ECCI/ECII/ECSI: ENVIRONMENTAL MANAGEMENT

INTRODUCTION: BASIC CONCEPTS

What is **Environment** and why do we now notice so much interest in Environmental Studies? And what do we exactly mean by Environmental Studies?

Definition: Environment

Environment is the sum total of all conditions and influences that affect the development and life of all organisms on earth.

The living organisms vary from the lowest micro-organisms such as bacteria, virus, fungus, etc. to the highest, including man. Each organism has its own environment.

The word "environment" can mean many things to many people:

1) Preservation of a scenic natural landscape or dwindling wildlife species
2) Industrial pollution or threat to citizens' amenities caused by the building of a road or a big factory
3) The mother of natural resources—energy, land, water, atmosphere and minerals

The functions of the environment in relation to man have been analysed:

(1) recreation
(2) source of natural resources— agricultural, mineral and forestry which man consumes directly or indirectly
(3) "sink" for receiving wastes produced by man and his activities

The capacity of the environment to carry out these functions is damaged by human activities which imposes four stresses on the environment:

i. **"eutrophic"**, i.e. the task of decomposing wastes produced by consumption and production activities;
ii. **"exploitative"**, i.e. cropping of plants, extraction of minerals and hunting of animals;
iii. **"disruptive"** — brought about by activities like deforestation, construction of highways and towns; and
iv. **"chemical"** and **"industrial"** stress which results from industrial development.

Environmental Studies and Management

- The earth provided the right environment—pure air, pure water, pure land, carbon dioxide which in presence of strong sunlight helped in the development of the living world consisting of plants, animals and man.
- Nature through its own cycles has readily helped in the evolution of life forms. These natural cycles—water cycle, oxygen cycle, nitrogen cycle, carbon cycle, etc.—are conducted in harmony with environment.

- In the early stage man lived in harmony with Nature but over the years this equilibrium was disrupted by man as he tried to improve his life style with the help of science and technology and as population grew beyond control which increased the need for more and more food, water and shelter.
- Man's greed and needs led to exploitation of natural resources which caused environmental degradation and world-wide crisis threatening human survival.
- It is now urgently felt that the public should be made aware of all aspects of human environment—physical, biological, socio-economic and cultural—in order to handle current environmental issues properly.
- The studies of all these aspects comprise Environmental Studies which is becoming important more than ever before.

ECOSYSTEMS

ECOLOGY AND ECOSYSTEM

- The word "Ecology" was coined by a German biologist in 1869 and is derived from the Greek word, "Oikos" meaning "House".
- **Definition**: ***Ecology*** is the branch of Science that deals with the study of interactions between living organisms and their physical environment. The latter are closely inter-related and they have continuous interaction so that any change in the environment has an effect on the living organisms and vice versa.
- Any unit or biosystem that includes all the organisms which function together (biotic community) in a given area where they interact with the physical environment is known as ecosystem.

Definition: ***The ecosystem*** is the functional unit in ecology as it consists of both the biotic community (living organisms) and abiotic environment. The latter have close interaction, essential for maintenance of life processes. The interaction is conducted by energy flow (solar energy) in the system and cycling of materials (natural cycles).

From biological points of view, the ecosystem has the following constituents:

(1) **inorganic substances** (carbon, nitrogen, carbon dioxide, water, etc.) involved in natural cycles;
(2) **organic compounds** (proteins, carbohydrates, humic substances, etc.;
(3) **air, water and substrate environment** including the climatic regime and other physical factors;
(4) **producers, autotrophic** (i.e. self-sustaining organisms) green plants that can manufacture food from simple inorganic substances;
(5) **heterotrophic** (i.e. depending on others for nourishment) organisms, mainly bacteria, fungi and animals which live on other organisms or particulate organic matter;
(6) **micro-consumers, decomposers**, mainly, bacteria, fungi which obtain their energy by breaking down dead tissues or by absorbing dissolved organic matter, extracted from plants or other organisms. The decomposers release inorganic nutrients that are utilised by producers. They also supply food for macroconsumers or heterotrophic organisms bacteria, fungi and (animals) and often excrete hormone-like substances that inhibit or stimulate other biotic components of the ecosystem.

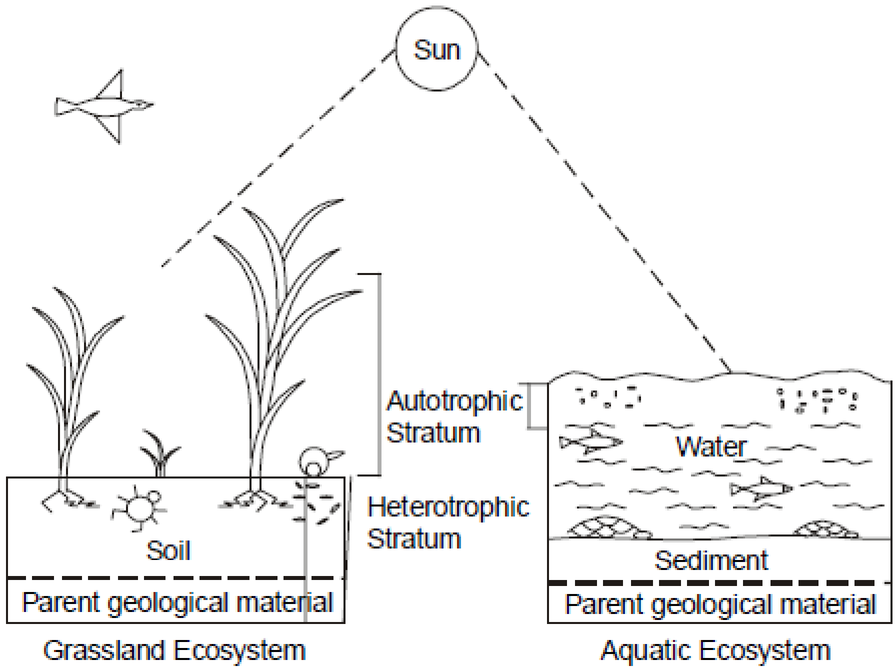

Figure: Grassland and pond ecosystem

- Typical profiles of a grassland ecosystem and of a pond ecosystem are shown in the figure above.
- The **common features of all ecosystems**—terrestrial, freshwater, marine and agricultural—are the ***interactions of the autotrophic and heterotrophic components***
- The major autotrophic metabolism occurs in the upper "green belt" stratum where solar energy is available while the intense heterotrophic metabolism occurs in the lower "brown belt" where organic matter accumulates in soils and sediments.

Biomes

- **Definition**: ***The Biome*** is a very large land community unit where the plant species is more or less uniform. It provides a basis of natural ecological classification.
- The **main Biomes of the world** are the Tundra, Temperate, Coniferous forest, Deciduous forest, Temperate grassland, Tropical Savanna, Desert and Tropical Rain Forest.

Carrying Capacity

Definition: The maximum population size that an ecosystem can support under particular environmental conditions is known as the ***carrying capacity***.

The Tragedy of the Commons

Garrett Hardin, a biologist penned "The Tragedy of the Commons" in 1968. The commons, is a parcel of land eligible to be used by all commoners of the village. Hence it is a ***public good or common-pool resource***. The villagers are ***free to use the land*** to graze livestock, which they do since it conserves use of their own personal land, which in turn allows them to raise even greater numbers of livestock. However, as Hardin points out: "The ***rational herdsman*** concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another.... But this is the ***conclusion reached by each and every other rational herdsman*** sharing a common. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a ***world that is limited***. ***Ruin is the destination*** toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. ***Freedom in a commons brings ruin to all***."*

- There are counter-arguments to Hardin's hypotheses. There is much scholarship and controversy regarding the assumptions of humans and states being purely rational short-term utility-maximizers:
    - "Although tragedies have undoubtedly occurred, it is also obvious that for thousands of years people have self-organized to manage common-pool resources, and users often do devise long-term, sustainable institutions for governing these resources."**

Nonetheless, the tragedy of the commons remains a foundational work in the study of open resource problems.

*Hardin, G. 1968. The tragedy of the commons. Science 162:1243.
**Ostrom, E., et al. 1999. Revisting the commons: Local lessons, global challenges. Science 284:278

Theory of Collective Action

"Rational, self-interested individuals will not act to achieve their common or group interests."*

Mancur Olson argued that many of the prevailing arguments, in what is now generally known as Rational Choice Theory were flawed in their conclusions that actors would necessarily choose to cooperate on issues of common or public interest.

Olson demonstrated that actors' willingness to engage in collective action is strongly dependent upon the relative costs and benefits of action or inaction to specific actors. For example, while reduction of sulfur emissions would likely reduce acid rain, which would benefit all by reducing water pollution, ground pollution, and infrastructure decay, the costs of such collective action are not necessarily borne equally by all actors. Actors with a large stake in sulfur-emitting industries may have to pay high and concentrated costs to reduce emissions, negatively affecting their profitability. The actors that will gain from reduced sulfur emissions and acid rain, the public, will see diffuse benefits (measured both in temporal and monetary terms). The argument underpinning the strength of special interests is that small and dedicated lobbies, who have much at stake, tend to win out over the larger public good.

Olsen also noted that there was tremendous temptation by actors to avoid the costs of cooperation while still reaping the benefits. This is called the free rider problem. Actors may calculate that collective action will be taken by others to address a common interest problem without the need for their own sacrifice or contribution. The free rider may then enjoy the benefits of collective action while evading their own share of the costs. For example, a regional group of 10 advanced states all suffer from the effects of acid rain. The 10 states negotiate a treaty to reduce sulfur emissions that contribute to acid rain. Nine states ratify the treaty while the tenth state declines. The efforts of the nine states to reduce sulfur emissions are successful and acid rain is reduced for the entire region. The nine ratifying states all paid the costs of sulfur emission reductions. The tenth state was able to enjoy the benefits of reduced acid rain while shouldering none of the costs—riding free. This result can harm continued and future collective action since other states will, rightfully so, feel they are disproportionately bearing costs of action being avoided by others.

*Olson, M. 1965. The Logic of Collective Action: Public Goods and the Theory of Groups. Cambridge: Harvard University Press.

The Precautionary Principle

One of the fundamental problems in global environmental governance is the level of uncertainty that exists in the science, economics, and policy prescriptions of environmental threats and solutions. Because of scientific uncertainty, the Precautionary Principle emerged. The principle has been adopted in several major environmental conventions of the United Nations.

Set out in the Framework Convention on Climate Change, the Rio Declaration, and the UN Global Compact, the principle states that "***where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental harm***." It includes several key concepts:

- *Preventative anticipation* Acting if necessary before full scientific proof is available
- *Proportionality of response* Selecting degrees of restraint that are not unduly costly
- *Burden of proof* Placing the onus of proof of safety on those creating the threat or risk

Eco-label/Certification

The goal of affecting consumer purchases by awarding a green "*seal of approval*," or ***eco-label***, to products and services with the least environmental impacts has been applied to forest products, fish products, paper products, new buildings, tourism facilities and operations, and many others.

Ecological footprint

- An audit or quantification of human use of nature is made in relation to the assessed biophysical constraints of the globe as an indicator of sustainability.
    - Starting point in ecological foot-printing: all organisms make some impact on earth.
    - That impact relates to the 'quantity' of nature that is used to sustain consumption patterns and the key question is of whether that load exceeds what nature can support.
    - Footprint analysis estimates the area of land that would be necessary to sustainably support those consumption patterns.
    - It is related to the notion of carrying capacity, but rather than asking 'how many people can the earth support?', ecological footprint analysis asks '**how much land do people require to support themselves**?'

BIOSPHERE AND THE SCIENCE OF ECOLOGY

The Biosphere

- The Earth has a total surface area of 509 million km^2; 359 million km^2 are water (the surface of the hydrosphere) and 149.6 million km^2 are land (surface of the lithosphere) (Table 2.1).
- In total, the land and water and the life they support are called the biosphere. The Russian geologist V. I. Vernadsky, who coined the term, described it thusly:

> The biosphere is the envelope of life, i.e., the area of existence of living matter … the biosphere can be regarded as the area of the Earth's crust occupied by transformers, which convert cosmic radiation into effective terrestrial energy: electric, chemical, mechanical, thermal, etc. (Vernadsky 1928)

- The "biosphere is a cosmic phenomenon and a geological force" (Margulis and Lovelock 1989).
- It is the upper thin mantle on the Earth's crust that is enveloped by the atmosphere and supports life (Figure 2.1).

- Major climatic patterns and local weather phenomena affect both the living and the nonliving components.
- Above the biosphere, air temperatures cool as the altitude increases; this occurs at an average lapse rate of 6.5°C for every 1-km ascent in the troposphere.

Approximate Area		
Continent	**Km^2**	**% of Earth's Land**
Total area	509,000,000	100.00
Oceans	359,000,000	71.00
Land	149,673,000	29.00
Asia	43,608,000	8.56
Africa	30,335,000	5.59
North and Central America	25,349,000	4.98
South America	17,611,000	3.46
Antarctica	13,340,000	2.26
Europe	10,498,000	2.06
Oceania	8,932,000	1.75

- The biosphere is home to a great variety of plants (about 300,000 species reported so far) and of animals (1.4 million species described).
- However, scientists have a surprisingly poor understanding of just how many species the biosphere contains, with estimates ranging from at least 5 million to as many as 100 million species.

- There is remarkable similarity between the changes that take place in the growth form of plants, as one proceeds from the equator to the poles, and changes that occur with increases in altitude.
- The lowest latitudes and altitudes display the greatest diversity of species, with a predominance of trees.
- As latitude or altitude increases, plant and animal communities show a diminution of species diversity, and tree forms give way to shrubs and perennial herbs until conditions become so harsh at high altitudes and far north and far south that no life exists.

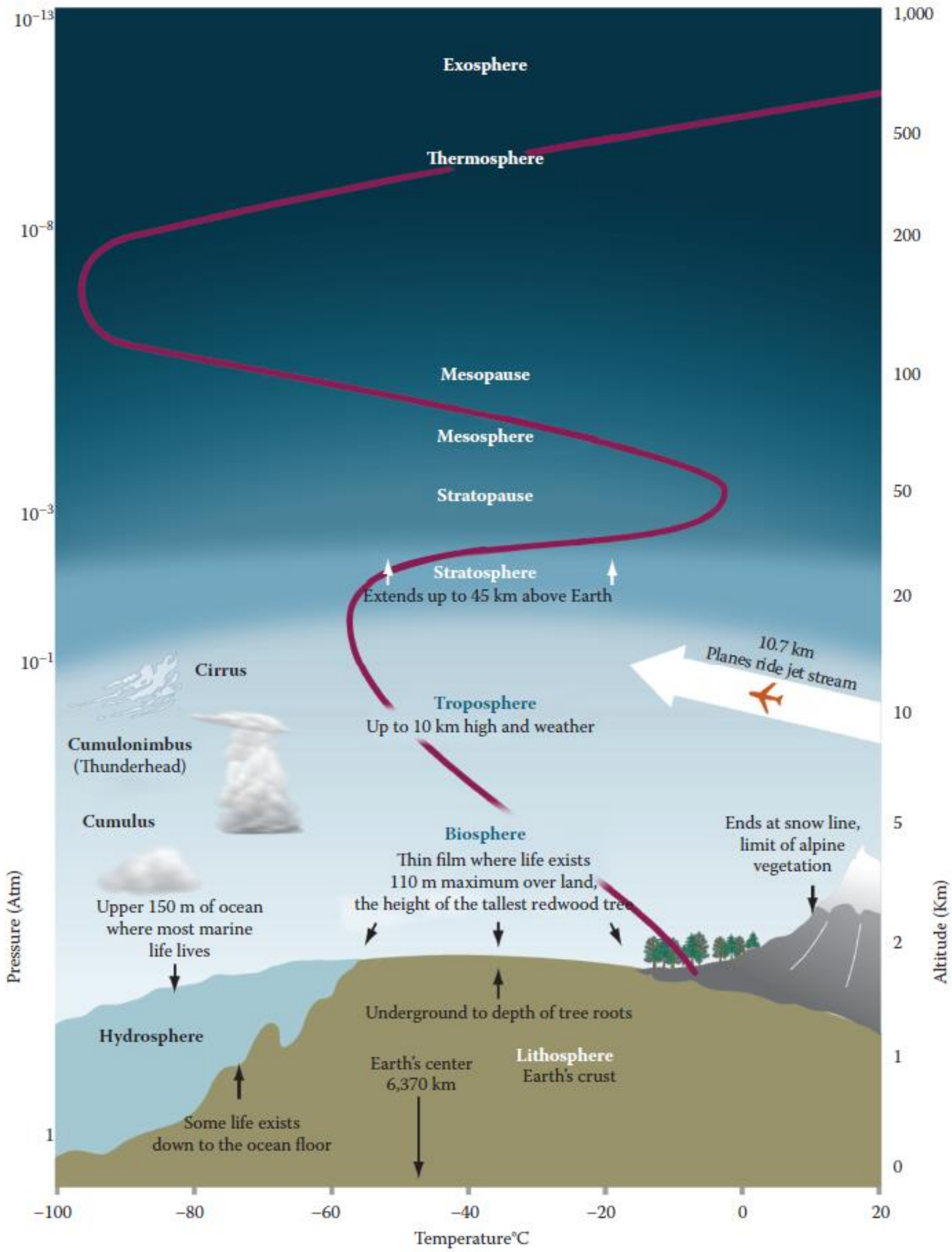

Figure 2.1 Spheres of the Earth, the biosphere, atmosphere, lithosphere, and hydrosphere, and the variation of atmospheric pressure and temperature (red line) with altitude above the Earth's surface. (Lower part based on a diagram by R. M. Chapin, Jr.)

The Lithosphere

- The lithosphere is the bedrock and other rocky material on which soils have developed.
- This includes the plant root zone, also known as the rhizosphere.
- Most plant roots are located in the upper one meter of the soil.
- However, in dry regions where water is scarce, plants may extend their root systems to depths of 10–20 m below ground to reach the ground water table.

The Hydrosphere

- The hydrosphere is the area of the Earth covered by water, which makes up 70.9% of the Earth's total surface.
- The volume of the oceans is estimated to be 1.3 billion km^3, with an estimated mean depth of 3.7 km.
- Compare this with the relatively small volume of freshwater, which amounts to only 35 million km^3, or 2.7% of the total water on Earth.

For humans, however, it is the interactions among the atmospheric, terrestrial, and aquatic processes in the biosphere that are perhaps of most interest.

THE SCIENCE OF ECOLOGY

- Understanding environmental issues, be they historical or contemporary, requires a firm grasp of the science of ecology.

- The word **ecology** is derived from "œkologie," a term first coined by the German zoologist, Ernst Haeckel; the term has the Greek roots oikos, meaning house, and logos, study of.
- Haeckel defined the content of his œkologie as "comprising the relation of the animal to its organic as well as its inorganic environment, particularly its friendly or hostile relations to those animals or plants that it comes in contact".
- To Odum (1959), ecology was simply the study of the structure and function of nature.

- Ecology deals with the adaptations of organisms to their environment over time, how and how many organisms live in a given space at a given time, and how they obtain food, occupy space, and reproduce.
- Although the roots of ecology have traditionally been grounded in the field of biology, its subject matter deals with every other fundamental and applied natural science: physics, chemistry, geology, mathematics, agriculture, soil science, and medicine.

- **Ecology is interdisciplinary and multidisciplinary**, but its strength is determined not only by how many fields it can cross, but also by how many disciplines it can integrate well to explain the complex workings of nature. The solutions of contemporary environmental issues lie in those integrations and syntheses.

- Ecology is central to study and understanding of the environment. When we speak of the environment, we mean the totality of everything that surrounds us and with which we come in contact. Climatic variables (such as temperature, precipitation, wind, and tropical storms), atmospheric variables (such as intensity of light, the nature of gases, and types of pollutants), and the nature and composition of soils are all part of the environment. The environment also encompasses relations of living organisms—whether of one's own kind or with individuals belonging to other species. Thus, the environment includes the entire interactive complex of physical, chemical, and biological factors encountered by organisms.

- The place where an organism lives and its surroundings, both living and nonliving, are its **habitat**.
- Habitats vary over large geographic regions but also over small distances when **microhabitats** are created by features such as small topographical variations or the growth of other organisms (e.g., trees). These can bring about small but distinct differences in habitat conditions.
- Tree growth, for example, can bring about differences in the light and heat received on the forest floor, creating a number of **microhabitats**.
- Different microhabitats support different species. Thus, as the number of microhabitats increases, species diversity tends to increase as well.
- The functional aspect of each species is described by its **niche.**
- Niche is the role of the species in the community—"How does an organism function in the community?"
- Contemporary ecologists make a **clear distinction between habitat and niche**; the latter is viewed as a summary of the tolerances and requirements of the species.
- Our understanding of the laws that govern ecological systems has been established through years of observations and experiments.
- A general law, the **"law of minimum"**: each organism has a number of minimal resource requirements that it needs to survive, function, grow, and reproduce.
- If any one of the required factors is in a small quantity relative to the needs of the organism, then the growth or reproduction of an organism will be limited by the factor in shortest supply.
- In some cases, one environmental factor or condition may compensate for the minimal supply of the other—for example, cases where a warmer temperature may compensate for low light.
- But universally, some environmental factors (such as water or specific nutrient elements like calcium and iron that are required for growth) can be neither substituted for nor replaced.
- A natural consequence of the law of minimum, sometimes stated as the "law of limiting factors" in plant physiology, is the "law of tolerance", which states that ***too much of something may be as bad as too little***.
    - In this case, an environmental factor that is required in small quantities for growth may be present in so large a quantity (salt, for example) that it inhibits or stops growth.

THE ECOSYSTEM CONCEPT

- The concept of interconnectedness of ecological processes occupies a premier place in ecology and is expressed in the term **ecosystem**.
- Originally proposed by the British ecologist Sir Arthur Tansley, the term ecosystem has gained currency in the common lexicon as well.
- He visualized an ecosystem as an interacting group of organisms with "the whole complex of physical factors" and emphasized that although our interest may be in living organisms, "we cannot separate them from their special environment, with which they form one system."
- Ecosystems are open to inflows and outflows, come in various kinds and sizes, and function in a relatively stable equilibrium.
- "It is the systems so formed … that are the basic units of nature on the earth" (Tansley 1935).
- **An ecosystem was defined as** "any area of nature that includes living organisms and nonliving substances interacting to produce an exchange of materials between the living and nonliving parts" (Odum 1959).

- Functionally, an ecosystem comprises the abiotic components such as climate, water, and soils; the **producer** (or autotrophic) components, including the green plants, algae, and chemosynthetic bacteria; the **consumer** (heterotrophic) components of herbivores, carnivores, and omnivores; and the **detritivore** (saprophytic) components of the decomposer community, dominated by the microbes that break down dead, organic matter and are fundamental to the cycling of nutrients (Figure 2.6).

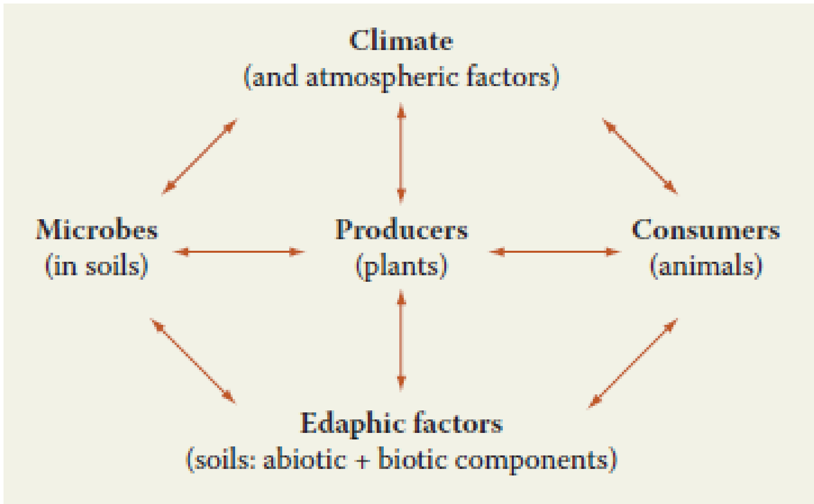

Figure 2.6 Functional and interacting components of a terrestrial ecosystem.

- From an ecological standpoint, the "producers" on planet Earth are the green plants, algae, and chemosynthetic bacteria (also known as the autotrophs or "self-feeders").
- All animals (including humans) are heterotrophic consumers.

The utility (usefulness) of the ecosystem concept is overwhelming because of the following attributes (Kimmins 2004). [Figure 2.7]

- **Structure**. Ecosystems are made of abiotic and biotic subcomponents. At the very least, a terrestrial ecosystem must have green plants, a substrate, and an atmosphere; in most ecosystems, there must be an appropriate mixture of plants, animals, and microbes if the ecosystem is to function. Terrestrial ecosystems normally consist of a complex biotic community, together with soil and atmosphere, a source of energy (the sun), and a supply of water.
- **Function**. The constant exchange of matter and energy between the physical environment and the living community constitutes function. Ecosystems at all times have organic materials that are alive or dead in various stages of decomposition. Thus, there are considerable advantages in looking at systems in biological–physical–chemical terms.
- **Complexity**. Each ecosystem has a high level of biological integration. As the number of abiotic and biotic components grows, so do the interactions between them and so does the complexity of the system. As ecosystem complexity increases, it becomes more difficult to predict how a system will behave—for instance, how it will respond to a disturbance.
- **Interaction and interdependence**. So complete is the interconnectedness of various living and nonliving components that a change in any one will result in consequent changes in almost all the others.
- **Spatial relationships**. All populations of animals and plants (a flock of birds, a buckeye forest) occupy a given space. Ecologists study populations in relation to their abundance in a given space. The ecosystem per se does not restrict a researcher or observer to be constrained by spatial limits.

- **Temporal change**. The entire structure and function of populations and communities in nature undergo change over time. This temporal change (sometimes called ecological succession) is universal and is a very significant ecological process in assessing methods to restore disturbed systems.

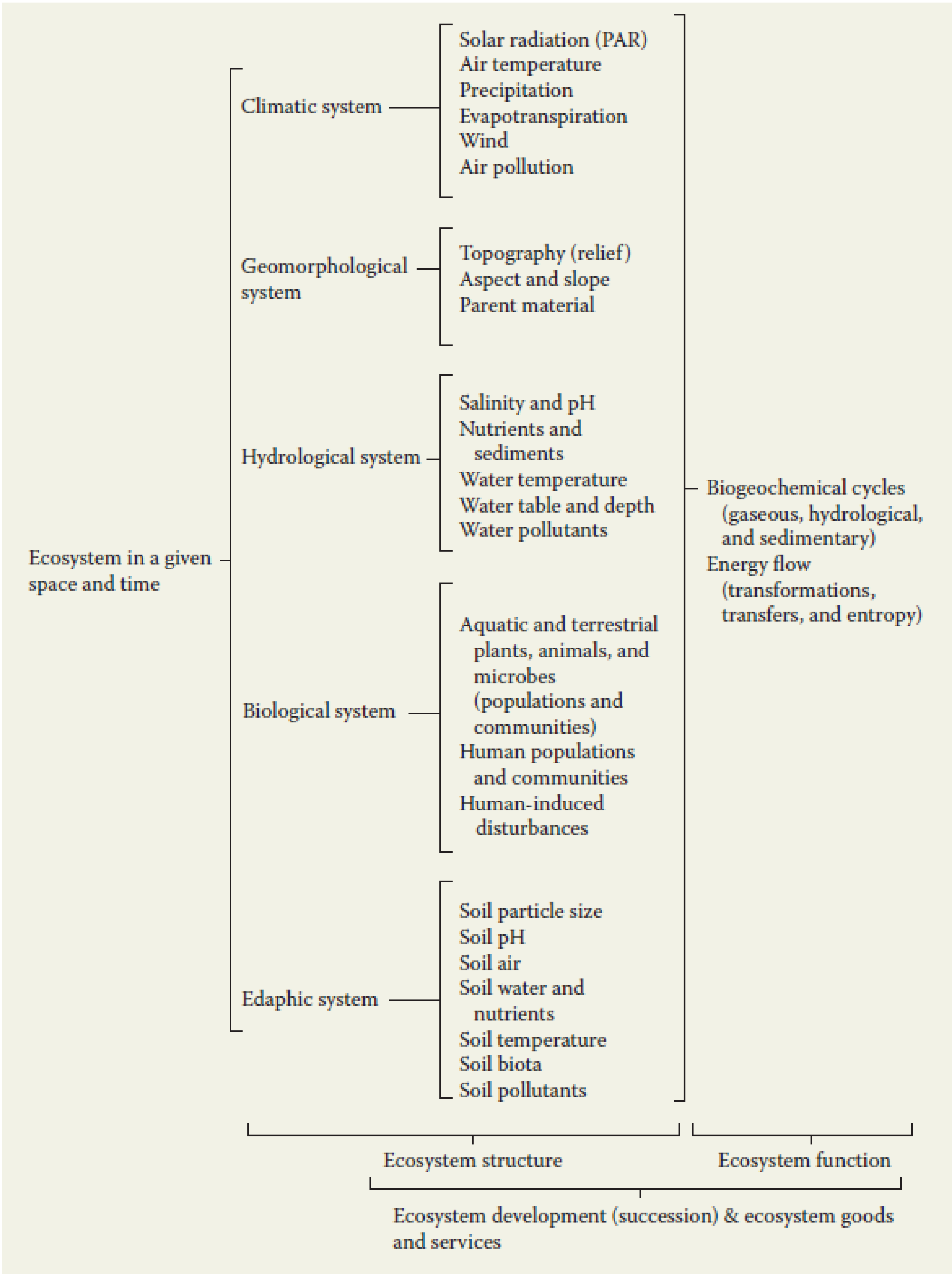

Figure 2.7 Structural and functional components of an ecosystem.

- Most recently, the United Nations embraced the ecosystem concept in its assessment of human impacts on ecosystems and the services they provide.
- Ecosystem services are the benefits that humans obtain from ecosystems, such as the supply of food, fiber, clean air and water, and climate regulation.
- This project, called the global Millennium Ecosystem Assessment (MEA 2003), was carried out between 2001 and 2005.
- The assessment provides information on the links between human well-being and the degree to which ecosystems have become degraded, thus establishing the scientific basis needed to promote their sustainable use.
- The number-one finding of the MEA confirms the extent of human impacts on the biosphere:

    - Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any other comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on earth.

- The fields of environmental sciences and environmental studies have become established.
- If ecology is a field of science, then environmental issues are considered in the broad context of human activities such as economic and social systems (Figure 2.8).

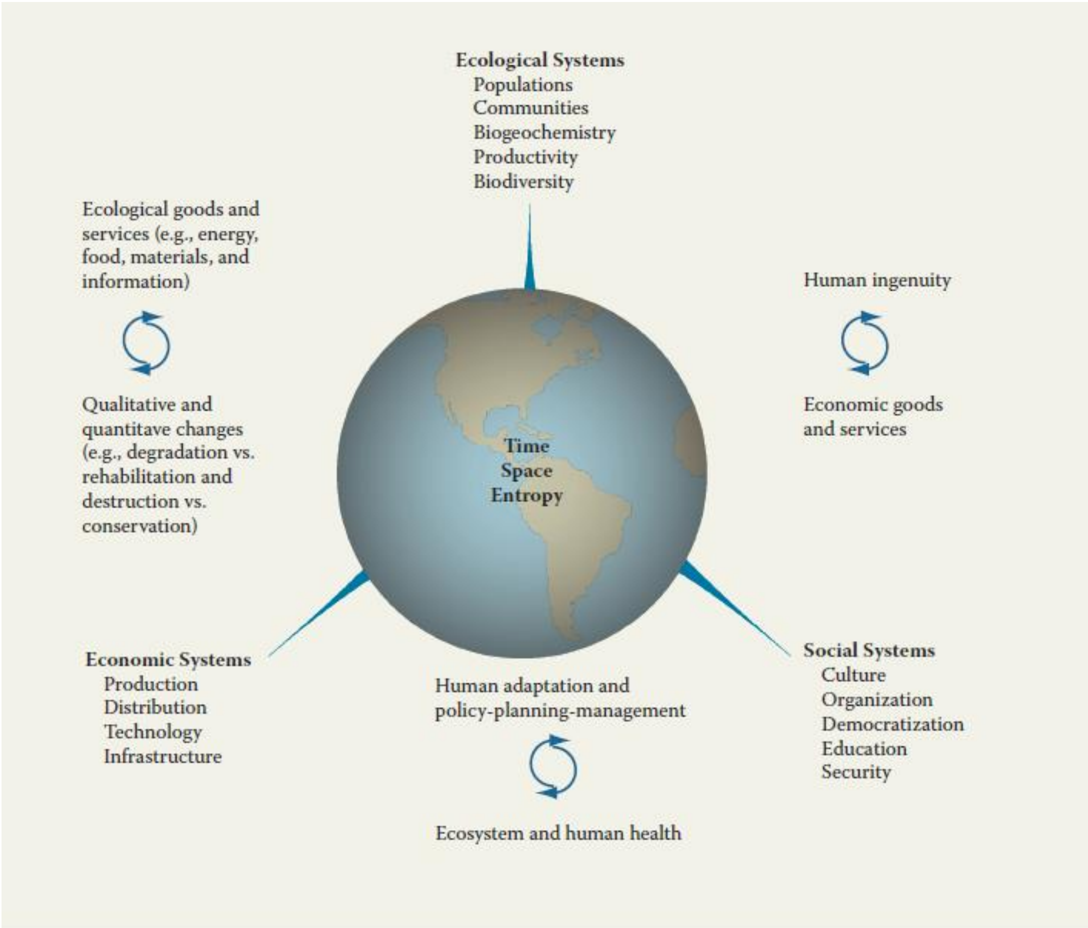

Figure 2.8 The interlocking relationships of ecological, economic, and social systems of the human domain. Note the centrality of time, space, and energy relations of all systems and fields of principle formation in each respective system. (Modified from Wali et al. 1999b.)

SUMMARY: ECOLOGY AND ECOSYSTEM

- The word "Ecology" was coined by a German biologist in 1869 and is derived from the Greek word, "Oikos" meaning "House".
- **Definition**: ***Ecology*** is the branch of Science that deals with the study of interactions between living organisms and their physical environment. The latter are closely inter-related and they have continuous interaction so that any change in the environment has an effect on the living organisms and vice versa.
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ATMOSPHERE, CLIMATE, AND ORGANISMS

Atmosphere

- The biosphere, hydrosphere, and lithosphere are all enclosed by an invisible gaseous mantle—the Earth's atmosphere.
- Life exists only near the zone of contact between the atmosphere and the Earth's land and water surfaces.
- Thus, living things are greatly influenced by changes in the atmosphere.

- Based on distinctive temperature gradients, several vertical regions of the atmosphere (see Figure 2.1).
- The layer of atmosphere closest to the Earth is the **troposphere**, which extends from the Earth's surface up to a height of about 10 km. Above it is the **stratosphere**, a region that extends from 10 to 45 km with calmer and clear air.
- The lower region of the stratosphere is the ozonosphere, or the **ozone layer**, which is vital to life because it absorbs much of the sun's damaging ultraviolet radiation. It is here that ozone (O_3) is both produced and destroyed. The ozone layer and how it is altered by human-made chemicals have been shown to be of great significance to life.
- The layer between 45 and 80 km is the **mesosphere**, characterized by the lowest temperatures in the atmosphere (as low as –138°C).
- Above it, from 80 to 500 km, is the **thermosphere**, a zone of very high temperatures that may approach 900°C. This zone is also referred to as the ionization zone because, in this zone, sunlight reduces molecules to individually charged particles called ions.
- The uppermost atmospheric region is the exosphere, which begins about 500 km above the Earth's surface and converges with interplanetary space

Climate and Weather

- The principal difference between the terms "climate" and "weather" is the timescale of each.
- **Climate** is an average condition derived from long-term periods of observation of day-to-day weather conditions.
- **Weather**, on the other hand, refers to the short-term conditions of the atmosphere at any time (e.g., daily, monthly, short-term annual) or place; it is expressed by a combination of:

  a. temperature;
  b. precipitation (rain, hail, snow, fog) and humidity;
  c. air pressure; and
  d. winds.

- Thus, the weather of a place is the sum of its atmospheric conditions for a short period of time.

- Habitats occupied by both plants and animals are greatly influenced not only by atmospheric weather patterns but also by modifications brought about by the organisms themselves.
- For example, forest trees can intercept light and rain and even absorb light differentially. As a consequence, those plants and animals that inhabit the forest floor must have the necessary adaptations to live under the modified conditions that are typical of the ground floor.

- Ecologists use the term **microclimate** to denote the small-scale atmospheric conditions that are actually encountered by growing organisms.

Global Climate and General Circulation

Several features of the Earth control the climate. These include:

- the angle of the sun as it strikes the Earth's surface as influenced by latitude and season;
- ocean currents;
- relative placement of land masses and bodies of water;
- semipermanent low- and high-pressure cells in the atmosphere;
- air masses, winds and storms, and the jet stream;
- altitude; and
- mountain barriers.
- These climatic controls help create the elements of climate such as temperature, precipitation, humidity, air pressure, and winds at any given place. The climatic elements, in turn, produce day-to-day variations in weather (Figure 3.1).

