional climate patterns, especially the rise in average global temperatures, primarily caused by human activities. Climate change is dangerously impacting the world in various ways. In February 2023, India recorded its hottest temperatures. Heatwaves in northern India are becoming more frequent and intense, affecting both public health and agriculture. Himalayan glaciers are retreating, threatening the freshwater supply for millions of people. Coastal cities like Mumbai and Chennai are increasingly at risk of flooding due to rising sea levels. Year by year, we experience more unpredictable monsoons, leading to floods in some areas like Assam and droughts in others like Maharashtra's Marathwada region, disrupting farming and food security. As a result, there has been a noticeable increase in natural disasters. One such event is the August Chooral Mala landslide in Kerala, which left an unforgettable mark on every person in the state. Therefore, we must create self-awareness about climate change and take preventive measures at the grassroots level. This is essential to protect our health, economy, and the natural environment. In this unit, we will study the causes, effects, and solutions related to climate change, and understand our role in building a more sustainable future

Keywords

Global warming, Climate Change, Positive and Normative Climate Change, Ozone Layer

Discussion

1.4.1 Global Environment Issues

- Economic development activities led to severe environmental degradation

The rapid pace of human development, including increased industrialisation, urbanisation, and population growth, has significantly impacted the natural environment. While economic development activities have improved living standards, they have also led to severe environmental degradation. The threats posed by these human activities are increasingly affecting the Earth's ecosystems. These environmental issues not only affect the environment but also threaten human health, food security, and global stability. The most pressing environmental problems, such as global warming, biodiversity loss, desertification, ozone depletion, acid rain, oil spills, and the dumping of hazardous waste, are interconnected and often stem from unsustainable practices. In order to protect the planet for future generations, it is critical to understand these issues and take immediate action to mitigate their effects. Let us now discuss these issues in detail.

1.4.1.1 Greenhouse Effect and Global Warming

- The Earth's atmosphere traps heat from the Sun

The greenhouse effect is a natural process that keeps the Earth warm enough to support life. It occurs when the Earth's atmosphere traps heat from the Sun. Let us see an Examples of how the greenhouse effect works. Think of a greenhouse, a glass structure used to grow plants. Sunlight passes through the glass, heating the inside. The heat then gets trapped, and even on cold days, the greenhouse stays warm to help the plants grow. This effect works on Earth as well, where the Earth's atmosphere acts like the glass of a greenhouse. The Sun's energy passes through the atmosphere, heats the Earth's surface, and then the Earth radiates heat back. However, not all of it escapes into space. The heat is trapped by gases in the atmosphere, keeping the Earth warm. The natural greenhouse effect is responsible for maintaining a temperature that allows life on Earth. Without it, the Earth's average temperature would be -17 °C, which is too cold for most life forms. However, in the current situation, human activities have added extra gases

to the atmosphere, causing the Earth to become too warm.

Global warming refers to the gradual increase in Earth's temperature, which has been rising in recent years due to human activities such as burning fossil fuels (coal, oil, and gas), deforestation, and industrialisation. These activities release large amounts of greenhouse gases into the atmosphere, which trap heat and cause the planet to warm. The most common greenhouse gases include carbon dioxide (CO_2), which is produced by burning fossil fuels and cutting down forests; methane (CH_4), which comes from livestock (like cows), paddy fields, and landfills; nitrous oxides ($N2_O$), released when fossil fuels are burned or from fertilizers; and chlorofluorocarbons (CFCs), found in refrigerators and air conditioners. These gases contribute significantly to the greenhouse effect, leading to rising temperatures and altering the global climate.

- Human activities release large amounts of greenhouse gases

Global warming has significant effects on both the climate and living beings. It leads to more extreme weather conditions, such as heat waves, heavy rains, and floods. Additionally, it disrupts ocean currents, contributing to the melting of polar ice caps and rising sea levels. These changes also impact living organisms. For plants, increased levels of CO_2 may boost growth in some species, but it can also promote the spread of weeds and pests that threaten other plants. For animals, shifting weather patterns can alter their habitats, making it difficult for some species to find food or survive. Humans are also affected, as rising temperatures could cause food shortages, spread diseases, and intensify extreme weather events like floods and droughts, threatening both health and livelihoods.

- Global warming negatively affects both the climate and living beings

To slow down global warming, it is crucial to take steps that reduce the amount of greenhouse gases in the atmosphere. Here are some effective ways to do this:

1. Use Clean Energy

- Fossil fuels are major contributors to greenhouse gas emissions and global warming

Fossil fuels are major contributors to greenhouse gas emissions and global warming. Therefore, we must shift from fossil fuels to clean energy sources such as solar energy, wind energy, and other renewable resources.

2. Stop Deforestation

Forests are large areas of land covered with trees, plants, and wildlife. They play a crucial role in maintaining the balance

- Forests maintaining the balance of the Earth's ecosystem

of the Earth's ecosystem. Forests absorb carbon dioxide (CO_2) from the atmosphere, helping to reduce the impact of greenhouse gases and combat climate change.

3. Reduce Pollution

- A comprehensive approach needs to cut down on air pollution

To cut down on air pollution, we must take a comprehensive approach that addresses both the sources and effects of pollution. Along with adopting cleaner technologies, increasing recycling, and using less plastic, there are other effective steps we can take. Shifting to electric vehicles (EVs) reduces emissions from transportation, while promoting public transportation and carpooling can decrease the number of vehicles on the road, further cutting pollution.

4. Increase Energy Efficiency

- Adopting energy-saving technologies can significantly cut down on energy waste

Increasing energy efficiency is one of the most effective ways to reduce energy consumption and decrease the environmental impact of human activities. In addition to using energy-efficient appliances and vehicles, several other strategies can contribute to better energy use. For example, improving building insulation can reduce the need for heating and cooling, lowering energy consumption in homes and offices. Smart thermostats and energy-efficient lighting, like LED bulbs, can also make a big difference in reducing energy usage. Upgrading infrastructure, such as better electrical grids and energy-efficient factories, can reduce losses in energy distribution.

1.4.1.2 Biodiversity

- Biodiversity refers to the variety of plants, animals, and microorganisms in a particular area

Biodiversity refers to the variety of plants, animals, and microorganisms in a particular area, as well as the ecosystems they form. It is a vital part of our natural wealth and essential for human survival as it supports ecosystems that provide food, clean air, and water. Biodiversity helps maintain ecosystem stability and provides resources such as food, medicines, and raw materials. It also supports essential services like pollination, water purification, and climate regulation.

Climate change is significantly impacting biodiversity, leading to shifts in species' ranges, disruptions in ecosystems, and an increased risk of extinction for many species. As global temperatures rise, species are moving to higher altitudes or further poles in search of suitable climates. However, many species, especially those with limited dispersal abilities or those inhabiting isolated environments like mountaintops,

- Climate change increased the risk of extinction for many species

cold-water habitats, or islands, struggle to keep pace with the rapid changes. These species face local extinctions, particularly in tropical and freshwater habitats, where the rate of climate change is accelerating faster than the species can adapt or migrate. The ongoing shifts in temperature, precipitation, and habitat loss make it increasingly difficult for ecosystems to maintain their balance, which threatens the many species that rely on them.

- Biodiversity loss due to climate change exacerbates global challenges

Biodiversity loss due to climate change also exacerbates other global challenges, such as food security and human health. Changes in temperature and precipitation patterns are affecting crop yields, and increased extreme weather events like droughts, floods, and heatwaves can destroy crops and reduce food availability. Additionally, the spread of pests and pathogens, often driven by climate change, puts even more pressure on agricultural systems. As ecosystems lose their biodiversity, they become less resilient to these disruptions, reducing their ability to provide vital services such as water purification, pollination, and climate regulation, all of which humans depend on for survival.

- Biodiversity plays a critical role in mitigating the effects of climate change

Despite these challenges, biodiversity plays a critical role in both adapting to and mitigating the effects of climate change. Diverse ecosystems, such as mangrove forests and coral reefs, act as natural barriers against extreme weather events like tsunamis and storms. Furthermore, healthy ecosystems help regulate carbon, water, and nutrient cycles, making them essential for climate change mitigation. Preserving biodiversity is not only vital for the survival of species but also for ensuring ecosystem resilience, maintaining human health, and securing food production in a changing climate. Therefore, protecting biodiversity should be central to climate change strategies to safeguard both nature and human well-being.

1.4.1.3 Desertification

- Desertification is the process of land degradation

Desertification is the process of land degradation where fertile land becomes barren and unproductive, ultimately transforming into desert-like conditions. It occurs due to various human activities, leading to a loss of biological potential in the land. A desert landscape supports very little vegetation and stunted plant growth. Currently, a significant portion of Earth's 132.4 million square kilometres of land area is facing desertification, primarily due to human activities like overexploitation and mismanagement of land resources. The

major causes of desertification are:

1. Over-cultivation

Over-cultivation occurs when the land is repeatedly ploughed to remove weeds and prepare it for planting. This process exposes the rich sub-soil to the elements, making it vulnerable to wind and water erosion. In areas with low rainfall, the soil becomes dry and more susceptible to further erosion. As the protective vegetation is removed and the soil is left bare, it becomes even more prone to evaporation, leading to a significant loss of moisture. Over time, this cycle of cultivation and erosion strips the land of its fertility, leaving it barren and unable to support plant growth, ultimately contributing to desertification.

2. Overgrazing

- Overgrazing happens when animals eat too much of the plants in an area

Overgrazing happens when animals eat too much of the plants in an area, especially in deserts where plants are already scarce. When animals graze too much, they remove the plants that protect the soil. Without these plants, the soil becomes exposed and can be easily blown away by the wind or washed away by rain. The hooves of the animals also break up the soil, making it even easier for erosion to happen. As the soil gets damaged, it becomes harder for plants to grow, and the land starts to turn into a desert.

3. Deforestation

- Forests help prevent soil erosion by holding the soil in place with their roots

Deforestation happens when forests are cut down for things like farming, timber, or firewood. Forests help prevent soil erosion by holding the soil in place with their roots. They also help retain water and recycle important nutrients for the soil. When forests are removed, the soil becomes exposed and can easily be washed away by rain or blown away by wind. Without trees, the land becomes barren, and it becomes much harder for plants to grow. This process contributes to desertification, where the land turns into desert-like conditions.

3. Salting due to irrigation

- Salinization, harms the soil by making it difficult for plants to grow

Salting due to irrigation happens when water is used to irrigate crops in areas that do not have enough natural water. The water used for irrigation contains dissolved salts, which build up in the soil over time. As the water evaporates, the salts stay behind, making the soil salty. This process, known as salinization, harms the soil by making it difficult for plants

to grow. Eventually, the land becomes unfit for farming, and this contributes to desertification, turning once fertile land into barren, desert-like areas.

1.4.1.3 Depletion of the Ozone Layer

The ozone layer is a thin layer of ozone (O3) molecules in the Earth's atmosphere, located between 10 and 50 km above the surface. This ozone layer acts as a natural shield, blocking harmful ultraviolet (UV) radiation from the sun. UV radiation has three types: UV-A, UV-B, and UV-C. UV-C is the most harmful, but the ozone layer protects us by absorbing much of this radiation. The major causes of Ozone layer depletion are:

1. **Natural Causes:** Some naturally occurring substances, like hydrogen oxide (HOx), methane (CH_4), and nitrogen oxides (NOx), can destroy ozone. Volcanic eruptions also release chlorine, which harms the ozone layer.
2. **Human-made Causes:** Human activities, especially the use of chemicals like chlorofluorocarbons (CFCs), contribute the most to ozone depletion. CFCs are used in products like refrigerators, air conditioners, and aerosol cans. In the stratosphere, chlorine from CFCs reacts with ozone molecules, breaking them down. One chlorine atom can destroy up to 100,000 ozone molecules.

- The ozone layer is a thin layer of ozone (O3) molecules in the Earth's atmosphere

1.4.1.4 Hazardous Waste

Hazardous waste refers to any substance that can cause significant damage to human health or the environment. It can cause serious, irreversible health effects with just a single exposure. Hazardous waste can come from various sources, such as household waste, including cleaning products and paints.

When hazardous waste is improperly dumped or disposed of, it releases harmful substances into the environment. These substances can pollute the air, water, and soil, leading to health problems and ecological damage.

1. **Industrial Waste**: Industrial waste, often disposed of through incineration or the burning of plastics, releases toxic fumes such as chlorine, polyvinyl chloride, and dioxins, which contribute to acid rain, carcinogenic effects, and widespread pollution.
2. **Nuclear Waste:** Nuclear waste, typically released slowly from hospitals and laboratories, introduces radioactive

substances into the environment, posing serious health risks like cancer and mutations.

3. **Agricultural Waste:** Agricultural waste, including fertilizers, pesticides, and animal manure, releases nitrogen compounds, phosphates, pesticides, and methane, leading to water pollution, soil degradation, and health issues such as cancer and renal failure.
4. **Plastic Waste:** When plastic waste is burned or incinerated, it releases toxic gases, contributing to air pollution and ecological harm.
5. **Chemical Waste**: Finally, chemical waste from hospitals and laboratories, if not properly disposed of, can contaminate the environment and pose carcinogenic risks to both human health and wildlife.

- Hazardous waste refers to any substance that can cause significant damage to human health or the environment

1.4.2 Climate Change

Climate change refers to long-term changes in Earth's weather patterns, especially the rise in average global temperatures. The climate naturally fluctuates over time, but now, the world faces climate change, which occurs because of human activities such as burning fossil fuels, deforestation, and industrial practices.

1.4.2.1 Causes of Climate Change

A. Natural Causes of Climate Change

Throughout Earth's history, natural factors have played a role in shaping the planet's climate. Some of these include volcanic eruptions, changes in solar radiation, and shifts in Earth's orbit. These factors have caused gradual changes in temperature and weather patterns over long periods.

1. **Volcanic Eruptions:** When volcanoes erupt, they release ash and gases, including carbon dioxide (CO_2), into the atmosphere. While this can cause short-term cooling, as ash and gases block sunlight, the overall effect is small compared to human activities. The warming we see today is much faster than the cooling caused by volcanoes.
2. **Solar Radiation:** The amount of energy Earth receives from the sun can vary over time due to changes in solar radiation. However, these variations are minor and happen over thousands of years. They can cause slight warming or cooling, but again, they are not responsible for the rapid warming we're experiencing today.
3. **Changes in Earth's Orbit:** Earth's orbit and tilt change over long periods, affecting the distribution of sunlight. These slow changes, called Milankovitch cycles, can

- Climate change refers to long-term changes in Earth's weather patterns

contribute to ice ages or warm periods, but they occur over tens of thousands to hundreds of thousands of years.

B. Human Causes of Climate Change

Climate change happens mainly because of human activities that release too many gases into the air. These gases, like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide ($N2_O$), trap heat from the sun, which causes the Earth's temperature to rise. This is called the greenhouse effect, and the result of the greenhouse effect is global warming. Human activities are the main reason for the rapid climate change we see today. Here, we explain how different sectors contribute to the problem:

1. Transportation

Cars, trucks, planes, and ships burning fuel, releasing carbon dioxide (CO_2) into the atmosphere, raise the temperature of the Earth. Cars and trucks are especially major sources of emissions. The good solution is to reduce these emissions by using electric vehicles and improving public transportation systems.

2. Electricity Generation

- Transportation, electricity generation, industry & manufacturing agriculture etc. contributes to climate change

Most of the electricity is made by burning coal and natural gas, which releases CO_2. Renewable energy sources like wind and solar are cleaner alternatives that help reduce pollution. Switching to these green energy sources can lower emissions.

3. Industry & Manufacturing

Factories that produce things like steel, cement, and chemicals use a lot of energy and release greenhouse gases. In particular, older factories can leak harmful gases into the atmosphere. We can reduce emissions by using cleaner energy, improving factory efficiency, and recycling more.

4. Agriculture

Farming can release methane and nitrous oxide, which are both powerful greenhouse gases. Livestock, such as cows and sheep, produce methane, and fertilizers release nitrous oxide. We can reduce emissions by using sustainable farming practices, reducing waste, and promoting plant-based diets.

5. Oil & Gas Development

Extracting and using oil and gas releases greenhouse gases, particularly methane. Even old, abandoned oil wells can leak harmful gases. Moving towards cleaner energy sources and reducing oil and gas extraction can help address this issue.

6. Deforestation

Cutting down forests and damaging wetlands releases stored carbon into the atmosphere, increasing CO_2 levels. Protecting forests, planting more trees, and practicing sustainable land use are important steps in fighting climate change.

7. Our Lifestyle Choices

- Human activities are the main reason for the rapid climate change

What we buy, how we travel, what we eat, and how much energy we use all impact the environment. For example, food waste alone contributes to 4% of total greenhouse gas emissions. We can make a difference by making sustainable choices, reducing waste, and using energy more efficiently. By making smarter choices in these areas, we can reduce the human impact on climate change and help protect the planet for future generations.

1.4.2.2 Effects of Climate Change

Climate change is a huge problem that affects our entire planet. It is happening because of human activities, like burning fossil fuels (coal, oil, and natural gas) that release greenhouse gases into the atmosphere. These gases trap heat, causing the Earth's temperature to rise. As the Earth gets hotter, it causes changes in the environment, weather, and even the lives of animals and humans.

1. Effects of Climate Change on Weather

As the planet gets hotter, weather patterns are changing, and the result is that heat waves are becoming more frequent and intense. This means that summers are getting hotter, with days breaking temperature records. In 2022, Europe experienced record-breaking heat, and many people lost their lives due to the extreme temperatures. In the U.S., heat waves are the number one cause of weather-related deaths.

Another change is long-lasting droughts. This is happening because the heat causes more water to evaporate from the soil, which leads to drier conditions. The western part of America

has been facing a “mega drought” for more than two decades, which means there is less water available for drinking and farming.

Storms are also becoming stronger. Warmer air can hold more moisture, which means that storms like hurricanes can become more intense. A good example is Hurricane Harvey in 2017, which brought devastating floods to Houston by dumping a huge amount of rain.

Effects on the Environment

- Ice melting in the Arctic Region

Climate change has severely impacted the atmosphere, especially in cold places like the Arctic. The ice there is melting because the region is warming up faster than the rest of the world. As ice melts, the darker water underneath absorbs more heat, which makes the ice melt even faster. This is a big problem because the Arctic ice helps keep global temperatures stable. If it melts completely, it will raise sea levels, which could flood cities around the world. Sea level rise is already happening. In low-lying areas, like small island nations or cities near the coast, the rising water is eating away at the land. For example, in places like Bangladesh, saltwater is invading freshwater supplies, making it hard to grow food.

Effects on Agriculture

- Unpredictable weather conditions hit the agricultural production

Climate change also affects how and what we can grow. Since temperature and rainfall patterns are changing, farming seasons are becoming unpredictable. For instance, a heat wave in Kansas in 2022 killed thousands of cows, affecting local farmers. Crops are also at risk because floods or droughts can destroy them. If a farmer in one part of the world gets hit by a flood, it can lead to food shortages and increased prices everywhere. Countries with less money, like those in Africa or Asia, are especially vulnerable to these changes.

Effects on Animals

Animals are also facing difficulties because their habitats are changing. For example, polar bears depend on sea ice to hunt for food, but as the ice melts, they lose their homes. Similarly, coral reefs, which are important for marine life, are dying because the ocean water is getting warmer. This is called coral bleaching, where the coral loses its colour and dies because the warmer water stresses it out.

- Animals cannot adapt to quick changes in climate

In addition, many animals rely on specific temperatures and seasons for food, mating, and migration. With climate change speeding up and delaying seasons, some animals cannot adapt quickly enough and are at risk of extinction.

Effects on Humans

Humans are also facing the effects of climate change. For example, hotter temperatures are making air quality worse. Wildfires, which are becoming more frequent, produce smoke that can be harmful to people's lungs. Also, diseases like malaria are spreading to more areas because warmer temperatures are allowing mosquitoes to live in places they did not live in before.

In some regions, extreme weather like hurricanes, wildfires, and floods is making it harder for people to live safely. People who do not have the resources to move or protect themselves are hit the hardest. For example, after Hurricane Katrina hit New Orleans in 2005, poorer communities that lived in areas most at risk were the last to receive help.

- Climate change is leading to food and water shortages

Climate change is also leading to food and water shortages, which force people to leave their homes in search of better living conditions. This is called displacement, and it's already happening. People from countries with few resources are being forced to move because of rising sea levels or the destruction of their food supplies. In some places, this could lead to wars over resources like water.

Future Effects of Climate Change

If we do not take action, climate change will continue to worsen. Scientists predict that by 2050, climate change could cause an additional 250,000 deaths each year from things like malnutrition, disease, and heat stress. By the end of the century, millions of people may be displaced due to rising sea levels, droughts, and other effects. The impacts of climate change will cost economies billions of dollars every year, hurting industries like farming, tourism, and fishing.

What Can We Do?

The good news is that there are ways to fight climate change. Countries around the world can reduce greenhouse gas emissions by using cleaner energy, like solar and wind power, instead of burning fossil fuels. We can also protect forests,

which absorb carbon dioxide and help cool the Earth.

People can also make changes in their own lives. For example, using less energy at home, driving less, eating more plant-based foods, and recycling can all help reduce emissions. Climate change is a big problem, but every small action counts. By taking these steps, we can help slow down climate change and make sure that future generations have a healthier, more stable world to live in.

- Countries should reduce greenhouse gas emissions

1.4.3 Positive and Normative Analysis of Climate Change

Positive analysis focuses on what is or what will happen. In positive analysis, we examine the cause-and-effect relationships of variables without making any judgments about whether something is good or bad. This type of analysis is objective, meaning it focuses on data and facts, not on opinions or values. For example, one aspect of positive analysis looks at how carbon emissions (from activities like burning fossil fuels) contribute to global warming. Studies show that as carbon emissions increase, global temperatures also rise. Scientific models predict that if emissions continue to grow, global warming will become more severe, leading to changes in weather patterns around the world.

- In positive analysis, examine the cause-and-effect relationships of variables without making any judgments

Another example is deforestation. Research shows that cutting down forests leads to a loss of species diversity because many animals and plants depend on forests for survival. Positive analysis helps us understand how deforestation is linked to the extinction of species, showing a clear relationship between forest destruction and biodiversity loss. Finally, a positive analysis looks at the rise in sea level due to melting polar ice. As the Earth's temperature increases, ice caps melt, causing sea levels to rise. Scientific models use historical data to predict which coastal areas will be most affected by flooding in the future. The goal of positive analysis is to explain how and why climate change is happening based on real data and predictions. It helps us understand the current situation and make informed decisions about what might happen in the future.

- Positive analysis helps us understand how deforestation is linked to the extinction of species

Normative analysis focuses on what ought to be or what should happen. It considers the value effects of things, meaning it takes into account what is considered good or bad for society, the environment, and future generations. Instead of just

explaining what is happening, normative analysis suggests solutions and actions that can improve the situation according to what society believes is morally right.

For example, a normative analysis might argue that reducing carbon emissions is morally important because if we don't act, global warming will cause severe harm to future generations, vulnerable people, and ecosystems. To solve this, it might recommend policies like carbon taxes (which charge people for emitting carbon), incentives for renewable energy, or international agreements like the Paris Agreement that encourage countries to work together to reduce emissions. Another example is environmental justice. A normative analysis could argue that wealthier countries should take more responsibility for addressing climate change because they have historically caused more pollution. It would suggest that richer nations should help poorer, vulnerable countries that are already facing the worst impacts of climate change, like rising sea levels or extreme weather events.

Finally, sustainable development is an important part of normative analysis. This idea focuses on making sure that economic growth today does not harm the environment in the future. Policies that promote sustainable agriculture, reduce waste, and protect natural resources might be recommended to ensure that future generations can enjoy a healthy planet. The goal of normative analysis is to give a moral framework for making decisions about climate change. It helps guide societies in making choices that reflect our values, like fairness and responsibility, to create a better future for everyone.

- Normative analysis focuses on what ought to be or what should happen

1.4.4 Economics of Global Warming and Climate Change

Climate change is a big problem that affects everyone around the world. As the planet gets warmer and weather becomes more unpredictable, it causes damage to the economy, industries like farming and fishing, and people's health. If we do not act now, these problems will worsen. This includes things like losing money, damaging important jobs, and making people sick. How we respond to climate change today decides how things will turn out in future.

- Climate change causes damage to the entire economy

1. Global Economic Losses

Climate change could lead to massive economic losses worldwide, especially if emissions continue to rise. By 2050, the global economy might lose up to 19% of its income.

Without action, the annual damages could reach $38 trillion, while taking steps to limit warming to 2°C would cost around $6 trillion per year. Extreme weather events, like those in the U.S. that cost over a billion dollars, are becoming more frequent and contributing to these rising economic losses.

- Massive economic losses worldwide, reach $38 trillion, $6 trillion

2. Sectoral Impact

Sectors like agriculture, energy, tourism, forestry, insurance, and fisheries will face severe disruptions due to climate change. Agriculture, in particular, could suffer from both direct impacts like droughts and floods, as well as indirect effects like reduced labour productivity due to heat stress. For instance, India's agriculture is highly vulnerable to climate change due to its dependence on monsoon rains. Changes in rainfall patterns, prolonged droughts, and extreme heat waves can damage crops and reduce yields. Heat stress has already led to a decline in wheat and rice production, while floods and droughts have made farming in certain regions more unpredictable. Additionally, India's coastal regions and its fisheries industry will be affected by rising sea temperatures and ocean acidification, which impact fish populations. This will reduce fish catches, negatively affecting the livelihoods of millions who depend on fishing.

- Climate change, negatively affecting the livelihoods of millions

3. Regional Disparities

Developing countries, particularly in regions like Sub-Saharan Africa, South Asia, and Southeast Asia, will be more affected by climate change than wealthier nations. These countries rely heavily on agriculture, so climate change can hurt crops, making many people even poorer. In richer countries, the economy will still be affected, but the impact will not be as serious as in poorer nations. While wealthier nations may experience slower growth, low-income countries could see much bigger drops in their income and more people falling into poverty.

- Developing countries will be more affected by climate change

4. High Emission vs. Low Emission Scenarios

Climate change will have a much bigger impact on the economy if we keep releasing high levels of greenhouse gases. For example, if the Earth warms by 4°C by 2100, the global economy could shrink by up to 30%. However, if we limit warming to 1.5°C or 2°C, the economic losses will be much smaller, and we can avoid many harmful effects. This shows how important it is to take action to reduce emissions and

- Action to reduce emissions switch to cleaner energy sources

switch to cleaner energy sources.

5. Health and Productivity

Climate change also affects people's health and work. Rising temperatures and pollution can make people sick and reduce how much work they can do. A report in 2020 predicted that heat stress could cause a loss of 2.2% of global working hours by 2030, which would cost $2.4 trillion every year. On top of this, climate change can also cause problems like hunger, breathing issues, and other health risks because of extreme weather and environmental damage.

- Climate change also affects people's health and work

1.4.4.1 Economic Analysis of Climate Change

An economic analysis of climate change tries to figure out how much money or resources will be lost or gained because of climate change. It also helps us decide what kind of policies or actions we should take to reduce or adjust to climate change. Climate change refers to long-term changes in weather patterns and temperatures around the world. It's largely caused by human activities, such as burning fossil fuels (coal, oil, and gas), which release gases like carbon dioxide (CO_2) into the air. Global warming is the rise in Earth's temperature due to the increase in greenhouse gases like CO_2, which trap heat in the atmosphere. The effects of climate change include melting ice caps, rising sea levels, and extreme weather events like floods and droughts. These impacts can hurt ecosystems, people, and economies worldwide

- Figure out how much money or resources will be lost or gained because of climate change

An economic analysis of climate change can help in:

1. **Estimating global costs**: Determining how much climate change will cost the world overall.
2. **Estimating regional or sector costs:** Understanding how different areas (like farming or energy) will be affected by climate change.
3. **Estimating the cost of solutions:** Calculating how much it will cost to prevent or adjust to climate change, such as reducing greenhouse gas emissions or building flood defences.
4. **Measuring the cost of carbon emissions:** Understanding how much each ton of carbon dioxide (CO_2) released into the air costs society (called the "social cost of carbon").
5. **Helping to make decisions:** Providing information that governments and organizations use to decide how to

- Figure out how much money or resources will be lost or gained because of climate change

manage climate change.

Types of Economic Models

Several economic models and tools are employed to understand the economic impacts of climate change, as well as the strategies for reducing or mitigating its effects and adapting to it. Here are the major economic models and tools used in this field:

1. Integrated Assessment Models (IAMs)

- Combine knowledge from both natural and social sciences to evaluate the economic costs and benefits of climate change

Integrated Assessment Models (IAMs) combine knowledge from both natural and social sciences to evaluate the economic costs and benefits of climate change mitigation and adaptation strategies. These models explain the interactions between the economy, energy systems, land use, and climate processes. GCAM (Global Change Assessment Model) is one example of an IAM. It explores future pathways for greenhouse gas emissions and climate change impacts. It evaluates the impact of various climate and energy policies on greenhouse gas emissions and the economy, as well as the effects of climate change on land use, including deforestation, food production, and land-based carbon sequestration. This model is widely used in climate scenario analysis, including by the IPCC (Intergovernmental Panel on Climate Change) and in studies related to food security, land use, and climate mitigation. IMAGE (Integrated Model for the Assessment of Global Environmental Change) is another example of an IAM. It focuses on the interactions between human and natural systems and is designed to simulate the effects of climate change, land use changes, and environmental policy on global and regional scales. This model is used by policymakers and researchers to analyse climate change scenarios, environmental sustainability, and potential policy interventions. It has been used for integrated assessments in international reports, such as the IPCC's Special Reports.

2. Cost-Benefit Analysis (CBA)

CBA is a decision-making tool that compares the monetary value of the costs and benefits of climate-related policies or actions. It is particularly useful in evaluating whether the benefits of taking action against climate change outweigh the costs of the interventions.

Key Elements of Cost-Benefit Analysis:

a. **Monetisation:** This involves converting both the costs and benefits of climate-related actions into monetary terms. Costs may include things like damage caused by climate change (e.g., extreme weather events, rising sea levels) or the expenses involved in adaptation efforts (e.g., building infrastructure, transitioning to renewable energy). Benefits can be measured in terms of the reductions in damages or improvements resulting from the policy (e.g., avoiding economic losses due to disasters, improving health outcomes through cleaner air).

- Involves converting both the costs and benefits of climate-related actions into monetary terms

b. **Discounting:** Discounting is the process of applying a discount rate to future costs and benefits. This is done to reflect the concept that people tend to value present benefits more than future ones. For instance, a benefit or cost incurred 20 years from now is typically considered less significant today, so its value is "discounted" to reflect its future impact in present-day terms. The choice of discount rate can significantly influence the analysis and conclusions.

- Discounting is the process of applying a discount rate to future costs and benefits

c. **Willingness to Pay (WTP) or Willingness to Accept (WTA):** WTP is the amount of money individuals or societies are willing to pay to avoid the negative impacts of climate change, such as health risks or environmental damage. WTA is the amount of compensation individuals or societies would be willing to accept for enduring such negative impacts (e.g., accepting the consequences of rising sea levels). These measures help quantify the value people place on climate-related outcomes, and they are essential for placing a monetary value on both the damages from climate change and the benefits of reducing or adapting to it. Cost-Benefit Analysis (CBA) offers several advantages, including

- The amount of money individuals or societies are willing to pay to avoid the negative impacts of climate change

- Provide a systematic and structured way to compare various climate-related actions,
- Help policymakers understand economic trade-offs and allow for the consideration of both direct and indirect economic impacts.

However, it also faces challenges and limitations, such as uncertainty about future climate outcomes (e.g., the extent of warming and the severity of impacts), making it difficult to

- WTP is the amount of money individuals or societies are willing to pay to avoid the negative impacts of climate change,

estimate costs and benefits accurately. Additionally, non-market impacts, like the loss of biodiversity or social equity issues, are challenging to monetize, and the practice of discounting future benefits and costs may lead to the underestimation of long-term impacts, particularly concerning the welfare of future generations.

