Environmental Science

Sustainability and climate Change

Lecture 2

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Natural resources and natural cycles

Natural resources can be divided as either as Biotic and Abiotic resources

or

Renewable and Non-renewable resources.

The environment provides us with a variety of goods and services necessary for our day- to- day life.
The earth's non- living (abiotic) resources include air, water, soil and minerals (which are linked to global climate and local weather).
The living parts (biotic) consists of plants, animals, fungi and microbes.
Resources are a part of nature on which human life and livelihood depends.
We need water to drink, food to eat, air to breathe, soil to grow crops, coal and oil for energy and minerals for industry for the products we use in our daily life.
So we refer to earth as "mother earth" as she sustains our existence.

- The interactions between the abiotic aspects of nature and specific living organisms together form ecosystems of various types.
- Classification of natural resources:
- One classification is into biotic and abiotic resources.
- Another is into renewable and nonrenewable resources.
- A resource is needed to sustain life and living organisms depend on materials available on earth.

Renewable resources may be replenished through relatively rapid natural cycles.

If harvested in a sustainable manner ,can be regenerated after its careful use.

Water, air, soil and biodiversity are rejuvenated in naturally in naturally occurring ecosystems. They are linked closely with the biogeochemical cycles in nature.

Non-renewable resources: these include soil, minerals and fossil fuels (such as coal, petroleum and natural gas) which have been formed millions of years ago and will be used up completely in the next few decades. They are present in a limited amount on earth.

non-renewable resources are now being consumed at

a faster rate than ever before.

Perpetual resources: these are ever lasting and will not run out, regardless of how much they are used.
Like solar energy that drives wind mills, tidal wave
power,
solar radiation is converted to electricity via solar panels
geothermal energy stored in earth’s core and
energy derived from flowing water by the force of gravity in hydroelectric turbines.

Another classification is biotic and abiotic resources:

biotic resources- all living material that we use are referred to

as biotic resources. These products people use directly from nature's living ecosystems like food, clothing, housing material, medicines. This is referred to as biological (bio) diversity resources which are an outcome of evolution in nature.

If biodiversity is collected and used by local people for their own needs, it is called consumptive resource.

Forest –resources: forest represents interrelation of trees, shrubs, creepers and other plants with animals, soil, atmosphere and water.

It is the area predominated by trees and other wooden plants.

They are classified as virgin forest, protected forests, commercial forests and planted forests.

The main use of forest is for the extraction of timber.
Another effect of forest is the protection of water resources.
Rainfall runs off forested land much more slowly than off clear land.
The trees intercept and retain the moisture on their leaves, or absorbs it into their roots and stems and this ensures a more gradual transfer of water.
Soil erosion, caused by rapid run off and flooding caused by too much water entering the rivers at one time, are prevented or considerably reduce.
Water catchment areas are thus usually protected by a forests cover to prevent excessive run off.

Forests also have great value of recreation. They may be beautiful in themselves or may beautify the landscape by adding variety to agriculture districts.
Forests are also home of many wild animals and birds and these may be watched as in national parks or hunted for sport.

Forest resources of India:

India has a very rich flora and fauna much of which is present in forest area.

The type of forest depends upon the climate of the region, particularly the temperature and rain fall.

On the basis of temperature of the region Indian forests y be divided into 4 main types –

-tropical forests (in hot climate)

-subtropical forests (hot but some winter climate also)

- temperate forests (very hot in summer but very cold in winter)

- alpine forests (cold climate generally)

Rains also affect the type of forests.
In India there is much variation in the quantity of rain fall in different parts of the country.
Whereas in Thar desert the annual rainfall is less than 150 mm, in Assam it measures more than 5000 mm per annum.
Water resources: life can not exist on earth without water.
It is found in all living beings in their tissues.
Water is recycled in nature through complex physical process.

Evaporation, transpiration, water vapor and rains are all a part of water cycle.
Types of water resources: water is found in marine, brackish and fresh water ecosystems.
Fresh water is found as surface water (rivers, lakes) and as ground water stores in the earth’s crust.
Wetlands, marshes, salt pans, mud banks shifts seasonally between terrestrial and aquatic ecosystem.
They contain species of plants and animals that are highly moisture dependent.
Amphibia, mollusks and aquatic insects are important parts of such ecosystems.

Availability and use of water resources: all aquatic ecosystems are used by large number of people for their daily needs such as drinking water, washing, cooking and irrigating fields.

In the urban sector people use large quantities of water.

Access to clean water is closely related to human health.

Water covers 70% of the earth's surface but only 3% of this is fresh water.