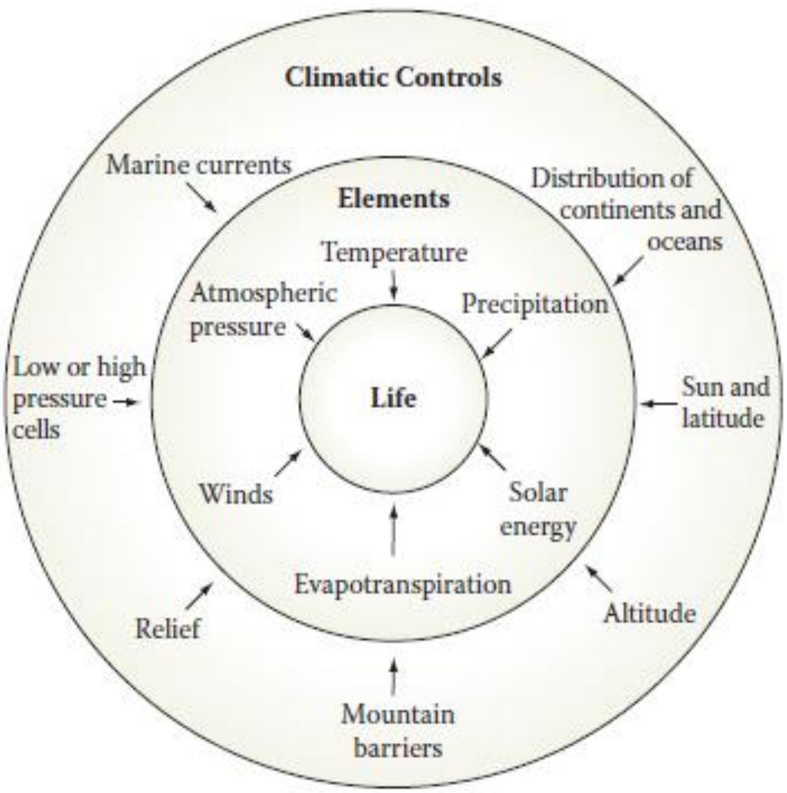


Figure 3.1 Climatic controls and elements acting upon ecosystems

Light

The energy from the sun that penetrates through the atmosphere—together with the green pigments in the chloroplasts of plants and a series of enzymes and other chemicals—powers **photosynthesis**, the process responsible for producing the food and fiber that all organisms use in one form or another.

Photosynthesis may be represented in a generalized way by the following equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

That is, carbon dioxide is chemically reduced to form sugar, while water is oxidized to form free oxygen. It is an energy-requiring biochemical reaction, and that energy comes from the sun.
The chemical energy stored in sugar (or protein or fats) can be oxidized later to carry out various synthetic reactions, growth, or even movement.

Precipitation, Humidity, and Wind

- **Precipitation** refers to rain, snow, hail, sleet, and fog, all forms of water that reach the surface of the Earth through the processes of **condensation** (vapor → liquid) and deposition (vapor → ice).
- Water returns to the atmosphere through **evaporation** and **transpiration** from plants (liquid → vapor) and sublimation (ice → vapor).
- Condensation of the water vapor into tiny droplets with decreasing temperatures forms clouds or fog.
- The temperature at which condensation occurs, called the **dew point**, is a function of the **humidity**, or the amount of water vapor in a given volume of air.
- Tiny suspended particles (aerosols) on which water droplets can collect are called condensation nuclei and must be present in air for precipitation to occur.
- Daily, seasonal, and yearly variations in temperatures and the amount of precipitation in a given area have produced a seemingly infinite variety of diverse ecosystems.
- How much and how sustained the biological production of a terrestrial ecosystem depends largely on the interaction of these two factors (Figure 3.10).
- Like air temperatures and other factors, the mean annual precipitation of an area is only part of the story. It is the yearly and seasonal distribution pattern of precipitation that determines the diversity of plant communities and, as a consequence, the animal communities.

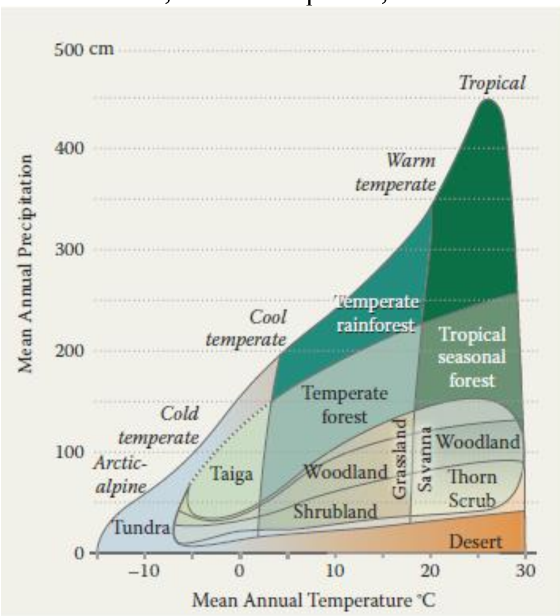


Figure 3.10 The distribution of the Earth's major vegetation as a function of the interaction of mean annual precipitation and temperature

Wind

- Wind contributes to the dispersal of pollen, seeds, and reproductive propagules of most plants over considerable distances, as well as to the transport of small animals.
- The cooling and drying effects of wind can contribute to growth reduction (dwarfing) and desiccation damage (water deficits) in plants, and they can influence the feeding behaviors of animals.
- Windblown salt or sand near marine ecosystems can kill the foliage and buds of vegetation and result in flag-shaped crowns or shrub-like growth form of trees (known as a krumholz formation).
- Soil erosion by wind contributes to the degradation and loss of productive lands.
- Strong winds can also adversely affect water quality in aquatic systems by increasing mortality, turbidity, nutrient loading, and dissolved organic carbon
- In forests, the high wind velocities typical of storms result in windbreaks (tree trunks snapped off) and windthrows (roots pulled out).

Influence of Topography

- The physical features of the landscape have a significant influence on a number of climatic factors, and this influence is directly reflected in the diversity of biotic communities at several scales.
- The surface features of land such as slope, elevation, and aspect (direction of exposure to sun) define the topography of an area.
- Variations in altitude greatly influence the distribution of precipitation by the formation of rain shadows. In turn, this also affects the structure and function of terrestrial populations and ecosystems.

Climate, Weather, and Humans

- The climates with comfortable temperature and adequate precipitation patterns is to a large extent the reason why, historically, human populations have shown a clumped distribution.
- The limitations of the homeothermal nature of humans have been somewhat overcome by our ability to use technology to make our dwellings livable in the face of widely fluctuating temperatures.

THE SOIL ENVIRONMENT

Soil Defined

- Soil is "the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants" (Soil Science Society of America 1997).

- But many potentially arable soils brought under cultivation throughout the world have been degraded by management practices.
- Soils have also been used as a repository for waste products that human society generates. These often exceed the capacity of soils to assimilate such wastes, resulting in the accumulation of toxins and the pollution of ground waters and adjacent ecosystems.

- Soils form the base and basis of life. All soils have three components: solid, liquid, and gaseous. Each of these phases affects the others, and their interactions result in the structure and function of soils.
- Plant productivity depends on the fertility, root environment, and stability of soils; this, in turn, defines the sustenance of and welfare for all consumers, including humans.
- Soils, therefore, must be viewed in a holistic way, noting the interconnectedness of their atmosphere, biosphere, lithosphere, and hydrosphere (Figure 4.1). The integration of these variables as a soil ecosystem is at the core of regional, national, and global sustainability issues.

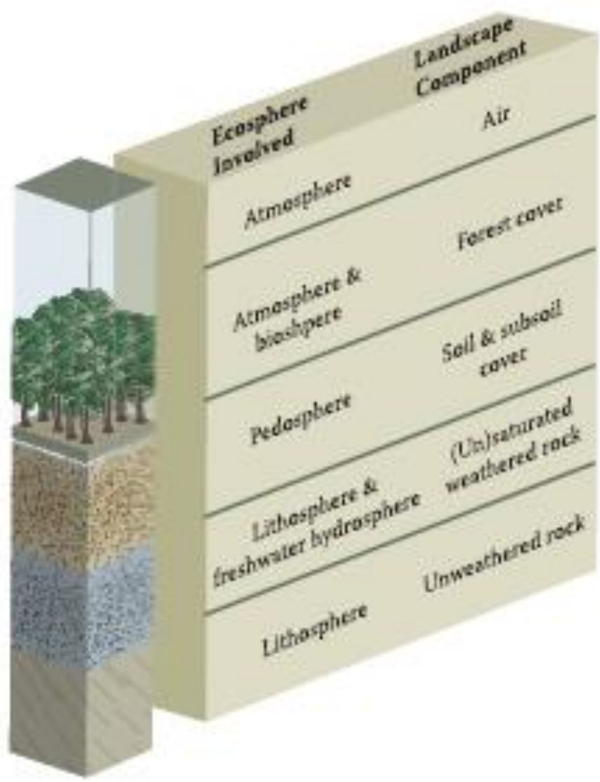


Figure 4.1 An ecological prism showing the relationships between the ecosphere involved and the landscape components in a forest ecosystem

Origin of Soils

All soils develop in parent materials that are derived from rocks. There are **three kinds of rocks**:

1. **Igneous** rocks are those formed from molten magma and may be of two types: volcanic or extrusive rocks (e.g., basalt) if lava cools quickly above ground after eruption, or plutonic or intrusive rocks (e.g., granite, diorite) if the cooling is underground and slow.

2. **Sedimentary** rocks are those formed from the deposition and recementing of weathering products of other rocks modified by the action of climatic variables and water (e.g., sandstone, shale).

3. **Metamorphic** rocks are products of the first two rock types that have been subjected to tremendous pressure and high temperature and are transformed (hence metamorphosed), for example, from igneous granite to form gneiss or from sedimentary shale to form slate.

- Over time, a complex group of processes, collectively termed **weathering**, brings about a breakdown and disintegration of any rock type.
- The immediate products of weathering are termed **parent materials**. When found where they are formed, parent materials are referred to as residual. However, they may be carried large distances by natural forces and are then called transported (Figure 4.2.).
- The natural forces of transport are so important to the formation of soils that the methods of transport are used to characterize them:
  - ice is the agent of transport, the parent materials are glacial,
  - wind is the agent, they are aeolian.
  - water and deposited as sediments in streams are called alluvial, in lakes they are called lacustrine, and those in seas and oceans are called marine (Figure 4.2)

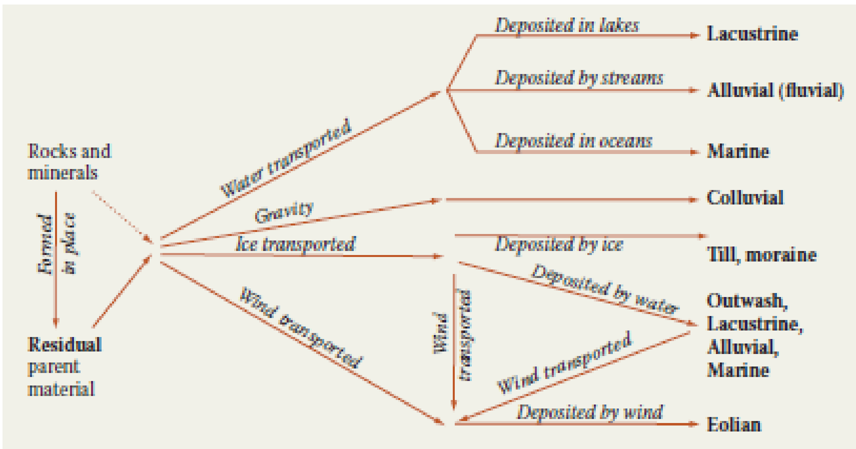


Figure 4.2 The weathering, transport, and deposition of parent materials

- Weathering includes both **physical forces** (such as freezing and thawing of water and abrasive action of water, wind, and snow) and **chemical processes** (such as hydration, hydrolysis, carbonation, and oxidation).

- Temperature, the quantity of precipitation, and the type of vegetation in a given area will determine how quickly soil formation can proceed.
- Biological activity significantly accelerates weathering, even at moderate temperatures.

Soil Physical Characteristics

Particle Size and Structure

- The primary mineral constituents of soil, arranged by their particle size, are:
  - ➢ sand (very coarse to very fine particles, ranging from 2.00–0.05 mm in diameter),
  - ➢ silt (0.05–0.002mm or 50–2 µm), and
  - ➢ clay (<0.002 mm or 2 µm).
- The relative percentages of sand, silt, and clay define the soil's particle size distribution or **soil texture** (Figure 4.4).
- The **textural triangle** aids scientists in grouping soils into convenient "textural" categories that indicate their physical and chemical properties.

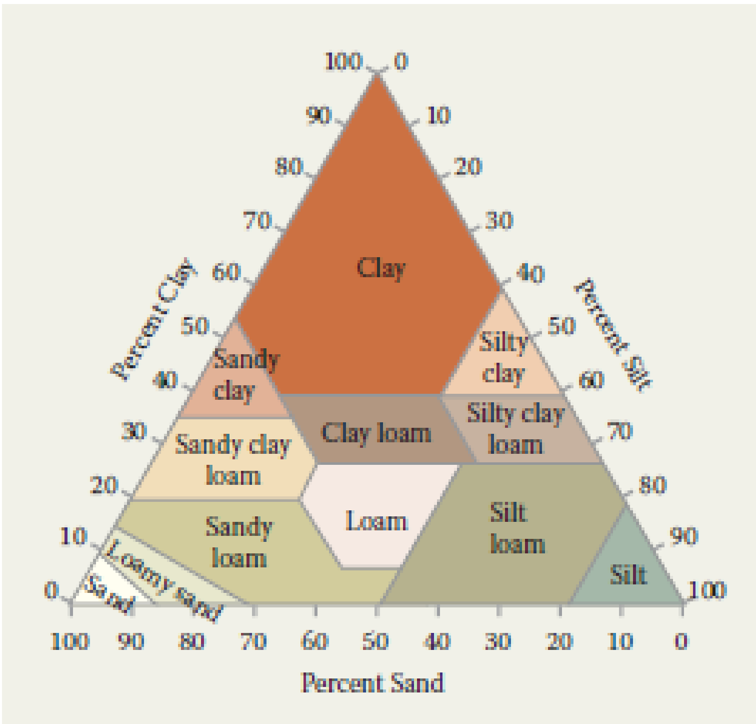


Figure 4.4 Textural triangle showing the grouping of soils by particle size and hence the relative contribution of sand, silt, and clay to their composition

- Soil **structure**, which may be described as platy, blocky, granular, columnar, or prismatic, is the aggregation of soil particles under field conditions into primary and secondary structural units.
- Micropores (small spaces or voids) are formed when the primary particles clump together into primary aggregates, leaving spaces between them.
- Further, as primary aggregates form larger secondary aggregates, the spaces or voids between structural units become larger, forming larger macropores.
- Together, the two kinds of spaces or voids (micropores and macropores) constitute the total soil porosity.

- Soil porosity is intimately related to the mass per unit volume of soils, referred to as their bulk density and typically expressed in units of grams per cubic centimeter.
- The lower the bulk density is, the lighter the soil is and the greater the void space to accommodate roots.
- Bulk density provides a good estimate of the physical resistance that roots will encounter as they penetrate into the soil.
- The average bulk density of agricultural soils is in the range of 1.1–1.5 g cm^{-3}; for organic soils, bulk densities are generally below 1.0 g cm^{-3}.
- For soils that are compacted, either naturally or by human activities (e.g., by cultivation, machinery or foot traffic, off-road vehicles), the bulk density may be 1.5 g cm^{-3} or greater.
- Conversely, natural phenomena, such as freeze–thaw and the activities of soil animals such as ants, termites, and earthworms, may considerably increase the soil porosity and, in doing so, decrease bulk density.
- Together, soil texture, structure, and the amount of organic matter present in the soil determine gas exchange rates, the soil's ability to retain water, nutrient availability, temperature relations, and the distribution and abundance of soil biota.
- These properties are routinely used to evaluate soil fertility and the potential productivity for the growth of agricultural crops, rangeland grasses, and forest trees.

Soil Water

- The amount of water remaining in the soil after a precipitation event after the excess water has drained away determines the potential for growth, abundance, and distribution of plant and animal life, fungi, and bacteria.
- When water is in short supply, as in the arid regions of the world, vegetation is sparse.
- When human practices accelerate the loss of vegetation in such arid areas, soils become unproductive, resulting in temporary or permanent desert conditions. This process is termed **desertification**.
- In high-rainfall areas, exposed soils and their nutrients are prone to erosion.
- In many tropical rain forest regions, vegetation is cut down, burned, and cleared away to make land available for farming. This practice is known as "slash-and-burn" agriculture, and these fields often lose their fertility in 5–10 years through a combination of crop removal (the harvested crops take nutrients with them), soil erosion, and nutrient leaching processes.

- The movement of water from the soil through the plant and to the atmosphere represents a more or less continuous stream of water; this is referred to as the soil–plant– atmosphere continuum.
- The availability of soil water depends on the quantity of water in the soil, soil particle and pore size, bulk density (because heavier soils present more mechanical resistance to roots), and the chemical composition of the soils.
- The availability of soil water for plant uptake is influenced by four forces: gravitational potential, pressure potential, osmotic potential, and matric potential (Figure 4.5).

Soil Air

- The rich biological diversity that soils support includes organisms adapted to both aerobic and anaerobic conditions.
- The **aerobic** organisms require oxygen. Small fauna—ants and termites, for example—can increase the pore space substantially by tunneling and churning the soil, increasing soil aeration.
- Soil air dynamics (or aeration) bear an intimate relationship with water.

- As water infiltrates soil and percolates into and through soil voids, it drives out gases, including oxygen.
- Once saturation occurs and the available oxygen is used up, chemical processes begin to take place under **anaerobic** conditions.

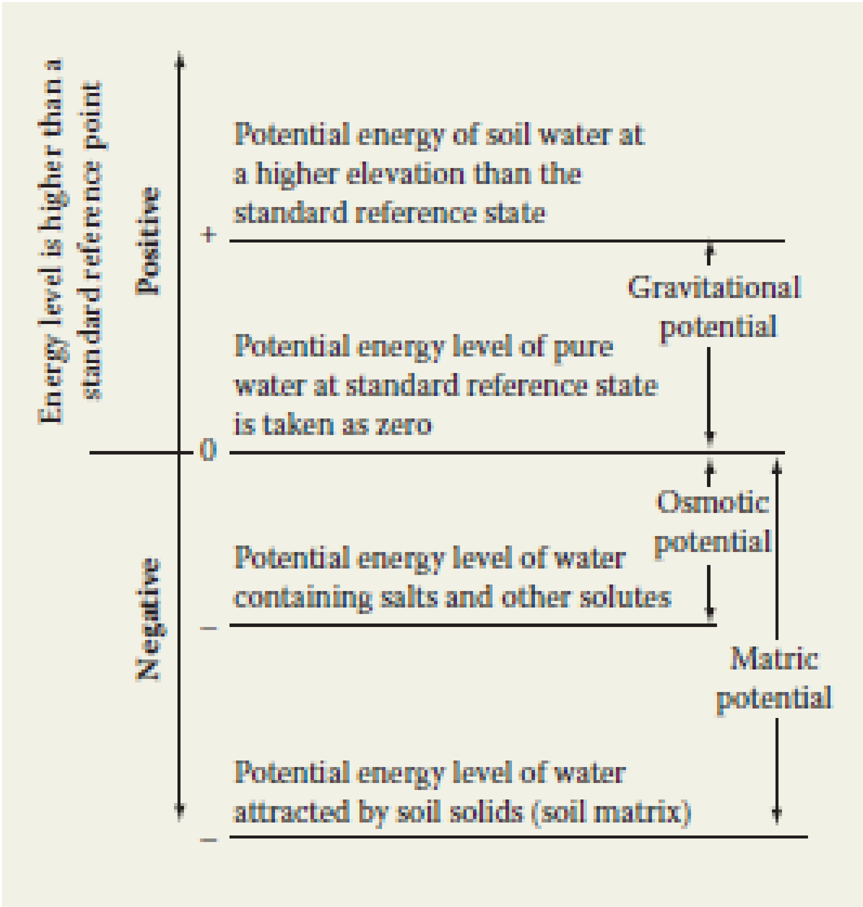


Figure 4.5 Factors making soil water more available (positive: elevation and gravity) or less available (negative: osmotic potential and matric forces) to plants relative to pure water

Thermal Relations

- Like all chemical and biochemical processes, soil processes are intimately related to energy transfers and hence temperature.
- Also referred to as **heat economy** or **heat budgets**.
- Soil temperatures fluctuate with air temperatures. However, a major distinction is that there is a daily (diurnal) time lag in the temperature change across the atmosphere–soil interface.
- Diurnal temperature extremes are thus dampened, and plant roots and microbial life forms are subject to narrower temperature fluctuations.
- Temperature dampening effects increase with soil depth to the point where daily temperatures are constant.
- At even greater depths, the soils have constant annual temperatures, modified only by the temperature changes in the groundwater and bedrock.

- Soil temperature is related to soil particle size, soil color, and water content. Soils with dark-colored surfaces absorb heat readily and are warmed quickly by the sun.

- Soils with high water content (e.g., wetlands) require greater energy to warm up because water requires about three times more energy to warm than does soil.

Soils and Plant Distribution

- Soils have a strong influence on the diversity, abundance, and distribution of plants. For example, the requirements of plants for, or their tolerance to, different micronutrients have been directly implicated in population and community differences at several levels and have been referred to as **edaphic specialization**.
- The concentrations of particular elements in soils and the ability of plants to take up these elements are important factors that define edaphic specialization.
- Many studies have shown that some plant species can accumulate high concentrations of metals in their tissues without ill effect (e.g., Al, Cu, Mo, Ni, and Se).
- These accumulators are referred to as **indicator plants**. They have been used in geochemical prospecting, in geological and soil mapping, and in groundwater surveys.

Soil Formation

- Relative to human timescales, soil formation is a very slow process. Indeed, soils have been characterized as the least renewable of our natural resources.
- The rate of soil formation s = f(cl, o, r, p, t), where soil formation (s) is a function (f) of the interactions of climate (cl), organisms (o), relief or topographic features (r), parent materials (p), and time (t).

- Soil varies in its horizontal and its vertical dimensions. The **dynamic and interactive nature** of the soil-forming processes results in general patterns that characterize soils throughout the world.
- In the vertical dimension, water percolates down through the soil, carrying with it soluble nutrients. In this process, clay is also removed from the upper horizons and accumulates in the deeper horizons.
- Two other major processes that contribute to soil formation are **biocycling** (plants act as nutrient pumps, continually bringing nutrients toward the surface from deeper soils' depths) and the churning of soil by animal activity (a process known as **pedoturbation**).
- **Removals, additions, biocycling**, and **pedoturbation** are universal in all ecosystems; their relative dominance depends on the geographic area.
- Under a given regional climate and the indigenous flora and fauna, these four processes result in soils that are characteristic of a region.

THE AQUATIC ENVIRONMENT

Characteristics of Water

- The surface area of the oceans (salt water) covers 71% of the Earth, but only 2.72% (by volume) of the Earth's total is freshwater.
- Most of the latter occurs as glaciers, polar ice caps, and deep groundwater, so the remaining quantity of freshwater in lakes, reservoirs, and river channels that is accessible for human use is less than 1% of the total freshwater on the Earth.
- The study of freshwater ecosystems, including inland waters, lakes, reservoirs, rivers, streams and wetlands, is the **science of limnology** (derived from limnos, the Greek word for lake).

- By their sheer size, area, and volume, water bodies (particularly the oceans) affect all climatic and weather systems of the Earth.
- This water undergoes transport around the Earth and transforms from gas to liquid to ice and back again, making up the **hydrological cycle**.

- Water is a universal solvent with unique chemical and physical properties. It affects every facet of life, from rocks and soils to biota, but its distribution is uneven.
- The availability and apportionment of water (especially freshwater) already ranks as one of the top causes for disputes among regions and political units.

Hydrological Cycle

- Precipitation, evaporation, transpiration, cloud formation, and subsequent runoff and percolation are all variables of the water cycle.
- The water cycle is the circulation of the Earth's fixed supply of water among land, freshwater lakes and rivers, the seas and oceans, and the atmosphere.
- This cycle collects, purifies, and distributes water around the world.
- Water on the land and in the oceans is evaporated into atmospheric water vapor by solar energy.
- Masses of water vapor are moved around the Earth by winds and then condensed into water droplets that form clouds or fog.
- Through precipitation, water returns to the Earth in the form of dew, rain, hail, or snow.

- Water that falls on the land is absorbed by the roots of plants, passed through their stems and other structures, and released from stomata in their leaves into the atmosphere as water vapor by transpiration.
- Through runoff, water moves from the land to water bodies and into the ground, where it is stored as groundwater.
- From there, it eventually returns to the surface, lakes, streams, or oceans.
- Human activities can adversely affect the quality and quantity of water. Water quality is degraded by agricultural runoff or by overloading a water supply with wastes, such as from wastewater treatment plants or factories.
- Water quantity to different regions may be affected if global precipitation patterns are altered through climate change.

Wetlands

- Wetland ecosystems (e.g., bogs, fens, swamps, and marshes) are areas where shallow water covers the land or saturates the soils for at least a portion of the growing season.
- Estimates of the global extent of wetlands vary, depending on the methods used to formulate the estimate, ranging from 5.3 to 12.8 million km^2, or approximately 4–6% of the Earth's land surface.

- Keddy (2000) describes wetlands as ecosystems that "arise when inundation by water produces soils dominated by anaerobic processes and forces the biota, particularly rooted plants, to exhibit adaptations to tolerate flooding."

- Wetlands include a diversity of ecosystem types—for example, marshes, bogs, swamps, tidal flats, coastal mangroves.
- Swamps (sometimes called deepwater swamps) are dominated by trees and shrubs with little else in the understory.

BIOGEOCHEMICAL CYCLING OF MATERIALS

- **Biogeochemical cycles** and energy flows establish not only the links among ecosystem components (biosphere, atmosphere, lithosphere, and hydrosphere) but also the link among ecosystems at local, regional, and global scales.
- Unlike energy that flows in one direction only, in nature, materials (including water) are cycled and reused within and among ecosystems over and over again.
- But together, the energy flow (energetics) and material cycling are the two fundamental and complementary models of ecosystems.

- Within the biosphere, biogeochemical cycles describe how an element moves through the biotic and abiotic portion of an ecosystem.
- In doing so, both the transformation and transport of elements occur.
- The transport of elements can occur by the movement of wind, water, or animals. In some cases, cycling involves little movement—only a conversion from one form of a chemical to another (e.g., the uptake of nitrate by a plant and its conversion to an amino acid) or by a chemical reaction (e.g., the oxidation of methane in a lake to carbon dioxide and water by a bacterium).
- These relationships are often summarized in compartmental models, or "box and arrow" diagrams. These consist of compartments (or pools) representing the mass of a given element in a particular chemical form and location.
- Compartments are connected to one another with links reflecting the movement of elements as they are transported or transformed between them.

- Because the cycles of materials involve biological, geological, and chemical components of an ecosystem, they are called **biogeochemical cycles**.
- In many cases, the cycles of elements are also referred to as nutrient cycles.
- Three groups of biogeochemical cycles are recognized:
  (i) the hydrological (or water) cycle;
  (ii) gaseous cycles, which have gas, liquid, and solid phases (e.g., those of carbon, nitrogen, oxygen, and sulfur); and
  (iii) sedimentary or mineral cycles (e.g., iron, calcium, magnesium, and phosphorus), where relatively insoluble elements are taken up from the soil or water by plants, passed on to the herbivores and carnivores, and, through excretion, death, and decay, are returned to the soil or water. These have no atmospheric component.

- The flux of solar energy is the engine that powers the hydrologic cycle, drives the Earth's climate patterns, and energizes the biogeochemical cycles.
- These cycles are crucial to the functioning and maintenance of the ecological processes that are requisite for the sustenance of life.
- The fluxes of biogeochemical cycles are determined by several factors: climatic variables—particularly temperature and precipitation, the nature of the element (for example, its solubility or the different forms it can take), and types and chemical compositions of soils, plants, and animals.
- Nutrients can be lost from and carried into ecosystems by wind, precipitation, flowing water, and migrating animals, as well as by various forms of pollution, management practices, and land uses.

- All these biotic and abiotic factors (including human activities) affect four ecological processes that drive biogeochemical cycles:

  (a) the removal of elements from a compartment—for example, by leaching, emissions, harvesting, and wind and water erosion;
  (b) the addition of elements to a compartment through processes such as the chemical weathering of rocks, biological fixation, and atmospheric deposition;
  (c) the transfer of elements between pools— for example, the uptake of nutrients; and
  (d) transformation—for example, chemical reactions in which the chemical form of the element changes (e.g., atmospheric nitrogen, N2, to ammonia, NH3).

  - **Ecosystem pools** or "stocks" refer to those phases of the cycle where a material is held in varying quantities in an ecosystem compartment such as in the atmosphere, water, soil, animals, or vegetation.
  - The materials in some reservoirs (e.g., phosphate in rock) may not be available for use by humans or other organisms without physical, chemical, or biological modification.

  - Biogeochemical cycles are often thought of as being in equilibrium or "steady state"; that is, the inflows and outflows to a given compartment are balanced.
  - However, if the reservoir size in an ecosystem component decreases (a greater magnitude of outflows compared to inflows, such as in vegetation, soils, geological formations, or oceans), then it has become a source for materials.
  - If the reservoir size increases (greater inflows than outflows), then it is referred to as a sink for materials; that is, **sequestration** occurs.
  - **Fluxes**, flows, or transfer rates refer to how much material passes through a reservoir over a given period.
  - The **residence time** of a material in a particular pool is the average length of time a molecule of that material stays in that pool before it moves on to another pool.
  - **Turnover time** describes how long it takes for all the material in a pool to be replaced (i.e., how frequently the pool "turns over").

HYDROLOGICAL OR WATER CYCLE

  - For each material cycle, the amount in each pool, the residence time in a particular pool, and the rate of transfer (flux) from one reservoir to another vary dramatically with the chemical character of the material.
  - Characteristics such as its solubility, volatility, and reactivity all have a bearing on elemental transfers. For example, water, which occurs in all three states (gaseous, liquid, and solid) within a relatively narrow and common temperature range, can be cycled in large volumes rather quickly (Figure 6.1).
  - Calcium and silicon, on the other hand, are chemical elements that are commonly tied up in sediments and rocks for long periods. Thus, it may take many years, even millennia, for them to be solubilized or physically moved (by erosive water, wind, glacial action, or volcanic eruption) from one pool or location to another.

  - Carbon, nitrogen, and oxygen are major elemental building blocks of the biosphere and constitute major components of the atmosphere.
  - They can cycle quickly through the biosphere, atmosphere, and hydrosphere as well as become lodged in sediments as part of the lithosphere.

- Finally, the turnover times of some pools (e.g., phosphate ions in lakes) can be extremely short (on the order of minutes or less) because organisms invest considerable energy in actively taking up and chemically transforming these compounds.
- In contrast, the turnover time of phosphorus in sea sediments (often as the calcium salt, apatite) is estimated as 200 million years.
- Water makes up most of life because it is the major compound in living biomass. Its cycle moves immense quantities of water.
- The hydrologic cycle (Figure 6.1) has a profound influence on the cycle of many other compounds because it carries lots of other compounds along with it.
- It also provides a good illustration of the complexity of global cycles: It is a compound that has three phases (gas, liquid, and solid), has vastly varying pool sizes and turnover rates, is influenced by global climate, and is extensively altered by human activity.
- Note that in Figure 6.1, the sizes of pools (referred to as "storage") are shown in boxes, the area covered by individual pools on land is shown in parentheses, and the annual fluxes are shown as numbers associated with each arrow.

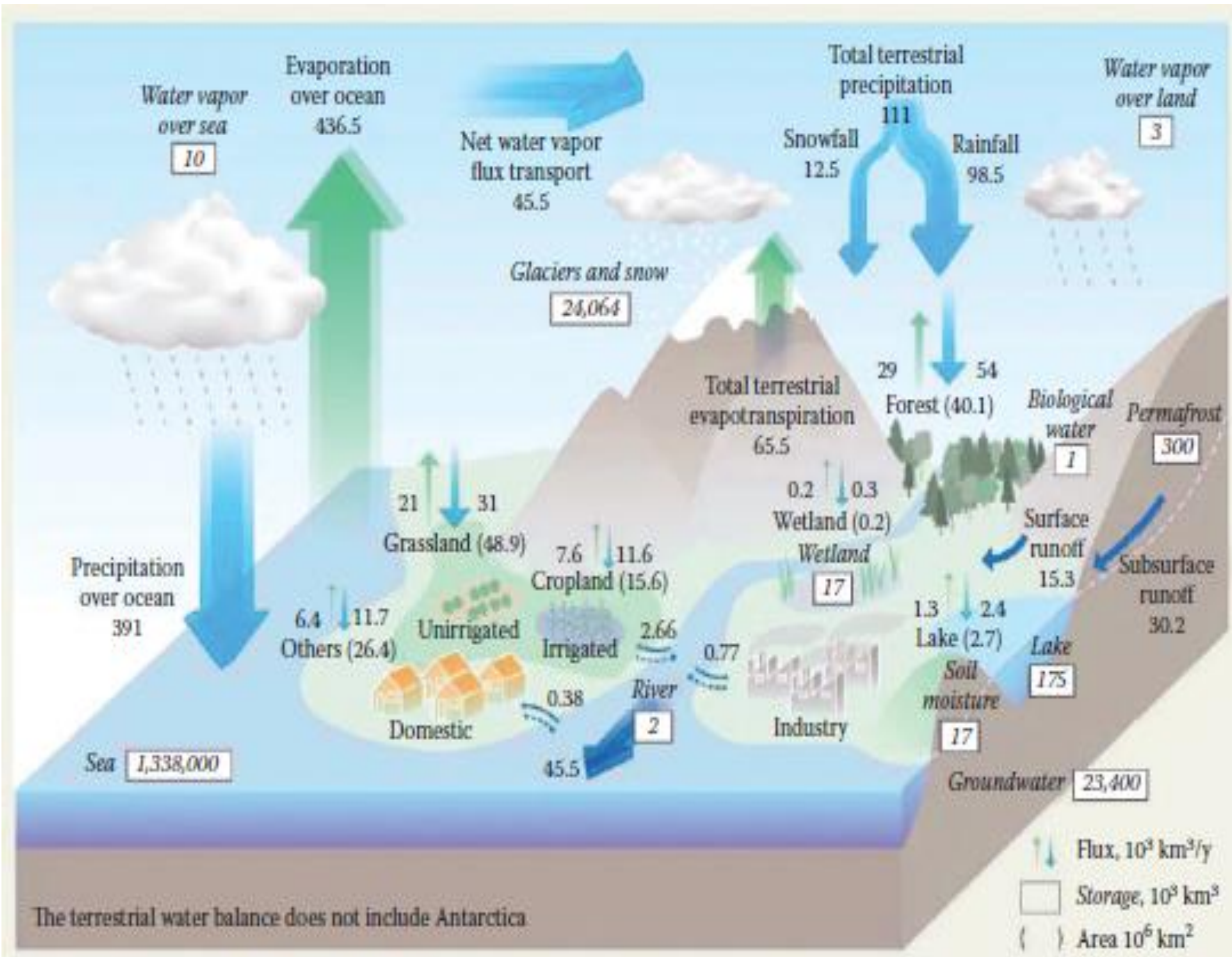


Figure 6.1 Global fluxes (103 km^3 yr^{-1}) and storages (103 km^3) of water are influenced by both natural and anthropogenic forces. The big vertical arrows show total annual precipitation and evaporation over land and ocean (103 km^3 yr^{-1}), which include annual precipitation and evapotranspiration in major landscapes (103 km^3 yr^{-1}) presented by small vertical arrows; parentheses indicate area (106 km^2). The direct groundwater discharge, which is estimated to be about 10% of total river discharge globally, is included in the river discharge. (From Oki, and S. Kanae. 2006. Science 313: 1068–1072.)

- Water is continuously circulated through the processes of evaporation, condensation, precipitation, runoff, infiltration, transpiration, snowmelt, and groundwater flow.
- The cycle is driven by solar energy, where the main "pump" of water into the cycle is the evaporation of ocean water.
- Other sources of water to the atmosphere include evaporation from freshwaters and transpiration from vegetation (combined, these two processes are referred to as evapotranspiration).
- Precipitation on land is the driving force for transporting chemicals and sediments, weathering rocks (ultimately changing the shape of the landscape), and filling freshwater ecosystems such as lakes, rivers, and wetlands. Given long enough, all this water makes its way downhill to rejoin the oceans.

- From an ecological standpoint, it is important to note that the global distribution of water is uneven, resulting in a surplus of water in some regions (precipitation > evapotranspiration) and a deficit in others (precipitation < evapotranspiration).
- This leaves a substantial proportion of the Earth's human population without an adequate supply of water.

CONTEMPORARY ENVIRONMENTAL ISSUES

How have human impacts altered the structure, function, and organization of ecosystems?

- How have the vast increase in our human population and its environmental influences impacted original ecosystems and altered both community structure and function?
- This human force, greatly aided and abetted by advances in technology, has been characterized as **“the mighty geological agent.”**

- Human activities determine the extent, magnitude, and nature of materials that finally find their way into the atmosphere and into our water bodies.
- Equally important, the resources that humans harvest from seas and oceans and materials are all related to land use.

Land Use Changes—Widespread and Worldwide

- Land use changes, without exception, are a phenomenon of worldwide concern, for as human and livestock populations are going up in numbers, our productive resources are shrinking
- The impact of this human force on both terrestrial and aquatic systems has been phenomenal and continues to be widespread and chronic.
- Removals of beneficial resources from the Earth are matched in their rapidity only by the additions of pollutants to the land, air, and water.
- Most recently, the magnitude of these processes has been illustrated by the remarkable effects of greenhouse gases on the global climate.
- The transitions of land use over time in a given region are shown in Figure B.1.