3. Scenario-Based Models

- Scenario-Based Models explore alternative futures and assess risks and uncertainties associated with different pathways

Scenario-based models are used to project different future outcomes under various assumptions about socioeconomic development, technology, and climate policies. These models explore alternative futures and assess risks and uncertainties associated with different pathways. The types of scenarios include Business-As-Usual (BAU), which assumes no additional climate policies beyond current practices; Mitigation Scenarios, which assume specific actions to limit climate change (such as achieving 2°C or 1.5°C targets); and Shared Socioeconomic Pathways (SSPs), developed by the IPCC to examine how different future development pathways affect greenhouse gas emissions and climate outcomes. Scenario-based models are valuable in exploring the potential consequences of different climate policies, assessing the economic costs, and determining the feasibility of achieving specific climate targets.

Summarised Overview

Climate change refers to long-term shifts in Earth's weather patterns, primarily driven by human activities such as burning fossil fuels, deforestation, and industrial practices, leading to rising global temperatures. While natural factors have historically influenced the climate, now human activities are the dominant cause of the rapid changes observed today. The impacts of climate change are far-reaching, affecting weather patterns, ecosystems, agriculture, and human health, resulting in heat waves, stronger storms, droughts, and habitat loss. Biodiversity, the variety of life on Earth, is key for ecosystem stability and the provision of essential services like food, clean air, water, and medicine. However, biodiversity is threatened by factors like habitat loss due to deforestation and urbanisation, pollution (air, water, and soil), overuse of resources like overfishing and hunting, the introduction of invasive species, and environmental degradation, including global warming and oil spills. These pressures contribute significantly to the ongoing loss of biodiversity. When analysing climate change, there are two primary approaches: positive and normative analysis. Positive analysis focuses on understanding what is happening based on factual data and scientific evidence, examining cause-and-effect relationships

without moral judgment. In contrast, normative analysis involves value-based judgments about what should be done to address climate change, advocating for actions such as reducing carbon emissions, promoting renewable energy, and ensuring climate justice. Both approaches are essential in addressing these urgent environmental challenges.

Assignments

1. Explain the primary causes of climate change.
2. Describe the impacts of climate change.
3. What is biodiversity, and why is it crucial for the stability of ecosystems?
4. Differentiate between positive and normative analysis when addressing climate change.
5. What actions can be taken at both the global and individual levels to combat climate change and preserve biodiversity?

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BLOCK 2

Sustainable Development

UNIT 1

Environmental Sustainability

Learning Outcomes

After completing this unit, the learner will be able to:

- understand the importance of sustainable development
- describe the concept of environmentally adjusted national product (ENP)
- discuss the difference between Green GNP and traditional GNP

Background

The concept of sustainable development has evolved significantly since the 1970s, gaining global attention through key milestones such as the 1972 UN Conference on the Human Environment, the Brundtland Commission's 1987 report, and the 1992 Rio Earth Summit. These events led to the establishment of the UN Environment Programme, the Commission on Sustainable Development, and the adoption of the Millennium Development Goals and Sustainable Development Goals. The SDGs represent a significant shift in the global development agenda, acknowledging the interconnectedness of economic, social, and environmental issues. In this context, Green Gross National Product has emerged as a key tool for measuring sustainable development, providing a more comprehensive picture of economic performance and highlighting the trade-offs between economic growth and environmental sustainability

Keywords

Sustainable Development, Environmentally Adjusted or Approximate Environmentally Adjusted National Product (ENP/AENP), Green GNP

Discussion

2.1.1 Sustainable Development

- Sustainable development was first introduced by the United Nations' in 1987

The concept of sustainable development was first introduced by the United Nations' Brundtland Commission in 1987. The commission, led by former Norwegian Prime Minister Gro Harlem Brundtland, aimed to address the growing concern about the impact of human activities on the environment. After extensive research and consultation, the commission published a comprehensive report titled "Our Common Future." This report laid the foundation for the concept of sustainable development, defining it as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

- Sustainable development for the future

In simple terms, sustainable development is about finding a balance between our current needs and the needs of future generations. It's about making sure that we use natural resources, manage waste, and protect the environment in a way that doesn't harm the planet or its inhabitants.

- Ethical concerns related to fairness and equity

According to the World Commission on Environment and Development (WCED) the definition of sustainable development must resolve two key concepts:

1. The concept of "needs" highlights the importance of prioritising the basic needs of the world's poor, which involves addressing ethical concerns related to fairness and equity.
2. The idea of environmental limits emphasises the need to balance current and future needs, ensuring that present demands do not compromise the ability to meet future needs.

The concept of sustainable development, introduced by the World Commission on Environment and Development (WCED), can be visualised as a three-pillar model, consisting of ecological, social, and economic dimensions, as depicted in Figure 2.1.1.

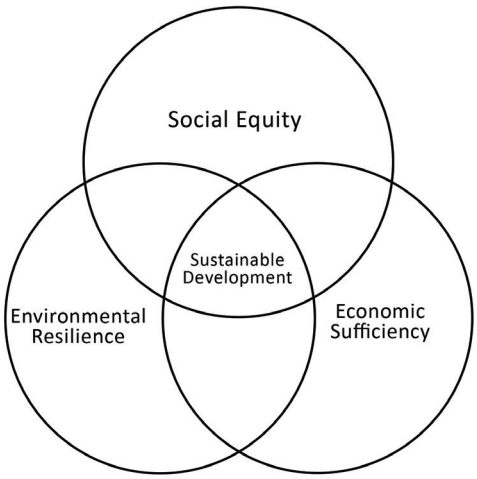

Fig. 2.1.1 Concept of Sustainable Development

- Sustainable development: three pillars

Sustainability is achieved at the convergence of three critical dimensions: environmental resilience, social equity, and economic sufficiency. This means ensuring that natural ecosystems can grow well and regenerate, that human basic needs are met to uphold dignity, and that economic activity provides sufficient production and employment. Each of these dimensions is essential for achieving full sustainability.

2.1.2 Indicators of Sustainability

- Economy operates within ecological boundaries

The concept of sustainable development acknowledges that the economy operates within ecological boundaries. This raises a crucial question, how do we measure the sustainability of economic development and its impact on the environment? Human resource consumption is not just a scientific issue; it's a major political and economic concern. Can our plans and policies truly be sustainable?

- Measuring sustainable economic development

Considering "carrying capacity" as a link between population (demography) and the environment, as defined by T.N. Srinivasan (1988) as "the maximum population that can be sustained indefinitely," makes measuring sustainability complex. Therefore, we need simple, practical indicators to assess both environmental and economic sustainability in development. Currently, GDP growth is the primary measure of development, but it ignores the depletion of natural resources and the environment's contribution to the economy. In the context of sustainable development, this is inadequate.

Current development measures are insufficient and should be replaced with a set of indicators that reflect changes in both the environment and economic activities. Environmental indicators, which measure the state of the environment, should be simple, practical, and expressed in non-monetary or physical terms. These indicators should be compared with their sustainable limits. Another set of indicators should track progress towards broader sustainable development goals within a national context. These indicators should consider both economic and social changes. Some important indicators of sustainable development include:

1. GDP Growth Rate

- National economic growth rate

The GDP growth rate indicates the overall health of the economy. A high growth rate is key for creating jobs, maintaining stable prices, and improving living standards. It contributes to poverty reduction, which in turn lessens the environmental burden and pollution associated with poverty.

2. Population Stability

- The population impacts the environment negatively

A country's population not only drives its economic activities but also contributes significantly to environmental pollution. The relationship between population and the environment has been a topic of discussion throughout history, although the focus has shifted over time. From early concerns about population growth and governance (Plato, Aristotle) to food production (Malthus), agricultural growth (Boserup), resource availability (neoclassical economists, Simon), pollution (Meadows), and land degradation (Blaikie and Moore), the impact of population has been a recurring theme. Many researchers highlight the pressure increasing populations place on land and the resulting environmental degradation. These studies consistently identify population growth as a contributing factor to various environmental problems. Therefore, controlling population growth is key. This requires focusing on managing the net increase in population over a defined planning period.

3. Water Use

- Water for sustainable development

For sustainability, it's essential to guarantee access to sufficient clean water for drinking, industry, and agriculture. As populations grow, more water will be needed for irrigation and livestock to produce enough food. Water is a key resource,

and in modern economies, regardless of development level, it's treated as a commodity primarily used for economic purposes.

4. Soil Degradation

- Soil conservation for sustainability

Soil is fundamental for meeting human needs. Soil degradation is a significant environmental issue. Soil erosion, in particular, is a major concern in India. To achieve sustainable development, we must minimise topsoil loss from erosion and the decline in soil fertility.

5. Forest Coverage Ratio

- Deforestation threatens sustainability

According to the Food and Agriculture Organisation of the United Nations (FAO), India experienced a 0.6% annual deforestation rate between 1981 and 1990, resulting in a loss of 339,000 hectares. Globally, with 70 million people added to the population annually (primarily in developing countries) and 15 million square kilometres of forest lost, many have suggested a direct link, more people, fewer forests (as supported by research from Allen & Barnes, Myer, Ehrlich & Ehrlich, and Rudel). However, deforestation leads to soil degradation and the loss of biodiversity. Therefore, maintaining adequate forest cover is essential for the long-term sustainability of economic development.

6. Human Resource Development Index

- Measuring human resource development

The Human Resource Development Index is a comprehensive measure that consolidates various aspects of human development into a single numerical value. It includes factors like economic conditions, healthcare, and education. An index score above 0.8 signifies a high level of Human Resource Development (HRD), while a score below 0.5 indicates poor HRD.

7. Clean Air Index

- Mitigating air pollution effects

Clean air is essential for all life. However, rapid development is causing increasing air pollution. Gases like carbon dioxide, sulphur dioxide, sulphur oxides, and hydrocarbons significantly degrade air quality. Some contribute to the greenhouse effect and global warming, while others cause acid rain, both of which are harmful to life. It is crucial to eliminate the negative impacts of air pollution.

8. Energy Intensity

Energy is a major component of development. Therefore, it's

• Energy and Sustainable Development

essential to understand how energy supply and demand impact sustainable development. Generally, a lower energy output relative to GNP (measured as the energy/GNP ratio) indicates greater sustainability.

9. Renewable Energy Proportions

The proportion of renewable energy sources in a country's energy mix plays a key role in determining its long-term sustainability. Renewable energy sources, such as solar, wind, hydro, and geothermal power, offer a cleaner and more sustainable alternative to fossil fuels. As the world transitions towards a low-carbon economy, a higher proportion of renewable energy sources is crucial for reducing greenhouse gas emissions and reduce climate change. Moreover, renewable energy can improve energy security, reduce dependence on imported fuels, and create new job opportunities in the clean energy sector. Therefore, increasing the proportion of renewable energy sources is essential for achieving greater long-term sustainability, and countries should strive to set ambitious renewable energy targets and implement policies to support their development and deployment.

10. Transport Intensity

• Greening the transport development path

While transportation is essential for economic development, it also contributes to environmental pollution. Therefore, both the level of transport activity (measured by the transport expenditure to GDP ratio) and the technology used in transportation should be aligned with sustainability goals.

2.1.3 Accounting for Environment

• Beyond traditional accounting

National income and product accounts measure a nation's economic growth. These accounts are based on the System of National Accounts (SNA), designed by the United Nations. Most countries calculate their economic data using this standard SNA format. However, it is no longer considered a complete measure of a country's economic performance. It overlooks non-market activities like unpaid work and leisure time, and it fails to account for environmental damage and the depletion of natural resources.

Gross National Product (GNP) is the total value of all finished goods and services produced in a year. Countries are often ranked by GNP, from richest to poorest. A rising GNP suggests a healthy economy, while a falling GNP indicates decline. GNP

• Flaws in the GNP measure

was a popular indicator when the environmental impact of production and consumption was minimal. Today, economic activities significantly harm the environment, creating costs for current and future generations.

(a) National Income Concepts

- GNP: The market value of all finished goods and services produced in a given period in a given economy.
- NNP: GNP - Depreciation
- Depreciation: Capital consumption allowance (provision made for the use of physical capital).

• Accounting for nature

India's National Accounts Statistics (NAS) has started integrating environmental factors into GDP and related measures like Gross Capital Formation and Gross Fixed Capital Formation.

(b) Gross Domestic Product (GDP) :

For the purpose of environmental valuation, Gross Domestic Product (GDP) encompasses key components related to the use and provision of natural resources and utility services.

It includes;

- Value added from electricity, gas, and water supply, including transmission and distribution, gas manufacturing, LPG production, and water distribution (excluding irrigation).
- Value of extracted minerals (solids, liquids, and gases), quarry and oil well income (excluding mineral depletion).
- Value of extracted timber, fuel wood, and non-timber forest products.
- Value of natural growth of specific cultivated crops.
- Output of dung manure.

• GDP includes natural resources

(c) Gross Capital Formation (GCF) :

Gross Capital Formation (GCF) refers to investments made to build new assets or upgrade and improve existing ones. It includes;

- Government capital transfers to corporations for water

supply.

- GCF includes eco Investments

- Household investment in biogas and wind energy systems.
- Estimated capital expenditure for wind energy system installation.
- Expenditure on improving land, mining sites, timber tracts, and plantations.

(d) Gross Fixed Capital Formation (GFCF) :

GFCF includes;

- GFCF includes environmental assets

- Estimates of improvements to land, irrigation, flood control projects, planting orchards and plantations, forestry, and fishing.
- Estimates of mineral extraction (major and minor) from public, private, and household sectors.

(e) Change in Stocks (CIS) :

CIS includes;

- CIS includes inventory changes

- Estimates of unsold mineral stocks (excluding depletion).
- Estimates for agriculture across all sectors.
- Estimates for electricity, gas, and water (public and private sectors only).
- Changes in unsold timber.

2.1.4 Environmentally Adjusted or Approximate Environmentally Adjusted National Product (ENP/AENP)

- Economic growth environmental impact

An 'environmentally adjusted national product' is a way to measure a country's economy while considering the harm done to the environment. It's calculated by subtracting the costs of environmental damage and resource depletion from the country's total economic output. This gives a clearer picture of whether a country's economic growth is sustainable and environmentally friendly.

The UN and World Bank developed System of Environment-Economic Accounting (SEEA) to integrate environmental data with existing national accounts while maintaining basic accounting concepts. It calculates the environmentally

adjusted Net Domestic Product (EDP) and Environmentally adjusted Net Income (ENI). Environmental assets (soil, biodiversity) are added to productive assets in SEEA if they are linked to economic activities. Additional environmental costs are included, such as:

- Integrating environment into accounting

- Imputed charges for mineral and natural resource depletion.
- Costs of land, water, and air degradation from production and consumption.

These costs are deducted from GDP to arrive at EDP.

To calculate. Environmentally adjusted Net Income (ENI), the following five items are subtracted from Environmentally adjusted Domestic Product (EDP)

- Calculating environmentally adjusted income

- Government and household spending on environmental protection.
- The impact of environmental factors on human health and other aspects of human capital.
- Environmental costs associated with household and government consumption.
- Environmental damage from discarded capital goods.
- Negative environmental effects within the country resulting from production in other countries, and vice versa.

2.1.5 Green GNP

- Integrating environment into GNP

Green Gross National Product (Green GNP) is a modified economic metric that integrates environmental costs and benefits into the traditional Gross National Product (GNP) framework. This approach provides a more comprehensive and accurate picture of a country's economic performance, highlighting the interdependencies between economic development and environmental sustainability.

- GNP with environmental costs

The traditional GNP metric solely focuses on the economic output of a country, neglecting the environmental degradation and resource depletion that often accompany economic growth. In contrast, Green GNP adjusts the traditional GNP by incorporating environmental costs and benefits, thereby providing a more clear understanding of a country's economic performance.

The Green GNP framework consists of three primary components:

1. Traditional GNP

The total value of goods and services produced within a country's borders, using standard accounting methods.

2. Environmental Costs

The economic value of environmental degradation, resource depletion, and other negative environmental impacts caused by economic activity. Examples include pollution costs, deforestation costs, and climate change costs.

- Green GNP Key Components

3. Environmental Benefits: The economic value of environmental conservation and sustainable practices. Examples include ecosystem services, recreation and tourism benefits, and carbon sequestration benefits.

- Green GNP Promotes Sustainability

By integrating these components, Green GNP provides a more comprehensive picture of a country's economic performance, highlighting the trade-offs between economic growth and environmental sustainability. This approach encourages policymakers to adopt sustainable development strategies, balancing economic growth with environmental protection.

The benefits of Green GNP include;

- Green GNP Key Benefits

4. Encourages Sustainable Development: By accounting for environmental costs and benefits, Green GNP promotes sustainable development and environmental conservation.

5. Provides a More Accurate Picture of Economic Performance: Green GNP offers a more comprehensive understanding of a country's economic performance, highlighting the interdependencies between economic development and environmental sustainability.

6. Supports Informed Decision-Making: Green GNP provides policymakers with a more nuanced framework for decision-making, enabling them to make more informed choices about economic development and environmental conservation.

However, Green GNP also faces several challenges. Estimating environmental costs and benefits requires high-quality data,

- Challenges of Green GNP

which may not always be available. Integrating environmental costs and benefits into the traditional GNP framework can be methodologically complex. Implementing Green GNP in policy decisions can be challenging, requiring significant changes in how policymakers think about economic development and environmental conservation.

Despite these challenges, Green GNP offers a more holistic framework for evaluating economic performance and promoting sustainable development. By integrating environmental costs and benefits into the traditional GNP framework, Green GNP provides a more comprehensive picture of a country's economic performance, highlighting the interdependencies between economic development and environmental sustainability.

Summarised Overview

The concept of sustainable development, introduced by the Brundtland Commission in 1987, emphasises meeting present needs without compromising future generations' ability to meet theirs. This concept is built on three pillars: ecological, social, and economic dimensions. The SDGs adopted by the UN in 2015, provide a blueprint for achieving sustainable development, incorporating environmental targets and traditional development objectives. To measure sustainable development, various accounting frameworks have been developed, including the SEEA and Green GNP. Green GNP integrates environmental costs and benefits into the traditional GNP framework, providing a more comprehensive picture of economic performance and promoting sustainable development. However, Green GNP faces challenges such as data availability and quality, methodological complexities, and policy implementation hurdles. Despite these challenges, Green GNP offers a more holistic framework for evaluating economic performance and promoting sustainable development, encouraging policymakers to adopt sustainable development strategies that balance economic growth with environmental protection.

Assignments

1. What is sustainable development, and why is it important?
2. Compare and contrast traditional GNP with Green GNP.
3. What are the three pillars of sustainable development?
4. Explain the concept of environmental accounting and its significance.
5. What are environmentally adjusted economic indicators?

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UNIT 2

Theories of Resource Use and Environmental Accounting

Learning Outcomes

After completing this unit, the learner will be able to:

- comprehend the theories of resource use
- understand the environment and development trade-off
- explain environmental accounting
- discuss the concept of Green GDP

Background

Natural resources are essential for economic growth and human well-being. However, these resources are not unlimited. Some, like coal, oil, and natural gas, are exhaustible - once used, they cannot be replaced. Others, like forests, water, and solar energy, are renewable, but only if managed sustainably. Overusing or mismanaging these resources can lead to environmental degradation, loss of biodiversity, and long-term economic problems.

As economies grow, there is often a trade-off between development and environmental protection. For example, building factories or expanding agriculture can boost income and jobs, but it may also lead to pollution, deforestation, or depletion of natural resources. Balancing these trade-offs is a key challenge for policymakers and economists.

To address these challenges, economists have developed tools like environmental accounting and Green GDP. Traditional GDP measures economic activity but ignores environmental costs, such as pollution or resource depletion. Green GDP adjusts GDP to account for these environmental impacts.

Keywords

Exhaustible Resources, Renewable Resources, Environmental Accounting, Green GDP

Discussion

2.2.1 Theories of Optimal Use of Exhaustible and Renewable Resources

Natural resources are essential for production and consumption in an economy. They originate from natural processes and exist either in fixed quantities or grow biologically over time. Understanding how to use these resources efficiently is important for sustainable development. Natural resources are broadly classified into renewable and non-renewable resources.

- Renewable resources regenerate naturally

Renewable resources are those that can be used without getting depleted, as they regenerate naturally. These are also called flow resources because their availability is continuous. For example, solar energy can be used without reducing its future availability. Some renewable resources, like fisheries and forests, have a biological growth rate because they replenish over time. However, if the rate of harvest exceeds the biological growth rate, these resources can become depleted.

- Non-renewable resources deplete, but can be managed sustainably

Non-renewable resources, also called exhaustible resources, have a fixed stock and are depleted when used. Examples include fossil fuels like coal and petroleum. Since their stock cannot be replenished naturally, they become scarce over time. However, through recycling and innovative technologies, it is possible to extend the use of these resources and reduce their depletion rate.

2.2.1.1 Theories of Optimal Use of Natural Resources

The increasing scarcity of fossil fuels and other raw materials has led to the development of various theories and models on the optimal use of natural resources. Most of these theories focus on the best way to use both exhaustible and renewable resources efficiently over time.

- Markets may regulate scarcity efficiently

Some economists believe that the relative scarcity of resources will not be a long-term problem because market forces will naturally regulate resource use. According to this optimistic view, the economic system will automatically adapt to shortages and ensure the efficient use of resources.

I. Inter-Temporal Choice and Resource Use

To understand the theoretical models of resource depletion, it is important to examine the concept of intertemporal choice. This theory analyses how individuals make decisions regarding the consumption of a commodity in different periods.

- Inter-temporal choice involves consuming the same good over time

In inter-temporal choice analysis, one unit of a commodity is consumed in the current period (t_0) and one unit of the same commodity consumed in a future period (t_1) are treated as two distinct commodities. This is similar to the concept of constrained choice in traditional static consumer demand theory, where consumers choose between two goods within the same period. However, inter-temporal choice differs because the decision involves the same good being consumed at two different points in time $(t_0$ and $t_1)$.

- Indifference curves to represent consumer preferences

Economists use indifference curves to represent consumer preferences between current and future consumption. The slope of the indifference curve, known as the marginal rate of substitution between current and future consumption, indicates how much future consumption $(\text{at } t_1)$ an individual is willing to sacrifice to consume more in the present (t_0). The slope is given by $(1 + d)$,,where d represents the marginal rate of time preference.

- Discounting balances, present and future resource use

People generally prefer to consume goods and resources now rather than in the future. This is because future consumption is uncertain, and immediate satisfaction is often more valuable. To compare present and future resource flows, economists use a technique called discounting. Discounting reduces the present value of future benefits or costs by applying a discount rate. This is similar to how money today is worth more than the same amount in the future due to inflation, risk, and opportunity cost. When managing natural resources (e.g., forests, fisheries, or fossil fuels), discounting helps to determine how much should be used today versus how much should be preserved for the future. If future resource flows are not discounted, they may appear too valuable, leading to excessive conservation and underuse today. On the other hand, if future benefits are

over-discounted, too many resources might be exploited now, leaving future generations with shortages.

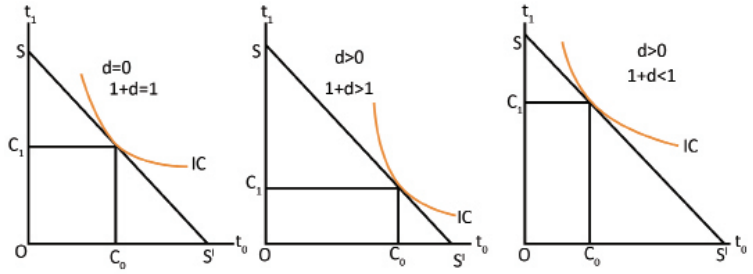

Fig 2.2.1 Inter-temporal Allocation of Fixed Resources Stock Under Different Levels of Social Time Preference

Figures 2.2.1 illustrate the determination of the optimal allocation of resource use between the current period (t_0) and the future period (t_1). In each figure, the total available stock of resources is represented by SS', where OS is the total resource stock. This stock can be fully consumed in the present period (t_0) or preserved entirely for future consumption (t_1). The straight line SS' represents all possible combinations of resource consumption in the two time periods. The society's indifference map, which shows preferences between current and future consumption, is then superimposed on this line.

- Resource use is balanced between the present and the future

In Figure 2.2.1 a, the marginal rate of time preference (d) is equal to zero (d = 0). Thus, individuals do not prefer current consumption over future consumption. This results in an equal allocation of resources between the two periods. The slope of the indifference curve is (1 + d) = 1, indicating no preference bias towards either time period. Therefore, the resource stock is divided equally, with OC_0 consumed in the current period (t_0) and C_0S' preserved for future consumption. Consequently, future consumption will be OC_1 in period (t_1).

- Individuals do not prefer current consumption over future consumption

In Figure 2.2.1 b, the marginal rate of time preference (d) is positive (d > 0), so that individuals prefer current consumption over future consumption. Since (1 + d) > 1, the indifference curve reflects a higher preference for present consumption, leading to an increased rate of resource extraction in the current period (t_0). This results in a higher level of resource use now (OC_0) and a lower amount of resource preservation for the future.

- Individuals prefer current consumption over future consumption

- Time preference affects resource consumption between periods

In Figure 2.2.1 c, the marginal rate of time preference is negative ($d < 0$), indicating that individuals prefer future consumption over current consumption. In this case, $(1 + d) < 1$, leading to a low level of current consumption and maximum preservation of resources for future use. Only OC0 is consumed in the current period (t_0), while C0S' is preserved to ensure a high level of future consumption (OC_1) in period (t_1). Thus, the optimal allocation of resources depends on the marginal rate of time preference (d). A higher preference for present consumption ($d > 0$) leads to greater resource extraction in the current period, whereas a higher preference for future consumption ($d < 0$) results in greater resource conservation for future use.

II) Renewable Resources: The Optimum Extraction Theory of Renewable Resources

- Renewable resources regenerate but can be depleted if overused

A renewable resource is a natural resource that can regenerate itself over time, i.e., its stock is not fixed. However, if the rate of extraction exceeds the rate of regeneration, the available stock can decline, which leads to resource depletion. Examples of renewable resources include fish stocks and forests, where proper management is essential to ensure sustainable use. If these resources are harvested at an optimal rate, they can continue to provide economic benefits indefinitely. However, over-exploitation can lead to long-term ecological and economic consequences, such as species depletion or deforestation.

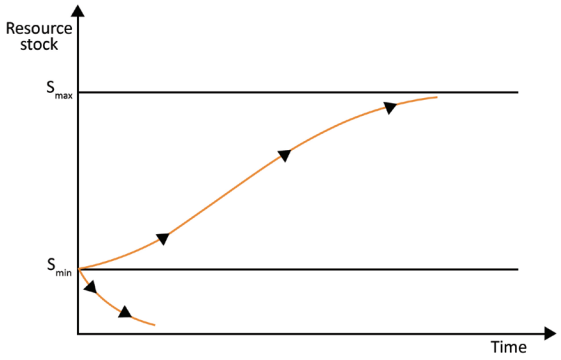

Fig 2.2.2 Growth of Renewable Resource Over Time

Figure 2.2.2 illustrates the population trends of a hypothetical renewable resource, such as a fish population, over time (t). The graph depicts the cumulative growth curve of the resource

- Fish population grows, faces limits, reaches maximum capacity

stock (S) as a function of time. Initially, the fish population grows at an increasing rate, as there are sufficient resources available. However, as population size increases beyond a certain level, competition for food and space intensifies, leading to a declining growth rate. Eventually, the population reaches its maximum sustainable level, Smax, which represents the carrying capacity of the ecosystem-the maximum stock size that the environment can support indefinitely.

- A minimum population is needed to prevent species extinction

The cumulative growth curve exhibits an initial phase of rapid growth (increasing increments), followed by a phase of slower growth (decreasing increments). The curve has a vertical intercept, indicating that there is a critical minimum population level (Smin) required for the species to survive and regenerate. If the stock size (S) falls below this threshold (Smin), the population will fail to sustain itself, ultimately leading to extinction.

- Resource growth depends on stock size and ecology

The optimum extraction theory of renewable resources is based on the growth function (G), which represents the biological growth of the resource. This function depends on the size of the existing stock (S) and the ecological characteristics of the ecosystem. This type of growth, where the growth rate depends on stock size, is referred to as density-dependent growth. Mathematically, the growth function can be expressed as follows.

G=G(S) where G represents the biological growth of the resource in a given period, and S denotes the current stock size.

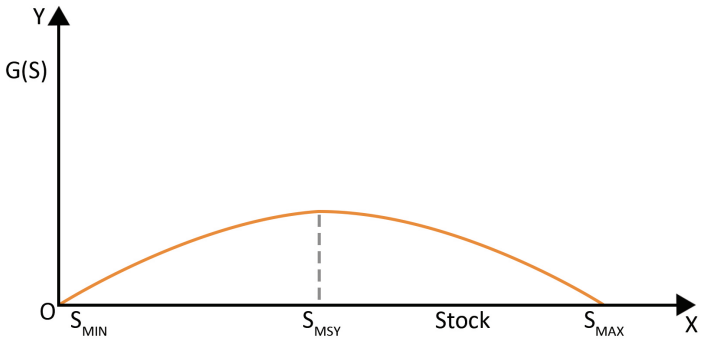

Fig 2.2.3 Logistic Growth Curve of a Renewable Resource

Figure 2.2.3 illustrates the relationship between the stock size (S) of a renewable resource and its biological growth rate (G). As the stock size increases from zero, the growth of the

- As stock size continues to grow, the growth rate declines

resource initially rises, reaching a maximum point. The stock size at which the maximum growth occurs is known as the Maximum Sustainable Yield (S_{MSY}). Beyond this point, as stock size continues to grow, the growth rate declines due to environmental constraints and resource competition.

- Maximum sustainable yield occurs before growth declines

The maximum stock size (S_{MAX}) represents the carrying capacity of the ecosystem, beyond which the resource cannot grow further. The slope of the growth-stock curve at any point is given by the derivative $\frac{dG}{dS}$, which represents the rate of change of biological growth with respect to stock size. Any changes in environmental factors, such as temperature variations in a river ecosystem, can alter the stock size (S) and shift the growth curve. However, another critical threshold is S_{MIN}, which represents the minimum viable stock size required for the survival of the species. If stock size falls below S_{MIN}, natural mortality exceeds reproduction, leading to species extinction. At both S = 0 and S = S_{MAX}, biological growth (G) is zero, while for all intermediate values, growth remains positive.

- Sustainable harvest prevents extinction and ensures resource stability

To ensure sustainable resource use, the rate of harvest (H) must be carefully managed. If the harvest rate (H) is set equal to MSY, the resource will sustain itself indefinitely. However, MSY does not necessarily indicate the optimal harvest level, as it does not account for economic factors such as costs and revenues associated with harvesting.

- The level of resource exploitation depends on effort

The level of resource exploitation depends on effort (E), which represents the resources and time devoted to harvesting. Effort is mathematically expressed as:

$$E = \frac{H}{S}$$

where S is the stock size and H is the actual harvest. For example, if the fish population (S) in a pond is 200 fish and 100 fish are harvested, then;

$$E = \frac{100}{200} = \frac{1}{2}$$

A higher effort level (E) leads to a higher harvest (H).

Figure 2.2.4 illustrates the relationship between effort level (E), harvest (H), and stock size (S). The harvest function is given by

$$H = E \times S$$

For example, if and S = 200, then:

Then $H = \frac{1}{2} \times 200 = 100$

- Harvest depends on the effort level and stock size

This equation $dE = \frac{1}{2}$ strates that the harvest level (H) depends on both the effort level (E) and the resource stock size (S).

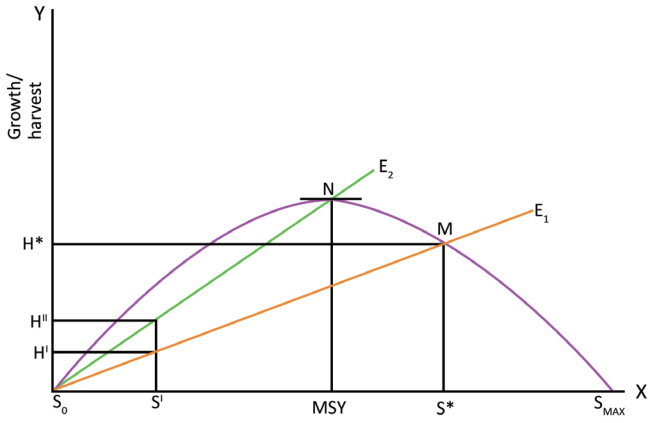

Fig 2.2.4 Effort-Growth Relationship

- Harvest depends on the effort level and stock size

In Figure 2.2.4, an effort level E_1 results in a harvest level H for a stock size S'. If effort increases to the harvest level increases to H. The sustainable harvest level (H)* occurs at the point where effort (E_1)ntersects the biological growth curve (point M in the figure), which signifies that the harvest rate equals the natural growth rate of the resource.

