Physics of Natural Resources

2.1 INTRODUCTION

The word resources means “a source of supply or support generally held in reserve”. By resource, one can refer to any physical entity which has limited availability. A natural resource is the stock that can be drawn from nature, i.e., air, water, minerals, land, vegetation, animals, solar energy and raw materials, for supporting life. For man, resources are those materials which are needed for his survival and prosperity. The nature of resources varies from society to society, depending upon culture, level of development and the nature of work of that particular society.

Natural resources can be classified as:

(1) **Renewable resources**: The resources that have the inherent capacity to reappear, or replenish themselves by quick recycling, reproduction and replacement within a reasonable time and maintain themselves, e.g., soil, water and living organisms.

(2) **Non-renewable resources**: The resources that lack the ability for recycling and replacement, e.g., fossil fuels like coal, petroleum and minerals.

In general, people are not aware that everything we use in our day-to-day life is derived from natural resources. For example, fat which comes from vegetation and animal source, salt and spices which comes from minerals and herb plants, milk and cheese from animals and vegetation, bicycle made from iron ore and chemical by-products, etc. Also by human intervention one natural resource can be used in several forms, e.g., wood coming from tree can be used to make house, or can be used for cooking, paper can also be made from wood. One can say man utilises these resources in various ways by processing them to meet his needs. Human interaction with natural resources made environmental science a very imperative subject for the present generation. While utilising the resources we are affecting the nature some way or other in order to maximise the benefits for the living being.

The table below shows an example in what way natural resources have been utilised:

### Table 2.1  Natural and man-made resources.

<table>
<thead>
<tr>
<th>Natural resources</th>
<th>Products made by humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water reservoirs, rivers</td>
<td>Electric power</td>
</tr>
<tr>
<td>Solar energy</td>
<td>Electric and thermal power</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Chips, crisps</td>
</tr>
<tr>
<td>Forest</td>
<td>Furniture</td>
</tr>
<tr>
<td>Wind</td>
<td>Electrical power</td>
</tr>
</tbody>
</table>
Provides raw material for a variety of industries: provides pulp for paper industry, ingredients for pharmaceutical industries, etc.

Provides fuelwood: fuelwood is the major source of household energy in the developing world. Worldwide about half the timber cut each year is used as fuel for heating and cooking, especially in less developed countries.

Provides employment: to millions of people, the world trade in forest produce is estimated to be 100 billion U.S dollars annually.

Serves as habitat: for a variety of species, which live on the edge of the forests and in the adjoining ecosystems, deep and continuous forests are important to other species, which require large habitats without human interference.

Serves as an important biodiversity: reserve and as a gene reserve of a variety of wild species. This biodiversity is a very vital source for evolving new economic varieties in agriculture, horticulture, veterinary and medical fields.

Moderates greenhouse effects: by absorbing atmospheric CO₂ they act as big sinks for CO₂ and moderate greenhouse effect.

Regulates stream flow: vast expansion of forests and other vegetation slows the runoff of water and allows water to percolate into the soil thus helping and regulating the stream flow. Further the plant and leaf debris on the forest floor slows water as it runs along the ground. This reduces erosion by allowing water to soak into the soil, rather than runoff.

Regulates earth’s temperature regimes and increases rainfall occurrences, balances/regulates CO₂, O₂, nutrient and water cycles.

Increases the water holding capacity of the soil: because of the thick layer, loose soil and soil-retaining capacity of the tree roots, forests are vitally important for preserving adequate water supplies. Tree roots penetrate compacted soils and increase soil porosity. This allows water to percolate into the soil and increase the water holding capacity of the soil.

Checks soil erosion/silting/landslides/floods.

Also have aesthetic and touristic values.

2.3 OVER-EXPLOITATION OF FORESTS

Forests being the storehouse of a variety of resources, which directly benefit the human society, are being plundered for short-term gains. Though the exploitation of forest resources has been happening since earliest times, the scale of exploitation was very much limited to local areas and so the environmental problems were not so widespread. But in the last few decades, exploitation at any cost attitude which was prevalent in most of the countries has led to the over-exploitation of the forests. Deforestation problem is not only prevailing in the developing countries but also increasing due to increase in population. The consequence of such over-exploitation has resulted in a variety of environmental and social problems—a few of which are global in nature, which threaten the living environment.

2.4 DEFORESTATION

Deforestation refers to the removal of plants and trees in the forests. According to the Food and Agriculture Organisation (FAO, 1997) of the United Nations, the annual rates of deforestation in
the developing countries is about 15.5 million hectares for the period 1980-1990 and 13.7 million hectares for 1990-1995. This clearly shows the increasing trend of the deforestation. It has also been estimated that the total forest area lost during the 15-year period was approximately 200 million hectares. To put this figure in perspective, 200 million hectares is more than the total area of Mexico or Indonesia.

2.4.1 Causes of Deforestation

1. Slash and burn farming
2. Commercial agriculture
3. Cattle ranching and livestock grazing
4. Mining and petroleum exploitation
5. Infrastructure development
6. Fuelwood collection
7. Charcoal kilns

2.4.2 Consequences of Deforestation

1. Economic loss
2. Loss of biodiversity
3. Destructs the habitats of various species
4. Reduction in stream flow
5. Increases the rate of global warming
6. Disruption of weather patterns
7. Degradation of soil and acceleration of the rate of soil erosion
8. Induces and accelerates mass movement/landslides
9. Increases flood frequency, magnitude/severity
10. Breaks the water cycle
11. Breaks the nutrients cycle
12. Loss of forests puts additional pressure on the pristine forests.
13. Increase in draught-hunger cycle.

