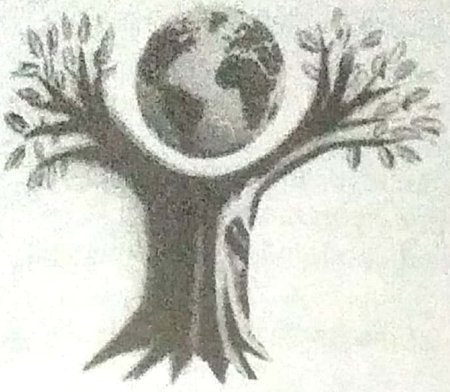


1

INTRODUCTION

"The earth provides enough to satisfy every person's need but not every person's greed."

Mahatma Gandhi

1.1 GENERAL

Throughout history, mankind has adapted to the natural variations of the Earth's system and its climate. Until very recently in the history of the Earth, humans and their activities have not featured as a significant force in the dynamics of the Earth system. But today, mankind has begun to match and even surpass the forces of nature in changing key Earth system processes.

Over the past two centuries, both the human population and the economic wealth of the world have grown rapidly. These two factors have increased resource consumption significantly, evident in agriculture and food production, industrial development, energy production and urbanization.

Human activities are now so pervasive and profound in their consequences that they too affect the Earth on a global scale in complex, interactive and accelerating ways. Humans now have the capacity to alter the Earth system in ways that threaten the very processes and components upon which humans depend. The following are few indicators of the above effect.

- In just a few generations, mankind has started the process of exhausting fossil fuel reserves that were generated over several hundred million years.
- By 2050, emissions of carbon dioxide and other gases into the atmosphere from fossil fuel burning and other human activities may raise the average temperature of the earth's lower atmosphere by several degrees. This would disrupt food production and flood low-lying coastal cities and crop lands.
- The concentrations of several climatically important greenhouse gases, in addition to CO_2 and CH_4, have substantially increased in the atmosphere.
- Chlorofluorocarbons and halons released into the lower atmosphere are drifting into the upper atmosphere and reacting with and gradually depleting the ozone faster than it is being formed. The

Environmental awareness among the public and policymakers has been growing since the 1960s, when it became widely recognized that human activities were having harmful and large-scale effects on the environment. Scientific and engineering research is also playing an increasing role in both understanding and protecting the environment. Research has demonstrated the importance of the environment to human health and well-being as well as the economic, social, and aesthetic harm that can stem from poor environmental practices. Research has suggested ways to curb harmful practices without incurring excessive costs. For example, scientific and engineering research has provided cost-effective ways to reduce the pollution in air and water in the world and has demonstrated the importance of areas, such as wetlands, that were once considered of little value to human societies and has helped to preserve natural ecosystems and the species that inhabit them.

1.2 IMPORTANCE OF ENVIRONMENTAL EDUCATION

Environment is the physical and biotic habitat that surrounds us. Environmental issues affect, and are affected by, all our activities to varying degrees. The need to have a working knowledge of environmental issues is not confined to environmental scientists, engineers, and policy makers. In our society, all educated citizens need to have a working understanding of the fundamental principles involved for environmentally responsible decision making. The knowledge and understanding of a range of concepts and connections are required in order for an interested person to think and make decisions coherently about individual and societal behaviours that affect the environment.

The major goals of environmental education programs are to raise consciousness about environmental conditions and to teach environmentally appropriate behaviour. Environmental education also aims to create an environmental ethic that fosters awareness about the ecological inter-dependence of economic, social and political factors in a human community and the environment. Changes in values, attitudes and behaviour towards the environment can ultimately result in a better quality of life.

Everything we need to survive comes from air, water, soil and energy. The greatest challenge we face is to rediscover our place on this planet. Our inventiveness has enabled us to overcome virtually any ecological barrier; hence we inhabit and exploit every part of the world. But like an exotic species moving into new areas, we lack the balances that keep us and our activities in harmony with everything else. The quality of our lives depends completely on the health and vigor of the web of living things that cleanse the air and water, create soil, capture sunlight and provides us with food and resources.

With the dawn of the new century, environmental education envisions a new paradigm of thinking that can meet the challenges of a rapidly changing world. Environmental education is evolving to be the education for sustainable and ethical development, both at a local and global level. It is environmental education that will prepare the next generation to plan appropriate strategies for addressing issues such as urban sprawl at a local level while still maintaining focus of the challenges that globalization presents on an international level. Knowledge about the environment is not an end, but rather a beginning. Knowledge about the environment promotes attitudinal and behavioural change. Therefore, environmental education is an agent of change and a step toward community empowerment.

Thus environmental education is aimed at increasing the public awareness and knowledge about environmental issues and provides facts, opinions or the skills to make informed decisions and take environmentally responsible actions. It does not advocate a particular view point or course of actions. It teaches individuals how to weigh various sides of an issue through critical thinking and it enhances their own problem solving skills.

that a comprehensive environmental literacy course include scientific, social, economic, organizational, and ethical dimensions. Environmental literacy is challenging to teach due to the complexities of the systems that make up the environment, and the roles of individual and institutional decision making with regard to the economy, ways of living, and technology choices. Interactions among the components of the environment including humans are complex and span space and time.

People of all ages have varying degrees of knowledge and comprehension about the components of the environment and their interactions. Many students are knowledgeable about the environment because of media exposure and personal interest. The ideal scheme of learning is a student centered and participatory process in which the students' existing framework of knowledge will be revealed, corrected, and enhanced.

1.4 ENVIRONMENTAL ENGINEERING

Environmental Engineering is one of the most complex and fastest-growing disciplines in engineering. The scope of the field includes issues from public health protection to aesthetics and from the impact on business development to the development of legislation, standards, regulations, and guidelines, to their enforcement and environmental protection. The issues include contaminants in gases, liquids, and solids and the phase transfers of the contaminants. The sub-specialties of environmental engineering address all these areas including the treatment of water, liquid waste, solid waste, and gaseous materials, protection of the environment through preventive measures, and the development of effective regulations. Environmental engineers should have the necessary skills to address these issues and improve the quality of life of humans and other living things in an effective, sustainable, and economical manner. A challenging aspect of environmental engineering is the rapid changes in the field due to the rate of knowledge increase in the fields of science, technology and health. Accordingly environmental engineers have to understand the fundamental change to sustainable management and the legal, social, and political components related to it.

1.5 ENVIRONMENTALISM

Although it can be argued that environmental consciousness is ancient, and forms part of many religions, it was not until the 1960s that environmentalism became an organized force. The milestone marking the birth of the environmental movement was the publication of the book ***Silent Spring*** by Rachel Carson in 1962 in the USA. *Silent Spring* inspired a new public awareness that human beings were harming the environment. Since the 1960s the movement has grown dramatically.

1.5.1 Silent Spring—The Story of DDT

In *Silent Spring*, Carson exposed the perils of the indiscriminate use of pesticides, particularly DDT (dichlorodiphenyltrichloroethane). Some twenty years earlier DDT had been identified as a powerful insecticide without precedent. It was hailed as a miracle compound and sprayed intensively on agricultural crops. People did not realize that it could cause massive harm to the environment and to human health until Carson sounded the alarm. DDT was the first synthetic insecticide, originally formulated in 1873 by a German scientist. Its inventor did not realise its potential as an insecticide. The chemical was re-discovered by Paul Hermann Müller of Switzerland in 1939. Müller's aim was to create the perfect

- Resol
- Conduct regular monitoring
- Develop, apply and enforce incentives, ... area of environmental and social performance.
- Recognition of rights and assessment of risks should be the basis for ... of stakeholders in decision making on energy and water resources development.
- Access to information, legal and other support should be made available to all stakeholders, particularly indigenous and tribal peoples, women and other vulnerable groups, to enable their informed participation in decision making processes.
- Demonstrable public acceptance of all key decisions should be achieved through agreements negotiated in an open and transparent process conducted in good faith and with the informed participation of all stakeholders.
- Decisions on projects affecting indigenous and tribal peoples should be guided by their free, prior and informed consent, achieved through formal and informal representative bodies.
- Corrupt practices should be avoided through enforcement of legislation, voluntary integrity pacts, debarment and other instruments.
- National water policies should make specific provision for basin agreements in shared river basins. Agreements may be negotiated on the basis of good faith among riparian States. They should be based on principles of equitable and reasonable utilization, no significant harm, prior information and the Commission's strategic priorities.
- Riparian states may go beyond looking at water as a finite commodity to be divided and embrace an approach that equitably allocates not the water, but the benefits that can be derived from it. Where appropriate, negotiations include benefits outside the river basin and other aspects of mutual interest.
- Dams on shared rivers may not be built in cases where riparian states raise an objection that is upheld by an independent panel. Disputes between countries can be resolved through various means of dispute resolution including, in the last instance, the International Court of Justice.