- Proper effort ensures sustainable harvest and resource preservation

If harvest exceeds H* (i.e., if extraction E_2, greater than the sustainable yield), the stock will decline, potentially leading to resource depletion and eventual species extinction in the long run. Conversely, if harvest is less than H*, the stock will grow due to positive biological regeneration. A harvest level below H*, such as H', implies that extraction is lower than the natural regeneration rate of the resource, allowing stock to recover to S*. However, it is crucial to note that H* is not the Maximum Sustainable Yield (MSY). For H* to be equal to MSY, the effort level must be E_2 instead of E_1 The correct choice of effort level determines both harvest sustainability and long-term stock preservation.

To determine the optimum harvest level, we introduce the Total Revenue (TR) and Total Cost (TC) functions into the

analysis. The following assumptions are made.

a. The price of the resource (e.g., fish) remains constant.

b. The marginal cost (MC) of extraction is constant.

c. The amount of harvest (H) per unit of effort (E) is proportional to the resource stock (S). It means that a smaller stock results in lower harvest levels.

- Optimum harvest depends on revenue, cost, and stock

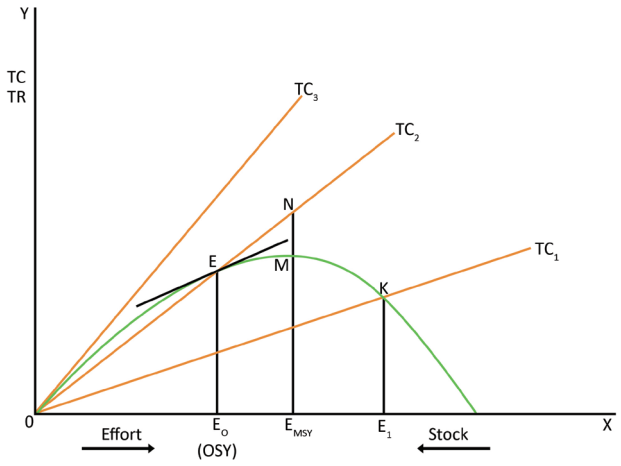

Fig 2.2.5 Optimum Sustainable Yield

The graph represents the relationship between total cost (TC), total revenue (TR), fishing effort, and stock levels to determine the optimum sustainable yield (OSY). The total cost (TC) function increases linearly, as it includes wages, fuel, and equipment costs. TR is represented by the curve passing through points E, M, and K. This curve shows how harvest (and revenue) increases with fishing effort up to a certain point, then decreases due to overfishing and stock depletion. The optimum sustainable yield (OSY) occurs at effort level E0, where the gap between TR and TC is the widest, indicating that profits are maximised. At this point, the marginal cost (MC) of harvesting equals the marginal revenue (MR). If effort increases beyond E_0, costs rise, and MC exceeds MR, leading to reduced profitability. If effort continues unchecked, overexploitation can occur, shifting the equilibrium to K, where TC equals TR, eliminating profits and endangering stock levels.

- Optimum yield maximises profit; overexploitation reduces sustainability

An open-access resource allows unrestricted

- Unrestricted access depletes resources

exploitation by anyone capable of harvesting it, often leading to negative externalities. This scenario reflects Hardin's 'Tragedy of the Commons', where unrestricted use depletes the resource. However, common property resources differ as they are jointly managed by a group with defined usage rights. While these resources may also face depletion, it largely depends on the effectiveness of enforcement mechanisms governing their use (Robert Wade, 1987).

- High discount rates cause overuse

Common property resources are shared by a community or village, but no single individual has exclusive ownership. Instead, specific rights are governing their use. These resources are often held as private property by a group, but weak enforcement of rules can lead to their overuse and depletion. The way these resources are used over time depends on the discount rate, which affects decisions about resource exploitation. The key rule for managing a renewable resource is based on its biological growth rate (b), the growth in capital value (c) from leaving it unharvested, and the discount rate (d). If $d > (b + c)$, the resource will be used immediately because waiting is not beneficial. If $d < (b + c)$, delaying harvest is better. High discount rates can lead to overexploitation and even extinction, as seen with species like elephants and whales, which have very low biological growth rates and struggle to survive against high discount rates.

III) Non-Renewable Resources: Theory of Optimum Extraction of Exhaustible Resources

- Non-renewable resources are limited in quantity

Non-renewable resources are limited in quantity; the more we extract today, the less will be available for future generations. This creates an opportunity cost, known as user cost, which is central to the theory of optimum extraction of exhaustible resources. For renewable resources, the fundamental rule for sustainable harvesting states that;

Biological growth rate + growth in capital value = discount rate

However, for exhaustible resources, there is no growth function. So the equation simplifies to;

Growth in capital value (c) = Discount rate (d)

This is the core idea of the Hotelling Rule, introduced by Harold Hotelling in 1931 in his paper 'The Economics of

Exhaustible Resources.' According to this rule, under optimal extraction, the price of the resource should increase at a rate equal to the discount rate or interest rate. In equilibrium, the net price of the resource (market price minus extraction cost) should rise at the same rate as the interest rate. If there are no extraction costs, the price of the extracted resource is the same as its price in the ground. If extraction costs exist, the final price of the extracted resource will be higher. The price of the resource in the ground is often called royalty, rent, or user cost, as it reflects the value of leaving the resource unextracted for future use. With a positive user cost, the price of an extracted resource at any time is given by;

- Exhaustible resources lack growth; extraction involves opportunity cost

$P = C + R,$

where C is the extraction cost, and R (royalty) is also known as rent or marginal user cost (MUC). The optimal price (P)* is determined as;

$P^* = MEC + MUC,$

- Hotelling rule states that resource price rises with time

where MEC is the marginal extraction cost and MUC is the marginal user cost. Optimal use and pricing of an exhaustible resource may be explained using a simple model, which is illustrated as follows.

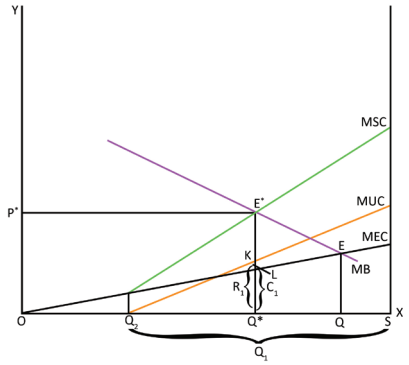

Fig 2.2.6 Optimum Use of Non Renewable Resource

- Overuse today reduces resource availability for future generations

The graph illustrates the optimal use of a non-renewable resource by balancing present consumption with future availability. The total stock of the resource is S, and the future demand for the resource is Q_1. If the resource is extracted within Q_2 (where Q_2, = S -Q_1) future availability is not affected, and there is no loss to future generations. However, if extraction exceeds the resource available for future use starts decreasing. This loss is known as the marginal user cost (MUC) or opportunity cost, which represents the value of future consumption that is forgone due to present use.

- Optimal extraction balances cost, benefit, and future availability

The marginal extraction cost (MEC) is the cost of extracting an additional unit of the resource. Since both MEC and MUC increase as more resources are extracted, the marginal social cost (MSC) curve slopes upward. The optimal extraction level (Q*) is determined at point E*, where the marginal benefit (MB) curve intersects the MSC curve. At this point, the resource price is P*, ensuring a sustainable balance between present and future use. The price is determined by the rule P=C+R, where C is the extraction cost, and R (resource rent) accounts for the opportunity cost.

At equilibrium extraction Q*, the cost components are;

Q*K (marginal user cost)

Q*L (marginal extraction cost)

Thus, the price P* is given by;

$P^* = Q^*K + Q^*L = MEC + MUC$

If MUC is ignored, the equilibrium shifts where MEC intersects MB, leading to over-extraction beyond Q*. This excessive use depletes the resource too quickly, harming future generations. By considering user costs, extraction is limited to Q*to promote sustainable resource management.

- Considering user cost ensures sustainable and profitable extraction

For a resource owner, the decision on how much to extract depends on maximising the present value of discounted profit. If future prices are expected to rise, the owner may choose to postpone extraction to sell the resource at a higher price. Similarly, if technological advancements are expected to lower extraction costs in the future, delaying extraction becomes a more profitable option. This highlights the importance of considering both marginal extraction cost and marginal user cost in the sustainable management of exhaustible resources.

2.2.2 Environment and Development Trade-Off

- Economic theory manages scarce resources for sustainable development

Economic theory addresses fundamental questions about resource allocation, such as what to produce, how to produce, and for whom to produce. It ensures that scarce resources are efficiently utilised to maximise human well-being. In earlier times, natural resources were considered abundant, and environmental concerns were treated as social issues. However, as industrialisation and economic growth have

intensified, environmental goods like clean air, water, and biodiversity have become scarce, making them economic goods. This shift has led economists to apply economic principles to environmental challenges, in order to recognising the trade-off between development and environmental quality.

- Balancing growth and environment requires careful trade-offs

The trade-off between environment and development refers to the necessity of sacrificing environmental quality to achieve economic growth. When a country focuses on increasing its production of goods and services, industries expand, urbanisation accelerates, and natural resources are heavily exploited. This leads to pollution, deforestation, and depletion of natural resources, leading to degradation of environmental quality. On the other hand, if a country prioritises environmental protection by limiting industrial activity and controlling resource use, economic growth may slow down, which affects employment and income levels.

2.2.2.1 The Production Possibility Frontier (PPF) and Opportunity Cost

The Production Possibility Frontier (PPF) illustrates the different combinations of environmental quality and other goods and services that a society can produce with its given resources and technology.

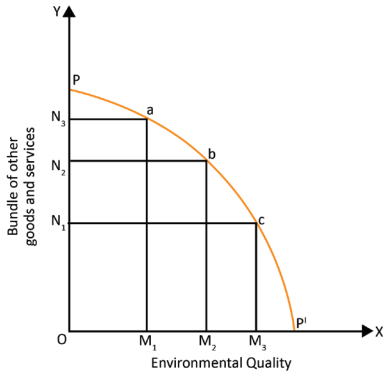

Fig 2.2.7 The Production Possibility Frontier

In the graph, the curve PP' represents the production possibility frontier (PPF), where points such as a, b, and c indicate different combinations of environmental quality and production of goods and services. At point 'a', society produces a high quantity of goods and services but maintains a lower environmental quality. Moving from point 'a' to

- Improving environmental quality requires sacrificing economic output

'b' increases environmental quality, but this comes at the opportunity cost of reducing the production of other goods and services. Further shifting to point 'c' achieves even greater environmental quality but requires giving up a substantial portion of economic output. This demonstrates that improving environmental quality involves trade-offs, where every additional unit of environmental quality comes at the cost of sacrificing other economic benefits.

- Environmental degradation rises, then falls with growth in income

Another important concept in this regard is the Environmental Kuznets Curve. The Environmental Kuznets Curve suggests that environmental degradation initially rises with economic growth but eventually declines after reaching a certain level of income. This results in an inverted U-shaped curve, as shown in the figure below. At low-income levels, people prioritise basic needs like food, shelter, and clothing, paying little attention to environmental quality. As income rises, industrialisation and urbanisation lead to increased pollution and resource depletion. However, once a country reaches a higher level of income, people demand a cleaner environment, and governments implement stricter environmental policies. This shift reduces pollution and promotes sustainable development.

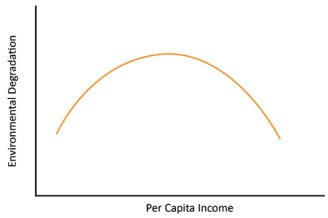

Fig 2.2.8 Environmental Kuznets Curve

- Economic growth may improve the environment with proper policies

The EKC suggests that economic growth, in the long run, can lead to improved environmental quality if proper policies and technological advancements are in place. However, it is not guaranteed. Some environmental damages, like climate change and biodiversity loss, may not reverse even with higher income levels. To balance economic growth with environmental conservation, policymakers focus on sustainable development, ensuring that present needs are met without compromising the future. This is achieved through green technologies that reduce pollution while maintaining industrial output, environmental regulations that set limits on pollution and resource use, and economic incentives such as pollution taxes and renewable

energy subsidies. These strategies help to address the trade-off between environment and development effectively.

2.2.3 Environmental Accounting

- Environmental accounting measures and values natural resources

Environmental accounting refers to the process of recording and valuing environmental goods, amenities, and services within a structured set of accounts. It involves identifying and measuring the benefits and costs of environmental resources, assigning appropriate values to them, and incorporating these values into national accounts. This system includes both physical accounts (measuring environmental resources in quantity) and monetary accounts (assigning financial value to these resources).

- Environmental accounting tracks resource use and trade-offs

The need for environmental accounting arises from the crucial role that natural resources play in economic performance and human welfare. The environment provides four main types of services, viz, material inputs such as raw materials, life-supporting services like clean air and water, recreational opportunities, and space for waste disposal. However, increasing the use of one service often reduces the availability of another.

- Traditional accounts ignore environmental impact and sustainability

Traditional national accounts primarily record the values of marketed environmental goods and services but fail to capture the overall contribution of the environment to human well-being. The depletion of natural resources and environmental degradation pose significant threats to long-term economic sustainability. Economic activities generate waste and pollutants, which, if not accounted for, can lead to incorrect assessments of economic progress. This omission can result in misleading signals for policymakers, potentially pushing society towards an unsustainable development path.

- Include environmental costs for sustainable economic growth

To ensure sustainable economic growth, it is necessary to incorporate the costs associated with environmental degradation and resource depletion into economic decisions. This would prevent the tendency to treat natural resources as 'free goods' and shift the costs of environmental damage to future generations. A macro-level system of environmental accounting can help to assess whether economic growth is improved or depleting the natural resource base. Furthermore, evaluating the environmental costs and benefits of different activities and policies ensures that these factors are considered in decision-making.

2.2.3.1 Genesis of Environmental Accounting

- Integrate environmental factors into economic accounting

Growing environmental concerns and increasing awareness about ecological sustainability have highlighted the need for integrating environmental factors into economic accounting. Conventional national accounts primarily focus on market activities and economic growth, overlooking non-marketed natural assets and income losses due to resource depletion. Unlike human-made capital, natural assets are not depreciated in traditional accounting, making it difficult to assess the true cost of environmental degradation.

- UN emphasised environmental accounting; SEEA framework introduced

Recognising this gap, the United Nations Conference on Environment and Development (Earth Summit) held at Rio de Janeiro in 1992 emphasised the need for environmental accounting. In response, the United Nations Statistics Division (UNSD) published the System of Environmental Economic Accounting (SEEA) handbook in 1993. Developed in collaboration with the United Nations Environment Programme (UNEP) and the World Bank, SEEA provided a framework for integrating environmental data into national accounts. Several countries, including Canada, Colombia, Ghana, Indonesia, Japan, Mexico, and the United States, tested parts of the SEEA framework, though full implementation was hindered by data limitations and valuation challenges. Due to the limitations of conventional national accounts, there has been significant interest in expanding their scope to include the monetary valuation of environmental goods, services, and functions. Over a hundred studies on green accounting have been conducted worldwide, particularly in developed and developing nations.

- Forest Resource Accounting (FRA) gains significant attention

Among different areas of environmental accounting, forest resource accounting (FRA) has received the most attention. The first major attempt to develop a forest accounting system was made in 1993 by the International Tropical Timber Organisation (ITTO), in collaboration with the International Institute for Environment and Development (IIED) and the United Nations Environment Programme - World Conservation and Monitoring Centre (UNEP - WCMC). This system was officially adopted by ITTO member countries. In 1997, the Food and Agriculture Organisation (FAO) recognised FRA as a crucial tool for managing forestry sector data and recommended its implementation. Countries such as Ecuador, Guyana, Indonesia, and Pakistan have adopted FRA, while others are considering its implementation. However, India has

yet to adopt this system as recommended by FAO.

Environmental accounting is essential for ensuring that economic growth does not come at the cost of environmental degradation. By incorporating the values of natural resources into national accounts, policymakers can make informed decisions that balance economic progress with ecological sustainability.

2.2.4 Measurement of Environmentally Corrected GDP

- Environmental factors impact economic sectors

Integrating environmental factors into national income accounting is a complex task due to challenges in valuation and measurement. To address this, economists use satellite accounts, which complement but remain separate from the conventional system of National Accounts. These accounts help to analyse how environmental factors interact with different sectors of the economy. One key approach is adjusting the Net Domestic Product (NDP) to account for environmental costs and benefits. This leads to the concept of Environmentally Adjusted Net Domestic Product (ENDP). The following adjustments need to be made to conventional GDP in order to account for the linkages of the forestry sector with other sectors of the economy.

The adjusted NDP is calculated as follows.

Adjusted NDP = Conventional GDP + Non-market values of forest benefits - Depreciation of human-made capital + Net accumulation of natural capital

- Adjusted NDP accounts for environmental costs and benefits

This modification incorporates both environmental degradation and the benefits derived from natural resources.

To integrate environmental factors systematically, the System of Environmental Economic Accounting (SEEA) maintains standard accounting identities.

1. Supply-Use Identity

O+M=IC+C +/- CF+X

Where;

O = Domestic output

M = Imports

IC = Intermediate consumption

C = Final consumption

CF = Capital formation

X = Exports

The Supply-Use Identity ensures that the total goods and services available in an economy, both those produced domestically and imported, are fully accounted for in terms of their usage. These can be used in production (intermediate consumption), consumed by households and government, invested in new assets (capital formation), or exported. If capital formation (CF) is positive, it means the economy is investing in new assets like buildings and machinery, leading to growth. If CF is negative, it indicates that assets are being used up or depreciated, reducing the economy's productive capacity over time.

- Supply-Use Identity tracks goods, services, and investments

2. Environmentally Adjusted Value-Added Identity

The Environmentally Adjusted Value-Added Identity modifies the traditional value-added calculation by accounting for environmental costs. It measures the actual contribution of an industry to the economy after deducting not just production costs but also the costs of natural resource depletion and environmental degradation.

$EVA_i = O_i - IC_i - CC_i - EC_i = NVA_i - EC_i$

Where;

EVA_i = Environmentally adjusted value added for industry i

O_i = Output of industry i

IC_i = Intermediate consumption

CCi = Fixed capital consumption (depreciation)

EC_i = Environmental costs (resource depletion and degradation)

NVA_i = Net value added

- EVA shows true industry contribution by including environmental costs

The above equation shows that an industry's environmentally adjusted value added (EVA_i) is obtained by subtracting intermediate consumption (IC_i), fixed capital consumption (Cc_i or depreciation), and environmental costs (Ec_i) from its total output (O_i). This gives a more realistic and sustainable measure of economic performance, preventing industries that cause significant environmental harm from appearing more successful than they actually are.

3. Environmentally Adjusted Domestic Product Identity

The Environmentally Adjusted Domestic Product Identity modifies the traditional measure of national income by incorporating environmental costs and benefits.

$$ENDP = \sum EVA_i - ECh - CC - EC - X + M$$

Where;

ENDP = Environmentally Adjusted Net Domestic Product

$\sum EVA_i$ = Sum of environmentally adjusted value added across industries

- ENDP adjusts national income by including environmental costs

EC_h = Environmental costs borne by households

CC = Capital consumption

EC = Overall environmental degradation costs

X and M represent net exports and imports

This identity ensures that environmental costs and benefits are reflected at the national level.

- ENDP reflects true economic cost of environmental impact

The above equation calculates the Environmentally Adjusted Net Domestic Product (ENDP) by summing up the environmentally adjusted value added ($\sum EVA_i$) across industries and then subtracting environmental costs borne by households (EC_h), capital consumption (CC), and overall environmental degradation costs (EC) while adjusting for net exports (X) and imports (M). This equation ensures that a country's economic performance reflects the true cost of resource depletion and environmental damage. It provides a more sustainable indicator of economic well-being.

- NEP 2006 promotes environmental accounting and sustainability

The National Environment Policy (NEP) 2006 outlines measures to enhance environmental accounting in India, including strengthening natural resource accounting, standardising environmental reporting by industries, integrating environmental costs into financial decisions, and promoting economic instruments for environmental regulation. These efforts aim to ensure that environmental sustainability is considered in economic decision-making, which will lead to a more accurate measure of economic progress.

2.2.5 Green GDP

Green GDP (Green Gross Domestic Product) is an economic indicator that adjusts traditional GDP by accounting for environmental costs such as resource depletion, pollution, and climate change effects. While conventional GDP (Gross Domestic Product) measures a nation's economic output, it does not take into account environmental degradation. Green GDP aims to bridge this gap by incorporating the economic value of environmental losses and conservation efforts.

The calculation of Green GDP follows the given equation.

Green GDP = GDP - Natural Capital Consumption

- Green GDP adjusts GDP for environmental costs

where Natural Capital Consumption includes factors like deforestation, water pollution, air quality degradation, and biodiversity loss. Similarly, Green NDP (Net Domestic Product) can be computed as follows.

Green NDP=NDP-Environmental Depreciation

where NDP (Net Domestic Product) accounts for capital depreciation, and environmental depreciation refers to the depletion of natural resources.

- Green GDP links economic growth with environmental sustainability

Green GDP emphasises the interconnectedness of economic growth and environmental sustainability. Nations such as China started adopting this concept in 2004, while India has also shown interest in implementing it. Green GDP offers several key advantages by integrating environmental sustainability into economic assessments. It establishes a crucial link between the economy and nature. Additionally, it enables comparability across time and regions, allowing countries to evaluate their environmental progress and benchmark sustainability efforts against other nations. Furthermore, Green GDP facilitates

depletion analysis, which helps investors to assess whether a country's natural resources are being overexploited.

However, challenges persist in Green GDP measurement. Assigning monetary values to intangible environmental benefits, such as clean air and biodiversity, is complex. Additionally, public resources like oceans and forests lack private ownership, making valuation difficult. Despite these hurdles, Green GDP remains a crucial step toward achieving a Green Economy.

Summarised Overview

Theories of optimal resource use aim to balance economic growth with sustainable management. Natural resources are classified as renewable (forests, water, fisheries) and non-renewable (coal, oil, natural gas). Renewable resources regenerate if used sustainably, while non-renewable resources are finite and require efficient extraction.

For renewable resources, the Maximum Sustainable Yield (MSY) and Optimal Sustainable Yield (OSY) models guide resource extraction and prevent depletion. Inter-temporal choice theory explains how societies allocate resources between present and future use, employing discounting to assess future value. Non-renewable resources require strategic extraction, with Hotelling's Rule stating that the price of a non-renewable resource should increase at the rate of interest (the opportunity cost of capital) to reflect the scarcity and ensure that the resource is conserved for future generations. Marginal extraction cost (MEC) and marginal user cost (MUC) determine equilibrium prices, preventing over-extraction and economic instability.

Economic growth can degrade the environment. The Production Possibility Frontier (PPF) illustrates this trade-off, while the environmental kuznets curve suggests that pollution rises with growth but declines at higher income levels with better regulations. Environmental accounting integrates ecological costs into national income, with the System of Environmental Economic Accounting (SEEA) valuing natural assets. Green GDP redefines traditional GDP by incorporating environmental depletion and pollution.

Assignments

1. Explain the theories related to the optimal use of exhaustible and renewable resources.
2. Discuss the trade-off between economic development and environmental sustainability with examples.
3. Describe the concept and significance of environmental accounting.

4. Compare Green GDP with traditional GDP and discuss its implications for sustainable development.
5. Explain how the Production Possibility Frontier (PPF) represents the balance between environmental conservation and economic growth

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Suggested Reading

1. Hotelling, H. (1931). *The Economics of Exhaustible Resources.* Journal of Political Economy, 39(2), 137-175.
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3. Conrad, J. M. (2010). *Resource Economics* (2nd ed.). Cambridge University Press.

Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

UNIT 3 Sustainable Development Goals: India and Kerala

Learning Outcomes

After completing this unit, the learner will be able to:

- comprehend the concept of Sustainable Development Goals (SDGs)
- explain India's efforts and policies to achieve the SDGs
- identify Kerala's progress on SDGs

Background

Learners have already studied economic growth, development, and the role of government in a country's progress during undergraduate studies. Development is not just about increasing income levels but also about improving the overall well-being of the people. Access to quality education, healthcare, clean water, employment opportunities, and environmental protection is essential for a nation's progress.

However, development is often uneven, with some regions and groups benefiting more than others. Issues like poverty, unemployment, pollution, and climate change continue to affect many parts of the world, including India. To address these challenges, the United Nations introduced the Sustainable Development Goals (SDGs) in 2015. These 17 global goals aim to eliminate poverty, reduce inequality, protect the environment, and promote sustainable growth.

India, as a developing country, has taken several initiatives to achieve these goals by 2030. Kerala, in particular, is considered a model for sustainable development due to its achievements in healthcare, education, and social welfare.

This unit will help learners to understand how India and Kerala are working towards achieving the SDGs, and the challenges involved.

Keywords

Sustainable Development Goals, Poverty, Education, Equality, Innovation, Climate Action, Life Below Water, Life on Land, NITI Aayog

Discussion

2.3.1 Sustainable Development Goals

- SDGs aim for inclusive and sustainable global development

The Sustainable Development Goals (SDGs) represent a comprehensive framework of 17 goals and 169 specific targets designed to guide development efforts worldwide. Adopted by 193 United Nations member states in September 2015, these goals aim to enhance human well-being and promote sustainable economic growth by 2030. The SDGs address a wide range of economic and social issues, including poverty eradication, health and sanitation improvements, urban development, and safeguarding global ecosystems. By focusing on inclusive growth and resource allocation, the SDGs strive to ensure that no one is left behind, which is based on the principles of equity and efficiency in economic development. These goals were established by the United Nations to address key challenges and ensure a better future for all by 2030.

Fig 2.3.1 Sustainable Development Goals

Here is a brief overview of each goal.

1. **No Poverty:** End poverty in all its forms everywhere, ensuring equitable resource distribution and access to basic needs.

2. **Zero Hunger**: Achieve food security, improve nutrition, and promote sustainable agriculture to combat hunger.
3. **Good Health and Well-being:** Ensure healthy lives and promote well-being for all ages, focusing on healthcare access and disease prevention.
4. **Quality Education:** Provide inclusive and equitable quality education and lifelong learning opportunities for all.
5. **Gender Equality:** Advance gender equality and empower all women and girls, promoting equal opportunities in all sectors.
6. **Clean Water and Sanitation:** Ensure availability and sustainable management of water and sanitation for all.
7. **Affordable and Clean Energy:** Ensure access to affordable, reliable, sustainable, and modern energy for all.
8. **Decent Work and Economic Growth:** Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
9. **Industry, Innovation, and Infrastructure**: Build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation.
10. **Reduced Inequality:** Reduce inequality within and among countries, focusing on fair economic policies and social protection.
11. **Sustainable Cities and Communities:** Make cities and human settlements inclusive, safe, resilient, and sustainable.
12. **Responsible Consumption and Production:** Ensure sustainable consumption and production patterns, emphasising resource efficiency.
13. **Climate Action:** Take urgent action to combat climate change and its impacts through mitigation and adaptation strategies.
14. **Life Below Water**: Conserve and sustainably use oceans, seas, and marine resources for sustainable development.
15. **Life on Land**: Protect, restore, and promote sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, and halt biodiversity loss.
16. **Peace, Justice, and Strong Institutions**: Promote peaceful and inclusive societies, provide access to justice

- SDGs outline 17 goals for global sustainable development

for all, and build effective, accountable institutions.

17. **Partnerships for the Goals:** Strengthen global partnerships and mobilise resources to achieve sustainable development.

2.3.2 India and The Sustainable Development Goals

- India integrates policies with SDGs for inclusive growth

As the most populous country, India plays a crucial role in achieving the Sustainable Development Goals (SDGs). Recognising this responsibility, India has actively integrated its policies with the 2030 Agenda for sustainable development. The Government of India has emphasised inclusive and sustainable growth, reflected in its motto, 'Sabka Saath, Sabka Vikas.' This vision harmonises with the SDG framework's core principle of 'Leaving No One Behind' (LNOB).

- India incorporates SDGs in policies through institutional efforts

India's efforts towards achieving the SDGs are driven by NITI Aayog, State governments, and other development partners. These stakeholders ensure that SDGs are embedded in core policy formulations. The universal and normative appeal of the SDG framework has further strengthened India's commitment to institutionalising sustainable development. Instead of treating SDGs as separate goals, India integrates them into national policies through institutional ownership, collaborative competition, capacity development, and a whole-of-society approach.

- State governments play a key role in SDG implementation

India's federal structure, which focuses on decentralised governance, plays a significant role in implementing the SDGs. State governments have a constitutional responsibility for many SDG-related sectors, and their combined capital expenditure exceeds that of the central government. However, there is an inequality in per capita social sector expenditure among different States. While increasing social sector spending is essential, ensuring its efficient allocation and effective translation into developmental outcomes is equally important.

- India implements schemes to advance SDG progress

To accelerate progress on SDGs, the Government of India has designed and implemented various interventions, programmes, and schemes. These include Central Sector Schemes, which are fully funded by the central government and focus on areas such as healthcare, education, and social protection. Centrally Sponsored Schemes, jointly funded by both central and state governments, target key sectors like agriculture, rural development, and infrastructure. Additionally, State

Government schemes address local priorities and challenges. These multi-layered strategies helps to alleviate poverty, improve health outcomes, increase educational attainment, promote gender equality, and ensure environmental sustainability.

Gender equality and women's empowerment are central to India's SDG efforts. Several key government initiatives have been mapped to specific SDGs, highlighting their impact on economic and social development.

- SDG localisation focuses on development in disadvantaged regions

Given India's vast and diverse terrain, SDG localisation is a major priority. Central, State, and local governments have implemented numerous schemes to tackle social, economic, and environmental challenges. NITI Aayog's Aspirational Districts and Blocks Programme is a notable initiative aimed at improving governance and service delivery in the least-developed regions. This programme enhances citizens' quality of life by converging existing schemes, setting clear outcome-based goals, and continuously monitoring progress to bridge development gaps. Such initiatives not only accelerate SDG progress but also create positive spillover effects across interconnected development goals.

- India's SDG initiatives inspire global development efforts

India's approach to SDG implementation offers valuable lessons for other nations. The country has demonstrated transformative success through initiatives like IndiaStack, CoWIN, and the Self-Help Group (SHG) movement. These large-scale programmes showcase India's ability to achieve significant economic and social milestones. Given India's scale and experience, these initiatives serve as models for South-South Cooperation, promoting knowledge-sharing and collaborative growth among developing nations.

2.3.2.1 Goal-wise Key Government Initiatives Integrated with Sustainable Development Goals (SDGs)

Goal 1: No Poverty

To eradicate poverty, the government implements multiple financial inclusion and social security schemes. The Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) provides rural employment opportunities with wage security. The Deen Dayal Antyodaya Yojana (DAY)

- India implements schemes to eradicate poverty effectively

has two components viz; the National Rural Livelihood Mission (NRLM) and the National Urban Livelihood Mission (NULM), both of which promote self-employment and entrepreneurship. The Pradhan Mantri Jan Dhan Yojana ensures financial inclusion by providing bank accounts to the unbanked. To strengthen social security, the Pradhan Mantri Jeevan Jyoti Bima Yojana, PM Jeevan Jyoti Bima Yojana, Atal Pension Yojana, and National Social Assistance Programme (NSAP) offer life insurance, pension benefits, and assistance to vulnerable groups. The PM Awas Yojana focuses on affordable housing, and the Deen Dayal Upadhyaya (DDU)-Grameen Kaushalaya Yojana enhances skill development for employment generation.

Goal 2: Zero Hunger

- Achieving food security through support and sustainability

Food security is vital for economic stability. The Pradhan Mantri Garib Kalyan Anna Yojana provides free food grains under the National Food Security Act (NFSA), 2013. The Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) offers direct income support to farmers. The PM POSHAN Abhiyan (formerly the Mid-Day Meal Scheme) ensures nutritional support for school children. The Kisan Credit Card (KCC) and PM Fasal Bima Yojana provide credit and crop insurance to farmers. Programmes like the PM Kisan Sampada Yojana, National Mission on Sustainable Agriculture, National Food Security Mission, and Mission for Integrated Development of Horticulture focus on improving agricultural productivity. Additionally, the National Mission for Edible Oils - Oil Palm (NMEO-OP), National Livestock Mission, Soil Health Card Scheme, and Scheme for Modernisation and Reforms through Technology in Public Distribution System (SMART - PDS) aim to enhance food production, distribution, and sustainability.