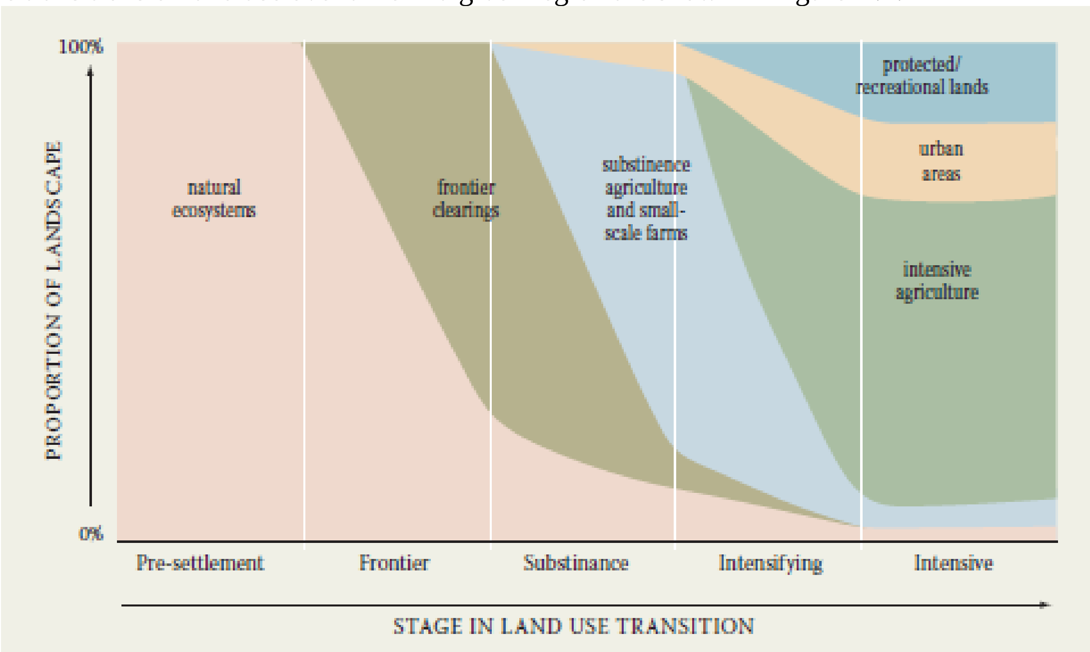


Figure B.1 Land use transitions

Expansionary Land Use Changes

- Some scientists estimate that between one-third and one-half of the Earth's land surface has been transformed by human action (Vitousek et al. 1997).
- Recent reports note the current loss of 13 million ha of forests each year—25 ha a minute (Leape 2006).
- A United Nations Environment Program (UNEP) commissioned study to quantify the extent of disturbance and soil degradation from agricultural systems on a worldwide basis found that approximately 2,000 million ha had been disturbed by 1983 and the rate of disturbance was 5–7 million ha per year (Oldeman 1994).
- In dryland zones alone, 3,600 million ha were found degraded; 2,600 million ha exhibited degraded rangeland vegetation without soil degradation; and 1,000 million ha had experienced degradation of both soil and vegetation (Dregne and Chou 1992).
- In any case, there is an urgent the need is for a systematic collection of quantitative data on the extent of total terrestrial lands disturbed around the world.

Disturbance Defined

- When a land area is converted from a forest to rangeland, the trees and shrubs are cut and the fodder grasses are promoted to grow.
- When the forests or natural grasslands, on the other hand, are converted to croplands, not only is the aboveground vegetation removed but the soils are also turned over.
- In both cases, the natural ecosystems have been disturbed— more so in the latter case than in the former.
- Given the extent and magnitude of disturbance, we need firm foundations for stating a problem as well as for seeking mitigative measures. Thus, it may be useful to define d**isturbance**.
- Among many definitions that have been advanced, the following two capture the essence of the problem:

  (a) A disturbance is "any discrete event in time that disrupts ecosystem, community, or population structure, changes resources, availability of substratum, or the physical environment" (White and Pickett 1985).
  (b) Following the attributes of the ecosystem concept, "an ecosystem disturbance may be defined as an event or a series of events that results in the altering of relationships of organisms and their habitats from their natural state both spatially and temporally" (Wali 1987).

Agents of Disturbances Are Many

- Ecosystem disturbances result from several major activities:

  - ➢ extensive clearing of natural vegetation for growing crops, for pasture, for roads and other transportation corridors, for housing developments, and for other purposes;
  - ➢ selective harvesting of desirable species and introduction of alien ones;
  - ➢ abandonment of unproductive agricultural and range land;
  - ➢ mining for coal and other minerals;
  - ➢ draining of wetlands for agriculture and human settlements;
  - ➢ introduction of chemicals into the environment;
  - ➢ the impacts of war that include bombing, defoliation by chemicals, and the movement of personnel and matériel; and
  - ➢ introduction of greenhouse gases into the atmosphere and climate change.

- Many of these disturbances are local or regional and their collective impact on the loss of productive ecosystems is enormous.
- These land use changes have already contributed to global climate change.
- As land use changes continue, they will further diminish considerably the multitude of services provided by ecosystems.
- This progressive diminution of ecosystem services assumes profound importance, particularly when one considers that human population numbers are increasing concomitantly.

- A useful metric that has entered the environmental lexicon is based on the concept of **ecological footprint**.
- **Definition: The ecological footprint** of a given population or a nation or, collectively, of all humans living on Earth is defined as "the total area of productive land and water required on a continuous basis to produce the resources consumed, and to assimilate the wastes produced, by that population, wherever on Earth the land (and water) is located" (Rees 1997).
- **In summary**: Although concept is discussed in great detail in Chapter 22, we mention it here to emphasize that growing crops and trees, using minerals and water, changing land use, and pouring emissions into the atmosphere all have their unique ecological footprints.

- Because many productive ecosystems have deteriorated considerably—some irreversibly for human or animal use—meeting natural resource demands in the future will depend largely on how well disturbed areas can be **rehabilitated and restored**.

E-WASTE AND ITS ENVIRONMENTAL CONSEQUENCES: AN EXAMPLE OF AIR, WATER AND SOIL POLLUTION

- A few questions to consider: Who still watches movies from a VCR player? Do you purchase the latest cell phone every time a new one is released? How often do you replace your computers? Have you recently updated any large house appliances?
- **Electronics waste or e-waste**: trash generated from surplus, broken and obsolete electronic devices.
- Electronics contains various toxic and hazardous chemicals and materials that are released into the environment if not properly dispose of.
- **E-waste or electronics recycling**: process of recovering material from old devices to use in new products.

What Happens to Devices at the End of Their Useful Life?

- The majority of e-waste ends up in landfills, and just 20% of e-waste is recycled. According to a UN study, about 50 million tons of e-waste was discarded worldwide.
- Electronics are full of valuable materials, e.g., copper, tin, iron, aluminum, fossil fuels, titanium, gold, and silver.
- Many of the materials used in making electronic devices can be recovered, reused, and recycled – including plastics, metals, and glass.

Benefits of E-Waste Recycling

Recycling e-waste enables us to:

- recover various valuable metals and other materials from electronics,
- save natural resources (energy)
- reduce pollution
- conserve landfill space
- create jobs

Energy and Material Costs of Production:
- It takes 1.5 tons of water, 530 pounds of fossil fuel, and 40 pounds of chemicals to manufacture a single computer and monitor
- 81% of the energy associated with a computer is used during production and not during operation.

The Electronics Recycling Process

- Electronics recycling can be challenging because discarded electronics devices are complex devices manufactured from varying proportions of glass, metals, and plastics.
- The process of recycling varies depending on the materials being recycled and the technologies employed, but in general occurs as outlined below:

1. Collection and Transportation:

- Collection and transportation are two of the initial stages of the recycling process for e-waste. Recyclers designate collection points and transport the collected e-waste from those sites to recycling plants and facilities.

2. **Shredding, Sorting, and Separation**:

- After collection and transportation to recycling facilities, materials in the e-waste stream are processed and separated into clean commodities that can be used to make new products.
- Shredding the e-waste facilitates the sorting and separation of plastics from metals and internal circuitry.
- A powerful overhead magnet first separates iron and steel from the waste stream on the conveyor. Further mechanical processing separates aluminum, copper, and circuit boards from the material stream – which now is mostly plastic. Water separation technology is then used to separate glass from plastics. The final step in the separation process locates and extracts any remaining metal parts from the plastics to purify the stream further.

Current Challenges for Electronics Recycling Industry

- The E-waste recycling industry exports – sometimes illegally – more than 50% of its materials to developing nations.
- Exporting e-waste, including hazardous and toxic materials, is leading to serious health hazards for the workers involved in dismantling e-waste in countries without adequate environmental controls.
- Overall, the inadequate management of electronics recycling in developing countries has led to various health and environmental problems.
- Although the volume of e-waste is increasing rapidly, the quality of e-waste is decreasing; devices are getting smaller and smaller, containing less precious metal. The material values of many end-of-life electronic and electrical devices have therefore fallen sharply.
- Increasingly, many products are being made in ways that make them not easily recyclable, repairable, or reusable (largely for proprietary reasons) to the detriment of overall environmental goals.
- The current recycling rate of 17.4% has much room for improvement as most e-waste still is relegated to the landfill.

ELECTRONICS RECYCLING IN KENYA

- Kenya generates over 44,000 tons of electronic waste (e-waste) each year and yet there is no law regulating such waste.
- "Only 1% of e-waste in properly managed in Kenya according to Mr. Boniface Mbithi, the managing director at the Waste Electrical and Electronic Equipment (WEEE) Centre (Business Daily, Thursday October 15 2020). He further goes on to state that "We have been collecting this waster from government offices, corporates and second-hand dealers for proper disposal. We have trained 600 dealers but still more capacity is needed.'
- The mandated government agencies dealing with waste management have limited capacity to deal with e-waste management and are uncoordinated.
- Consequently, there are no adequate resources – both monetary and human - to address the problems and challenges the problem is therefore largely handled in ad hoc manner.
- Kenya is signatory to most of the international conventions related to e-waste but it lacks adequate national regulatory framework to deal effectively with the problem.
- Moreover, existing regulatory and legislative framework are not properly enforced.
- Most e-waste recycling is handled by the informal sector through inefficient approaches because the government has also not streamlined mechanisms for the local authorities to separate e-waste from other solid wastes, store, collect, transport and process it in a structured manner.
- Despite the many challenges and harmful effects of e-wastes, there are several useful benefits such as both formal and informal employment opportunities; revenue generation; and e-waste bi-products.
- The Kenya Government has only recently developed the National E-Waste Management Strategy – a five-year plan covering the period 2019/20 to 2023/24. But real action on the ground remains thin.

THE DANGERS OF E-WASTE ON THE ENVIRONMENT AND HUMAN HEALTH

- The consequences of improper e-waste disposal in landfills or other non-dumping sites pose serious threats to human health and can pollute ecosystems for generations to come.
- When electronics are improperly disposed and end up in landfills, toxic chemicals are released, impacting the earth's air, soil, water and ultimately, human health.

The Negative Effects on Air

- Occurs when e-waste is informally disposed by dismantling, shredding or melting the materials, releasing dust particles or toxins, such as dioxins, into the environment that cause air pollution and damage respiratory health.
- Burning of e-waste also serves a way to get valuable metal from electronics, like copper. Chronic diseases and cancers are at a higher risk to occur when burning e-waste because it also releases fine particles, which can travel thousands of miles and create numerous negative health risks to humans and animals.
- Higher value materials, such as gold and silver, are often removed from highly integrated electronics by using acids, desoldering and other chemicals, which release fumes in areas where recycling is not regulated properly.
- The negative effects on air from informal e-waste recycling are most dangerous for those who handle this waste, but the pollution can extend thousands of kilometers away from recycling sites

The Negative Effects on Soil

- When improper disposal of e-waste in regular landfills or in places where it is dumped illegally, heavy metals can seep directly from the e-waste into the soil, and contaminate underlying groundwater or nearby crops for many decades.
- The contamination of soils by heavy metals can lead to their absorption by crops and lead to many illnesses to both humans and wildlife.
- The burning, shredding or dismantling e-waste also leads to re-deposition – due to their size and weight – to the ground and eventual contamination of the soil.

The Negative Effects on Water

- Heavy metals from e-waste, such as mercury, lithium, lead and barium can leak through the soil and reach groundwater and eventually make their way into ponds, streams, rivers and lakes.
- This way, acidification and toxification of the water occurs and makes it unsafe for animals, plants and communities.

The Negative Effects on Humans

- E-waste contains toxic components that are dangerous to human health, such as mercury, lead, cadmium, polybrominated flame retardants, barium and lithium.
- Negative human health effects of these toxins include brain, heart, liver, kidney and skeletal system damage. They also affect the nervous and reproductive systems of the human body, leading to disease and birth defects.

Conclusion

- Improper disposal of e-waste is extremely dangerous to the global environment and human health and it is therefore important to urgently spread awareness on this growing problem.
- To avoid the toxic effects of e-waste, it is crucial to properly recycle, refurbish, resell or reuse them

THE CHALLENGES OF SUSTAINABLE DEVELOPMENT

Summary

- the ***limitations of past patterns and processes of development across the globe which have underpinned the call for sustainable development***.
- Examination of ***aspects of the contemporary context of sustainable development in the twenty-first century such as the nature and impacts of globalisation***.
- ***Greater insight into what sustainable development means in practice***:
- ***Economic development processes in the past have been closely associated with rising extraction of the resource stocks*** of the globe and continue to be so.
- ***But the creation of a sustainable society also depends fundamentally on the absence of violent conflict, yet it is now widely recognised that many human rights abuses, humanitarian disasters and civil wars are closely linked to environmental resources.***
- ***Although*** the ***linkages between poverty and the environment are complex, the numbers of people in poverty worldwide remains large and it is the poorest groups who suffer the impacts of environmental degradation most extensively and acutely.***

Spatialities of development

- the ***analysis of the integrated economic, social and environmental outcomes of development in the past, that many of the challenges and opportunities for the future are manifested spatially.***
- ***people pursue different activities and practices in different places, for example in rural and urban areas, which generate different environmental and socioeconomic challenges and opportunities***.
- ***different places are characterised by different resource endowments and by unique ecologies that emerge through adaptation to local conditions and processes of change***.
- ***nature of the challenges and opportunities for sustainable development is going to be locally distinct***

Sustainable Development Defined

- Sustainable development has been defined in many ways, but the most frequently quoted definition is from ***Our Common Future***, also known as the ***Brundtland Report***:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

- Sustainability is the foundation for today's leading global framework for international cooperation—the **2030 Agenda for Sustainable Development** and its **Sustainable Development Goals** (SDGs).

- The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future.
- At its heart are the **17 Sustainable Development Goals (SDGs)**, which are an **urgent call for action by all countries - developed and developing - in a global partnership [169 Targets].**

- They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests

Example: SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation **Target 9.c**; Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020 **SDG 9: Indicators**: Proportion of population covered by a mobile network, by technology
Example: SDG 4: Quality Education **Target 4.5**: By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations **SDG 4**: **Education Target 4.b:** By 2020, substantially expand globally the number of scholarships available to developing countries, …., for enrolment in higher education, including vocational training and **information and communications technology**, technical, engineering and scientific programmes, in developed countries and other developing countries

Centrality of resources in future development worldwide

- All forms of economic and social activity make demands on the resource base (see Figures 1.1 and 1.2 below)
- absolute resource scarcities have not generally materialised, economic development in the past has been closely correlated with mounting rates of resource extraction.
- E.g. global water withdrawals which expanded throughout the twentieth century at rates in excess of population growth

Environmental Problems

- All production and consumption activities also produce wastes in the form of various gases, particulate matter, chemicals and solid matter.
- Past development processes have depended substantially on the capacity of natural systems to absorb, transport and dissipate such wastes.
- Where the rate of waste generation exceeds the natural capacity of the atmosphere, oceans, vegetation or soils to absorb these, there are detrimental effects to human health and to the operation of ecological systems.

Inequalities in access to resources

- in some countries the ability of governments to provide basic needs of shelter, food, water and employment for their populations becomes increasingly difficult with rising numbers. For example, between 1990 and 2001, the population of Kenya increased every year by over 600,000 (an average of 2.5 per cent per year).
- However, it is generally appreciated that inequalities in people's access to resources and the resultant ways in which they use them constitute the greater challenge for sustainable development than issues of population numbers per se (WCED, 1987).
- Examples: Commute into New York, 35% biomass fuels of total consumption in Africa
- Differences may also exist within the household

- Inequality in access to resources threatens the prospects for sustainable development in many ways.
    - inequalities allow a minority of people globally, within each nation and even at the community level, to use resources in a wasteful manner or in ways which cause environmental damage.
    - patterns of inequality confine large numbers of people to poverty which often leaves them with no choice but to degrade and destroy the resource base on which their future livelihood depends.
    - The call for sustainable development stems from the fact that such inequalities not only are morally wrong but also threaten the environmental basis for livelihoods and development aspirations across the globe.

The geography of poverty

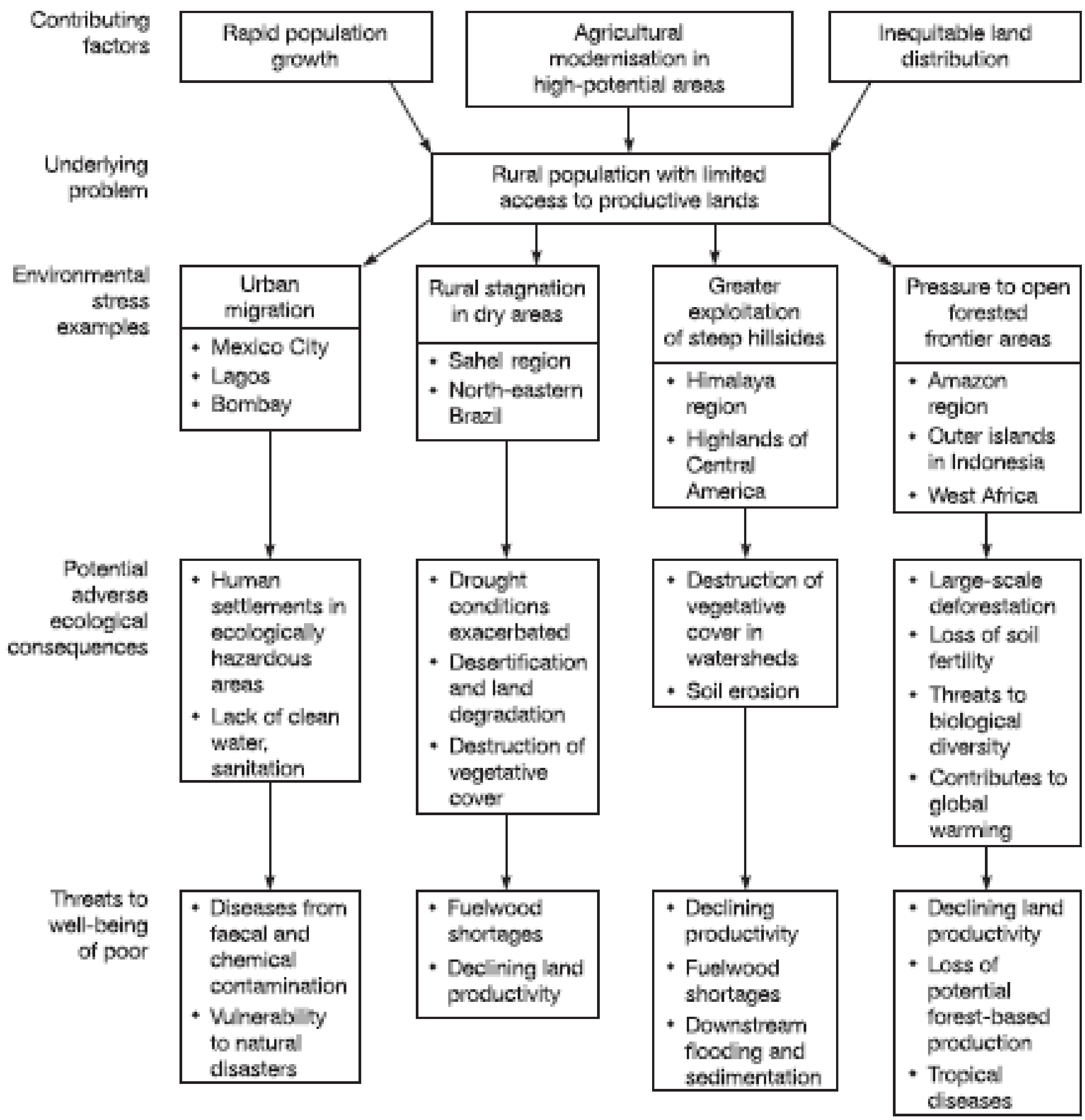
- impoverishment is no more a cause of environmental deterioration than its obverse, namely affluence/capital
- 70% of the world's poor are now resident in South Asia and sub-Saharan Africa combined.
- Poor people are regularly portrayed as both the 'victims and unwilling agents' of environmental degradation in developing regions.
- 'one of the greatest environmental ***vulnerabilities that poverty brings is a high dependence on natural resources for subsistence***' (WRI, 2002: 16)
- Living in poverty restricts the options people have for resource management: they may have to cultivate marginal lands, live in unsafe housing or remove remaining woodlands in order to survive in the short term, often with detrimental effects on the resource base and their own longer-term livelihoods (Figure 2.8)
- Their environmental concerns are those associated with immediate survival needs, such as for fuel, access to clean water and sanitation, or in securing productive lands.

- mid-1980s, suggested that 57 per cent of the rural poor and 76 per cent of the urban poor were resident in areas where ecological destruction and/or severe environmental hazards threatened their well-being.
- In 2003, the World Bank reported that one-quarter of all people in the developing world, 1.3 billion people in total, survive on fragile lands and this proportion had doubled since the 1950s.
- poverty has also become associated with ecological marginality. Worldwide, across urban and rural areas, the poor are often concentrated in environments that are 'inherently' poor.
- These lands require high levels of investment in order to become productive (the resources that the poor don't have)
- In urban areas, the concentration of the poor in environments impoverished through their 'acquired' characteristics, such as alongside hazardous installations or railway tracks, often reflects the operation of market forces, these environments having low commercial value

Poverty and marginalisation

- **political ecology** has done much to explore how and why the poor are so often marginalised ecologically, economically and politically
- causes are found to be diverse and specific to particular places and times but emphasise the political structures and relations that influence access and control over resources (rather than poor land practices, culture or population growth as in other explanations of environmental degradation).
- an estimated 600 million urban residents of developing countries were considered to have their lives threatened every day by the health impacts associated with the inadequate provision of quality water supplies, sanitation and sewage disposal, and the lack of health and emergency services

- Poorer groups in society also have less power to resist and prevent ‘detrimental developments’, those that make their environments more impoverished in some way.
- Sustainable development in the future will require a commitment to overcoming poverty through a focus on the welfare issues of the poorest sectors of society [Figure 2.8]
- Their environmental concerns and their development needs are certainly often in stark contrast to ‘wealthy’ or ‘northern’ priorities, and typically are associated with securing the most basic levels of economic and social well-being.
- Poverty denies millions of people basic rights in the short term and the potential to achieve development aspirations in the future.



Source: Leonard (1989).

Figure 2.8 The poverty and environment connection

The human cost of contemporary development

- Over 10 million children currently die every year before they reach the age of five. Some 98 per cent of these children are born in the developing world (WHO, 2003).
- Whilst average life expectancy at birth has increased globally from 46.5 years in 1950 to 65.2 years in 2002, increasingly the gap in life expectancy is between the very poorest developing countries and the rest of the world
- Every year, at least 3 million children under five die of environment-related diseases (WHO, undated); 2 million from diarrhoeal diseases (80–90 per cent of these cases are related to environmental conditions and contaminated water and inadequate sanitation in particular), a further 2 million children die through acute respiratory infections (60 per cent of these infections worldwide are considered to be related to environmental conditions) and almost 1 million children die of malaria before they are five years old (90 per cent of malaria cases are attributed to environmental factors).

The environment cannot cope

- since the 1980s, there has been increasing recognition of a series of environmental problems which now affect the global community as a whole.
- New global environmental issues are now recognised in two senses:
    - firstly, those human impacts on the environment that have a 'supranational' character such as ***climate warming*** and ozone depletion through the connectedness of atmospheric systems, where change generated anywhere has potential effects around the globe.
    - Secondly, local issues such as the loss of forest, soil erosion or accessing clean water, now occur and are repeated in numerous locations (on a worldwide scale) and pose threats to resources on which more and more people of the globe depend.
- The major effects of climate warming will relate to water resources: ***through the rise of sea levels as a result of the thermal expansion of the oceans, the melting of glaciers and ice-sheets, and increased precipitation via enhanced evaporation from warmer seas*** (Potter et al., 2004)
- the ***impact of climate warming will not be distributed evenly over the globe***.

Resource Curse

- Whilst past development processes have been closely linked to the rising exploitation of physical resources, there is also evidence of a ***negative relationship between natural resource endowment and development trajectories***.
- Auty (1993) was one of the first to investigate what he termed this **'resource-curse'**.
- In recent years there has been substantial attention to this relationship between natural resources, economic growth, democracy and civil war and in terms of the contemporary geo-strategic significance of oil to capitalism and to US hegemony in particular.
- In 1995, a study was conducted by Harvard University on the links between natural resources and economic performance encompassing the experience of 97 countries.
- It identified that over time, the more a country depended on those resources, the lower their economic growth rate (with oil-producing countries amongst the worst performers).
- A stark illustration of the resource curse thesis is Nigeria, where, despite being the world's seventh largest oil exporter, the proportion of households living on less than a dollar a day increased from 27 per cent in 1980 to 66 per cent in 1996 (Christian Aid, 2004: 8).
- In 2004, Christian Aid took the analysis further in comparing the economic, poverty and human development statistics over four decades for six oil-producing nations (Angola, Iraq, Kazakstan, Nigeria, Sudan and Venezuela), with six non-oil-producers (Bangladesh, Bolivia, Cambodia, Ethiopia, Peru and Tanzania).

- The oil economies were found to have achieved slower growth (1.7 per cent per annum on average compared to 4 per cent in non-producing countries). Life expectancy and literacy rates also both improved slightly more in non-oil economies than oil economies.

- It is now increasingly recognised that many of the world's persistent and grave conflicts are resource-related and also that they are being fought in areas of great environmental value, particularly in terms of biodiversity (Renner, 2002).
- Such conflicts sweep away decades of development efforts as well as creating long-term economic, political and environmental impacts (Bannon and Collier, 2003).
- In countries like the Congo, Sudan, Colombia and Afghanistan, whilst the trigger for civil unrest in a country may not have been the minerals, gems, timber or oil per se, the pillaging of those resources generates the finances that allow conflict to continue and make the conflict harder to resolve.
- Often, those resources represent one of the few sources of wealth in otherwise very poor societies and conflicts are very much centred on gaining and maintaining control over those lucrative resources.
- In the Democratic Republic of Congo, civil war has killed over 1.7 million people and displaced another 1.8 million.

- There is also widening concern that resource extraction in many parts of the developing world, whilst not fuelling full-fledged civil war, is having profound consequences.
- In many instances, the benefits of logging, mining, etc, go to government elites and foreign investors, whereas the burdens are felt by local people (and more insidiously) in terms of loss of land, environmental devastation, social impacts and the abuse of human rights.

Making globalisation work for the poor

What is Globalisation?

  - **Describes the growing interdependence of the world's economies, cultures, and populations**, brought about by **cross-border trade in goods and services, technology, and flows of investment, people, and information**

- whilst the world is becoming more global, it does not necessarily mean that it is becoming more uniform
- Castree (2003: 279) notes, it is apparent that as human–environment relations have become more globalised or 'stretched', 'the more spatially and temporally uneven their causes and consequences seem to be'.
- not only are processes of globalisation uneven in their reach but they operate through existing patterns of uneven development and are creating increased differences between places (some good, some bad).
- The exclusion of large sections of the world's population from the benefits of globalisation is now recognised by many major institutions in development as the major global challenge
- Making globalisation work for the poor is recognised as a moral imperative.
- But it is also understood as being in the common interest of all as many of world's challenges, of environmental degradation, war and conflict, refugee movements, human rights violations, international crime and terrorism, and health pandemics like HIV/Aids, are caused or exacerbated by poverty and inequality.
- Economic processes of globalisation are controlled substantially by transnational enterprises (TNCs), firms which have operations in more than one other country as well as in their country of origin.
- Their influence comes partly from their size: many TNCs have larger sales and income than whole countries
- The information revolution, particularly the development of the Internet, has been a fundamental characteristic of globalisation.

- suggested that Internet technology creates new opportunities for development that were not previously available and therefore has the potential to speed development through ‘bypassing previous stages’.
- However the global reach of such technologies is not uniform.
- (Kenya: M-Pesa?)

Questions of responsibility and response

- The current interdependence of peoples and environments throughout the world is clear in the case of supranational environmental problems.
- The need for a coordinated international approach to such environmental issues is self-evident.
- However, in the moves to determine the response to such problems, the question of responsibility is inevitably raised.
- Where change involves (as it usually does) expense and/or compromise of some sort, there is substantial debate as to whether these costs should be borne equally by all or whether there should be some adjustment according to relative responsibility, if this can be ascertained (and also with respect to ability to pay).
- mechanisms for minimising pollution is the ‘**polluter pays principle**’ (PPP)
- The challenge of costing the impact of pollution is seen clearly in the case of ‘**acid rain**’, which refers to the abnormally low pH of some rainfall resulting from the concentration of primarily sulphur dioxide as a result of burning fossil fuels. Whilst it may be possible to cost the damage to trees in terms of the loss of timber resources, for example, it is much more difficult to assign a market value to the loss of diversity of flora and fauna supported by such forests, or to their decreased amenity value with regard to recreational opportunities lost for the local population as a result of acid rain.
- it is rarely those who contribute most to pollution that suffer the greater impacts.

Questions of sovereignty

- many actions towards sustainable development undertaken in recent decades by the international community have involved the setting of standards for nations to follow.
- There remain fears in the developing world in particular that global environmental objectives are being set according to the agenda of countries in the North.
- Priority is thus still given to issues of global climate change, deforestation and species extinction, for example, which are quite different from the environmental problems of the South, which concern, most regularly, basic standards of living and life itself.

INTENSITY OF DEMANDS ON ECOSYSTEMS

- There is a close connection between the sustainability of human– ecosystem interaction and the intensity of demands that people place on ecosystems.
- We all depend on ecosystems for material and energy resources.
- Some resources such as mineral deposits and fossil fuels are **non-renewable**; other resources such as food, water and forest products are **renewable**.
- People use these resources and return them to the ecosystem as waste, such as sewage, garbage, or industrial effluent (see Figure 1.6).
- In general, greater demands on ecosystems in the form of more intense resource use are less sustainable.
- Intense use of nonrenewable resources exhausts the supply more quickly.
- Intense use of renewable resources can damage the ability of ecosystems to provide the resources.
- Sustainable interaction with ecosystems is only possible if demands are kept within bounds. This has not been the case in recent decades as human population growth, as well as industrial and economic growth and burgeoning material consumption, have dramatically increased the scale of natural resource use.
- As environmental awareness has increased, there have been changes in the social system to reduce the intensity of demands on ecosystems. There has been a shift in recent years from technologies that are wasteful of resources toward technologies that use resources more efficiently and reduce pollution.

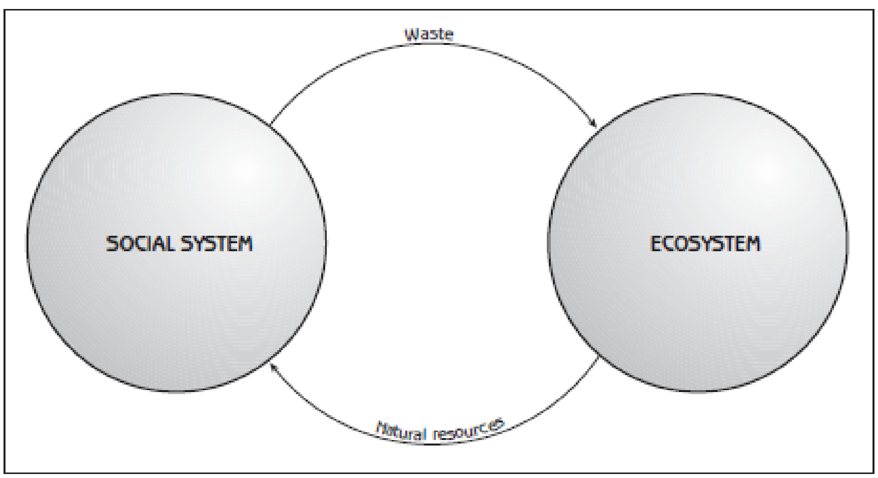


Figure 1.6 Human use of natural resources

- A small population can enjoy high levels of consumption without placing excessive demands on the environment.
- Too many people can employ the most efficient technologies imaginable and still be forced to make unsustainable demands on the environment while living in poverty.
- The level of consumption of wealthy nations is enormously greater than that of poor nations. The significance of the population in wealthy nations lies not only in the large numbers of people that they already have but also the fact that their heavy demands extend to ecosystems beyond their own boundaries.
- Developing world nations aspire to economic development with higher levels of industrial production and consumption, aspirations that may be thwarted by rapid population growth typical in these regions.

Intensity of demands on ecosystems = Population x Level of consumption x Technology

***Intensity of demands on ecosystems*:**

- the total quantity of material and energy resources required for industrial and agricultural production; plus
- pollution generated by industrial and agricultural production.

Population: the number of people who use the industrial and agricultural products.

Level of consumption: the per capita quantity of industrial and agricultural production. It is closely connected to a society's material affluence.

Technology: the quantity of resource used and pollution generated per unit of industrial and agricultural production.

ECOSYSTEM SERVICES

- We all depend upon ecosystems for the food and natural resources that sustain our lives. Most of the resources are **renewable** because ecosystems supply them on a continual basis.
- People use the resources and return them to the ecosystem as waste such as sewage, rubbish or industrial effluent.
- Ecosystems renew the resources by processing the waste so it is once again available for use by people (see Figure 8.1).
- A continuous supply of energy from the sun is required to do this. Solar energy fuels the cyclic movement of materials through the ecosystem providing all animals, including humans, a supply of renewable natural resources and a repository for their wastes.
- The provision of renewable natural resources is a major part of ecosystem services. These services depend not only on sunlight but also on a healthy biological community to pass materials and energy to humans in a form they can use.
- The ability of ecosystems to provide these services derives from two important emergent properties: **material cycling** and **energy flow**.
- Materials cycle, but energy does not cycle because energy passes out of the ecosystem as it flows through it.

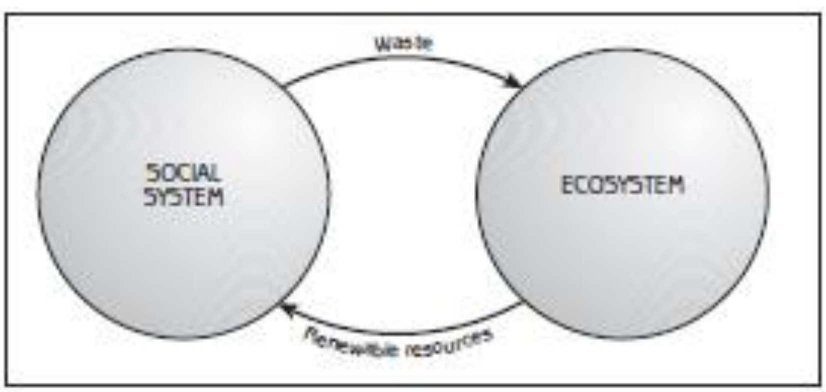


Figure 8.1 Human use of renewable resources and return to the ecosystem as waste

- Human population growth and increasing levels of consumption with economic development have recently generated increasing demands on ecosystems for these services.
- When people try to take too much from ecosystems – when they overexploit ecosystem services – they get less because they damage the ecosystem's capacity to provide the services.
- If people persist with excessive demands, the ecosystem can be changed so much that the services disappear entirely.
- The loss of services can be irreversible. O**verexploitation** can switch an ecosystem to a new stability domain so that the service does not return even when demand is reduced.

ECOSYSTEM SERVICES

Figure 8.9 shows how dependent humans are on the functioning of other parts of the ecosystem. Humans are consumers – just one among all the consumers in an ecosystem. Almost everything that people require for survival comes from material cycling and energy flow as two essential services:

1. Supply of renewable resources (plants, animals and microorganisms as food; plant and animal fibres for clothing; timber for construction; and water).
2. Absorption of pollution and wastes (consumption and decomposition of organic wastes by bacteria, removal of mineral nutrients from water by aquatic plants, dilution of toxic materials by rivers, oceans and the atmosphere).

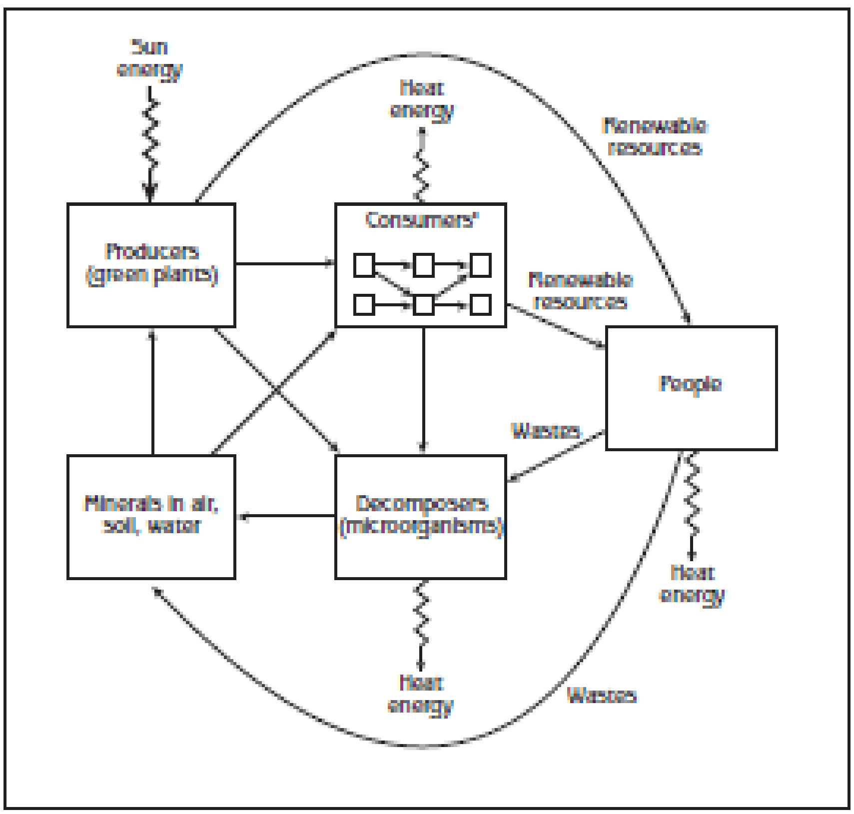


Figure 8.9 Ecosystem services as material cycling in the ecosystem

Note: * Consumers are animals (herbivores, predators, parasites) and pathogenic microorganisms (diseases), arranged in a food web.