2.3 WATER RESOURCES

The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water. The amount of water in the world is limited. The human race, and the other species which share the planet, cannot expect an infinite supply. Even though water covers about two-thirds of the Earth's surface, most of it is too salty for use. Only 2.5% of the world's water is not salty, and two-thirds of that is locked up in the icecaps and glaciers. Out of the remaining about 20% is in remote areas, and much of the rest arrives at the wrong time and place, as monsoons and floods. Less than 0.08% of all the Earth's water is available to humans for real use. Yet over the next two decades our use is estimated to increase by about 40%. In 1999 the United Nations Environment Programme (UNEP) reported that 200 scientists in 50 countries had identified water shortage as one of the two most worrying problems for the new millennium (the other was global warming). We use about 70% of the water we have in agriculture. But the World Water Council believes that by 2020 we shall need 17% more water than is available to feed the world. The major factors worsening the present water crisis are the following.

- Growing populations
- Inefficient irrigation
- Pollution

There are several reasons for the water crisis. One is the simple rise in population, and the desire for better living standards. In China it takes 1 000 tonnes of water to produce one tonne of wheat. Another is the inefficiency of the way we use much of our water. Irrigation causes wastage on a large scale, with the water trickling away or simply evapour before it can do any good. Pollution is making more of the water that is available to us unfit for use.

Water on the earth is in motion through the hydrological cycle. The utilization of water for most of the users, i.e. human, animal or plant involves this movement of water. The dynamic and renewable nature of the water resources and the recurrent need for its utilization requires that water resources are measured in terms of its flow rates. Thus water resources have two facets. The dynamic resource, measured as flow is more relevant for most of developmental needs. The static or fixed nature of the reserve, involving the quantity of water, the length of area of the water bodies is also relevant for some activities like pisciculture, navigation, etc.

Increasingly, countries are seeking to solve their water problems by turning away from reliance on rainfall and surface water, and using groundwater instead. But this is like making constant withdrawals from a bank account without ever paying anything into it. Using up groundwater with out replenishing it not only causes its depletion but can also cause the rivers, wetlands and lakes that depend on it to dry out. Saline seawater can flow in to replace the fresh water that has been pumped out. The emptied underground aquifers can be compressed, causing surface subsidence—a problem familiar in Bangkok, Mexico City and Venice.

There are some ways to begin to tackle the problem. Irrigation systems which drip water directly onto plants are one, precision sprinklers another. There will be scope to plant less water-intensive crops, and perhaps desalination may play a part—though it is energy-hungry and leaves quantities of brine for disposal. Climate change will probably bring more rain to some regions and less to others and its overall impact remains uncertain. But if we are to get through the water crisis, we should heed the UNEP report's reminder that we have only one interdependent planet to share. It said: "The environment remains largely outside the mainstream of everyday human consciousness, and is still considered an add-on to the fabric of life."

Some Water Facts

- Global consumption of water is doubling every 20 years.
- Available fresh water amounts to less than one-half of 1% of all the water on earth.
- Fresh water is renewable only by rainfall at the rate of only 40 000 – 50 000 km^3 per year.
- If current trends continue by 2025 the demand for freshwater is expected to rise by 56% more than is currently available.
- The United Nations reports that currently 31 countries face water stress and scarcity.
- Throughout the world, more than one billion people drink unsafe water. Two point four (2.4) billion people, 40% of the human race are without adequate sanitation and 3.4 million people, mostly children, die every year of water-related diseases.

- By 2025 it is predicted that two-thirds of the world's population will be living in conditions of absolute serious water shortage. One-third will be living in conditions of absolute
- The world's quest for freshwater has led to widespread environmental destruction. The number of large dams built to divert water has risen from 5,000 in 1950–45000 today. The environmental impact resulting from such diversions has been devastating.
- Only 2% of the continental US rivers and streams remain free flowing, they have lost over 50% of that country's wetlands.
- Every 8 seconds, a child dies from a water-related disease.
- 50 per cent of people in developing countries suffer from one or more water-related diseases.
- 80 per cent of diseases in the developing world are caused by contaminated water.
- 50 per cent of people on earth lack adequate sanitation.
- 20 per cent of freshwater fish species have been pushed to the edge of extinction from contaminated water.

2.3.1 Drought

Drought is a complex physical and social process of widespread significance. It is not usually a countrywide phenomenon, with differing conditions in the country often making drought a regional issue. Despite all of the problems that droughts have caused, drought has proven to be difficult to define and there is no universally accepted definition because of the following.

- drought, unlike floods, is not a distinct event;
- drought is often the result of many complex factors such that drought often has no well-defined start nor end;
- the impacts of drought vary by affected sector, thus often making definitions of drought specific to particular affected groups.

The most commonly used definitions of drought are based on meteorological, agricultural, hydrological and socioeconomic effects.

Meteorological

Meteorological drought is often demarked by a period of substantially diminished precipitation duration and/or intensity. The commonly used definition of meteorological drought is an interval of time, generally in the order of months or years, during which the actual moisture supply at a given place consistently falls below the climatically appropriate moisture supply.

Hydrological

Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is measured as streamflow, snowpack, and as lake, reservoir and groundwater levels. There is usually a delay between lack of rain and less measurable water in streams, lakes and reservoirs. Therefore, hydrological measurements tend to lag other drought indicators. This drought deals more with the effects of lack of moisture has on the hydrological system as a whole. It takes longer periods of time for the lack of moisture to show up in places such as the ground water, reservoir, and lake levels. When the flow in these places is affected significantly enough, this can have economic effects on the area on things such as hydroelectric power plants and recreational areas. Though the climate/weather is the main contributor to hydrological drought, things such as changes in landscape, land use, and construction of dams also

- Drought is a slow natural hazard. Its effects often accumulate slowly over a considerable period of time and may linger for years after the termination of the event. Therefore, the beginning and the end of drought is difficult to determine.
- The absence of a precise and universally accepted definition of drought adds to the confusion about whether or not a drought exists and, if it does, its degree of severity. Realistically, definitions of drought must be region and application (or impact) specific. This is one explanation for the scores of definitions that have been developed.
- Drought impacts are nonstructural and spread over a larger geographical area than are damages that result from other natural hazards. Because drought can affect such large areas, it is far more difficult to quantify impacts and respond effectively.

Although many people consider drought a natural or physical event, it has both a natural and social component. The risk associated with drought for any region is a product of both the region's exposure to the event (i.e. probability of occurrence at various severity levels) and the vulnerability of that area or region to the event. The natural event (i.e. meteorological drought) is a result of the occurrence of persistent large-scale disruptions in the global circulation pattern of the atmosphere. Exposure to drought varies spatially, and we can do little to alter drought occurrence. Vulnerability, on the other hand, is determined by social factors such as population growth, population shifts (regional and rural to urban), demographic characteristics, technology, policy, environmental awareness, and social behaviour. These factors change over time and thus vulnerability will increase or decrease in response to these changes.

2.3.2 Conflicts Over Water

Future global conflicts could arise over control of the shared river basins on which millions of people depend for drinking water, irrigation and energy. Water could be the source of the world's next big conflicts if nations do not start cooperating to share their resources. The following facts points to the severity of the above problem and the potential for global conflicts in the near future.

- Billion people lack access to safe water and 2.4 billion lack access to adequate sanitation.
- More than 6,000 children die every day from diseases associated with unsafe water, and unsafe water and sanitation causes an estimated 80% of all diseases in the developing world.
- Water use has grown at twice the rate of the population during the past century.
- As much as 90% of wastewater is discharged without treatment in developing countries.
- One flush of a Western toilet uses as much water as the average person in the developing world uses for a whole day for washing, drinking, cleaning and cooking.

The conflicts over water around the world may be classified into the following categories.

1. ***Control of water resources*** – where water supplies or access to water is at the root of tensions.
2. ***Military tool*** – where water resources, or water systems themselves, are used by a nation or state as a weapon during a military action.
3. ***Political tool*** – where water resources, or water systems themselves, are used by a nation, state, or a group for a political goal.
4. ***Terrorism*** – where water resources, or water systems, are either targets or tools of violence or coercion by terrorists.
5. ***Military target*** – where water resource systems are targets of military actions by nations.
6. ***Development disputes*** – where water resources or water systems are a major source of contention and dispute in the context of economic and social development.