2.5 WATER RESOURCES

Water is the most important natural source for the living beings on the earth. Specially, over increasing population is putting lots of pressure on the availability of potable water around the world especially in African continent and India. Around the world, human activities and natural forces are reducing available water resources. Only a tiny fraction of the planet’s abundant water is available to us as fresh water. About 97% is found in the oceans and is too salty for drinking, irrigation and industry.

The remaining 3% is fresh water. About 2.997% of it is locked in the ice caps or glaciers or buried so deep that it costs too much to extract. Only about 0.0035% of earth’s total volume of water is easily available to us as soil moisture, exploitable groundwater, water vapour, and lakes and streams.
Although awareness of the need to better manage and protect water has grown over the last decade, economic criteria and political considerations still tend to drive water policy at all levels. Science and best practices are rarely given adequate consideration. Pressure on water resources is increasing mainly as a result of human activities, namely, urbanisation, population growth, increased living standards, growing competition for water and increasing power demand from hydroelectricity. These are aggravated by climate change and variations in natural conditions. Few methods being developed by scientists around the world, e.g., rain water harvesting but still, in order to achieve water conservation and effective utilisation a long way is ahead. More and more, policy makers, social scientists, climate change experts and government officials are evaluating water quantity and quality together, and also coordinating water management efforts across borders.

2.5.1 Forms of Water

Water exists naturally in different forms and locations: in the air, on the surface, below the ground, and in the oceans. Fresh water accounts for only 2.5% of the earth’s water, and most of it is frozen in glaciers and icecaps. The remaining unfrozen fresh water is mainly found as groundwater, with only a small fraction present above ground or in the air. Looking at how water moves through the earth’s water cycle will help us to understand how water interacts with the environment and how much is available for human use.

Precipitation – rain, snow, dew, etc. – plays the key role in renewing water resources and in defining microclimate conditions and biodiversity. Depending on the local conditions precipitation may feed rivers and lakes, replenish groundwater or can return to the air by evaporation.

Glaciers store water as snow and ice, releasing varying amounts of water into local streams depending on the season. But many are shrinking as a result of climate change.

River basins are a useful “natural unit” for the management of water resources and many of them are shared by more than one country. The largest river basins include the Amazon and Congo Zaire basins. River flows can vary greatly from one season to the next and from one climatic region to another. Because lakes store large amounts of water, they can reduce seasonal differences in how much water flows in rivers and streams.

Wetlands – including swamps, bogs, marshes, and lagoons – cover 6% of the world’s land surface and play a key role in local ecosystems and water resources. Many of them have been destroyed, but the remaining wetlands can still play an important role in preventing floods and promoting river flows.

Almost all of the fresh water is found below the surface of earth as groundwater. Generally of high quality, groundwater is withdrawn to supply drinking water and support farming in dry climates. The resource is considered renewable as long as groundwater is not withdrawn faster than nature can replenish it, but in many dry regions the groundwater does not renew itself or only very slowly. Few countries measure the quality of groundwater or the rate at which it is being exploited.

2.5.2 Indian Water Resources

In India, in an area of 3290 lakh hectares, 4000 billion cubic metres (bcm) of rainfall occurs annually. Out of the total, 41% is lost by evaporation, 40% is lost by runoff, 10% is retained by soil-moisture and remaining 9% seeps in for recharging groundwater. Of the 40% stream flow water or runoff water, 8% is used for irrigation, 2% for domestic use, 4% for industry and 12% for electric generation. In available total water resource of 1869 bcm, the usable, water resources is
Fig. 2.2  Global distribution of the world’s water.

Fig. 2.3  Schematic of the hydrologic cycle components in the present-day setting.
only 1122 bcm, which consists surface water 690 bcm and ground water 432 bcm. If one considers the present per capita availability of water resources is 1122 cm, which makes India a water stress country and if the water sources are used with the same rate by 2050 it is likely to be reduced to only 748 cm.

When the countries per capita water availability is less than 1700 cm it is considered as water stress country.

### 2.5.3 Classification of Water Related Diseases

![Diagram showing classification of water-related diseases]

**Fig. 2.4** Classification of water related diseases.

**Fig. 2.5** Worldwide access to safe water.

#### 2.5.4 Waterborne Diseases

Diseases caused by ingestion of water contaminated by human or animal excrement, which contain pathogenic microorganisms.

- Includes cholera, typhoid, amoebic and bacillary dysentery, hepatitis A & E and other diarrhoeal diseases.

In addition, waterborne diseases can be caused by the pollution of water with chemicals that have an adverse effect on health.

(i) **Other Diarrhoeal Diseases and their source:**

- Giardiasis (protozoan)
- Cryptosporidiosis (bacteria)
- Campylobacteriosis (bacteria)
- Viral Gastroenteritis (virus)
- Cyclosporiasis (parasite)
Prevention and Control
• Generally, through improvement of microbiological water quality, either through water treatment or source protection.
• Maintain safe water chain.
• Improvement in sanitation facilities.
• Promotion of hygiene practices.
• Identification and treatment of cases (disease surveillance).
• Treatment of wastewater/sewage.

(ii) Water-Washed Diseases
• Diseases resulting from poor personal hygiene due to inadequate amounts of water supply for washing and bathing and eye contact with contaminated water.
• These include skin diseases— scabies, lice (typhus and relapsing fevers), tick-borne diseases and fungal infections, ringworms.
• Eye infections: trachoma and conjunctivitis.
• Parasitic infection like jiggers.