Goal 3: Good Health and Well-being

The National Health Mission (NHM) strengthens healthcare services across the country. Pradhan Mantri Jan Arogya Yojana (Ayushman Bharat) provides health insurance to economically weaker sections. Maternal health schemes like PM Matru Vandana Yojana, Pradhan Mantri Surakshit Matritva Abhiyan (PMSMA), and Janani Suraksha Yojana (JSY) ensure financial assistance and safe delivery for pregnant women. The Anaemia Mukt Bharat initiative tackles malnutrition, while Saksham Anganwadi and POSHAN Abhiyan 2.0 focus on improving nutrition. The PM Jan Aushadhi Scheme makes affordable

- India strengthens healthcare access through various national initiatives

medicines accessible, and the National Ayush Mission (NAM) promotes traditional medicine systems. The Pradhan Mantri Swasthya Suraksha Yojana enhances healthcare infrastructure, and Mission Indradhanush 5.0 aims to increase immunisation coverage. Additionally, the Pradhan Mantri TB Mukt Bharat Abhiyaan works towards eliminating tuberculosis, and Ayushman Bharat Health and Wellness Centres enhance primary healthcare services.

Goal 4: Quality Education

- Nation promotes inclusive and quality education for all

The Samagra Shiksha Abhiyan integrates school education, while the New India Literacy Programme promotes adult education. The Mid-day Meal Scheme (PM POSHAN) ensures nutritional support for students. Scholarships like Pre & Post Matric Scholarships for SCs and the National Means-cum-Merit Scholarship help marginalised students. The PM SHRI (School for Rising India) initiative and Eklavya Model Residential Schools ensure quality education. Additionally, the Rashtriya Avishkar Abhiyan (RAA) promotes scientific temper, Padhe Bharat Badhe Bharat (PBBB) supports early reading and writing, and Skill Strengthening for Industrial Value Enhancements (STRIVE) enhances vocational training. The PM Uchchatar Shiksha Abhiyan (PM-USHA) focuses on improving the infrastructure of higher education.

Goal 5: Gender Equality

- Empowering women through education, financial support, and safety

Gender empowerment is essential for economic development. The Beti Bachao Beti Padhao Scheme promotes female education, while the Sukanya Samriddhi Yojana encourages savings for girls. The MUDRA Yojana supports women entrepreneurs through micro-financing. The Janani Suraksha Yojana (JSY) ensures safe motherhood, and the Kasturba Gandhi Balika Vidyalaya (KGBV) provides residential schools for girls. The Pragati Scholarship Scheme for Girls supports higher education, while the One-Stop Centre Scheme and Women Helpline Scheme assist women in distress. Additionally, the Shakti Sadan initiative focuses on women's safety and empowerment.

Goal 6: Clean Water and Sanitation

Water and sanitation are crucial for public health. The Swachh Bharat Mission (SBM) focuses on sanitation infrastructure, while the Jal Jeevan Mission (JJM) ensures tap water supply to rural households. The Atal Bhujal Yojana promotes

- Ensuring clean water, sanitation, and sustainable water management

groundwater conservation, and the Namami Gange Mission works on river rejuvenation and pollution control. The AMRUT 2.0 Scheme aims to improve urban water supply and sewage management, while the PM Krishi Sinchayee Yojana (PMKSY) enhances irrigation efficiency. Initiatives like Mission Amrit Sarovar, Jal Shakti Abhiyan: Catch the Rain, and the National River Conservation Programme (NRCP) focus on water conservation and river rejuvenation. Additionally, the National Perspective Plan (NPP) addresses long-term water resource management.

Goal 7: Affordable and Clean Energy

- Promoting clean, affordable, and sustainable energy access

It focuses on enhancing economic growth through access to clean energy. Initiatives like the SAUBHAGYA Scheme and PM Ujjwala Yojana provide electricity and LPG connections to households, while the Unnat Jyoti by Affordable LED for All (UJALA) promotes energy-efficient lighting. The PM-KUSUM Scheme supports solar energy in agriculture, and the Rooftop Solar Programme encourages solar power generation. Green Energy Corridors (GEC) and the Bio-Energy Programme aim to improve energy infrastructure and bioenergy usage. The National Green Hydrogen Mission promotes alternative fuels, and schemes like the Faster Adoption and Manufacturing of Electric Vehicles (FAME) and Electric Mobility Promotion Scheme (EMPS) boost clean transportation. Additionally, the Deen Dayal Upadhyaya Gram Jyoti Yojana and National Solar Mission further enhance rural electrification and solar energy adoption. The PM Surya Ghar Muft Bijli Yojana also contributes to providing free electricity to households.

Goal 8: Decent Work and Economic Growth

- Enhancing jobs, skills, and entrepreneurship for growth

It emphasises job creation and skill development to drive economic growth. The Production Linked Incentive (PLI) Scheme supports manufacturing, while the PM Employment Generation Programme (PMEGP) promotes self-employment. Skill development initiatives like Skill India, Pradhan Mantri Kaushal Vikas Yojana (PMKVY), and the National Skill Development Mission (NSDM) enhance workforce capabilities. The Pradhan Mantri Mudra Yojana (PMMY) provides financial support to small businesses, and the National Apprenticeship Promotion Scheme (NAPS) encourages apprenticeship training. Additionally, the Deendayal Upadhyaya Antyodaya Yojana and the National Urban Development Mission focus on poverty alleviation

and urban development. The Udyami Bharat Scheme further supports entrepreneurship and economic growth.

Goal 9: Industry, Innovation, and Infrastructure

This goal focuses on driving economic expansion through infrastructure and industrial growth. The Digital India initiative promotes digital infrastructure, while PM GatiShakti, with its National Master Plan, enhances multi-modal connectivity. The Industrial Corridor Development Programme and National Logistics Policy aim to improve industrial and logistics infrastructure. The North East Industrial Development Scheme (NEIDS) and Udyami Bharat Scheme support regional and entrepreneurial development. The Bharatmala Project and Pradhan Mantri Gram Sadak Yojana (PMGSY) enhance road connectivity. The PM Mega Integrated Textile Region and Apparel (PM MITRA) scheme supports textile manufacturing, and the Border Area Development Programme (BADP) focuses on border region development. Additionally, the Make in India and Start-up India programmes encourage entrepreneurship, complemented by ease of doing business initiatives to create a conducive business environment.

- Boosting infrastructure, industry, innovation, and entrepreneurship growth

Goal 10: Reduced Inequalities

Reduced Inequalities aims to ensure inclusive growth by addressing income disparities and supporting marginalised communities. The Aspirational Districts and Blocks Programme and Vibrant Village Programme focus on developing underprivileged regions. The Pradhan Mantri Vishwakarma Scheme supports artisans and craftsmen. Various umbrella programmes target the development of minorities, Scheduled Castes, Scheduled Tribes, and other vulnerable groups. Additionally, schemes for the development of Other Backward Classes, Denotified, Nomadic, and Semi-nomadic Tribes, as well as Economically Backward Classes (EBCs), aim to uplift these communities. The PM Development Initiative for the North East Region and Pradhan Mantri Jan Vikas Karyakram (PMJVK) further enhance development efforts in specific regions and for disadvantaged groups.

- Ensuring inclusive growth by uplifting marginalised communities

Goal 11: Sustainable Cities and Communities

It focuses on improving urban living standards through various initiatives. The Smart Cities Mission and Atal Mission for Rejuvenation of Urban Transformation (AMRUT) enhance

urban planning and infrastructure. The PM e-bus Seva Scheme, MRTS, and Metro Projects promote efficient and sustainable urban transportation. The Swachh Bharat Mission-Urban aims to improve urban cleanliness, while the Pradhan Mantri Awas Yojana-Urban (PMAY) ensures affordable housing. The National Heritage City Development and Augmentation Yojana (HRIDAY) preserves cultural heritage, and the Prime Minister's Street Vendors' Atmanirbhar Nidhi (PM SVANIDHI) provides micro-financing to street vendors. Additionally, the National Livelihood Mission - Ajeevika supports urban livelihoods, and the City Investment to Innovate, Integrate and Sustain 2.0 (CITIIS 2.0) encourages sustainable urban development. These initiatives collectively aim to create more sustainable and inclusive urban environments.

- Improving urban living with infrastructure and sustainability

Goal 12: Responsible Consumption and Production

It emphasises sustainable resource use for long-term economic and environmental health. The Lifestyle for Environment (LiFE) initiative promotes eco-friendly practices, while the National Policy on Biofuels supports the adoption of clean energy sources. The PM-KUSUM Scheme encourages the use of solar energy in agriculture. Additionally, the Renewable Energy Global Investment Promotion Meet and Expo (RE-INVEST) encourages investment in renewable energy projects, and the National Clean India Fund (NCEF) supports initiatives aimed at reducing pollution and promoting sustainable development. These efforts collectively aim to ensure responsible consumption and production patterns.

- Sustainable resource use for economy and environment balance

Goal 13: Climate Action

This focuses on environmental conservation to ensure economic sustainability. The National Action Plan on Climate Change (NAPCC) supports climate resilience through various missions. The National Mission for Sustaining the Himalayan Ecosystem and the National Clean Air Programme address specific environmental challenges. The National Mission for a Green India and the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) promote forest conservation and afforestation. The National Solar Mission and National Mission for Enhanced Energy Efficiency encourage the adoption of renewable energy and energy efficiency practices. Additionally, the National Water Mission aims to improve water resource management, while the National Mission for Sustainable Agriculture and the National Cyclone Risk Mitigation Project focus on sustainable

- Environmental conservation for resilience and sustainable development

agricultural practices and disaster risk reduction, respectively. These initiatives collectively aim to mitigate climate change impacts and promote sustainable development.

Goal 14: Life Below Water

- Marine conservation for sustainability and economic growth

This emphasises marine conservation to support the fishing economy and protect aquatic ecosystems. The Neel Kranti Mission (Blue Revolution) focuses on the development of fisheries, while the National Plan for Conservation of Aquatic Ecosystems (NPCA) aims to preserve aquatic habitats. The Pradhan Mantri Matsya Sampada Yojana enhances fish production and fishermen's livelihoods. The Sagarmala Project improves port-led infrastructure, and the Interlinking of Rivers aims to optimise water resource management. The National Coastal Mission and Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI) protects coastal ecosystems and promotes sustainable livelihoods. Additionally, the Ocean Services, Technology, Observation, Resources, Modelling and Science (OSTORMS) initiative supports marine research and resource management. These efforts collectively aim to ensure the sustainable use and conservation of marine and freshwater resources.

Goal 15: Life on Land

- Importance of sustainable land use

This gives importance to sustainable land use to preserve biodiversity and combat environmental degradation. The National Afforestation Programme and National Mission for a Green India focus on increasing forest cover and restoring ecosystems. The Integrated Development of Wildlife Habitats, Project Tiger, and Project Elephant aimed to protect and conserve wildlife and their habitats. The Nagar Van Yojana promotes urban forestry to enhance green spaces in cities. The National Action Programme to Combat Desertification addresses land degradation, while the National Agroforestry Policy encourages the integration of trees into farming systems for sustainable land use. These initiatives collectively work towards preserving terrestrial ecosystems and promoting biodiversity.

Goal 16: Peace, Justice, and Strong Institutions

It focuses on promoting good governance and economic stability. The PRAGATI 2.0 platform ensures proactive governance and timely implementation of projects. The Modernisation of Police Forces strengthens law enforcement

capabilities. The Right to Information (RTI) Act enhances transparency and accountability in governance. The Rashtriya Gram Swaraj Abhiyan promotes local self-governance and rural development. The Integrated Child Protection Scheme (ICPS) safeguards children's rights and welfare. Additionally, the development of infrastructure facilities for the judiciary, including Gram Nyayalayas, aims to improve access to justice and judicial efficiency. These initiatives collectively work towards building strong, transparent, and effective institutions.

- Efforts focus on governance, justice, transparency, security, and child protection

Goal 17: Partnerships for the Goals

It highlights the importance of international cooperation in accelerating development. India's active participation in the G20, UN SDG Forum, and BRICS initiatives strengthens economic partnerships. Additionally, Bilateral and Multilateral Trade Agreements enhance global trade and collaboration, contributing to sustainable development worldwide.

- India strengthens global cooperation through trade and development partnerships

2.3.2.2 Sustainable Development Goals - India Index 2023-24

India is ranked 109th out of 166 countries in the Sustainable Development Report 2024, which tracks global progress toward the Sustainable Development Goals (SDGs). India's SDG index score is 63.99, reflecting the percentage of progress made toward achieving all 17 SDGs. A score of 100 would mean all goals are fully met. India is in the yellow zone, indicating that while progress has been made, significant challenges remain.

- India ranks 109th in SDG progress, facing challenges

The top-performing countries in SDG achievement are Finland (86.4), Sweden (85.7), Denmark (85.0), Germany (83.4), and France (82.8). On the other end, countries with the lowest scores include Yemen (46.9), Somalia (45.4), Chad (45.1), the Central African Republic (44.2), and South Sudan (40.1).

- India improved SDG scores

At the national level, India has shown notable progress in achieving the Sustainable Development Goals (SDGs), with its composite score improving from 66 in 2020-21 to 71 in 2023-24. This indicates accelerated progress despite global challenges. Significant advancements have been made in Goal 1 (No Poverty), Goal 8 (Decent Work and Economic Growth), and Goal 13 (Climate Action), which are now in the front-runner category. Goal 13 saw the highest increase, from 54 to 67, followed by Goal 1, which rose from 60 to 72.

- Progress in multiple SDGs, inequalities remain challenging

Since 2018, there have been positive developments in Goal 1 (No Poverty), Goal 3 (Good Health and Well-being), Goal 6 (Clean Water and Sanitation), Goal 7 (Affordable and Clean Energy), and Goal 11 (Sustainable Cities and Communities). Eleven goals, including Goal 10 (Reduced Inequalities), Goal 12 (Responsible Consumption and Production), Goal 15 (Life on Land), and Goal 16 (Peace, Justice, and Strong Institutions), have scores between 65 and 99.

However, Goal 2 (Zero Hunger), Goal 4 (Quality Education), and Goal 9 (Industry, Innovation, and Infrastructure) have scores between 50 and 64, indicating room for improvement. Goal 5 (Gender Equality) requires special attention, with a score below 50 and 14 states and union territories in the aspirant category.

- India progresses on SDGs, faces gender equality gaps

The government's focus on food and nutrition security, health, education, electrification, housing for all, sanitation, and clean cooking fuel has significantly contributed to these improvements. These efforts highlight India's commitment to achieving sustainable and inclusive development, though challenges remain in certain areas.

- India must focus on equity, sustainability, and data-driven policies

Despite India's impressive progress, several areas require greater focus to ensure sustainable and inclusive growth. Skill development and creating gainful employment opportunities are essential to drive income growth and reduce economic disparities. Addressing the low labour force participation rate of women is crucial, alongside ensuring their full involvement in political and social spheres. By 2030, around 590 million people are expected to live in urban and developed rural areas, with a significant portion being senior citizens. Identifying and promoting future growth centres is vital to reduce social and spatial inequalities. Additionally, emerging challenges like non-communicable diseases, air and water pollution, and waste management need urgent attention. High-quality data is also critical for designing, financing, monitoring, and evaluating policies effectively, ensuring that the right information is available at the right time to address these pressing issues. These steps are necessary to build a more equitable and sustainable future for India.

2.3.3 Sustainable Development Goals - Kerala

India has adopted a strong localisation model to achieve the Sustainable Development Goals (SDGs) by customising

strategies at the state level. To track progress, the government has introduced the State-level SDG Index, which measures how well different states and Union Territories (UTs) are performing in meeting these global goals.

- India advances SDGs with state-level progress and localisation

The SDG India Index 2023-24, published by NITI Aayog, mentions that states have achieved scores ranging from 57 to 79, while UTs have scored between 65 and 77. This shows an improvement compared to the 2020-21 report, where state scores ranged from 52 to 75, and UT scores were between 62 and 79. A higher score indicates better progress in areas like economic growth, social development, and environmental sustainability.

Among the states, Kerala and Uttarakhand have emerged as the top performers, both securing a score of 79. Among the Union Territories, Chandigarh has retained its position as the best-performing UT, with a score of 77.

- Kerala excels in SDGs, reduces poverty, and faces employment hurdles

Kerala has made remarkable progress in achieving the Sustainable Development Goals (SDGs) by improving various socio-economic indicators. In Goal 1 (No Poverty), the state has successfully reduced multidimensional poverty, with the Multi-Poverty Index Headcount Ratio declining from 1.10% to 0.55%. Thus, fewer people are facing deprivations in income, health, and education. Additionally, 57.8% of households are now covered by health schemes, up from 47.7%, which shows improving access to affordable healthcare. However, there are concerns in employment generation, as the percentage of beneficiaries under the Pradhan Mantri Mudra Yojana (PMMY) has dropped from 97.75% to 50.4%, indicating fewer small businesses and self-employment opportunities.

- Ensures food security, but child undernutrition persists

In Goal 2 (Zero Hunger), Kerala has achieved 100% coverage under the National Food Security Act (NFSA), ensuring food security for all citizens. However, undernutrition remains a concern, with 18.7% of children under 5 being underweight and 23.4% being stunted due to inadequate nutrition. On a positive note, the percentage of anaemic pregnant women has decreased from 31.4% to 22.5%, which reflects better maternal healthcare and nutrition.

Kerala has made significant achievements in Goal 3 (Good Health and Well-being). The Maternal Mortality Ratio (MMR) has improved to 19 per 100,000 live births, down from 43 per 100,000 live births. The Under-5 Mortality Rate (U5MR) has

- Excels in healthcare, faces mental health and TB challenges

also declined to 8 per 1,000 live births, showing better child healthcare. Additionally, 99.85% of deliveries now take place in hospitals, ensuring safer childbirth. However, concerns remain as suicide rates have increased to 28.5 per 100,000 population, and the tuberculosis notification rate has risen, which shows the need for mental health awareness and better disease control.

- Kerala excels in education with high enrolment and infrastructure

Education remains one of Kerala's strongest areas under Goal 4 (Quality Education). The Gross Enrolment Ratio (GER) stands at 85% for higher secondary education and 41.3% for higher education, indicating more students are continuing their studies. The Gender Parity Index (GPI) of 1.44 suggests that more women than men are enrolling in higher education. Furthermore, 99.51% of schools have access to electricity and drinking water, and 98.3% of schools are equipped with computers, ensuring better learning infrastructure.

- Advances in gender equality, but faces low workforce participation

For Goal 5 (Gender Equality), Kerala has made progress in women's empowerment. The sex ratio at birth is 951 girls per 1,000 boys, and 86.6% of women own mobile phones, improving digital access. However, the female labour force participation rate (LFPR) remains low at 0.33, indicating that fewer women are actively working in the formal economy. On a positive note, spousal violence has decreased, with only 9.8% of married women reporting such incidents.

- Ensures water access and sanitation, but overuses groundwater

Under Goal 6 (Clean Water and Sanitation), 98.5% of rural households have access to safe drinking water, and 100% of homes now have toilets under the Swachh Bharat Mission (SBM). However, groundwater extraction remains a challenge, as 54.55% of blocks are classified as over-exploited.

- Achieves full electrification, slight dip in clean energy progress

In Goal 7 (Affordable and Clean Energy), Kerala has achieved 100% household electrification, and 100.18% of households have LPG/PNG connections. However, there has been a slight decline in clean energy coverage compared to previous years.

- Kerala grows economically, faces high unemployment, and improves financial inclusion

Kerala's economic growth under Goal 8 (Decent Work and Economic Growth) shows a GDP growth rate of 6.25%, which is a sign of steady economic expansion. However, the unemployment rate remains high at 8.4%, and only 55.5% of workers in the non-agricultural sector receive regular wages with social security benefits, indicating the need for more stable employment opportunities. Financial inclusion has improved, with 98.1% of people having bank accounts.

- Excels in connectivity but needs industrial growth

Under Goal 9 (Industry, Innovation, and Infrastructure), Kerala has ensured that 99.5% of habitations are connected by all-weather roads. However, the contribution of manufacturing to Gross Value Added (GVA) has declined to 9.51%, which highlights the need for industrial diversification. Digital connectivity is strong, with 97.3% of people having access to mobile phones.

- Advancement in waste management and urban road safety

For Goal 11 (Sustainable Cities and Communities), Kerala has improved urban waste management, achieving 100% door-to-door waste collection and 88.41% processing of municipal solid waste. Road safety has also improved, with deaths due to road accidents in urban areas reducing to 4.88 per 100,000 population.

- Increased renewable energy and disaster readiness, but faces pollution

Under Goal 13 (Climate Action), Kerala has increased its share of renewable energy to 48.42%, reducing dependence on fossil fuels. However, the state continues to face air pollution and extreme weather events, which pose risks to public health and infrastructure. Kerala has also improved its disaster preparedness score to 24.50, indicating better readiness to handle natural calamities.

- Preserves forests but faces land degradation and wildlife crimes

In Goal 15 (Life on Land), Kerala has maintained 54.7% forest cover, which helps to conserve biodiversity. However, challenges like land degradation and wildlife crimes persist, with 20 wildlife crime cases reported per mile of protected area.

- Kerala ensures social stability, but needs stronger SC/ST protection

Kerala's progress under Goal 16 (Peace, Justice, and Strong Institutions) highlights social stability. The state has a low murder rate of 0.90 per 100,000 population, reflecting a peaceful society. However, crimes against Scheduled Castes (SCs) and Scheduled Tribes (STs) have increased, with rates of 34.5 and 35.5 per 100,000 population, respectively, indicating the need for stronger legal protection. On the positive side, Kerala has an efficient law enforcement system, with a 98% charge-sheeting rate for crimes. Additionally, 99% of births are now registered, ensuring better governance and access to services.

Kerala's achievements in the Sustainable Development Goals (SDGs) reflect its commitment to sustainable and inclusive development. The state has made significant progress in poverty reduction, health, education, gender equality, and financial inclusion. However, challenges

persist in employment generation, industrial diversification, groundwater sustainability, and gender participation in the workforce. By addressing these issues, Kerala can further strengthen its economic and social development.

Summarised Overview

The Sustainable Development Goals (SDGs) were adopted by the United Nations in 2015 with 17 goals and 169 targets aimed at addressing poverty, hunger, health, education, gender equality, clean energy, climate action, and sustainable economic growth by 2030. These goals include No Poverty, Zero Hunger, Good Health and Well-being, Quality Education, Gender Equality, Clean Water and Sanitation, Affordable and Clean Energy, Decent Work and Economic Growth, Industry Innovation and Infrastructure, Reduced Inequality, Sustainable Cities and Communities, Responsible Consumption and Production, Climate Action, Life Below Water, Life on Land, Peace Justice and Strong Institutions, and Partnerships for the Goals.

India has integrated its national policies with the SDG framework, focusing on inclusive growth under the vision of 'Sabka Saath, Sabka Vikas.' NITI Aayog plays a crucial role in monitoring SDG implementation through the SDG India Index, tracking progress across states.

Kerala ranks among the top states in SDG implementation, excelling in healthcare, education, and poverty reduction. The state has reduced multidimensional poverty, improved maternal and child health, and achieved high literacy rates and gender parity in education. However, challenges remain in employment generation, groundwater sustainability, and industrial diversification. Kerala has also focused on sustainable urbanisation, gender empowerment, and renewable energy adoption.

Assignments

1. Explain the importance of Sustainable Development Goals (SDGs) in global development.
2. Describe India's efforts in achieving the SDGs with examples of government initiatives.
3. Discuss Kerala's progress in key areas such as healthcare, education, and social welfare related to the SDGs.
4. List and explain major challenges India faces in meeting SDG targets.

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3. Jeffrey, R. (2001). *Politics, women, and well-being: How Kerala became a model.* OUP India

Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

UNIT 4 Global Environmental Issues

Learning Outcomes

After completing this unit, the learner will be able to:

- analyse the key outcomes of the World Summit on Sustainable Development
- evaluate the major global environmental issues
- know different types of environmental pollution

Background

As you advance in your studies, it is important to understand the link between economic activities and environmental challenges. Economic growth, industrial expansion, and resource consumption have led to serious issues such as global warming, biodiversity loss, acid rain, deforestation, and pollution. As you have learned about production, markets, and efficiency in your undergraduate studies, it is now time to examine how these activities impact the environment.

Global warming affects climate patterns and economies, while deforestation disrupts ecosystems. Acid rain damages soil and water resources, and pollution from industries and vehicles leads to health and environmental risks. These issues not only harm nature but also create economic challenges.

As learners of economics, understanding these problems will help you to analyse the need for sustainable policies. By balancing development with environmental protection, we can ensure long-term economic stability while safeguarding our planet.

Keywords

World Summit on Sustainable Development, Global Warming, Biodiversity Loss, Acid Rain, Deforestation, Environmental Pollution

Discussion

2.4.1 World Summit on Sustainable Development

- WSSD 2002 united global stakeholders for sustainable development

The World Summit on Sustainable Development (WSSD) 2002 was a pivotal international conference held from August 26 to September 4, 2002, in Johannesburg, South Africa. This summit brought together representatives from governments, businesses, non-governmental organisations (NGOs), and other stakeholders to discuss and promote sustainable development globally.

- WSSD 2002 assessed Agenda 21, reinforced sustainable development commitments

Building upon the foundations laid by the 1992 Earth Summit in Rio de Janeiro, the WSSD aimed to assess progress and address challenges in implementing sustainable development initiatives over the preceding decade. The primary objectives included evaluating the effectiveness of Agenda 21, a comprehensive plan of action for sustainable development and reinforcing commitments to integrating environmental protection with socio-economic growth.

Key Outcomes of the Summit

The summit culminated in two significant documents viz; the Johannesburg Declaration on Sustainable Development and the Johannesburg Plan of Implementation.

- The summit produced the Johannesburg Declaration and Implementation Plan

Johannesburg Declaration: This declaration reaffirmed the global commitment to sustainable development and emphasised the importance of multilateralism in addressing environmental and developmental challenges. It highlighted the need for collective action to eradicate poverty, promote human rights, and protect natural resources.

Johannesburg Plan of Implementation: This comprehensive action plan outlined specific targets and measures across various sectors to achieve sustainable development.

Water: The plan encouraged partnerships between public and private sectors within regulatory frameworks established by governments to improve water access and sanitation. One of the key achievements was in water and sanitation, where governments agreed to halve the number of people without access to clean drinking water and basic sanitation by 2015.

This was seen as a positive and concrete step.

Energy: It underscored the necessity to diversify energy sources by incorporating renewable energy into the global supply, aiming to reduce dependency on fossil fuels and mitigate climate change.

Health: The commitments to combat HIV/AIDS were reaffirmed, and the plan emphasised the rights of states to interpret the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) to promote universal access to essential medicines.

Agriculture: The plan called for comprehensive negotiations on the World Trade Organisation's Agreement on Agriculture, focusing on improving market access and reducing export subsidies to support fair trade practices.

Biodiversity: It advocated for establishing an international regime to ensure fair and equitable sharing of benefits arising from the use of genetic resources, aiming to protect biological diversity.

- Plan set targets for water, energy, health, agriculture, biodiversity, climate action

Climate Change: The plan included provisions related to the Kyoto Protocol, urging countries that had not ratified it to do so promptly to address greenhouse gas emissions.

Innovative Approaches-Type II Partnerships

A notable feature of the WSSD was the introduction of 'Type II Partnerships', which are voluntary, multi-stakeholder initiatives involving governments, private sectors, and civil society organisations. These partnerships aimed to complement traditional intergovernmental agreements by focusing on the practical implementation of sustainable development goals at various levels. An example is the Global Water Partnership, a network of organisations working together to manage water resources sustainably.

- WSSD introduced voluntary partnerships for sustainable development

In the years following the summit, progress has been mixed. While there have been advancements in areas like renewable energy adoption and increased awareness of sustainability issues, challenges persist. Global crises such as economic downturns, geopolitical conflicts, and the climate crisis have hindered efforts, creating a 'polycrisis' that threatens the liberal international order. To achieve the Sustainable Development

- Mixed progress on sustainability

Goals (SDGs) by 2030, innovative, large-scale solutions are necessary. Initiatives focusing on climate and energy transitions, enhanced connectivity, and financial inclusion are among the proposed solutions to get back on track.

2.4.2 Global Environmental Issues

Global environmental issues are becoming increasingly significant due to the rapid growth of the world's population and the expansion of human activities. In 1950, the global population was 2.5 billion, but by 2050, it is expected to reach 9 to 10 billion. This population growth, combined with advancements in technology, has led to greater human impact on the planet.

- Rapid population growth and human activities drive global environmental crises

Key global environmental problems include climate change, depletion of the stratospheric ozone layer, the spread of persistent organic pollutants, loss of biodiversity, and ocean degradation. These issues are interconnected and have significant economic implications. For instance, the burning of coal and oil in one country can affect global temperatures, leading to climate change, which in turn impacts agriculture, health, and infrastructure worldwide. Similarly, the use of banned pesticides in one region can harm ecosystems and human health in distant areas through long-range air transport.

- Environmental issues threaten health, resources, and stability

From an economic perspective, these environmental problems pose direct threats to human health and ecosystems, which can lead to increased healthcare costs and reduced agricultural productivity. Additionally, competition for scarce resources, such as clean water and arable land, can lead to geopolitical instability, conflicts, and the displacement of populations, creating international refugees. This competition can also drive up the prices of essential resources.

- Global environmental challenges demand international cooperation

On the positive side, addressing global environmental issues can create economic opportunities. The demand for environmental technologies and expertise can stimulate innovation and job creation in sectors such as renewable energy, waste management, and conservation. However, solving these global problems requires international cooperation, as they cannot be addressed by individual nations alone. Effective monitoring and assessment of environmental issues also necessitate global collaboration. Let us discuss the major global environmental issues.

2.4.3 Global Warming

Global warming refers to the long-term increase in the Earth's average temperature due to the excessive accumulation of greenhouse gases (GHGs)in the atmosphere. These gases trap heat, leading to rising temperatures and significant environmental and economic consequences.

- Global warming accelerates, and ecosystems affected

The Provisional State of the Global Climate 2023 report, published by the World Meteorological Organization (WMO) states that the year 2023 recorded the highest global mean temperature since observations began 174 years ago, surpassing the previous records set in 2016 and 2020. The past nine years (2015-2023) have been the warmest on record, with increasing temperatures affecting both land and ocean ecosystems. The ten-year average (2014-2023) also marked the hottest decade ever recorded.

- GHG levels hit record highs

The concentration of the three main greenhouse gases-carbon dioxide, methane, and nitrous oxide reached an all-time high in 2022, and early data suggests that these levels continued to rise in 2023. This increase in GHGs has led to an escalation in ocean heat content, causing further warming of the seas and contributing to rising global mean sea levels. Over the past decade, the rate of sea-level rise has more than doubled compared to the first decade of satellite records.

- Antarctic ice and glaciers melted rapidly

The Antarctic Sea ice reached its lowest level ever recorded in February 2023, with significantly reduced ice extent from June onwards. Similarly, glaciers in North America and the European Alps experienced severe melting, leading to a 10% reduction in Switzerland's glacier volume over just two years. This loss of ice contributes to sea-level rise and affects global water availability, impacting agriculture and human settlements.

- Extreme weather in 2023 caused deaths, destruction, and economic losses

The intensification of extreme weather events in 2023 had severe socio-economic impacts. Heatwaves, wildfires, and floods disrupted lives, caused economic losses, and increased air pollution. Countries like Hawaii, Canada, and parts of Europe suffered devastating wildfires, leading to loss of life, destruction of property, and financial damage. Similarly, flooding caused by Mediterranean Cyclone Daniel resulted in high mortality rates and economic devastation in regions such as Greece, Bulgaria, Türkiye, and Libya.