Of this 2% is present as polar ice caps and only 1% is usable water in the rivers, lakes and subsoil aquifers.

Only a fraction of this can be practically used.

At a global level 70% is used for agriculture, about 22% for industry and 8% for domestic purposes.

This proportion may vary in different countries.

India uses 87% of its fresh water for agriculture, 8% for industry and 5% for domestic purposes.

Soil and mineral resources:
soil is protected by the roots of the trees and grasses which bind the soil. If forests are depleted or grassland overgrazed, the soil becomes unproductive and wasteland is created.
Intensive irrigation leads to waterlogged and salanised soil on which crops can not grow.
The use of unnecessarily large quantities of chemical fertilizers poisons the soil and eventually the land becomes unproductive.
Important minerals: a mineral is a naturally occurring substance of specific chemical composition and identifiable physical properties.
An ore is a mineral or combination of minerals from which a metal can be extracted and used to manufacture several products.
Minerals are a non-renewable resource. Using them sustainably and recycling them from waste is a key to sustainable development.

India is rich in mineral resources.
Most of our heavy industries requires minerals such as iron to make steel, copper, bauxite, aluminum and other heavy and specialized metals for the electronics and nuclear industry.
Mineral exploitation- while mining is essential for economic growth and development, it frequently impacts the overlying forests and other natural ecosystems, disturbs the hydrological cycle and leads to severe biodiversity loss.
This change in land use creates climate change and impedes adaptation and mitigation to counter the ill-effects of climate change.
Most minerals need to be processed before they become usable. Thus the presence of resources and the energy necessary to make them usable at a minimum cost is required.

Mines are of two types –surface (open cast or strip mines) or deep (shaft) mines.
Coal, metals and non-metal ferrous minerals are all mined differently depending on the above criteria.

The method chosen for mining will ultimately depend on how the maximum yield may be obtained under existing conditions at a minimum cost, with the least danger to the mining personnel.

- Surface mining is less hazardous than the underground mining and metal mining is less hazardous than coal mining.
  Large explosions have occurred in coal mines, killing many miners. More miners have suffered from disasters due to the use of explosives in metal mines.

Soil as a resource and its degradation: the formation of soil has taken millions of years. Soil erosion through rain, wind and anthropogenic causes leads to degradation of the soil's nutritional capacity for growing crops.
Soil degradation in its severe forms end in desertification which is extremely difficult to reverse.
It is essential to use organic, ecofriendly fertilizers , safe pesticides, insecticides and herbicides.
The characteristics of natural ecosystems depend on the type of soil. Different types of soil support diverse varieties of ecosystems and crops.
The roots of the trees in the forest hold the soil. Deforestation thus leads to rapid soil erosion.
The link between the existence of forests and the presence of good soil cover is greater than the forest's physical soil binding function alone. The soil is enriched by the leaf litter of the forest.

This detritus is broken down by soil microorganisms, fungi, worms and insects, which help to recycle nutrients in the ecosystem

Desertification occurs due to severe soil erosion. The chemical fertilizers and pesticides that have been used, along with the intensive irrigation to boost agricultural productivity, finally results in completely unproductive ecosystem.
Excessive irrigation leads to salt accumulation in the top soil which prevents crops from growing in the desertified land.

Biogeochemical cycles: the chemical elements , including all the essential elements of protoplasm , tend to circulate in the biosphere in characteristic paths from environment to organisms and back to the environment. These are known as biogeochemical cycles.

For each cycle we can designate two compartments or pools as the reservoir pool – the large slow moving generally non-biological component and the exchange or cycling pool- a smaller but more active portion that is exchanging (moving back and forth) rapidly between organisms and their immediate environment.

From the standpoint of biosphere as a whole the biogeochemical cycles can be divided into two basic groups:
gaseous types- in which the reservoir is in the atmosphere or hydrosphere (ocean) and
sedimentary types- in which the reservoir is in the earth's crust.
Some elements such as carbon, hydrogen, oxygen and nitrogen are needed in large quantities.
Others are needed in small, or even minute quantities.
Essential elements (as well as non-essential elements) exhibit definite biogeochemical cycles.
Bio- refers to living organisms and geo- to the rocks, air and water of the earth thus biogeochemistry is the study of exchange or flux of materials between living and non-living components of the biosphere.

Some cycles such as those involving carbon, nitrogen or oxygen, self adjust rather quickly to perturbations because of the large atmospheric reservoir.
Sedimentary cycles which involve elements such as phosphorous or iron , tend to be much less perfect and more easily disrupted by local perturbations.
Because the great bulk of material is in a relatively inactive and immobile reservoir in the earth's crust.
Consequently, some portion of the exchangeable material tends to get "lost" for long periods of time.
When "downhill" movement is more rapid than "uphill" return.
Recycle mechanisms in many cases are chiefly biotic.