Prevention and Control
• Adequate quantity of water supply.
• Closer, easier access to water
• Health education to improve personal and domestic hygiene
• Improve personal hygiene.
• Disrupt the route of transmission.
• Identify and treat cases.

(iii) Water-related Insect Vectors
• Diseases spread by insects that breed or feed near contaminated water or bite near water such as malaria, onchocerciasis, trypanosomiasis and yellow fever.

Prevention and Control
• Through spraying with pesticides destruction of breeding grounds (improving environmental sanitation).
• Construction of piped water supplies
• Reducing man-insect contact.
• Destroy breeding sites.
• Improving on housing conditions.
• Decrease the need for visiting infected areas.
• Identify and treat cases.

(iv) Water-based Diseases
• Are transmitted by hosts which live in water or require water as part of their life cycle, e.g., schistosomiasis and guinea worm.
• Transmission is more likely due to human activities like fishing, swimming, farming-rice.

Prevention and Control
• Prevent water contamination with excreta (water protection and safe disposal of excreta).
• Control direct contact of human beings with water sources.
• Prevent human contact with infected or suspicious water bodies.
• Control intermediate vector population.
• Provide protective wear.
• Identification and treatment of cases.

2.6 FLOODS

Floods occur most commonly when water from heavy rainfall, melting ice, or snow or a combination of these, exceeds the carry capacity of the receiving river system. During the floods, the river carries fertile sediment and deposits it on the level land along its lower course. Such areas are called floodplains which are very fertile. Some rivers with extensive floodplains are: the Nile, Ganga, Brahmaputra, Yellow River, Mekong, and Godavari. Often, the floodplains become areas for human settlement. People are lured to them by the productive soils, reliable water supply, inexpensive means of transport and fishing potential. To reduce the flooding of the floodplains, flood banks are built along the river. Another way of controlling floods is through impounding river water by building upstream dams.

In India, floods bring much havoc causing loss of life and property each year. Due to floods, the plains have become silted with mud and sand, thus affecting the cultivable land areas. Extinction of civilization in some coastal areas is mainly due to such natural calamities as flood. The national commission on floods has calculated that the land area prone to floods has doubled from 20 million hectares in 1971 to 40 million hectares in 1980. Flood damages cost the country INR 21 crore in 1951 which increased to INR 1130 crore in 1977. It was INR 128 crore per year during the decade 1960-1970, increasing to INR 739 crore per year during 1970-78. Assam, Bihar, Orissa, U.P, and West Bengal are worst suffering states in India. Through modern technology and scientific knowledge, there is need of a proper understanding of the ecosystem so that changes could be forecast well in time. Thus, management of rainfall and resultant runoff is very important. Such management can be best based on a natural unit called watershed. A watershed is an area bounded by the divide line of water flow. Thus it may be drainage basin or stream. The Himalayas are one of the most critical watersheds in the world. Our water regimes in the mountain ranges are threatened resulting in the depletion of water resources. The damage to reservoirs and irrigation systems and misuse of Himalayan slopes are increasing every year; which leads to increase in the costs for control measures during the flood season each year. The vast hydroelectric power potential can be harnessed from the Himalayan watershed only when proper control measures are taken. These include soil and land use survey, soil conservation in catchments of river valley projects and flood-prone rivers, afforestation/social forestry programmes, drought prone area development programmes and desert development and control of shifting cultivation.

2.7 DROUGHT

Drought is a devastating phenomenon. In comparison to fast onset disasters, drought destroys an area slowly, taking hold and tightening its grip with time. In severe cases, drought can last for many years, and can have devastating effects on agriculture, water supplies, local vegetation and microclimate.

In general, drought is defined as an extended period-a-season, a year, several years of deficient rainfall relative to the statistical multiyear average for the region. The lack of rainfall leads to
inadequate water required by plants, animals, and human beings. A drought leads to other disasters, namely food insecurity, famine, malnutrition, epidemics and displacement of population from one area to another.

Rural communities can sometimes cope with one or two successive rain failures and crop or cattle losses: the situation becomes a crucial emergency when they have exhausted all their purchasing resources, food stocks and usual coping mechanisms.

These natural phenomena of drought, flood, etc., affect the different cycles of natural microclimate, e.g., nitrogen cycle, carbon cycle; which further make problem worse and havoc for civilisation. These different cycle are discussed in the next section.

2.8 MINERAL RESOURCES

A mineral is an element of an inorganic compound that occurs naturally and is solid. Mineral resources of the earth include metals and materials extracted from the soil. It usually has a crystalline internal structure made up of an orderly, three-dimensional arrangements of atoms or ions. All of the earth’s crust, except the rather small portions composed of organic materials, is made of minerals. Mineral resources are limited and thus non-renewable.

The most frequently expressed concern is that high levels of consumption of minerals will lead to their depletion, thereby retarding industrial growth. However, estimates have suggested that the mineral reserves are adequate to support human development for the next few decades. Moreover, advanced scientific technology has helped in the discovery of newer reserves from time to time.

2.9 NITROGEN CYCLE

Nitrogen is essential to life on the earth. Nitrogen gas makes up 78 per cent of the air we breathe.

The nitrogen cycle is the continuous series of natural processes by which nitrogen passes from the air to the soil, to plants, and ultimately to sustain all animal life, and then returns back to the air or soil through decay or denitrification (the loss of nitrogen).