THE RELATION BETWEEN ECOSYSTEM SERVICES AND INTENSITY OF USE

- An important emergent property of ecosystems is that ecosystem services decline if they are used so intensively that the ecosystem's ability to provide services is damaged (see Figure 8.10).

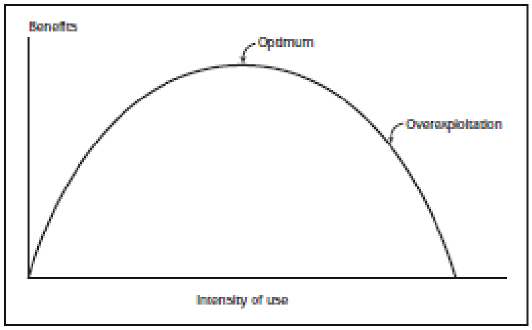


Figure 8.10 The relation between ecosystem services and intensity of use

- **Overexploitation** has depleted the ecosystem's **natural capital**.
- ***An emergent property of ecosystems: ecosystem services may disappear if the intensity of use is excessive***
- This typically happens when **human-induced succession** changes an ecosystem from a stability domain that is 'okay' to one that is 'not okay'.
- Fisheries succession – when commercially valuable fish disappear because fishermen focus their fishing on particular species of fish – is an example. The ecosystem switches from providing commercially valuable fish to not providing them. Desertification due to overgrazing is another example.
- The relation between intensity of use and benefits can change from that in Figure 8.10 to the relation in Figure 8.11.

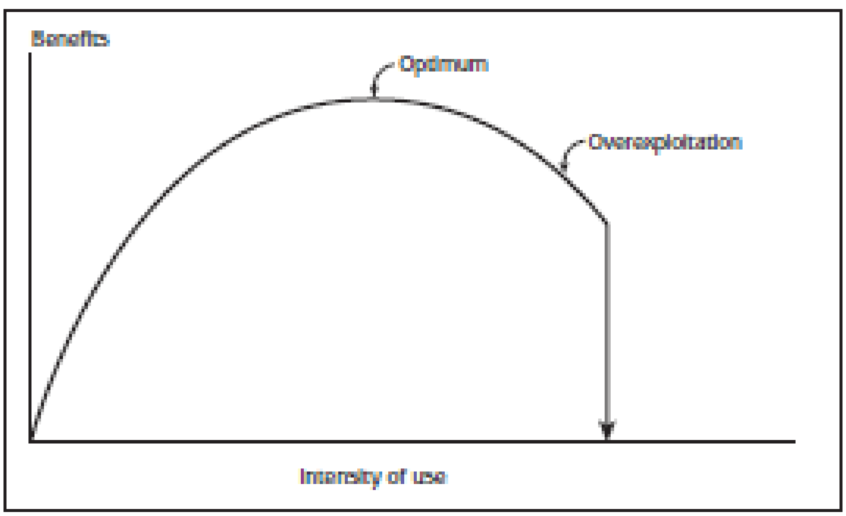


Figure 8.11 Disappearance of an ecosystem service due to overexploitation

- Another example is the intensification of food production by extending inappropriate agriculture to hillsides – a common practice in the developing world today.
- When crops are grown year after year on hillsides, soil erosion can remove all of the topsoil, leaving the land unsuitable for further cultivation.
- Similarly, inappropriate intensification of food production by means of irrigation can render the land unsuitable for food production.

- The use of irrigation in arid regions where there is insufficient water can lead to **salinization** that makes the soil toxic for crops.
- When irrigation water evaporates from the soil, it leaves behind minerals that can accumulate to concentrations that are toxic for crops unless the field is flushed with extra water to carry away the salts.
- If extra water is not available, the salts accumulate until crop yields are so low that agricultural production is not worth the effort.
- The same thing happens with absorption of wastes by rivers, lakes, the ocean and other aquatic ecosystems.
- Dumping too much waste into an aquatic ecosystem can reduce its capacity to absorb wastes. Ecosystems absorb organic wastes, for example, when decomposers such as bacteria use the wastes as food.
- The decomposers use oxygen from the water for respiration, and they release partly broken-up carbon chains into the water as byproducts of decomposition.
- Increasing amounts of waste that must be absorbed means more respiration and more by-products. If too much organic waste is dumped into the water, decomposers use all of the oxygen in the water, and by-products released by the decomposers reach toxic concentrations.
- The chemical condition of the water changes so much that even the waste-consuming decomposers can no longer survive.
- The waste-consuming decomposers are replaced by other kinds of bacteria, which do not purify the water, and the natural capacity of the aquatic ecosystem to absorb organic wastes is reduced.
- When in doubt about overexploitation, it is prudent to follow the **precautionary principle**.

THE FALLACY THAT ECONOMIC SUPPLY AND DEMAND PROTECT NATURAL RESOURCES FROM OVEREXPLOITATION

- Some people assume that the invisible hand of supply and demand protects renewable resources from overexploitation (see Figure 8.12).
- This belief is based on the idea that excessive use of a resource is prevented by higher prices when the resource becomes scarce. The protection comes from a negative feedback loop.
- For example, if too many fish are caught, fish become scarce, the price of fish increases, there is less demand for fish, fewer fish are caught, and the fish population increases again.

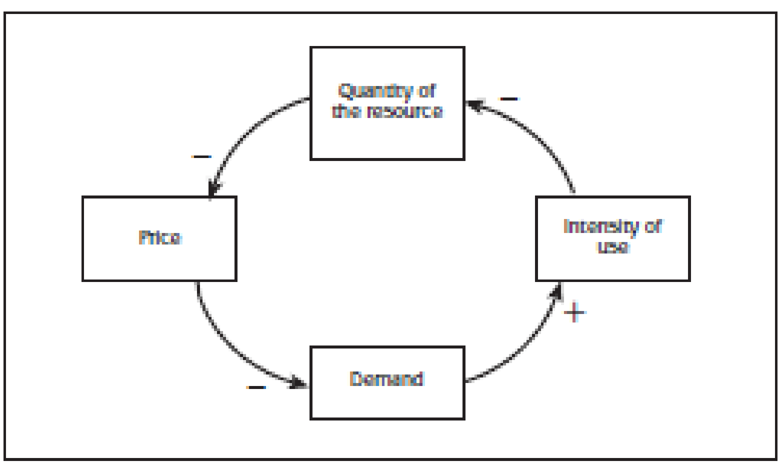


Figure 8.12 The control of resource use by supply and demand

Note: Negative arrows represent negative effects: if the quantity of resource increases, price decreases; if quantity of resource decreases, price increases. Positive arrows represent positive effects: if demand increases, intensity of use increases; if demand decreases, intensity of use decreases.

- The negative feedback loop for supply and demand is real, but the belief that market forces protect renewable resources from overexploitation is based on a ***simplistic view of ecosystems that ignores irreversible human-induced successions***.
- There can be ***a switch from one stability domain to another***. When commercially valuable fish are replaced by 'trash fish' because of overfishing, the valuable fish may not return even if fishing is stopped completely.
- Forests provide another example. If trees are cut too frequently, ***the biological community may change from forest to grass or shrub dominated ecosystems***.
- If forests are clear-cut over a large area, they may not regenerate at all because there are no seeds from mature trees to generate new trees.
- In addition, without trees to provide leaf litter, the soil can lose the cover of leaves that protects it from erosion, and erosion can reduce soil fertility to such an extent that trees can no longer survive.
- There are social as well as ecological reasons for irreversible loss of forest after excessive logging. The same roads that logging companies build to remove trees from a developing world forest can also provide a way for land-hungry people to reach recently logged areas in order to plant crops. The forest never regenerates if people continue to use the land for farming.

WHAT IS HUMAN ECOLOGY?

- **Ecology** is the science of relationships between living organisms and their environment.
- **Human ecology** is about relationships between people and their environment.
- In human ecology the environment is perceived as an **ecosystem** (see Figure 1.1).
- An ecosystem is everything in a specified area – the air, soil, water, living organisms and physical structures, including everything built by humans.
- The living parts of an ecosystem – microorganisms, plants and animals (including humans) – are its **biological community**.

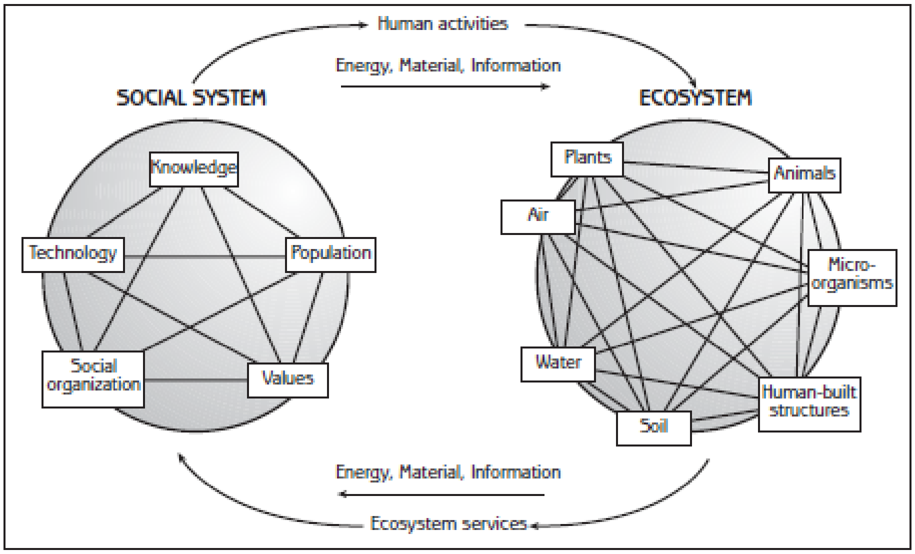


Figure 1.1 Interaction of the human social system with the ecosystem

- Ecosystems can be any size. A small pond in a forest is an ecosystem, and the entire forest is an ecosystem. A single farm is an ecosystem, and a rural landscape is an ecosystem. Villages, towns and large cities are ecosystems. A region of thousands of square kilometres is an ecosystem, and the planet Earth is an ecosystem.
- Although humans are part of the ecosystem, it is useful to think of human–environment interaction as interaction between the human **social system** and the rest of the ecosystem (see Figure 1.1).
- The social system is everything about people, their **population** and the psychology and **social organization** that shape their behaviour.
- The social system is a central concept in human ecology because human activities that impact on ecosystems are strongly influenced by the society in which people live.
- Values and knowledge – which together form our worldview as individuals and as a society – shape the way that we process and interpret information and translate it into action.
- Technology defines our repertoire of possible actions.
- Social organization, and the social institutions that specify socially acceptable behaviour, shape the possibilities into what we actually do.
- Like ecosystems, social systems can be on any scale – from a family to the entire human population of the planet.
- The ecosystem provides services to the social system by moving materials, energy and information to the social system to meet people's needs.
- These **ecosystem services** include water, fuel, food, materials for clothing, construction materials and recreation.

- Movements of materials are obvious; energy and information are less so.
- Every material object contains energy, most conspicuous in foods and fuels, and every object contains information in the way it is structured or organized.
- Information can move from ecosystems to social systems independent of materials. A hunter's discovery of his prey, a farmer's observation of his field, a city dweller's assessment of traffic when crossing the street, and a refreshing walk in the woods are all transfers of information from ecosystem to social system.
- Material, energy and information move from social system to ecosystem as a consequence of human activities that impact the ecosystem:

  - People affect ecosystems when they use resources such as water, fish, timber and livestock grazing land.
  - After using materials from ecosystems, people return the materials to ecosystems as waste.
  - People intentionally modify or reorganize existing ecosystems, or create new ones, to better serve their needs.
- With machines or human labour, people use energy to modify or create ecosystems by moving materials within them or between them.
- They transfer information from social system to ecosystem whenever they modify, reorganize, or create an ecosystem.
- The crop that a farmer plants, the spacing of plants in the field, alteration of the field's biological community by weeding, and modification of soil chemistry with fertilizer applications are not only material transfers but also information transfers as the farmer restructures the organization of his farm ecosystem.

An example of social system–ecosystem interaction: destruction of marine animals by commercial fishing

- **Human ecology** analyses the consequences of human activities as a chain of effects through the ecosystem and human social system.
- The following story is about fishing. Fishing is directed toward one part of the marine ecosystem, namely fish, but fishing has unintended effects on other parts of the ecosystem. Those effects set in motion a series of additional effects that go back and forth between ecosystem and social system (see Figure 1.2).

Drift nets are nylon nets that are invisible in the water. Fish become tangled in drift nets when they try to swim through them. During the 1980s, fishermen used thousands of kilometres of drift nets to catch fish in oceans around the world. In the mid-1980s, it was discovered that drift nets were killing large numbers of dolphins, seals, turtles and other marine animals that drowned after becoming entangled in the nets – a transfer of information from ecosystem to social system, as depicted in Figure 1.2.

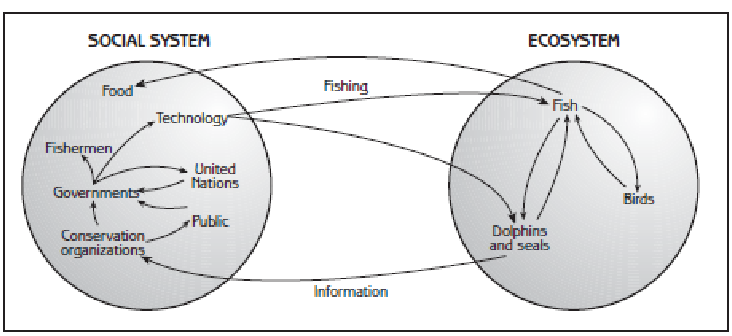


Figure 1.2 Chain of effects through ecosystem and social system (commercial fishing in the ocean)

When conservation organizations realized what the nets were doing to marine animals, they campaigned against drift nets, mobilizing public opinion to pressure governments to make their fishermen stop using the nets. The governments of some nations did not respond, but other nations took the problem to the United Nations, which passed a resolution that all nations should stop using drift nets. At first, many fishermen did not want to stop using drift nets, but their governments forced them to change. Within a few years the fishermen switched from drift nets to long lines and other fishing methods. Long lines, which feature baited hooks hanging from a main line often kilometres in length, have been a common method of fishing for many years. The long lines that fishermen now use put a total of several hundred million hooks in the oceans around the world.

The drift net story shows how human activities can generate a chain of effects that passes back and forth between social system and ecosystem. Fishing affected the ecosystem (by killing dolphins and seals), which in turn led to a change in the social system (fishing technology). And the story continues today. About six years ago it was discovered that long lines are killing large numbers of sea birds, most notably albatross, when the lines are put into the water from fishing boats. Immediately after the hooks are reeled from the back of a boat into the water, birds fly down to eat the bait on hooks floating behind the boat near the surface of the water (see Figure 1.3). The birds are caught on the hooks, dragged down into the water and drown. Because some species of birds could be driven to local extinction if the killing is not stopped, governments and fishermen are investigating modifications to long lines that will protect the birds. Some fishermen are using a cover at the back of their boat to prevent birds from reaching the hooks, and others are adding weights to the hooks to sink them beyond the reach of birds before the birds can get to them. It has also been discovered that birds do not go after bait that is dyed blue.

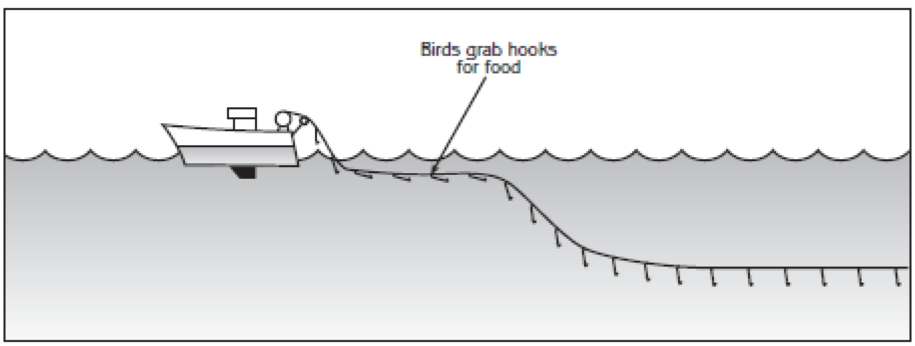


Figure 1.3 Long line fishing

This story will continue for many years as new effects go back and forth between the ecosystem and social system. Another part of the story concerns seals and other fish-eating animals that may be declining to extinction in some areas because heavy fishing has reduced their food supply. The effects can reverberate in numerous directions through the marine ecosystem. It appears that the decline of seals in Alaskan coastal waters is responsible for the disappearance of impressive kelp forests in that region. Killer whales that previously preyed on seals have adapted to the decline in seals by switching to sea otters, thereby reducing the sea otter population. Sea urchins are the principal food of sea otters, and sea urchins eat kelp. The decline in sea otters has caused sea urchins to increase in abundance, and the urchins have decimated kelp forests that provide a unique habitat for hundreds of species of marine animals.

Cooking fuel and deforestation in India

The problem of deforestation in India provides another example of human activities that generate a chain of effects back and forth through the ecosystem and social system. The following story shows how a new technology (biogas generators) can help to solve an environmental problem.

For thousands of years people in India have cut branches from trees and bushes to provide fuel for cooking their food. This was not a problem as long as there were not too many people; but the situation has changed with the radical increase in India's population during the past 50 years (see Figure 1.4). Many forests have disappeared in recent years because people have cut so many trees and bushes for cooking fuel. Now there are not enough trees and bushes to provide all the fuel that people need. People have responded to this 'energy crisis' by having their children search for anything that can be burned, such as twigs, crop residues (bits of plants left in farm fields after the harvest) and cow dung. Fuel collection makes children even more valuable to their families, so parents have more children. The resulting increase in population leads to more demand for fuel.

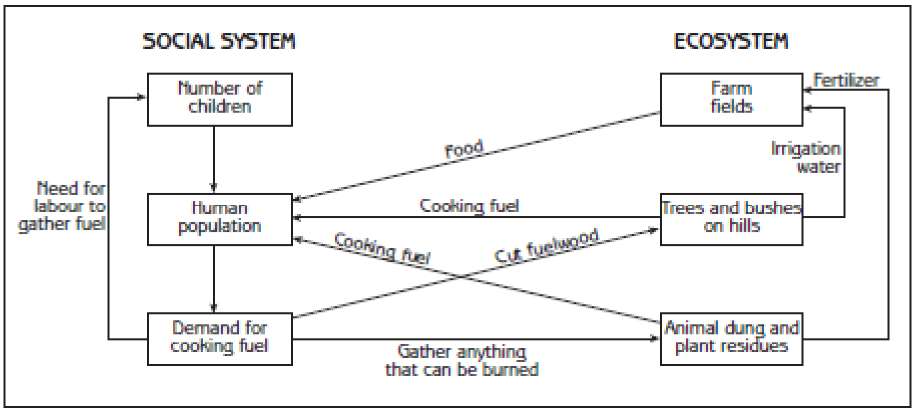


Figure 1.4 Deforestation and cooking fuel (chain of effects through ecosystem and social system)

Intensive collection of cooking fuel has a number of serious effects in the ecosystem. Using cow dung as fuel reduces the quantity of dung available for use as manure on farm fields, and food production declines. In addition, the flow of water from the hills to irrigate farm fields during the dry season is less when the hills are no longer forested. And the quality of the water is worse because deforested hills no longer have trees to protect the ground from heavy rain, so soil erosion is greater, and the irrigation water contains large quantities of mud that settles in irrigation canals and clogs the canals. This decline in the quantity and quality of irrigation water reduces food production even further. The result is poor nutrition and health for people.

This chain of effects involving human population growth, deforestation, fuel shortage and lower food production is a vicious cycle that is difficult to escape. However, biogas generators are a new technology that can help to improve the situation. A biogas generator is a large tank in which people place human waste, animal dung and plant residues to rot. The rotting process creates a large quantity of methane gas, which can be used as fuel to cook food. When the rotting is finished, the plant and animal wastes in the tank can be removed and put on farm fields as fertilizer.

If the Indian government introduces biogas generators to farm villages, people will have methane gas for cooking, so they no longer need to collect wood (see Figure 1.5). The forests can grow back to provide an abundance of clean water for irrigation. After being used in biogas generators, plant and animal wastes can be used to fertilize the fields, food production will increase, people will be better nourished and healthier, and they will not need a large number of children to gather scarce cooking fuel.

However, the way that biogas generators are introduced to villages can determine whether this new technology will actually provide the expected ecological and social benefits. Most Indian villages have a few wealthy farmers who own most of the land. The rest of the people are poor farmers who own very little, if any, land. If people must pay a high price for biogas generators, only wealthy families can afford to buy them. Poor people, who do not have biogas generators, will earn money by gathering cow dung to sell to wealthy people for their biogas generators. Poor people may not care much about the ecological benefits from biogas generators because a better supply of irrigation water offers the greatest benefits to wealthy farmers who have more land.

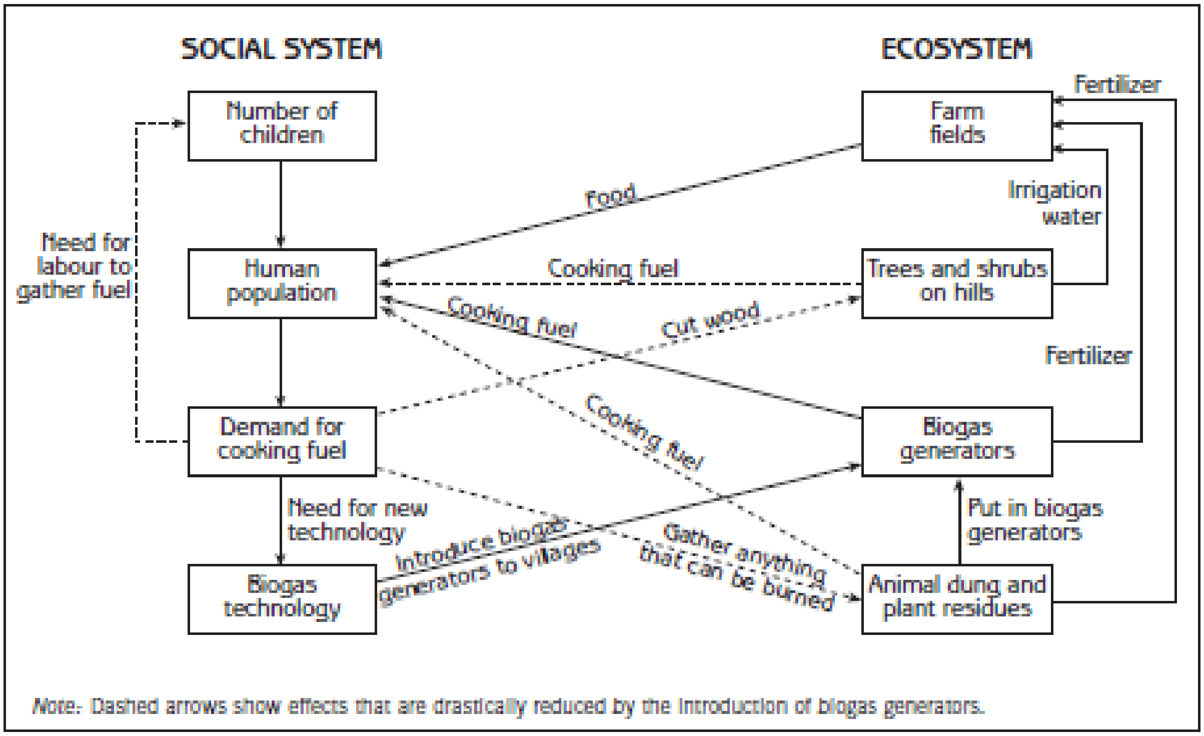


Figure 1.5 Chain of effects through social system and ecosystem when biofuel generators are introduced to villages

As a consequence, the benefits from biogas generators could go mainly to the wealthy, widening the gap between the wealthy and the poor. Poor farmers, who see few benefits for themselves, might continue to destroy the forests, and the community as a whole might receive little benefit from the new technology. To improve the situation, it is important to make sure that everyone can obtain a biogas generator. Then everyone will enjoy the benefits, and the vicious cycle of fuel scarcity and deforestation will be broken.

POPULATION THEORIES

1. Thomas Malthus: 'An Essay on the Principle of Population' – population growing faster than food supply

2. Neo-Malthusian: Underdevelopment and poverty are direct products of the population problem

- **Paul Ehrlich**: The Population Bomb
- **Club of Rome**: Club of Rome (1972) developed *the Limits to Growth Model* that shows dire results of rising population

3. Cornucopian Thesis:

- Growth is limited only when science and technology do not make any further advances. But new technologies all time = new resources
  - **Ester Boserup**: 'The conditions of Agricultural Growth' (1965, 1993)

4. Marxists:

- **Argument:** Malthusian concept of overproduction is a dangerous political idea.
- **Solution:** eliminate poverty and exploitation so that poor will opt for smaller families, labour value of children will decrease and costs of children to parents will increase

EXAMPLES OF POPULATION THEORIES
(***Malthus, Boserup and the Club of Rome***)

Thomas Malthus

- 1766-1834
- Wrote 'An essay in the First Principle of population' first published in 1798
- Debatable whether the principles of Malthus two hundred years ago (*that were very revolutionary and controversial*) have any relevance to the modern world.
- The world population in 1798 was at nine million people. We have now passed the six billion mark

The Core Principles of Malthus:

- Food is necessary for human existence
- Human population tends to grow faster than the power in the earth to produce subsistence
- The effects of these two unequal powers must be kept equal
- Since humans tend not to limit their population size voluntarily - "preventive checks" in Malthus' terminology.

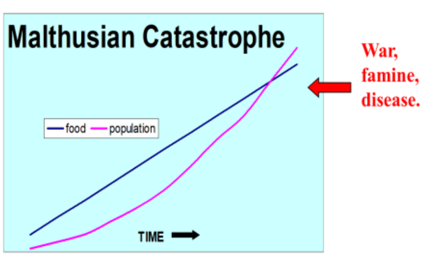
Malthus recognised that population if unchecked, grows at a geometric rate:

1 2 4 8 16 32

However, food only increases at an arithmetic rate, as land is finite.

1 2 3 4 5 6

and therefore he said....



CHECKS
Malthus suggested that once this ceiling (catastrophe) had been reached, further growth in population would be prevented by negative and positive checks. He saw the checks as a natural method of population control. They can be split up into 3 groups….

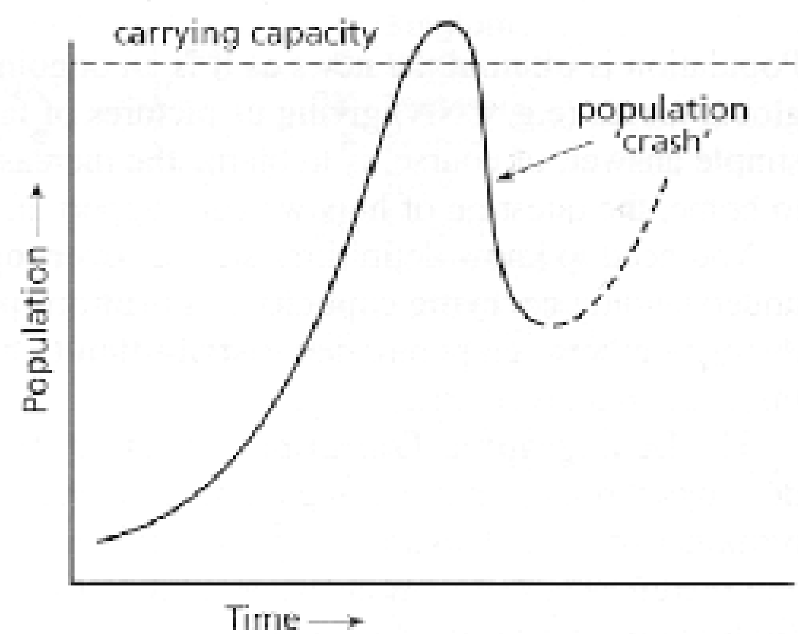
Negative checks (decreased birth rate)

1. Negative Checks were used to limit the population growth. It included abstinence/ postponement of marriage which lowered the fertility rate.
2. Malthus favoured moral restraint (including late marriage and sexual abstinence) as a check on population growth. However, it is worth noting that Malthus proposed this only for the working and poor classes!

Positive checks (increased death rate)

3. Positive Checks were ways to reduce population size by events such as famine, disease, war - increasing the mortality rate and reducing life expectancy.

'J' Curve - Population Crash Model



Was Malthus right?

- There has been a population explosion…?
- Africa – repeated famines, wars, food crisis, environmental degradation, soil erosion, crop failure and disastrous floods – so was he right?

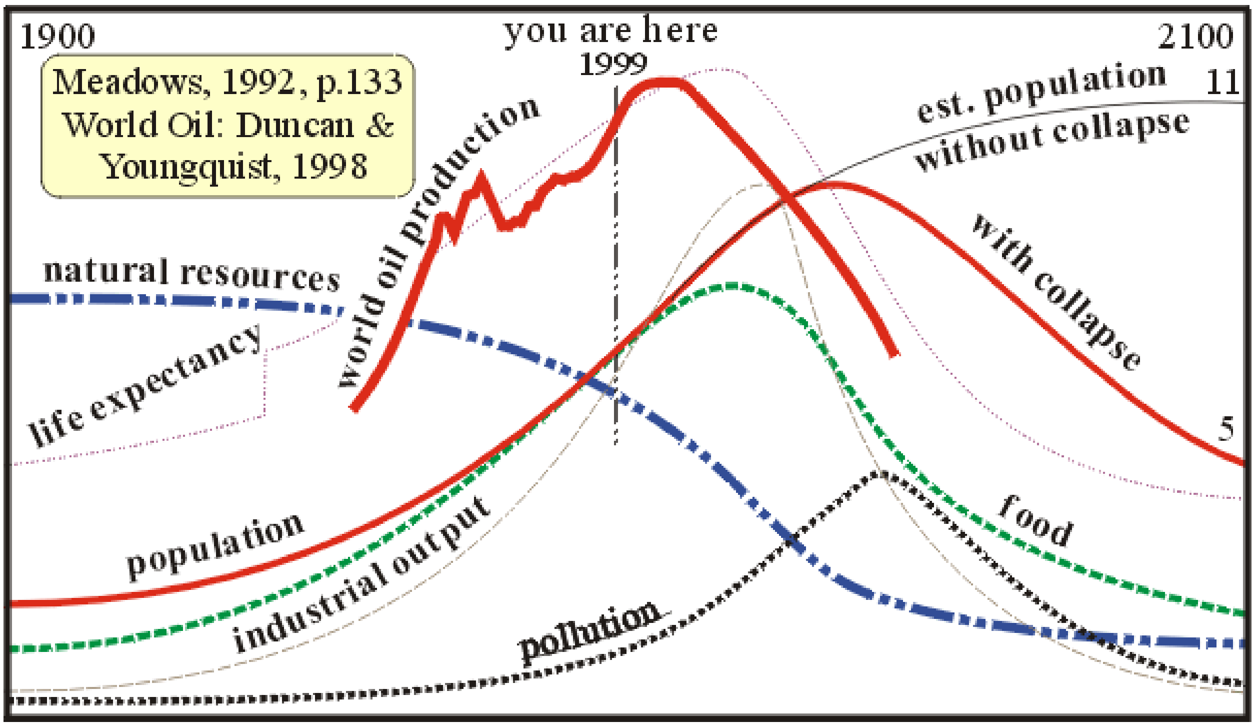
But ….
- Technological improvements which he could not have foreseen
- The increased amount of cropland due to irrigation
- Reduced population growth as countries move through the DTM

The Club of Rome

- Group of industrialists, scientists, economists and statesmen from 10 countries
- Published 'The Limits to Growth' in 1972

The Club of Rome – basic conclusion….

- If present growth trends in world population continue and if associated industrialisation, pollution, food production and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime in the next 100 years.
- The most probable result will be sudden and uncontrollable decline in both population and industrial capacity



Is the Club of Rome right?

- Don't panic yet!
- Doesn't take human dimension sufficiently into account
- Human race is adaptable and innovative
- Human responses have changed – e.g. alternative sources of fuel (to replace fossil fuels), HYVs seeds to prevent starvation in parts of Asia

Esther Boserup 1965

- Boserup believed that people have the **resources of knowledge and technology** to increase food supplies.
- Opposite to Malthus – she suggested that **population growth has enabled agricultural development to occur**
- Assumes people knew of the techniques required by more intensive systems and used them when the population grew.

That is ….

- **Demographic pressure (population density) promotes innovation and higher productivity** in use of land (irrigation, weeding, crop intensification, better seeds) and labour (tools, better techniques).

Was she right?

Boserup argued that the **changes in technology allow for improved crop strains and increased yields**.

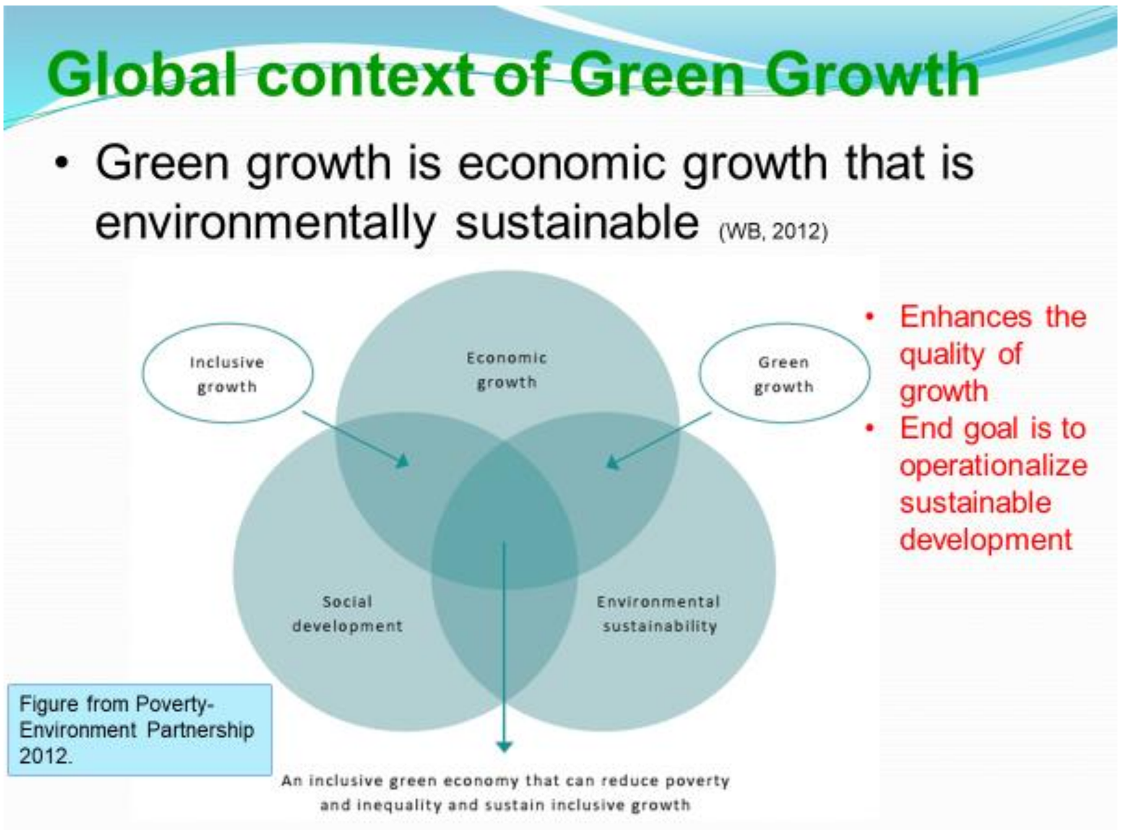
- GM crops
- ‘Green revolution’

But ….