... two-thirds of its **iron deposits** lies in a belt along Orissa and Bihar border. Other haematite deposits are found in Madhya Pradesh, Karnataka, Maharashtra and Goa. Magnetite iron-ore is found in Tamil Nadu, Bihar and Himachal. ... and they constitute one-quarter of the world's

India has the world's largest **deposits of coal**. Bituminous coal is found in Jharia and Bokaro in Bihar and Ranigunj in West Bengal. Lignite coals are found in Neyveli in Tamil Nadu.

Next to Russia, India has the largest supply of **Manganese**. The manganese mining areas are Madhya Pradesh, Maharashtra and Bihar–Orissa area. **Chromite deposits** are found in Bihar, Cuttack district in Orissa, Krishna district in Andhra and Mysore and Hassan in Karnataka. **Bauxite deposits** are found in western Bihar, southwest Kashmir, Central Tamil Nadu, parts of Kerala, Uttar Pradesh Maharashtra and Karnataka.

India also produces 75% of the world's **mica**. Belts of high quality mica are, Bihar, Andhra and Rajasthan. **Gypsum** reserves are in Tamil Nadu and Rajasthan. **Nickel ore** is found in Cuttack and Mayurbanj in Orissa. **Ileminite** reserves are in Kerala and along the east and the west coastal beaches.

Silimanite reserves are in Sonapahar of Meghalaya and in Pipra in Madhya Pradesh **Copper ore** bearing areas are Agnigundala in Andhra, Singhbum in Bihar, Khetri and Dartiba in Rajasthan and parts of Sikkim and Karnataka.

The Ramagiri field in Andhra, Kolar and Hutti in Karnataka are the important **gold mines**.

The Panna **diamond belt** is the only diamond producing area in the country, which covers the districts of Panna, Chatarpur and Satna in Madhya Pradesh, as well as some parts of Banda in Uttar Pradesh. **Petroleum deposits** are found in Assam and Gujarat. Fresh reserves were located off Bombay. The potential oil bearing areas are, Assam, Tripura, Manipur, West Bengal, Punjab, Himachal, Kutch and the Andamans.

India also possesses the all-too-valuable nuclear **uranium** as well as some varieties of **rare earths**.

2.2 DAMS

It can be unequivocally stated that dams have made significant contributions to human development and the benefits derived from them have been considerable. In the following sections, the evolution of dams and the current debate on dams are discussed in detail.

2.2.1 Dams and Civilization

Farmers and rulers have been impounding water for millennia. Eight thousand years ago, the Sumerians built an irrigation-based civilization between the Tigris and Euphrates rivers. By the first century BC, low dams had been built in the Mediterranean, the Middle East, Central America, and China. Limited technology kept their height down: a fifth-century Sri Lankan dam, 34 m high, was the worlds highest for a millennium. The Grand Anaicut of Tiruchirapalli (Tamilnadu) is a dam built in the second century on river Cavery and is still in use. The age of hydropower and large dams emerged following the development of the turbine in 1832. In the beginning of the 20th century, hydro-electric plants were operating in the United States, Italy and Norway. Improvements in turbine design ushered in the mega-dam boom in the 1930s. During the last century, much of the world turned to dams to help meet escalating demands for water. Indeed, from the 1930s to the 1970s the construction of large dams became synonymous with development and economic progress. Viewed as symbols of modernization and humanity's ability to control and use nature's resources, dam construction saw a dramatic increase. This trend reached a peak in the 1970s, when on average two or three new large dams were commissioned each day somewhere in the world. The decline in dam building since then has been equally dramatic, especially in North America and Europe, where most technically attractive sites are already developed. Today, most of the world's large rivers are dammed. Worldwide, some 45 000 "large" dams (over 15 m high, according to the International Commission on Large Dams) and about 800 000 smaller ones have been constructed. Men have built dams for thousands of years for:

- Conversion of available water to useable water. 1.4 billion km^3 of water is available in the world in form of liquid water, ice and water vapour. 97% is sea water.
- Reducing variability in seasons of low flow in rivers.
- Water storage to provide insurance against uncertainty in natural water availability due to climatic variability.
- Regulating release of water for various uses such as drinking and irrigation.
- Safety from social and economic tragedies due to flood and drought conditions.
- Sustainable energy generation.

2.2.2 Purposes of Dams

- Most of the single purpose dams around the world (48% approx.) are for irrigation and therefore it contributes greatly to food production and a considerable proportion (15%) of those dams serve for domestic and industrial water supply.
- For the world as a whole, nearly 20% of dams generate electricity. However, in Europe alone, about 40% are hydro power dams.
- Other purposes include flood control (8%), recreation (4%) and to a lesser degree, inland navigation and fish farming.
- Multi-purpose dams account for a large proportion. Irrigation comes first in this category also, followed by flood control, hydro power, domestic and industrial water supply and recreation, with fish farming and navigation.
- In India, more than 80% of the rain occur during monsoon (100 days span –45 rainy days) and 60–80% precipitation occur in just 6–8 intense rainfall spells. Harness it where and when we can—in situ; by extending residence time to encourage infiltration/groundwater recharge; by digging, repairing, replenishing tanks, ponds wetlands; watershed management, building little check dams, small and medium irrigation works. Even if we do all that, we still need large dams to store the excess water.

2.2.3 Benefits of Dams

Out of the 45 000 large dams in the world today, two-thirds are in the Peoples Republic of China. Asia, North America and Europe account for more than 95% of dams built. Africa is marginal in these statistics with hardly more than a few hundred. Dams have made a major contribution to the progress of human societies, enabling them to control their water resources for human needs:

- 40% of world food production comes from irrigated farming, with a direct 16% contribution from land irrigated from dam reservoirs. 30–40% of the 268 million hectares of irrigated land is watered from dams.

- Hydro-electric power produces 19% of world energy and is used in more than 150 countries. It accounts for more than 90% of all energy in 24 countries and more than 50% in 63 countries.
- 12% of large dams supply towns and cities with water (60% in North America).
- 13% of the world's dams help control river floods and flooding in nearly 75 countries.
- Some dams have helped improve ecosystems by creating new wetlands and new opportunities for fishing and recreation in the reservoirs.

On the topic of dams and developments the following facts are undisputed.

- Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable.
- In too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers and by the natural environment.
- Lack of equity in the distribution of benefits has called into question the value of many dams in meeting water and energy development needs when compared with the alternatives.
- By bringing to the table all those whose rights are involved and who bear the risks associated with different options for water and energy resources development, the conditions for a positive resolution of competing interests and conflicts can be created.

2.2.4 Problems with Dams

Some of the problems associated with dams are as follows:

- Most of the world's large dams have been unable to achieve the technical, economic and social objectives for which they were designed. Many of them have typically fallen short of physical targets, did not recover their costs and have been less profitable in economic terms than expected. Large dams built for municipal and industrial water supply have generally fallen short of intended targets for timing and delivery of bulk water supply and have exhibited poor financial cost recovery and economic performance.
- The impacts of large dams on ecosystems are more negative than positive and in many cases, this has led to serious irrecoverable loss of species and ecosystems. It is impossible to mitigate many of the effects of new reservoirs on ecosystems and terrestrial biodiversity, and efforts to 'save' wild species have not been affective in the long term.
- Large dams have serious consequences on the living conditions and culture of populations, especially indigenous people. They have displaced large numbers of people, who, when resettled, have been unable to recover acceptable conditions of existence. People affected by the negative impacts have not always enjoyed the benefits from the dam.
- The loss of forests and wildlife habitat and the degradation of upstream catchment areas due to inundation of the reservoir area.
- The loss of aquatic biodiversity, of upstream and downstream fisheries, and of the services of downstream floodplains, wetlands, and riverine, estuarine and adjacent marine ecosystems.
- Cumulative impacts on water quality, natural flooding and species composition where a number of dams are sited on the same river.
- Sedimentation and the consequent long-term loss of storage is a serious concern globally, and the effects will be particularly felt by basins with high geological or human-induced erosion rates, dams in the lower reaches of rivers and dams with smaller storage volumes.

- Waterlogging and salinity affect one-fifth of irrigated land globally (including land irrigated by large dams) and have severe, long-term and often permanent impacts on land, agriculture and livelihoods where rehabilitation is not undertaken.