Nitrogen is a basic element of all living cells. Through nitrogen fixation, nitrogen gas is converted into inorganic nitrogen compounds to be used by plants, animals, and people. This conversion is accomplished through the nitrogen cycle, in which nitrogen as a gas is carried to the earth’s surface in precipitation. Nitrogen is then used by plants and incorporated in their tissues as plant protein. Nitrogen then passes through the food chain to animals and humans.

Human intrusion in the nitrogen cycle can result in more or less nitrogen being cycled as part of the natural system. For example, cultivation of croplands, harvesting of crops, and cutting of forests has caused a decline in the natural occurring nitrogen in the soil. Soil nitrogen can be replenished with manufactured nitrogen fertilizer, animal manure and legumes. Nitrogen from over-fertilization of plant life, industrial discharges, and human and animal waste discharges can add too much nitrogen to the natural system and may have an impact on soil, water, and air quality.

2.9.1 Forms of Nitrogen

Nitrogen is present in the environment in many forms. The predominant form is nitrogen gas. Nitrate and ammonia are the two forms used by plants. Organic nitrogen is mineralized by microorganisms to create these two forms that are found in our soils and water. Microorganisms to create these two forms that are found in our soils and water.
Lifestyles and behaviours are the most important factors to quality of life (diet, exercise, etc). The environment is another key factor affecting quality of life. We need to make decisions and develop policies that balance economics, resource utilization, and quality of life.

We are exposed to nitrogen in the food we eat, the water we drink, and the air we breathe. Drinking water sources are susceptible to watershed run-off. Groundwater contamination from over-fertilization of plant life, human and animal waste discharges can occur. Excessive amounts of nitrogen as nitrate in drinking water may cause health problems. In infants under 6 months of age, nitrogen as nitrate may transform into nitrite and cause Blue Baby Syndrome (BBS). Requirements of the Safe Drinking Water Act set a maximum contaminant level for nitrate nitrogen in community drinking water supplies at 10 parts per million.

2.10 THE IMPORTANCE OF THE CARBON CYCLE

Carbon is an element found in all living substances as well as in many inorganic materials. Both diamond and coal are nearly pure carbon, but with different structures. Carbon is a key element for life, composing almost half of the dry mass of the earth’s plants (that is, the mass when all water is removed). The carbon cycle is the exchange of carbon among three reservoirs or storage places: the land, the oceans, and the atmosphere. The amount of carbon in these reservoirs is so large that it is expressed in gigatons (Gt): 109 metric tons (1 metric ton equals 1000 kilograms or 2200 pounds).

The atmosphere is the smallest pool of actively cycling carbon, in this reservoir carbon stays less than a thousand years or so. The land, its plants and animals, which scientists call the terrestrial biosphere, is the next largest reservoir of carbon. The oceans are the earth’s largest active carbon reservoir by so far.
The carbon budget is the balance of carbon among the three reservoirs. The carbon cycle is vitally important to life on the earth. Through photosynthesis and respiration, it is the way the earth produces food and other renewable resources. Through decomposition, it serves as the earth’s waste disposal system. In addition, the carbon cycle is important because carbon-containing gases in the atmosphere affect the earth’s climate. Increased carbon dioxide (CO$_2$) in the atmosphere has been responsible for more than half of the global warming observed in recent decades.

The processes by which carbon moves through the earth’s reservoirs take place on very different time scales. The short-term carbon cycle includes processes that transfer carbon from one reservoir to another in a matter of years, including photosynthesis, plant and animal respiration, and the movement of CO$_2$ across the air-sea interface. Other processes, such as the transformation of carbon into limestone and its subsequent release as the rock is weathered, occur very slowly (thousands to millions of years). Scientists call these slower transfers of carbon among reservoirs the long-term carbon cycle.

The carbon cycle is inextricably linked to other chemical cycles, including those of nitrogen, phosphorus, and sulfur, as well as to the global hydrological cycle. Actively cycling carbon in its three reservoirs affects human life every day. Carbon in the atmosphere serves as food for plants (in the presence of sunlight); carbon in the soil serves as energy for the growth of miniature animals called microbes; carbon in plants feeds humans and other animals; and carbon in the oceans makes up the homes of many marine animals. Obviously, carbon is critically important in all the reservoirs where it is found.

### 2.10.1 The Atmosphere

Carbon composes much less than 1% of the atmosphere. Even this small percentage adds up to 750 Gt of carbon, which is a lot (although, as noted earlier, much less than in the other two reservoirs). Carbon in the atmosphere occurs almost entirely as CO$_2$; small amounts of methane (CH$_4$), carbon monoxide (CO), and chlorofluorocarbons (CFCs) are also present. These gases are all radiatively active, and can trap heat near the surface of the earth. That’s why they are also considered greenhouse gases.

### 2.10.2 Photosynthesis and Respiration

In the short-term carbon cycle, photosynthesis and respiration are the primary processes that involve the atmosphere. Photosynthesis is the process by which green plants make their food. In this process, plants combine CO$_2$ and water using light energy to make carbon-containing compounds (sugars and starches, called carbohydrates). Oxygen is produced during the reaction and released to the atmosphere. On land, plants use CO$_2$ from the atmosphere. In the oceans, phytoplankton use CO$_2$ dissolved in seawater; much of this dissolved CO$_2$ also originally comes from the atmosphere. Photosynthesis also releases oxygen to the atmosphere. Thus, thanks to the activity of photosynthetic organisms, all other forms of life on the earth have oxygen to breathe and food to eat—even carnivores feed on animals that eat plants.