The natural cycles in the environment: the biosphere in its widest sense consists of the earth's crust, the atmosphere and various species of life which exists in the zone 600 meters above and 10000 meters below sea level.

The biosphere is very large and complex and hence divided into smaller units called ecosystems.

An ecosystem consists of plants, animals and micro- organisms which live in a definite zone along with physical factors such as soil, water and air.

Within an ecosystem there are dynamic interrelationships between the living forms and their physical environment.

These relationships are manifested as natural cycles which provide a continuous circulation of the essential constituents necessary for life.

The natural cycles and ecosystems operate in a balanced manner which stabilizes the entire biosphere and sustains the life processes on earth.

Hydrological cycle: this is a continuous process by which water is circulated between the earth and atmosphere. Key processes in the water cycle: evaporation – water from oceans, lakes, rivers and land evaporates into the atmosphere as water vapor.
Condensation – water vapors cool and condenses into clouds.
Precipitation – water falls back to earth as rain, snow, sleet or hail.
Runoff and infiltration – water flows over land or infiltrates soil to recharge ground water.
Importance: supports life. It sustains ecosystems and human activities like agriculture.
Climate regulation. Influences weather pattern and climate conditions.
Water resources. Impacts availability of fresh water for drinking, agriculture and industry.
Temperature regulation. Water vapor is a greenhouse gas and evaporation/condensation processes affect local temperatures.

About one third of the solar flux absorbed by the earth is used to drive the hydrological cycle massive evaporation of the water from the oceans, cloud formation and precipitation which provides us with our supply and reserves of fresh water.

The more water evaporates from the sea than returns via rainfall and vice versa for land.

A part of the rainfall that supports land ecosystems, including most of man's food production, comes from water vapors over the sea.

Water on land surfaces seeps into soil as ground water. Below the ground water there is a natural water level or water table.

The soil below the water table is sustained by the underlying clay and rock strata. Ground water does not remain stationary but moves in various direction.

Water moves up above the water table by capillary actions and thereby maintains a continuous supply of water to the surface layer of soil, where it is absorbed by plant roots in absence of vapor exist above impermeable rock strata – water percolates through the porous rock and forms underground lakes or reservoirs. From these aquifers water can be extracted by sinking wells, tube wells and pumping it to the surface.

The rain water precipitated on land does not percolate into the soil. Surface water flows into streams, rivers, lakes and catchment areas or reservoirs.

Plants absorbs capillary ground water but gives off excess water through leaves by the process of transpiration.

Effect of climate change on water cycle: changing precipitation pattern- more intense droughts or floods in various regions.

Increased evaporation – warmer temperatures increase evaporation, affecting water availability.

Impact on water resources – altered timing and amount of water availability impact agriculture, ecosystems and human use.

Carbon cycle: the carbon cycle involves movement of carbon in various forms (carbon di oxide, organic carbon
etc.) through the atmosphere, biosphere and hydrosphere.

Key processes in carbon cycle:
Photosynthesis – plants, algae and some bacteria convert carbon di oxide into organic carbon.
Respiration – organisms break down organic carbon releasing carbon di oxide.
Decomposition – microbes break down dead organic matter ,releasing carbon di oxide.
Fossil fuel burning – human activity releases stored carbon into the atmospheric carbon di oxide.

Significance: climate regulation impact global temperature and climate.
Life support – carbon is a fundamental element in organic molecules.
Oxygen cycle: oxygen is a major component of all living organisms.
Oxygen is needed by most plants and animals and human beings for aerobic respiration or enzymatic oxidation of organic food which sustains growth and general metabolism.
Thus, it is absorbed from the environment during aerobic respiration but released by plants during photosynthesis thereby setting up the oxygen cycle.

There is also continuous exchange of oxygen between the atmosphere and all water surfaces of earth.

The total amount of oxygen in the biosphere is relatively constant so that the oxygen cycle is stable.
The oxygen cycle is based on the exchange of oxygen among the atmosphere, lithosphere, hydrosphere and biosphere.
Oxygen contributes largely to the processes on earth's surface.
It participates in combustion reactions, degradation of organic materials and some oxidative weathering processes.

Nitrogen cycle: it involves movement of nitrogen through the atmosphere, soil, water and living organisms.