The worsening climate conditions have aggravated food security issues, leading to population displacements and economic hardship, particularly in vulnerable regions. Extreme weather patterns have disrupted agricultural production, affecting food supply and increasing inflationary pressures on food prices. Additionally, people displaced by climate-related disasters have faced increased financial instability and economic vulnerability.

Causes of Global Warming

- Human activities increase greenhouse gases

Global warming is primarily caused by human activities that have significantly altered the Earth's atmosphere over the past 50 years. The main contributors to this phenomenon are greenhouse gases, such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), which trap heat in the atmosphere, leading to an increase in global temperatures. This process is known as the greenhouse effect. Since the Industrial Revolution, the concentration of CO2 in the atmosphere has risen by nearly 30%, methane levels have more than doubled, and nitrous oxide levels have increased by about 15%. These changes have enhanced the atmosphere's ability to trap heat, causing the Earth's temperature to rise.

- Fossil fuels, deforestation and agriculture drive greenhouse gas emissions

The primary source of these greenhouse gases is the combustion of fossil fuels, which are used to power vehicles, heat homes, and run industries. In the United States, for example, fossil fuel combustion accounts for about 98% of CO2 emissions, 24% of methane emissions, and 18% of nitrous oxide emissions. Other human activities, such as agriculture, deforestation, industrial production, and waste management, also contribute significantly to greenhouse gas emissions. For instance, deforestation reduces the number of trees that can absorb CO2, while landfills and agricultural practices release methane.

- Human-made pollution fuels climate change and risks

The Intergovernmental Panel on Climate Change (IPCC) has reported that human-produced air pollutants are the key drivers of recent climate change. Without effective emissions control policies, CO2 concentrations are projected to increase by 30-150% by the year 2100, leading to a global temperature rise of 1°C to 3.5°C. This increase in temperature has far-reaching economic implications, including impacts on agriculture, health, and infrastructure, as well as potential increases in the frequency of extreme weather events.

Managing Global Warming

- Global warming is managed through prevention, mitigation, and adaptation

Managing global warming involves three main strategies. They are prevention, mitigation, and adaptation. Prevention focuses on stopping the increase of greenhouse gases in the atmosphere. This can be achieved by developing alternative energy sources to replace fossil fuels, such as solar or wind power, and by implementing economic policies like taxes on greenhouse gas emissions to discourage their release. Mitigation aims to reduce or delay the effects of global warming. One effective way to do this is by increasing carbon sinks, such as planting more trees, which absorb CO2 from the atmosphere. Adaptation involves adjusting to the changes caused by global warming. For example, farmers might shift agricultural zones or change crop patterns to adapt to new climate conditions.

Each of these strategies plays a crucial role in addressing global warming. Prevention reduces future emissions, mitigation lessens the current impact, and adaptation helps societies cope with the changes that are already happening. Together, these approaches require economic planning, technological innovation, and policy interventions to create a sustainable future and minimise the economic and environmental costs of climate change.

2.4.4 Biodiversity Loss

Biodiversity, or biological diversity, refers to the variety of living organisms, including plants, animals, and microorganisms, within a specific region. It plays a crucial role in maintaining ecological balance and supporting economic activities.

Biodiversity provides several direct and indirect benefits to humanity, such as;

Natural Resources: It supplies food, fuelwood, raw materials for industries, and construction materials for housing and shelter.

Ecosystem Services: Biodiversity helps in oxygen production, carbon-dioxide reduction, water cycle regulation, and soil protection, which are essential for sustainable economic development.

Climate Impact: Biodiversity loss contributes to the

greenhouse effect, leading to global temperature rise, droughts, and floods, which affect agricultural productivity and economic stability.

Preserving Ecological Processes: Biodiversity supports nutrient cycling, soil formation, air and water purification, river flow regulation, and flood control, which are vital for environmental sustainability.

- Biodiversity sustains life, economy, climate, and health

Health and Biotechnology: Many medicines originate from biodiversity, particularly benefiting tribal communities and pharmaceutical industries. Bio-rich regions also serve as research hubs for developing better crops and livestock.

- Biodiversity loss threatens ecosystems, the economy, and life

Biodiversity Loss is a critical global issue highlighted in the 2020 WWF (World Wide Fund for Nature) Living Planet Report, which shows alarming declines in species populations worldwide. The report identifies five major threats to biodiversity viz; land and sea use change, pollution, species overexploitation, climate change, and invasive species and disease (Fig. 2.4.1). These threats are interconnected and have significant economic implications, as they disrupt ecosystems that provide essential services like food, clean water, and climate regulation.

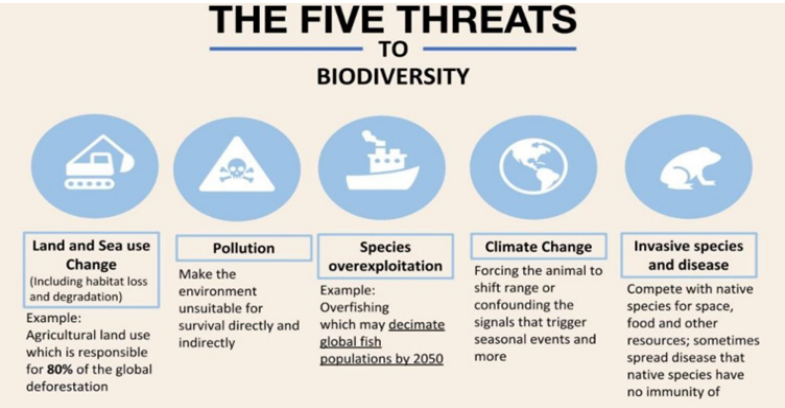

Fig 2.4.1 Threats to Biodiversity Source: Living Planet Report 2020, WWF

Land and sea use change, particularly due to agricultural expansion, is responsible for 80% of global deforestation. For example, in Latin America and the Caribbean, species populations have declined by 94% since 1975, the highest loss among all regions. Pollution makes environments unsuitable for survival, directly and indirectly harming species. In North America, chemical pollution, particularly pesticides,

has contributed to the loss of nearly 3 billion birds over the past 50 years. Species overexploitation, such as overfishing, hunting, and other forms of exploitation, is driving species to extinction, with overfishing potentially leading to the collapse of global fish populations by 2050. Climate change forces species to shift their ranges or disrupts seasonal behaviours, intensifying droughts and habitat loss. In Africa, the Grauer's gorilla population has declined by 87% due to illegal hunting and mining. Invasive species and disease also pose significant threats, as they compete with native species for resources and spread diseases. For example, a chytrid fungus from Asia has caused declines in 500 amphibian species and driven around 90 to extinction.

- Land use, pollution, overexploitation, climate change, and diseases threaten biodiversity

The report also highlights regional impacts of biodiversity loss. In North America, nearly 3 billion birds have been lost in the past 50 years due to habitat loss and pesticide use, while the Great Lakes, the largest freshwater reservoir in North America, have seen historically low water levels. Additionally, 30% of the plant-pollination network has disappeared, affecting agriculture and food production. In Europe and Central Asia, habitat loss and degradation are the primary drivers of biodiversity decline, with invasive species and pollution also posing significant threats. Latin America and the Caribbean have experienced the most severe biodiversity loss, with a 94% decline in species populations since 1975, particularly affecting reptiles, amphibians, and fish. The region also faced record-breaking dry seasons and forest fires in 2019, leading to a 30% increase in deforestation compared to the previous year. In Africa, the Mara River Basin, which supports the livelihoods of 1.1 million people, is under threat, and 76% of endemic freshwater species in Lake Victoria are at risk of extinction. Illegal hunting and mining have caused an 87% decline in the Grauer's gorilla population in the Congo. In the Asia Pacific region, more than 60% of wetlands in East and Southeast Asia are threatened due to human activities, with significant challenges from pollution, habitat loss, and climate change.

- Biodiversity loss harms ecosystems, species, and regions globally

Biodiversity loss has profound economic implications. The decline of pollinators like bees affects agriculture, reducing crop yields and increasing food prices. The loss of wetlands, which provide flood protection and water filtration, increases the risk of natural disasters and water scarcity. Overfishing and the collapse of fish stocks threaten the livelihoods of

millions of people who depend on fishing for food and income. Deforestation and habitat destruction reduce the availability of natural resources, such as timber and medicinal plants, which are vital for industries and local communities. The report emphasises that biodiversity loss is not just an environmental issue but also an economic and social crisis. Protecting biodiversity requires sustainable economic policies, such as regulating land use, reducing pollution, and promoting conservation. By investing in sustainable practices and international cooperation, we can mitigate the economic and environmental impacts of biodiversity loss and ensure a healthier planet for future generations.

- Threatens agriculture, livelihoods, resources, and the economy

2.4.5 Acid Rain

Acid precipitation, commonly known as acid rain, refers to rain or snowfall with a pH of less than 5.6, making it more acidic than normal precipitation. The term was coined by British chemist Angus Smith in 1858. Acid rain is primarily caused by the release of sulphur dioxide (SO_2) , nitrogen dioxide (NO_2) and nitrous oxide (NO) into the atmosphere due to fossil fuel combustion in thermal power plants, industrial furnaces, and motor vehicles. These gases mix with water vapour in the atmosphere to form sulphuric acid and nitric acid, which then fall back to the Earth's surface. These acid droplets can be transported over long distances by wind before they precipitate, affecting regions far from the original source of pollution.

- Acid rain forms from pollutants like SO2 and NO2

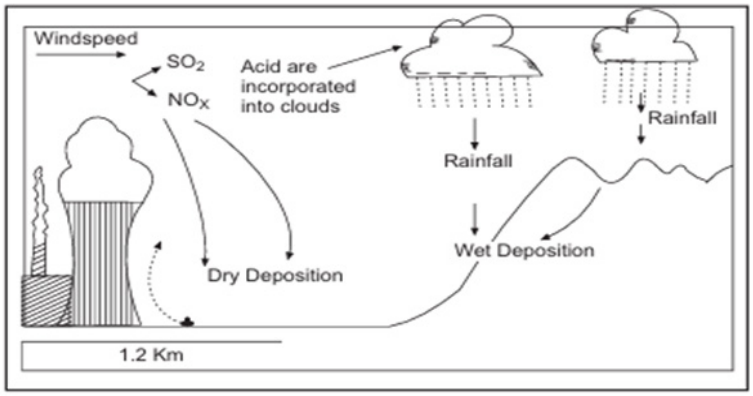

Fig 2.4.2 Acidification

The economic and environmental impact of acid rain is significant. It degrades aquatic ecosystems, particularly freshwater lakes, by lowering the pH of water, making it too

acidic for fish and other aquatic species. Fish populations decline when pH levels drop below 5.5, and most species stop reproducing between pH 5.3 and 5.6. The ability of lakes to neutralise acid deposition depends on the mineral composition of the surrounding rocks. Lakes in areas with igneous and metamorphic rocks, which contain silicates, are highly sensitive to acidification, while those in regions rich in calcium, magnesium, and phosphorus are better able to resist acidification due to their naturally alkaline properties. Over 1,000 lakes worldwide have become too acidic to support aquatic life, with Scandinavian countries being among the worst affected.

- Acid rain harms aquatic ecosystems, reducing biodiversity

The terrestrial impact of acid rain is evident in widespread forest degradation in regions such as North America, Europe, East China, and the Western Ghats of India. Acid rain acidifies the soil, leading to the leaching of essential nutrients like potassium, calcium, and magnesium, which weakens trees and forests, ultimately leading to their death. Additionally, acid rain affects agricultural productivity, making soils less fertile and reducing crop yields, which has economic implications for farmers and food security.

- Acid rain degrades forests, soil, and agriculture

Acid rain also has severe economic costs due to damage to infrastructure and cultural heritage. It erodes buildings made of marble and limestone, including iconic monuments such as the Taj Mahal in India and the Parthenon in Greece. This leads to increased costs for maintenance, restoration, and preservation efforts. Urban areas affected by acid rain experience higher levels of smog, which can cause respiratory illnesses such as asthma, pneumonia, and other lung diseases, leading to increased healthcare costs and productivity losses.

- Acid rain damages infrastructure and health

Thus, acid rain is a major environmental and economic issue caused by industrial emissions and fossil fuel use. Its effects range from damaging ecosystems and reducing biodiversity to deteriorating infrastructure and affecting human health. Addressing acid rain requires effective pollution control measures, such as reducing sulphur and nitrogen emissions, promoting clean energy sources, and implementing sustainable industrial practices. Economic policies that encourage green energy investment and environmental conservation can help mitigate the long-term impacts of acid rain and ensure sustainable development.

- Needs pollution control and sustainable practices

2.4.6 Deforestation

- Deforestation drives environmental degradation

Deforestation is a growing concern worldwide, driven by rapid population growth in developing countries and industrialisation, urbanisation, and consumerism in developed nations. Large-scale forest clearing in tropical and subtropical regions occurs to meet the rising demand for agricultural land, fuelwood, timber, and raw materials for agro-based and forest-based industries. Expanding grazing lands to support the increasing demand for meat production, such as mutton, chicken, beef, and pork, further contributes to forest loss. While deforestation may seem economically beneficial because it boosts Gross National Product (GNP) through the production of paper, timber, charcoal, and furniture, it does not account for the negative externalities, such as soil erosion, flooding, climate change, and biodiversity loss, which can have long-term economic costs. Ecologists consider deforestation a leading cause of environmental degradation, which ultimately affects sustainable economic development.

Major Causes of Deforestation

Several factors contribute to the high rate of deforestation, including;

- Population growth increases the demand for housing, food, and fuel.
- Agricultural expansion and grazing lands, leading to the conversion of forests into farmlands and pastures.
- Rising demand for timber, paper, fuelwood, and other forest products, accelerating logging activities.
- Industrialisation, urbanisation, and consumerism, particularly in developed and emerging economies.
- Expansion of infrastructure, including roads, highways, railways, and irrigation systems, which often require clearing forests.
- Construction of multi-purpose dams, affecting vast forested regions.
- Shifting cultivation in tropical regions, where farmers clear forests for temporary farming.
- Changing food habits, with rising consumption of non-veg-

etarian diets, are increasing the need for livestock grazing lands.

- Poverty in developing countries forces landless populations to encroach upon forests for survival.
- Natural and human-induced forest fires, which destroy vast areas of vegetation.
- Acid rain damages trees and accelerates forest degradation.
- Weak enforcement of forest conservation laws, particularly in developing nations, where illegal logging is rampant.

- Deforestation is driven by population growth, agriculture, industry, and weak enforcement

Food and Agriculture Organisation (FAO) Assessment of Global Deforestation

Deforestation and forest degradation are occurring at alarming rates and are major contributors to the ongoing loss of biodiversity (FAO and UNEP, 2020). Since 1990, an estimated 420 million hectares of forest have been lost due to conversion to other land uses, such as agriculture and urban development. Although the rate of deforestation has slowed over the past three decades, it remains a significant issue. Between 2015 and 2020, the rate of deforestation was estimated at 10 million hectares per year, down from 16 million hectares per year in the 1990s. Despite this decline, the area of primary forest worldwide has decreased by over 80 million hectares since 1990 (FAO, 2020).

- Deforestation, causing biodiversity loss and forest degradation

The primary driver of deforestation and forest degradation is agricultural expansion, which is responsible for the loss of forest biodiversity. Large-scale commercial agriculture, including activities like cattle ranching and the cultivation of soybean and oil palm, accounted for 40% of tropical deforestation between 2000 and 2010. Additionally, local subsistence agriculture contributed another 33% to deforestation during the same period (FAO and UNEP, 2020). These agricultural practices not only lead to the destruction of forests but also disrupt ecosystems, reducing the availability of natural resources and ecosystem services such as carbon sequestration, water regulation, and soil fertility.

- Agricultural expansion drives deforestation

Addressing deforestation requires sustainable land-use policies and economic incentives to promote conservation and reduce the pressure on forests. For example, promoting agroforestry,

- Sustainable policies, agroforestry, and incentives are key to addressing deforestation

which integrates trees into agricultural land, can help to maintain biodiversity while supporting local livelihoods. Additionally, international cooperation and financial mechanisms, such as payments for ecosystem services (PES), can provide economic incentives for countries and communities to protect forests. By balancing economic development with environmental conservation, we can mitigate the impacts of deforestation and ensure the sustainable use of forest resources for future generations.

2.4.7 Environmental Pollution

- Environmental pollution disrupts ecosystems the economy

Environmental pollution refers to the contamination of air, water, and soil due to human activities, leading to harmful effects on ecosystems and economic productivity. Pollution results from the release of harmful substances or waste into the environment, disrupting the natural equilibrium. While natural pollution, such as volcanic emissions, exists, anthropogenic pollution caused by industrialisation, urbanisation, and deforestation has become a major global concern. Rapid economic expansion, population growth, and increasing energy demands have intensified pollution and threaten sustainable development.

2.4.7.1 Types of Environmental Pollution

Air Pollution

- Air pollution harms health and contributes to climate change

Air pollution occurs when harmful gases, particulate matter, and toxic substances are released into the atmosphere, mainly from burning fossil fuels, industrial emissions, and vehicular pollution. The major pollutants include carbon dioxide (CO2), nitrogen oxides (NO2), sulphur dioxide (SO2), and particulate matter (PM10, PM2.5). Air pollution has severe economic and health impacts, increasing healthcare costs due to respiratory diseases such as asthma, bronchitis, and lung cancer. It also contributes to climate change through the greenhouse effect, leading to rising global temperatures, extreme weather conditions, and economic losses in agriculture and infrastructure.

Water Pollution

Water pollution results from the discharge of industrial effluents, sewage, agricultural runoff, and plastic waste into water bodies. It affects freshwater ecosystems, marine life,

- Water pollution harms ecosystems, health, agriculture, and productivity

and drinking water supplies. Pollutants like heavy metals, nitrates, and synthetic chemicals cause bioaccumulation and eutrophication, reducing fishery resources and harming public health. Contaminated water sources increase waterborne diseases such as cholera and typhoid, which impact human productivity and increase healthcare expenditures. Moreover, declining water quality reduces agricultural yields and affects industries that rely on clean water.

Soil Pollution

- Soil pollution reduces productivity

Soil pollution occurs due to excessive use of chemical fertilisers, pesticides, mining activities, deforestation, and industrial waste disposal. Degraded soil leads to lower agricultural productivity, food insecurity, and economic hardships for farmers. Toxic chemicals enter the food chain, causing health hazards, while soil erosion and salinisation further reduce land fertility. The economic cost of soil pollution is reflected in declining crop yields, loss of biodiversity, and increased costs of land reclamation.

Noise Pollution

- Noise pollution causes health issues, reduces productivity

Noise pollution, caused by traffic congestion, industrial operations, construction activities, and loudspeakers, leads to stress, hearing loss, and reduced work efficiency. It affects urban productivity, reducing workforce efficiency and increasing healthcare burdens due to stress-related illnesses. Governments incur costs in enforcing noise regulations and implementing urban planning measures to mitigate its effects.

Marine Pollution

- Pollution in oceans disrupts marine ecosystems

Oceans, covering 71% of the Earth's surface, are heavily polluted due to oil spills, plastic waste, sewage disposal, and industrial effluents. Oil spills disrupt marine ecosystems, causing economic losses in fisheries, tourism, and maritime industries. The accumulation of plastics in oceans affects marine biodiversity and poses a long-term threat to the global food chain.

Nuclear and Radiation Pollution

- Nuclear pollution causes health issues and ecological damage

Nuclear pollution results from radioactive waste disposal, nuclear accidents, and atomic testing. Exposure to radiation causes genetic mutations, cancer, and ecological damage.

The economic burden of nuclear pollution includes high costs of medical treatment, environmental clean-up, and loss of habitable land.

Economic Impact of Environmental Pollution

Pollution imposes significant economic costs on societies, which include the following.

Healthcare Expenditures: Increased cases of respiratory, cardiovascular, and waterborne diseases raise medical costs.

Loss of Productivity: Pollution-induced health problems reduce worker efficiency, affecting economic output.

Declining Agricultural Yields: Soil and water pollution lower food production, increasing food prices.

Infrastructure Damage: Acid rain and air pollution corrode buildings, roads, and monuments, increasing maintenance costs.

- Pollution increases healthcare costs, reduces productivity, and damages infrastructure

Biodiversity Loss: Damage to ecosystems disrupts food supply chains and affects industries dependent on natural resources.

Solutions and Management Strategies

To combat environmental pollution, governments and industries must implement sustainable development practices as follows.

a) Strict Environmental Regulations: Implementing policies to control emissions, industrial waste disposal, and plastic usage.

- Sustainable practices, regulations, and awareness tackle environmental pollution effectively

b) Renewable Energy Promotion: Shifting from fossil fuels to solar, wind, and hydroelectric power.

c) Sustainable Agriculture: Encouraging organic farming, crop rotation, and afforestation to restore soil fertility.

d) Waste Management: Recycling, composting, and enforcing proper disposal of hazardous industrial waste.

e) Public Awareness and Education: Promoting responsible consumption, green technology, and conservation efforts.

We can say that environmental pollution is a major global challenge that threatens public health, economic stability, and ecological balance. While economic activities such as industrialisation, transportation, and agriculture contribute to pollution, their long-term costs outweigh the short-term economic gains. Sustainable policies, technological innovations, and global cooperation are essential to mitigate pollution and to ensure long-term economic growth and environmental protection.

Summarised Overview

The World Summit on Sustainable Development (WSSD) 2002, held in Johannesburg, reinforced global commitments to sustainable development, focusing on poverty eradication, environmental protection, and human rights. Key outcomes included the Johannesburg Declaration and Plan of Implementation, which set targets for water security, energy diversification, agriculture, biodiversity conservation, and climate action. The summit introduced Type II Partnerships, promoting multi-stakeholder collaborations for sustainability initiatives.

Global environmental issues have worsened due to industrialisation, population growth, and resource overuse. Major challenges include global warming, biodiversity loss, acid rain, deforestation, and pollution. Global warming, driven by excessive greenhouse gas emissions, leads to rising temperatures, extreme weather, and ecosystem disruptions. Biodiversity loss, caused by habitat destruction and pollution, threatens species and ecosystem stability. Acid rain, from industrial emissions, degrades soil, water, and infrastructure. Deforestation, mainly due to agriculture and urbanisation, increases carbon emissions and disrupts ecosystems. Pollution, including air, water, and soil contamination, poses severe health and economic risks.

International co-operation is essential to address these challenges. Effective policies, renewable energy adoption, and green technologies are necessary for long-term environmental and economic stability.

Assignments

1. Explain how global warming affects economic growth and development.
2. Discuss the impact of biodiversity loss on agriculture and industries.
3. Describe the causes and consequences of acid rain on the environment and human health.
4. Analyse the economic and environmental effects of deforestation.
5. Suggest sustainable solutions to reduce environmental pollution in industrial areas.

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BLOCK 3 Environmental Management

UNIT 1

Valuation of the Environment

Learning Outcomes

After completing this unit, the learner will be able to:

- understand the concept of environmental valuation
- analyse the economic concept of value
- identify the types of environmental values

Background

Environmental economics plays a vital role in assigning economic values to environmental resources, facilitating informed decision-making and policy development that balances human needs with environmental sustainability. Likewise, environmental valuation is a critical process that involves estimating the economic value of natural resources, goods, and services, thereby facilitating informed decision-making about environmental projects and resource management. This approach enables the assignment of economic values to natural resources, holding individuals and organisations accountable for environmental damage, and promoting sustainable resource usage.

Keywords

Environmental Valuation, Use- Value, Option Value, Non-Use or Passive Use Values

Discussion

3.1.1 Valuing the Environment

- Economic valuation guides sustainable natural resource use

Environmental valuation and accounting are tools used to estimate and record the economic value of natural resources, goods, and services. This helps in making informed decisions about projects that impact the environment, preparing national accounts that consider environmental costs and benefits, and determining the trade-offs between economic growth and environmental quality. By assigning economic values to natural resources, we can hold firms and households accountable for environmental damage and make better choices about using these resources.

3.1.2 The Economic Concept of Value

- Environmental valuation measures impact on human welfare

Environmental values refer to the economic values of environmental assets, goods, and services. The economic value of a natural resource is calculated by summing the present values of the goods and services it provides over its lifespan. Based on neoclassical welfare economics, the purpose of economic activity is to enhance individual well-being, with each person being the best judge of their own interests. Therefore, estimating the economic value of a resource or environmental amenity is based on its impact on human welfare. Although economic valuation has an anthropocentric focus, it also considers the value of other species, not only for their utility to humans but also due to altruistic and ethical concerns.

The economic value of a natural resource or an environmental good can be expressed as follows:

Total Economic Value (TEV) = Use Value (UV) + Non-Use Value (NV)

where Use Value (UV) refers to the direct benefits derived from using the resource.

Non-Use Value (NUV) includes indirect benefits, such as existence value, bequest value, and altruistic value.

The economic value of a natural resource or environmental good can be further categorised as follows:

Total Economic Value (TEV) = Use Value (UV) + Non-Use Value (NUV)

Use Value (UV) = Direct Use Value (DUV) + Indirect Use Value (IUV)

Non-Use Value (NUV) = Bequest Value (BV) + Existence Value (EV).

3.1.3 Types of Value

In economics and environmental studies, the concept of value is divided into three main categories: Use Value, Option Value, and Non-Use Value. These categories help explain how individuals and society benefit from natural resources, ecosystems, and other assets in different ways.

3.1.3.1 Use Value

Use value refers to the benefits people get from using a resource. It has two sub-categories:

1. **Direct Use Value**

   Benefits from directly using resources, such as consuming food and water, harvesting timber, recreational activities like tourism, fishing, etc.

- Benefits from resource use

2. **Indirect Use Value**

   Benefits from ecosystem services that support human life, such as water purification, climate regulation and pollination of crops.

3.1.3.2 Option Value

Option Value refers to the potential benefit of preserving a resource for future use, even if it is not being used currently. People may be willing to pay to conserve a resource, like biodiversity or rare species, to ensure that it is available for future generations, who may discover new uses for it, such as the medicinal properties of plants.

3.1.3.2 Non-Use Value

Non-Use Value refers to the benefits people get from simply knowing that a resource exists, even if they do not use it. This

includes;

a. Existence Value

The value people place on knowing that something, like a species or ecosystem, exists, even if it does not directly benefit them.

b. Bequest Value

- Intangible benefits of resources

It is important to preserve resources today so that future generations can enjoy and benefit from them.

c. Altruistic Value

The value people get from knowing others can benefit from or enjoy a resource.

The classification of economic value of a natural resource or environmental good is shown in the figure (3.1.3)

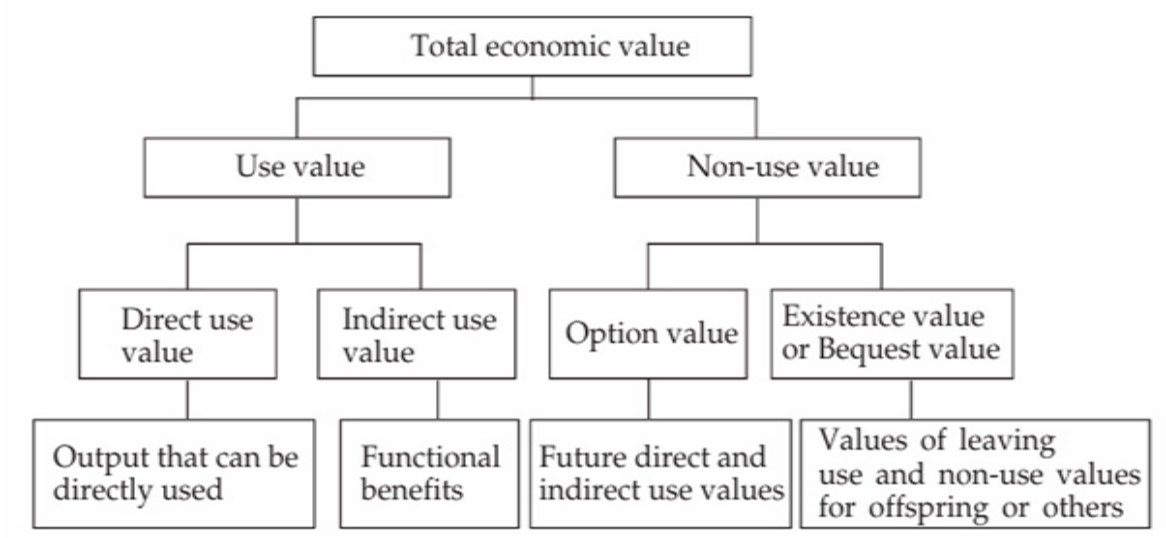

Fig. 3.1.1 Use and Non-use Values of Benefits from the Environment

Let us take the example of forests to demonstrate the different types of environmental benefits they provide.

Direct benefits from forests involve using forest resources as commercial products sold in markets, such as timber, fuel, pulpwood, poles, fruits, and medicines. Additionally, local communities benefit from non-commercial products and services, including fuel, animals, skins, poles, fruits, and nuts, which are essential for their livelihoods.

Forests also provide benefits through non-consumptive uses, including:

- Recreational activities, such as jungle treks, wildlife cruises, photography, and adventure tourism.
- Scientific research and educational opportunities, such as studying forest ecosystems and biodiversity.
- Cultural, spiritual, and social values, including traditional practices, spiritual ceremonies, and community gatherings.

• Non-consumptive forest benefits

Forests also provide indirect benefits, including:

- Protecting watersheds, which safeguards downstream areas from flooding and erosion.
- Maintaining soil fertility and preventing erosion, which is especially crucial in tropical regions.
- Regulating the atmosphere by exchanging gases and storing carbon, which improves air quality and mitigates climate change.
- Preserving biodiversity and habitats, which is essential for discovering new medicines, protecting genetic resources, and maintaining ecosystem balance.
- Enhancing soil productivity on converted forestland, allowing for more efficient agricultural and horticultural practices.

• Indirect forest ecosystem benefits

People place value on natural forests and environmental amenities in two ways:

- **Existence value:** They value the forest's mere existence, regardless of whether they plan to use it directly. This includes the forest's intrinsic value, which is its worth beyond human use.
- **Option value:** They value the possibility of using the forest in the future, or simply having it available as an option. Although these values are hard to quantify, they should be considered when evaluating the importance of forests to human well-being.

• Value of forest existence

Measures of Economic Values

Assigning economic values to natural resources and environmental assets is a challenging task. To overcome this,

- Valuing environmental resources economically

various valuation methods are employed, including market valuation, maintenance valuation, contingent valuation, avoided losses, travel cost, and hedonic pricing methods, which help estimate the economic worth of environmental goods and services.

Evaluating the intangible benefits and costs of environmental changes remains a challenge due to the lack of universally accepted valuation methods. To optimise the use of natural resources, society should weigh the social benefits against the social costs of proposed changes. Only changes with expected social benefits that significantly outweigh the expected social costs should be implemented.

Summarised Overview

Environmental valuation is a multifaceted process that entails assigning economic values to natural resources and services, thereby providing a comprehensive framework for informed decision-making regarding environmental projects and resource management. This approach acknowledges that natural resources possess diverse values, including use value, which comprises direct benefits derived from resource utilisation, such as consumption and recreation, as well as indirect benefits from ecosystem services, like water purification and climate regulation. Furthermore, environmental valuation considers option value, which represents the potential benefits of preserving resources for future use, and non-use value, which encompasses existence value, bequest value, and altruistic value, thereby accounting for the intrinsic value of natural resources, their importance for future generations, and their contribution to human well-being.

Assignments

1. What is environmental valuation?
2. What are the three main types of environmental value?
3. Define use value and provide an example.
4. What is existence value?
5. What is the difference between use value and non-use value?

Reference

1. Hussen, A. M (1999), *Principles of Environmental Economics*, Routledge, London.
2. Katar Singh Anil Shishodia (2007), *Environmental Economics Theory and Applications*, Sage Publications India Pvt Ltd.
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1. Bromerly D.W.(Ed.) (1995). *Handbook of Environmental Economics.* Blackwell, London.
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UNIT 2 Environment Valuation Methods

Learning Outcomes

After completing this unit, the learner will be able to:

- distinguish between market-based and survey-based environment valuation methods
- know about different revealed preference methods of valuation

Background

Environmental resources and services often lack a formal market, making it challenging to assign them explicit prices. However, valuing these non-market goods is essential for informed decision-making, environmental policy design, and sustainable resource management. This has led to the development of a variety of valuation methods aimed at estimating the economic value of environmental goods and services.