Respiration is the chemical process by which carbon-containing compounds are broken down within cells. It is essentially the opposite of photosynthesis: oxygen and carbohydrates react to produce CO$_2$ and water, releasing energy during the process. Living organisms use the energy released by respiration to power everything they do. For example, reading this page requires energy, and that energy is supplied by respiration.
2.10.3 The Oceans

The oceans absorb and store about 39,000 Gt of carbon—more than 60 times as much as the atmosphere (see Fig. 2.7). Over 95% of oceanic carbon is in the form of dissolved inorganic carbon (particularly dissolved CO$_2$, bicarbonate and carbonate ions); the remainder comprises various forms of organic carbon (living organic matter, particulate and dissolved organic carbon). Scientists make a distinction between the inorganic and organic forms of carbon because the two forms go through different chemical reactions and also are affected in different ways by physical ocean processes.

![Fig. 2.7](image)

**Fig. 2.7** Cycle of photosynthesis and respiration.

2.10.4 The Terrestrial Biosphere

Within this reservoir, the largest pool of carbon (roughly 65.5 million Gt) is in sedimentary rocks—mostly limestone, carbonate rocks, and also organic sediments containing fossil fuels. However, aside from human use of these fuels (which will be discussed in the next chapter), rocks do not play a role in the short-term carbon cycle. Carbon storage in plants and soils is more important for carbon cycle. Plants and soils store and release carbon on time scales ranging from seasons to thousands of years, and they contain about 2200 Gt carbon (C)—almost three times as much total carbon as the atmosphere and more organic (but not total) carbon than in the oceans.

Not only is the amount of carbon in the terrestrial biosphere big, but it is also readily modified by human activities. Therefore, this reservoir may be thought of as the most active part of the global carbon cycle. However, it is difficult, to pin down the role of the terrestrial biosphere in the global carbon cycle because of the complex biology underlying carbon storage, the great heterogeneity of vegetation and soils, and the somewhat unpredictable nature of human land use and land management.

2.10.5 Release of Fossil Fuels to the Atmosphere

When carbon in the short-term carbon cycle changes form or flows to a different reservoir (for example, moving from the land to the atmosphere when organic matter is burnt), the total amount of carbon in the cycle remains the same. The short-term carbon cycle is roughly balanced, and the amount of carbon-containing greenhouse gases is steady.
(ii) Biological Processes: Biological processes in the oceans are driven by the marine biota (oceanic plants and animals). The marine biota are believed to play a minor role, if any at all, in the oceans’ ability to absorb the CO₂ added to the carbon cycle by humans.

In fact, marine biota contribute only about 3 Gt of C to the world’s total carbon balance. However, the marine biota play a crucial role, in keeping the level of atmospheric CO₂ steady. Phytoplankton (microscopic ocean plants) take up dissolved inorganic carbon through photosynthesis, just as terrestrial plants take up atmospheric CO₂ during photosynthesis. If that dissolved inorganic carbon remained in the ocean waters, the oceans could not absorb as much CO₂.
and vitamins. From the start of nature people secured food through mainly two methods either by hunting (or gathering) and agricultural. As civilisations grew, food supply chain developed in most countries which provide different types of natural and processed food. Due to the growing number of living beings on the planet earth pressure on food resources is increasing day by day.

### 2.11.1 World Food Problems

Hunger, which is usually preceded by food shortages, is caused by a complex set of events and circumstances (climatic, social, economical, and political) that differ from place to place and from time to time. Though hunger has been a part of human experience from centuries and a dominant feature of life in many low-income countries, the causes of hunger and starvation are not very well understood. Our awareness of the main causes of hunger and starvation has been hampered by myths and misperceptions about the interplay between hunger and population growth, land use, farm size, technology, trade, environment, and other factors.

### 2.11.2 Population Growth and Land Use

There is a myth that the hunger and malnutrition afflicting many of the populations of poor nations are the direct result of rapid population growth and the persistence of traditional agricultural technologies. This perception implies that if population increases were to be curbed and modern technologies widely adopted, the problem would disappear. However, the population explosion is not the main cause of hunger and malnutrition, even though it exacerbates the situation. The growth of global food and agricultural production has been faster than the unprecedented population growth of the past 50 years. Hungry part of the world suffers from the lack of food, caused mainly by poverty. The poverty remains deep-rooted in 65% of the world’s population.

Poverty and rapid population growth are positively correlated. Where per capita income increases, population growth rates decline and vice versa. In other words, the higher the incidence of poverty, the higher is the population growth, and consequently hunger and malnutrition afflict relatively more people. That means poverty, rather than population growth, is the leading cause of hunger and malnutrition. It is also evident that most of the people afflicted by hunger and malnutrition live in the poorest parts of the world (particularly South Asian and Sub-Saharan African countries) where unemployment is high, income distribution is skewed, and the standard of living is low—reinforcing the obvious connection between hunger and poverty, not between hunger and population growth.