- Boserup admits overpopulation can lead to unsuitable farming practices which may degrade the land
    - e.g. population pressure as one of the reasons for desertification in the Sahel region (so fragile environments at risk)
- Boserup’s theory based on assumption of ‘closed’ society - not the case in reality (migration)

GREEN GROWTH

- What is **green growth** in the global and regional context?
- Why green growth should be inclusive?
- How to visualize green growth?
- Overview of opportunities and challenges in pursuing green growth
- Different approaches for different development stages



Regional context of Green Growth

"*In Africa, green growth will mean pursuing **inclusive economic growth** through policies, programs and projects that invest in **sustainable infrastructure**, **better manage natural resources**, **build resilience to natural disasters**, and **enhance food security**.*" (AfDB, 2012)

And the quality of current economic growth is neither inclusive nor sustainable

- growth is heavily dependent on either a resources boom which cannot last forever or exports to a shrinking developed world
- GDP growth drivers do not create the most jobs, leading to jobless growth
- 50% of Africa's population are without access to energy, other basic infrastructures and services; likely exacerbated by climate change impacts

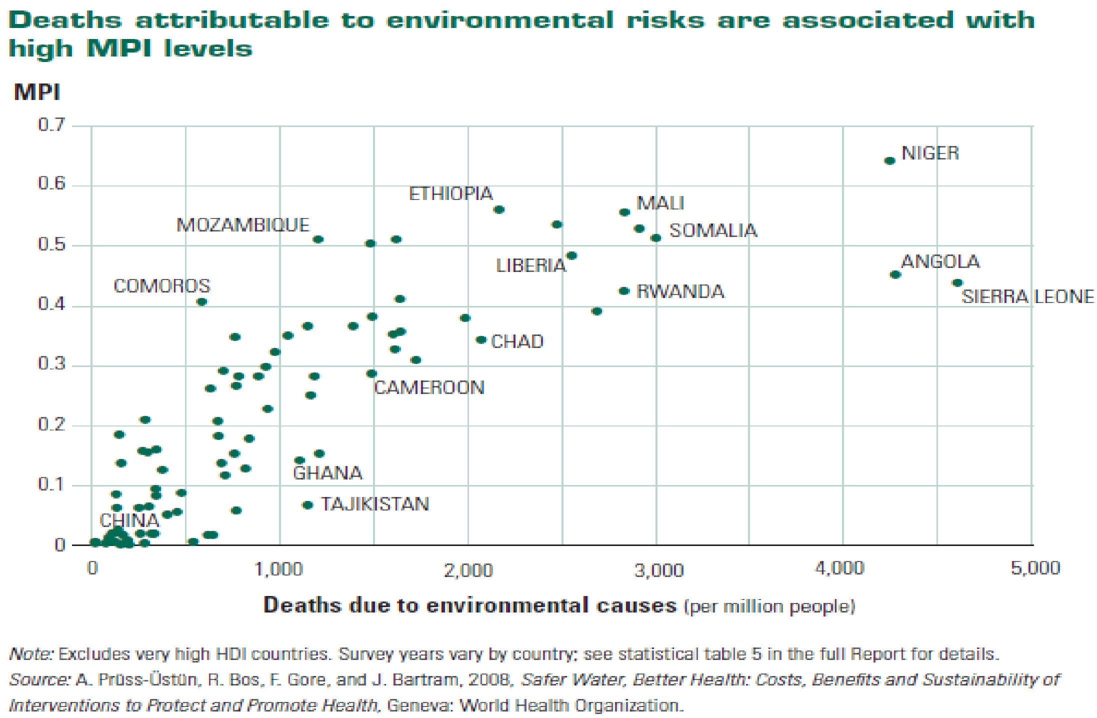
Sustainability pressures in developing countries

Determinant	Trend	Characteristic
Population	Increasing	High fertility rates, especially among less educated and poor populations; but the overall rate of population growth is predicted to decrease in the mid-term future.
Economy	Increasing	High GDP growth rates per year; mainly from agriculture and natural resources exploitation.
Rural-urban migration	Increasing	Many young people move to cities to seek employment opportunities; rural areas drained of youth, reducing social vitality; urban lifestyles are energy and resource intensive.
Consumer-class	Increasing	The so-called 'good life' typified by media images of western-style consumerism now define the lifestyles of the consumer class and aspirations of the poor.
Market pressure	Increasing	Innovative ways of stimulating consumption, such as aggressive advertising, credit card use, consumer loans, and rebates after purchase are on the rise.
Poverty	Variable, but absolute numbers not declining	Developing world is home to most of the world's total poor. They predominantly live in slums in cities and in rural areas (unsustainable livelihoods).

Why pursue green growth?

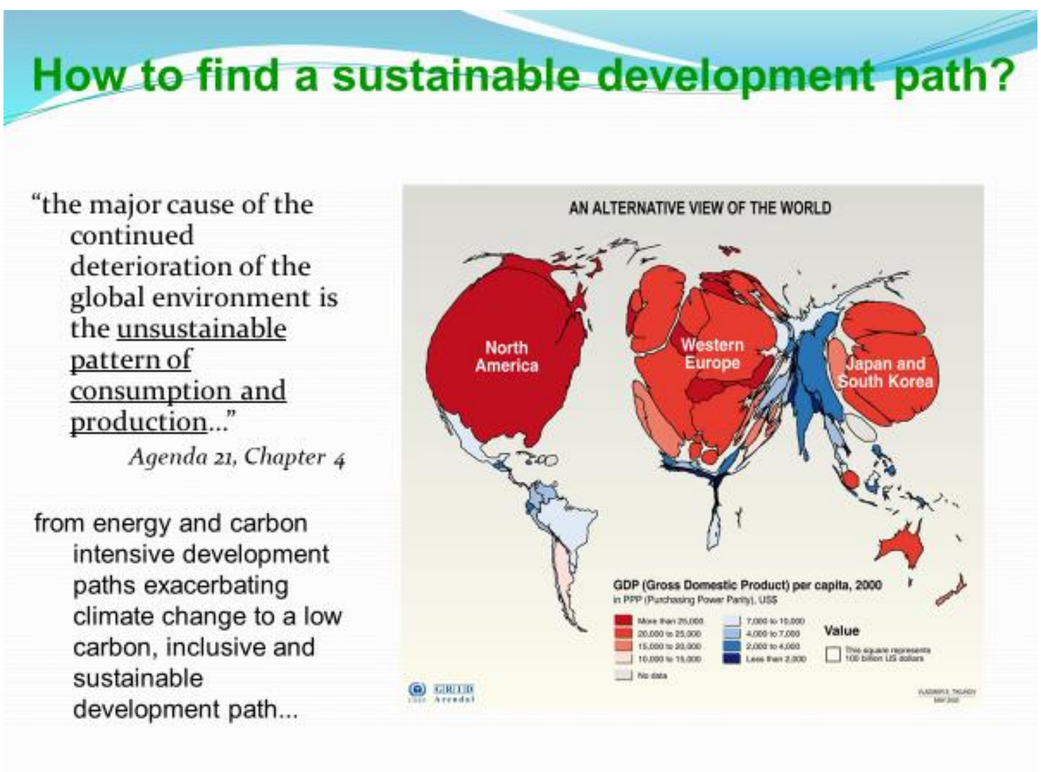
- to sustain growth beyond minerals and oil and gas boom
- to avoid natural resource overexploitation
- to make growth resilient to climate change and other diverse environmental impacts
- to ensure food, water and energy security
- to explore new opportunities for job creation
- to prepare the infrastructure for the future
- Above all, to overcome poverty

Deaths due to environmental causes



(Source: UNDP, 2011)

How to find a sustainable development path?



Green growth is…

Adapting to changing realities for development
…which operate over multiple scales (local to global) and time-horizons (near to long-term)

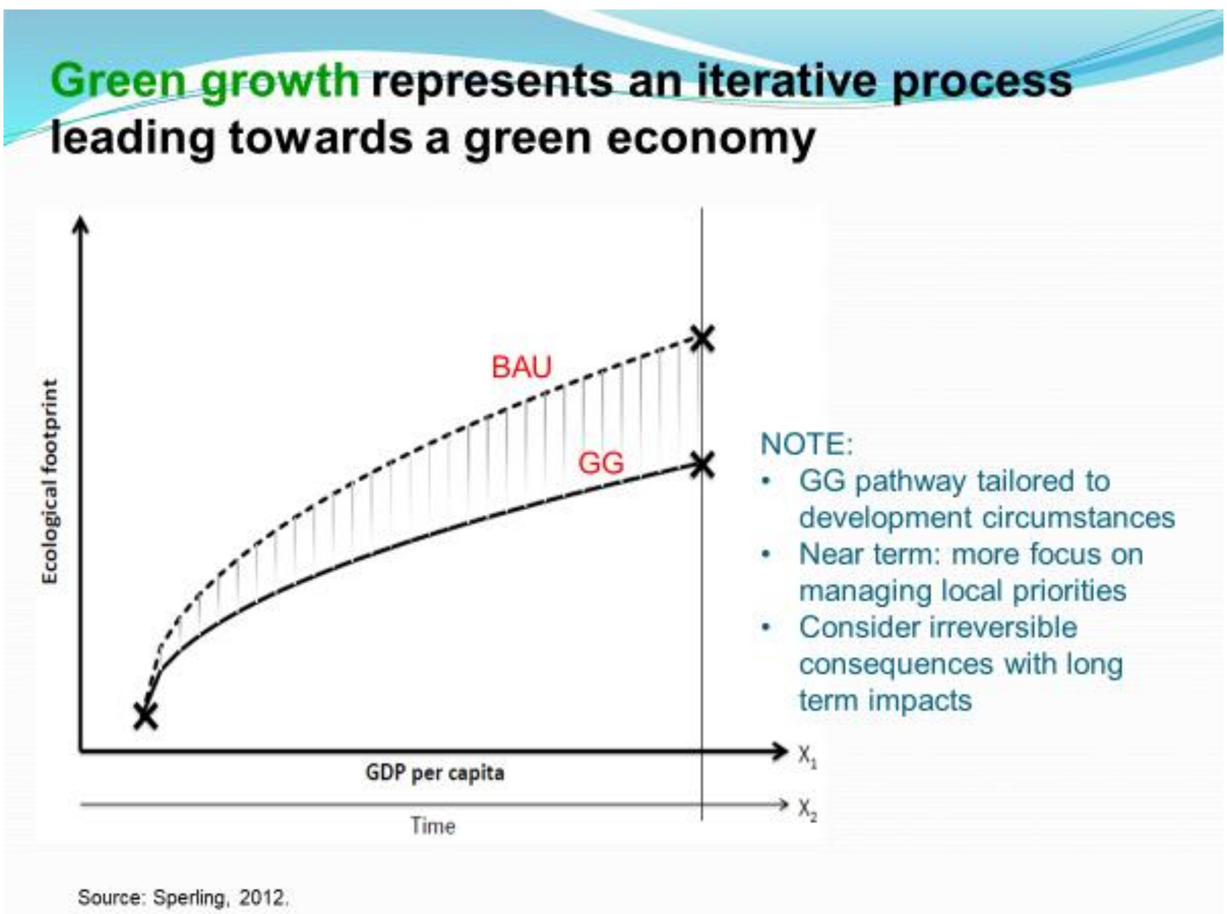
Addressing Deprivation

- ❑ Uneven economic growth
- ❑ Lack of energy access
- ❑ Lack of access to markets
- ❑ Lack of education
- ❑ Air and water pollution
- ❑ Depletion of natural resources
- ❑ Land degradation

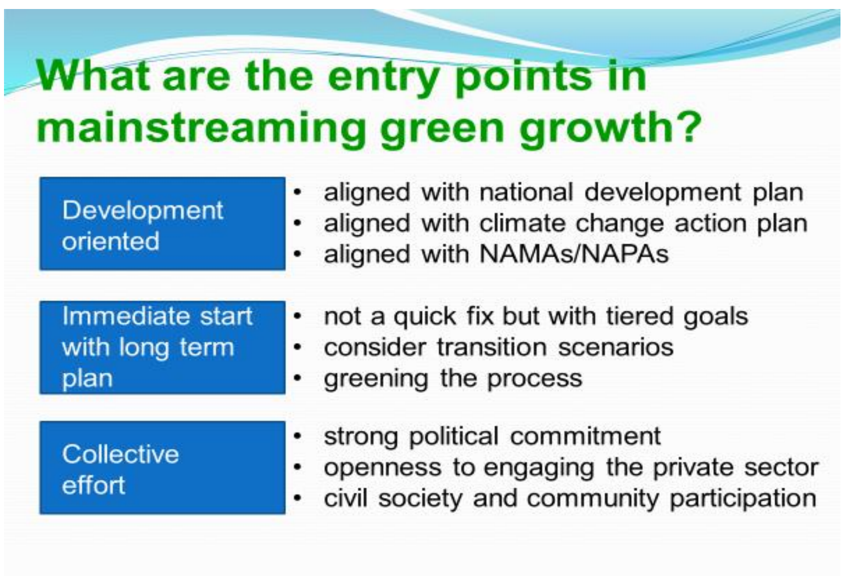
Managing Trends

- ❑ Rapid Population Growth
- ❑ Urbanization
- ❑ Globalization, economic volatility and shifting consumption patterns
- ❑ Disaster Risk and Climate change

Green growth represents an iterative process leading towards a green economy



What are the entry points in mainstreaming green growth?



Key messages…

- greening growth now makes economic sense in all countries, but will vary from country to country;
- green growth is beyond low carbon energy - strategies vary depending on the country circumstances but complement climate change actions;
- green growth pathway can guide the diversification of resource-rich economies and create new jobs: and
- green growth is a collective, contributory process towards sustainable development, not a substitute.

KEY CHALLENGES TO A GREEN ECONOMY IN KENYA

Challenge 1

- **First**, although several laws and regulations have been developed to encourage sustainability across sectors, compliance and enforcement remains problematic.

Challenge 2

- **Second**, there currently exist few standards for green technologies, goods or services. This is evidenced by an inadequacy of information about green technologies, thus stifling technology transfer and adoption and adaptation.
- But, progress e.g. current efforts to set minimum energy efficiency standards for certain appliances.
- Needed: environmental standards for green technologies (such as solar panels), food safety, & animal & crop products.
- Approach that organizes & addresses opportunities to strengthen environmental standards by sector will benefit the environment as well as Kenya's ability to trade internationally.
- Various regulations & standards are increasingly being applied in international trade; therefore, need to create an enabling environment where small & medium sized enterprises are both able to meet them & also enhance profitability.

Challenge 3

- **Third**, the current economic policy framework in Kenya needs to account for the intrinsic value of its natural capital and support sustainable development.
- Prices & policy regime do not fully account for the external costs associated with technologies, products & practices that are environmentally friendly.
- This diminishes any nascent demand for green alternatives.
- Need to incorporate natural resources in the System of National Accounts i.e. the derivation of indicators & statistics to monitor the interaction between Kenya's economy & key natural resources & use the results for decision making e.g. design of fiscal policy instruments to achieve desired outcomes on the stocks of NRs and/or environmental quality.
- There is potential to use fiscal policy instruments such as environmental taxes, subsidies, pollution charges, public expenditure on green infrastructure, public procurement, feed-in tariffs & grants.
- Kenya already has a feed-in tariff to promote green energy but it excludes some resources such as wave, tidal and ocean thermal energy conversion – such tariffs help to level the playing field with fossil fuel energy sources.

Challenge 4

- **Fourth**, increased funding will be needed to effect a transition to a green economy due to challenges in up front capital costs, particularly in areas like energy where up-front costs for clean technologies can be high.
- Funds will need to originate from both the private and public sector.
- Internationally, Kenya may be underutilising international donor funds available for low-carbon development.
- Domestically, enhancing its ability to mobilise domestic funds for investment in new renewable technologies will & products will require addressing current disincentives.

Challenge 5

- **Fifth**, there is insufficient knowledge regarding the costs and performance characteristics of available green technologies.
- Studies shown that the costs of turning over the current fossil-fuel based technology stock in transport & power supply to green alternatives are low relative to its benefits.
- E.g., the International Energy Agency asserts that fuel savings in transport & power supply could offset the cost of green investments (IEA, 2012).
- However, there are entrenched policy, market & financial barriers that prevent the transition from fossil fuel-based technology to greener options.
- Efforts to increase awareness of energy efficiency & renewable energy technologies can improve knowledge of best practices, promote the concept of a green economy & provide needed education & outreach.

Cross-sectoral Barriers to Transition to a Green Economy

- Inaccessibility to local/international markets;
- The growing concerns over youth employment;
- Training and skills necessary for new green opportunities;
- Insufficient awareness about green economy best practices;
- Obsolete and slow adoption of technology;
- Devolution transitional challenges regarding capacity and policy coordination;
- Capacity to leverage private sector investment;
- Insufficient incentives, low rate of return on green investment; and
- Inadequate access to information on climate and weather data, which can impact resilience

Project Assessment: Environmental Impact Assessment (EIA)

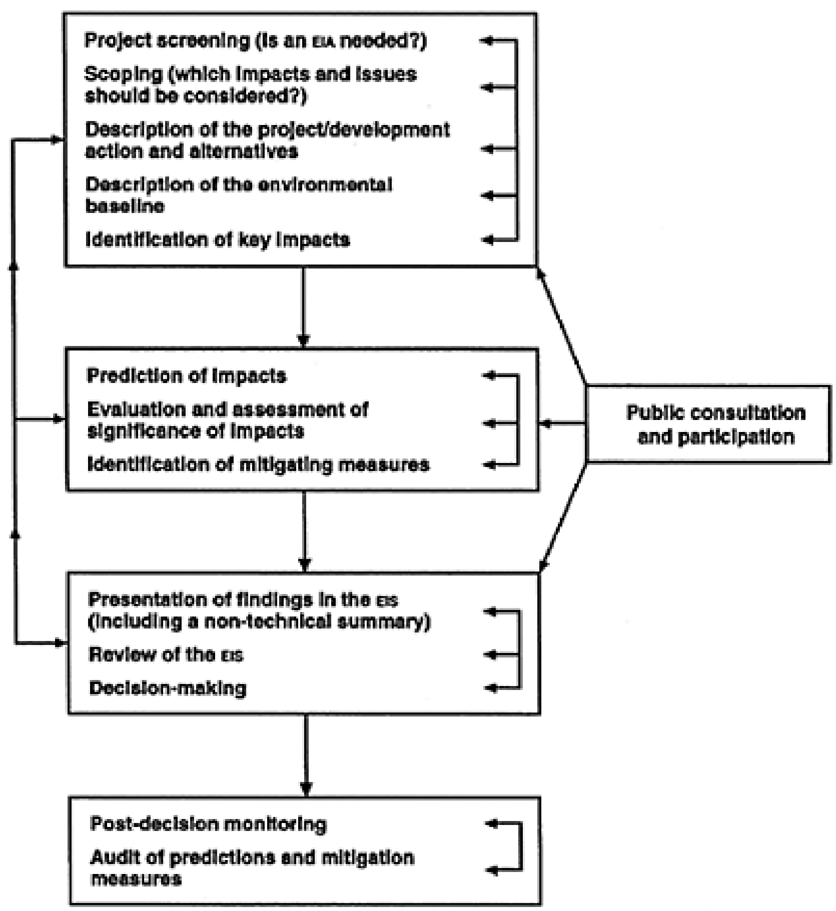
Definitions:

- Munn (1979): "**to identify and predict the impact on the environment and on man's health and well-being of legislative proposals, policies, programmes, projects and operational procedures, and to interpret and communicate information about the impacts**"
- UK DoE (1989) operational definition: "The term 'environmental assessment' describes a technique and a process by which information about the environmental effects of a project is collected, both by the developer and from other sources, and taken into account by the planning authority in forming their judgements on whether the development should go ahead."
- The UNECE (1991): "an assessment of the impact of a planned activity on the environment".

EIA Process

- In essence, EIA is a process, a systematic process that examines the environmental consequences of development actions, in advance.
- The emphasis, compared with many other mechanisms for environmental protection, is on prevention.
- Planners have traditionally assessed the impacts of developments on the environment, but invariably not in the systematic, holistic and multidisciplinary way required by EIA.
- The process involves a number of steps

Important steps in the EIA Process



TECHNOLOGY AND SUSTAINABLE DEVELOPMENT

Three Roles of Technological Change

Technology: Role 1

- **First**, technological advances are the ***main driver of long-term global economic growth***
- The rapid growth of the world economy since 1750 is the result of 250 years of technological advances, starting with the steam engine and steam-powered transportation, the internal combustion engine, electrification, industrial chemistry, scientific agronomy, aviation, nuclear power, and today's information and communications technologies
- Without these advances, the world economy and world population would have stopped growing decades or centuries ago.

Technology: Role 2

- **Second,** technological advances often have ***negative side effects***, even when their direct effects are enormously positive.
- Example: coal enabled modern civilization through the invention of the steam engine.
    - ➢ Yet coal is now used on such a scale that it endangers civilization itself. In 2010, humanity emitted around 14 billion tons of CO_2 through coal burning, close to half of the world's total emissions of carbon dioxide (CO_2) due to fossil fuels
    - ➢ Unless coal is phased out rapidly, or used with new technologies (such as carbon capture and sequestration), the damage to the planet and the global economy will be overwhelming

Technology: Role 3

- **Third,** technological advance is, at least to some extent, ***under human guidance***
- Perceptions of technological advance:
    1. A great lottery, determined by the luck of the draw of individual inventors and scientists.
    2. Simply following the market - companies invest in research and development (R&D) in order to pursue profits and ignore and ignore vital needs of the poor and the environment
    3. Directed technological change – to achieve human goals
- In the age of sustainable development, we will ***need such directed technological change***, in order to develop new technologies for sustainable energy, transport, construction, food production, health delivery, education, and more
- Governments will rely on many policy tools to drive innovations in a targeted direction, including the public financing of R&D, direct research in public laboratories, regulations, prizes for new inventions, and modifications of patent laws (e.g. to encourage R&D on specific diseases).

Sustainability Principles Applied in Technology Assessment

1. Protection of human health

- ***Dangers and intolerable risks for human health due to anthropogenically-caused environmental impacts have to be avoided***
- Production, use, and disposal of technology often have impacts which might negatively affect human health both in the short or long term (industrial accidents, road deaths, emissions)

- But notable successes realized in combating diseases or the prolongation of the human life expectancy due to medical progress or sanitary supply and disposal technologies; and also, food preservation technologies and the resulting improvement of nutrition

2. Securing the satisfaction of basic needs

- ***A minimum of basic services (accommodation, nutrition, clothing, health) and the protection against central risks of life (illness, disability) have to be secured for all members of society.***
- Technology plays an outstanding role in securing the satisfaction of basic human needs through the economic system; energy supply is also essential for this
- Applies directly in the production, distribution, and operation of goods to satisfy the needs (e.g. technical infrastructure for the supply of water, energy, mobility, and information, waste and sewage disposal, building a house, household appliances)
- **But note**: over-consumption in industrialized countries

3. Sustainable use of renewable resources

- ***The usage rate of renewable resources must neither exceed their replenishment rate nor endanger the efficiency and reliability of the respective ecosystem***
- Renewable natural resources e.g. renewable energies (wind, water, biomass, geothermal energy, solar energy), ground water, biomaterials for industrial use (e.g. wood for building houses) and wildlife or fish stock
- Technology plays an important role in using the extracted resources as efficient as possible (e.g. energetic use of biomass) and minimizing problematic emissions

4. Sustainable use of non-renewable resources

- ***The reserves of proven non-renewable resources have to be preserved over time***
- The consumption of non-renewable resources may only be called sustainable if the temporal supply of the resource does not decline in the future
- Only possible if technological progress allows for such a significant increase in efficiency to limit negative effects on the temporal supply of the remaining resources
- A minimum speed of technological progress is assumed.
- Alternatives: substitution with renewables; recycling management

5. Sustainable use of the environment as a sink

- ***The release of substances must not exceed the absorption capacity of the environmental media and ecosystems***
- Extraction of natural resources, processing of materials, energy consumption, transports, production processes, manifold forms of use of technology, operation of technical plants, and disposal processes produce an enormous amount of material emissions which are then released into surface and ground water, oceans, air, and soil
- These processes can cause serious regional problems, e.g. in air and water quality; and damage of ecosystems
- "End-of-pipe" technology can reduce emissions at the end of technical processes, e.g. in form of carbon capture and storage (CSS)
- Also, technical processes can be designed in a way that unwanted emissions do not occur at all - requires significant investment in research and development

6. Avoidance of unacceptable technical risks

- ***Technical risks with potentially disastrous impacts for human beings and the environment have to be avoided***
- This principle is closely linked to the ***precautionary principle***
- Can be applied to the problems discussed in the context of a severe nuclear reactor accident, for securing the long-term safety of a final repository for highly radioactive waste, or possible risks of the release of genetically modified organisms

7. Conservation of nature's cultural functions

- ***Cultural and natural landscapes or parts of landscapes of particular characteristic and beauty have to be conserved***
- A sustainability only geared towards the significance of resource economics of nature ignores additional aspects of a "life-enriching significance" of nature
- The normative postulate to guarantee similar possibilities of need satisfaction to future generations like the ones we enjoy today can therefore not only be restricted to the direct use of nature as supplier of raw materials and sink for harmful substances but has to include nature as subject of sensual, contemplative, spiritual, religious, and aesthetic experience

8. Participation in societal decision-making processes

- ***All members of society must have the opportunity to participate in societally relevant decision-making processes***
- Regarding technology, this principle has a substantial and a procedural aspect
- (substantially) it affects the design of technologies which (might) be used for participation call for exploiting these potentials of participation as far as possible
- (procedurally) it aims at the conservation, extension, and improvement of democratic forms of decision-making and conflict resolution, especially regarding those decisions which are of key importance for the future development and shaping of the (global) society, e.g. design of future energy systems

9. Equal opportunities

- ***All members of society must have equal opportunities regarding access to education, information, occupation, office, as well as social, political, and economic positions***
- Free access to these goods is a prerequisite for all society members getting equal opportunities to realize their own talents and plans for life
- Primarily relates to questions of societal organization where technology only plays a minor role; however, the availability of energy is often a crucial precondition for being able to participate in societal processes at all, e.g. for having access to information and communication technologies which need energy or mobility which is also impossible without energy.
- But "digital divide" might persist due to differentiated access

10. Internalization of external social and environmental costs

- ***Prices have to reflect the external environmental and social costs arising through the economic process***
- Negative ecological and social impacts in economic processes, suboptimal allocation of resources, and the resulting sustainability deficits are often caused by neglecting the "external effects" or "external costs"

    - refer to the effects of production and consumption activities which are not borne by the causer but by third parties and are a priori not subject to a regulation via market or pricing mechanisms
- External effects lead to distortions of prices and the structure of goods and therefore also to discrepancies between commercial and societal costs and/or between micro and macro rationalities of the market process which contributes to the development of sustainability deficits

11. Appropriate discounting

- ***Discounting shall neither discriminate against today's nor future generations***
- Discounting procedures enable comparison and assessment of economically relevant quantities occurring at different times
- Cost and benefit items are discounted to their current or cash value
- Main question: how much a subsequent loss or benefit is worth compared to today's losses or benefits. - answers are crucial for long-term developments
- Examples include: the determination of strategies to deal with the climate change, with highly radioactive wastes which have to be controlled for millenniums and burden future generations with costs and possible risks
- Appropriate discount rate cannot be decided ethically or scientifically but only politically – albeit in accordance with scientific information and ethical orientation

12. Society's reflexivity

- ***Institutional arrangements have to be developed, which make a reflection of options of societal action possible, which extend beyond the limits of particular problem areas and individual aspects of problems***
- The intended aims of technology and the subsequent real impacts of its use are not always identical
- Given the far-reaching societal impacts of technology, the instrumental sustainability principle on reflexivity calls for:
    a. strengthening the awareness for impacts, conducting impact research and impact reflection, and sensitizing societal subsystems (especially policy, economy, and science) for this,
    b. establishing a comprehensive and multi-perspective view on the impacts instead of just focusing on specific fields of impact, and
    c. providing enough resources and time for impact reflection in societal opinion-making and decision-making processes. Technology assessment as a process accompanying technology development (Grunwald, 2009) can help to achieve this.

- the real challenges of sustainable development, those of reconciling the ambitions of various interest groups, of identifying basic versus extravagant needs and of balancing present and future development aspirations, have all become clearer.
- Inevitably, the practice of sustainable development is proving more difficult than professing an intention, yet there are signs of progress.
- multilateral environmental agreements (MEAs) have been among the most visible manifestations of the intergovernmental community's interest in sustainable development
- Examples: Montreal Protocol, UNFCCC-Kyoto Protocol
- Also Priciples such as at Jo'Burg, Rio, etc
- continued challenges in practice: in ensuring that they are relevant to local realities, for example, and that agreements are implemented and their impacts monitored. The long delays in reaching full ratification of the Kyoto Protocol also illustrate how MEAs can be threatened by narrow national interests.

Aid and the environment

- Foreign aid is defined as any flow of capital to the developing nations which meets two criteria. First, its objective should be non-commercial from the point of view of the donor; second, it should be characterised by interest and repayment terms which are less stringent than those of the commercial world.
- The notion of foreign aid is that these grants and loans are broadly aimed at transferring resources from wealthy to poor nations for development or income redistribution.
- substantial debate over the impact of aid on the recipient nations.
- Opinions range from the belief that it is an essential prerequisite for development, supplementing scarce domestic resources, to the view that aid perpetuates neo-colonial dependency relationships which will ensure that recipient nations remain underdeveloped
- evidence that aid can be (and has been) environmentally damaging.: e.g. the widespread damage to environments and local peoples caused by resettlement projects, large dams and road building
- the recent debate on aid impacts has shifted from preoccupation with 'supply' issues, i.e. enhancing the inflow of financial resources for development, towards 'demand' side issues, of the capacity of individuals, communities, governments and development institutions to access and effectively use those resources
- support for capacity building is often more effective than provision of concessional assistance per se
- See table 3.2

The World Bank in sustainable development

- the major source of multilateral aid for developing countries
- In addition, for each dollar that the World Bank lends, it can be expected that several more will also flow to these projects from other agencies, from private banks and from the recipient governments.
- The rhetoric and actions of the World Bank with regard to the environment are therefore crucial in determining the prospects for sustainable development.
- In 1993, the World Bank announced a fourfold environmental agenda in recognition of the way in which environmental degradation was threatening the attainment of its objectives, stated as being 'to reduce poverty and promote sustainable development' (World Bank, 1994).

- A further element of the World Bank's environmental agenda has been to provide funds for projects which specifically aim to strengthen environmental management.
- Such projects include funds for research, capacity building, training and monitoring, as well as direct investment in pollution prevention and treatment, the conservation of biodiversity, integrated river management and establishing national parks.

GEF

- The World Bank was also integral in establishing (with UNEP and UNDP) ***the Global Environment Facility (GEF)*** in 1991.
- This is a programme of new monies (over and above existing ODA contributions) to assist the least developed nations in tackling explicitly global environmental problems, including the limitation and reduction of greenhouse gases, the protection of biodiversity, international water management and energy conservation.

Critique of GEF

- It has been praised by some as an important tool for future multilateral cooperation on environmental issues, but is criticised by others for not addressing the key environmental concerns of developing countries.
- For example, 24% of GEF projects are focused on climate change issues. Furthermore, membership of GEF is limited to those countries making a minimum contribution of US$4 million to the fund and has been dominated, 'just like the World Bank's board of executive directors', by developed countries (Werksman, 1995: 282). During the pilot phase, 80 per cent of GEF projects were linked in some way to larger ongoing World Bank projects (1995).
- See Table 3.3

NGOs and Sustainable Development (SD)

- The term non-governmental organisation encompasses all organisations that are neither governmental nor for profit.
- NGOs are one aspect of 'civil society' that has been receiving substantial interest in the literature of SD
- Commonly, ***civil society*** is identified as 'an arena for association and action that is distinct and independent from both the state and the market, a voluntary, self-regulating, "third sector" sector in which citizens come together to advance their common interests (excluding business)'
- This broader arena also encompasses '***social movements***', the term generally used to refer to coalitions and networks of actors (some of whom may be members of more formalised NGOs), which increasingly are seen to mobilise around issues including the environment and operate transnationally.
- NGOs are not able to sign treaties, pass legislation or set targets for emissions as governments are able to. Historically, however, they have been a strong force in lobbying for such actions to be taken, in modifying governmental activities and in contesting the operation of international institutions such as the World Bank
- Increasingly, NGOs have been prominent participants in international summits
- NGOs have a long-established tradition of working in direct actions at village level around relief and welfare issues in particular.
- Many have moved subsequently into actions to address the underlying causes of suffering and deprivation, into promoting self-reliant development, and towards facilitating development by other organisations

- the distinction between groups working for members or the public benefit is becoming more blurred in recent years, as NGOs are increasingly working together with both multilateral institutions and governments, for example

Growth of NGOs

- NGOs are considered to have a number of ***characteristics that are thought to make them particularly suited to effecting sustainable development:*** size, tradition of working closely with local people and their environment & flexibility
- More official aid now goes through NGOs than governments
- Historically NGOs vociferous opponents of the World Bank, but increasingly collaborating with it.
- However, there are questions concerning the nature and extent of this collaboration: whether NGOs are merely informed, consulted at the initial stages of a project or engaged in sustained partnerships
- Community organisations need to move beyond actions in their traditional arena of immediate practical concerns, to engage with wider political processes to act strategically.
- Empowering the poor implies a very different role for the state in development and it may be unpopular and resisted at many levels

NGO challenges

- maintain their accountability to local communities and 'watchdog' functions as more official aid is now channelled through them and they are increasingly required to operate in commercial markets in the delivery of services
- There is the prospect that the original missions of NGOs and power to control their own agendas may become compromised.
- In competing in the marketplace, smaller NGOs may be squeezed out, and NGOs generally may be forced to become more bureaucratic, leading to more finances being spent in those arenas rather than on their beneficiaries.
- Critically, it cannot be assumed that all interests are served through 'community development efforts' (Potter et al., 2004);
  - ➢ all societies are highly differentiated including by gender, ethnicity and class, for example, that ensures that NGOs do not offer a simple panacea for sustainable development.

SUSTAINABLE RURAL LIVELIHOODS

Main Themes

- Rural areas worldwide provide a range of functions central to SD
- The extension of models of industrialised agriculture has been a dominant characteristic of much rural development to date
- The 'gene revolution' for world agriculture alternative
- 'Putting Farmers First'
- Gender and Development (GAD) school of thought.
- Lessons from Community Based Natural Resource Management (CBNRM)

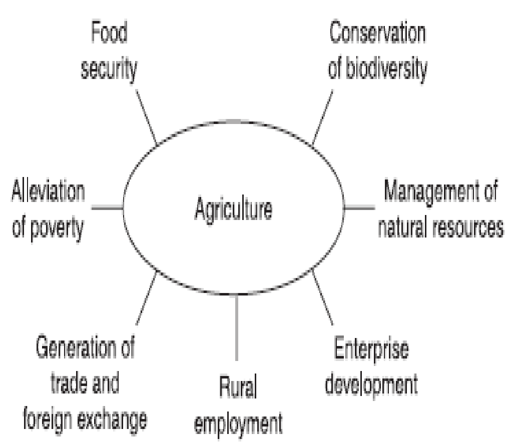
Introduction

- For the large numbers of people resident in the developing world, their ***basic needs*** in terms of both development and conservation are immediate and local; ***survival in the short term*** is their primary concern and for this they ***depend largely on the resources of the surrounding area***.
- providing ***sustainable rural livelihoods***, not just for the present population but for many billions more under projected population increase, is an urgent endeavour
- a large share of the world's most impoverished people live in some of the most ***fragile' ecological zones***, in terms of slopes, soils and constraints set by aridity
- impacts of processes of ***globalisation*** identified in including trade liberalisation and structural reform, have often ***hit the rural poor hardest***

The Place of Agriculture

- Rural people generally have weaker purchasing power & thereby suffered more as currencies were devalued.
- The ***collapse of extension systems*** (i.e. support structures) as governments had to cut their budgets, the ***removal of concessional credit and subsidised inputs*** to agriculture & the worsening terms of trade for agricultural goods all had Particular adverse impacts on farmers.
- The significance of creating sustainable rural livelihoods also emerges through the varied (public and private) functions that agriculture is now expected to deliver worldwide, as displayed in Figure 4.1.
- Over and above individual subsistence & food security needs, e.g. primary commodity production, remains the principal source of exports and access to foreign exchange for many developing countries
- The loss of the world's tropical forest ecosystems (including through the expansion of agriculture) is also a global challenge in terms of global warming & for the future conservation of biodiversity.

Figure 4.1 *The multi-functional role of agriculture*



Urban Bias

- significance of rural development in overall considerations of sustainable development stems also from the prevalence of poverty in the rural sector
- Yet, rural areas of the developing world have often been left out of development initiatives in the past.
- 1977 Michael Lipton suggested the now classic thesis on **'urban bias'** – the major explanation of the persistence of poverty in developing countries has been the 'anti-rural' development strategies followed therein.
    - i.e. urban sector benefited disproportionately from the public allocation of resources in DCs, e.g. in education & other services and through cheap food policies and other public subsidies

"Chambers' Biases"

- Chambers' (1983) well-cited work detailed a range of biases that have served to limit the understanding of the needs of rural communities and environments and compromised rural projects and programmes in practice.
    - 'tarmac bias', referring to the way in which bureaucrats, academics and journalists the world over rarely venture into remote areas;
    - 'person bias', resulting from the tendency to speak only to influential community leaders; and
    - 'dry-season bias', which comes through visiting rural areas when travel is easiest.

Shepherd (1998)

- New paradigm in the theory and practice of rural development in recent years.
    - These included the move from an emphasis on technical fixes towards holistic approaches and sustainable solutions,
    - the move from technocratic management to participatory developments and
    - the shift from control by external organisations to local institutions in management.

Linkages between rural and urban sectors

- Policy-making and agency practice continues to treat rural & urban separately.
- Separating people into 'rural' and 'urban' has become increasingly problematic as empirical evidence demonstrates the significance of 'fluid, fragmented and multi-location households to survival strategies.
- 'Static' definitions of urban and rural cannot accommodate the significant flows of migrant populations.
- Other forms of the interconnecting and multi-directional flows: money, food & ideas.
- Very often, rural communities closely tied to urban centres – both within the country and internationally – as markets for agricultural goods, sources of income & as centres of political power.
- there are sectoral interactions between rural and urban: rural sectors such as agriculture are important in urban areas and urban sectors such as manufacturing are found in rural ones. In addition, 'many households live in peri-urban areas outside the urban boundary but derive their livelihoods from work within it, while people living inside the urban boundary engage in activities such as farming, fishing, collecting wood or trading which take them to the surrounding rural area

Differences between rural & urban

- E.g. access to land, capital & labour to maintain productivity in rural contexts or environmental health Vs the lack of social and human capital to secure employment in an urban setting

- Governance: increasingly distant in the case of many rural areas as state capacity is reduced under structural reform Vs stronger in some cities with processes of decentralisation.
- Residents of urban centres generally depend on markets to a greater extent than rural people so that security of cash incomes becomes particularly important in understanding the nature and impacts of urban poverty.

‘De-agrarianisation’ of the rural sector

- In sub-Saharan Africa, at the end of the 1990s, it was estimated that between 60 and 80 per cent of rural household income came from such non-farming sources, an increase from 40 per cent in the 1980s
  - non-farm activities include:
  - waged employment,
  - self-employment and
  - migration.