Among these, methods based on observed market behaviour are particularly significant because they utilise actual choices made by individuals in real-world markets. These choices provide indirect evidence of how people value environmental attributes and services. Such methods fall under the category of Revealed Preference Methods, as they are based on the assumption that preferences can be inferred from consumer behaviour.

Keywords

Environment Valuation methods, Revealed Preference Method, Hedonic property values, Household models

Discussion

3.2.1 Valuation Methods

- There are direct and indirect market valuation for environmental goods

A variety of methods exist for evaluating non-market goods, such as environmental goods and services. Munasinghe (1992) classifies these valuation techniques based on the type of market involved. According to his classification, environmental benefits can be assessed through different approaches. If market data is available, environmental impacts on production, health, and other economic activities can be measured directly. However, when direct market information is not accessible, indirect valuation through proxy markets can be used. In cases where no market exists, constructed markets based on hypothetical or simulated conditions help in estimating environmental benefits.

Valuation techniques are primarily categorised based on two key factors.

1. The first classification is based on Revealed vs. Stated Preference Approaches. Revealed preference methods derive values by analysing actual market behaviour, whereas stated preference methods use surveys to assess individuals' willingness to pay for environmental goods.
2. The second classification differentiates between Direct vs. Indirect Valuation Approaches. Direct valuation techniques estimate values from actual market transactions, while indirect valuation techniques infer values from related or surrogate markets.

- Methods: Revealed, Stated Preference Approaches

In addition to these classifications, cost-based methods and conventional market-based approaches also contribute to environmental valuation. These approaches evaluate environmental benefits through financial assessments related to damage costs, mitigation efforts, or replacement expenses.

Direct and Indirect Valuation Techniques

Pearce and Turner categorise valuation techniques into direct and indirect methods. Direct valuation techniques estimate the monetary value of environmental services by constructing a demand curve. This can be done either by conducting surveys to determine individuals' willingness to pay or by analysing related markets that reflect environmental values, such as

property prices affected by air or water quality. Common direct valuation methods include the Travel-Cost Method (TCM), which assesses recreational site value based on visitor travel expenses, the Hedonic Pricing Method (HPM), which evaluates property value fluctuations due to environmental factors, and the Contingent Valuation Method (CVM), which uses surveys to determine individuals' willingness to pay for environmental improvements.

- Direct Method considers demand

3.2.2 Revealed Preference Techniques (Method Observed Market Behaviour)

Revealed preference techniques assess the value of environmental goods and services by observing individual choices in real markets. These methods operate on the principle that economic agents' choices reflect their preferences, allowing researchers to infer the value of non-market environmental benefits. Also referred to as the Surrogate Market Approach, these techniques derive valuations from markets for private goods and services related to the environmental resource under study. The private goods traded in these markets function as complements or substitutes for environmental commodities, allowing analysts to estimate implicit values based on consumer behaviour.

- Considering real market data

The two primary methods within this approach include:

The Hedonic Pricing Method (HPM) – Encompassing the Property Valuation Approach and the Wage Differential Approach.

The Household Production Function Method – Comprising the Travel Cost Approach and the Preventive Expenditure Method.

3.2.2.1 Hedonic Pricing Method (HPM)

The Hedonic Pricing Method (HPM) estimates the implicit price of environmental attributes by analysing real markets where such characteristics are implicitly factored into pricing. It determines the value of non-market environmental services by treating them as measurable components of marketed goods. In essence, the approach assumes that environmental attributes influence the value of market goods, such as property or wages, and that these variations can be used to infer the economic worth of the environmental factors.

- Based on implicit pricing

The Property Valuation Approach (PVM)

The Property Valuation Method (PVM) derives environmental values by analysing price variations in substitute or complementary goods. It estimates an implicit price for environmental characteristics by examining their impact on real estate markets. Since environmental factors such as air quality, access to parks, water quality, and greenery are not directly traded, they are reflected in the overall property value. For instance, 'clean air' and 'aesthetic views' are attributes embedded in real estate prices, meaning that individuals purchasing homes inherently consider these environmental aspects.

- Property price based on environmental quality

The Property Value Approach establishes a relationship between environmental quality and property prices. This method has been applied to estimate the value of urban air quality, noise pollution near airports, earthquake risks, and forest amenities. Property prices are influenced by multiple factors, including size, construction, location, and environmental quality. When non-environmental variables (e.g., location near schools, hospitals, or shopping centres) are controlled, price variations between similar properties provide an estimate of the implicit price of environmental benefits.

- Factors of environmental quality - air quality, noise pollution

For example, a house in a less polluted, aesthetically pleasing area is likely to be valued higher than a similar property in a congested and polluted neighbourhood. The observed price differences can serve as a surrogate measure for environmental quality, making it possible to estimate unpriced environmental variables through property market analysis.

The fundamental assumption of the Hedonic Pricing Model is that property buyers reveal their preferences for environmental attributes through their willingness to pay. The price of housing can be represented as a function of:

$P = f\ (\ Si,Ni,ENVi)$

- $P = f\ (\ Si,Ni,ENVi)$

Where Si represents structural characteristics (e.g., house size, number of rooms, construction type, presence of gardens or garages), Ni includes neighbourhood characteristics (e.g., proximity to schools, hospitals, parks, shops, and workplaces). $ENVi$ captures environmental quality indicators (e.g., air quality, water quality, noise levels, waste management facilities, and access to green spaces).

If comprehensive data on housing prices and characteristics is available, and non-environmental attributes are controlled, price variations can be attributed to differences in environmental quality. The implicit price of an environmental characteristic is estimated using multivariate regression analysis, where the hedonic price function is partially differentiated with respect to the environmental variable:

$$P_{ENV} = \partial P_H / \partial ENV$$

This equation provides an estimate of the economic value of a marginal improvement in environmental quality (e.g., a reduction in air pollution). By analysing variations in property prices, a demand curve for environmental quality can be constructed.

Empirical studies have validated the Hedonic Pricing Model in various contexts. For example, a study conducted in Boston found that households with higher incomes were willing to pay more for marginal improvements in air quality, particularly for reductions in nitrogen oxide pollution. This reflects how property prices encapsulate individuals' valuation of environmental attributes.

However, the Property Valuation Approach has several limitations.

i. **Data Requirements** – This method demands extensive data on real estate transactions, making it challenging to apply in developing countries where such records may be sparse.

ii. **Omitted Variable Bias** – If critical independent variables (e.g., crime rates, infrastructure quality) are not included in the analysis, the estimated implicit price may be biased.

iii. **Multicollinearity Issues** – Some environmental attributes are correlated with one another. For instance, a house located near an industrial zone may experience both higher air pollution and increased noise pollution, making it difficult to isolate the effect of each factor.

- Drawbacks – need extensive data, require apt variables

iv. **Choice of Functional Form** – The appropriate mathematical model must be selected to ensure interpretative and predictive accuracy.

v. **Static Nature** – This method does not account for future changes in environmental quality, which can

influence property values over time.

3.2.2.2 Household Production Function Approach

The Household Production Function Approach is a revealed preference method based on the premise that households make decisions to maximise utility by combining market goods with non-market goods (such as environmental quality) to produce desired outcomes. This approach views environmental goods and services as inputs in a household's production process. Two widely used techniques within this approach are:

- Decision making based on market and non-market goods

a. The Travel Cost Method (TCM)

b. The Preventive Expenditure Method

Both methods are essentially hedonic and rely on observed behaviour to infer the value of environmental amenities.

Travel Cost Method (TCM)

The Travel Cost Method (TCM) is one of the oldest and most widely applied techniques for valuing non-market environmental goods, especially in the context of recreational sites. Originally suggested by Harold Hotelling in 1947 and later developed by Wood and Trice, as well as Clawson and Knetsch, the method estimates the value of environmental goods by observing how much people are willing to pay to travel to a site. The underlying idea of TCM is that the cost incurred by individuals to visit a site (including travel expenses, time costs, and entrance fees) reflects their true valuation of that site. Even if the site has no admission fee, these indirect costs act as a proxy for the price of accessing the recreational or environmental resource.

- Cost of visiting a site shows the value of the site

The total travel cost (TTC) can be represented as TRC + AC

TTC = TRC+AC

Here, TRC = Transportation cost and AC = Accession cost (e.g., entrance fee). If there is no entry fee, AC = 0.

- TTC = TRC+AC

Travel costs vary depending on distance, time spent travelling, and individual socio-economic factors. Generally, individuals located farther from the site are expected to visit less frequently.

TCM can be implemented using two primary approaches:

a. Zonal Travel Cost Approach (ZTCM):

i. Simpler and less expensive.

ii. Visitors are grouped into zones based on their distance from the site (e.g., concentric circles or administrative divisions).

iii. For each zone, a visitation rate (visits per 1,000 population) is calculated.

iv. This rate is then plotted against the average travel cost to estimate demand.

b. Individual Travel Cost Approach (ITCM):

i. More detailed and statistically robust.

ii. Based on surveys of individual visitors, information is collected on asking questions related to:

   a. Distance travelled

   b. Frequency of visits

   c. Travel expenditure

iii. Allows a more precise estimation of the trip generating function (TGF) and demand curve.

iv. Estimating Demand and Consumer Surplus

The distance travelled is converted into cost, including all influencing variables. Using this, a Trip Generating Function (TGF)is generated. The general form of the demand function is:

$VR=f(C+X)$

Here, VR = Visitation rate, C = Cost of visiting the site, X = Other relevant factors (e.g., income, availability of substitutes, site quality)

Using regression analysis, the relationship between visitation rate and travel costs is estimated. The area under the demand curve and above the cost curve represents the consumer surplus, an indicator of the recreational value derived by users from the site. By aggregating consumer surplus across all zones, the total economic valuation of the recreational site can be estimated.

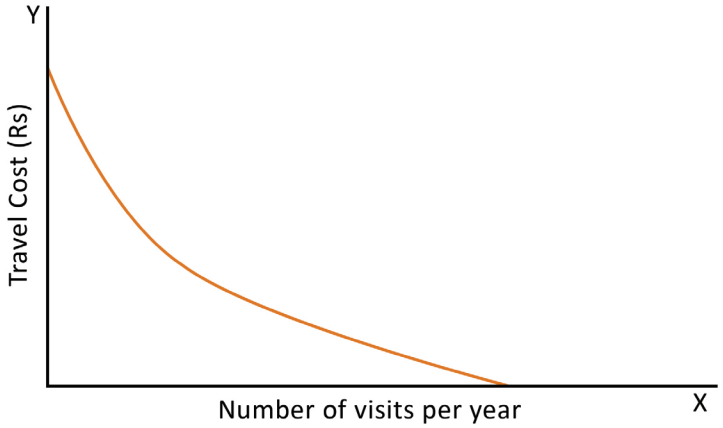

Fig 3.2.1 Demand Curve under Travel Cost Method

Limitations of the Travel Cost Method

Despite its strengths, TCM has several limitations:

i. Choice of Dependent Variable: Analysts must decide whether to use data based on visits per zone or individual, which can affect outcomes.

ii. Distinguishing Purposeful Visitors from Meanderers: Some visitors may include the site as part of a larger trip, making it difficult to isolate the site's specific value.

iii. Captures Only Use Value: TCM does not account for non-use values such as existence or bequest values.

- It captures only use value, subjective data makes error

iv. Excludes Off-site and Non-User Benefits: The method cannot measure values associated with off-site ecological functions or those held by non-visitors.

v. Valuation of Time: Estimating the opportunity cost of travel time is complex and subjective.

vi. Statistical Challenges: Measurement errors, omitted variable bias, and model specification can affect the accuracy of demand estimation.

Advantages of the Travel Cost Method

- Receives actual data, practical method

i. Based on Actual Behaviour: TCM relies on observed decisions rather than hypothetical choices, enhancing its credibility.

ii. Relatively Inexpensive and Practical: Especially suitable for evaluating recreational sites, parks, and protected areas where direct pricing is absent.

Summarised Overview

Valuing environmental goods and services is crucial for effective policy-making and sustainable resource management, especially when these goods are not traded in formal markets. Valuation methods based on observed market behaviour, also known as revealed preference methods, infer values from actual consumer decisions in related markets. This section focuses on two major revealed preference approaches. Hedonic Property Value Method. This method estimates the value of environmental attributes by analysing property prices. It assumes that housing prices reflect various characteristics, including environmental quality (e.g., clean air, scenic views, low noise). By isolating the effect of environmental variables, this method reveals the implicit value of these attributes. Household Models / Household Production Function Approach.

These models consider how households combine market goods and environmental inputs to produce utilities such as health or recreation. Key methods include the Travel Cost Method (TCM), which uses the cost incurred by individuals to visit recreational sites as a proxy for the site's value. Preventive/Defensive Expenditure Method: Estimates the value of environmental quality based on expenditures made to avoid or mitigate pollution-related harm (e.g., healthcare costs, water filters). These methods rely on actual behaviour rather than stated preferences, making them particularly useful for evaluating use values of environmental goods. While powerful, they have limitations in capturing non-use values (like existence or bequest values) and often require complex data and statistical analysis.

Assignments

1. What is meant by valuation methods based on observed market behaviour? How do these methods differ from stated preference methods in environmental valuation?
2. Define the Hedonic Property Value Method. What is the theoretical basis behind it?
3. What is the Travel Cost Method (TCM)? How is it used to estimate the recreational value of natural resources?
4. Discuss the strengths and weaknesses of using household models in environmental valuation.

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2. Hussen, A. M (1999), *Principles of Environmental Economics*, Routledge, London.
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UNIT 3

Stated Preference Methods and Cost-Benefit Analysis

Learning Outcomes

After completing this unit, the learner will be able to:

- understand stated preference methods
- discuss the contingent valuation method
- know about cost-benefit analysis

Background

In the field of environmental and resource economics, valuing non-market goods, such as clean air, biodiversity, or scenic beauty, presents a significant challenge. Traditional market-based valuation techniques often fall short when dealing with these intangible assets, as they lack observable market prices. To address this gap, economists have developed Stated Preference Methods, which rely on individuals' expressed preferences rather than actual market behaviour.

One of the most widely used stated preference techniques is Contingent Valuation (CV). This method involves directly asking people their willingness to pay (WTP) for specific environmental benefits or their willingness to accept (WTA) compensation for the loss of those benefits under hypothetical scenarios. Contingent valuation has been applied to a range of policy areas, including environmental preservation, public health, and cultural heritage conservation.

When integrated into Cost-Benefit Analysis (CBA), contingent valuation enables decision-makers to quantify the social and economic value of non-market outcomes. This is particularly useful for public sector projects and environmental policies where market signals are absent or incomplete. By incorporating the values derived from CV surveys, CBA can offer a more comprehensive and inclusive assessment of a project's total impact.

Keywords

Stated Preference Methods, Contingent Valuation, Cost-Benefit Analysis

Discussion

3.3.1 Stated Preference Method

- Survey based approach

The stated preference method is a survey-based approach used to evaluate environmental goods and services that are not traded in conventional markets. It involves directly asking individuals to express the monetary value they place on various environmental attributes, including both use values, which are associated with direct utilisation and non-use values such as existence and bequest values. This method is especially useful when no observable market data is available to infer preferences and valuations.

There are two major techniques under the stated preference approach:

- Uses questionnaires under CVM, alternatives under CM

- **Contingent Valuation Method (CVM):** This technique uses carefully designed questionnaires to ask individuals how much they are willing to pay (WTP) for the improvement or preservation of an environmental good or service. Alternatively, respondents may be asked how much compensation they would be willing to accept (WTA) for its degradation or loss.
- **Choice Modelling (CM):** In this method, individuals are presented with a series of alternatives, each comprising a different combination of attributes, including a monetary component such as price or subsidy. Respondents are required to make trade-offs among the attributes, thereby revealing their preferences through the choices they make.

3.3.1.1 Contingent Valuation Method

- Based on hypothetical scenario

The Contingent Valuation Method constructs a hypothetical market scenario to determine how individuals value environmental goods or services. Participants are asked to state their willingness to pay for gaining or preserving

a specific environmental benefit or their willingness to accept compensation for its loss. These valuations are said to be "contingent" because they are based on the specific hypothetical scenario provided in the survey.

- Value goods that lack market prices

CVM is particularly significant for valuing environmental goods that lack market prices, such as clean air, biodiversity, and scenic landscapes. The primary goal is to approximate the value individuals would reveal if a real market for the good existed. To accomplish this, detailed descriptions of the current environmental condition and the expected changes (due to policy interventions, natural occurrences, etc.) are provided to the respondents. Following this, individuals are asked how much they are willing to pay to secure a positive environmental outcome or avoid a negative one.

- WTA and WTP are used

The theoretical underpinning of the CVM lies in microeconomic welfare theory, which examines how individuals maximise their utility given income constraints or minimise expenditure to achieve a specified level of utility. The survey responses provide data to estimate either WTP or WTA, representing the change in consumer surplus associated with a given environmental change. These measures reflect the individual's valuation of marginal improvements or degradations in environmental quality.

- Compensating variation – maximum amount an individual would pay to maintain the utility level

The Hicksian welfare measures, namely the compensating variation and equivalent variation, serve as the conceptual foundation for interpreting WTP and WTA values. The compensating variation represents the maximum amount an individual would pay to maintain their initial utility level when prices rise or environmental quality deteriorates. Conversely, the equivalent variation is the minimum amount the individual would accept to forego a potential improvement, while remaining at the higher utility level that would have resulted from that improvement.

- Example for CVM - Exxon Valdez oil spill in Alaska in 1989

CVM has been applied in several high-profile environmental valuation cases. A prominent example is the Exxon Valdez oil spill in Alaska in 1989. The State of Alaska used CVM to estimate the loss of passive-use values resulting from the disaster. Economists reported a lower-bound WTP estimate of $28 billion to prevent a similar spill in the future. This application highlighted the method's ability to capture not only direct-use values but also the broader societal value placed on preserving environmental integrity.

Historically, Bob Davis pioneered the use of CVM in 1963 to estimate the recreational value of outdoor sites. Since then, the method has been widely adopted in environmental economics and policy to assess the benefits of initiatives such as air and water quality improvements, conservation of endangered species, and habitat protection.

While CVM offers unique advantages, especially its capacity to capture non-use values, it is also subject to limitations. Results can be influenced by strategic bias (respondents manipulating their answers), hypothetical bias (differences between stated and actual behaviour), and information bias (effects of how the scenario is described). Additionally, the discrepancy often observed between WTP and WTA values has been attributed to the theoretical distinctions underlying Hicksian welfare measures. Despite these challenges, CVM remains a valuable tool in environmental valuation, enabling policymakers and researchers to make informed decisions regarding resource allocation and conservation strategies.

- CVM suffers from bias related to manipulated answers, information

Methods of Calculating WTP/WTA

The calculation of willingness to pay (WTP) or Willingness to Accept (WTA) is a fundamental aspect of contingent valuation methods used in environmental economics. It involves a series of systematic steps that ensure the elicited values are credible, meaningful, and relevant to the environmental changes being assessed.

- Calculation of WTP or WTA involves a series of systematic steps

Step 1: Constructing the Hypothetical Market

The first stage in estimating WTP/WTA is the creation of a hypothetical market that clearly defines the environmental good or service being valued. This step requires a detailed identification and description of the environmental attributes under consideration. For example, it might involve improving the quality of a river to enhance its usability for fishing, water sports, or recreational purposes.

Key considerations in this stage include:

- **Stakeholder Engagement:** Stakeholders to determine the specific environmental good to be evaluated.
- **Market Definition:** Decide on the scope and nature of the hypothetical market, including the improvement or preservation of the environmental service.
- **Information Clarity:** Assess the quantity and quality of

- Hypothetical market may be considered having looking into stakeholders engagement, cost-benefit distribution

information required for respondents to make informed decisions.

- **Cost-Benefit Distribution:** Determine who will bear the cost and who will benefit from the proposed environmental change.
- **Sampling Strategy:** Select a suitable sampling method, such as convenience, representative, or stratified sampling, to ensure accurate representation of the target population.

Step 2: Designing and Administering the Questionnaire

The second step involves the careful design and implementation of a survey instrument to elicit individual preferences. The effectiveness of this step depends significantly on the structure and administration of the questionnaire.

Important elements include:

- **Mode of Administration:** Decide on the method of delivery (e.g., face-to-face interviews, telephone surveys, online questionnaires). In-person interviews are often preferred due to the opportunity to clarify information and encourage participation.
- **Use of Visual Aids:** Employ visual tools such as photographs or videos to improve the respondent's understanding of the environmental change being valued.
- **Incentivising Responses:** Consider the use of inducements to increase the response rate.
- **Administration Strategy:** Determine whether the survey will be conducted by researchers themselves or outsourced to a professional agency. Surveys administered by researchers often yield more reliable results.

- Questionnaire may be created considering method of delivery, employing visual tools, with proper strategy

The questionnaire should include:

- A clear description of the environmental good or service being evaluated.
- Demographic and socioeconomic questions to characterize respondents (e.g., age, income, residential location, use of related goods).
- WTP or WTA elicitation questions that specify the method of payment or compensation (e.g., taxes, entrfees, voluntary donations).

- Questionnaire may include details of demography, socio-economic condition, payment mechanism, institution responsibility

The questionnaire should also provide comprehensive information regarding. The expected availability of the environmental service, The payment mechanism and timing, The contributions of others, The responsible institutions or authorities involved in the implementation. An example of a WTP question might be: *"Would you be willing to pay an entry fee of Rs. X if the river site were developed into a recreational area offering fishing, boating, and swimming facilities?"*

Step 3: Survey Implementation and Elicitation of Bids

This step focuses on collecting data on WTP or WTA using structured elicitation formats. Several formats are commonly used:

- **Open-Ended Format:** Respondents are asked to state their maximum WTP or minimum WTA without being prompted with any specific amount. The average responses are calculated and then aggregated to estimate the total WTP or WTA for the population. While simple, this method may yield highly variable results.
- **Bidding Game Format:** This iterative approach begins with a specific bid amount. If the respondent agrees to pay it, the bid is increased; if not, it is decreased. The process continues until the respondent reaches a final value, representing their maximum WTP or minimum WTA. Although interactive, this method may suffer from starting-point bias.
- **Dichotomous Choice Format:** This is one of the most widely adopted methods and involves presenting respondents with a binary choice: *"Would you be willing to pay Rs. X to ensure the environmental improvement?"* The respondent answers "Yes" or "No," and the response is recorded. A "Yes" response indicates that WTP exceeds Rs. X; a "No" response suggests the opposite. However, this method only provides a qualitative estimate of WTP.

- Survey can be open ended, bidding, dichotomous choice format

To improve its accuracy, a follow-up dichotomous choice (double-bounded dichotomous choice) can be used. If the respondent initially says "No" to Rs. 20, a lower amount (e.g., Rs. 10) is proposed. If they say "Yes," a higher amount is offered. This method allows WTP to be bracketed within a range and provides more information about individual

valuation. The resulting response patterns, Yes/Yes, Yes/No, No/Yes, No/Non, can be analysed using regression models, incorporating bid amounts, demographic characteristics, and other relevant variables. These models allow for the estimation of average and median WTP values and help monetize the perceived benefits of the environmental change.

Step 4: The Payment Card Method

The Payment Card Method, originally developed by Mitchell and Carson, is an alternative to the bidding game and is used to quantify the value individuals assign to environmental changes. It provides a structured format to elicit WTP/WTA by offering a visual range of monetary amounts from which respondents choose their preferred value.

Key Characteristics are:

- **Quantification of Change**: The method specifies environmental change in quantitative terms.
- **Market Context**: It provides detailed information about the institutional and policy setting of the hypothetical market.
- **Format**: Can be open-ended (respondents specify an exact value) or closed-ended (respondents answer "yes" or "no" to a given value).

- Quantity Value assigned by individuals on environmental goods

Respondents are presented with a card listing various monetary amounts and are asked to select the figure that best represents their WTP. According to Cameron and Huppert, this specified value is a lower bound of the respondent's true WTP.

Step 5: Analysing Survey Results and Estimating the Bid Curve

A general form of the WTP function, derived from survey responses, may be represented as:

$$WTP=f(Q,Y,T,S)$$

Where:

- Q: Quantity or quality of the environmental good
- Y: Respondent's income

- T: Index of individual preferences or tastes
- S: Socio-economic characteristics

- WTP=f(Q, Y,T,S)

Open-ended format: Use the sample mean to estimate average WTP/WTA.

Dichotomous choice format: Use econometric techniques to estimate the expected WTP/WTA.

Bid curves model the relationship between WTP and influencing variables. In the case of dichotomous choice formats, logit or probit regression models are commonly employed to estimate the probability of a "Yes" response at different bid levels.

Step 6: Aggregating Results

To derive the total economic value of an environmental good or service:

1. Calculate the Mean WTP/WTA from sample responses.
2. Multiply the sample mean by the size of the relevant population (local, regional, or national).
3. If benefits accrue over time, apply discounting techniques to obtain present value estimates of future benefits.

Critical Assessment of the Contingent Valuation Method (CVM)

Despite its growing use, the Contingent Valuation Method faces several challenges that affect the reliability and validity of its results.

Common Sources of Bias in CVM

1. Hypothetical Bias:

One of the most critical limitations of the Contingent Valuation Method (CVM) is the presence of hypothetical bias. Since CVM relies on a hypothetical scenario, respondents are not required to make actual payments, and their responses may therefore fail to represent their true preferences or willingness to pay. In many cases, individuals may lack a clear understanding of their actual preferences, making it difficult for them to provide valid responses. Even when they are aware of their

preferences, there may be a tendency to misreport them if they believe it serves their interest. For instance, if respondents suspect that their answers could influence the pricing of the good in question, they may understate their willingness to pay. Conversely, they may exaggerate their responses if doing so appears beneficial. Hypothetical bias thus represents the gap between the stated willingness to pay in a simulated market situation and the actual payment behaviour observed in real-life markets. This bias can manifest in either a positive or negative direction. When respondents do not perceive the scenario as realistic or serious—especially when there is no actual payment required—their responses can become exaggerated or detached from real-world decision-making. However, this bias can be reduced by ensuring that respondents are given more comprehensive and accurate information about the proposed project or good.

2. Information Bias:

Information bias arises when respondents are either inadequately informed or misled due to insufficient or incorrect information provided during the valuation exercise. This can result in overestimation or underestimation of willingness to pay. Such distortions may be caused by limited or unclear information about the nature and characteristics of the good, lack of awareness regarding available substitutes or complementary goods, misunderstanding of the relative expenditure involved, or incomplete knowledge of the behavior or preferences of others. Numerous studies have found that the reliability of willingness to pay estimates improves significantly when respondents are provided with fuller and more accurate information. To mitigate this bias and ensure more dependable valuation outcomes, it is essential to supply clear, complete, and unbiased information to all participants.

3. Strategic Bias:

Strategic bias occurs when individuals attempt to manipulate the outcome of the valuation for personal gain. This form of bias depends largely on what respondents believe will be done with their answers. If they think their responses will influence policy decisions or financial obligations, they may deliberately conceal their actual preferences. For example, someone who supports a policy might inflate their willingness to pay to increase its chances of being implemented, while another person who opposes a user fee or tax might understate their willingness to pay to prevent such measures from being

introduced.

4. Starting Point Bias:

Starting point bias refers to the influence that initial values presented in a survey can have on the final responses. When respondents are provided with a starting value or reference point, it can shape their perception of what is reasonable or expected, thereby affecting their own stated willingness to pay. This bias becomes more pronounced when individuals are unfamiliar with the item being valued or the valuation process itself, leading them to anchor their responses around the suggested starting point rather than independently evaluating their own valuation.

5. Payment Vehicle Bias:

Payment vehicle bias arises from the specific mode of payment suggested in the survey. The willingness to pay reported by respondents can vary depending on whether the payment is framed as a tax, a user charge, an entry fee, or a voluntary donation. People may respond more negatively when the payment is presented in the form of a tax due to emotional or ideological aversion. Thus, the chosen payment method can influence the outcome, and this variation is termed payment vehicle bias.

6. Sampling Bias:

Sampling bias is a concern when the sample of respondents does not accurately represent the broader population. If the selected individuals differ systematically from the general population—whether in demographics, preferences, income levels, or awareness—then the derived willingness to pay estimates will not be generalizable and may lead to misleading conclusions.

- Bias include Sampling, hypothetical, information, startegic

7. Embedding Effect

WTP changes depending on whether the good is presented alone or as part of a package. Kahneman and Knetsch (1992) identified two forms:

- **Perfect Embedding**: The value assigned to a good is the same whether valued alone or as part of a broader category.
- **Regular Embedding**: The good receives a lower valuation when presented as part of a set than when evaluated in isolation.

3.3.2 Cost-Benefit Analysis (CBA)

- Evaluates all benefits and cost of a project

Cost-Benefit Analysis (CBA) is a systematic framework used to evaluate all potential benefits and costs associated with a proposed course of action, compared to alternative options. Developed and refined over the past several decades, CBA serves as an essential tool for informing social and public decision-making. Unlike financial appraisal, which considers only the private costs and benefits relevant to an individual or firm, CBA incorporates all societal costs and benefits, regardless of who experiences them. Typically employed by governments and public institutions rather than private entities, CBA is particularly useful when evaluating actions with wide-ranging social or environmental impacts. It ensures transparency and accountability by attempting to quantify, as comprehensively as possible, the trade-offs involved in any policy or project decision.

- Usually done by public isntitutions

CBA has been widely adopted to evaluate the efficiency of projects, programmes, and policies, especially those with environmental implications. It is commonly used to assess the trade-offs in projects such as the construction of large dams, highway expansions, and power plants that may have ecological and social side effects.

3.3.2.1 Steps in CBA

1. Core Principles and Decision Rule

- Benefit be greater than cost

The basic decision rule of CBA is that a project should be undertaken if the total expected benefits exceed the total expected costs. In other words, the action is justified if the present value of the expected benefits, E(B), is greater than the present value of the expected costs, E(C). If $E(B) < E(C)$, the action should not be pursued. This criterion ensures that the course of action selected yields a net gain to society. It is also important at this stage to identify the stakeholders affected by the decision and to define the relevant time frame over which the costs and benefits will be evaluated.

2. Determining the Optimal Scale

Once a potential project has been identified, the next step is to determine the optimal scale or size. For example, if the project involves building a dam, CBA can guide whether a small, medium, or large structure would yield the highest net benefits. In the case of a policy to improve environmental quality, CBA helps determine the optimal level of improvement by

comparing the marginal social benefits and marginal costs. If a policy or programme is mandated by law, a CBA may not be necessary. However, where the undertaking of a project is optional or contested, a CBA justifies by demonstrating that its benefits outweigh its costs. In cases where multiple mutually exclusive projects are under consideration, all alternatives must be evaluated. CBA identifies the option with the highest net benefit. For instance, if three different projects cost the same, the one with the greatest total benefit would be recommended.

- Project yielding highest benefit may be selected

3. Identifying and Predicting Impacts

- identifying all relevant impacts, and prediction of the expected consequences

The third step involves identifying all relevant impacts, both direct and indirect that may result from the proposed project. This is followed by a prediction of the expected consequences, both positive and negative, for each alternative. For example, the construction of a dam might result in improved irrigation and power generation, but also lead to deforestation, ecosystem disruption, and the displacement of communities.

4. Valuing Costs and Benefits

- Assign monetary value to cost and benefit

The next step involves assigning monetary values to the various costs and benefits. This process enables comparisons across different dimensions and simplifies the aggregation of impacts. All values must be measured in consistent monetary terms at the time they are expected to occur.

5. Discounting for Present Value

- Value of money today compared to future

Since costs and benefits often occur at different times, discounting is necessary to convert them into present values. Discounting reflects the time value of money the principle that a benefit today is more valuable than the same benefit in the future. For instance, if ₹100 is received today, it can earn 5% interest, and it will amount to ₹105 in a year. Conversely, to receive ₹100 a year from now, one would need to invest approximately ₹95 today at 5% interest. Therefore, when applying a discount rate, the present value of future costs and benefits becomes lower as the rate or time horizon increases.