Key processes in nitrogen cycle

- nitrogen fixation : conversion of atmospheric nitrogen to usable forms by bacteria or lightening.
- nitrification: ammonia converted to nitrite then nitrate by bacteria.
- denitrification: nitrates converted back to nitrogen by bacteria

importance of nitrogen cycle

essential nutrient : nitrogen is crucial for amino acids, proteins, and nucleic acids in living organisms.

Ecosystem balance: nitrogen availability affects plant growth and ecosystem productivity.

The air which contains 80% nitrogen is the greatest reservoir and safety volve of the system

nitrogen is continually entering the air by the action of denitrifying bacteria and continually returning to the cycle through the action of nitrogen fixing bacteria or algae and through the action of lightening (electrification).

The trace element molybdenum is also required as part of the nitrogen fixing enzyme system and may sometimes be a limiting factor.

The importance of nitrogen fixing bacteria associated with legumes is well known.

Fertility of the field is maintained as much by crop rotation involving legumes as by the application of nitrogen fertilizers.

Human impacts on nitrogen cycle:

- fertilizer use : synthetic fertilizers increase nitrogen in soils leading to runoff and water pollution.
- combustion : fossil fuel burning releases nitrogen oxides contributing to air pollution.

Effects of nitrogen cycle alterations

- eutrophication- excess nitrogen in water bodies leads to algal blooms and decreased oxygen.
- air quality – nitrogen oxides contribute to smog and acid rain.

Plants and animals continuously produce proteins, which are organic compounds containing nitrogen.

Plants absorb nitrates from the soil to produce plants.
The death and decay of plants and animals as well as excreta of animals comprise the major load of organic residues containing proteins to the soil.
Various types of micro-organisms in the soil utilize these nitrogenous organic residues for their metabolism.
This yields a chain of intermediate products such as ammonia, nitrites and nitrates.
Plants absorb nitrates and re-enter the nitrogen cycle.
Some soil micro-organisms break down soil nitrate into nitrogen by denitrification process while others transform nitrogen into soluble nitrogen compounds at a rate of about 0.1 ton per hectare per year.
In total cycle about 4-7 tons of nitrogen per hectare is added to the soil each year.

There is some loss from the soil through the leaching of nitrates into fresh water courses and the sea. However, by all these processes the nitrogen cycle is balanced and thus the N2 concentration in the atmosphere is relatively constant.

This natural cycle is upset by nitrogen agricultural practices which dump about 40 M tons of nitrogenous fertilizers each year to the world's cultivated land. Fresh water resources viz. streams, rivers and lakes get polluted by agricultural run off I e leaching of excessive nitrate from agricultural lands.

Phosphorous cycle is a biogeochemical cycle involving the movement of phosphorous through the environment, living organisms and earth's crust.

Key aspects of phosphorous cycle –

- sources: phosphorous is primarily found in rocks and minerals like phosphate rock.
- release: weathering of rocks releases phosphorous into soil and water.
- uptake: plants absorb phosphorous from soil; animals get it through food.
- return: decomposition returns phosphorous to soil.

Significance of phosphorous cycle :
- nutrients for life : phosphorous is essential for plants and animals for growth and development.
- eutrophication risk : excess phosphorous in water bodies can lead to eutrophication, harming aquatic ecosystems.
Human impact:
- fertilizer use: agricultural runoff of phosphorous based fertilizers can lead to water pollution.
- wastewater: phosphorous in detergents and human waste can enter water bodies.

In fresh water phytoplankton quickly absorbs soluble inorganic phosphates and convert them into organophosphates.

Algae are the source of food for zooplankton which in turn are eaten by other aquatic animals.

All these forms of life after their death and decay settle to the bottom of water.

In due course the organic waste decomposes by the action of micro-organisms, releasing phosphates into water body for recycle again.

Sulfur cycle: plants and animals depend on continuous supply of sulfur and its compounds for synthesis of some amino acids and proteins.
Some sulfur bacteria serve as the media for exchanges of eutrophication sulfur within ecosystems.
In polluted waters under anaerobic conditions H_2S is produced by bacteria giving deposits of FeS.
In unpolluted waters under aerobic conditions sulfur bacteria transform sulphides into sulphates for further production of proteins.

Source : Sulphur is released from volcanic activity, fossil fuel burning and decomposition of organic matter.
Atmospheric sulfur : Sulphur dioxide can lead to acid rains when combined with water vapor.
Biological role: Sulphur is essential for some amino acids and thus for life.
Human impacts:
fossil fuel burning releases SO2 contributing to acid rain and air pollution.
Reduced sulfur emissions have mitigated acid rain in some regions.
Sulfur dioxide leads to acid rain, harming ecosystems, buildings and water quality.
Sulfur pollutants can affect respiratory health.