Diversity at all scales

Diversity at one time and at all scales is one of the key features of rural livelihood systems.
  - secure sustenance in close proximity but through very different agricultural systems, based on permanent cultivation and semi-nomadic pastoralism respectively.
  - farmers are also industrial workers, travelling perhaps a few kilometres daily or seasonally much further, to take up waged employment, without giving up agriculture altogether.
  - rural people secure a living through agriculture, but as wage labour on plantation estates owned by others.
  - Contract farming, whereby production remains in the hands of smallholders but is linked to contracts with larger enterprises (which may variously be with the state or agribusiness concerns).

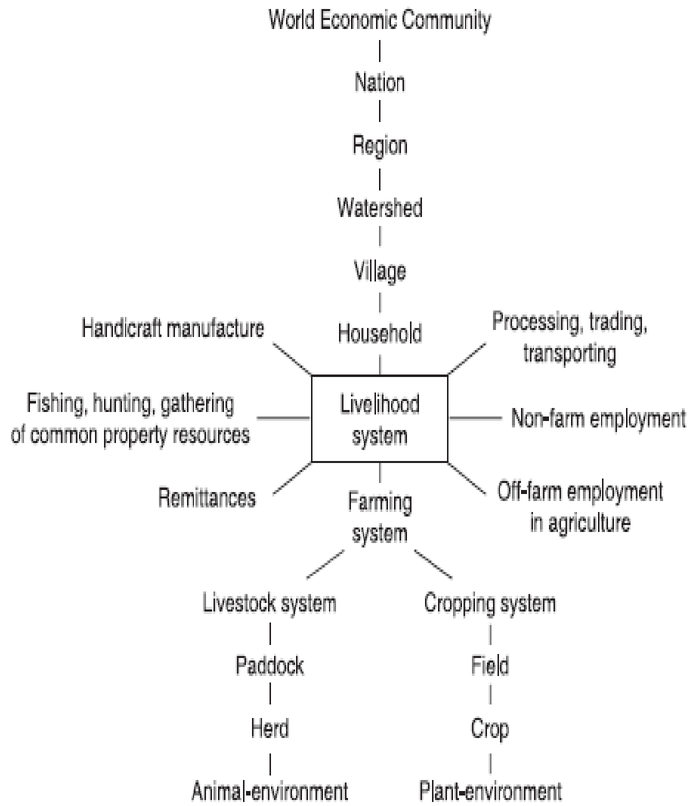
Dynamism

- ***Dynamism is diversity over time***
- capacity to move the emphasis of any particular element within the livelihood system or to introduce new components has been central often to survival itself.
- E.g. how poor households cope with food insecurity in times of drought highlights the varied adaptations to changing environmental and social circumstances which households can and do make.
- But do these responses constitute movement towards more secure rural livelihoods or greater vulnerability?

Agro-ecosystems Model

- Farming is only one option for securing basic needs for food & cash in rural areas
- Farming is based on a combination of livestock (including fish) and/or cropping (including forestry) systems.
- Diversity stems from the limitless number of factors shaping individual farming & livelihood systems, each farming system involving the manipulation of basic ecological processes (such as the competition between species or the predation by pests), via agricultural processes of cultivation or pest control, and led by human goals (which may be set at the individual, community, state or international levels).
- Change in the agro-ecosystem comes via the full range of environmental, economic, political & social factors across this hierarchy.

Figure 4.4 *The hierarchy of agro-ecosystems*



Source: adapted from Conway (1987).

Rural areas and the global economy

- Agriculture as an economic sector & as an activity has become globalised
- it is increasingly dependent on an 'economy and set of regulatory practices that are global in scope & organisation
- the 'farm', which had been the core of agricultural production now just one part of an integrated, multilevel industrial system encompassing production, processing, marketing & distribution of food & fibre products
- E.g in the global expansion & reach of the trade of fresh horticultural goods – these now make up approximately 5 %of global commodity trade (equivalent to the trade in crude petroleum)

Consequences of Globalised Agriculture

- Supplying non-staple crops (such as fresh flowers or other horticultural goods) to overseas markets requires farmers of the DCs to enter into ***contract*** with a buyer e.g. tea production in Kenya
- Agribusinesses that formerly owned land & employed labour directly within plantation systems now switched to ***contracting out production***
- The ***relationships between people in rural areas & between people and the environment have changed*** dramatically through all these forms of incorporation into an increasingly globalised world.
- A few have made profits by expanding into non-agricultural activities but ***a majority (mainly small-scale peasant households) led to increased hardship & insecurity of rural livelihoods***

Types of Agriculture (WCED 1987)

1. ‘**industrial**’ agriculture largely confined to the industrialised countries, but also as occurring in specialist enclaves of the DCs (e.g. TNCs control of seed market , biotech – Monsanto)
2. ‘**green revolution**’ agriculture of 2.5 billion people in countries of the DCs, mostly in Asia through the 1960s & 1970s - rainfall or irrigation technologies and close to markets and sources of inputs, high-yielding varieties of wheat and rice
3. ‘**resource poor**’, supporting over 2 billion people in the DCs – less integrated into the world economy & generally ‘forgotten’ within agricultural developments including through the ‘biases’

Towards sustainable rural development

- The deterioration of rural livelihoods ,e.g.:
    - In Kenya, on the banks of Lake Victoria, the livelihoods of fishing communities are becoming increasingly compromised by the growth of water hyacinths which inundate the shoreline and prevent the launch of fishing boats.
    - Fertiliser and pesticide use on neighbouring agricultural lands is a major factor in the eutrophication of the lake and the rise of algal blooms.
    - Further loss of control over the resources essential to the livelihoods of local fishing communities is also occurring with the increased costs of boats, nets and labour, in part prompted by the rise of absentee boat owners, many of whom are Nairobi-based business people and politicians.

Challenges of industrial agriculture

Food health and quality that are generally dominating issues.

- ‘Food scares’ such as those surrounding the health risks of additives, pesticides, high fat, variant CJD and BSE in beef cattle are now proving powerful influences on consumer choice in the UK and USA.
- The environmental impacts of high external input systems of agriculture including the loss of biodiversity under mono-cropping, the pollution of groundwater through pesticides, and the water shortages and draining of wetlands.
- The moral issue of the existence of food surpluses through huge state subsidies (i.e. economic aspects).

Challenges of Green Revolution

- Similar concerns in Green Revolution areas
- WHO says 25M workers in DCs suffering from pesticide poisoning in 1990
- 0.5M deaths in Asia-Pacific region
- Pesticide residues appeared in human foods & local diets have changed so much that, even as food supply has increased, people may still suffer deficiencies in certain minerals and vitamins.
- Mounting evidence that previous yield increases under traditional plant breeding methods are slowing
- Problems such as chemical toxicity & changing soil carbon–nitrogen ratios are necessitating further external inputs in order to maintain yields.

From Green to Gene Revolution

- Public monies & charitable foundations funded the experimentation and research centres of the Green Revolution but commercial biotechnology companies are the major financers & architects of the Gene Revolution.
- Genetically modified organisms (GMOs) – alien genetic material is introduced artificially rather than through traditional breeding or cross-breeding from one organism to another.

- Proponents of the Gene Revolution argue that biotechnology offers the means to feed an expanding population from a restricted land base with fewer environmental costs.
- Crop varieties are created to require less pesticide, to be herbicide tolerant, to fix their own nitrogen, to yield in very challenging conditions & to be drought resistant, all of which can reduce overall commercial energy requirements

Challenges to GMOs

- Serious reservations over rising corporate control over the food chain encompassed by these developments
- Small farmers become tied into dependence on certified seeds and external inputs.
- GM "solutions" is the 'antithesis' of a sustainable option for further agricultural development'.
- Characteristically, this externally & technology-led approach to sustainable agricultural development is very different from those of participatory & community-based development

The environmental concerns over GMOs

1. Most agricultural crops have toxic ancestors and introduced genes could switch back on ancestral genes making agricultural crops toxic.
2. Genes inserted into GMOs will spread to other non-target organisms with unknown and unpredictable consequences.
3. We do not know enough about ecological interactions to be able to predict accurately the long-term consequences of the introduction of genes into the environment.
4. It is possible that development of herbicide-resistant plants could cause changes in the patterns of herbicide use in agriculture in ways that will be more environmentally damaging than existing systems.
5. It is difficult to predict what will turn into a plant or a weed. Once an organism becomes a pest it can be difficult to eradicate.
6. A gene does not necessarily control a single trait. A gene may control several different traits in a plant and the placement of genes is a very imprecise science in many cases.
7. A gene which is safe in one country and one soil type may behave differently under changed conditions. Therefore there are problems of scaling from field trial to commercial release.
8. The majority of the new GM crops require high-quality soils, high investment in machinery and increased use of chemicals. They do not solve the food needs of the world's poorest people.
9. GMOs encourage continuous cropping and thus discourage rotations, polycultures and the conservation of biodiversity.

The socioeconomic concerns

1. Genetic engineering is leading to the patenting of life forms, genetic information and indigenous knowledge of local ecology. Such commodification or privatisation of nature and knowledge is morally wrong.
2. Corporations are concentrating research and development on the most profitable elements of biotechnology rather than the applications that best promote sustainable development.
3. The control of the global food economy by fewer large corporations is leading to more genetic uniformity in rural landscapes.
4. Competition to gain markets and hence profits is resulting in companies releasing GM crops without adequate consideration of the long-term impacts on people or the ecosystem.
5. Without adequate labelling, consumers have no choice as to whether they eat food derived from GMOs.
6. There is no conclusive evidence that GMOs are superior to conventional crops. They may divert resources from exploring more appropriate, sustainable low-technology alternatives to intensive agriculture.

7. Using GMOs to increase agricultural productivity in the North may lead to reduced imports from the South. Farmers in the South may then turn to more environmentally damaging alternatives with adverse effects on biodiversity.

The importance of the local context

- Pretty (1995) has documented cases of agriculture delivering economic and environmental benefits across the broad spectrum of the three categories of agriculture identified by the WCED.
- Whilst the technologies and specific practices may vary, they share ***three*** common elements:
  i. the use of locally adapted resource-conserving technologies,
  ii. coordinated actions at the local level and
  iii. supportive external institutions.

Agricultural technologies with high potential sustainability

- **Intercropping -** The growing of two or more crops simultaneously on the same piece of land. Benefits arise because crops exploit different resources, or interact with one another. If one crop is a legume it may provide nutrients for the other. The interactions may also serve to control pests and weeds.
- **Rotations -** The growing of two or more crops in sequence on the same piece of land. Benefits are similar to those arising from intercropping.
- **Agro-forestry -** A form of intercropping in which annual herbaceous crops are grown interspersed with perennial trees or shrubs. The deeper-rooted trees can often exploit water and nutrients not available to the herbs. The trees may also provide shade and mulch, while the ground cover of herbs reduces weeds and prevents erosion.
- **Sylvo-pasture -** Similar to agro-forestry, but combining trees with grassland and other fodder species on which livestock graze. The mixture of browse, grass and herbs often supports mixed livestock.
- **Green manuring -** The growing of legumes and other plants in order to fix nitrogen and then incorporating them in the soil for the following crop. Commonly used green manures are Sesbania and the fern Azolla, which contains nitrogen-fixing, blue-green algae.
- **Conservation tillage** - Systems of minimum tillage or no-tillage, in which the seed is placed directly in the soil with little or no preparatory cultivation. This reduces the amount of soil disturbance and so lessens run-off and loss of sediments and nutrients.
- **Biological control -** The use of natural enemies, parasites or predators, to control pests. If the pest is exotic these enemies may be imported from the country of origin of the pest; if indigenous, various techniques are used to augment the numbers of the existing natural enemies.
- **Integrated pest management -** The use of all appropriate techniques of controlling pests in an integrated manner that enhances rather than destroys natural controls. If pesticides are part of the programme, they are used sparingly and selectively, so as not to interfere with natural enemies.

Lessons for the achievement of sustainable rural livelihoods

Chambers (1988)

1. A learning-process approach
2. People’s priorities first
3. Secure rights and gains
4. Sustainability through self-help
5. Staff calibre, commitment and continuity.

Farmer-First: A learning-process approach to planning

- ‘blueprint’ approach to planning: in short, new technological packages are developed in research stations and laboratories for transfer via extension systems to farmers.
- criticism led to calls for ‘another’ or ‘alternative’ development that prioritises people’s needs, ecological soundness and popular empowerment.
- ‘Farmer-First’ Chambers et al., 1989) approach to agricultural development based on a ‘learning-process approach’ – projects are continually modified rather than being held to a rigid set of aims and procedures.
- Changes made in response to dialogue between all interested parties & the experience gained during the course of the operation of the project.
- A learning-process approach has widespread implications for how projects are defined, the value of particular kinds of ‘expertise’ and the systems of communication.

Figure 4.11 *The contrasting ‘blueprint’ and ‘learning process’ approaches to rural development*

	Blueprint	*Learning process*
Idea originates in	capital city	village
First steps	data collection and plan	awareness and action
Design	static, by experts	evolving, people involved
Supporting organisation	existing, or built top-down	built bottom-up, with lateral spread
Main resources	central funds and technicians	local people and their assets
Staff training and development	classroom, didactic	field-based learning through action
Implementation	rapid, widespread	gradual, local, at people’s pace
Management focus	spending budgets, completing projects on time	sustained improvement and performance
Content of action	standardised	diverse
Communication	vertical: orders down, reports up	lateral: mutual learning and sharing experience
Leadership	positional, changing	personal, sustained
Evaluation	external, intermittent	internal, continuous
Error	buried	embraced
Effects	dependency creating	empowering
Associated with	normal professionalism	new professionalism

Source: Chambers (1993).

Secure rights and gains

- When people are sure that they have the rights to the products from trees that they plant, invest in and manage, they plant many more than they do when there are restrictions on the use or appropriation of such resources.
- Because of the centrality of agricultural production in rural livelihoods, issues of land ownership & tenure are central to the question of security of rights to resources and benefits.
- Land is both the foundation for economic opportunity and a major correlate of social prestige & political power in rural societies of the developing world.
- Yet substantial inequality in the distribution of landholdings is a widespread, entrenched and worsening feature of many DCs despite decades of land reform programmes

Gender in Agriculture

- 80% of food in sub-Saharan Africa is produced by women.
- Twice as many women as men currently work in agriculture-related activities. Yet, women own less than 2% of the world's total agricultural area.
- Clearly rights to control the products of labour defined by gender relations matter a great deal.
- Often in DCs women receive rights to land through their husbands on marriage, but have few rights to decide what is cultivated or marketed or how any profits made are spent.
- Gender divisions of labour are clearly not equivalent to gender divisions of responsibility or control over income.
- Also, there is often a gender bias in terms of access to training (such as technical assistance from extension workers) & access to modern inputs to agriculture that ensures that many agricultural development interventions have very different impacts on women and men.

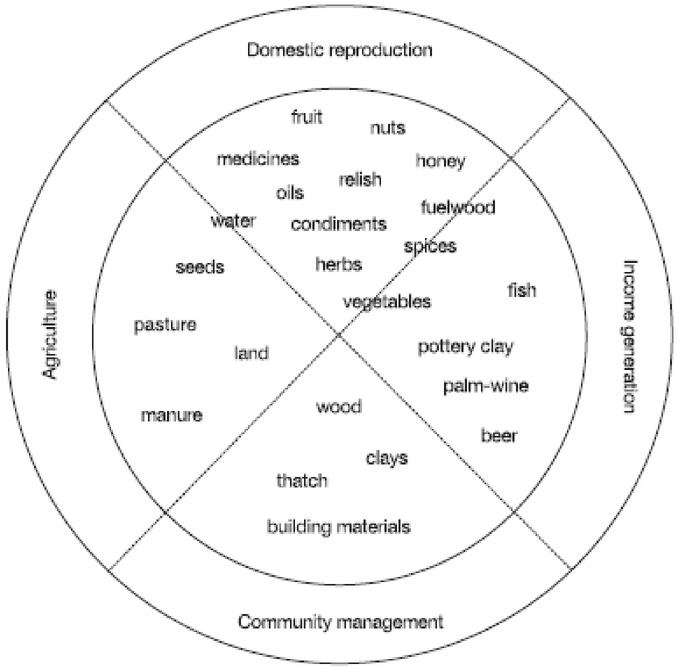
The role of women in conservation

- 'the achievement of sustainable development is inextricably bound up with the establishment of women's equality' (WRI, 1994: 43)
- Women were considered to have a 'substantial interest' in environmental resources
- Ecofeminists took these notions further to suggest that women have a natural affinity with nature aligned to their childbearing qualities that men do not have e.g. Vandana Shiva (1989)

Emergent problems of women & Environment

- As the main 'users' and 'managers' of natural resources at the local level implies accepted gender roles and a lack of alternative opportunities for women rather than any chosen or inherent empathy with conservation and natural resources.
- Through the gendered division of labour (whereby women take primary responsibility for collecting and managing the energy and water needs of the household), women's immediate 'practical gender needs' regularly centred on accessing environmental resources and environmental degradation was seen to affect women most.
- Women tend to take greater responsibility for maintaining communal services such as schools, health posts (and community woodlots and wells) and generally often provide the 'glue' between the elements and activities of the community.
- Many 'Women, Environment and Development' (WED) project interventions placed the 'fourth burden' on women to add to their gendered responsibilities in production, in the reproduction of the household and in community management, particularly through the way that they assumed that women had the spare time to undertake these projects.

Women's substantial interest in the environment



Source: Barrett and Browne (1995

The capacity of local institutions and the role of outsiders

- When people have secure rights to resources and gains from investments, they also have a perceived self-interest in project development & implementation
- Pretty and Ward (2001) suggest, 'for as long as people have managed natural resources, they have engaged in forms of collective action'
- Huge variety of local associations such as work teams, burial societies and credit groups and with varied rules of behaviour & values guiding the association between individuals that shape resource management.
- These comprise the 'institutions' that are now the focus of much of the development theory & practice.
- Many rural development interventions now recognise the importance of strong local institutions not only for their potential to foster SD but also through understanding that it can be the breakdown of such institutions that partly explains environmental degradation.
- The work on **social capital** is emphasising the value of social bonds and norms of behaviour within local institutions for facilitating actions for mutual advantage such as are required in many conservation efforts.

Community Based Natural Resource Management' (CBNRM)

CBNRM encompasses a breadth of policies and programmes in practice, but typically involves one of three kinds of experiences:

1. Some kind of joint or collaborative management involving local communities in the management of (typically) previously defined 'state' resources,
2. Those that look to decentralise authority to (usually newly created) local/community institutions, and
3. Those that work to strengthen the traditional, local institutions and controls that are already in place (Elliott, 2002).

Problems of CBNRM

- issues of sustainability where such high levels of donor support are involved (and the negative impact this may have, for example, on incentives for the development of local and national capacity).
- many traditional institutions in resource management are being broken down through processes of resource scarcity, immigration and a decline in authority of traditional leadership.
- many CBNRM initiatives assume distinct ‘communities’ exist, whereas they are in fact highly diverse and dynamic, contain many different interests & environmental priorities within them and have very varied abilities or power to negotiate and make change.
- accommodating internal differences & dynamics within communities presents substantial challenges

SUSTAINABLE URBAN LIVELIHOODS

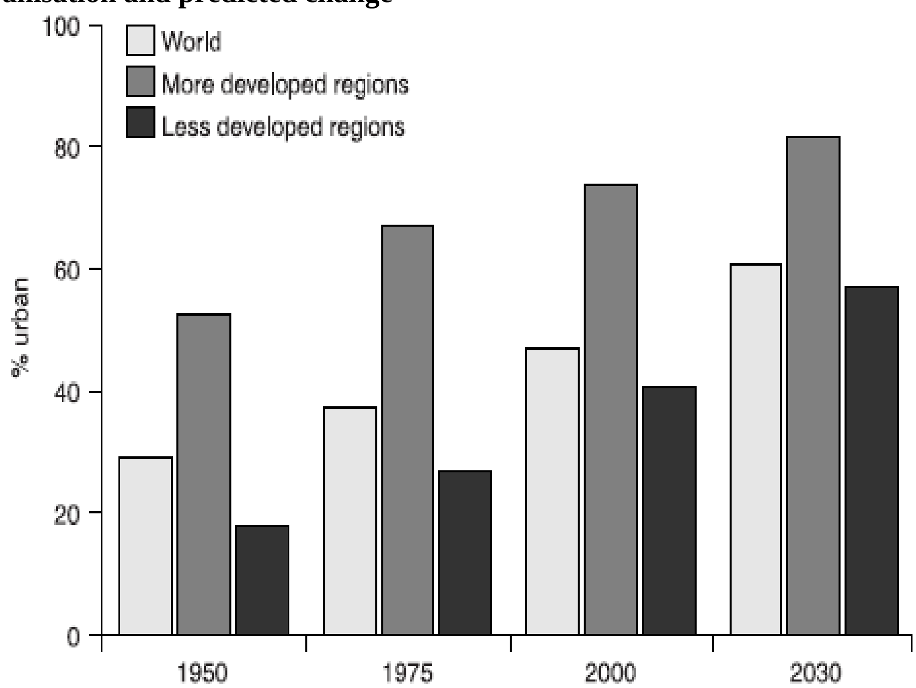
Summary

- Rising concentration of the world's population in urban centres presents opportunities & challenges for SD
- Reliant on income for food from markets, basic needs and services
- Low-income groups face substantial environmental health risks in the course of basic activities of living and working mediated through class and gender differences.
- Immediate local issues of inadequate sanitation and water supplies, of poor housing and cramped living conditions are at the centre of the environmental agendas of these cities.
- Processes of decentralisation of authority and decision-making from the state to city level and of privatisation of many basic services
- Capacity, accountability & transparency of local authorities is a key factor in the prospects for SD

Introduction

- the world, is now almost 50 per cent urban
- 93% of the urban growth worldwide to the year 2020 will occur in the developing world
- Due mainly to unprecedented growth rates observed and the challenge of meeting the immediate needs of an expanding urban poor urban challenge lies 'firmly in the developing countries (WCED, 1987: 237)
- World Bank estimated that approximately one-quarter of the developing world's absolute poor were living in urban areas (World Bank, 1990). In 2001, it was estimated that the number of urban poor will treble to 1,500 million by 2025 (UNCHS, 2001)
- City-based production currently accounts for the majority of resource consumption and waste generation worldwide (WRI, 1996)

Levels of urbanisation and predicted change



Source: compiled from UN (2003)

Causes and consequences of rapid urbanization in the Third World

- Poverty, unemployment and deprivation in rural areas of DCs is main reason for rural-urban migration
- If jobs exist – pay is higher in urban areas
- Social and health facilities are better in the urban areas

Urban bias in development

- **Critiques**: Michael Lipton (1977) against the path to industrialization based on starting with import-substituting industrialization
- **Argued**: agriculture tends to be neglected in the allocation of public investment, whereas the aim of policy should be to reduce the riskiness of agriculture
- Urban bias acted against more efficient and equitable ways of using public resources in the agriculture sector
- **Lipton**: urban classes (both rich and poor) have vested interest in forming a powerful political alliance in maintenance of urban bias

Rural-urban interrelations in developing countries

- Urban and rural areas are closely interrelated

- ***Rural urban interaction***
    - Differences between urban and rural at their extremes are maintained by the strong functional inter-linkages which exist between them on a day-to-day basis

- ***The nature of peri-urban zones***
    - These are areas that exist at the very edges of cities in the developing world (within daily commute)
    - Represent areas of active assimilation of agricultural lands into the urban network; large peripheral squatter settlements and shanty towns;

- ***Extended metropolitan regions (EMRs)***
    - These are areas within which new urban-rural forms are to be found mixed together

Green and Brown environmental agendas

Green Versus Brown Agendas

- The term 'Green environmental agenda' encompasses issues such as the depletion of water and forest resources. These concerns are most relevant to cities of the more developed world, to future generations and natural ecological systems.
- The 'Brown environmental agenda' encompasses issues of access to basic water supplies, sanitation and housing; the 'pollution' of urban poverty that is most relevant to poor urban residents of today and to human health.

Features of problems on the agenda	**The Brown Agenda**	**The Green Agenda**
Principal impact	Human health	Ecosystem health
Timing	Immediate	Delayed
Scale	Local	Regional and global
Worst affected		Future generations
Aspects emphasized in relation to		
Water	Inadequate access and poor quality	Overuse; need to protect water sources
Air	High human exposure to hazardous pollutants	Acid precipitation and greenhouse gas emissions
Solid waste	Inadequate provision for collection and removal	Excessive generation
Land	Inadequate access for lowincome groups for housing	Loss of natural habitats and agricultural land to urban development
Human wastes	Inadequate provision for safely removing faecal material (and water) from living environment	Loss of nutrients in sewage and damage to water bodies from its release of sewage into waterways

Source: adapted/compiled from McGranahan and Satterthwaite (2002)

- Whilst affluent cities can be considered to have performed better in terms of meeting the needs of their current populations, historically these have been met by displacing the environmental burdens over space (elsewhere) and time (delayed).
    - E.g., sewers have been put in to take human waste out of the city and goods whose production may have been resource intensive or damaging have been imported.
    - The burden of dealing with the levels of waste generated or high levels of fossil fuel combustion will fall on the next generations through their contribution to global warming, for example.
    - In wealthier cities, the key challenges for action lie in reducing excessive consumption of natural resources and the burden of wastes on the global environment.
- The environmental burdens in low-income cities are much more generally falling now and within the city, where particularly the most impoverished groups suffer ill-health, vulnerable and shortened lives. Moreover, there is a serious danger that as new "green" concerns are added to the environmental agenda, the "brown" concerns will be neglected or misrepresented

Urbanization and Sustainable Development

- **Urbanization:** an increase in the proportion of a given population living in urban spaces
- Urbanization, industrialization and development occur together as joint processes
- In developing world, urbanization much more rapid than ever occurred in European countries
- Dwyer (1975:13) "in all probability we have reached the end of an era of association of urbanization with Western style industrialization and socio-economic-characteristics"

- Cities central to sustainable development (SD) – majority f the world's population will soon be located there, with all the associated physical demands (such as for food and shelter& the political, social & cultural requirements associated with the adoption of urban values.
- However, cities also provide opportunities for more SD:
    - The large numbers and concentration of people and activities provide opportunities for economies of scale (lower unit costs) in providing services such as piped water, roads, electricity.

- Risks from natural disasters can be reduced more cheaply and effectively through measures such as drainage to reduce the risk of flooding & improved buildings to better withstand flooding when it does occur.
- Potential to reduce fossil fuel consumption through increased provision & use of public transport rather than private motor vehicles & the enhanced scope for recycling & reuse presented where large numbers of people live in close proximity.
- Facilitate their involvement in local district & city level politics & partnerships; & easier for authorities to collect charges & taxes for public services & to fund environmental management

Trends

- urban change now dependent on global economy
- ‘world cities’, e.g. New York, London, Paris, Singapore, Hong Kong, Shanghai, Johannesburg, etc are the nodal points for processes of global capitalism
- decentralisation policies devolving greater authority, decision-making & finances to city and local levels
- Many ‘urban’ area residents also work in agricultural enterprises or in industries that serve rural demand
- significant environmental linkages with rural areas – through the resources they draw on (e.g. agriculture, energy supply) & the pollution they generate (influencing air & water qualities in surrounding areas)
- ‘extended metropolitan’ regions
- the influence of good (or bad) governance more significant in shaping poverty outcomes in urban than rural areas

Key processes of urban change

- without historical precedent
- Contemporary urban growth and rural–urban shifts in the South are occurring in a context of far higher absolute population growth,
- at much lower income levels,
- with much less institutional and financial capacity,
- and with considerably fewer opportunities to expand into new frontiers, foreign or domestic’ (UNCHS, 2001: 3)

Formal and Informal Economy

- ‘jobless growth’ continued to be a feature of urban change in the developing world into the 1990s and most recently is seen in the decoupling of urbanisation from economic growth in Africa
- the failure of modern urban industries to generate a significant number of employment opportunities’ (Todaro 1997)
- SAPs led to contraction in formal sector employment opportunities in the cities
- Reliance on ‘informal’ economy – refers to small-scale, unregulated, semi-legal economic activities which often rely on local, internal resources, family labour & traditional technology (60% of urban population)

Opportunities and challenges of informal sector employment

Advantages	Limitations
More buoyant and elastic in generating jobs for an increasing urban labour force than the formal sector	Low productivity of sector and its lack of bargaining power means incomes generally lower than in formal sector
Small scale of operations and low levels of capital required lowers costs of creating employment	Nature of employment means that earnings tend to be more intermittent and erratic, making access to formal credit mechanisms by households difficult
Produces jobs that require fewer skills and less training than the formal sector	Irregular and often illegal nature of many activities makes operators in the informal sector vulnerable to official and non-official harassment and persecution
Lack of regulation and control and ease of entry makes informal sector well suited to absorption of migrants and other newcomers to the urban labour market	Unregulated nature of informal sector makes it difficult for people to obtain access to services and supports necessary for increasing earnings and moving out of poverty
Provides a safety net in times of economic crisis for those made redundant	Informal nature makes it difficult to protect those who are engaged in them, whether as paid workers or as unpaid family members, against child labour abuses or against hazards in the workplace, for example. Informal sector jobs don't produce government revenues to support welfare policies, social safety net programmes

Source: compiled from UNCHS (2001)

Poor people in poor environments

- privatisation of public utilities such as water and electricity has led to increased tariffs and charges to consumers to levels where poor families can no longer afford sufficient quantities to secure their most basic needs
- urban poverty is unlikely to be captured by indicators based on income alone
- other aspects of deprivation such as poor-quality housing or people's capacity to challenge detrimental changes in their local environments
- the inadequacy of basic services and their links to good health and education
- of the multiple deprivations that most of the urban poor face, many of these deprivations have little or no direct link to income levels, while many relate much more to political systems and bureaucratic structures that are unwilling or unable to act effectively to address these deprivations

Vulnerable environments

- many residents of cities in the developing world live in locations & settlements which are hazardous and detrimental to their own well-being.
- poverty becomes more concentrated into certain locations, often those of high ecological vulnerability, the urban poor may degrade these environments further in the course of securing their basic needs
- such locations are close to hazardous installations, e.g. chemical factories & suffer continuous air & water pollution, & the prospect of sudden fire or explosion.
- But critically for the urban poor, these locations may be close to jobs.
- Living on municipal dumps, slope failures, etc

Informal settlements

- Accessing affordable and quality housing is a considerable challenge for the urban poor.
- just one formal housing unit was added to the total urban housing stock for every nine new households in the developing world during the 1980s
- The majority of the urban population in such cities is housed in unauthorised infomal settlements
- Increasing homelessness

The urban environmental challenge

- With higher levels of economic development, industrial and energy-related pollution become more problematic, as does the inability to deal with wastes (including toxic).
- The geographical location of cities is a further factor shaping the nature of the environmental challenge (cold, mountainous, coastal, etc)
- It is important not to underestimate the significance of economic and political dimensions to sustainable urban development

The household and community level

- poorer households use their homes as centres for income generation, as workshops, as stores for goods for sale, as shops or as bars or cafés.
- The environmental risks are often greater for women & children because of the longer hours spent at home & in the immediate vicinity.
- environmental problems: hazards to health associated with poor ventilation, inadequate light, the use of toxic or flammable chemicals & the lack of protective clothing.
- A high proportion of disablement & serious injury in cities of the DCs is caused by household accidents & these are strongly aligned to poor-quality, overcrowded conditions.
- Many low-income urban dwellings are constructed of flammable materials like wood &cardboard & accidental fires are more common where families often live in one room & where it is difficult to provide protection from open fires or kerosene heaters
- Indoor air pollution aggravated by the burning of low-quality fuels such as charcoal for domestic heating & lighting. The major impacts are on respiratory health, whereby irritant fumes cause respiratory tract inflammation, repeated exposure leading to the onset of chronic obstructive lung disease.
- Urban indoor pollution is currently a major cause of premature death in the developing world

Water and sanitation

- Most critical determinant of human health (wherever people live) is access to adequate supplies of clean water
- WHO estimates 80% of all sickness & disease worldwide related to inadequate water (quantity and quality) & sanitation
- Environmental improvements made in the quality of available water & in the disposal of excreta, illness & the burden of disease have been dramatically reduced & the impact on mortality has been even greater
- More than 250 million urban residents currently have no ready access to safe piped water
- When access to water is restricted due to time taken in queuing and transporting water back to homes, low-income urban residents often draw water from surface sources (often, in effect, open sewers) or purchase water (of unknown quality) from vendors.
- Costs of such water: 4-100 X higher than piped supply

- Costs further limits the amounts of water used at the household level & is therefore an important determinant of environmental health
- For households with no provision for individual or shared sanitation within their homes, defecating within ditches, streams, parks or other open spaces or into some container
- poor sanitation leads to dangers for the widest community of direct exposure to faeces near homes and the contamination of drinking water.
- Cramped housing conditions of many informal settlements aggravate the rapid transmission of disease between individuals, such as pneumonia and tuberculosis.
- Where waste is collected, in 90% of cases it is discharged untreated & directly into rivers, lakes and coastal waters thus compounding local environmental burdens.

Means for ensuring better access to environmental services by low-income groups

- Reducing the cost of better-quality housing, infrastructure, services – keeping down unit costs, changing the 'official' standards required
- Using credit as a means to allow low-income households to afford/spread costs/cope with fluctuating incomes
- Recovering costs from users and using these to finance other improvements
- Strengthening community organisations to increase their capacity to improve conditions themselves, to negotiate with others, secure additional resources and to contest measures that may impoverish them.

The city and the wider region

- on a global scale only around 1% of the total land surface is under urban use
- Still urban developments worldwide are encroaching on some of the last remaining & most-valued reserves of natural vegetation, including mangrove swamps, protected wetlands, prime agricultural lands and forests.
- Environmental degradation in peri-urban areas is also occurring through the expansion of unplanned, squatter settlements into areas susceptible to flooding or landslides
- lack of stringent pollution control legislation generally in the developing world has been an important factor in attracting industrial production facilities (often transnational enterprises) to cities
- EPZs popular policy for governments of DCs
- sulphur dioxide pollution & the concentration of suspended particulates resulting mainly from industrial production & the burning of coal, oil & biomass fuels is a major problem
- Congested roads and poorly maintained vehicles, for example, are a growing source of 'photochemical' (particularly lead and carbon monoxide) pollution as vehicles increase
- Pollution could account for between 2 and 5% of all deaths in these regions
- commercialisation of land and agricultural markets in surrounding regions and its attendant problems
- Rural to urban migration positive impacts on rural economies e.g. wage remittances, but often negative consequences: e.g. supply of labour at key points in the agricultural calendar & loss of entrepreneurial skills
- Water, fuelwood, electricity supply all have environmental impacts on rural areas; also, water pollution due to inadequate provision for the safe disposal and dispersal of industrial and domestic waste into rivers

Towards sustainable urban development

- Important: capacity of citizens' groups to 'identify local problems & their causes, to organise & manage community-based initiatives & to monitor the effectiveness of external agencies working in their locality' – depends substantially on city authority level establishment of an ***effective stakeholders' participation system in decision-making***

- City authorities remain responsible for many functions critical to improving urban environments but are constrained due to ***inadequate transfer*** of national finances to this level.
- There are also many issues, e.g. reduction of greenhouse gas emissions, promotion of more sustainable international trade practices & other essential elements of sustainable urban development that require ***actions on behalf of institutions beyond the city level***.

The effectiveness of city authorities

- City authorities responsible for: regulating building and land use, providing systems of water supply, sanitation and garbage collection, controlling pollution, managing traffic, delivering emergency services, and providing health care and education.
- National and city authorities responsible for providing the framework within which private as well as community-based developers operate, including the political context in which markets and local democracy work.
- The political nature of sustainable urban development should not be underestimated.
- Environmental management is an intensely political task, as different interests compete for the most advantageous locations, for the ownership or use of resources and waste sinks, and for publicly provided infrastructure and services'.
- Yet many city governments in the developing world are seriously constrained in terms of the finances and professional and technical competencies necessary to provide the investments, services and pollution control central to healthy urban environments
- If local authorities are to address their challenges of environmental management more effectively, there is a need to devolve more responsibility for initiating, determining the rate of, and administering systems of local taxation.
- The fact that capital is limited demands a more profound knowledge of the nature of environmental problems and their causes to allow limited resources to be used to best effect . . . potential solutions will need to be discussed locally and influenced by local citizens' own needs and priorities'
- Often a mismatch between conventional professionally led urban development strategies and the realities of urban development as experienced by the poor
- Need to support the strategies that emerge from people's own activities to better meet the needs of urban poor, with new relationships between professionals/the state & local residents that enable both parties to contribute to new solutions in urban development
- Establishing new alliances & partnerships and tapping into the knowledge & capacities of the local urban population are two core (interrelated) characteristics of 'good city governance' – a critical condition for sustainable urban development

Utilising community organisations and local innovation

- 'Often through no choice of their own, low-income households are de facto managers of the local environment' (WRI, 1996: 134)
- understanding is now emerging not only of the value of local initiatives per se, but of the preconditions which enable successful urban environmental management based on community organisations to be generated more widely

Figure 5.9 ***The meaning of sustainable development as applied to urban centres***

Meeting the needs of the present . . .

- Economic needs: include access to an adequate livelihood or productive assets; also economic security when unemployed, ill, disabled or otherwise unable to secure a livelihood.
- Social, cultural and environmental health needs: include a shelter which is healthy, safe, affordable and secure, within a neighbourhood with provision for piped water, sanitation, drainage, transport, health care, education and child development. Also a home, workplace and living environment protected from environmental hazards, including chemical pollution. Also important are needs related to people's choice and control – including homes and neighbourhoods which they value and where their social and cultural priorities are met. Shelters and services must meet the specific needs of children and of adults responsible for most child-rearing (usually women). Achieving this implies a more equitable distribution of income between nations, and in most, within nations.
- Political needs: includes freedom to participate in national and local politics and in decisions regarding management and development of one's home and neighbourhood – within a broader framework which ensures respect for civil and political rights and the implementation of environmental legislation.