2.2.5 Socioeconomic Impacts of Dams

- Poorly managed involuntary displacement and loss of livelihood.
- Many of the displaced people were not recognized and therefore were not resettled or compensated.
- Depriving the indigenous people of the means to support traditional ways of life, particularly in case of culturally vulnerable indigenous/ethnic minority groups which are largely dependent on locally available natural resources.
- Higher incidences of waterborne diseases particularly among vulnerable communities.
- Low Regional economic development reforms and inadequate distribution of project benefits to affected communities.
- It is not possible to mitigate many of the impacts of reservoir creation on terrestrial ecosystems and biodiversity, and efforts to 'rescue' wildlife have met with little long-term success.
- The use of fish passes to mitigate the blockage of migratory fish has had little success, as the technology has often not been tailored to specific sites and species.
- Some 40–80 million people have been physically displaced by dams worldwide.
- Millions of people living downstream from dams (particularly those depending on natural flood plain function and fisheries) have also suffered serious harm to their livelihoods and the future productivity of their resources has been put at risk.
- Where compensation was provided it was often inadequate, and where the physically displaced were enumerated, many were not included in resettlement programmes.
- Those who were resettled rarely had their livelihoods restored, as resettlement programmes have focused on physical relocation rather than the economic and social development of the displaced.
- The larger the magnitude of displacement, the less likely it is that the livelihoods of affected communities can be restored.

2.2.6 Displacement Due to Dams

Displacement, by definition is involuntary. Displacement is often regarded as a one time phenomenon by which a person is forced to leave his/her original location and go elsewhere. Displacement needs to be viewed as a process rather than an event which starts much before the actual physical displacement and continues for a long time after uprootment has taken place. Displacement is not a single event, but a series of happenings, affecting human lives in many ways. In most cases, there is a gap of not just years but decades between the first announcement of the dam and its completion. As a consequence, areas likely to be submerged stop getting funds for building or maintaining infrastructure. Government itself encourages deforestation in the catchment areas, as in the case of Sardar Sarovar dam in Gujarat. This period is likely to be marked with uncertainty and fear as systematic information about the date and extent of submergence is almost never imparted. Indigenous and tribal people and vulnerable ethnic minorities have suffered disproportionate levels of displacement and negative impacts on livelihood, culture and spiritual existence. Affected populations living near reservoirs as well as displaced people and downstream communities have often faced adverse health and livelihood outcomes from environmental change and social disruption. Among affected communities, gender gaps have widened and women have frequently borne a disproportionate share of the social costs and were often discriminated against in the sharing of benefits.

- *wind and water erosion of exposed topsoil;*
- *soil compaction;*
- *loss of soil organic matter;*
- *loss of water holding capacity;*
- *reduction in biological activity;*
- *salinization of soils and irrigation water in irrigated farming areas;*
- *desertification due to overgrazing*

Over the past 50 years, the negative effects of soil erosion on farm productivity have been masked by improved technology and increasing use of fertilizers and pesticides. Ironically, many of these measures are used to increase the short-term productivity of farms and are also causing excessive erosion, which threatens productivity in the long term.

Contamination of Water

Farming is one potential source of water contamination. Surface runoff carries manure, fertilizers, and pesticides into streams, lakes, and reservoirs, in some cases causing unacceptable levels of bacteria, nutrients, or synthetic organic compounds. Similarly, water percolating downward through farm fields carries with it dissolved chemicals, which can include nitrate fertilizers and soluble pesticides. In sufficient quantities these can contaminate groundwater supplies. Agriculture is the largest single non-point source of water pollutants including sediments, salts, fertilizers (nitrates and phosphorus), pesticides, and manures. Pesticides from every chemical class have been detected in groundwater and are commonly found in groundwater beneath agricultural areas. Eutrophication and "dead zones" due to nutrient runoff affect many rivers, lakes, and oceans. Reduced water quality reduces agricultural production, drinking water supplies, and fishery production.

Water Scarcity

Water scarcity in many places is due to overuse of surface and ground water for irrigation with little concern for the natural cycle that maintains stable water availability.

Global Climate Change

Agriculture's link to global climate change is just beginning to be assesed. Destruction of tropical forests and other native vegetation for agricultural production has a role in elevated levels of carbon dioxide and other greenhouse gases. Recent studies have found that soils may be sources or sinks for greenhouse gases.

Waterlogging

Waterlogging results when soils are over irrigated. Generally waterlogging occurs in areas that have clayey soils or an impermeable layer of clay lies beneath the surface. Here water cannot move efficiently through the soil and cannot adequately be drained. Eventually the soil root zone becomes saturated with so much water that plant roots can no longer obtain adequate amounts of oxygen for growth and the soils are no longer suitable for cultivation. Hence waterlogging is too much water in the root zone of a plant and under these conditions roots cannot absorb enough oxygen to breathe and the plant stops growing within a few days and may die. Other gases, such as carbon dioxide and ethylene, may also accumulate around the roots and affect the plants.

Soil Salinity

Farmers generally have a tendency to over irrigate their crops to ensure that they are receiving enough moisture, this practice, however, can increase salinity both in the soil and in water supplies. When crops are over irrigated, the surplus water evaporates and the salts that are dissolved in it are left behind increasing the salinity of the soil. Increased soil salinity can cause a decrease in plant productivity and interferes with water uptake by plants. Fruit crops are the most sensitive to soil salinity followed by vegetables and then field and forage crops. Generally the problem is inadequately solved by flushing the root zone with excess water, which generally ends up contaminating the ground water or irrigation canals. The water is then reapplied to crops either on the same field or somewhere else downstream resulting in the same problem over again.

2.4.4 Problems with Fertilizers

The main environmental problem associated with fertilizer use is contamination of water with nitrates, phosphates and potassium.

Nutrients are lost from agricultural fields through runoff, drainage, or attachment to eroded soil particles. The amounts lost depend on the soil type and organic matter content, the climate, slope of the land, and depth to groundwater, as well as on the amount and type of fertilizer and irrigation used.

The three major nutrients in fertilizers are nitrogen, phosphorus and potassium. Of these, nitrogen is the most readily lost because of its high solubility in the nitrate form. Leaching of nitrate from agricultural fields can elevate concentrations in underlying groundwater to levels unacceptable for drinking water quality. The nitrogen from fertilizers and manures are eventually converted by bacteria in the soil to nitrates. These nitrates can be leached into the groundwater or be washed out of the soil surface into streams and rivers. High nitrate levels in drinking water are considered to be dangerous to human health. Phosphorus cannot be readily washed out of the soil, but is bound to soil particles and moves together with them. Phosphorus can therefore be washed into surface waters together with the soil that is being eroded. The phosphorus is not considered to be dangerous, but it stimulates the excessive growth of algae and this process is called eutrophication. These algae eventually die and decompose, removing the oxygen from the water which in turn kill the fish.

Potassium, the third major nutrient in fertilizers, does not cause water quality problems because it is not hazardous in drinking water and is not a limiting nutrient for growth of aquatic plants. It is tightly held by soil particles and so can be removed from fields by erosion, but generally not by leaching.

2.4.5 Pesticides

The ideal pesticide The following are the qualities of an ideal pest-killing chemical.

- Kills only the target pest,
- has no short or long-term health effects on non-target organisms, including people,
- can be broken down into harmless chemicals in a fairly short time,
- prevents the development of genetic resistance in target organisms, and
- saves money compared to making no effort to control pest species.

Unfortunately, no known pest control chemical meets all these criteria.

Use of pesticides Since 1945, chemists have developed many different types of synthetic organic chemicals for use as pesticides. Worldwide about 2.3 million metric tons of these pesticides are used

The Problems of Pesticides

Development of genetic resistance The most serious drawback to using chemicals to control pests is that most pest species, especially insects, can develop genetic resistance to a chemical poison through natural selection. When an area is sprayed with a pesticide, most of the pest organisms are killed. However a few organisms in a given population of a particular species survive because by chance they already had genes that made them resistant or immune to a specific pesticide.

Because most pest species—especially disease organisms have short generation time, a few surviving organisms can produce a large number of similarly resistant offspring in short time.

When populations of offspring of resistant parents are repeatedly sprayed with the same pesticide, each succeeding generation contains a higher percentage of resistant organisms. Thus, eventually widely used pesticides (especially insecticides) fail because of genetic resistance and usually lead to even larger populations of pest species, especially insects with large numbers of offspring and short generation times. In temperate regions most insects develop genetic resistance to a chemical poison within 5-10 years and much sooner in tropical areas. Weeds and plant disease organisms also develop genetic resistance, but not as quickly as most insects.

Between 1950 and 1990 almost 500 major insect pesticides have developed genetic resistance to one or more insecticides and at least 20 insect species are now apparently immune to all widely used insecticides. About 80 species of more than 500 major weed species are resistant to one or more herbicides. Because half of all pesticides applied worldwide are herbicides, genetic resistance in weeds is expected to increase significantly. Genetic resistance has also appeared in 70 species of fungi treated with fungicides and in 10 species of rodents (mostly rats) treated with rodenticides.