### 2.11.3 Scarcity of Arable Land

Scarcity of agricultural land is not the primary cause of food shortages, although it does exacerbate the problem. There is adequate arable land for cultivation and food production in the world. For instance, Bangladesh, where starvation and malnutrition are prevalent, has just half the people per cultivated acre compared to Taiwan. Yet Taiwan has no starvation and malnutrition. Ethiopia, Somalia, Sudan, Mozambique, and Bangladesh have adequate arable land for food and agricultural production, but they have been thought of as the countries hardest hit by hunger and starvation for many years. China has twice as many people per cultivated acre as India. Yet people in China do not suffer from hunger to the extent experienced in India. China, with the world’s largest population (around 1.2 billion), is self-sufficient in food and agricultural products, and produces grain and meat in large quantities for the domestic and world markets.
Hunger is a more complicated phenomenon than merely a problem that can be rectified by simply expanding agricultural production, although in most instances, expanding agricultural output is a necessary condition to feed the growing number of people. This is because of issues surrounding hunger go to the heart of the political economy of nations. The key obstacle in alleviating hunger is that the rural poor populations in most developing countries primarily depend and live on local agricultural production, exercise little control over the prices they receive and the productive resources they need to produce efficiently. When the control of resources is in the hands of the actual farmers and tenants rather than in the hands of absentee landlords, the farmers are likely to make efficient use of their land.

When farmers own land and work for themselves, they have the motivation to work hard to make the land more productive.

### 2.11.4 Technology in Food Production

It is often assumed that world food shortages can be eliminated by increasing food and agricultural production through the application of modern technology. It is also argued that supplying modern inputs—such as large-scale irrigation, chemical fertilizers, farm machinery, and pesticides—can improve the productive capacity of the land. However, when a new agricultural technology enters a system characterized by unequal power relationships, it brings greater profits only to those who already have some combination of land, financial resources, creditworthiness, and political influence.

For example, a research study completed by the International Labor Organization (ILO) showed that in the South Asian countries (Pakistan, India, Thailand, Malaysia, the Philippines, and Indonesia), where the focus was on increased agricultural production and where the gross national product (GNP) has risen, the majority of the rural population was worse off than ever before.

### 2.11.5 Farm Size and Credit Services

The disparities in the availability of institutional support systems in the distribution of services between large and small farmers work to the disadvantage of the latter. Since large farmers are conventionally considered to be more productive than small farmers, the big landholders are provided with public subsidies and credit facilities. The small farm operators are usually disqualified from farm credit loans because of their disadvantaged economic condition and the generally conservative lending practices of financial institutions. Small farmers have low equity positions and can offer little security, which implies high cost for lenders. The lending institutions often limit access of small farm operators to the capital market by imposing rigid rules on lending in order to fully protect the loan capital. Small farmers are often excluded from the modern marketing process, and have high input costs relative to large farmers because they lack bargaining power and do not buy farm inputs in bulk. In addition, tradition plays a large role in the system of production in developing countries. Agricultural and extension service systems consistently fail to serve the majority of small farmers effectively—especially in developing countries. This is partly because small farmers lack the formal channels to communicate their needs and ideas to the public sector. Also the new technologies are quite slow in replacing old techniques. The small farm systems are highly diverse and location specific, make adoption of new technologies very difficult. Public institutions cannot afford to accurately adapt appropriate technologies to each local set of circumstances.
When more water goes into a catchment than comes out, the water-table rises, bringing salt to the surface. Salts are carried in water moving through soils and the landscape. Salts can then accumulate at the soil surface when groundwater evaporates from shallow water-tables.

**Fig. 2.10** Salinity imbalances between inputs of water into groundwater.

(ii) **Inputs to groundwater are known as recharge**: Recharge can come either from the small amount of rainfall that percolates below the root zone of plants, or from the water seeping into the groundwater from streams, rivers, lakes and dams. The amount of water that percolates below the root zone of crops and pastures can be 10–100 times that percolating below trees. While all sources of recharge can contribute to dryland salinity, increased groundwater recharge under crops and pastures is the major cause of dryland salinity.

(iii) **Loss of water from groundwater are known as discharge**: Discharge can occur by subsurface lateral flow when the groundwater flows directly into a stream or river or when it evaporates from soils or transpires from plants. As the groundwater level comes closer to the soil surface, discharge into streams and from soils and plants increases, resulting in increased stream and soil salinity (particularly if the groundwater is saline). If water-table levels are regularly less than about 2 m deep, salts can build up at the soil surface, eventually killing plants and leaving the soil bare and salt-crusted.

However, it should be remembered that groundwater also discharges through transpiration from vegetation on the perimeter of the bare areas, where water-tables are deeper (e.g. within 4 m of the surface) and surface soil salinity is less obvious. Groundwaters are often saline in discharge areas, with an electrical conductivity ranging from 6 to over 60 dS/m.

Dryland salinity will be controlled by restoring the balance in a catchment (Figure 2.11). This can be achieved in two ways:

- reducing groundwater recharge; or
• increasing groundwater discharge.

Planting trees can help in both these processes.

Fig. 2.11  Restoring the balance between groundwater recharge and discharge for dryland salinity control.

There are four factors that can be manipulated when designing agroforestry systems for controlling dryland salinity mentioned below:
• area planted;
• the arrangement of the trees;
• their location within a catchment; and
• the tree species selected.

All of these can impact on recharge and/or discharge of groundwater and all need to be considered when undertaking tree planting for dryland salinity control. The principles associated with these factors are described below in general. The optimum design will always be dictated by specific landscape and climatic conditions, as well as by the overall land management objectives and restrictions relevant to the site. Also, the design may be varied to capture some of the other positive benefits of agroforestry (see table at the end of this chapter). Thus, the final design will most likely be a compromise between salinity control and other factors.