6. Sensitivity Analysis

- Conducting a sensitivity analysis

Given the inherent uncertainties in forecasting future outcomes, the seventh step involves conducting a sensitivity analysis. This technique consists in recalculating the net present value

3.3.2.2 Theoretical Foundations of Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) is firmly rooted in the principles of welfare economics, drawing on key theoretical concepts such as Pareto efficiency, Pareto improvement, the Kaldor-Hicks compensation criterion, and the notions of consumer and producer surplus. Central to CBA is the idea of maximising net social benefit, often expressed in monetary terms through the concept of net present value (NPV). This is grounded in the concepts of willingness to pay (WTP) and willingness to accept (WTA), the two measures used to evaluate consumer preferences. WTP refers to the maximum amount an individual is prepared to pay for a benefit, while WTA represents the minimum compensation required to accept a loss. These measures correspond to Hicksian concepts of compensating and equivalent variation, forming the basis of consumer surplus evaluations. CBA aims to measure economic surplus, the total net benefits that accrue to individuals. Robert Sugden defines economic surplus as the difference between what an individual is willing to pay and what they actually pay (for benefits), or between what they are willing to accept and what they actually receive (for costs). A policy or project is deemed socially desirable if it results in a positive net surplus, i.e., if aggregate WTP exceeds aggregate WTA.

- Maximise net social benefit

Pareto efficiency is a theoretical condition where no individual can be made better off without making someone else worse off. While ideal, this standard is rarely met in practice. Thus, economists often rely on the more pragmatic Kaldor-Hicks criterion, which considers a policy socially beneficial if those who gain could, in theory, compensate those who lose, regardless of whether compensation actually occurs. This approach underpins much of CBA, where actual Pareto improvements are rare, but potential Pareto improvements provide a justifiable basis for decision-making.

- Theoretical concepts used – Economic surplus, Pareto effeciency

CBA thus suggests that only those projects with a positive net present value should be adopted, indicating that the benefits to society outweigh the associated costs. The theoretical robustness of CBA stems from its integration of welfare economic principles, including allocative efficiency and surplus-based decision criteria.

- Projects with a positive net present value should be adopted

3.3.2.3 Rules of Cost-Benefit Analysis (CBA)

- Maximise economic efficiency = Benefits > Cost

The primary goal of Cost-Benefit Analysis is to maximize economic efficiency, which requires that the total benefits (B) of a project exceed the total costs (C). The fundamental decision-making criterion in CBA is the Net Present Value (NPV), which ensures that future costs and benefits are appropriately discounted over time. The NPV formula is:

$$\text{NPV} = \sum_{t-0}^{T}(B_t - C_t)/(1+r)^t$$

Where:

- Bt and Ct are benefits and costs in year *t*, *r* is the discount rate, *T* is the time horizon

Decision Rules for Project Selection

Rule 1: If there are no budget or resource constraints, accept all projects with a positive NPV.

Rule 2: If there are constraints (e.g., budget limits), select the combination of projects that maximizes total NPV.

Corollary: Never undertake a project with a negative NPV, as it implies a loss in economic efficiency.

Additional Guidelines

- **Single Project Decision:** Accept the project if NPV > 0; reject it if NPV < 0.
- **Mutually Exclusive Projects:** Choose the project with the highest NPV.

Choosing the Appropriate Scale of a Project

Economic theory suggests using marginal analysis when determining the optimal scale of a project. Continue expanding the project until the Marginal Cost (MC) = Marginal Benefit (MB), which is the point of maximum net benefits. In an environmental project like pollution reduction, reduce pollution until the marginal cost of reduction equals the marginal benefit derived from it. Projects are also evaluated using the Benefit-Cost Ratio (B/C). If B/C > 1, the project is generally considered viable.

Alternative Evaluation Criteria in CBA

1. **Internal Rate of Return (IRR):** The IRR is the discount rate at which NPV becomes zero.
   - A project is acceptable if IRR > discount rate (r), which implies NPV > 0.
2. **Benefit-Cost Ratio (BCR):** This criterion compares the present value of benefits to the present value of costs.
   - Accept the project if B/C > 1.

- Project is acceptable if IRR > discount rate (r) or if B/C > 1

While both IRR and BCR are useful, NPV remains the most widely used and reliable method due to its straightforwardness and comprehensiveness.

Limitations of Cost-Benefit Analysis

Despite its usefulness, especially when market data is scarce or incomplete, CBA faces several criticisms, particularly in evaluating environmental and social impacts:

1. **Challenges in Valuation:** It's difficult to assign accurate monetary values to environmental goods, species, or long-term benefits felt by future generations.
2. **Incomplete Coverage:** CBA might not account for **externalities**, i.e., unintended side-effects (positive or negative) that impact third parties.
3. **Equity Concerns:** While CBA prioritizes efficiency, it often overlooks equity. The gains and losses of a project may not be evenly distributed, and compensating the losers is only theoretical.
4. **Measuring Intangible Benefits:** Valuing ecosystem services, environmental quality, or human life (e.g., in health projects) poses ethical and technical challenges. Methods like Willingness to Pay add subjectivity.
5. **Errors and Discounting Bias:** Measuring future costs/ benefits accurately is difficult. The use of discounting often underrepresents long-term harms, especially in the context of irreversible environmental damage.

- Difficult to accurately measure monetary value for environment goods

Summarised Overview

Stated Preference Methods, particularly Contingent Valuation (CV), are essential tools in environmental economics for valuing non-market goods and services that lack observable prices. CV involves directly surveying individuals to determine their willingness to pay (WTP) for specific environmental improvements or their willingness to accept (WTA) compensation for environmental losses under hypothetical scenarios. These values are then integrated into Cost-Benefit Analysis (CBA) to assess the economic viability of projects or policies, especially those with environmental or social impacts. By capturing public preferences for intangible benefits such as clean air, biodiversity, or ecosystem services, CV enriches the CBA framework, making it more inclusive and representative of societal values. Despite challenges like hypothetical bias and response validity, contingent valuation remains a widely used method for informing sustainable policy and investment decisions where market data is insufficient.

Assignments

1. Explain the Contingent Valuation Method (CVM). What are its key components and assumptions?
2. What roles do Willingness to Pay (WTP) and Willingness to Accept (WTA) play in contingent valuation studies?
3. Illustrate with examples how CVM can be applied in evaluating an environmental or health project.

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Suggested Reading

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3. Goudie, A. S. (2018). *Human Impact on the Natural Environment: Past, Present, and Future* (8th ed.). Wiley-Blackwell

Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

BLOCK 4

Environmental Management

UNIT 1 Approaches for Environmental Protection

Learning Outcomes

After completing this unit, the learner will be able to:

- understand how emission taxes function to internalise the external costs of pollution
- know about tradable pollution permits
- discuss the role of pigouvian fees
- understand the significance of regulatory limits on pollutant emissions

Background

Environmental protection has become a major global concern due to the increasing ecological degradation caused by industrialisation and economic activities. To address these challenges, various policy instruments have been developed to regulate and reduce environmental harm. Among the key mechanisms are emission taxes, tradable pollution permits, Pigouvian fees, and emission standards, which serve as regulatory and market-based approaches to controlling pollution. Emission taxes are designed to internalise the environmental costs associated with pollution by imposing a tax on emissions, thereby encouraging firms to adopt cleaner technologies and reduce their environmental pollution. Tradable pollution permits, on the other hand, create a market-oriented approach where companies are allocated a fixed number of emission allowances that can be traded. This will encourage cost-effective pollution reduction. Pigouvian fees, named after economist Arthur Pigou, function as corrective charges imposed on activities that generate negative externalities, compelling polluters to bear the social costs of environmental damage. Meanwhile, emission standards establish legally binding limits on the amount of pollutants industries can release, ensuring regulatory compliance and promoting sustainable practices.

These measures collectively contribute to environmental protection by coordinating economic incentives with ecological sustainability. The effectiveness of these policies

depends on their design, enforcement, and the specific environmental challenges they aim to address. Understanding these approaches is essential for developing an effective strategy for sustainable environmental management.

Keywords

Emission taxes, Tradable Permits, Pigouvian Fee, Emission Standards

Discussion

4.1.1 Methods of Environmental Protection

- Government fiscal policies influence environmental conservation

Government tax, subsidy, and expenditure policies have a significant impact on shaping economic activity. These economic instruments distribute funds between the public and private sectors of the economy. These instruments can also be utilised to redistribute resources within the private sector. The government employs measures like taxes and subsidies in an effort to promote private sector actions that contribute to better environmental conditions. Using fiscal tools can bring external environmental costs into account and prompt both consumers and businesses to consider the complete societal implications of their actions, including both positive and negative outcomes. Government policies have been implemented to manage and reduce environmental pollution, as well as to redistribute land and water resources in a manner that promotes environmental conservation. Many of these public policies were developed and implemented relatively recently, but unfortunately, they often fall short of their intended objectives.

The public policies aimed at addressing pollution control include:

1. **Levying taxes** or charges on those producing pollutant by-products or side effects, equivalent to all or part of the environmental costs their emissions impose on the affected population.
2. **Providing government subsidies** to polluters to cover the expenses associated with reducing or eliminating their pollutant emissions.

- The key public policy for pollution control includes taxation on polluters

3. **Establishing legal thresholds** for the quantity of various pollutants or restricting the production of processes and products that exceed these emission limits.
4. **Involvement of government** in steering the development and adoption of production technologies or product designs that result in reduced pollutant by-products or side effects.
5. **Imposing outright bans** by the government on the production of certain items or processes.

4.1.1.1 Emission Taxes

- Reduced pollution through tax

Emission taxes, also known as Carbon Taxes, are imposed on the industries that produce pollution and release it into the environment untreated. The industry's effluent discharge is the basis for its classification. When the amount of pollution is substantial and its characteristics are likely to have a significant impact on society, the tax rate will be high. In contrast, a smaller amount of pollution with less severe effects will have a lower tax rate. When a tax is properly levied, it will ensure that the entire external costs associated with production are borne by the company. This causes companies to reduce their production, resulting in a cleaner environment. Overall, well-designed tax and subsidy systems are effective ways to shape the distribution of resources and protect the environment by maintaining good air quality. Currently, 27 countries have introduced Carbon taxes.

- Effluent charges incentivize businesses to reduce emissions

Environmental quality problems are being most directly addressed by effluent charges as one of the categories of tax weapons. Implementing a per unit tax in effluent charges eliminates the zero-cost associated with utilising air and water resources for waste disposal, thus limiting the unrestricted property rights inherent in the free use of environmental resources. The government formally sets out its property rights to air and water resources through its policy on effluent charges . Also, it determines the price that must be paid for utilising these resources. Consequently, businesses and individuals must factor effluent charges into their overall business expenses. Imposing an effluent charge motivates companies to assess the additional expenses they incur by trying to avoid paying the tax. The investor's desire for profit motivates him to select the lowest-cost solution. Introducing 'Effluent charges' will likely generate the following response from business owners.

a. Tax avoidance through reduction of emissions,

b. Output reduction, and

c. Payment of the effluent charge and shifting the tax burden to the customers.

The figure below shows the effects of an effluent charge on environmental quality through waste reduction.

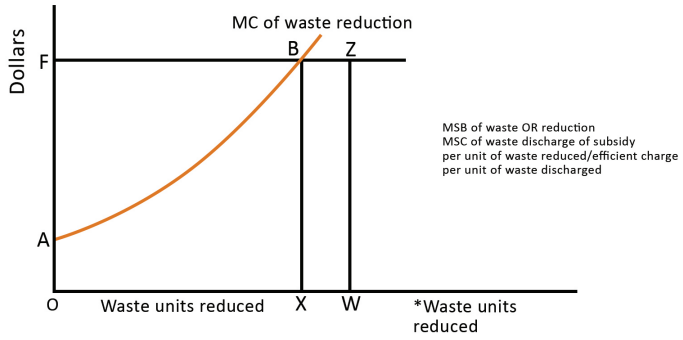

Fig: 4.1.1 Effect of Effluent Charges on Environmental Quality

- The firm minimises waste discharge by balancing the marginal cost of waste reduction

Here, MC is the Marginal Cost of waste reduction. The company incurs an effluent charge of OF dollars per unit for waste discharged, prompting it to refrain from discharging its first OX units in order to save AFB dollars compared to what would have been spent on charges for discharging OX units of waste. To the right of point B, the company will bear the effluent charge and release waste, rather than incur the substantial costs associated with not doing so. Thus, the firm will act along the line AB, taking internal measures to prevent waste discharge from point A to point B. If the waste load surpasses OX units, the firm is prepared to pay OF dollars per unit for excess effluent charges. If a firm's total waste load is OW units, the company would then opt to decrease OX waste units and allow XW units to be released into the environment. The company is required to pay OF dollars for each unit of waste. So, the overall expense would be XBZW. This exact amount reimburses society for the external costs incurred as a result of the XW waste unit's operations (under the assumption that the marginal social cost of each unit of waste discharged is OF). Under the effluent charge method, the total cost of the firm is:

Total waste disposal costs payment = Waste reduction cost (OABX) + Effluent cost (XBZW).

The Effect of Tax on Emissions

- Tax is expected to reduce production or consumption by increasing private costs

The tax would be equivalent to all or a portion of the environmental expense incurred per unit of output or usage. Implementing a tax that matches the total external environmental costs at each output level would equate the producer/consumer's private costs with the average and marginal costs of production/consumption, including environmental expenses. Two primary outcomes of this taxation policy are expected. Initially, in all instances, it should lead to a decrease in the volume of production or consumption of the taxed product, as the increased private costs will be reflected in higher prices. A second consequence is particularly significant when the taxed manufacturer is able to decrease his environmental production expenses by modifying either his production process or the product itself.

- The impact of effluent charges must be carefully considered

However, no policy tool is free from limitations. This is a pressing concern because companies may shift the burden of this tax to consumers by increasing the price of their products. The tax also affects consumers across different socioeconomic backgrounds, such as a comparison between low-income individuals and high-income earners. This serves as a warning that we must take into consideration the impact of effluent charges on income distribution. It is worth noting that an effluent charge produces revenue. Implementing a financially neutral taxation policy allows governments to offset the revenue generated from pollution taxes, thereby addressing income inequality or other adverse consequences resulting from the tax. Others contend that it is crucial to be aware of the double dividend aspect of the pollution tax. A pollution tax can be employed to rectify market imbalances caused by externalities stemming from excessive utilisation of environmental services and generate revenue that could be used to fund valuable social initiatives, including assistance to low-income individuals and encouragement for companies to undertake eco-friendly projects.

Economists have expressed considerable concern over the fact that effluent charges are determined through a trial-and-error process. As a result of this concern, an alternative policy tool has been created to regulate pollution, namely tradable

- Alternative policy tool to regulate pollution

pollution permits or transferable emission permits. The policy tool discussed in the following section combines the benefits of effluent charges and is not based on trial and error.

4.1.1.2 Tradable Pollution Permits

- Transferable emission permits create a market for pollution allowances

The fundamental concept behind transferable emission permits is to establish a market for the purchase and sale of pollution allowances. A pollution right essentially represents a permit that is quantified by a specific unit, such as a pound or a ton, of a particular pollutant. The regulatory mechanism of the transferable emission permit approach is characterised by two primary government roles: 1) Setting overall cap on total emissions: They set the total number of permits allowed or overall cap on total emissions. 2) and allocation of pollution permits: deciding the method for allocating the initial pollution permits among polluters.

- Effectiveness depends on the careful determination of the total number of permits

Government authorities typically establish the total number of permits or units of pollutants by taking into account both the damage and control costs from a societal perspective. In reality, precise estimates of the damage and control expenses are often not easily accessible because they may require extremely high transaction costs. Government agencies typically determine the total number of permits by utilising the most current data regarding both the costs of damage and control at a specific point in time. The effectiveness of a transferable permit scheme, intended to mitigate the exploitation of the natural environment, hinges crucially on the overall number of pollution permits issued. This decision should not be made without careful consideration, as government authorities can still adjust the number of pollution permits given to a polluter whenever necessary.

After the total number of emission permits has been established, the next step involves identifying a process for allocating the total permits among polluters. There is no one-size-fits-all solution for apportioning initial rights among polluters, particularly when fairness is a key factor to take into account. Despite the emphasis on equity, the free transferability of pollution permits means that the initial allocation of rights will not influence how the total permits are ultimately distributed through market forces. So, a system of transferable permits operates based on the following basic postulates:

- Permits being clearly defined, freely transferable, and subject to penalties for overuse

1. It is possible to obtain a legally sanctioned right to pollute.
2. These rights (permits) are clearly defined.
3. The total number of permits and the initial distribution of the total permits among the various polluters are assigned by government agencies. In addition, polluters emitting in excess of their allowances are subject to a stiff monetary penalty.
4. Pollution permits are freely transferable. That is, they can be freely traded in the marketplace.

- Varying waste processing efficiencies between the firms

To explain this, we will use the following example. Suppose that after careful consideration of all the relevant information, government agencies of a hypothetical jurisdiction would grant a total of 300 permits for twelve months. Each permit entitles the holder to release one ton of sulfur dioxide. Only two companies, Firm 1 and Firm 2, are releasing sulfur dioxide. Government authorities distribute an equal quantity of permits to both companies based on a fair criterion. The highest amount of sulfur dioxide each company is allowed to emit annually is 150 tons. In the absence of government regulation, each firm would have emitted 300 tons of sulfur dioxide. The government aims to cut the total sulfur emissions in the area by half through the issuance of 300 permits, which corresponds to a reduction goal of 300 tons. The hypothetical data presented thus far is incorporated in the figure below. In this figure, it is assumed that the marginal control costs (MCC) for these two firms are different. It is particularly assumed that Firm 1 employs a more efficient waste processing technology than Firm 2.

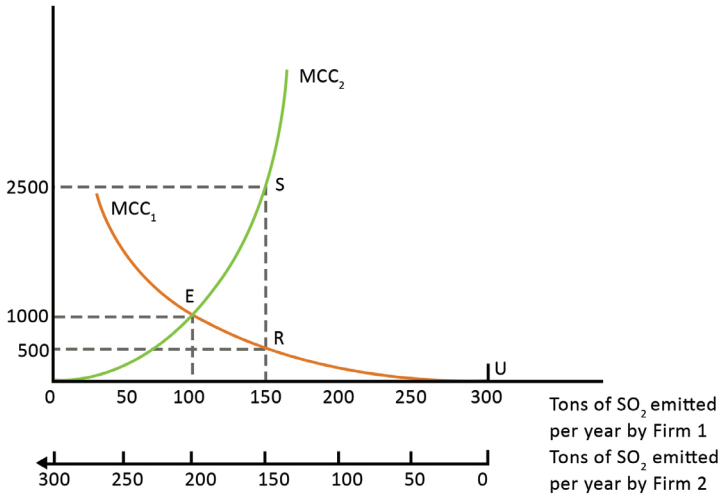

Fig: 4.1.2 Working of Transferable Emission Permits

- Different marginal control costs highlight the potential for mutually beneficial negotiations.

Considering the circumstances described earlier, these two companies can engage in negotiations that offer advantages to both parties. Let us start by examining the circumstances confronting Firm 1. Firm 1 is currently operating at point R of its marginal cost curve, with a maximum allowable sulfur emission discharge of 150 units. It is currently regulating 150 units of its sulfur emissions. The marginal control cost for the final unit of sulfur dioxide (SO_2) is \$500 for this particular firm. Conversely, Firm 2 is functioning at point S on its MCC, whilst managing 150 units of its waste output and discharging the remaining 150 units into the environment. At this operational level, point S, Firm 2's marginal control cost is \$2,500. It is clear that at their present operational level, the marginal control costs of these two companies are not identical. Firm 2 incurs a cost that is five times greater than that of Firm 1.

Purchasing a pollution permit from Firm 1 would be in Firm 2's best interest if it costs less than \$2,500. Firm 1 will be willing to sell a permit, provided its price is in excess of \$500. This mutually beneficial exchange of permits will endure as long as, at each step of the negotiation between the two parties, the cumulative costs to company 2 exceed the cumulative costs to company 1. As long as the marginal control cost of Firm 2 is higher than that of Firm 1, Firm 1 will be able to supply pollution permits to Firm 2. This relationship will cease to occur when the marginal control costs of the two firms become

- Both firms engage in a mutually beneficial exchange until marginal control costs are equal

equal, specifically $MCC_2 = MCC_1$. This equilibrium condition is attained at point E in the above figure. At this equilibrium point, Firm 1 is emitting 100 tonnes of sulfur or controlling 200 tonnes of sulfur. Firm I is currently releasing 50 tons less in sulfur emissions than the maximum amount permitted. Conversely, at the equilibrium point, Firm 2 is releasing 200 tons of sulfur, 50 tons over its allotted maximum allowable pollution allowances. Firm 2 compensates for this deficit by acquiring 50 tons' worth of pollution permits from Firm 1. At equilibrium, the combined sulfur emissions from these two firms total 300 tons, matching the exact amount of pollution permits issued by government authorities.

- Cost-effective pollution control with a reduction in overall costs and a mutually beneficial exchange

What distinguishes the initial situation of these two firms at points R and S from the new equilibrium condition achieved through a system of transferable pollution permits at point E is that in both cases, the overall amount of sulfur released is identical at 300 tons. The desirable aspect of the new equilibrium position (point E) is its cost-effectiveness. It should be noted that it satisfies the usual condition for cost-effective allocation of resources – that is, the marginal control cost of the firm under consideration is equal. The new position can also be illustrated in the above figure, which demonstrates that both firms benefit from it. The total cost of pollution control for these two companies at their initial operational level (points R and S) is depicted by area 0ESRU. The total cost of pollution control at the new equilibrium is represented by the area 0EU. As a result, the overall control cost decreases by an amount equal to area ERS when transitioning to the new equilibrium. Moving from the old to the new position does not worsen anyone's situation, which indicates a Pareto improvement. This outcome is achieved through a voluntary and mutually advantageous exchange between the two firms.

- As the number of participants increases, more investment in pollution prevention technologies

Similar to an effluent charge system, implementing transferable permits would generate strong incentives for companies to invest in pollution prevention technologies. A notable aspect of transferable permits as a public policy tool is that, once the total number of permits is established, the distribution of these permits among competing users is determined solely by market forces. The simplicity of the case employed above, featuring only two firms, clearly illustrates the point. What makes the transferable pollution permit system truly effective is its ability to function more efficiently as the number of participants in the permit exchange process grows. The sole prerequisite for this system, as previously mentioned, is

the establishment of clearly defined new property rights, specifically pollution permits.

4.1.1.3 Pigouvian Tax

- Raising prices and reducing demand to internalise environmental externalities

Taxes that are used to internalise environmental externalities are commonly referred to as Pigouvian taxes, named after economist Arthur Pigou. A tax imposed on each unit of output of goods and services that results in pollution or environmental harm is a Pigouvian tax. As illustrated in the figure below, introducing a tax of this type would cause the supply curve to move from S to S_1. At point A, market conditions are optimal, where supply meets the demand. Nevertheless, the market is not socially optimal since it does not take into account the costs incurred by others. To compensate for the negative consequences of an externality, a Pigouvian tax is implemented, and imposing a tax of this nature would shift the supply curve from S to S_1. The new supply curve intersects the demand curve at point B, where the price increases from P_1 to P_2. Implementation of the tax and subsequent rise in price to the consumer results in a decrease in quantity demanded from Q_1 to Q_2. Consequently, the tax reduces the demand for output, lowering overall emissions, and the revenue generated can be utilised to rectify environmental damage or invest in cleaner generation technologies. At point B, market conditions are socially optimal since the external costs to others have been internalised through taxation. This reduces the deadweight loss in the market.

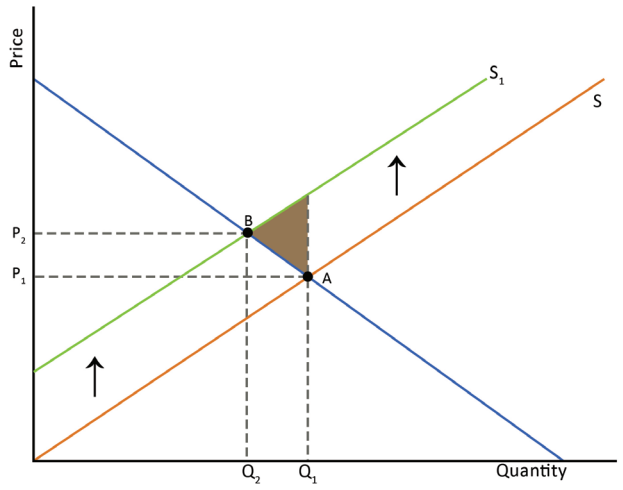

Fig. 4.1.3 Effect of a Pigouvian Tax

A key advantage of a Pigouvian tax based on output is its relative simplicity in implementation and tax collection. The tax is calculated based on a firm's final output, and its accuracy can be confirmed by analysing the financial reports, which companies are legally obliged to produce. Once the output level is confirmed, calculating the tax requires only an understanding of the applicable tax rate, which is determined by regulatory authorities. In this regard, a Pigouvian tax is often preferred because it involves relatively low transaction costs for implementation and oversight. Despite this advantage, however, a tax of the above nature has several serious drawbacks.

1. The purpose of introducing the tax is to enhance environmental standards. If a tax is based on the amount of output produced, rather than the volume of waste it generates, it may ultimately fall short of achieving the desired environmental quality. To illustrate this, let us start by outlining the key factors necessary for a method that utilises tax per unit of output to produce a result consistent with a socially optimal level of environmental quality. To establish a clear understanding, we must comprehend the connection between output and waste. To determine the environmental impact, we need to verify the exact amount of waste generated per unit of production. We must also consider that the relationship between output and waste conversion is relatively stable. Establishing a direct correlation between the tax paid per unit of production and the cost incurred per unit of waste is challenging without this information. Regulating the firm's behaviour in waste disposal is arguably the most crucial aspect.

- Simple to implement, but fails to achieve optimal environmental outcomes

2. For an environmental tax to achieve the socially optimal level of environmental quality, the full tax burden must be borne by the polluting firms, as stipulated by the polluter-pays principle. This principle asserts that firms lack adequate incentives to limit output (and the associated waste) to socially optimal levels if they can transfer the tax burden to other segments of society.
3. When the penalty imposed on firms is tied to their output rather than the waste they generate, a Pigouvian tax policy focused on output fails to incentivise firms to explore better waste disposal methods.
4. An environmental tax also faces criticism from a non-economic perspective. Some economists contend that such tax-based policies inherently grant excessive

authority to public institutions. The primary concern is not simply the transfer of funds from the private sector to the public sector but the risk that bureaucratic inefficiency in public intervention could distort markets, resulting in resource misallocation. In this context, the potential for government failure is a genuine concern.

4.1.1.4 Emission Standards and Environmental Protection

- A command-and-control policy that sets legal limits on effluent discharge

An emission standard sets the legally allowable limit for the rate of effluent discharge. As these standards are designed to reflect the broader public interest, violators face legal action. If found guilty, they may be penalised through fines and/or imprisonment. Thus, emission standards represent a "command-and-control" approach to environmental policy. Responsibility for enforcing these standards typically falls to state or local authorities, although many enforcement efforts require collaboration and resources from both federal and state agencies.

- Emission standards can set ambient pollution thresholds

Emission standards can be established in various forms. The most important type is a standard that limits the quantity of waste discharged into the environment over a specific period. For instance, a regulation might stipulate that no more than 100 tons of untreated sewage may be released into a river within a week. In some cases, emission standards aim to preserve the overall quality of a broader environmental medium by setting ambient standards based on acceptable pollution concentrations. For example, an ambient standard for dissolved oxygen in a river might require that the level remains above three parts per million (ppm). Another widely used regulatory approach involves technology standards, where authorities mandate the use of specific technologies by potential polluters.

- Effective in limiting harmful pollutants

The advantages of emission standards are evident from their general characteristics. Firstly, these standards are simple and direct, as they focus on achieving specific numerical or technological objectives. Secondly, they are highly effective in controlling the levels of particularly harmful pollutants, such as DDT and industrial toxic waste, ensuring they remain below dangerous thresholds. In cases where a pollutant is known to have severe and long-lasting ecological or human health impacts, command-and-control strategies can often

prove to be the most cost-effective approach. Lastly, emission standards tend to enjoy political support due to their moral appeal. Since pollution is widely viewed as a "public bad," polluters' activities should be subject to considerable public scrutiny.

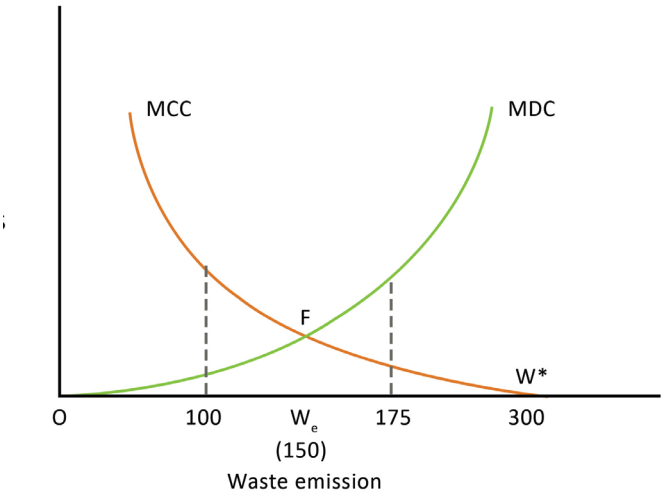

Fig. 4.1.3 Emission Standards as a policy tool to control Pollution

- Ensuring environmental protection while imposing control costs

The basic economics of emission standards can be illustrated using the above figure. Assume that, without any regulatory intervention, 300 units of waste would be emitted. Suppose public authorities possess complete information about the damage and control cost functions. In that case, they can identify that the socially optimal level of pollution is 150 units, which is lower than the unregulated level. To achieve this optimal pollution level, the authorities would establish and strictly enforce an emission standard of 150 units. The outcomes of this policy are twofold: first, if effectively implemented, the standard ensures the socially optimal pollution level is maintained. Second, polluters are compelled to bear the cost of reducing emissions to this level. As depicted in the figure, polluters would need to cut their waste from 300 to 150 units, and based on their marginal control cost (MCC) curve, the total cost incurred would correspond to the area W_eFW^*. Without this emission standard, polluters could have entirely avoided these costs.

In our discussion, we have assumed that public authorities possess perfect information about damage and control costs, a strong assumption given the complexities of these cost

functions, particularly the challenges in estimating marginal damage costs (MDC). Is this assumption necessary? The short answer is no. However, without perfect information, there is no certainty that the outcome will be socially optimal. In the absence of complete knowledge of damage and control costs, authorities may set the initial emission standard based on the best available information at the time of the decision. For instance, in the above figure, suppose the emission standard is initially set at 100, which is stricter than the socially optimal level of 150 units. This policy is likely to provoke opposition from polluters, prompting them to request a reassessment of the standard. If, after a thorough review of damage and control costs, the initial standard is deemed too stringent, authorities may revise it to allow for more pollution. Conversely, if the emission standard is set below the socially optimal level, such as at 175 units, environmental advocates will likely challenge this decision strongly.

- Authorities can set emission standards based on available data

Despite their simplicity, flexibility, and political appeal, emission standards as a tool for environmental regulation have significant drawbacks, some of which have serious economic and social consequences. One major issue is that these standards are set by government fiat, which makes them highly interventionist and deviates from the principles of a "free market." Additionally, implementing pollution control measures through administrative laws, such as emission standards, often necessitates the establishment of a large bureaucracy for managing the program. As a result, the administrative and enforcement costs—referred to as transaction costs—can be substantial. These costs represent an opportunity cost to society and should be considered part of the overall pollution control expenses. Assuming the damage cost remains unchanged, this implies that the socially optimal level of pollution would shift to a higher point (somewhere to the right of We), indicating a more lenient emission standard. This leniency arises from the inherent limitations of the policy instrument, specifically the high administrative and enforcement costs, which reflect a failure in government policy.

- Emission standards are highly interventionist

Summarised Overview

The discussion of various methods of environmental protection explains a wide range of strategies designed to reduce environmental damage and encourage long-term sustainability. Market-based mechanisms such as emission taxes, tradable pollution permits, and Pigouvian fees incentivise polluters to take on the environmental costs of their actions, providing economic benefits for reducing hazardous emissions. These instruments create disincentives for pollution and incentivise innovation in cleaner technologies. In contrast, emission standards and regulations provide a more straightforward way of protecting the environment, establishing strict guidelines for permissible emissions and guaranteeing that companies comply with the established thresholds. By integrating multiple approaches, policymakers can prevent environmental issues more efficiently, reconciling economic development with sustainable ecological well-being over the long term. A comprehensive framework is established through the integration of both market-based and regulatory measures to lower environmental degradation and promote sustainable development.