. . . without compromising the ability of future generations to meet their own needs

- Minimising use or waste of non-renewable resources: including minimising the consumption of fossil fuels in housing, commerce, industry and transport plus substituting renewable sources where feasible. Also, minimising waste of scarce mineral resources (reduce use, re-use, recycle, reclaim). There are also cultural, historical and natural assets within cities that are irreplaceable and thus non-renewable – for instance, historic districts and parks and natural landscapes which provide space for play, recreation and access to nature.
- Sustainable use of renewable resources: cities drawing on freshwater resources at levels which can be sustained; keeping to a sustainable ecological footprint in terms of land area on which producers and consumers in any city draw for agricultural crops, wood products and biomass fuels.
- Wastes from cities keeping within absorptive capacity of local and global sinks: including renewable sinks (e.g. capacity of river to break down biodegradable wastes) and non-renewable sinks (for persistent chemicals; includes greenhouse gases, stratospheric ozone-depleting chemicals and many pesticides).

Common characteristics of sustainable urban development

1. Support in terms of housing improvement in accessing land, finance and materials
2. A more holistic view of human settlements than just the physical structure; includes the critical issue of social organisation ('building the community'); essential for solving immediate problems & long-term benefits
3. Involving women in community development brings substantial urban improvements; women regularly take responsibility for providing family consumption needs as well as the needs of the community
4. NGOs are important 'outsiders' - acting in the role of support & facilitation rather than taking on what community organisations can do on their own
5. The limited financial capacities of low-income can be overcome (next section)

Understanding the processes and patterns

- A comprehensive, more flexible and less ideographic conceptual approach for urban management
- "Sustainable urbanization" [**Figure below]**

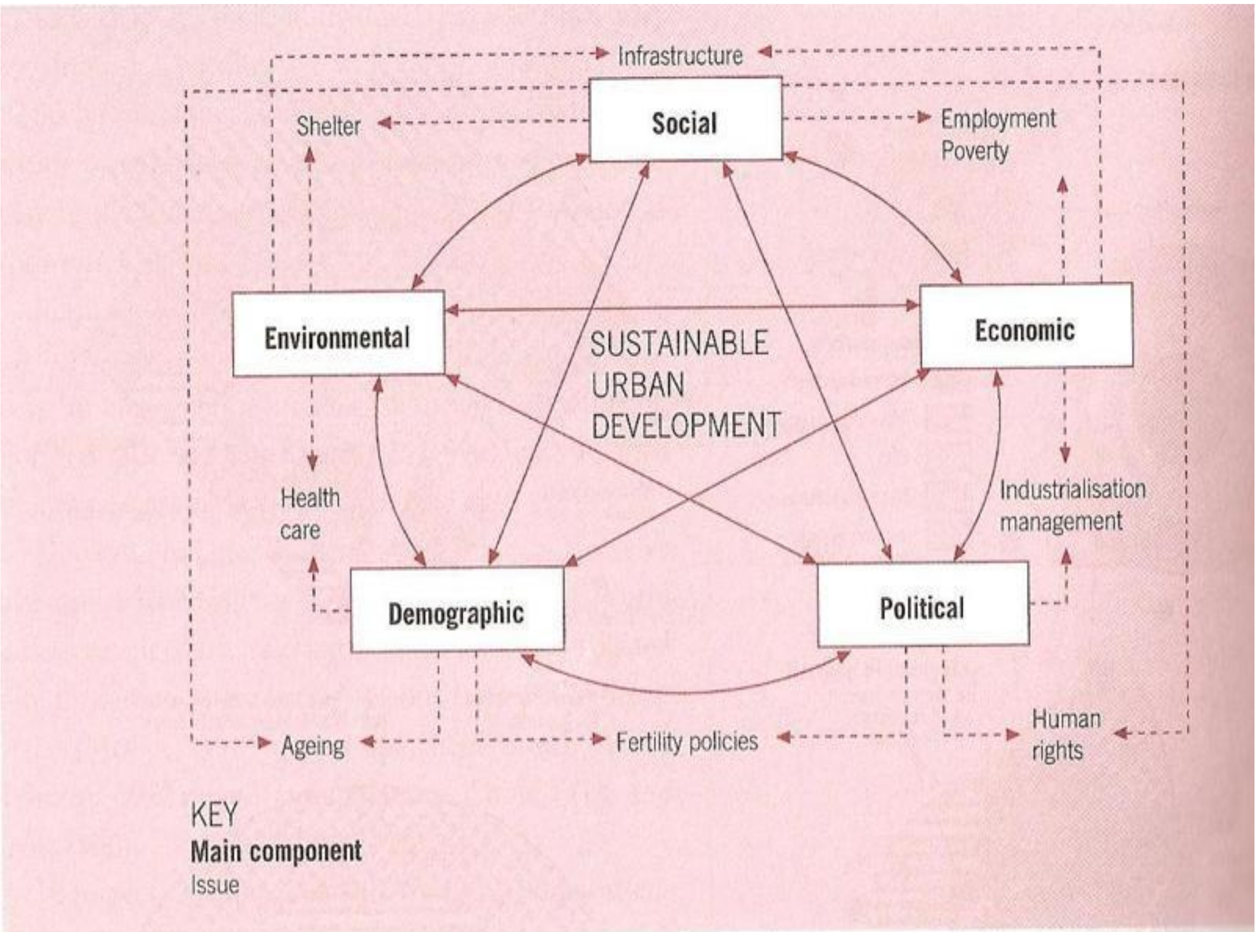


Figure 9.22 The main components of sustainable urbanisation

Sustainable development in the developing world: an assessment

Summary

- There has recently been a rapid development of tools for assessing sustainable development targets and outcomes, but there continue to be challenges for capturing processes of change and the more qualitative dimensions of sustainability.
- The notion of 'common futures' is used to assess recent evidence of progress towards sustainable development at a number of scales in terms of the extent to which more inclusive patterns and processes or areas of widening dispute and difference are revealed.
- Assessing the financial needs to implement sustainable development is problematic. There is much evidence that more sustainable patterns can be created without large finances and also that there are many barriers that are not closely linked to income. Ongoing challenges of debt relief and enhancing the global benefits of further trade expansion in particular are argued to be more important than questions of levels of targeted finance for conservation or aid per se.
- Whilst there have been substantial successes towards more sustainable development interventions based on community participation, these outcomes require changes also by institutions beyond the local level. Processes of empowerment involve difficult political challenges and community participation cannot be considered a panacea for sustainable development.

Introduction

- The practice of sustainable development has to be understood as an inherently political and conflictual endeavour with those with more power best able to influence outcomes in their favour (Peet and Watts, 2004; O'Riordan, 2000).
- SD fostered new ways in which organisations relate with each other
- sustainability rests on inclusivity and reconciling different needs and interests at the local level

Assessing progress towards sustainable development

- the United Nations has been working to develop a set of indicators based on the chapters of Agenda 21, for use by individual countries
- For some authors, trying to 'tie down and measure' sustainability is a 'futile exercise in measuring the immeasurable'
- Furthermore, the holistic nature of sustainable development (the many interdependent dimensions) and the importance of temporal scale (intergenerational issues) present substantial challenges for the development of indicators which fundamentally seek to break down a complex system into its component parts
- But, to make the right decisions we all need credible, accessible and timely information. Hence the advent of the indicator

Assessment initiatives

- companies are now reporting to stakeholders (including consumers) not just in terms of financial excellence but also social and environmental performance (so-called 'triple bottom line accounting').
- the Sustainable Development Goals which replaced the Millennium Development Goals in 2015 can be considered as key indicators of global sustainable development; all the SDGs are specific, quantifiable and directly measurable
- 1999, experts from 5 continents assembled by the International Institute for Sustainable Development - the outcome was the ***Bellagio Principles***: provide guidelines for the assessment process as a whole,

from establishing the vision of sustainable development through to ensuring that continued capacity for assessing progress exists

The Bellagio Principles for Assessment

1. Guiding vision and goals assessment of progress toward sustainable development should:
   - be guided by a clear vision of sustainable development and goals that define that vision

2. Holistic perspective Assessment of progress toward sustainable development should:
   - include review of the whole system as well as its parts
   - consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts
   - consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms

3. Essential elements Assessment of progress toward sustainable development should:
   - consider equality and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate
   - consider the ecological conditions on which life depends
   - consider economic development and other, non-market activities that contribute to human/ social well-being

4. Adequate scope Assessment of progress toward sustainable development should:
   - adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short-term decisionmaking
   - define space of study large enough to include not only local but also long-distance impacts on people and ecosystems
   - build on historic and current conditions to anticipate future conditions – where we want to go, where we could go

5. Practical focus Assessment of progress toward sustainable development should be based on:
   - an explicit set of categories or an organising framework that links vision and goals to indicators and assessment criteria
   - a limited number of key issues for analysis
   - a limited number of indicators or indicator combinations to provide a clearer signal of progress
   - standardising measurement wherever possible to permit comparison
   - comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate

6. Openness Assessment of progress toward sustainable development should:
   - make the methods and data that are used accessible to all
   - make explicit all judgements, assumptions, and uncertainties in data and interpretations

7. Effective communication Assessment of progress toward sustainable development should:
   - be designed to address the needs of the audience and set of users
   - draw from indicators and other tools that are stimulating and serve to engage decision-makers

- aim, from the outset, for simplicity in structure and use of clear and plain language

8. Broad participation Assessment of progress toward sustainable development should:
    - obtain broad representation of key grassroots, professional, technical and social groups, including youth, women, and indigenous people – to ensure recognition of diverse and changing values
    - ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action

9. Ongoing assessment Assessment of progress toward sustainable development should:
    - develop a capacity for repeated measurement to determine trends
    - be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently
    - adjust goals, frameworks, and indicators as new insights are gained
    - promote development of collective learning and feedback to decision-making

10. Institutional capacity Continuity of assessing progress toward sustainable development should be assured by:
    - clearly assigning responsibility and providing ongoing support in the decision-making process
    - providing institutional capacity for data collection, maintenance, and documentation
    - supporting development of local assessment capacity

Ecological footprint

- An audit or quantification of human use of nature is made in relation to the assessed biophysical constraints of the globe as an indicator of sustainability.
    - Starting point in ecological foot-printing: all organisms make some impact on earth.
    - That impact relates to the 'quantity' of nature that is used to sustain consumption patterns and the key question is of whether that load exceeds what nature can support.
    - Footprint analysis estimates the area of land that would be necessary to sustainably support those consumption patterns.
    - It is related to the notion of carrying capacity, but rather than asking 'how many people can the earth support?', ecological footprint analysis asks '**how much land do people require to support themselves**?'

A common future?

- global nature of sustainable development
- suffering from environmental degradation is almost universal in the sense that contemporary pollution has an international impact and local pollution problems are repeated the world over (Yearley, 1995). Furthermore, deprivation in its many guises is also a problem which affects individuals, communities and countries worldwide
- concerns for how the *justices* (development and environment) are distributed across society (as well as spatially)
- Many international fora on environment and development & expansion of Multilateral Environmental Agreements is evidence of the common nature of the global challenge of SD has been recognised at the highest political level
- An understanding of *common* futures was also seen to underpin the activities of transnational social movements
- increasingly people and places of the globe are being linked in empathy and solidarity

- Transnational social movements currently connect people globally through what are understood as related and shared struggles and resistances in the spheres of environment, economy and culture.
- But, evidence of *difference* and *disputed* understandings of the future challenges in sustainable development. For example, it is widely argued (by academics and representatives of developing world governments) that the sustainable development agenda at the international level is not commonly shared, but rather, dominated by a narrower 'northern' interest.
- In short, the argument is that the concern is for issues of 'Global Environmental Change, GEC' (such as the implications of climate warming and biodiversity conservation on future generations) rather than for international distributive issues of poverty that impact on current generations. Furthermore, as suggested by Leach and Mearns (1996), global images of shared environmental crises get a lot more airing than local views of those supposedly experiencing the problems.
- During the UNCED proceedings of 1992, for example, the *mutually incompatible* demands of the industrialised and developing regions - the northern countries focused on the conservation of the 'sinks' whilst countries of the South wanted the causes of climate change to be tackled.
- tension continues such as over the 'fairness' of the targets within the Kyoto protocol.
- lack of concern at UNCED about poverty and distributional issues: 'In fact, as a comparison between the report [WCED] and the conference [UNCED] shows, the lack of relationship between them is bewildering, when one is explicitly a follow up to the other' (Kirkby et al., 1995: 11)

Level playing field?

- Proponents of free trade (and neo-liberal development ideas generally) emphasise the global benefits that will flow from enhanced trade and economic activity, the campaigns of NGOs such as Oxfam are centred around how the international trade rules currently don't constitute a '***level playing field***'.
    - Their argument is that multilateral trade arrangements do not constitute a common starting point nor do they present equal opportunities for development in the near future.
    - Furthermore, the Oxfam campaign looks to expose the unfairness and inequality now occurring, whereby the less developed nations are expected (and conditioned to do so under SAPs) to act in certain ways (i.e. open their economies and markets to trade and foreign investment), whilst others (more powerful countries like the US, the UK and Japan) continue to operate protectionist policies.
- At all scales, the ***more economically powerful groups*** are generally more able to ***displace their environmental*** problems onto others in different places and/or into the future
- Contested priorities in SD within communities, often underpinned by ***differences in power*** according to wealth, but also by ***gender***
- The substantial challenges for SD in practice that emerge through the requirement to ***understand heterogeneous communities*** at the local level and to engage in participatory processes of research and planning

EXPLOITATION AND POLLUTION OF NATURAL RESOURCES: IMPACTS ON HUMAN AND ENVIRONMENTAL WELLBEING

WATER RESOURCES AND WATER USES

- Water has no alternative—it is known as “life”. It is essential for the sustenance of all living organisms including plants, animals and man.
- All plants, insects, animals and humans have 60–95% water in their bodies. This water is partly released in the form of sweat, excreta, urine and vapour
- Besides much water is also needed for body growth, nutrition, etc. So, it is absurd to think of life without water.
- But our usable water resources like any other natural resource is finite and is likely to be exhausted within a century.
- Moreover, it is getting polluted by man-made activities and unfit for use sooner than expected.
- Water crisis is more serious than food or population crisis since food production or population problems are irrelevant without water supply.
- Use of polluted water itself takes toll of 25,000 people all over the world every day.
- The world’s total quantum of water is 1.4 billion cubic kilometers; if all the sea beds could be filled up and brought at the level of the earth’s surface, then the entire water in the seas would cover the earth’s surface and make it 2.5 km.—deep water mass.
- About 97 per cent of earth’s water supply is in the ocean which is unfit for human consumption and other uses due to high salt content. Of the remaining 3 per cent, 2.3 per cent is locked in the polar ice caps and hence out of bounds. The balance 0.7 per cent is available as fresh water but the bulk of it, 0.66 per cent, is ground water and the rest 0.03 per cent is available to us as fresh water in rivers, lakes and streams.
- The break-up of this 0.03 per cent fresh water is—lakes and ponds 0.01 per cent, water vapour 0.001 per cent, rivers 0.0003 per cent and water confined in plants, animals and chemicals 0.0187 per cent [United National Water Conference Report, Argentina (1977)]

WATER POLLUTION

- The normal uses of water for public supply are—recreation (swimming, boating, etc.), fish, other aquatic life and wild life, agriculture (irrigation), industry, navigation, etc.
- Any change in the dynamic equilibrium in aquatic ecosystem (water body/biosphere/atmosphere) disturbs the normal function and properties of pure water and gives rise to the phenomenon of water pollution.
- The symptoms of water pollution of any water body/ground water are:
  - Bad taste of drinking water
  - Offensive smells from lakes, rivers and ocean beaches
  - Unchecked growth of aquatic weeds in water bodies (eutrophication)
  - Dead fish floating on water surface in river, lake, etc
  - Oil and grease floating on water surface
- The quality of water is of vital concern for mankind since it is directly linked with human welfare
- Historically, faecal (human excreta or stool) pollution of drinking water caused water-borne diseases which wiped out entire populations of cities; water-borne diseases, e.g. jaundice, hepatitis, cholera, dysentery, etc kill thousands globally

- The major sources of water pollution are domestic sewage from urban and rural areas, agricultural runoff (wash water) and industrial waste which are directly or indirectly discharged into water bodies.

Water Pollutants

The large number of water pollutants are broadly classified under the categories:

1. Organic pollutants
2. Inorganic pollutants
3. Sediments
4. Radioactive materials
5. Thermal pollutants

1. Organic Pollutants

- Include ***domestic sewage, pesticides, synthetic organic compounds, plant nutrients (from agricultural run-off), oil, wastes from food processing plants, paper mills and tanneries***
- These reduce dissolved oxygen (D.O.) in water; dissolved oxygen (D.O.) is essential for aquatic life, the optimum level being 4–6 ppm (parts per million)
- Decrease in D.O. value is an indicator of water pollution; organic pollutants consume D.O. through the action of bacteria present in water
- ***Sewage and agricultural run***-off provide plant nutrients in water giving rise to the biological process known as eutrophication
- ***Large input of fertiliser*** and nutrients from these sources leads to enormous growth of aquatic weeds which gradually cover the entire waterbody (*algal bloom*). This disturbs the normal uses of water as the water body loses its D.O. and ends up in a deep pool of water where fish cannot survive.
- The production of ***synthetic organic chemicals*** multiplied more than 10 times since 1950; these include fuels, plastic fibres, solvents, detergents, paints, food additive, pharmaceuticals, etc.; their presence in water gives objectionable and offensive tastes, odour and colours to fish and aquatic plants
- ***Oil pollution*** of the seas has increased over the years, due to increased traffic of oil tankers in the seas causing oil spill and also due to oil losses during off-shore drilling
- Oil pollution reduces light transmission through surface water and hence reduces photosynthesis by marine plants, decreases D.O. in water causing damage to marine life (plants, fish, etc.) and also contaminates sea food which enters the human food chain
- ***Pesticides*** have been largely used for killing pests and insects harmful to crops and thereby boosting crop production. They include insecticides (for killing insects), e.g. DDT (dichloro diphenyl trichloroethane), herbicides (for killing weeds and undesirable vegetation) and fungicides (for killing fungi and checking plant disease).
- But pesticide residues contaminate crops and then enter the food chain of birds, mammals and human beings. The persistent pesticide, viz., DDT (which is not degraded in the environment) accumulates in food chain, getting magnified in each step from sea weed to fish and then to man by about ten thousand times
- Thus, the average level of DDT in human tissues is found to be 5–10 ppm

2. Inorganic Pollutants

- Consists of inorganic salts, mineral acids, metals, trace elements, detergents, etc.
- ***Acid mine drainage***: Coal mines, particularly those which have been abandoned, discharge acid (sulphuric acid) and also ferric hydroxide into local streams through seepage
- The acid on entering the waterbody destroys its aquatic life (plants, fish, etc.)

3. Sediments

- Soil erosion, as a matter of natural process, generates sediments in water
- Solid loadings in natural water are about 700 times as large as the solid loading from sewage discharge
- Soil erosion is enhanced 5–10 times due to agricultural and 100 times due to construction activities
- Bottom sediments in aquatic bodies (streams, lakes, estuaries, oceans) are important reservoirs of inorganic and organic matter, particularly trace metals, e.g. chromium, copper, nickel, manganese and molybdenum

4. Radioactive Materials

- Radioactive pollution is caused by mining and processing of radioactive ores to produce radioactive substances
- Radioactive materials are used in nuclear power plants, radioactive isotopes in medical, industrial and research institutes and nuclear tests
- The discharge of radioactive wastes into water and sewer systems is likely to create problems in future

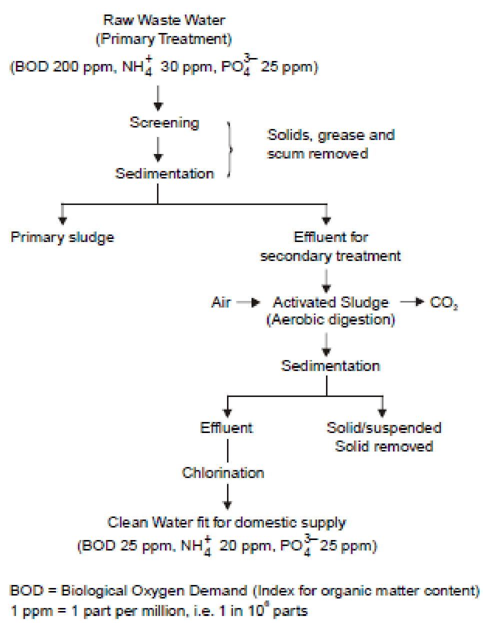
5. Thermal Pollutants

- Coal-fired or nuclear fuel-fired thermal power plants are sources of *thermal pollution*
- The hot water from these plants is dumped as waste into nearby lake or river where its temperature rises by about 10° C
- This has harmful effect on aquatic life in the water body whose D.O. is reduced and as a result, fish kill is quite common

Ground Water Pollution

- Ground water is relatively free from surface contamination as it is located more than about 15 meters below the land surface and the surface water gets filtered or screened by the underlying layers of soil, sand and stone pieces
- Nevertheless, it gets contaminated due to leaching of minerals below the earth's surface

WASTE WATER TREATMENT



Municipal waste water treatment (primary and secondary)

Domestic Waste Water Treatment

- Sewage treatment plants, in general, depend on biological decomposition of non-toxic organic wastes using bacteria
- Such biological decomposition is carried out under aerobic conditions, i.e. in presence of plenty of oxygen
- The process, commonly used for municipal waste water, is shown in Figure above

$$\begin{array}{llll} \text{Organic wastes} & + \quad O_2 & \xrightarrow{\text{bacteria}} & CO_2 \text{ (carbon dioxide)} \\ \text{(carbon, oxygen,} & \text{(oxygen)} & & + H_2O \text{ (Water)} \\ \text{hydrogen, sulphur,} & & & + NO_3^- \text{ (nitrate)} \\ \text{fluorine)} & & & + NH_4^+ \text{ (ammonium ion)} \end{array}$$

- In the first stage, solid wastes are removed from water by screening—any scum (suspended matter) is removed and the sludge (muddy solid or sediment) allowed to settle at the bottom
- The residual liquid is exposed to biological oxidation of soluble organic materials through a bed of microbes in activated sludge
- Then the solids are removed after sedimentation
- Finally, the liquid effluent is subjected to chlorination for destroying pathogenic micro-organisms. Now this effluent is fairly clean and suitable for domestic use

Drinking Water Supply

- Treatment of drinking water supply is a matter of public health concern
- Water treatment plants, in general, are simpler than sewage treatment plants
- They operate in three steps:
  (i) aeration to settle suspended matter;
  (ii) coagulation of small particles and suspended matter by lime and ferric chloride;
  (iii) disinfection by chlorination to kill viruses, bacteria, etc.
- The purified water is then supplied by municipalities through pipes for domestic uses.

Industrial Waste Water Treatment

- Industrial wastes contain toxic chemicals which can damage the environment (water, soil, air) much more than domestic sewage
- These waste liquids (effluents) can be purified by filtration using activated charcoal or ion exchange resins
- Activated charcoal has large surface area and is an effective filter medium for adsorption of organic molecules
- Synthetic organic ion exchange resins are very useful for removal of industrial waste metals (cations) and non-metals (anions)

WATER QUALITY

- It is essential to enforce water quality standards in the interest of public health
- Polluted water generates water-borne diseases which kill millions of people every year all over the world, particularly in developing countries
- Standards for water quality parameters (indicators) for drinking water are a matter of priority for national governments

AIR RESOURCES

- The atmosphere has, broadly speaking three types of constituents—major, minor and trace
- Pure (pollution-free) dry air at ground level has the components as follows, expressed in percentage by volume (within brackets):
    - (i) Major components Nitrogen (78.09) Oxygen (20.94) Water vapour (0. 1)
    - (ii) Minor components Argon (0.9) Carbon dioxide (0.032)
    - (iii) Trace components Neon (0.0018) Helium (0.0005) Methane (0.0002), etc

Structure

- The atmosphere may be broadly divided into four regions as shown in the Table below
- It extends up to 500 km. with temperature varying from a minimum of –2° C to a maximum of 1200° C at 500 km. and above (see Table 6.1)
- The Troposphere contains 70% of the mass of the atmosphere
- Density decreases exponentially with increasing altitude
- The temperature decreases uniformly with increasing altitude. In this region air masses are constantly in circulation as there is global energy flow arising from the imbalances in heating and cooling rates between the equator and the pole

Table 6.1 Major Regions of the Atmosphere

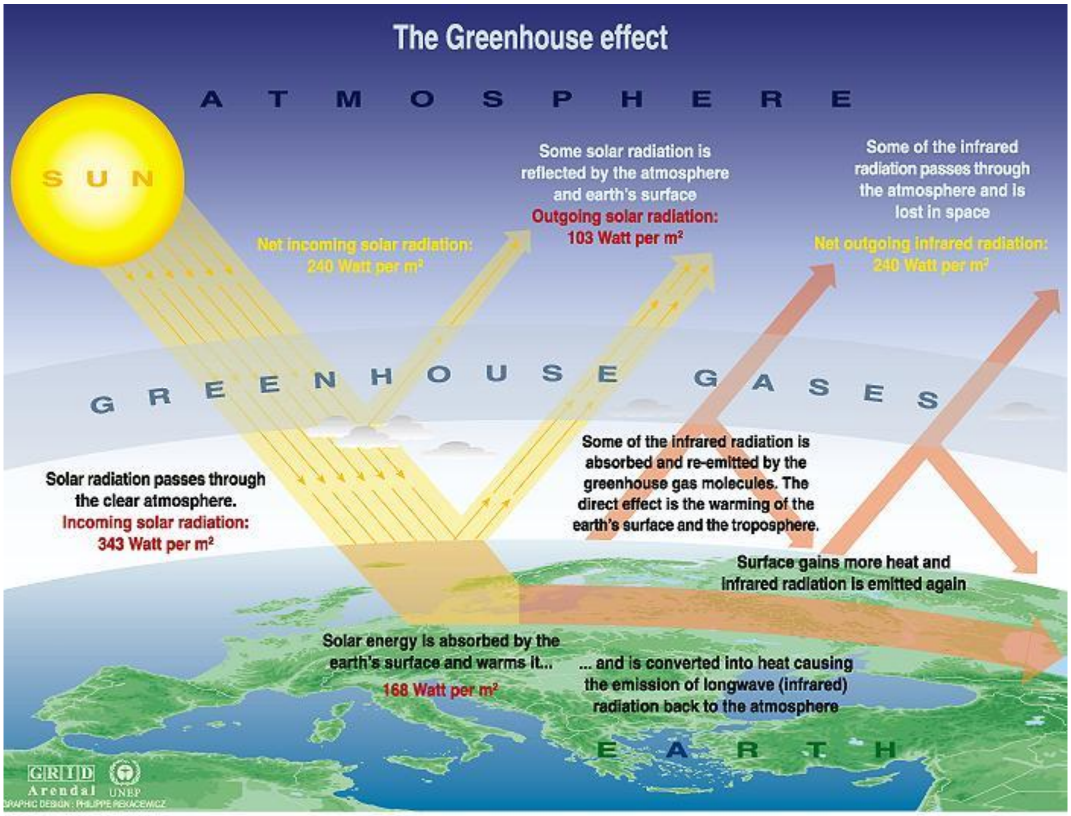
Region	*Altitude range, km*	*Temperature range °C*	*Important chemical species*
Troposphere	0–11	15 to –56	Nitrogen, oxygen, carbon dioxide, water vapour
Stratosphere	11–50	–56 to –2	Ozone
Mesosphere	50–85	–2 to –92	Oxygen$^+$, nitric oxide
Thermosphere	85–500	–92 to 1200	Oxygen$^+$, Nitric oxide$^+$

Oxygen+ = oxygen molecule/atom with +ve charge.
Nitric oxide+ means nitric oxide molecule with +ve charge.

GREENHOUSE EFFECT (GLOBAL WARMING)

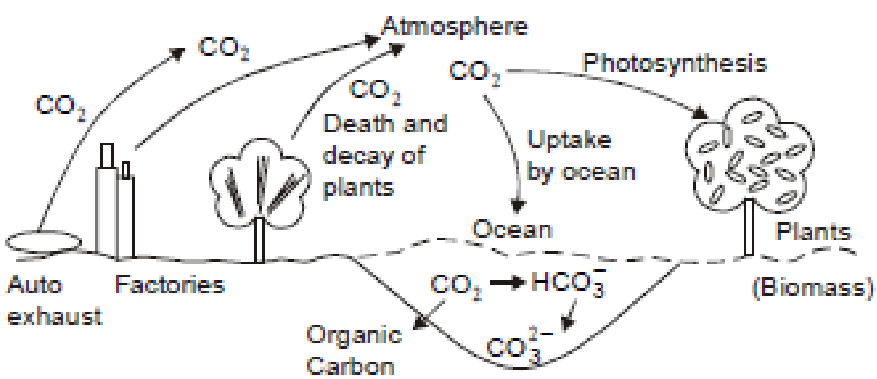
- Carbon dioxide is a non-pollutant gas in the atmosphere and a minor constituent (356 parts per million) but it is of serious concern for the environment for its ability to change global climate
- The earth's surface partly absorbs sun's rays while emits long-wave infra-red radiation (8000-25000 nanometres; 1 nanometre = 10^{-9} metre = 1 nm)
- Carbon dioxide and water vapour in the atmosphere strongly absorb infra-red radiation (14,000–25,000 nm) and effectively block a large fraction of the earth's emitted radiation
- The radiation thus absorbed by carbon dioxide and water vapour is partly returned to the earth's surface

- The net result is that the earth's surface gets heated and the phenomenon is known as the Greenhouse Effect



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

- The carbon dioxide level in air has increased from 280 ppm (pre-Industrial revolution era 1780) to 350 ppm at present in two centuries
- Fossil fuel (petrol, diesel, coal) combustion is the major source of increase of carbon dioxide level increasing at the rate of 1–2% per year
- At this rate of increase, the earth's surface temperature may rise as much as 2° C in the next 100 years
- However, nature has its check and balance system. The rate of increase of carbon dioxide is only 50 per cent of its expected magnitude due to the sinks, viz. oceans and photosynthesis by green plants (Fig. 6.3)



CO_3^{2-} = Carbonate, HCO_3^- = Bicarbonate

Fig. 6.3 Sources and sinks of carbon dioxide

Impacts of global warming

1. A slight rise in temperature even by 1°C, can have adverse effect on world food production
2. The biological productivity of the ocean will fall due to warming of the surface layer. This reduces transport of nutrient from deeper layers of the ocean to the surface by vertical circulation. Moreover, there will be less photosynthesis by marine plants. In other words, the production of sea food (marine plants and fish) will decline.
3. Another disastrous effect is the rise in sea levels by as much as 15 cm in the next 100 years due to partial melting of polar ice caps. This sea level rise would threaten coastal cities

Other Greenhouse Gases

Carbon dioxide and other gases responsible for Greenhouse Effect and global warming:

- Carbon dioxide 50%
- Methane 19%
- Chloroflurocarbons 17%
- ozone 8%
- nitrous oxide 4%
- water vapour%

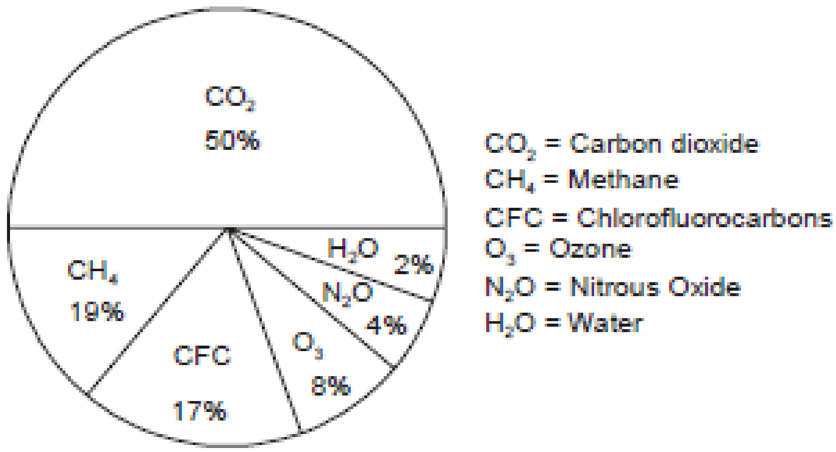


Fig. 6.4 Greenhouse gases (relative shares)

The Paris Agreement

- The Paris Agreement is a **legally binding international treaty on climate change**. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016.
- Its goal is to **limit global warming** to well below 2, **preferably to 1.5 degrees Celsius**, compared to pre-industrial levels.
- To achieve this long-term temperature goal, countries aim to **reach global peaking of greenhouse gas emissions as soon as possible** to achieve a climate neutral world by mid-century.
- The Paris Agreement is **a landmark** in the multilateral climate change process because, for the first time, a binding agreement brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects.

OZONE LAYER DEPLETION

- In the stratosphere, the second region of the atmosphere, ozone is present in small quantities but it is protective shield for the earth
- Ozone strongly absorbs ultraviolet radiation from the sun (295–320 nm) which is injurious for life on earth
- Thus, it protects living species on earth
- But recent human activities have injected some dangerous chemicals in the stratosphere which consume ozone and reduce its concentration
- This is the phenomenon of ***ozone hole in the stratosphere***
- Exhaust gases from jet aircrafts and artificial satellites discharge nitric oxide (NO), nitrogen dioxide (NO_2), etc. which immediately react with ozone

$$\underset{\text{(ozone)}}{O_3} + \underset{\text{(nitric oxide)}}{NO} \longrightarrow \underset{\text{(oxygen)}}{O_2} + \underset{\text{(nitrogen dioxide)}}{NO_2}$$

$$O_3 + NO_2 \longrightarrow O_2 + \underset{\text{(nitrogen trioxide)}}{NO_3}$$

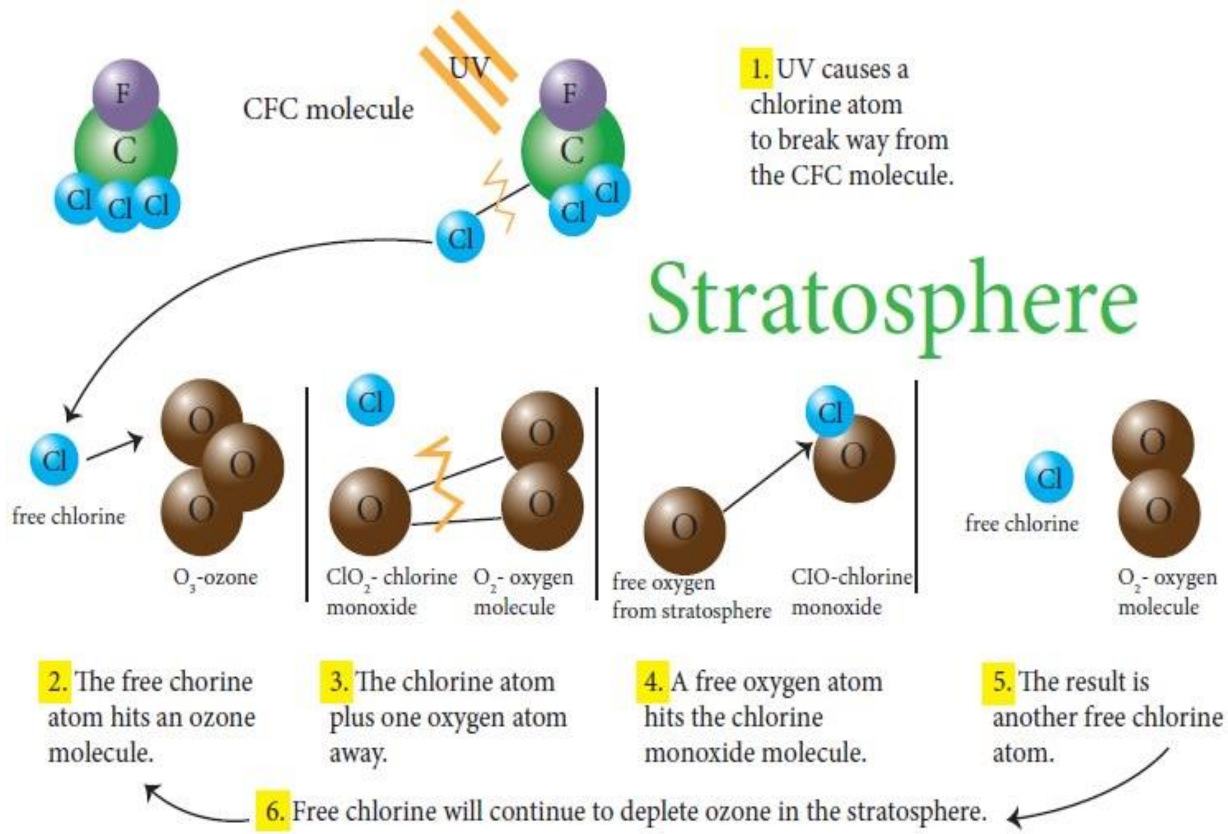
- Chloroflurocarbons (CFC) are used as coolants in refrigerators and air-conditioners. These slowly pass from troposphere to stratosphere and once there, they stay for 100 years
- In presence of ultraviolet radiation (200 nm) from the sun, CFC breaks up into chlorine-free radical (Cl) which readily consumes ozone

$$CFCl_3 \xrightarrow[\text{ultra-violet radiation}]{h\nu} CFCl_2 + Cl^{\cdot}$$

$$Cl^{\cdot} + O_3 \longrightarrow ClO^{\cdot} + O_2$$

$$ClO^{\cdot} + O \longrightarrow Cl^{\cdot} + O_2$$

- The free radical (Cl•) is regenerated and continues the chain reaction [See Figure Below]
- It is estimated that one molecule of CFC consumes one lakh molecules of ozone
- The damage by CFC continues for 100 years
- Even if CFC production is stopped now all over the world, the CFC that is already there in the stratosphere will continue to damage the ozone layer for the next 100 years
- In 1979 ozone hole was observed in the sky over Antarctica—here ozone layer thickness was reduced by 30%
- Later on, ozone hole was discovered in the sky over the thickly populated northern hemisphere. Here in winter ozone thickness was reduced by 4% and in summer by 1%
- Ozone hole allows passage of ultraviolet radiation to the earth where it causes skin cancer, eyesight defect, genetic disorder, etc. in the biosphere (man, animal and plant)
- In Montreal Conference (Montreal Protocol, 1987) and London Conference (1992) it was decided that the developed countries would totally ban CFC production by 2000 and the developing countries by 2010
- But even after the ban is enforced, the CFC and Cl• shall continue their havoc for another 100 years
- Research is on for development of CFC-substitutes as coolants for refrigerators and air-conditioners



ACID RAIN

- Much of the nitrogen oxides, NO_X and sulphur oxides, SO_X entering the atmosphere are transformed into nitric acid (HNO_3) and sulphuric acid (H_2SO_4) respectively
- These combine with hydrogen chloride (HCl) from HCl emissions (both by man-made and natural sources) and generate acidic precipitation, known as ***acid rain***
- Acid rain is a major environmental issue as it badly damages the environment including buildings and structural materials of marble, limestones, slate and mortar
- These materials become structurally weak as calcium carbonate reacts with sulphuric acid to form soluble sulphate, which is leached out by rain water:
-

$$\underset{\text{(limestone)}}{CaCO_3} + \underset{\text{(sulphuric acid)}}{H_2SO_4} \longrightarrow \underset{\text{(calcium sulphate)}}{CaSO_4} + CO_2 + H_2O$$

TEN MAJOR GLOBAL ENVIRONMENTAL CHALLENGES

- Accompanying the twentieth century's vast economic expansion have been two categories of change of enormous consequence for the natural environment

(i) First is the dramatic increase in the consumption of the earth's natural resources, principally the so-called renewable resources—the forests, the air, the soils, the fish and animal life, the freshwater

  - Renewable resources have been appropriated by humans at rates far in excess of sustainable yields. (In an ironic twist, the supply of the earth's nonrenewable resources—principally the fossil fuels and the nonfuel minerals—originally thought to be most subject to scarcities, have thus far been regularly available.)