(iv) Waterlogging: Waterlogging is caused by the same processes as dryland salinity. The difference is that salts do not accumulate at the soil surface, either because the groundwater is of very low salinity (less than 6 dS/m) or it flows out of the soil (i.e. from a small spring), flushing the salts away. Waterlogging problems can also be ephemeral, such as when a perched water table develops on impermeable subsoil in a wet season. Most of the information given in this chapter is also directly relevant to management of waterlogging, except the references to salt accumulation and its effects. Thus, waterlogging will not be discussed separately.
Currently, India’s per capita GHG emissions are 24% of global average, 5% of the US, 12% of EU, 11% of Japan.

In cumulative terms, India has 2% of global GHG emissions. According to World Energy Outlook’s projections, China’s share in cumulative emissions between 1900 to 2030 would rise to 16% approaching that of the US (25%) and the EU (18%). India’s cumulative emissions are projected to reach 4% which would be comparable to those of Japan.
These Programmes were started in different years. DPAP was started in 1973-74 and DDP in 1977 whereas IWDP was started in 1988-89. Till 1995-96, the programmes were being implemented on sector basis and after 1995-96; they are being implemented on watershed basis.

The Land Reforms Division has been monitoring the progress of implementation of various land reforms measures such as abolition of Zamindari System, distribution of ceiling surplus lands, consolidation of land holdings, implementation of tenancy laws, etc. In addition, it has been administering the Land Acquisition Act, 1894. A draft Bill on Resettlement and Rehabilitation of Project Affected Persons/Families is also under formulation in this Division.

The plan allocation for the Department of Land Resources has been increased from Rs. 324 crore in 1999-2000 to Rs. 1000 crore for 2002-2003. Year-wise approved outlays of the Department since 1999-2000 is given in Annexure-XXVII.

Presently 972 blocks of 182 districts in 16 states are covered under Drought Prone Areas Programme (DPAP). Similarly, 235 blocks of 40 districts in 7 states are covered under Desert Development Programme (DDP). The coverage under Integrated Wastelands Development Programme (IWDP) extends generally to blocks not covered in the above programmes.

Projects covering an area of 139.72 lakh hectares have been taken up from 1.4.1995 to 31.3.2002 under the three programmes, namely, DPAP, DDP and IWDP. In addition, an area of 63.50 lakh hectares had been taken up for development prior to 31.3.99 under Employment Assurance Scheme (EAS).

Besides the above schemes, the Wastelands Development Division also implements the Technology Development, Extension & Training (TDET) Scheme and the Investment Promotional Scheme (IPS).

A statement showing state-wise release of funds under these programmes, as on 31.1.2003, is in Annexure –XXVIII.

In the area of land reforms, the task of abolition of intermediary tenures has been completed all over the country. Besides, an area of 5.39 million acres of ceiling surplus land has been distributed to 5.65 million rural poor, 50% of which constitute SC/ST beneficiaries. An area of 14.74 million acres of Government wastelands and 2.18 million acres of Bhooland land has been distributed among the eligible rural poor. Similarly, 0.43 million acres of alienated land has been restored to Scheduled Tribes. Consolidation of landholdings has taken place in an area of 161.53 million acres. 582 districts have been brought fewer than 100% Centrally Sponsored Scheme of Computerization of Land Records and its operationalisation has been extended to 2970 taluks/tehsils/blocks.

For the purpose of strengthening of survey and settlement operations for updating the land records and other allied matters, a 50:50 Centrally Sponsored Scheme of Strengthening of Revenue Administration and Updating of Land Records is under implementation in collaboration with the State Governments. Besides, amendment of Land Acquisition Act, 1894 and a Bill on Resettlement and Rehabilitation of Project Affected Persons/Families is under formulation. With the formation of a separate Department of Land Resources, all the Watershed Development Programmes of the Ministry of Rural Development have already been brought within its purview.

However, the programmes relating to conservation, development and management of land resources remain scattered in different Ministries and Departments. At the Joint Session of Parliament in February, 2000, the President of India had made the following announcement:

“...There is an imperative need to put in place an integrated mechanism capable of responding effectively to the challenges of managing our scarce land resources, especially those arising from globalization, liberalization and privatization. The Government will, therefore, bring all the
programmes and schemes as well as the institutional infrastructure relating to land in rural areas, under the control of the newly created Department of Land Resources in the Ministry of Rural Development.”

The Department of Land Resources has already taken further action for implementation of the above announcement. It is hoped that a final decision in the matter will be taken very shortly.

2.12.3 Soil

The soil covering the surface of the earth has taken millions of years to form and we must learn to respect it. Soil is formed at a rate of only 1 cm every 100 to 400 years and it takes 3 000 to 12 000 years to build enough soil to form productive land. This means that soil is a non-renewable resource and once destroyed it is gone forever.

If we disregard this, a time will come when there would not be enough soil left to sustain life on the earth, because the soil is a necessary growth medium for plants, a home for certain insects and animals, as well as a medium from which we get minerals. It is important therefore to treat soil, especially topsoil, as a living entity.

2.12.3.1 Soil erosion

• Soil erosion occurs when soil is removed through the action of wind and water at a greater rate than it is formed.
• When a raindrop hits soil that is not protected by a cover of vegetation and where there are no roots to bind the soil, it has the impact of a bullet.
• Soil particles are loosened, washed down the slope of the land and either end up in the valley or are washed away out to sea by streams and rivers.
• Erosion removes the top soil first. Once this nutrient-rich layer is gone, few plants will grow in the soil again.
• Without soil and plants the land becomes desert-like and is unable to support life.