2.4.6 Alternative Methods of Insect Control

Modifying cultivation procedures Opponents of the widespread use of pesticides argue that there are many safer, and in the long-run cheaper and more effective, alternatives to the use of pesticides by farmers. For centuries farmers have used cultivation methods that discourage or inhibit pests. The following is a list of such practices.

- Crop rotation, in which types of crops planted in fields are changed from year to year so that population of pests that attack a particular crop don't have time to multiply to uncontrollable sizes.
- Planting rows of hedges or trees in and around crop fields to act as barriers to invasions by insect pests, provide habitats for their natural enemies, and serve as windbreaks to reduce soil erosion.
- ... to ensure that most major insect pests starve to death before the crop is

Many of the political groupings in the world are influenced by access to the raw materials for energy production. It is interesting to imagine how significant the Middle East would be in world politics if there were no oil reserves.

Many global industries have strong vested interests in energy supplies. Some of these are pushing to exploit new technologies. Others are blocking new energy technologies because they might threaten their dominant position in current energy markets. But there is no ideal energy source. Energy sources have a number of characteristics which influence their usefulness to humans. In general, the most concentrated forms of energy are the fossil fuels, where millennia of solar power have become concentrated into gas, coal or oil. But these, by their nature, are the least long lasting and the most environmentally damaging. As well as tapping into millennia of stored energy, they release millennia of stored carbon dioxide.

2.5.4 Energy and the Environment

The production and consumption of energy is one of the biggest causes of environmental damage on earth. It has lead to large amounts of destruction of natural landscapes and habitats through the process of fuel extraction, pollution of soil, water and air, poisoning of wildlife, and is generally believed to be the main cause of modern climate change. Energy is at the heart of many of the world's current environmental problems, and poses many problems for sustainable development.

The production and consumption of energy have always had environmental consequences. Historically when human population densities were low, small impacts were highly localized. Increases in population densities, industrialization and consumerism over the past few centuries, especially following the industrial revolution, have lead to dramatic rises in energy demands for both industrial and domestic purposes. Studies show that there was a 25% increase in energy consumption every 10 years between 1961 and 1990, with this trend continuing into the new millennium. Fossil fuels and the energy markets now have a major impact on global economies and politics, as well as being one of the main casual factors driving changes in environmental legislation.

Environmental impacts associated with energy can be split in to two main areas

1. Impacts that arise due to energy production (from fuel extraction to energy supplies), and
2. Impacts that arise due to energy use (including air pollution and climate change).

Impacts as a result of energy production are varying according to the type of fuel, method of use or extraction, and the way in which it releases energy. For example, fossil fuels such as coal and oil are associated with high levels of gaseous emissions during the energy production process, notably carbon dioxide and other green house gases that have been linked with climate change. This contrasts with nuclear fuel, which produces no greenhouse gas emissions, but uses uranium (which is highly toxic) and results in the production of radioactive wastes that are highly dangerous to all life forms and take a long time to decay.

The environmental issues associated with current levels of energy production and its use are recognized as being responsible for increasing damage to global ecosystems, and as a result are currently high on government agendas around the world. A series of World Conferences on Climate Change commencing with the Rio conference in 1992 have subsequently led to the development of global agreements such as the Kyoto Protocol to address some of the issues associated with gas emissions and global warming. It has been recognized that energy production at present is largely unsustainable and has both direct impacts on the environment as well as many associated social and economic implications, such as those associated with the industries that energy supplies, transport, the construction industry, urban development, health, education, etc.

Renewable energy sources generally have low impacts compared to no... sources, and likely to take over from traditional fuels for both environmental, economic and supply reasons in future.

Impacts of the most commonly used fuels can be summarized as follows:

Fossil Fuels – (coal, oil, gas, peat, lignite, etc.)

- Extraction of fuel by mining, drilling, quarrying and/or excavation leads to significant impacts on the surrounding environment and landscape (habitat modification and destruction, pollution etc.)
- Spoil and solid wastes from mining and extraction have both visual and environmental impacts.
- Wastewater and leachates from mining, drilling and excavations, and gas leaks from piplines can pollute surrounding waters, air and land.
- Purification or modification of raw products for use as fuels requires energy, and may lead to secondary sources of pollution.
- Transportation of fuels to energy production sites uses fuel (causes air pollution) and possibly a pollution risk, e.g. oil tankers are at risk from accidents and may lead to oil spills at sea.
- Combustion of fuels to produce energy leads to air pollution (carbon, nitrogen and sulphur oxides) and in some cases, the production of solid wastes (in the form of ash).

Nuclear Power

- Uranium (fuel used in nuclear power stations) mining can cause high levels of pollution in the surrounding environment, as well as posing health risks for mine workers.
- Transport of uranium and nuclear fuels carries potential pollution and environmental contamination risks.
- The radioactive waste produced in nuclear power plants remains highly toxic for centuries. There are currently no safe ways to either store this waste or dispose of it permanently.
- Health and safety of power plant employees is at risk.
- Accidents arising from nuclear plants can have widespread effects, e.g. the Chernobyl (Russia) disaster in 1986 caused radioactive fallout to spread across Europe.
- Wastes (such as cooling water) from nuclear power and fuel reprocessing plants can cause radioactive pollution in the surrounding environment.

Bioenergy (biomass fuels, wood and natural products)

Not all biomass products currently come from sustainable sources and their use may be causing large areas of natural woodlands, forests and vegetation to be destroyed in some areas of the world. However, biomass production that is managed in a sustainable way can be considered as a renewable form of energy.

- Biomass harvesting may cause impacts that include soil damage and erosion, habitat loss and pollution, if not managed properly.
- Transportation of biomass fuels from production to combustion sites requires the use of fossil-fuel driven transport systems, causing air pollution.
- Combustion of biomass leads to air pollution (notably carbon dioxide emissions) that may contribute to global warming if not managed sustainably.
- Combustion may lead to the production of waste residues such as ash.

2.5.5 Renewable Energy

Renewable energy sources are those which can be replaced or can be used indefinitely, without fear of running out. They are generally more sustainable than non-renewable energy sources, such as fossil fuels, and tend to have a much lesser impact on the environment (many forms of renewable energy do not result in carbon dioxide production). The following are the major renewable energy sources

Solar Power

This uses the sun's energy. Three types of technologies can currently harness sunlight energy:

- Photo-voltaic cells – uses photoreceptive cells to generate electricity from sun light.
- Solar-thermal – uses solar panels to recover the heat from the solar radiation.
- Solar-air heating – mainly used to heat incoming fresh air for ventilating a house.

Wind Power

Uses air movements (or wind) to turn turbines to generate electricity. Turbines can be built on a small scale (for private electricity generation) or large scale (wind farms feeding in to the national power grid). This will be feasible only in areas where there is considerable winds round the year.

Geothermal Energy

Uses geothermal energy from below the earth's surface to generate power. Subsurface temperatures vary throughout the world, but generally as we go deeper into the earths crest the temperature rises. Ground-source heat pumps can access this source to provide heating. (This method of heating requires the use of electricity to operate the pump, but this will be only a fraction of the actual energy recovered from the earth).

Hydro-electric Power

Uses small or large scale hydro-electric generators in rivers and streams to produce electricity. Construction of a dam is necessary for the production of power through out the year.

Marine Power

Uses the sea's energy (either wave action or tidal flow) to generate electricity.

Biomass

Although biomass material is not strictly 'infinite' as a resource, it is considered as a renewable energy source because it can be replaced at the same rate at which it is used. Biomass power generation generally uses crops that grow quickly and can be easily used and replanted on a rotation system (farm wastes such as slurry can also be dried and used). Though using biomass to produce energy releases carbon dioxide into the atmosphere, the theory is that the same amount of carbon dioxide will be removed from the atmosphere by replanting the crop.

Hydrogen Energy

This is a new technology that is generally not widely available, but for which there are high hopes in the future. Hydrogen fuel cells are used to produce water, electricity and heat by combining hydrogen with oxygen.

2.5.6 Fuel Cell

A fuel cell is an **electrochemical** energy conversion device that converts hydrogen and oxygen into water, producing electricity and heat in the process. It is very much like a battery that can be recharged

- using sun light to dry clothes in the summer rather than a mechanical cloth drier,
- choosing low energy rating appliances for cooking, washing and refrigerating,
- making sure that hot water boilers and pipes are well insulated.

2.6 LAND RESOURCES

Land Resources

"Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the near-surface climate the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)."

Natural resources, in the context of "land" as defined above, are taken to be those components of land units that are of direct economic use for human population living in the area, or expected to move into the area such as the following:

- near-surface climatic conditions;
- soil and terrain conditions;
- freshwater conditions; and
- vegetation and animal conditions.