(ii) The second development has been the exponential growth of what we have come to call pollution. Pollution is a case of too much of something in the wrong place

  - In appropriate quantities, many potential pollutants are beneficial. For example, phosphates and nitrates are plant nutrients essential to life
  - Too much of these nutrients in aquatic systems, however, and plant growth and decay sap the water of vital oxygen needed by fish and other organisms in the water. Eutrophication is the result.
  - Were it not for carbon dioxide (CO_2) occurring naturally in the atmosphere, our planet would be a frozen wasteland. The CO_2 creates a greenhouse blanket, keeping heat in to warm our atmosphere. Yet, the buildup of too much CO_2 from fossil fuel burning and other sources now threatens to alter the planet's climate and disrupt both ecosystems and human communities.
  - Today, pollution is occurring on an unprecedented scale worldwide. It is pervasive, affecting in some way virtually everyone and everything on the globe, from CO_2 in our atmosphere, to polychlorinated biphenyl (PCB) in our bodies, to acid rain on our land.

- It is the combination of these developments—high demands on renewable resources and large-scale pollution—that has given rise to the ***major global threats*** we now face.

1. Acid rain and regional-scale air pollution
2. Ozone depletion by chlorofluorocarbons and other industrial and agricultural chemicals
3. Global warming and climate change due to the increase in "greenhouse gases" in the atmosphere
4. Deforestation, especially in the tropics
5. Land degradation due to desertification, erosion, compaction, salinization, and other factors
6. Freshwater pollution and scarcities
7. Marine threats, including overfishing, habitat destruction, acidification, and pollution
8. Threats to human health from persistent organic pollutants and heavy metals
9. Declines in biodiversity and ecosystem services through loss of species and ecosystems
10. Excessive nitrogen production and overfertilization

Trend	**Overuse of Renewable Resources**	**Pollution**		
Effects of Trend*	Biotic Impoverishment Resource Scarcity	Toxification and Threats to Public Health	Atmospheric Change	Chemical Imbalances in Ecosystems
Issues	Marine Losses Desertification Deforestation Freshwater System Decline Biodiversity Loss	Persistent Toxic Chemicals	Ozone Depletion Climate Change	Acid Rain Nitrogen Excess

*Interactive effects are possible between the loss of renewable resources and pollution. Pollution impoverishes natural systems, and biotic impoverishment can make natural systems more vulnerable to pollution.

1. Acid Rain and Regional Air Pollution

Emissions of sulfur and nitrogen oxides, primarily from fossil fuel combustion such as coal-fired power plants, can be transformed chemically in the atmosphere into sulfuric and nitric acids. These acids then come back to Earth's surface through deposition, primarily through rain, giving us the popular term ***acid rain***.

- Before acid rain, most people viewed air pollution as primarily a local, urban event. In fact, the atmosphere can transport many air pollutants hundreds of miles before returning them to Earth's surface
- While these pollutants are being picked up and moved, the atmosphere acts as a chemical laboratory, transforming the pollutants as they interact with other substances, moisture, and solar energy
- Emissions of sulfur and nitrogen oxides, primarily from fossil fuel combustion such as coal-fired power plants, can be transformed chemically in the atmosphere into sulfuric and nitric acids
- These acids then come back to Earth's surface through deposition, primarily through rain, giving us the popular term *acid rain*
- Acid rain can cause damage to buildings and exposed metals, eating through surfaces over time, but its impacts on the natural environment have attracted by far the most concern
- When these acids come down in wet or dry deposition and pollute lakes and rivers, they change these water bodies' pH balances
- Increasing acidity has enormous ramifications for fish and aquatic plants, and thousands of lakes in the United States and Europe have essentially "died" from excessive acid (low pH). Acidity can also affect some forests and soils adversely
- Acid rain is also a classic transborder pollution problem. Examples of regions with transboundary acidification include the United States–Canada, Europe, and China–Japan

2. Ozone Depletion

- The Molina-Rowland research sparked an international response. The United States, Canada, and Sweden first banned inessential uses of CFC propellants, and several other countries followed suit
- World production of the two major CFCs decreased in the late 1970s, but then increased again due to non-aerosol uses
- Nations acted in concert in 1985 when they adopted a landmark treaty, the Vienna Convention for the Protection of the Ozone Layer.
- This convention and its better-known progeny, the 1987 Montreal Protocol, have now required the virtual elimination of CFCs and other ozone-destroying chemicals in the industrial countries, and the

process is now moving to focus primarily on the developing countries, with an ultimate goal of eliminating the remaining emissions.
- Scientists estimate that the ozone layer could recover by midcentury if necessary actions are taken, but the recovery process has hardly begun today

3. Climate Disruption

- Global climate change is the most threatening of the major global change issues. It is also the most complex and controversial
- We know that the "greenhouse effect" works: without the naturally occurring heat-trapping gases in Earth's atmosphere, the planet would be about 30ºC cooler on average—an iceball rather than a life-support system
- The problem arises because human activities have now sharply increased the presence of greenhouse gases in the atmosphere
- These gases prevent the escape of Earth's infrared radiation into space
- In general, the more gases, the greater the atmosphere's heat-trapping capacity
- The atmospheric concentration of carbon dioxide, the principal greenhouse gas, has increased by a third over the preindustrial level due principally to the use of fossil fuels (coal, oil, natural gas) and to large-scale deforestation
- Carbon dioxide in the atmosphere is now at its highest level in over 420,000 years.
- The concentration of methane (CH_4), another greenhouse gas, is about 150 percent above preindustrial levels
- Methane accumulates from the use of fossil fuels, cattle raising, rice growing, and landfill emissions
- Atmospheric nitrous oxide (N_2O) concentrations are also up due to fertilizer use, cattle feed lots, and the chemical industry, and it is also an infrared-trapping gas
- A number of specialty chemicals in the halocarbon family, including the CFCs of ozone-depletion fame, are also potent greenhouse gases.
- These gases are contributing to rising temperatures, about 1°F global average rise in the twentieth century, and these warming trends could increase by 2.5°F to 10.5°F in this century
- The global temperature will continue to rise well into the next century even if the levels of greenhouse gases in the atmosphere are stabilized much earlier
- The likely direct consequences of this phenomenon include a warmer and wetter planet (with greater warming toward the poles), changes in precipitation patterns leading to more floods and droughts, more severe hurricanes and cyclones, and significant sea level rise
- The following possibilities have been noted in recent surveys:
    - Significant increases in the geographic range and incidence of insect borne diseases, particularly malaria and dengue, in the tropics and subtropics. In 2004 the World Health Organization (WHO) estimated an annual human toll of 150,000 lives already lost due to climate change
    - Increased risk of hunger and famine for many of the world's poorest people who depend on traditional agricultural systems and coral fisheries
    - The displacement by rising sea levels of tens of millions of people from small island states and the low-lying delta areas of the world
    - Shifts in the distribution, structure, and functioning of terrestrial and aquatic ecosystems, and potentially irreversible changes such as loss of biodiversity and forests in national parks and protected areas
    - Decreased amounts of precipitation in many arid and semiarid areas, and decreased water supply in areas that depend on melting snow and ice from glaciers

- Although many people assume that climate change is happening gradually, as Earth's temperature slowly rises, the buildup of greenhouse gases may in fact lead to abrupt and sudden, not gradual, changes
- There is little doubt that the process of human-induced global warming has begun. Ice is melting at the poles and glaciers are retreating; spring is arriving earlier; and ranges of various species are shifting.
- Meanwhile, the process of reducing greenhouse gas emissions has hardly started. Global carbon dioxide emission climbed by 22 percent between 1980 and 2000
- To date, the industrial countries have contributed far more to the buildup of greenhouse gases than the developing countries—the United States alone is responsible for 30 percent—and they have reaped huge economic benefits in the process
- The United States emits roughly the same amount of greenhouse gases as 2.6 billion people living in 150 developing nations. Industrial countries account for about 70 percent of carbon dioxide emissions, about 3.3 tons per capita
- By contrast, the developing countries emit the rest at only half a ton per capita. Although developing country emissions of greenhouse gases are increasing rapidly, especially in China and elsewhere in Asia, it is doubtful that the developing nations will act to curb their emissions unless the industrial nations—both richer and the source of most of the climate problems we face—validate the seriousness of the issue and demonstrate their commitment to action by taking the first steps
- At the same time, the developing world is more vulnerable to climate change. Its people are more directly dependent on the natural resource base, more exposed to extreme weather events, and less capable economically and technologically to make needed adaptations. The disruption of water supplies or agriculture, the loss of glacial melt water in spring and summer, as well as rising sea levels and other impacts, could easily contribute to social tensions, violent conflicts, humanitarian emergencies, and the creation of ecological refugees. If these North–South differences are not addressed with great care, they could easily emerge as an increasing source of international tension.

4. Deforestation

- It is estimated that about half of the world's temperate and tropical forests have been cleared, mostly for agriculture
- A recent study of deforestation indicates that only about 20 percent of Earth's original forests remain in a wild, unmanaged state, and these areas are decreasing
- Forest loss has been particularly serious in the tropics, which are home to about two-thirds of our planet's plant and animal species
- The tropical forests encompass almost a billion acres of forested land in the area between the Tropics of Cancer and Capricorn
- Brazil, Indonesia, and the Democratic Republic of Congo alone contain half of the world's tropical forests, and the rest are scattered throughout Latin America, Africa, and Asia
- In recent decades, the rate of tropical forest loss has been about an acre a second. In terms of total forest area globally, these large losses are only very partially offset by increases in forest area in the United States and some other countries
- Tropical forests are particularly sensitive to disturbances. Although they are among the most productive ecosystems in terms of biological productivity, this productivity is deceptive. Most nutrients are in the plant matter itself, not in the soil
- Soils in the tropics are notoriously poor. Furthermore, the sheer diversity of species that makes tropical forests so valuable also diminishes their ability to regenerate. In a 1-acre area of forest, one could find literally hundreds of species of plants, but perhaps only a few specimens per species
- After deforestation, often the only plants that can survive in the open, nutrient-poor soil are fire-resistant grasses like Imperata, which chokes off the growth of the original species and prevents regeneration of a forest canopy

- Today, central governments own almost 80 percent of the remaining intact forests in developing countries. Forest ownership and management by central governments have sometimes resulted in mismanagement, heavy political and economic pressures to allow cutting and in-migration, and widespread corruption, cronyism, and illegal logging
- Around the world, corruption and mismanagement of forests have often gone together
- Timber concessions—the right to take trees—have been granted at below market rates and without safeguards or requirements for good management
- Government subsidization of projects like road building has further fueled both timber booms and large-scale settlement
- Another favorite policy of forest-rich countries is to promote agricultural development and ranching in previously forested areas, sometimes with government subsidies so deep that the enterprises would be essentially uneconomical without them
- These pressures for forest destruction have been both worsened and ameliorated by international factors. International development agencies like the World Bank, in the past poured many millions into dams, highways, power development, and transmigration schemes, often to the detriment of forest areas
- Critics of globalization charge that economic globalization and the World Trade Organization are magnifying the trend toward expanded logging by encouraging high levels of foreign investment, weaker domestic regulation in the face of international competition, and loss of local community controls
- On the other hand, international aid agencies (including the World Bank), conservation groups, and local authorities have cooperated in protecting many areas of unprecedented size and importance

5. Land Degradation and Desertification

- Today, about a fourth of Earth's terrestrial surface is devoted to crops, orchards, and rangelands for livestock
- Arid and semiarid zones constitute a large share of this area. These drylands are a critical source of food and account for about a fifth of the world's food production
- About a fourth of the developing world's people—some 1.3 billion in all—live on these dry and other fragile lands
- They are not naturally the most productive of agricultural lands, though irrigation can make a remarkable difference, and they are among the most ecologically vulnerable.
- Land degradation when most serious is often called desertification
- Desertification is sometimes thought of as spreading sand dunes, and though that is a modest part of the problem, the concept of desertification in use today is much broader
- **Definition**: ***Desertification*** refers to the impoverishment of ecosystems and productive capacity in drylands and has many symptoms:
  - Desolation of native vegetation and landscape de-vegetation
  - Salinization of topsoil and water
  - Reduction of surface waters and declining groundwater tables
  - Unnaturally high soil erosion

- An estimated 80% of agricultural land in dry regions suffers from moderate to severe desertification
- Africa, which is 70% dryland areas, is particularly affected
- Among desertification's many consequences are huge losses in food production, greater vulnerability to drought and famine, ecological refugees, loss of biodiversity, and social unrest.
- Desertification is typically ***caused by*** overcultivation, overgrazing, and poor irrigation practices. But behind these immediate pressures are deeper factors such as population growth, poverty and lack of alternative livelihoods, concentrated patterns of landownership and control, and large-scale

movements of people stemming from the vulnerability of many developing country populations to natural disasters and economic turmoil

- Not all the contributing factors are domestic. Desertification's immediate causes are often reinforced by international circumstances. The developing world's agricultural producers lose about US$24 billion a year due to industrial country trade barriers and subsidies, indirectly pushing many agriculturalists into marginal lands to make a living

6. Freshwater Degradation and Shortages

- Freshwater systems are one of the most degraded natural areas by human activities
- Natural water courses and the vibrant life associated with them have been extensively affected by dams, dikes, diversions, stream channelization, wetland filling, and other modifications, as well as pollution
- 60% of the world's major river basins have been severely or moderately fragmented by dams or other construction
- Much of this activity is done to secure access to the water, but power production, flood control, navigation, and land reclamation have also been important factors
- As freshwater is diverted away from natural sources, other ecosystems dependent on that water suffer, such as aquatic systems, wetlands, and forests
- Human demand for water climbed nine-fold in the twentieth century, much faster than population growth, and the trend continues today
- It has been estimated that demands for irrigation and other water needs now claim 20% of the world's river supply and that the portion will grow to 40 percent by 2020
- Yet water shortages are already apparent in many countries. Rising demands for water have meant that many rivers no longer reach the sea in the dry season
- Moreover, natural watercourses are recipients of truly enormous volumes of pollutants around the world, from raw sewage, manufacturing effluents, agricultural and urban runoff and waste heat
- Meeting the world's demands for freshwater is proving problematic. About a third of the world's people already live in countries that are classified as "water stressed," meaning that already 20-40% of the available freshwater is being used by human societies
- Projections indicate that the number of such people could rise from about 40-65% by 2025
- About a billion people, a fifth of the world's population, lack clean drinking water; 40 percent lack sanitary services
- According to WHO calculations, each year about 5 million people die from diseases caused by unsafe drinking water and lack of water for sanitation and hygiene; dehydration and diarrhea are among the most common causes of infant mortality in developing countries
- The most serious consequences of these freshwater problems are widespread poor health, constrained development of industry and agriculture, loss of services provided by natural aquatic ecosystems (including freshwater fisheries and natural flood control and water purification), species loss, and pollution of coastal areas
- Freshwater systems become matters of international concern for many reasons. Countries share over 200 river basins around the world, and many of the world's great rivers are shared by five or more countries, including the Nile
- Resolving international disputes over freshwater has long been a focus of international law and promises to be one of the major international issues of the future
- Freshwater is also becoming a commodity in national and international trade as supplies decrease in many parts of the globe
- Furthermore, safe water and sanitation have increasingly become focal points for international development cooperation. The United Nations'2003 World Water Development Report concludes that 25 years of international conferences have thus far generated only modest action on freshwater problems

7. Marine Fisheries Decline (overfishing, habitat destruction, acidification, and pollution)

- Currently, 75% of marine fisheries are fished to capacity or overfished and the global catch of fish has gone down steadily since 1988. In 2003, scientists reported that populations of large predator fish—including popularly consumed varieties such as swordfish, marlin, and tuna—are down 90 percent over original stocks; only 10 percent remain. Each year 44 billion pounds of fish—about a quarter of the total landed weight—is discarded as unwanted bycatch
- Overfishing is the key culprit, but the marine environment is also being affected by destruction of mangroves and coastal wetlands, about half of which have been lost, and by pollution and silt from runoff. The coral reefs have been particularly hard hit (about 20% lost, and 20% severely threatened).
- Beyond biodiversity loss, there are major consequences for human societies stemming from the depletion of the oceans. A fifth of the world's people get a fifth or more of their protein from fish. Fishery exports are an important economic asset for developing countries; they are responsible for half the world's export of fish. Indirectly fish products serve as a major source of fertilizer and nutrient for commercial livestock
- Many factors contribute to overfishing. A major cause has been the efforts of countries like the US and Japan to subsidize their fishing industries. In addition, many migratory species of fish are caught in the open oceans—outside the national sovereignty of any particular country (no country able to enforce limits on fisheries takings)

8. Toxic Pollutants (persistent organic pollutants and heavy metals)

- Among the most serious environmental threats to human health and to ecosystems are chemicals known as persistent organic pollutants (POPs)
- Rachel Carson's book Silent Spring, published in 1962, highlighted for a wide audience the dangers of these new manufactured chemical compounds, such as the then commonly used pesticide DDT that threatened with extinction several bird species among others
- Carson's book ignited environmental litigation that led to the banning of DDT, aldrin-dieldrin, and several other pesticides in the 1970s
- Many of the substances Carson first brought to attention were persistent and not easily biodegradable; as a result, they remain in human and animal systems and can build up, or bioaccumulate, to harmful levels in the fatty tissues of living organisms
- Certain POPs can cause cancer and birth defects as well as interfere with hormonal and immune system functioning (today virtually every person on Earth can be shown to harbour detectible levels of dozens of POPs)
- Apart from POPs, many other toxic and hazardous substances have attracted international attention, e.g. inorganic chemicals, notably the heavy metals like mercury particularly from coal-burning power plants - mercury is a potent neurotoxin
- Other toxic substances continue to pose environmental threats—hazardous and radioactive wastes and other heavy metals including lead and arsenic among them

9. Loss of Biological Diversity

- While attention has typically focused on endangered species and their possible extinction, the broader concept of biological diversity, or biodiversity, is more fundamental
- **Three dimensions of biodiversity**: the ***genetic variety*** within a given species; the millions of ***individual species*** of plants, animals, and microorganisms; and the diversity of ***different types of ecosystems*** such as alpine tundra, southern hardwood bottomlands, or tropical rainforests

- A large amount of biodiversity is concentrated in a relatively small number of "hotspots." Thirty-four biodiversity hotspots covering about 2.3% of Earth's surface, mostly in developing world regions, are home to about two-thirds of the world's species
- Species diversity (in terms of numbers per area) generally increases from the poles to the equator, and this pattern has led to biodiversity protection efforts centered heavily in the tropics and, more recently, on the biodiversity hot spots
- The generally high species counts in many tropical forests have been one of the main reasons that conservationists have been calling for the protection of these areas for last few decades
- Scientists estimate that the past loss of about half the tropical forests may have cost us 15% of the species in these forests
- Destruction of aquatic and wetland habitats has also contributed to serious biodiversity declines
- After habitat loss, the leading cause of species loss is other species, as nonnative invasive species have emerged as a huge threat to biodiversity
- But overharvesting of particular plant and animal species is also a major cause of biodiversity loss
- Toxic chemicals, extra ultraviolet radiation, and acidification from acid rain can also contribute to ecosystem impoverishment
- Climate change is not yet a major source of biodiversity loss, but many scientists expect it soon to become a major one
- The cumulative effect of all the factors is that species loss today is estimated to be perhaps 1,000 times the natural or normal rate species go extinct
- Many scientists believe we are on the brink of the sixth great wave of species loss on Earth, and the only one caused by the human species.
- Reasons for the world community to be concerned about the loss of biodiversity: The preamble to the 1982 *World Charter for Nature*: "Every form of life is unique, warranting respect regardless of its worth to man, and to accord other organisms such recognition, man must be guided by a moral code of conduct."
- In addition to ethical considerations, biodiversity is the source of the ecosystem services that make life possible—ecosystem services such as nutrient cycling, pollination, air and water purification, climate regulation, drought and flood control, not to mention the commercial products of field, forest, and stream
- Consider that many oils, chemicals, rubber, spices, nuts, honey, and fruits were first harvested in the wild; moreover, a third of all prescription drugs were originally harvested as substances found in nature
- Many nongovernmental organizations (NGOs) have made protection of biodiversity a centerpiece of their land conservation strategies and now often include attention to the economic benefits of biodiversity as a factor in protected areas plans

10. Excess Nitrogen

- The problem of excess nitrogen in ecosystems has not received similar recognition as the first nine but it deserves to be on this list of serious threats
- Earth's atmosphere is mostly nitrogen, bound together as N_2 and not reactive. Bacteria such as those associated with legumes "fix" nitrogen, changing it to a biologically active form that plants can use
- But the problem is: we humans have started fixing nitrogen too, industrially. Today humans are fixing as much nitrogen as nature does. Once fixed, nitrogen remains active for a very long time, cascading through the biosphere
- Today, the anthropogenic nitrogen is coming primarily from two sources: about 75% from fertilizers and 25% from fossil fuel combustion.

- Nitrogen fertilizers are often ammonia based; their use is a huge global enterprise: 90% of this fertilizer is wasted, though, ending up in waterways and in the air and soil. High-temperature combustion in power plants oxidizes the nitrogen to produce a variety of nitrogen oxides
- Nitrogen in waterways leads to overfertilization and, when heavy, to algal blooms and eutrophication—aquatic life simply dies from lack of oxygen. There are now over 150 dead zones in the oceans, mostly due to excess fertilization
- Nitrate in ground and surface waters is also a threat to human health
- And there is another pathway; 40% of the world’s grain goes to feed livestock, which produce vast volumes of nitrogen-rich manure, much of which ends up in the water. All this extra nitrogen is also having effects on biodiversity and natural systems—shifting the species composition of ecosystems by favoring those that respond most to nitrogen
- Absent corrective action, nitrogen added to waterways is projected to increase by 100% in the developing world between 1995 and 2020
- In the air, nitrogen oxide from fossil fuel combustion reacts with volatile hydrocarbons and sunlight to produce smog, a nasty mix of photochemical oxidants, one of which is ozone. It can also become nitric acid and contribute to acid deposition
- Ozone (from smog) and nitrous oxide (from fertilized soils) are greenhouse gases, so nitrogen fixation also contributes to global warming
- Serious though this problem is, it has yet to attract the attention that CFCs or carbon dioxide have received

ICT AND SUSTAINABLE DEVELOPMENT

1. Introduction

- Information and communication technologies (ICT or IT for short) are set of knowledge, methods, techniques and technical equipment that by means of computer and communications provide acquisition, storage and distribution of any data. Therefore, they provide tools, which can be used to address problems in all sectors of development. ICT has played an important role from the very beginning of the sustainable development era.

2. Different ICT roles in sustainable development

- Questions about sustainable IT can be focused on information that includes specific systems such as **software, hardware, resources, disposal, care, storage, and networks**. Each system represents one aspect related to the sustainable use of IT.
- The development and use of these systems are affecting the global ecosystem that sustains life on earth. For example, many observations prove that the **impact of information systems and telecommunications has as great an effect on environment as the air transport system**.
- Assessing the impact of ICT on sustainability does **not include only environmental pollution. We have to look more widely including view of how we design, maintain and operate the information systems that support our everyday life**.
- It should be done in a way which considers not only the impact on the planet today, but also how we **develop, use and preserve information resources for ourselves and for future of mankind**.
- It means that people must learn to plan use of information systems to **maximize material efficiency while minimizing their environmental impact by making IT tools more sustainable**.
- We should know when equipment has reached the end of its useful life and how to **dispose of it safely**, as well as how IT devices can be **upgraded or recycled** and given a new opportunity of functioning.

2.1. Internet and sustainable development

- Trends of development of internet services suggest a future where one will be able to connect to the internet anywhere and at any time, as well as a future where the internet will be the foundation for all information and communication exchanges.
- Together with many benefits the ICT sector itself has become a **significant source of damage to the environment, through both electronic waste and greenhouse gas emissions**.
- ICT innovation is a **complex system of interactions involving all areas of production and consumption and civil society activities**.
- The **trajectory of ICT innovation** is neither “natural” nor predetermined. It **emerges from self-fulfilling visions based on the decisions of multiple actors and their expectations about the future**” (Mansell, 2012).
- **Internet governance** should extend beyond domain name systems and IP address allocation mechanisms, and the underlying technical standards and protocols. It **should incorporate politics, security, intellectual property rights, economic issues and many others** (i.e. requires more broad-based collaboration and participation than is currently happening).

- There is a wide range of stakeholders and interests connected to the internet: the private sector, the public sector, end users, and academics.
- One of the proposed **Sustainable Development Goals targets** calls for significantly increased access to information and communications technology, and ICT are specifically mentioned in three other targets. The internet's central role in meeting information needs and facilitating development, particularly in sectors such as agriculture, health, education and enterprise are increasingly recognised.
- **Three things** in particular will be crucial to the internet's success: **multi-stakeholder participation, open, universal, interoperable standards, and collaborative security approach**.
- ICT will have even greater impact on development implementation and outcomes in the coming years. This will be especially important in five areas: **sustainable development policy, implementing sustainable development, monitoring sustainable development, leveraging big data for development, and sustainable multi-stakeholder approaches to developments**.

2.2. Impact of ICT to sustainable development

- Looking at the importance of ICT tools for sustainability, much attention is paid to the concerns of harmful effects of ICT sector.
- Most of green IT initiatives have focused on **energy efficiency strategies** by reducing the electrical energy consumption of devices such as computers, printers and networks.
- Despite some minor achievements in energy efficiency, the **direct energy consumption and carbon dioxide emissions of the ICT sector continue to increase**.
- The ICT sector already represents 8% of global electricity consumption and this is predicted to grow to 10–12% of all electrical consumption in the next decade.
- Future broadband internet alone is expected to consume 5% of all electricity.
- It is high time now to look seriously at how the ICT sector itself can adapt to a warming planet as well as assist other sectors of society in their adaptation strategies.
- A valuable framework for analysing sustainability impacts is described (Souter et al., 2010). In the core of this framework is a simple matrix:

	1st order effects	2nd order effects	3rd order effects
Economic sustainability			
Social sustainability			
Environmental sustainability			

- In this matrix, "first order effects" refer to the immediate and direct effects of a particular factor on sustainability (in this case of ICT); "second order effects" refer to indirect impacts; and "third order effects" refer to societal impacts taking place over a longer period of time.
- The matrix can be applied to the interface between any sector or policy domain and sustainable development, but is particularly helpful to understanding the impact of ICT on sustainable development
- The **first order** effects of ICT on climate change are both strong and negative.
- The **second order** effects of ICT on climate change are generally considered first order effects. These fall into two main categories. First, ICT can be used to increase the efficiency of other industries, most notably power generation and distribution and logistics in sectors such as transport. The second category of second order effects is more directly related to wider access and usage. This is the impact of dematerialization that allows the displacement of physical with virtual activity.
- **Third order** effects of ICT on climate change are those that result or will result from the kind of large scale behavioural and social structural changes. Innovations such as social networking,

homeworking and home-shopping do not just have immediate direct impacts on individual behaviour. They also have longer term direct and indirect impacts on the ways in which societies and organizations work.

- ICT may have systemic effects within society as a whole related in changes of the behaviours and values of individuals who are citizens and consumers. These effects may be positive or negative from the perspective of environmental sustainability.
- In conclusion, what happens in the ICT and internet contexts will affect what is sustainable and what can be done about sustainability in future.

3. Review summary

3.1 Summary of positive impacts of information technology:

- ICT provides new technologies, methods and tools for the development of scientific research. With ICT help it becomes possible to handle expanding data sets using new data processing and visualization capabilities. For example, **ICT provides opportunities to model, manage and control ecosystem processes at multiple scales**. ICTs also have significant potential for climate change adaptation, particularly in data collection, analysis and dissemination of information on weather, land and water resources.
- In economic development ICT and particularly the internet provides a basic platform for the growth of digital economy, in which production, distribution and consumption depend on broadband access and services. Producers have developed more intensive and more interactive relationships with suppliers and this **helps innovators and entrepreneurs to create green jobs throughout the economy and improve business sustainability**. Positive direct effects in terms of economic are connected with creation of new jobs. ICT methods and tools improve efficiency in manufacturing and trade, and industrial production is using much higher levels of automation and has become quite widely globalized. Financial markets have been transformed by electronic trading. This has made access to financial markets much more open.
- ICT **enable vastly more efficient uses of energy and material resources through the development of "smart" energy, transportation, building, manufacturing, water, agricultural, and resource management systems**. "Smart systems" also help to achieve reductions in carbon emissions.
- **Virtualization can eliminate wasteful network equipment, reducing energy and floor space**. The ICT sector's own impact on environmental wellbeing is already substantial and growing in importance. It's direct and rapidly growing contribution is particularly **important to waste and greenhouse gas emissions**.
- IT enables teams of employees to **work on projects collectively from diverse locations**. Employers in areas of high labour costs outsource development and management to contractors in areas of lower labour cost. ICT have enabled major changes in the ways that businesses are run. Most administrative functions have become computerized.
- The ICT sector itself has become a significant part of many economies.
- Technology and new software have created an environment full of **online learning opportunities, both formal and non-formal**.
- ICT is promoting lifestyle change, support the transformation of organizations and institutions in the private and public sectors through the dematerialization of products and services and the virtualization of processes and relationships. Homeworking and telecommuting are gradually becoming widespread, with increasingly significant impacts on family structure and working hours. Telework can **reduce not only automobile travel but overall energy used by reducing the amount of dedicated office space**. The internet enables anyone with basic literacy skills and the right equipment to access information and to interact directly with other users in any part of the world. It

has a large influence in domestic and small business environments, and therefore **direct effect to social equity**.

- The internet has altered and continues to alter decision-making capabilities, including **more inclusive participation in governance**. The internet alters relationships between governments and citizens.
- The internet and social media provide young people with a range of benefits, and opportunities to **empower** themselves in a variety of ways. Young people can maintain social connections and support networks that otherwise wouldn't be possible, and can access more information than ever before. The communities and social interactions young people form online can be invaluable for bolstering and developing young people's self-confidence and social skills. For individuals using the internet can be a social opportunity to meet and interact with new people online.
- ICT is a very powerful tool for enabling people with similar problems, e.g., health problems or interests like politics, films, music, to **form meaningful online communities**.

All of these new opportunities provide **positive impacts which are not always necessarily promoting sustainability**.

3.2 Summary of negative impacts of information technology:

- The **loss of jobs** in sectors undermined by internet-enabled businesses.
- Large amounts of **waste generated by the sector**; short life cycle of ICT devices; rapidly **growing greenhouse gas emissions** that result from equipment manufacturing, network operations, data centres and the use of an ever-growing range of terminal devices by an ever-growing consumer base.
- The problems with highly complex mixtures of materials in e-waste, and recovering the substances they contain without causing any toxic pollution. Even when the best reclamation technology is used, and high recycling rates are achieved, **toxic waste streams requiring safe long-term disposal are still produced**.
- The **fastest growing energy use is in the ICT sector**, following the rapid development of information technology.
- Increasing of volatility of financial market as a consequence of their transformation. This has destabilized these markets, leading to higher levels of risk, and giving greater economic power to speculators at the expense of economic planners and business managers.
- Undermining the boundaries between work and leisure, and altering relationships between employers and employees in the result of continuous availability online and through mobile phones.
- New security challenges that have arisen from the internet for both governments and citizens, from the threat of disruption to the internet itself to new forms of criminality (cybercrime). A range of questions arise about the relationship between security, surveillance, rights and privacy.
- The risk of facilitating antisocial behaviour that raises from several aspects of ICT. Using IT can be addictive and a form of social escapism.
- Possible formation of **digital divide**. If only a portion of society has access to information tools such as online learning, electronic health records, and e-government services, then society will move in direction of **greater inequality**.
- Creation of new structural problems from an information quality standpoint due to increase of computer-mediated communication, driven by dramatically lowered cost.

Short list of new opportunities provided by ICT and generated threats gathered from the reviewed literature is given in Table 1.

Table 1. Opportunities and Threats of ICT

No	Opportunities	No	Threats
1.	Creation of new jobs	1.	Natural pollution formation
2.	Economic stimulation	2.	Increase in energy consumption
3.	Waste reduction	3.	E-waste generation
4.	Power saving	4.	Access to information
5.	Work automation	5.	Information quality drop
6.	Access to information	6.	Formation of the digital divide
7.	Growth of educational opportunities	7.	Job losses
8.	Communication options	8.	Security issues
9.	Lifestyle changes	9.	Health problems
10.	Facilitation of social benefits		
11.	Development of scientific research		
12.	Security problems solving		
13.	Carbon emissions reduction		
14.	Financial market changing		
15.	Formation of new field of science and industry (ICT)		
16.	Changing of business forms		
17.	Environmental protection promotion		
18.	Decision-making process improvement		

4. Conclusions and recommendations

- The Information and Communication Technology sector's fast pace of innovation can render today's advanced technology outdated in a year or two. Information technology professionals are continually learning throughout their working lives. Therefore, one of the main requirements to young professionals by ICT companies is initiative and ability to learn. It means that in **education of information technology specialists' knowledge acquisition of special subjects and learning how this knowledge constantly can be improved are equally important things**.
- A framework should be devised for ensuring the sustainability of professional knowledge in information technology. One of the possible strategies is to **base teaching and learning processes on four milestones**:

  (i) **The first step** is to understand the requirements of the software to be developed. It means to find an answer to the question "what to do?" System analysis and modelling are an example of methods of requirements identification, and requirements specification, user stories, business needs, and prototypes are possible forms of their documentation.
  (ii) **The second step** is to plan how the requirements will be implemented in the program. It means to find an answer to the question "how to do?". Again, a lot of methods and tools can be used for development of the design, and a lot of approaches for its documentation.
  (iii) **The third step** is implementation (coding and testing).
  (iv) **The fourth step** is operation, which starts after delivery and is supported by maintenance.

- All these milestones are **connected by organizational processes, which together form the software life cycle**.
- New techniques, tools and methods should be taught and learned mainly as different forms of implementation of these basic steps. For each innovation, the essential new contribution should be highlighted without focusing exclusively on the learning of new terminologies.
- Such an approach would lay the basis for **sustainable education of information technology**.

- The **information technology industry cannot exist without education authorities**. The sector should work closely with industry and research institutions. Industry associations and other organizational structures have an important role in mutual cooperation and exchange of information. Of primary importance should be **co-operation, information exchange and coordination** both within industry and through external links.
- **Cooperation with legislative bodies** and support to introduction of innovative ideas into production are very significant. The scope of information that is related to the industry methodologies, techniques, standards and regulatory legislation is so huge that without the participation of such subsidiary bodies it becomes difficult to manage it.
- At the same time the establishment of **too large number and diversity of associations and other public organizations would create a risk**, because it may threaten communication with each other.

The need for international consensus in identifying positive and negative effects of ICT on sustainability are increasingly important. The major issues to be considered include:

(1) Information technology as necessary tools for sustainable development in all sectors
(2) ICT and the internet as a new stage of humanity in information exchange
(3) Requirements for ICT sustainability
(4) Inclusion of sustainability in software product quality characteristics
(5) Quality characteristics of internet and their evaluation, including assessment of sustainability impact
(6) Threats to the environment generated by the ICT product development and use ("Green IT" development)
(7) ICT role in education
(8) Threats dissemination with the help of IT tools.

- From the viewpoint of IT, the main task is not only universal cooperation to **promote rapid and extensive development**, but also to **ensure the sustainability of information technology itself**.
- In the ICT sector the **sustainability problems** which should be urgently tackled are a **lack of a common framework on which to base the present evolution of software development methods** and tools, and **development of internationally harmonized ICT legislation and regulations**.