Assignments

1. Explain the concept of emission taxes and their role in safeguarding the environment. What are the primary benefits and difficulties linked to this approach?
2. Explain the concept of Pigouvian fees. What sets them apart from traditional taxes, and how do they influence businesses' attitudes toward pollution?
3. Assess the relative efficacy of market-based tools, in comparison to regulatory measures. Which approach do you think is more efficient, and what are the reasons behind your opinion?

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UNIT 2 Environmental Regulations and Assessment in India

Learning Outcomes

After completing this unit, the learner will be able to:

- understand the key environmental laws, regulations, and policies in India
- discuss the process and importance of Environmental Impact Assessments
- know the role of public participation in environmental assessment

Background

The Indian economy, classified as one of the fastest-growing economies globally, encounters a dual challenge: it must attain economic growth while guaranteeing environmental sustainability. The country is experiencing severe environmental deterioration due to rapid industrial expansion, urban development, and a substantial increase in population. This results in notable pollution of air and water, widespread deforestation, and a significant decline in biodiversity. Environmental concerns have driven the creation of environmental regulations designed to reduce adverse effects and safeguard natural resources. There is a growing concern for stricter pollution regulations and environmental protection measures. Unchecked industrial development and the spread of cities are making environmental damage worse.

With ongoing industrialisation in India, the significance of conducting environmental impact assessments (EIA) has increased in promoting sustainable development. An environmental impact assessment, or EIA, is a tool that helps evaluate the potential environmental effects of proposed projects or policies prior to their implementation. The EIA process aids in recognising, forecasting, assessing, and minimising the detrimental environmental consequences of development projects.

Keywords

Environmental Regulations, Impact Assessment, EIA, Environmental Protection Act

Discussion

4.2.1 Environmental Regulation in India

- Country addressing ecological security in its Constitution

Environmental problems in India can be broadly divided into two categories: (a) those arising from poverty and underdevelopment, and (b) those resulting from the adverse impacts of the development process itself. Recognising these issues, India is among the few nations explicitly addressing the importance of ecological security in its Constitution. The Directive Principles of State Policy include provisions for environmental protection, such as Article 48: "The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country." Furthermore, the Seventh Five-Year Plan significantly focused on environmental protection and pollution control, focusing on the nation's commitment to sustainable development.

4.2.1.1 Need for Pollution Control and Environmental Protection

- Neglecting environmental protection affects both animal and human survival

The increasing pressure on natural resources due to growing human and animal populations has led to various forms of environmental degradation. Environmental phenomena such as the greenhouse effect, acid rain, and ozone layer depletion threaten life on Earth. Immediate corrective and preventive measures are essential, as delaying action could lead to irreversible consequences. Numerous animal species have already become extinct, highlighting the interconnectedness of all life. Humanity cannot continue to view itself as the sole beneficiary of these resources. If the environment becomes unsuitable for animal life, it will inevitably become unfit for humans as well. To ensure survival, humans must acknowledge their responsibilities and make an endeavour to control pollution and protect the environment.

In India, the primary instruments for controlling water, air, and noise pollution are the Water (Prevention and Control

of Pollution) Act, 1974; the Air (Prevention and Control of Pollution) Act, 1981; and the Environment (Protection) Act, 1986. Amendments to the Water and Air Acts in 1988 introduced stricter provisions, empowering Pollution Control Boards to shut down industries or suspend essential services like water and electricity to non-compliant industries when necessary. The Environment (Protection) Act, 1986, is enforced by State Governments and relevant authorities such as Pollution Control Boards and Factory Inspectorates. The Central Pollution Control Board (CPCB) oversees the implementation of the Water and Air Acts, working in coordination with State Pollution Control Boards (SPCBs). While the Central Board is responsible for pollution control in Union Territories, it also plays a coordinating role at the national level. Currently, 28 out of 28 states and 8 Union Territories in India have established State Pollution Control Boards or Pollution Control Committees.

- India controls pollution through Environment Protection Acts

According to the report of the Central Pollution Control Board (CPCB), as of January 2025, the CPCB has expanded its monitoring infrastructure to include 1,510 ambient air quality monitoring stations across 543 cities in 28 states and 8 Union Territories. This network comprises 545 real-time Continuous Ambient Air Quality Monitoring Stations (CAAQMS) and 965 manual stations under the National Air Quality Monitoring Programme (NAMP). Additionally, the CPCB operates 4,000 continuous water quality monitoring stations nationwide. Industries failing to adhere to pollution control regulations face legal actions, including potential shutdowns and denial of essential services. To incentivise pollution control, the Central Government has introduced several financial measures. Notably, the steel ministry has sought ₹150 billion ($1.74 billion) in the 2025-26 budget to encourage the production of low-carbon steel, aiming to reduce greenhouse gas emissions. Additionally, the government has proposed incentives worth ₹885 billion ($12.4 billion) to encourage power plants to install equipment to curb emissions and to develop infrastructure for electric vehicles. To address vehicular pollution, the government has implemented nationwide emission standards under the Motor Vehicles Act, with recent amendments to strengthen these regulations. Despite these efforts, challenges remain in promoting electric vehicle adoption, as they currently hold just a 2% market share.

- Stricter regulations to promote pollution control

4.2.1.2 Environmental Impact Assessment

- Aims to inform decision-making and promote sustainable development

To understand the Environmental Impact Assessment (EIA) process in India, it is essential to understand the concept of EIA first. The United Nations Environment Programme (UNEP) defines Environmental Impact Assessment as a tool utilised to evaluate the environmental, social, and economic impacts of a proposed project before a decision is made. Understanding the goals of the Environmental Impact Assessment (EIA) process in India is integral to appreciating its importance. The objectives of EIA can be categorised into two broad types: immediate and long-term. The primary immediate objective of EIA is to provide information for the decision-making process by identifying potential environmental risks and impacts associated with proposed development projects. The long-term objective is to promote sustainable development by ensuring that development activities do not compromise essential ecological and resource functions or the health, livelihoods, and well-being of communities dependent on them.

Immediate Objectives of EIA

- Improve the environmental design of proposed projects.
- Ensure the efficient and judicious use of resources.
- Identify and implement appropriate measures to mitigate potential adverse impacts of the proposal.
- Facilitate informed decision-making, including the establishment of environmental terms and conditions for project implementation.

Long-term Objectives of EIA

- Conserve valuable resources, natural habitats, and ecosystem components.
- Safeguard human health and safety.
- Prevent irreversible damage and significant environmental degradation.
- Improve the social dimensions of proposed projects to benefit communities.

4.2.1.3 Environmental Impact Assessment (EIA) Process in India

- Growing awareness of environmental concerns

The Environmental Impact Assessment (EIA) process in India has evolved significantly over time, with distinct phases reflecting the country's growing awareness and responsiveness to environmental concerns. These periods mark milestones in the incorporation of environmental considerations into developmental decision-making. This discussion explores the historical progression of the EIA process in India, its legislative evolution, and the changes in its methodology over time. Since gaining independence in 1947, India has pursued rapid technology-driven economic growth without fully accounting for its impact on the ecosystem. Environmental considerations during this period were limited to the direct financial costs of resource depletion, such as the monetary value of timber from forests, while long-term and comprehensive environmental costs were largely ignored.

- Introduction of simplified EIA process

The Stockholm Conference of 1972 marked a turning point in India's environmental policies, leading to the establishment of the National Committee on Environmental Planning and Coordination (NCEPC). The NCEPC played a pivotal role in addressing environmental concerns associated with developmental projects, tackling complex national issues such as the Silent Valley Project. This project, which aimed to construct a dam, was eventually abandoned to preserve the region's rich ecological resources. During this period, the EIA process followed a simplified methodology. Special task forces comprising environmental experts reviewed projects that faced public criticism and controversy. Decision-making was based on a combination of project feasibility study reports and task force evaluations, emphasising ecological considerations alongside development objectives.

- Expert committees to evaluate the environmental impacts

In 1980, the establishment of the Department of Environment (DoE) marked the institutionalisation of environmental assessment processes in India. The DoE was tasked with evaluating the environmental impacts of development projects, and its functions were supported by landmark legislation, including the Forest Conservation Act (1980), the Environment Protection Act (1986), and amendments to the Air (Prevention and Control of Pollution) Act (1981 and 1987). The DoE's Impact Assessment Division (IAD) became responsible for implementing the EIA process, aided by an inter-ministerial appraisal committee comprising experts in fields such as

ecology, forestry, environmental sciences, pollution control, and engineering. The contemporary EIA methodology includes several structured steps: screening, scoping, and preparation of progress reports, drafting interim and final EIA reports, reviewing the final reports, and making informed decisions. This systematic approach reflects the growing complexity and interdisciplinary nature of environmental assessments in India.

4.2.1.4 Various components of the EIA process in India

The Environmental Impact Assessment (EIA) process in India involves several key components that collectively underscore the necessity of such an assessment. These components assess various environmental factors that could be affected by development projects. The primary environmental components considered in the EIA process in India are as follows:

Air Environment

- Predicted and actual ambient air quality.
- Meteorological data, including parameters such as wind speed, direction, and humidity.
- Estimated emissions from the proposed project.
- The extent of the area's exposure to these emissions.
- Compliance with air quality standards and the need for pollution control measures.

Water Environment

- Assessment of the potential impacts of the project on water resources.
- Evaluation of the quality and quantity of both surface and groundwater resources in the project area.

- A well developed pollution control technology used by India

Noise Environment

- Measurement of existing and projected noise levels.
- Identification of strategies to mitigate noise pollution.

Biological Environment

- Assessment of potential environmental harm due to emissions, effluents, and other project-related activities.
- Evaluation of the impacts on flora and fauna in the af-

fected zone.

- Prediction of biological stress resulting from the project's activities.

Land Environment

- Analysis of the effects of the proposed project on heritage sites and historical monuments.
- Study of potential negative impacts on the soil, land use, and drainage patterns.

- Advanced equipment to meet the country's stricter regulations

In India, the pollution control and monitoring equipment industry is well-established and provides advanced technology and systems to various industries. The sector has developed solutions customised to suit the specific needs of the Indian environment. Locally manufactured equipment meets global standards and is equipped to handle the stricter pollution control regulations being implemented in the country.

Summarised Overview

India's environmental regulations have evolved significantly to address pollution control and sustainable development. The country's legal framework includes key acts such as the Water (1974), Air (1981), and Environment Protection Acts (1986), enforced by Pollution Control Boards at the central and state levels. The need for pollution control and environmental protection arises from rapid industrialisation, urbanisation, and resource depletion, which contribute to environmental degradation. India has taken proactive steps to reduce these impacts. Environmental Impact Assessment (EIA) serves as a crucial tool for evaluating the environmental, social, and economic effects of proposed projects. It ensures that development activities align with ecological sustainability. The EIA process in India has evolved, with structured steps including screening, scoping, impact assessment, report preparation, review, and decision-making. Institutions like the Department of Environment and inter-ministerial expert committees play a pivotal role in its implementation. India has also developed an advanced pollution control and monitoring industry, ensuring compliance with environmental regulations through locally manufactured, globally competitive equipment. These measures collectively contribute to India's commitment to sustainable and environmentally responsible development.

Assignments

1. Select a significant environmental law in India, like the Environment Protection Act of 1986 or the Air (Prevention and Control of Pollution) Act of 1981. Evaluate its effectiveness by identifying a genuine case study where it was implemented.
2. Write about the necessity of pollution prevention and environmental conservation in India. Highlight key environmental concerns and policy responses by referencing recent reports from organisations such as the Central Pollution Control Board (CPCB) and the United Nations Environment Programme (UNEP), and incorporating relevant data and examples.
3. Explain the key components of the EIA process in India. Use visuals to describe how air, water, noise, biological, and land environments are assessed in development projects.

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UNIT 3 Solid Waste Management: A Case Study from Lucknow City, India

Learning Outcomes

After completing this unit, the learner will be able to:

- understand issues in waste generation, segregation, disposal, and recycling in India
- discuss the environmental, social, and health consequences of improper waste management
- know the importance of public participation in reducing waste pollution

Background

Rapid industrialisation, urbanisation, and population growth are causing severe environmental degradation in India. Concerns like deforestation, air and water pollution, loss of biodiversity, and climate change have become more serious over the years. Weak enforcement of environmental regulations, overexploitation of resources, and a lack of sustainable practices have made these issues even more severe. Cities across the globe are struggling with increasingly poor air quality, tainted water sources, and diminishing parks and green areas, whereas rural regions are experiencing widespread deforestation and soil degradation, which in turn affect agricultural productivity and local economies. Implementing effective solutions to these challenges necessitates strong policies, the active engagement of the public, and environmentally responsible resource management practices.

In addition to this, the country produces millions of tons of solid waste each year, resulting in air, water, and soil pollution due to insufficient waste disposal methods. Uncontrolled landfills, the pollution caused by plastics, electronic rubbish, and toxic waste from industry all cause significant health and environmental hazards. Despite the government's introduction of waste management legislation, including the Solid Waste Management Rules 2016 and the Plastic Waste Management Rules 2016, obstacles such as inadequate waste

sorting, inadequate recycling facilities, and insufficient public awareness are impeding the effective implementation of these laws. Implementing effective waste management strategies, such as separating waste at its origin, composting, recycling, and fostering a circular economy, is vital for reducing pollution caused by waste in India.

Keywords

Solid Waste, Biomethanation, Policy Implications

Discussion

4.3.1 Waste Management

- Establishment of a biomethanation plant to process organic waste daily

The rapid growth of the population and changing lifestyles in Indian cities have intensified challenges in solid waste management. In larger cities, the average per capita waste generation is approximately 0.5 kg per day. In response to this issue, the Municipal Corporation of Lucknow, responsible for managing 1,500 tonnes of waste daily, is exploring the establishment of a biomethanation plant. This facility aims to process around 200 tonnes of organic waste to generate biogas, which would power a gas engine, producing approximately 5 MW of electricity for supply to the state grid. Additionally, the plant is expected to yield 75 tonnes of organic manure per day, which could be marketed to tea plantations and other buyers.

- Increased solid waste generation

With rapid urbanization and evolving lifestyles, managing solid waste has become a significant challenge in Indian cities and towns. As per the 2001 Census, India's urban population stood at approximately 285 million and was projected to rise to nearly 400 million by 2011. Rising income levels and improved living standards have contributed to a surge in waste generation, particularly in materials like plastics and paper. In major cities, the average per capita waste generation is around 0.5 kg per day, meaning a city with a population of four million would produce nearly 2,000 tonnes of household waste daily, excluding construction debris and industrial or commercial waste. Efficient collection, transportation, and disposal of this waste in an environmentally sustainable manner are essential to address this growing concern.

- Efficient waste collection is crucial for public health

The efficiency of garbage removal from streets is a major public concern, as accumulated waste not only creates an unpleasant sight but also poses serious health risks. The outbreak of plague in Surat highlighted the environmental dangers of uncollected waste, raising awareness among both the public and municipal authorities. Consequently, uncollected garbage imposes social costs, whereas clean streets offer significant benefits to residents and visitors alike. Therefore, waste collection at the household level should be seen not just as a municipal responsibility but also as an essential environmental service for the community. As a local public good, primary waste collection must be managed efficiently by balancing the benefits of cleanliness against the costs of collection. Various institutional approaches are being explored in many cities, including partnerships with neighbourhood organizations, non-governmental organizations (NGOs), and private contractors working alongside municipal authorities. This marks the initial phase of urban solid waste management.

- Secondary waste collection requires efficient management

Secondary waste collection involves gathering waste from transfer stations and transporting it to the nearest landfill. This process is primarily technical and can be managed by either municipal authorities or private operators. Effective planning is required to optimize routes, estimate vehicle and fuel requirements, and ensure efficient transportation. Municipal agencies typically handle this stage efficiently, as the number of transfer stations is relatively limited. Waste collection vehicles transport waste from these stations to designated landfills. Since transfer stations and landfills are usually located away from residential areas, most people remain unaware of their existence unless they live nearby.

- Decentralised waste management reduces the burden on municipalities

Waste disposal remains one of the most overlooked aspects of solid waste management. Some NGOs advocate for decentralized disposal methods, such as vermiculture, to manage a portion of organic waste. However, it is important to acknowledge that such methods alone cannot handle the entirety of urban solid waste. Encouraging decentralized waste management can help alleviate the pressure on municipal authorities. Additionally, promoting recycling and reuse of non-organic materials can significantly reduce the volume of waste that needs to be collected and disposed of, contributing to a more sustainable waste management system.

In many cities and towns, collected waste is often disposed of in low-lying areas, commonly referred to as landfills, under

the pretext of land reclamation. However, this practice leads to significant environmental issues, including contamination of surface and groundwater, emission of hazardous gases that pose explosion risks, and the proliferation of rodents and disease-carrying pests. Despite these concerns, improper waste disposal is often overlooked, as public attention is primarily focused on visible aspects like waste collection. Additionally, landfills are now widely recognized as major contributors to greenhouse gas (GHG) emissions. The issue of urban solid waste disposal in India was first formally addressed by a High-Power Committee established by the Planning Commission in 1995. According to its findings, beyond the metropolitan cities, 33 urban centers with populations exceeding one million required dedicated solid waste disposal systems during the Ninth Five-Year Plan period. Various techno-economic studies have since been conducted to evaluate waste disposal and recycling alternatives. Notable examples include research by Reyer, which used a linear programming model to explore solutions for Bangalore, and an assessment by Reddy and Galab focusing on Hyderabad's solid waste management system.

- Improper waste disposal in landfills leads to environmental hazards

Options for the Proper Disposal of Urban Solid Waste

There are several methods available for solid waste disposal, each with distinct benefits. One approach is sanitary landfilling, which not only provides a designated space for waste disposal but also facilitates land reclamation for future use. Composting is another option, where organic waste is decomposed to produce nutrient-rich fertilizer. Incineration involves burning waste at high temperatures, utilizing it as a fuel source. Biomethanation offers a dual benefit by breaking down organic matter to generate both fertilizer and biogas, which can be converted into energy. Additionally, advanced techniques like pyrolysis, commonly adopted in other countries, provide alternative waste management solutions.

- Solid waste disposal methods create waste reduction

Each waste disposal method comes with its own set of costs and advantages. Sanitary landfilling and composting demand extensive land areas, which poses a challenge as urban land values continue to rise. Local authorities must carefully evaluate whether allocating large tracts of land for waste management is justifiable, even if the reclaimed land can later be repurposed for public spaces like parks. Additionally, repurposing land reclaimed from waste disposal for residential or commercial construction is generally not recommended

- Each waste disposal method poses challenges in urban spaces

due to potential environmental and structural risks. An often-overlooked factor is the opportunity cost associated with using public land for waste disposal instead of alternative, potentially more valuable, purposes.

Another important consideration in waste disposal is the potential energy and resource value that can be derived from waste materials. Two key outputs fertilizer and energy can be generated from waste. Composting is often recommended in India due to the high organic content in the waste, making it well-suited for this process. However, unlike the waste in Western countries, which typically has high calorific value and low moisture content (making it suitable as fuel), India faces the need for alternative approaches to power generation, such as biomethanation. This method involves the generation of biogas, which can then be used to produce electricity through a gas turbine. While such technologies have been explored on a small scale with more uniform waste types, such as vegetable and poultry waste, their application at the municipal level for urban solid waste remains untested and requires further research and development.

- Composting and biomethanation offer potential for generating fertilizer and energy

This case study is an attempt to study the economics of one method of resource recovery, namely biomethanation. The biomethanation process for resource recovery involves three key stages:

1. **Segregation and Sorting** – Non-organic materials must be separated from the waste stream, allowing recyclable items to be sorted and sold.
2. **Anaerobic Digestion** – Organic waste is broken down to generate biogas, primarily composed of methane and carbon dioxide. The remaining solid byproduct can be processed into fertilizer and packaged for sale.
3. **Energy Generation** – The biogas is fed into a gas engine to generate electricity, which can be utilized locally or supplied to the power grid.

- Reduced environmental impact through methane emission reduction

Each stage of the biomethanation process requires significant investment and operational expenses. However, the process yields three primary benefits power generation, fertilizer production, and recyclable materials,making it a valuable resource recovery method. Additionally, reducing methane emissions contributes to global environmental sustainability. At the same time, local benefits include preventing water pollution, mitigating explosion risks from gas accumulation,

and preserving wetlands and water bodies from being filled with waste.

The Context of Biomethanation Case Study

Lucknow, the capital of Uttar Pradesh, faces the challenge of managing 1,500 tonnes of solid waste daily in an environmentally sustainable manner. In 1996, the Supreme Court of India directed all local bodies and state governments to enhance solid waste management practices in Class I cities (those with a population exceeding one lakh) without delay. In response, numerous urban local bodies across the country are exploring different approaches for waste collection and disposal. Additionally, as part of its policy framework, the government has encouraged state and local authorities to consider privatizing urban services and infrastructure where feasible.

- Lucknow, faces the challenge of managing 1,500 tonnes of solid waste daily in a sustainable manner

Lucknow, with a population of approximately 25 lakhs, generates around 0.6 kg of solid waste per person daily. Of this, nearly 1,300 tonnes are collected by the Municipal Corporation. The waste composition includes over 65% volatile matter and has a calorific value exceeding 2,500 cal/gm on a dry basis. Additionally, recyclables such as paper, plastic, cloth, and metal make up about 10-12% of the total waste. By segregating recyclables and inert materials, the organic fraction can be effectively utilized for biogas production. However, the current practice of open dumping in low-lying areas and wetlands leads to significant environmental issues. After evaluating multiple waste management options, including landfilling, incineration, pyrolysis, and briquetting, the Municipal Corporation has opted for anaerobic digestion with power generation as the most viable solution (NIDC, 1996).

- Current practice leads to significant environmental issues

The Municipal Corporation has engaged a consortium of engineering firms to establish a plant capable of processing approximately 300 tonnes of solid waste daily. Before being fed into the digester, the waste will undergo pre-treatment and sorting to remove around 100 tonnes of inorganic materials. The remaining 200 tonnes of organic waste will be processed to generate biogas, which will then be utilised in a gas engine to produce approximately 5 MW of electricity. During this process, all methane will be converted into carbon dioxide and water. Given the project's substantial capital investment, funding is expected to be recovered through the sale of electricity and organic manure, with contractual agreements

- Lucknow Municipal Corporation has opted for anaerobic digestion with power generation as a sustainable solution

already in place. To support the initiative, the Central Government has approved a capital grant of ₹15 crore to offset initial costs. Additionally, a financial institution, considering an investment in the project, intends to conduct an economic evaluation of its societal and environmental benefits before making a final decision.

The Global Environmental Benefits of the Biomethanation Project

- Ability to reduce greenhouse gas (GHG) emissions

The global environmental advantages of biomethanation primarily stem from its ability to reduce greenhouse gas (GHG) emissions compared to conventional sanitary landfilling. While the total emissions from both methods may not differ significantly, their global warming potential (GWP) varies considerably. Biomethanation effectively captures all methane and converts it into carbon dioxide, whereas sanitary landfills, even with gas collection systems, allow approximately 60% of methane to escape into the atmosphere. For this analysis, methane is assumed to have a GWP of 24.5 times that of carbon dioxide. This means that releasing one tonne of methane is equivalent to emitting 24.5 tonnes of CO_2. Based on this assumption, the GWP in CO_2 equivalents for both landfill and biomethanation options can be calculated, as illustrated in the table below.

Table 4.3.1 Global Environmental Benefits of Biomethanation (Emission in tonnes per day-tpd)

Option	CO_2 emissions	Methane emission	GWP in CO_2 equivalents	GWP reduction in CO_2 equivalents
Landfill (with gas collection)	53.32 tpd	9.55 tpd	287.3 tpd	0
Biomethanation	98.3 tpd	0	98.3 tpd	189tpd

Source: Economic Benefit and Cost Analysis of Proposed Solid Waste Resource Recovery Plant, by Paul. P. Appasamy

The yearly reduction in the global warming potential (GWP) of emissions through biomethanation, as opposed to landfilling, is estimated to be 68,985 tonnes of CO_2 equivalent. If the

landfill operated without a gas collection system, the reduction in GWP would be even greater, further enhancing the global environmental benefits of biomethanation. Therefore, selecting an appropriate baseline for comparison is crucial in accurately assessing the environmental impact.

Emission reduction credits can be obtained through collaborative ventures between institutions in developing countries and partners from developed nations. If these reductions are verified as legitimate, the investing developed country may claim them as credits under the Clean Development Mechanism (CDM) outlined in the Kyoto Protocol. However, the decision to engage in the CDM process ultimately rests with the host developing nation. Certified emission reductions must demonstrate 'environmental additionality,' meaning that the greenhouse gas (GHG) reductions achieved must be beyond what would have occurred without the project. In this case study, the additionality arises from the capture and conversion of methane through biomethanation, whereas sanitary landfilling allows a significant portion of methane to be released into the atmosphere.

- Biomethanation offers environmental benefits by capturing methane and converting it to carbon dioxide

The Policy Implications of the Study

Cities are often hesitant to adopt technologies like biomethanation due to the significant capital investment required. Instead, landfilling remains the preferred option, as public land is frequently available at minimal cost, and the ongoing expenses are relatively low. However, with urban land becoming increasingly scarce, securing suitable landfill sites may pose challenges in the future. Additionally, methane emissions from landfills represent a significant environmental externality that will need to be managed. Currently, local governments may have limited awareness or concern regarding global environmental issues.

- Cities prefer landfilling over biomethanation due to lower costs

Private sector companies may be reluctant to invest in projects with high capital costs unless there is public support or a guarantee in place. Given the substantial societal benefits, financial institutions or government bodies might consider providing financial assistance through subsidies, grants, or low-interest loans to encourage the adoption of such technology. If the technology proves to be feasible, this support could be expanded to other major cities to facilitate its wider implementation.

- Government funding could encourage adoption of high-cost projects

Moreover, we can find similar issues in our state, Kerala. One

of them is discussed below:

- Improper management of solid waste

The Brahmapuram waste management plant in Kochi has become a serious environmental issue due to the improper management of solid waste, having transformed into a dumping ground over time. Following a significant blaze in March 2023, a major fire drew serious attention, ultimately resulting in thousands of residents being exposed to toxic airborne pollution. The current crisis emphasises the urgent requirement for environmentally friendly waste management strategies.

- Combustion of plastic waste resulted in air pollution

More than 390 tonnes of waste are disposed of every day, with a substantial amount consisting of non-biodegradable plastic. The waste management plant, which was launched in 2008, experienced recurring malfunctions and eventually ceased to operate effectively. The combustion of plastic waste resulted in air pollution, causing respiratory problems for residents. Only a fraction of plastic waste is being recycled, with the majority ending up as a mounting pile. Despite efforts by the National Green Tribunal and the State Pollution Control Board, no improvement has been seen in the situation.

Proposed Solution to Resolve the Problem:

- Promoting the use of biodegradable and recyclable materials

Reducing waste at its source is essential, and strict enforcement of waste segregation should be implemented in both households and commercial establishments. Encouraging the adoption of zero-waste projects in residential communities and industrial settings can significantly minimise waste generation. Additionally, promoting the use of biodegradable and recyclable materials over plastics will contribute to a more sustainable and environmentally friendly waste management system.

- Upgrading the existing waste treatment plant

Effective waste management and disposal systems require a well-structured approach. Implementing a residential waste collection program, where waste collectors visit households and segregate trash into organic and non-recyclable materials, can enhance efficiency. Upgrading the existing waste treatment plant with cutting-edge waste-to-energy systems will help manage waste sustainably. Additionally, establishing decentralized micro composting facilities in multiple neighbourhoods can reduce reliance on a central authority. Promoting green waste management practices and encouraging the reuse of materials will further contribute to a more sustainable waste disposal system.

- Strict ban on open waste dumping and incineration must be enforced

Joint plastic recycling facilities should be established in partnership with private companies and non-governmental organizations to enhance waste management efficiency. A strict ban on open waste dumping and incineration must be enforced to prevent environmental pollution. Additionally, implementing Extended Producer Responsibility (EPR) regulations will hold manufacturers accountable for the disposal of plastic waste, ensuring a more sustainable and responsible approach to waste management.

- Actively engaging citizens, resident welfare associations, and environmental activists in the decisionmaking process

Reforming policy and governance structures is essential to improving waste management. Strengthening municipal waste management regulations can help prevent unlawful dumping practices. Actively engaging citizens, resident welfare associations, and environmental activists in the decision-making process will ensure more effective and community-driven solutions. Additionally, securing government funding and collaborating with private companies to establish a waste-to-energy facility can significantly enhance waste treatment efficiency. Prioritizing environmental and public health protections will further contribute to a cleaner and more sustainable waste management system.

- The Brahmapuram waste crisis highlights the urgent need for sustainable waste management and community participation to reduce environmental and public health risks

Regular and consistent monitoring of air and water quality in and around Brahmapuram is essential to assess environmental impact and ensure public health safety. Public awareness initiatives should be launched to promote waste segregation and effective pollution control practices. Additionally, implementing a system of penalties and incentives will encourage compliance with waste management regulations, fostering a more responsible and sustainable approach to waste disposal.

The Brahmapuram waste crisis poses a grave environmental threat, necessitating swift action. Kochi can transition towards a more sustainable and pollution-free waste management system by adopting a comprehensive approach that includes waste reduction, efficient processing, recycling, policy enforcement, and community involvement.

In the same way, you can identify an environmental problem in your local area and propose ways to address or solve it. It encourages looking at issues such as pollution, waste management, or resource depletion within your community and coming up with practical solutions to improve the situation.

Summarised Overview

The case study of solid waste management in Lucknow highlights the growing challenges faced by Indian cities due to rapid urbanization and changing consumption patterns. With an average per capita waste generation of 0.5 kg per day in larger cities, the need for sustainable waste management solutions has become crucial. The Municipal Corporation of Lucknow's initiative to establish a biomethanation plant is a proactive step towards addressing these challenges. By processing organic waste into biogas for electricity generation and producing organic manure, the plant offers a dual benefit of reducing waste and contributing to renewable energy production, while also providing an economic opportunity through the sale of manure. This approach demonstrates a potential model for other cities in India to adopt in their efforts to manage solid waste more efficiently and sustainably.

Similarly, the waste management crisis in Kochi's Brahmapuram has worsened due to inadequate waste disposal methods, ultimately resulting in severe air pollution caused by plastic fires. This facility, originally designed to handle waste, has increasingly become a disposal site, with more than 390 tonnes of waste piling up every day. Possible solutions encompass strict waste separation, zero-waste projects, the adoption of biodegradable materials, localised composting systems, and waste-to-energy technologies. Effective waste management requires a combination of policy reforms, strengthened regulations, community participation, enforcing open dumping bans, and implementing Extended Producer Responsibility (EPR) to hold manufacturers accountable. Monitoring the environment regularly, running public awareness campaigns, and using incentive-based measures to encourage compliance are key components for implementing a sustainable waste management system with minimal pollution in Kochi.

Assignments

1. Choose a local environmental problem and describe its reasons and effects on the nearby residents.
2. Identify and examine the key elements that are causing the environmental problem you have noticed in your local area. Examine the interaction between these elements and how they collectively worsen the situation.
3. Compare an environmental problem in your area with a similar issue in another place or country. What lessons can you learn from this, and how can they be applied to your area

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

സർവ്വകലാശാലാഗീതം

വിദ്യയാൽ സ്വതന്ത്രരാകണം
വിശ്വപൗരരായി മാറണം
ഗ്രഹപ്രസാദമായ് വിളങ്ങണം
ഗുരുപ്രകാശമേ നയിക്കണേ

കൂരിരുട്ടിൽ നിന്നു ഞങ്ങളെ
സൂര്യവീഥിയിൽ തെളിക്കണം
സ്നേഹദീപ്തിയായ് വിളങ്ങണം
നീതിവൈജയന്തി പാറണം

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ബോധരശ്മിയിൽ തിളങ്ങുവാൻ
ജ്ഞാനകേന്ദ്രമേ ജ്വലിക്കണേ

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Environmental Economics

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