To a large degree, these resources can be quantified in economic terms. This can be done irrespective of their location (intrinsic value) or in relation to their proximity to human settlements (situational value).

Environmental Resources

Environmental resources are taken to be those components of the land that have an intrinsic value of their own, or are of value for the longer-term sustainability of the use of the land by human populations, either regional or global. They include the following:

- biodiversity of plant and animal populations,
- scenic, educational or research value of landscapes,
- protective value of vegetation in relation to soil and water resources,
- the functions of the vegetation as a regulator of the local and regional climate and of the composition of the atmosphere, and
- water and soil conditions as regulators of nutrient cycles (C, N. P. K, S), as influencing human health and as a long-term buffer against extreme weather events.
- Environmental resources are to a large degree "intangible" in strictly economic terms.

2.6.1 Land Degradation

Land degradation, a decline in land quality caused by human activities, has been a major global issue during the 20th century and will remain high on the international agenda in the 21st century. The importance of land degradation among global issues is enhanced because of its impact on world food security and quality of the environment. High population density is not necessarily related to land degradation. What a population does to the land determines the extent of degradation. People can be a major asset in reversing a trend towards degradation. However, they need to be healthy and politically

- Local actions have g... targets?
- Is there a link between land degradation ...
- Declining soil quality leads to diminishing economic gr... agrarian. How can the rates of resource consumption be quantified?
- Land degradation often destroys or reduces the natural beauty of landscapes. How might the aesthetic value of land be quantified?
- How to create greater awareness of the perils of land degradation in society and political leadership?

There are three steps involved in the process of addressing the problem:

1. Assessment,
2. Monitoring, and
3. Application of mitigating technologies.

All the above steps are in the purview of agriculturists and specifically, soil scientists. The latter clearly have the responsibility for soil science, and over the past decade substantial progress has been made in communicating the dangers of land degradation. However, much remains to be done.

Land degradation results from mismanagement of land and thus deals with two interlocking, complex systems—the natural ecosystem and the human social system. Interactions between the two systems determine the success or failure of resource management programmes. To avert the catastrophe resulting from land degradation, which threatens many parts of the world, the following concepts are relevant:

- Environment and agriculture are intrinsically linked and research and development must address both of them.
- Implementation of mitigation research to manage land degradation can only succeed if land users have control and commitment to maintain the quality of the resources.
- The focus of agricultural research should shift from increasing productivity to enhancing sustainability, recognizing that land degradation caused by agriculture can be minimized and made compatible with the environment.
- Land use must match land quality; appropriate national policies should be implemented to ensure this occurs to reduce land degradation.

2.6.2 Soil Erosion

Soil erosion is a natural process. It becomes a problem when human activity causes it to occur much faster than under natural conditions.

Causes of Soil Erosion

- Wind and water are the main agents of soil erosion. The amount of soil they can carry away is influenced by two related factors:
- Speed—the faster either moves, the more soil it can erode;
- Plant cover—plants protect the soil and in their absence wind and water can do much more damage.

Politics, Economics and Soil Erosion

To understand soil erosion we must be aware of the political and economic factors affecting land users. For example in South Africa apartheid policies ensured that 42% of the people lived on 13 % of the land. This overcrowding has resulted in severe erosion. As the land became increasingly degraded and thus less productive, subsistence farmers were forced to further overuse the land. The intensive agriculture and overgrazing that followed caused greater degradation. Soil erosion can be seen as both, a symptom of underdevelopment (i.e. poverty, inequality and exploitation), and as a cause of underdevelopment. A reduced ability to produce, invest one's profit and increase productivity, contributes to increasing poverty, and can lead to desertification, drought, floods, and famine.

On commercial farm lands, overstocking, mono-cropping, and the ploughing of marginal lands unsuitable for cultivation has led to soil erosion and desertification. Frequently these practices have been unwittingly encouraged by the state offering subsidies which made it profitable to exploit the land in the short-term.

Preventing Soil Erosion

Preventing soil erosion requires political, economic and technical changes. Political and economic changes need to address the possibility of incentives to encourage farmers to manage their land sustainably. Aspects of technical changes in agriculture that could substantially contribute to the prevention of soil erosion are the following:

- Use of contour ploughing and wind breaks;
- Leaving unploughed grass strips between ploughed land;
- Making sure that there are always plants growing on the soil, and that the soil is rich in humus (decaying plant and animal remains). This organic matter is the "glue" that binds the soil particles together and plays an important part in the prevention of erosion;
- Avoiding overgrazing and the over-use of crop lands;
- Allowing indigenous plants to grow along the river banks instead of ploughing and planting crops right up to the water's edge;
- Encouraging biological diversity by planting several different types of plants together; and
- Conservation of wetlands.