2.12.3.2 Causes of soil erosion

Erosion occurs when farming practices are not compatible with the fact that soil can be washed away or blown away. These practices are:

• Overstocking and overgrazing
• Inappropriate farming techniques such as deep ploughing land 2 or 3 times a year to produce annual crops
• Lack of crop rotation
• Planting crops down the contour instead of along it.

2.12.3.3 Water erosion

Water erosion causes two sets of problems:

• A non-site loss of agricultural potential
• An off-site effect of downstream movement of sediment, causing flooding and the silt up of reservoirs.
2.12.4.3 **Soil structure**
The term soil structure means the grouping or arrangement of soil particles. Over-cultivation and compaction cause the soil to lose its structure and cohesion (ability to stick together) and it erodes more easily.

2.12.4.4 **Terrain unit**
The crest (top of slope) is usually well drained as soil moisture moves downhill, leaving air in the pore spaces most of the time. Over time, the fine (clay) particles are carried down slope leaving the soil sandy. Plant roots can penetrate easily to deep levels and withdraw enough soil water from there. These soils have a lower erosion potential and are normally more stable.

In the mid slope soil moisture moving from the crest starts to dam up as a result of the clay-rich soil just downhill. The soils are moderately well drained with a higher erosion potential.

In the foot slope the soil has been waterlogged (saturated with water) as a result of the long-term accumulation of clay which does not allow water to infiltrate. Plants that grow on these soils are limited to those that can adapt their root systems to grow laterally above the hard clayey layer. These imperfectly drained soils have a high erosion potential.

2.12.4.5 **Organic material**
Organic material is the “glue” that binds the soil particles together and plays an important part in preventing soil erosion. Organic matter is the main source of energy for soil organisms, both plant and animal. It also influences the infiltration capacity of the soil, therefore reducing water run-off.

2.12.4.6 **Vegetation cover**
The loss of protective vegetation through overgrazing, ploughing and fire makes soil vulnerable to being swept away by wind and water. Plants provide protective cover on the land and prevent soil erosion for the following reasons:

- Plants slow down water as it flows over the land and this allows much of the rain to soak into the ground.
- Plant roots hold the soil in position and prevent it from being blown or washed away.
- Plants break the impact of a raindrop before it hits the soil, reducing the soil’s ability to erode.
- Plants in wetlands and on the banks of rivers are important as they slow down the flow of the water and their roots bind the soil, preventing erosion.

2.12.4.7 **Land use**
Grass is the best natural soil protector against soil erosion because of its relatively dense cover. Small grains, such as wheat, offer considerable obstruction to surface wash. Row crops such as maize and potatoes offer little cover during the early growth stages and thereby encourage erosion. Fallowed areas, where no crop is grown and the entire residue has been incorporated into the soil, are most subject to erosion.

2.12.5 **Preventing Soil Erosion**
Some of the following measures can be implemented to prevent soil erosion:

- The use of contour ploughing and windbreaks
- Leave unploughed grass strips between ploughed lands (strip cropping)
• Make sure that there are always plants growing on the soil, and that the soil is rich in humus
• Avoid overgrazing
• Allow indigenous plants to grow along riverbanks
• Conserve wetlands
• Cultivate land, using a crop rotation system
• Minimum or no tillage
• Encourage water infiltration and reduce water run-off.

2.12.5.1 Desertification
Desertification is persistent degradation of dry land ecosystems by variations in climate and human activities. Home to a third of the human population in 2000, dry lands occupy nearly half of the earth’s land area. Across the world, desertification affects the livelihood of millions of people who rely on the benefits that dry land ecosystems can provide. In dry lands, water scarcity limits the production of crops, forage, wood, and other services ecosystems provide to humans. Dry lands are therefore highly vulnerable to increases in human pressures and climatic variability, especially sub-Saharan and Central Asian dry lands.

At least 10 to 20% of dry lands are already degraded, and ongoing desertification threatens the world’s poorest populations and the prospects of poverty reduction. Therefore, desertification is one of the greatest environmental challenges and a major barrier to meeting basic human needs in dry lands.

2.12.5.2 Linkage between desertification and human well-being
In dry lands, more people depend on ecosystem services for their basic needs than in any other ecosystem. Indeed, many of their resources, such as crops, livestock, fuelwood, and construction materials, depend on the growth of plants. Vegetation in any place around the world depends on water availability and local climatic conditions. Fluctuations in the services supplied by ecosystems are normal, especially in dry lands, where water supply is irregular and scarce.

However, when a dry land ecosystem is no longer capable to recover from previous pressures, a downward spiral of desertification may follow, though it is not inevitable.

Desertification affects a wide range of services provided by ecosystems to humans: products such as food and water, natural processes such as climate regulation, but also non-material services such as recreation, and supporting services such as soil conservation. Changes can be quantified and methods are available to prevent, reduce, or reverse them. When faced with desertification, people often respond by making use of land that is even less productive, transforming pieces of rangeland into cultivated land, or moving towards cities or even to other countries. This can lead to unsustainable agricultural practices, further land degradation, exacerbated urban sprawl, and socio-political problems. Desertification takes place in dry lands all over the world. Some 10 to 20% of all dry lands may already be degraded, but the precise extent of desertification is difficult to estimate, because only few comprehensive assessments have been done so far.

A large majority of dry land populations live in developing countries. Compared to the rest of the world, these populations lag far behind in terms of human well-being, per capita income, and infant mortality. The situation is worst in the dry lands of Asia and Africa. Dry land populations are often marginalized and unable to play a role in decision-making processes that affect their well-being and making them even more vulnerable.