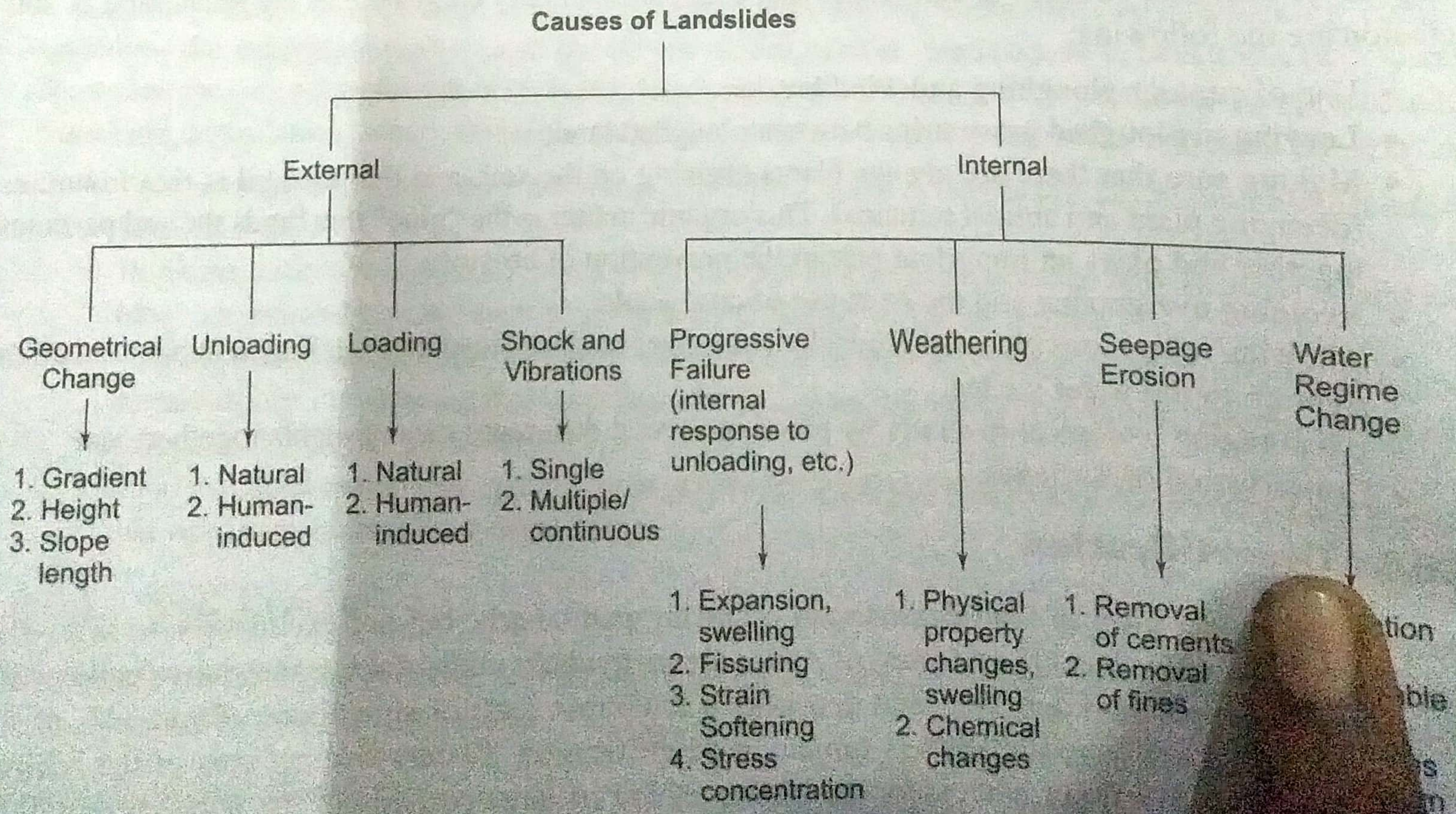
2.6.3 Desertification

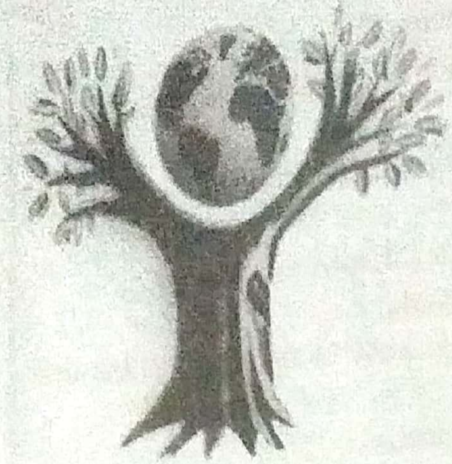
Desertification is a form of land degradation occurring particularly, but not exclusively, in semi-arid areas. The semi-arid to weakly arid areas of Africa are particularly vulnerable, as they have fragile soils, localized high population densities, and generally a low-input form of agriculture. About 33% of the global land surface (42 million km^2) is subject to desertification. Twenty-five per cent of the African region is affected and if not addressed, the quality of life of large sections of the population will be affected. Many of the affected countries cannot afford losses in agricultural productivity. There are no reliable estimates of the number of persons affected by desertification nor of the number who directly or indirectly contribute to the process.

While there is a clear distinction between 'soil' and 'land' (the term land refers to an ecosystem comprising land, landscape, terrain, vegetation, water, climate), there is no clear distinction between the terms 'land degradation' and 'desertification'. Desertification refers to land degradation in arid, semi-arid, and sub-humid areas due to anthropogenic activities. Many researchers argue that this definition of desertification is too narrow because severe land degradation resulting from anthropogenic activities can also occur in the temperate humid regions and the humid tropics. The term 'degradation' or 'desertification' refers to irreversible decline in the 'biological potential' of the land. The 'biological potential' in turn depends on numerous interacting factors and is difficult to define. The confusion is further aggravated by the definition of 'dryland' where different definitions are used. United Nations Convention to Combat Desertification (UNCCD) in those countries experiencing serious drought and/or desertification, particularly in Africa is taking initiatives for solving this problem. There is an urgent need to address these issues through a multi-disciplinary approach, but the most urgent need is to develop an objective, quantifiable, and precise concept based on scientific principles.

2.6.4 Landslides

Geologists use a variety of classification schemes to describe the causes of landslides. Because of wide variety of causes, no single scheme has yet been developed that address or describe all types of landslides. Even the terms assigned to types of landslides are undergoing standardization among geological and scientific international agencies. The major causes of landslides can be classified into two groups namely external and internal as illustrated in Fig. 2.2.





3

ECOLOGY

"The first law of ecology is that everything is related to everything else."

Barry Commoner

3.1 ECOSYSTEM

Ecology is the study of the relationship between organisms and their environment. An ecosystem is a biotic assemblage of plants, animals, and microbes, taken together with their physico-chemical environment. In an ecosystem the biological cycling of materials is maintained by three groups, viz., producers, consumers, and decomposers/recyclers (Figs 3.1 (a) and 3.1 (b)). The producers are plants and some bacteria capable of producing their own food photosynthetically or by chemical synthesis. The consumers are animals that obtain their energy and protein directly by grazing, feeding on other animals, or both. The decomposers/recyclers are fungi and bacteria that decompose the organic matter of producers and consumers into inorganic substances that can be reused as food by the producers, thus decomposers are the "recyclers of the biosphere". Nature is capable of sustaining the producer-consumer-decomposer cycle indefinitely with the sun as the energy source. The smallest such entity that is self-sufficient is an ecosystem. Figure 3.1(a) shows an ecosystem with producers, consumers and recyclers.

Functionally, human activities that disturb the natural environment can also be divided into three similar components (Fig. 3.1(b)). Producing activities include energy production (fossil fuels), manufacturing (non-fuel minerals), and growing food. The consumers are humans and their domestic animals. Decomposing or recycling activities include treatment of waste water, recycling of metals and solid wastes. However, an ecosystem relies on its decomposers for a complete recycling of its elements, the anthroposystem lacks such efficient decomposers and recyclers. As such, manufactured materials that are no longer needed and waste by-products of industrial activity are largely disposed into the physical environment. The process of adding unwanted materials to the environment is called pollution. The waste by-products are disposed by the atmosphere and the hydrosphere, and delivered to the biological and geochemical receptors. Thus the anthroposystem, as defined above, is an open system.

3.5 ECOLOGICAL SUCCESSION

Ecological succession is the gradual process by which ecosystems change and develop over a period of time. In the process of succession, the species present in an area will gradually change. Succession takes place because of the changes in the environmental conditions in a particular place over a period of time. Each species is adapted to thrive and compete best against other species under a very specific set of environmental conditions. If these conditions change, then the existing species will be replaced by a new set of species which are better adapted to the new conditions.

Ecological succession may also occur when the conditions of an environment suddenly and drastically change. A forest fire, wind storm, and human activities like agriculture all greatly alter the conditions of an environment. These massive forces may also destroy species and thus alter the dynamics of the ecological community triggering a scramble for dominance among the species still present.

Observed changes in the structure and function of communities in the intermediate stages of ecological succession generally result from natural selection of individuals within their current environment. Three mechanisms by which species may replace each other have been proposed; the relative importance of each depends on the nature of the community and stage of development. The following are the three proposed hypothesis pertaining to the mechanism of replacement.

The facilitation hypothesis

This hypothesis states that invasion of later species depends on conditions created by earlier colonists. Earlier species modify the environment so as to increase the competitive ability of species which are then able to displace them. Succession thus proceeds because of the effects of species on their environment.

The tolerance hypothesis

This suggests that later successional species tolerate lower levels of resources than earlier occupants and can invade and replace them by reducing resource levels below those tolerated by earlier occupants. Succession proceeds despite the resistance of earlier colonists.

The inhibition hypothesis

This hypothesis is that all species resist invasion of competitors and are displaced only by death or by damage from factors other than competition. Succession proceeds towards dominance by longer-lived species.

None of these models of succession is solely applicable in all instances; indeed most examples of succession appear to show elements of all three replacement mechanisms.

3.6 FOOD CHAINS AND WEBS

A food chain is the path of food from a given final consumer back to a producer. For instance, a typical food chain in a field ecosystem is

grass → grasshopper → mouse → snake → hawk

The real world, is more complicated than a simple food chain. While many organisms specialize in their diets (e.g. Anteaters), other organisms do not. Hawks don't limit their diets to snakes, snakes eat things other than mice, mice eat grass as well as grasshoppers. A more realistic representation of who eats whom is called a food web; an example is shown in Fig. 3.3.

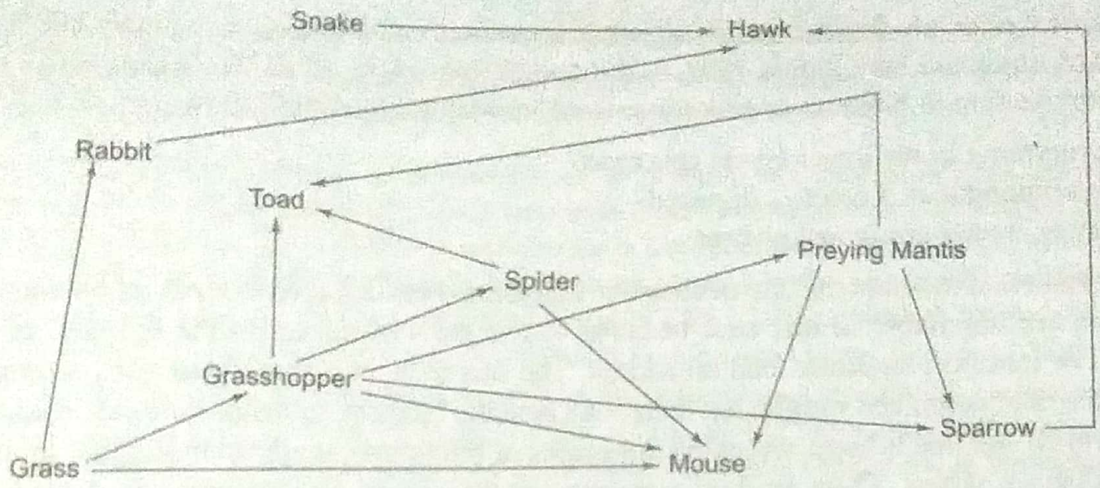


Fig. 3.3 ***Food Web***

When we have a picture of a food web the definition of food chain makes more sense. Thus a food web consists of interlocking food chains, and that the only way to untangle the chains is to trace back along a given food chain to its source.

3.7 ECOLOGICAL PYRAMIDS

In a food chain the number of individuals decreases at each trophic level (a trophic level refers to an organism's position in the food chain) with huge number of tiny individuals at the base and a few large individuals at the top. This formation is known as ecological pyramid. Figure 3.4 illustrates the above concept.

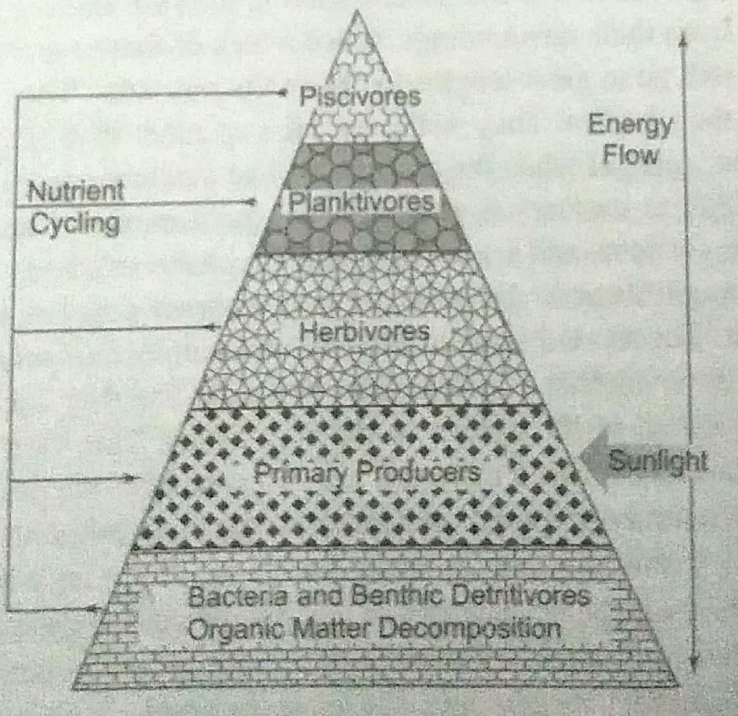


Fig. 3.4 ***The Ecological Pyramid in a Lake***

The grassland ecosystem consists of several components. Producers are plants that use the sun energy to capture carbon as carbon dioxide from the atmosphere and available nutrients and water from the soil to produce more plant materials. Consumers are animals and micro-organisms that feed upon plant parts and other animals. Decomposers are bacteria, other micro-organisms and invertebrates that convert dead organic matter to carbon dioxide and available nutrients in the soil. Thus the carbon cycle is maintained by the transfer of carbon from the atmosphere into plants through various animals and micro-organisms, and back into atmosphere. Energy is captured first from the sun and then cycled through the system as organic material until it is decomposed to carbon dioxide.

At times grassland ecosystem has been burned naturally, probably from fires sparked by lightening. Human inhabitants have started fires intentionally to remove predators, insects for improving the condition of the rangeland. These influences may extend to other components of the grassland ecosystem and increase the vulnerability of the soil erosion. As a result the environment may change and ultimately it affects the human and animal life.

3.19 AQUATIC ECOSYSTEMS

Aquatic ecosystems exist in ponds, lakes, rivers, wetlands, etc. The components of an aquatic ecosystem are very diverse, but can be divided into several basic units:

Abiotic substances The abiotic substances that make up the aquatic environment include basic inorganic and organic substances such as water, carbon dioxide, oxygen, phosphorus salts, amino acids and nitrogen. Small portions of the necessary nutrients that organisms need in order to survive in the water is always available. The rates at which these nutrients are released into the water are regulated by the temperature cycle (seasons), the amount and availability of sunlight, and the climatic regimes.

Producer organisms There are two different kinds of producer organisms that make up an aquatic environment:

1. Small minute and/or microscopic floating plants call phytoplankton. The word phytoplankton comes from the prefix "phyto" which means plant and the suffix "plankton" which means floating. If the aquatic environment produces a large amount of algae, the water will have a green colouration. This can be hazardous to the aquatic community. Phytoplankton can be found all over the aquatic environment, as long as there is sunlight to sustain its life. Algae are good examples of phytoplankton.
2. The second type of producer organism is the rooted or large floating plants which are found growing in the shallow water area.

Macroconsumer organisms Fish, crustaceans, and insect larvae are examples of the macroconsumer organisms that can be found in an aquatic environment. The primary macroconsumers consist of zooplankton and benthos. They are herbivores that feed directly on living plants and the remains of those plants. The secondary consumers consist of carnivores (insects and game fish) which feed on the primary consumers.

Saprotrophic organisms Saprotrophic organisms are the aquatic bacteria, fungi, and flagellates which are widely distributed throughout the aquatic environment. Large numbers of these organisms can be found in the mud at the bottom of the aquatic environment where dead plants and animals accumulate. Under the correct climatic conditions, decomposition of the dead matter occurs rapidly.

Some saprotrophic organisms are pathogenic because they have the ability to cause diseases in other living organisms. However, most of these organisms only feed on dead organic matter.

Trophic levels that exist within the aquatic environment community could be classified as follows:

- First Trophic Level—green plants such as phytoplankton, algae, microscopic plants, pond lilies, etc. which manufacture food through photosynthesis.
- Second Trophic Level—herbivores such as mayflies, small crustaceans, nymphs, and certain types of beetles that feed on the plants in level one.
- Third Trophic Level—carnivores such as fish which consume plants and animals from the first and second trophic levels.

In aquatic ecosystems, the sun hits the water and helps the algae grow. Algae produces oxygen for animals like fish, and provides food for microscopic animals. Small fish eat the microscopic animals, absorb oxygen with their gills and expel carbon dioxide, which plants then use to grow. If the algae disappeared, everything else would be affected. Microscopic animals wouldn't have enough food, fish wouldn't have enough oxygen and plants would lose some of the carbon dioxide they need to grow.

Fresh-water ecosystems focus either on water bodies themselves or the surrounding land that interacts with a lake or stream. Fresh-water ecosystem may be classified into two types:

- flowing water ecosystems in which the water moves steadily in a uniform direction.
- standing water ecosystems in which the water tends to remain in the same area for a longer period

Fresh-water ecosystem studies consider an interacting array of the geological, physical and chemical features along with the biota. For example: in a lake the presence of a fish species may have a major effect on lake chemistry while in a river water flow patterns may determine the types of fishes that are present.

3.19.1 Environmental Factors Affecting the Aquatic Ecosystem Performance

Light Light is the ultimate source of energy for all biological processes. Its' quantity and spectral quality have major influences on the distribution of biota and play a major role in the thermal structure of biota. Quantity of light is measured as the total amount of energy, which falls on an area or as the portion of that energy which helps photosynthesis. Wavelength of light is associated with the interactions of water with biota. When a light is passed through water, some is reflected, scattered within the water or it may be absorbed. Longer wavelength of light (red and orange) is absorbed after passing through only a short distance in water, warming the water surface, whereas shorter wavelength (green and blue) penetrates deeper. This penetration depends upon the nature of water, dissolved and suspended particles.

Temperature Water exhibits a number of unusual thermal properties. When water is warmed at the surface of a water body, it becomes less dense, and resistance develops to block the mixing of water with lower layer. Hence a distinct upper warmer layer of water (epilimnion) is maintained over a deeper cooler region (hypolimnion). The region in which sharp temperature changes between these two layers is called metalimnion. The characteristic establishment of these layers are very important in the chemical cycling within aquatic environments and consequently for the biota. On the other hand if the surface water is cooled, then the density of epilimnetic water increases, which decrease the resistance to mixing with the hypolimnion. If cooling continues, the entire water column will mix called turnover. However below 3.94°C, water at epilimnetic layer becomes less dense and an inverse thermal gradient is established. This is the reason why ice and very cold water float above slightly warmer water.

Many ponds and lakes in the temperate zones exhibit two periods of mixing annually. One is in the summer and the other is in winter. During moderate winter season, mixing may occur continuously from fall to spring so that these water bodies exhibit a period of summer stratification. But in some shallow ponds and lakes, due to strong wind mixing happens completely throughout the year. In river system (iotic system) there is little temperature change with depth due to water movement which ensures a constant mixing. However during downward flow of river water, temperature of water may increase.

Chemical environmental factors The following are the chemical environmental factors that could affect the performance of an aquatic ecosystem.

1. Dissolved and particulate matter
2. Oxygen
3. Carbon dioxide and pH
4. Phosphorus
5. Nitrogen and trace elements